PROCEEDINGS

11th International Conference

KERPİC'24

12-13-14 September 2024

Kayseri / TURKEY

'CHALLENGES IN EARTH-BASED INTERIOR ARCHITECTURE; CURRENT ISSUE IN EARTH-BASED MATERIALS, CONSTRUCTION TECHNIQUES AND APPROACHES'

Organized By:

Prof. Dr. Bilge ISIK

Assist. Prof. Dr. Masoumeh KHANZADEH

Supported By:

Nuh Naci Yazgan University Faculty of Fine Arts and Design

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Edited By:

Assist. Prof. Dr. Masoumeh KHANZADEH

Assist. Prof. Dr. D. Merve CETINKAYA SONMEZ

Assist. Prof. Dr. Gozde KUZU DINCBAS

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Proceedings

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Edited by

D. Merve CETINKAYA SONMEZ
Gozde KUZU DINCBAS
Masoumeh KHANZADEH

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Kerpic'24

11th International Conference PROCEEDINGS

Challenges in Earth-Based Interior Architecture; Current Issue in Earth-Based Materials, Construction Techniques and Approaches

History of Conferences

The International Conference on Kerpic 2005, "Living in Earthen Cities", was hosted by Istanbul Technical University; International Conference on Kerpic 2008, "Learning from Earthen Architecture in Climate Change", was hosted by Cyprus International University; International Conference on Kerpic 2013, "New Generation Earthen Architecture: Learning from Heritage" and International Conference on Kerpic 2015, "Built Environment on Silk Road" and International Conference on Kerpic 2016, "Cultural Landscape, Rebuilding After Decay", were hosted by Istanbul Aydin University; International Conference on Kerpic 2018, "Back to Earthen Architecture: Industrialized, Injected, Rammed, Stabilized", was hosted by Hasan Kalyoncu University in Gaziantep; International Conference on Kerpic 2019, "Earthen Heritage, New Technology, Management" took place in Koycegiz, Mugla, Turkey. The 8th International Conference on Kerpic 2020 "Healthy Buildings: The Role of Earthen Materials on Providing Healthy and Sustainable Indoor Environment" was hosted by the Fatih Sultan Mehmet Vakif University in Istanbul, Turkey.

The 10th International Conference on Kerpic 2023 "Gain Information from the Traditional Earthen Architecture" was hosted by Dicle University, Diyarbakır /Turkey.

Our recent 11th International Conference on Kerpic 2024 "Challenges in Earth-Based Interior Architecture; Current Issue in Earth-Based Materials, Construction Techniques and Approaches" will be hosted by Nuh Naci Yazgan University, Kayseri /Turkey.

Prof. Dr. Bilge IŞIK

Theme of Conferences

- Sustainability and Environmental Impact: Earth-based materials are valued for their sustainability, but concerns over the environmental impact, resource extraction, and carbon footprint of certain materials and construction techniques remain. Research and innovation in low-impact earth-based materials and construction practices are ongoing.

- Regulatory Challenges: Building codes and regulations often do not adequately address earth-based construction, which can create obstacles for architects and builders. Advocacy for more inclusive and supportive regulations is an ongoing issue.

- Moisture Management: Earth-based materials can be susceptible to moisture damage, which is a significant concern in interior architecture. Developing effective moisture management strategies, such as appropriate sealing and ventilation, is critical.

- Landscape architecture: Includes considerations such as selecting earth-based materials that seamlessly transition from the interior to the exterior, incorporating sustainable landscaping practices, and ensuring that the natural environment and the built environment coexist in a way that is aesthetically pleasing, ecologically sound, and functional.

- Structural Integrity: Ensuring the structural stability and load-bearing capacity of earth-based structures in interior spaces is an ongoing challenge. Research is focused on enhancing structural engineering solutions for earth-based buildings.

- Modernization of Techniques: Integrating traditional earth construction techniques with modern building practices and technology is an ongoing issue. Researchers and architects are exploring ways to make earth-based construction more efficient and compatible with contemporary needs.

- Energy Efficiency: Improving the energy efficiency of earth-based interior architecture is crucial. This involves finding ways to enhance insulation properties and reduce energy consumption in earthen buildings.

- Health and Indoor Air Quality: Maintaining healthy indoor air quality is a challenge due to dust and potential off-gassing from earth-based materials. Research aims to identify and mitigate potential health risks.

- Education and Training: There is a need for more education and training in earth-based construction techniques to ensure that architects, builders, and designers have the necessary skills and knowledge to work with these materials effectively.

- Cultural Preservation: Preserving and reviving traditional earthen building techniques, as well as addressing issues related to cultural preservation, are vital in many regions where earth-based construction has historical and cultural significance.

- Innovation in Design: Continuously innovating in the design and aesthetics of earth-based interiors is essential to make them more attractive and appealing to a broader audience.

- Case Studies and Best Practices: Gathering more case studies and sharing best practices for successful earth-based interior architecture projects can help advance the field and showcase the benefits of this approach.

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Bilge ISIK, Prof. Dr.

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In Memorioam

Prof. Dr. Bilge ISIK
Conference Chair Istanbul Technical University (Emeritus), Istanbul, Turkey

Dear participants, first of all, I would like to thank you all. Summarizing 40 years of work on earthen construction in a short time is quite difficult, but I would like to share the important points. While studying my doctoral degree in Germany, I observed the use of earthen structures.
After my doctoral period, I focused on earthen buildings. At the ITU (İstanbul Technical University), Prof. Dr. Ruhi Kafesçioğlu, who researched the durability of materials with stabilizing earth with gypsum and lime. The formulas he obtained are unique and applicable worldwide.

Study from Prof Dr Bilge IŞIK, at the Civil Engineering Laboratories of Istanbul Technical University (ITU), earthquake safe construction techniques have been developed with horizontal flexibility. Using this technique, the TÜBİTAK-622 building was constructed on the ITU Ayazağa campus at 1995 and faced the earthquake at 1999 without any crack or damage. Construction period with the stabilized earthen material is very short and a variety of construction machines can be used.
Earthen buildings from BKM Film Sets at Köyceğiz withstood flood from the river, without damage. Earth construction in Van, despite snowfall, no water penetrated into the walls, and they remained perfect against the climatic conditions.

If the loadbearing wall doesn't have lateral flexibility in other words if the Wall is homogeneously strength the wall will crack diagonal; earthen buildings will collapse with the lateral force of earthquake. To protect the loadbearing walls and earthen buildings from earthquakes, horizontal flexibility should be achieved. As seen from the tests conducted in the laboratory in Ayazağa, we ensure horizontal flexibility.

Finally with this earthquake safe construction technique: 75,000 rural house demand after the earthquake at 2023.6. February: can be solved.

In order to share the experiences, we have gained, we organized the 11th International Earthen Architecture Conference. I would like to thank everyone who contributed and participated.

Prof. Dr. Hülya UÇAR
Dean of the Faculty of Fine Arts and Design; Kayseri Turkey

Dear Mayor of Talas, Dear Vice Rectors, Dear Deans, Institute Directors, Esteemed Faculty Members, Honorable President of the Chamber of Architects, Distinguished Members of the Press, Esteemed Guests, and Dear Students,

Welcome to the 11th International Kerpiç Conference. It is a great pleasure and honor to see you here in Kayseri, a city that has hosted many civilizations throughout history, and at our University. Thank you for honoring us with your participation.

Conference Chair Prof. Dr. Bilge IŞIK and esteemed Aydan ÖZKAN have already shared their valuable insights on the content and significance of the Kerpiç Conference. While I am not an expert in this field, as a healthcare professional, I would like to emphasize the importance of using adobe in living spaces in terms of human, animal, and environmental health. This highlights the relevance of this topic to all of us and underscores the need for multidisciplinary studies.

Esteemed Guests,
During this conference, our distinguished speakers, who are experts in their respective fields, will share their knowledge and experiences with us. We extend our heartfelt thanks to these esteemed speakers for their valuable participation.

It was of utmost importance to us that the conference be organized in a way that meets your expectations. This endeavor required tremendous effort and dedication. We express our gratitude to our Rector, Prof. Dr. Ahmet Fazıl ÖZSOYLU, and our Vice Rectors for their moral and financial support in realizing this event.

We would also like to thank those who worked diligently on organizing the event, including Bahadır KILIÇ and Arif APAYDIN from the IT Department, Özlem ÇEŞMEBAŞI and Saim KOÇ from the Administrative and Financial Affairs Department, Turan İlbey from the Health, Culture, and Sports Department, Saim Yıldız from the Press and Public Relations Unit, Gülsüm BAYKAN, Acting Head of the Personnel Department, and all other support staff who contributed to this event.

Special thanks go to the Conference Chair, Prof. Dr. Bilge IŞIK, who worked tirelessly and with great enthusiasm and dedication, as well as to Dr. Merve ÇETİNKAYA SÖNMEZ, Head of the Department of Interior Architecture and Environmental Design, Conference Co-Chair Dr. Masoumeh KHANZADEH, Dr. Gözde KUZU DİNÇBAŞ, Research Assistants Melike ŞERBET and Rümeysa AYDIN, and the students on the organizing committee. Thank you for your invaluable contributions.

We also extend our gratitude to Aydan ÖZKAN for hosting the workshop to be held in Zile as part of the technical tour on the second day of the conference, and to our esteemed sponsors, whose support has been crucial for this event. Additionally, we sincerely thank the Mayor of Talas and the Mayor of Develi, who have supported us both morally and materially, even though their names could not be included as official sponsors.

Dear Guests and Participants,
The meaning of our efforts and endeavors comes to life only through your contributions and participation. Thank you for providing that through your presence here today, In concluding my remarks, I would like to once again welcome you and express my hope that the conference will meet your expectations both scientifically and socially, yielding successful and fruitful results.

With my deepest regards.

Assist Prof. Masoumeh KHANZADEH
Conference Co-Chair; Kayseri Turkey

Good morning!

Esteemed protocol members, dear colleagues, and treasured friends, it is a tremendous honor and pleasure to be here today as co-chair of the 11th Earthen Architecture Conference, which is being held by Nuh Naci Yazgan University's Faculty of Fine Arts and Design. I extend a hearty greeting to everyone.

Today, we are not only commemorating the tenth anniversary of this conference, but also convening to investigate new aspects of earthen construction that resist the passage of time.
Earthen architecture is more than simply my grandfather's crumbling village home or a discarded construction material. As you are aware, it represents sustainability, cultural legacy, and resilience. But have you ever pondered why this mineral, utilized thousands of years ago, is still so important? Why, in an age of advanced materials, are we still talking about earth-based construction? Let us dive a little further. What benefits does earthen architecture provide for a more sustainable future?
Let us pause to reflect: In the face of climate change, why is earthen building, one of the oldest construction forms, gaining popularity again? Is it any surprise that eco-friendly solutions and community-centered design given by earthy materials are becoming increasingly important in our day and age, when we all live in contemporary cities? We will examine these topics and discover answers together. This hall will include meaningful talks, informative lectures, and smart idea exchanges throughout the following three days. We will also offer a session on current clay methods and have the opportunity to see earthen buildings. Through these activities, we will investigate and debate how earthen construction practices adapt to technology improvements, battle climate change, and promote sustainable, community-centered design.

Many determined people worked hard to make this conference a reality. I'd want to express my profound gratitude to everyone involved, from the organizing committee to the Department of Interior Architecture, from our kind sponsors to all of you who have come from far and wide. What distinguishes this conference is your involvement, the expertise you provide, and your shared enthusiasm for earthen architecture.

As we begin on this trip together, let us push limits, question assumptions, and learn how earthen buildings might be used more efficiently in our quickly changing environment.

I'd want to thank everyone again for being here. I hope you a productive, inspirational, and memorable conference.

Thank you.

Assist Prof. D. Merve ÇETİNKAYA SÖNMEZ
Chair of the Department of Interior Architecture and Environmental Design; Kayseri Turkey

Adobe is a natural building material that is almost as old as human history. In the first years of its use, it was preferred as an easily accessible and easily processable material. Today, with the understanding that some resources are not unlimited on Earth, it has been reused as a sustainable material with new recipes. The use of adobe, which is an important product of ancient culture, by adapting it to today's world is an extremely important issue in terms of both sustainability and construction technologies. In this context, it has become an important issue to develop adobe as a building material and adobe construction technique as a form of application. Within the scope of this conference, scientists will present the adobe "**Challenges in Earth-Based Interior Architecture; Current Issue In Earth-Based Materials, Construction Techniques and Approaches**".

I would like to express my gratitude and respect to Kayseri Nuh Naci Yazgan University for hosting the "Kerpic'24" conference for their support during the conference process. At the same time, I would like to express my gratitude to all the authors and participants who participated in the conference from different parts of the world and Turkey.

Gözde KUZU DİNÇBAŞ
Co-Chair of the Department of Interior Architecture and Environmental Design; Kayseri Turkey

Mr. Mayor, Vice Rectors, Deans, Directors of Institutes, President of the Chamber of Architects, esteemed lecturers, dear students, and distinguished guests, I would like to extend my heartfelt gratitude for your participation in the 11th International Adobe Conference, organized by Kayseri Nuh Naci Yazgan University, Faculty of Fine Arts and Design, Department of Interior Architecture and Environmental Design. I greet you all with respect. Today, we are gathered here to discuss "The Challenges Faced in the Use of Earth-Based Materials in Interior Architecture: Current Problems in Construction Techniques and Approaches." I would like to express my gratitude to Prof. Dr. Bilge Işık once again for graciously accepting our request to host this year's conference after our presentation at the 10th International Adobe Conference held at Diyarbakır/Dicle University on October 26-28, 2023.

The topic of soil is so extensive that it appeals not only to professionals in this field but also to others interested in its applications. It bridges many disciplines, offering a multidisciplinary perspective. As the Department of Interior Architecture and Environmental Design, we believe we represent this multidisciplinary approach quite effectively. Kayseri, with its rich cultural heritage, showcases a diverse range of structures shaped by its climate, topography, and socio-economic dynamics. Iconic buildings such as Kayseri Castle, Gevher Nesibe Healing Complex, churches, and traditional houses highlight this diversity. While the region primarily utilizes Erciyes Mountain stone as a building material, we can also observe adobe structures across its 16 districts. Tomorrow, we will visit Zile, a neighborhood in Develi district, which is one such significant location. On the second day of our conference, we will embark on a technical trip to Zile to observe traditional and contemporary construction practices. During this visit, we will also engage in on-site adobe casting as part of a workshop led by Prof. Dr. Bilge Işık. The "prescription" she provides will further enrich our understanding of adobe's applications.

To organize this conference, we collaborated closely with our core team, our esteemed Conference Chair, Prof. Dr. Bilge Işık and her team, and our greatest supporters—our students. We held meetings, visits, and interviews throughout the year. We also organized technical trips to study adobe structures and applied our findings in interior architecture projects as part of our coursework. Our students' dedication, their sincere approach, and the project exhibition they have prepared are valuable contributions to this event. I sincerely thank all our team members and students. Lastly, I would like to acknowledge the crucial support of our esteemed sponsors, without whom this conference would not have been possible. Their contributions have allowed us to enhance the event and offer a better experience for all participants. I extend my special thanks to Ms. Aydan Özkan, Mr. İbrahim Kozanoğlu, and Mr. Bilgehan Köhler for their hospitality and assistance in organizing the workshop in Develi/Zile.

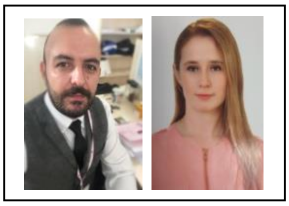
With the support of all contributors, I hope this event will be both scientifically enriching and practically rewarding for all attendees.

Thank you.

Contents

PROCEEDINGS: ABSTRACT AND FULL PAPER OF AUTHOR (S)

An Investigation into the Design Management of Green Roofs: Recycled Material Selection



Ahmet Tuz, Gizem Şimşir

Istanbul Medipol University, Department of Architecture

ahmet.tuz@medipol.edu.tr

ABSTRACT

The increase in energy demand and greenhouse gas emissions of the built environment (BE), the increase in global air temperature and the worsening effects of climate change have prioritized the development of green design management (GDM) in the construction industry. The development of green building rating systems and sustainable rating metrics to create a sustainable BE has led to the advancement of GDM in line with Sustainable Development Goals (SDGs). Green roofs (GRs), one of the GDM metrics, offer nature-based solutions in greening the BE and promote the triple bottom line (TBL) (social, economic, environmental) of the SDGs. GRs and their benefits have been widely accepted and researched in the literature, with increasing attention being drawn to the environmental benefits of GRs. There is still a gap in the literature regarding the social and economic benefits of GRs, especially in terms of material selection in GDM. Therefore, this study aims to investigate how the literature addresses GDM, especially from the perspective of recycled material selection, in terms of the social and economic benefits that GRs will provide. Systematic literature review was used as the research methodology. The results showed that academic interest is mainly focused on the environmental impacts of GRs. Additionally, there is a lack of social and environmental assessments regarding GRs in the literature, especially the selection/use of recycled materials. This study will pave the way for academicians and professionals interested in the selection of recycled materials in the GDM of GRs to create a sustainable BE.

Keywords: Green Design, Green Roofs, Recycled Material, Sustainable Built Environment

1 INTRODUCTION

Increasing environmental challenges and initiatives to combat climate change have made the concept of sustainability, which expresses the responsible management of resources to meet current and future needs, the cornerstone of contemporary development practices. These environmental challenges encountered in today's conditions (e.g. climate change, green gas emissions, increase in carbon footprint) necessitate a radical change towards sustainability in all dimensions of development, especially the built environment (BE) [1]. In particular, increasing urbanization and the resulting continuous increase in environmental concerns make the need for a sustainable BE increasingly important [2]. While the integration of sustainability into the creation of the BE guides and enables the establishment of goals in the social, economic, and environmental context, it supports the BE to develop these goals and turn them into concrete results that ensure harmony between architectural design and the environment [2].

The creation of a sustainable BE aims to reduce the ecological footprint of human activities through energy-efficient buildings, the use of renewable resources and innovative waste management practices [3]. Thus, it aims to improve quality of life and develop the circular economy by promoting healthier, more resilient communities [3]. Therefore, the sustainable BE emerges as an integrated concept that encompassing green design that will result in green operations of construction projects and green construction practices to promote environmental, economic, and social well-being.

Green design is one of the most important pillars of creating a sustainable BE by prioritizing environmental awareness and resource efficiency [4]. Green design, which aims to minimize the ecological footprint in creating a sustainable BE, is shaped in line with principles such as energy efficiency, water saving, use of renewable materials and waste reduction [5]. Green design, in which not only the environmental dimension of the TBL sustainability approach but also all dimensions (social, economic, and environmental) are considered and adopted as a principle, plays an important role in creating a sustainable BE by incorporating the technological support dimension that enables the integration of building information modelling. In today's conditions, where urbanization is constantly increasing, green design supported by technological contributions in the face of environmental problems will both meet today's needs and increase the capacity to meet the needs of future generations in increasing and expanding the creation of a sustainable environment.

Sustainability in architecture and construction refers to the practice of designing and building structures that minimize environmental degradation, enhance energy efficiency, and utilize resources responsibly. The concept of sustainability aims to meet today's needs while ensuring the ability of future generations to meet the future needs. [6]. Sustainable practices encompass a broad range of strategies, from reducing carbon footprints and enhancing energy efficiency to using renewable materials and creating healthier living environments [7].

Green design, often synonymous with sustainable design, focuses on creating buildings that are environmentally friendly and focus on efficient resource allocation throughout their progress, in every stage of construction stages such as pre-construction, construction and post construction stages [8]. Green design enhances the practice of sustainability in the construction process by focusing on energy efficiency, green material allocation, interior quality; Additionally, green design aims to create healthy buildings as well as reduce the harmful effects of construction projects on the environment. for residents [9].

Building Information Modeling (BIM) provides digitalization of all characteristics of any construction projects. In addition, BIM acts as a information-sharing resource about the any projects and enhance the decision making process and enable life cycle management [10]. Furthermore, BIM enables the integration of various fundamentals of design, construction, and management into a cohesive model, allowing for improved collaboration, increased accuracy in planning and execution, and enhanced efficiency [11].

Combining sustainability and green design principles with BIM technology offers a powerful approach to modern construction. BIM provides the tools to simulate and analyze the environmental impacts of different design choices, optimize energy performance, and facilitate the integration of renewable energy systems [12]. This synergy enhances the capability to achieve high sustainability standards, ensuring that buildings are not only environmentally friendly but also economically viable and socially responsible [13].

Green roofs (GRs)are a prominent feature in sustainable design, providing numerous advantages for minimizing environmental impacts such as reducing urban heat island effects, improving air quality, and increasing rainwater management [14]. GRs also contribute to energy savings by insulating buildings and reducing the need for air conditioning [15]. When integrated with BIM, GR designs can be optimized for performance and cost-effectiveness.

The use of recycled materials in construction is another critical aspect of sustainable building practices. Recycled materials reduce the demand for new resources, minimize waste, and lower the environmental footprint of construction projects [16]. BIM facilitates the tracking and management of these materials throughout the construction process, ensuring compliance with sustainability standards and improving project outcomes [17].

While green design with the principle of using renewable resources and BIM-oriented green design applications in the technological dimension have an important place in creating a sustainable BE, the integration of recycled materials into GR design can contribute to the creation process of a sustainable BE. Reducing the need for new materials, protecting natural resources, and using recycled materials that reduce greenhouse gas emissions play an important role in green design. The integration of these materials into GR BIM designs, as a green design criterion, can increase resource efficiency and make a holistic contribution to sustainability by promoting BEs compatible with nature. Therefore, this study aims to evaluate how the literature addresses the green design management of GR(s) in terms of the TBL sustainability approach, especially from the perspective of recycled material selection. This study structured as follows: following the introduction, the research methodology is represented in the second chapter, the findings are evaluated in the third chapter, and the conclusion is included in the fourth chapter.

2 METHODOLOGY

This study aims to evaluate how the literature addresses the green design management of GR(s) from the perspective of the TBL sustainability approach, especially the selection of recycled materials. In this study, a structured literature review consisting of 4 consecutive steps was adopted, allowing the existing studies in the literature to be examined and evaluated in depth according to their focus and results [18]. The methodology of this study was developed based on the research methodology of [18].

The successive steps of the methodology are summarized in Figure 1. Determining the purpose of this study enabled the selection of keyword(s) and keyword combinations that would facilitate finding existing research articles written in English between 2014 and the second quarter of 2024 from Elsevier (www.sciencedirect.com), which was designated as the search engine.

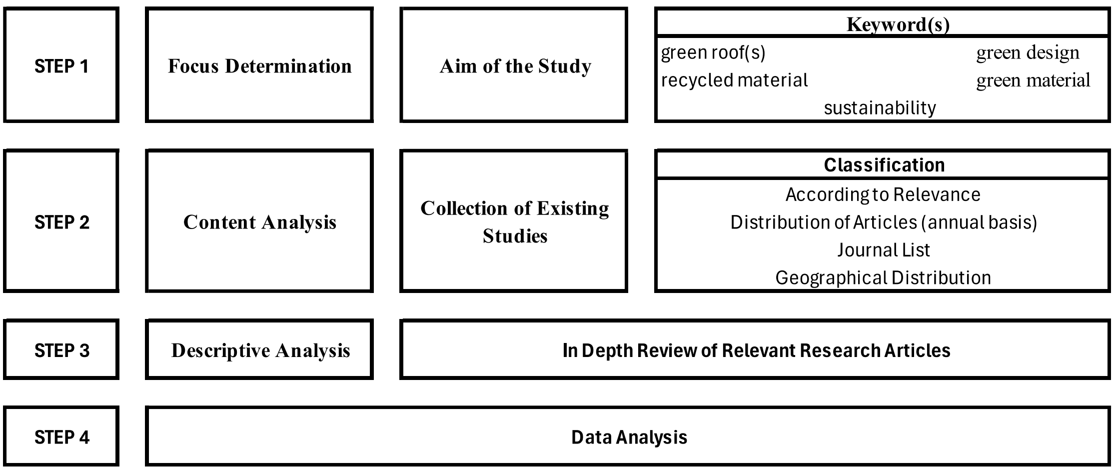


Figure 1. Research Methodology Process Steps

The second step of the research method involves Content analysis, which allows the collected research articles to be classified according to their suitability for the purpose of this study. In addition, content analysis was conducted to classify the relevant studies according to their distribution by year (Fig. 2), journal (Table 1) and geographical distribution (Fig. 3).

3 CONTENT ANALYSIS

The first step of the literature review analysis involves obtaining 28 research articles written in English from the specified search engine within the time period specified in the study. As a result of an in-depth examination of the articles obtained in accordance with the purpose of this study, it was determined that 8 out of 28 articles were not suitable for the purpose of the study, therefore the remaining 20 articles formed the sampling frame of the study.

In the determined period of the study (2014-2024 2nd Quarter), 2022 was the year in which the most research articles were published within the scope of the purpose of the study (4 articles), followed by 2023, 2021, 2020 and 2017 (3 articles per each) (Fig. 2).

The majority of articles were published in Building and Environment (30%), followed by Ecological Engineering (15%) and Energy and Buildings (15%) (Table 1). Belgium makes the largest contribution to the total research articles within the scope of this study, with 20% (4 articles), followed by Spain (15%- 3 articles), Turkey (10%- 2 articles) and Italy (10%-2 articles). The remaining articles within the sampling framework are distributed equally to 9 countries (5% -1 article per each country) (Fig 3).

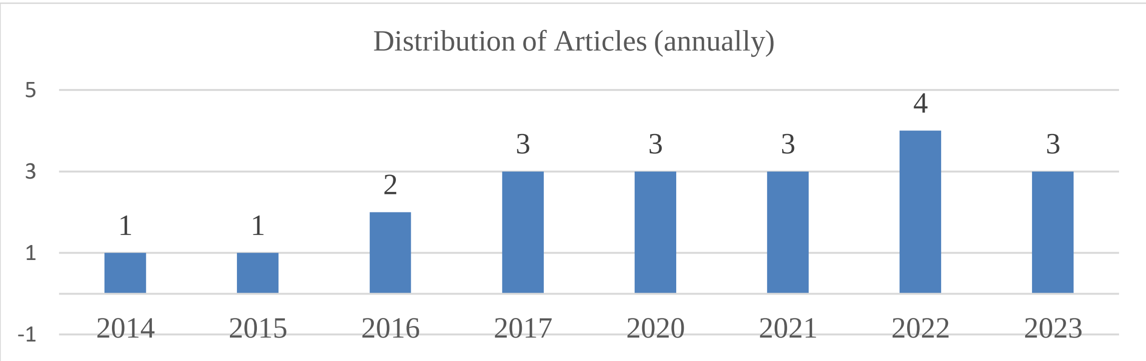


Figure 2. Distribution of Articles

Table 1. Journal List

Journal Name	***n***	***%***
Building and Environment	6	30%
Ecological Engineering	3	15%
Energy and Buildings	3	15%
Urban Forestry & Urban Greening	2	10%
Journal of Building Engineering	2	10%
Agriculture and Agricultural Science Procedia	1	5%
Journal of Environmental Management	1	5%
Nano Energy	1	5%
Omega	1	5%
Total	**20**	**100%**

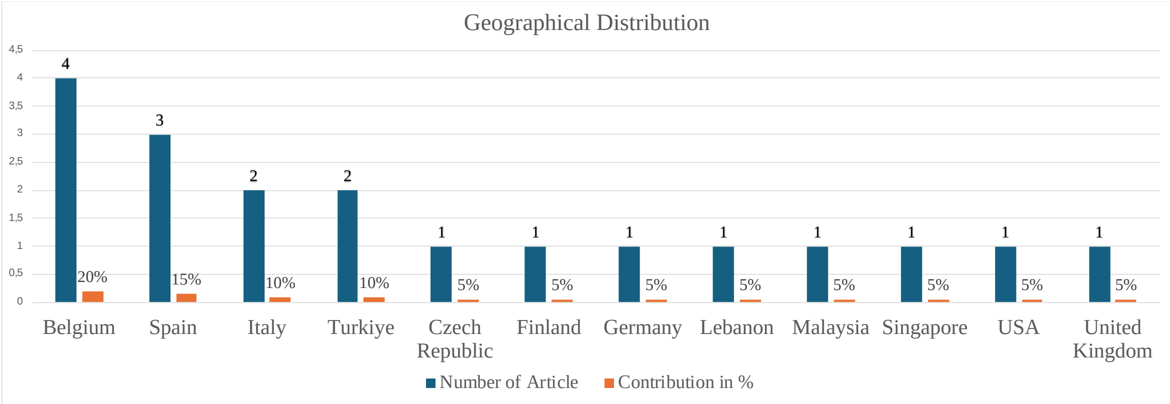


Figure 3. Geographical Distribution of Articles

3 FINDINGS

The purpose of the research necessitated the evaluation of the obtained research articles according to their focus points. Since this study addressed green design management by focusing on the use of recyclable materials in GR systems towards sustainability, the resulting research articles were grouped according to primary, secondary, and tertiary focus. Therefore, the research articles included in the sample frame of this study were evaluated according to four basic pillars of GR design management in line with sustainability: green design focus, green economy focus, recycled material focus and BIM focus.

Table 2. Focus Classification

Primary Focus	*Secondary Focus*	*Tertiary Focus*	*Year*
GD	RM	Hygrothermal Performance	2023
GE	RM	Hydrophysical Properties	2023
GD	RM	Thermal Resistance	2023
GD	RM	Thermal Resistance	2022
GD	RM	General Performance	2022
GD	RM	Energy Performance	2022
GD	RM	Heat Performance	2022
GD	RM	Hygrothermal Performance	2021
GD	RM	Air pollution	2021
GE	Cost Benefit	Flood Control	2021
GD	RM	General Performance	2020
GD	RM	Plant Growing	2020
GD	Energy Saving	Layering	2020
GD	RM	Energy Performance	2017
GD	Thermal Benefits	Water Retention Performance	2017
GD	Energy Saving	Green Materials	2017
GD	RM	Environmental Impact	2016
GD	RM	Water Retention Performance	2016
GD	RM	Plant Growing	2015
GD	RM	Heat Performance	2014

GD : Green Design RE : Recycled Material
GE : Green Economy

Descriptive analysis provided to evaluate existing research articles according to their primary, secondary, and tertiary focus (Table 2). The majority of articles focused on green design as their primary focus (e.g., [4], [5], [19], [20], [24], [28]), however, a minority focused on green economics towards sustainability (e.g., ref). Moreover, RM in GR design was a secondary focus of existing research articles (e.g., [4], [5], [19], [20], [24], [28]); where energy savings (ref), thermal benefits, and cost benefit/advantage were secondary focuses of minority research articles. Additionally, research articles evaluating green design as a primary focus and RM as a secondary focus evaluated and/or investigated overall performance [5], heat resistance [20], energy performance [19], thermal performance, hygrothermal performance [4], and plant growth [24] as a tertiary focus (Table 2). Existing relevant research articles focusing on the use of RMs in green design have mostly evaluated the use of coarse and/or fine aggregates as RMs to improve the drainage system in GR design. On the other hand, the results showed that there is a lack of green design-oriented, RM-focused BIM modeling in the literature.

4 CONCLUSION

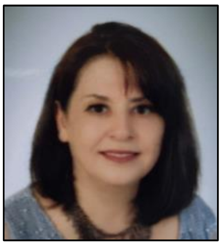
This study was conducted to examine how green design management is discussed in the literature in terms of the environmental, social, and economic benefits that a GR will provide, especially from the perspective of RM selection. This study used a structured literature review and evaluated 20 research articles that were relevant to the purpose of this study and published between 2014 and the second quarter of 2024. The results showed that there is a lack of focus on the use of RM as a design criterion for GR system, especially the BIM modeling system focus on GR system design management. In all relevant articles obtained as a result of the literature review, the environmental (mostly) and economic (minority) dimensions provided by the use of RMs as design materials in GR design in accordance with the TBL sustainability approach are emphasized. The results showed that there is a lack of focus in the literature on the technological dimension of sustainability (BIM modeling) in the design management of sustainable GR systems, which can increase the sustainability advantages of supporting GRs. This study will provide information to academicians and professionals interested in the selection of RMs in GR design management to create a sustainable BE with BIM.

5 REFERENCES

[1] Lee, E., Seo, Y., & Woo, D. K. (2024). Enhanced environmental and economic benefits of green roofs in a humid subtropical region under future climate. *Ecological Engineering, 201*, 107221.
[2] Jamei, E., Chau, H. W., Seyedmahmoudian, M., Mekhilef, S. S., & Sami, F. A. (2023). Green roof and energy–role of climate and design elements in hot and temperate climates. *Heliyon*.
[3] Balasbaneh, A. T., Sher, W., Madun, A., & Ashour, A. (2023). Life cycle sustainability assessment of alternative green roofs–A systematic literature review. *Building and Environment*, 111064.
[4] Kazemi, M., Rahif, R., Courard, L., & Attia, S. (2023). Sensitivity analysis and weather condition effects on hygrothermal performance of green roof models characterized by recycled and artificial materials' properties. *Building and Environment*, *237*, 110327.
[5] Carrera, D., Lombillo, I., Carpio-García, J., & Blanco, H. (2022). Assessment of different combinations of substrate-filter membrane in green roofs. *Journal of Building Engineering, 45*, 103455.
[6] Brundtland Commission. (1987). Our Common Future. Oxford University Press.
[7] Kibert, C. J. (2016). *Sustainable Construction: Green Building Design and Delivery*. John Wiley & Sons.
[8] U.S. Green Building Council. (2021). LEED v4.1 Reference Guide for Building Design and Construction.
[9] Woolley, T. (2013). *Low Impact Building: Housing Using Renewable Materials*. John Wiley & Sons.
[10] Eastman, C., Teicholz, P., Sacks, R., & Liston, K. (2018). *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors*. John Wiley & Sons.
[11] Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry. *Leadership and Management in Engineering*, 11(3), 241-252.

[12] Chong, H. Y., Lee, C. Y., & Wang, X. (2017). A Mixed Review of the Adoption of Building Information Modelling (BIM) for Sustainability. *Journal of Cleaner Production*, 142, 4114-4126.
[13] Krygiel, E., & Nies, B. (2008). *Green BIM: Successful Sustainable Design with Building Information Modeling.* John Wiley & Sons.
[14] Oberndorfer, E., Lundholm, J., Bass, B., Coffman, R. R., Doshi, H., Dunnett, N., ... & Rowe, B. (2007). Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services. *BioScience*, 57(10), 823-833.
[15] Berardi, U., GhaffarianHoseini, A., & GhaffarianHoseini, A. (2014). State-of-the-art Analysis of the Environmental Benefits of Green Roofs. *Applied Energy*, 115, 411-428.
[16] Tam, V. W., & Tam, C. M. (2006). Evaluations of Existing Waste Recycling Methods: A Hong Kong Study. *Building and Environment,* 41(12), 1649-1660.
[17] Akinade, O. O., Oyedele, L. O., Ajayi, S. O., Bilal, M., Alaka, H. A., Owolabi, H. A., ... & Kadiri, K. O. (2015). Design for Deconstruction (DfD): Critical Success Factors for Diverting End-of-life Waste from Landfills. *Waste Management*, 39, 266-274.
[18] Tuz, A., & Sertyeşilışık, B., (2018). *An investigation into the state of the art of the literature on marketing in the construction industry* . The 5th International Project and Construction Management Conference (pp.629-636). Lefkoşa, Cyprus (KKTC).
[19] Cascone, S. (2022). The energy-efficient design of sustainable green roofs in Mediterranean climate: An experimental study. *Energy and Buildings*, *273*, 112427.
[20] Tams, L., Nehls, T., & Calheiros, C. S. C. (2022). Rethinking green roofs-natural and recycled materials improve their carbon footprint. *Building and Environment*, *219*, 109122.
[21] Molineux, C. J., Gange, A. C., Connop, S. P., & Newport, D. J. (2015). Using recycled aggregates in green roof substrates for plant diversity. *Ecological Engineering*, *82*, 596-604.
[22] Sisco, L., Monzer, S., Farajalla, N., Bashour, I., & Saoud, I. P. (2017). Roof top gardens as a means to use recycled waste and A/C condensate and reduce temperature variation in buildings. *Building and Environment*, *117*, 127-134.

Adaptation of a Historic Mudbrick House into a Cafe in Kütahya



Assoc. Prof. Ayşe Esin KULELİ

Antalya Bilim University, Antalya/ TURKEY
esin.kuleli@antalya.edu.tr

ABSTRACT
Houses were built to meet the need for shelter, using local architectural traditions in the historical process. Since adobe is an easily available and economical building material, it has been used extensively in Anatolia. In this context, one of the provinces with adobe architectural heritage is Kütahya, which is located in the inland regions of Turkey. This city is known for its rich historical heritage and traditional architecture. Especially in the center of Kütahya, adobe (mud brick) structures are commonly found. These adobe houses constitute an important part of the region's architectural heritage.

Adobe is known for its positive qualities such as preserving heat, being healthy, economical, and fire resistant, but one of the most important negative aspects is being a material that is very affected by water and frost when wet. For this reason, it is important to take the necessary precautions to protect the mudbrick architectural heritage.

In this study, an abandoned mudbrick house located in Kütahya, which is a registered architectural heritage, was examined. The house, situated in Kütahya, Börekçiler neighborhood, was built with three floors. The construction period of the house, which has an L-shaped plan and an external sofa, is dated to the late 19th century.

In recent years, there has been a trend of repurposing historical houses for different uses. In this context, the conversion of an adobe house into a café in Kütahya is also a significant project. This project aims to both restore a historical house and create a new café space in the city. The adaptation of this adobe house into a café in Kütahya requires careful planning and restoration processes. It is crucial to focus on preserving the characteristic features of the original building materials and construction system during the development of conservation interventions and to apply the suggested interventions with sensitivity during the implementation process.

Traditional elements are combined with modern touches to create a warm and inviting atmosphere. Additionally, the house's garden or courtyard can be arranged as an open space for café customers, providing an opportunity to spend time in a natural and historical environment.

The conversion of this historical adobe house into a café in Kütahya contributes significantly to the region's cultural heritage. It also adds color to the city's social, cultural, and tourist life. This project serves as an important example of increasing awareness about the preservation and sustainability of historical houses.

Keywords: Mudbrick, Kütahya houses, reuse, conservation, sustainability of historical houses.

1 INTRODUCTION

Viollet-le-Duc, who first theoretically discussed the topic of assigning new functions to historical structures, suggested that the best method for preserving a building is to give it a new function and meet the requirements of that function [1]. Since the second half of the 20th century, the adaptation of historical buildings for reuse has significantly increased. The approach of preserving a historical building by adapting it for reuse aligns with contemporary conservation theory. If a building can no longer serve its original purpose, adapting it to a new function will contribute to its sustainability. Additionally, considering the environmental damage caused during the construction process of every new building, adapting an existing one for new use provides both environmental and economic benefits [2].

National and international documents prepared for the conservation of architectural heritage, such as the Venice Charter (1964) [3], the Amsterdam Declaration (1975) [4], and the Australia ICOMOS Burra Charter (2013) [5], guide and encourage conservation efforts. Within the context of contemporary conservation theory, the approach of adapting a building to a new function is regarded as a crucial strategy for the preservation of architectural heritage.

The houses in the historic urban fabric of Kütahya are generally designed as two or three-story structures. Examining the construction system of these houses reveals that they were built with a stone-ground floor and an upper floor with a wooden structure and adobe infill. The main floor of the building often features overhangs. The plastered facade surfaces are painted in traditional colors. The roofs are hipped or gabled, with wide eaves and covered with corrugated tiles. The overhangs reflecting the desire for openness in Kütahya houses are sometimes applied in tiers on three-story buildings [6].

In addition to the studies by researchers like Lami Eser [6], Sadat Hakkı Eldem [7], Doğan Kuban [8], and Önder Küçükerman [9], which document and interpret the architecture of Kütahya houses, numerous postgraduate theses, articles, and other academic research have been published regarding these houses, which hold significant architectural heritage value.

Kütahya, one of the oldest settlements in Anatolia, possesses a multi-layered architectural heritage from various periods. The loss of traditional houses, which are significant elements of this heritage, due to various reasons, means the loss of important elements that reflect past lifestyles.

This study examines a registered adobe house located in Börekçiler neighborhood, plot no. 310, parcel no. 2, owned by the Kütahya Municipality. It is proposed that this house, which is considered part of the local architectural heritage, can be reused as a book café. The transformation of this historical adobe house into a book café will provide a space where the city residents can read books while enjoying tea or coffee on the second floor, and taste local delicacies like “gözleme, börek etc” in the garden on the ground floor and the first floor. In this context, the information obtained during the research process aimed at the conservation of the building, the findings, decisions, and proposals are shared with researchers through produced drawings.

2 TRADITIONAL KÜTAHYA HOUSES AND REUSE PROPOSAL

The ground floors of Kütahya houses were planned as stone-paved areas used for services like stables and storage. Due to privacy concerns, the ground floor windows are few and small. The upper floors, arranged for daily needs, also served as winter quarters. While the houses from the 17th and 18th centuries had open exterior sofas (verandas), examples dating to the late 19th and early 20th centuries show a transition to interior and central sofas. On the upper floors, there are guest reception areas called "baş oda/ main room" and other rooms designed to accommodate functions such as sitting, sleeping, eating, and washing. These rooms, especially the baş oda, feature ornate wooden carvings on the ceiling, fireplace hood, wall niches, and the doors facing the sofa [9].

The house, located in the Börekçiler neighborhood of Kütahya, was built with three floors (Fig. 1, 2, 3). Based on the data from the conducted research, the plan features, construction technique, and materials of the building were evaluated, leading to the conclusion that the construction date is the late 19th century, with renovations occurring in the mid-20th century. Traces from the building and results from research on the local architectural fabric and analogical studies were used to identify elements that have undergone changes, partially or completely disappeared, or been added later. This restitution study has also guided the restoration project.

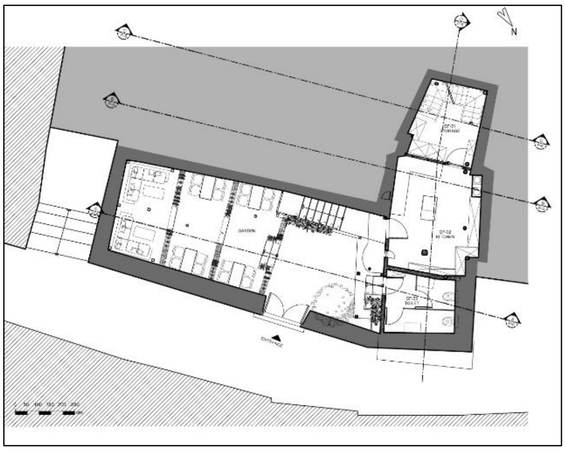


Figure 1. Ground Floor Plan.

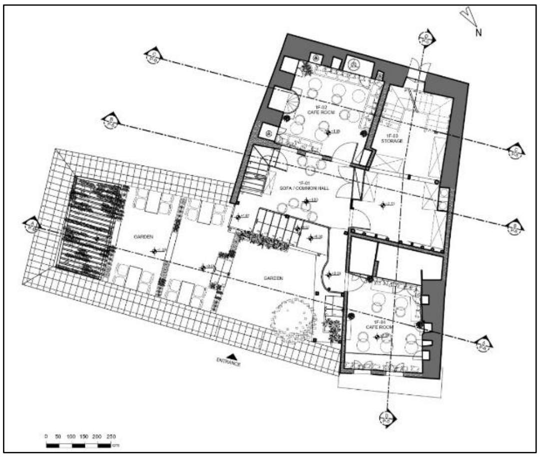


Figure 2. First Floor Plan.

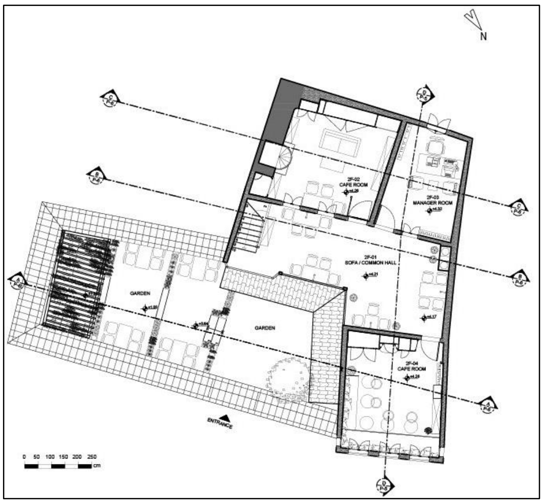
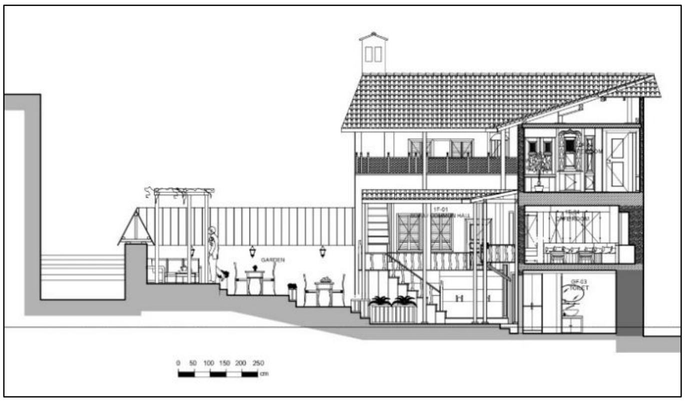


Figure 3. Second Floor Plan.
Figure 4. Second Floor Sofa.

Research on Kütahya houses classifies them based on the main floor plan, which includes the başoda. The shape and position of the "sofa/common area", or "hayat/ life" space, directly help determine the types of houses [6]. In this context, it can be said that the subject house was planned in an L shaped plan with a garden and falls under the typology of three-story houses with an exterior sofa (Fig. 2, 3, 4, 5, 6, 7, 8, 9, 10). The ground floor is constructed with stone, while the upper floors are built with adobe walls framed with wooden structures and plastered surfaces. The floor and roof systems are made of wooden beams and coverings, with a tiled hipped roof.

Figure 5, 6. Relationship between building and garden on the ground floor.

Like many Kütahya houses, the main facade, referred to as the "Hayat Facade," is oriented towards the garden due to its inward-facing structure (Fig. 4, 5, 6, 7). The entrance to the building is from the facade facing Kayadibi Street to the northeast. The main entrance gate of the house, a double-leaf wooden door located in the garden wall, retains its original character.



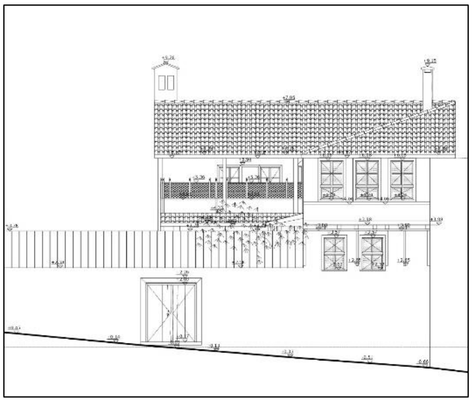


Figure 7. A-A Section

Figure 8. Main Facade

The ground floor wall on the entrance facade has no window, and the first floor windows are smaller than those on the main (second) floor (Fig: 7, 8, 9, 10). The windows are rectangular. The second floor which can be called as the main floor, emphasizes the facade more. In the room designed as the başoda on the main floor, a bay window /cumba was opened to benefit more from the view, air, and sunlight.

The northwest facade of the building is positioned according to the slope of the terrain, and the entire facade is plastered and painted. The horizontal, vertical, and diagonal connections of the wooden frame system used in the building, the stone walls and adobe plaster on the ground floor, and the bricks at the roof level can be seen on this facade.

Conservation problems of the house can be classified as follows;

• Structural Issues: During measurement and inspection work on the historical building, it was determined that the house has significant structural problems due to long-term lack of repairs and maintenance. Particularly on the upper floors, mass deflection and cracks and separations observed in the walls indicate structural issues. For example, from the facade view, it is evident that the wooden floor beam has deflected along the width of the facade at the level of the second floor (Fig. 11 a, b, c).

- Drainage Issues: Due to the neglect of the roof, the building has suffered significant damage from rain. Additionally, moisture problems have been observed in various parts of the basement floor.
- Material Issues: Due to the lack of maintenance and necessary repairs, severe material problems have been identified throughout the building. In this context, the plaster layers on the facade and interior walls have extensively peeled off, and in addition to that, mortar gaps have been observed in the joints of stone and mudbrick walls. Moreover, most of the wooden elements have decayed due to exposure to moisture and are unable to function in some places (Fig: 9, 10, 11 a, b, c).
- Inappropriate Interventions: Although minor interventions have been made at different times, the original planning system and construction technique of the building are still readable.
- Neglect and Vandalism: Since the building has been abandoned for quite a long period and the necessary maintenance and repair work has not been carried out, the structure has entered a rapid deterioration process.

Figure 9, 10. Main facade of the house; Original door and cumba/ bay window.

Figure 11. a, b, c. The structural problems and material deteriorations observed on the northeast façade of the building.

3 CONVERSION OF THE REGISTERED BUILDING FROM RESIDENTIAL TO CAFÉ FUNCTION

The building, constructed in the late 19th century with its original function as a residence, has been vacant for a long time. Considering the preservation of its original traditional architectural values, it is proposed to repurpose the building as a "Book Café" (Fig. 12, 13, 14).

In this context, the necessary structural conservation interventions required by the building should be carried out first. Under the supervision of an experienced engineer, the wooden frame system of the building should be temporarily supported, and decayed or deteriorated wooden elements in the wooden frame walls should be renewed in accordance with the original material and construction system. The same approach applies to the wooden floor beams where deflections are observed. After removing the later-added sections and covering of the hipped roof, the wooden elements should be repaired according to the restoration project, and where they cannot be repaired, they should be renewed to match the original details.

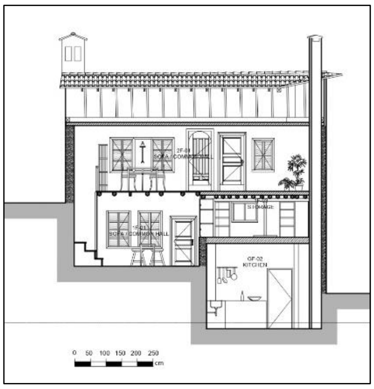


Figure 12. B-B Section.

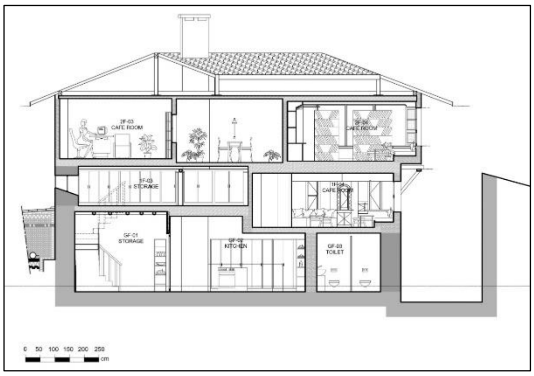


Figure 13. D-D Section.

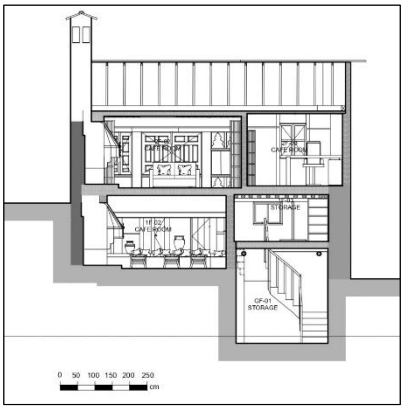


Figure 14. C-C Section.

The main approach adopted in the conservation project aims at proposing interventions that ensure the preservation of the building's original values in terms of design, architectural features, construction system, and material use (Fig. 15 a, b, 16 a, b). During the intervention proposals, it was aimed to preserve original and period-appropriate building elements in situ and the scope of intervention was increased where necessary due to the intensity of the building's problems.

Figure 15 a, b. Original architectural features of the room 2F04 (Seating place/ Sedir and traditional cupboards).

Figure 16 a, b. Original architectural features of the room 2F02 (Door of the room and original cupboards).

The successful adaptation of this building, which can no longer maintain its original function, to a book café will contribute to its preservation in the long term. In this context, a planning layout showed in the drawings, is proposed, and all interventions are recommended to be carried out accordingly. The proposed layout is detailed as follows:

- **Ground Floor:**
  - The two rooms originally used as stables and storage (GF01 and GF02) will be repurposed as service areas for staff. Specifically, GF02 will be designated as the kitchen, and GF01 as the storage room.
  - GF03, originally another service area, will be divided into two cabins for separate male and female restrooms.
  - The garden area, accessed through the double-leaf wooden gate, will feature three-tiered open seating areas on the left, where beverages and local delicacies can be served.
- **First Floor:**
  - The staircase from the ground floor, with its original wooden handrails, leads to the first floor's central hall (Sofa).
  - The first floor features rooms 1F02, 1F03, and 1F04 surrounding the Sofa. Rooms 1F02 and 1F04 will serve food and drinks, maintaining traditional elements like the wooden fireplace and seating in 1F02.
  - The room with low ceiling height (1F03) will be combined with the storage room below (GF01) for additional storage.
- **Second Floor:**
  - The second floor, which is the main floor of the building, will serve as a quieter area for reading and drinking tea or coffee. The central hall (2F01) and rooms 2F02 and 2F04 will be used for this purpose.
  - Room 2F03 will be designated as the manager's office.

4 CONCLUSION

Adapting a historical building that can no longer serve its original function to a suitable new purpose can significantly contribute to its preservation. Numerous successful examples of such adaptive reuse projects can be seen worldwide and in Turkey.

It is proposed that the house can be reused as a book café. Such conservation efforts allow the integration of past architectural traditions and creativity into contemporary life. Following the necessary conservation interventions, the building's traditional elements can be combined with modern touches to create a warm and inviting atmosphere. Additionally, the garden or courtyard can be organized as an open space for café customers, providing an opportunity to spend time in a natural and historical setting.

Converting a historical Kütahya house into a "Book Café" is an ideal project for both preserving the structure and giving it a new social and cultural function. In this context:

- **Ground Floor:** Service areas, kitchen, storage, and restrooms.
- **First Floor:** Café areas, seating arrangements, and reading spaces.
- **Second Floor:** Quiet reading areas and a manager's office.

In the restoration process, where it is proposed to transform the historical house into a modern cafe by assigning a new function, an approach that respects the original values of the building should be adopted. This approach is also considered valuable for raising awareness on how sustainability can be achieved by giving a different function to historical houses that can no longer maintain their original purpose.

Note: Photographs and drawings that are not referenced belong to the author.

5 ACKNOWLEDGMENTS

I would like to thank Kütahya Municipality and the staff of the Conservation Implementation and Inspection Bureau (KUDEB), who aimed to repair the historical Kütahya house, which is an architectural heritage.

6 REFERENCES

[1] Viollet-le-Duc, E.-E. "*Dictionnaire raisonné de l'architecture française du XIe au XVIe siècle*, Paris, 1875.
[2] Kuleli, A. E. "Tarihi Yapıların Yeni İşlevle Değerlendirilmesi Yaklaşımının İrdelenmesi; Bursa Yeşil Külliyesi Medresesi Örneği" in *Tarihi Yapı Sektöründe Yenilikçi Yaklaşımlar*, pp. 13-30, 2018.
[3] Venice Charter, "International Charter for the Conservation and Restoration of Monuments and Sites." ICOMOS, (1964).
[4] Amsterdam Declaration, "Congress on the European Architectural Heritage." Council of Europe. (1975).
[5] Burra Charter, "The Australia ICOMOS Charter for Places of Cultural Significance." Australia ICOMOS, (2013).
[6] Eser, L. Kütahya Evleri (Doçentlik Çalışması), Pulhan Matbaası, İstanbul, 1955.
[7] Eldem, S. H. Türk Evi Plan Tipleri, Pulhan Matbaası, İstanbul, 1954.
[8] Kuban, D. *Türk "Hayat"lı Evi*, Mısırlı Matbaacılık A.Ş., İstanbul, 1995.
[9] Küçükerman, Ö. *"Turkish House: In Search of Spatial Identity"* Türkiye Turing ve Otomobil Kurumu, Temel Matbaacılık, İstanbul, 1991.

Comparative Analysis of Load-Bearing Wall Design Using Concrete and Earthen Materials for Office Buildings


Ayse Pekrioglu Balkis[1]
Aya Ahmad [2]
[1]Cyprus International University, North Cyprus
[2]Final International University, North Cyprus
[1]apekrioglu@ciu.edu.tr
[2]aya.ahmad@final.edu.tr

ABSTRACT

This study presents a comprehensive analysis of load-bearing wall design for office buildings, focusing on the comparative performance of two distinct materials: conventional concrete and earthen materials. As the demand for sustainable construction practices rise, the exploration of alternative building materials gains prominence. The research aims to evaluate the structural, environmental, and economic aspects of load-bearing walls constructed with concrete and earthen materials. The investigation begins with an in-depth review of existing literature on load-bearing wall design, emphasizing the significance of material selection in achieving structural integrity and sustainability goals. Subsequently, the study delves into the mechanical properties of concrete and earthen materials, exploring their respective strengths, weaknesses, and suitability for load-bearing applications. Office with 100 m^2 has been designed by using ETABS with concrete and adobe to compare the advantages of earthen material considering cost, environmental effect and construction time over concrete. The focus extends beyond structural considerations to encompass environmental impacts, including embodied energy and carbon footprint, as well as economic factors such as material cost and availability. Findings from this research provide valuable insights for architects, engineers, and construction professionals seeking sustainable solutions for office building projects. The study contributes to the growing body of knowledge of eco-friendly construction practices, offering a balanced perspective on the trade-offs and benefits associated with the use of concrete and earthen materials in load-bearing wall design. Ultimately, this research aids in informed decision-making, promoting the adoption of environmentally conscious and economically viable building practices in the construction industry.

Keywords :

Adobe, Concrete, Earthen Materials, Load Bearing Walls, Sustainability

1 INTRODUCTION

Importantly, earthen buildings offer a holistic approach to construction that prioritizes harmony with nature [9]. By utilizing earth's abundant resources and minimizing energy-intensive processes, they embody principles of environmental stewardship and resource efficiency. Moreover, their thermal mass properties provide natural insulation, contributing to energy efficiency and climate resilience in a changing world [22]. Often built using traditional techniques passed down through generations, they foster a sense of community and cultural identity. Furthermore, their affordability and accessibility make them a vital housing solution for marginalized communities, offering safe and sustainable shelter where conventional construction methods may be impractical or unaffordable.

In contrast, reinforced concrete buildings, emblematic of modernity and technological prowess, represent a departure from the natural world [12]. Utilizing steel reinforcement and cementitious materials, these structures have reshaped skylines and urban landscapes, offering unparalleled strength, versatility, and architectural freedom. Yet, their reliance on energy-intensive materials and processes comes at a significant environmental cost, contributing to carbon emissions and resource depletion on a global scale. Concrete, hailed as the "backbone of modern construction," has earned its reputation as a preferred material for load-bearing walls due to its exceptional compressive strength and moldability. The ubiquitous use of concrete in office buildings underscores its reliability and widespread acceptance in the construction industry [14]. However, the environmental toll exacted by cement production, a key component of concrete, raises pertinent concerns regarding its long-term sustainability.

Opting to construct load-bearing walls using eco-friendly materials transcends mere ethical or aesthetic considerations. It represents a deliberate, tactical approach to addressing the pressing demand for transformative solutions. By acknowledging the capacity to reduce the environmental footprint of construction endeavors, this initiative is dedicated to thoughtfully curating and incorporating materials distinguished by their renewability, recyclability, and minimal embodied energy [8].

In conclusion, this study represents a beacon of change within the construction realm. Through the utilization of innovative materials and construction methods, it seeks to establish a new benchmark for eco-friendly building practices, marking the beginning of a transformative journey towards a sustainable and resilient future.

2 METHODOLOGY

Designing load-bearing walls with environmentally friendly materials necessitates navigating a myriad of practical constraints to ensure structural integrity, sustainability, and adherence to building codes. This involves a meticulous process of evaluating material properties, construction techniques, and regulatory requirements to strike a balance between eco-conscious design principles and practical feasibility within the context of office building construction. The office layout depicted in Fig. 1 serves as the blueprint for this investigation.

Figure 1. Office Plan

2.1 Concrete Walls

Table 1 illustrates the properties of Concrete Wall Material, while Fig. 2 demonstrates the Axial Load Analysis for a Concrete Wall with a thickness of 20 cm.

Table 1. Concrete Wall Material Properties

Story	Object Type	Material	Weight kN	Floor Area m2	Unit Weight kN/m2
Story1	Beam	4000Psi	3.1103	10.24	0.3037
Story1	Wall	C25	162.96	10.24	15.9141
Story1	Floor	C25	24.576	10.24	2.4
Sum	Beam	4000Psi	3.1103	10.24	0.3037
Sum	Wall	C25	162.96	10.24	15.9141
Sum	Floor	C25	24.576	10.24	2.4
Total	All	All	190.6463	10.24	18.6178

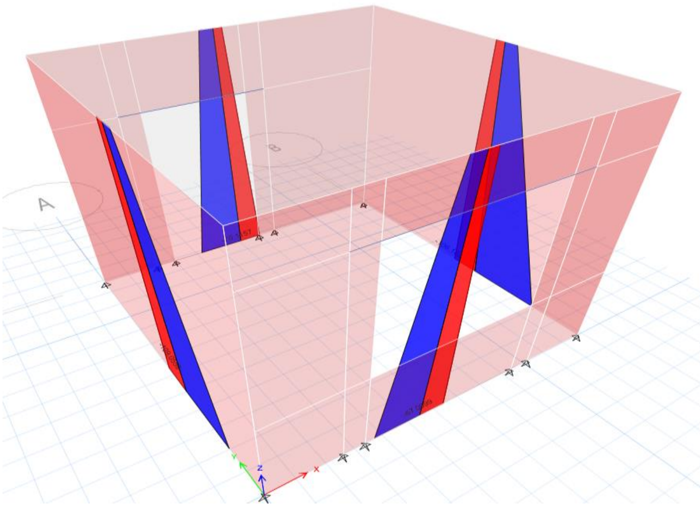


Figure 2: Axial Load Analysis for Concrete Wall with 20 cm Thickness

2.2 Earthen Walls

Table 2 displays the material properties of Earthen walls, while Fig. 3 presents the Axial Load Analysis for a Masonry Wall with a thickness of 25 cm.

Table 2. Material Properties - General

Material	Type	SymType	Grade	Color
4000Psi	Concrete	Isotropic	f'c 4000 psi	Blue
A416Gr270	Tendon	Uniaxial	Grade 270	Yellow
A615Gr60	Rebar	Uniaxial	Grade 60	Red
A992Fy50	Steel	Isotropic	Grade 50	Gray8Dark
C25	Concrete	Isotropic	f'c 25 MPA	Cyan
MASSONARY	Masonry	Isotropic	fcm 2000 psi	Green

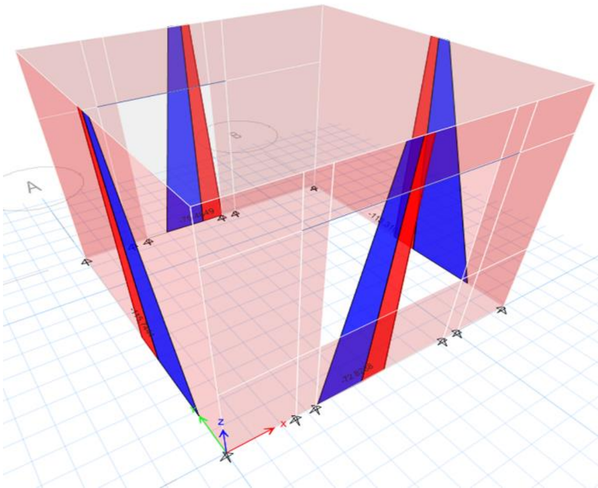


Figure 3: Axial Load Analysis for Masonry Wall with 25 cm Thickness

2.3 Earthen Wall Design

Earthen walls, characterized by their use of natural materials such as adobe, rammed earth, and compressed earth blocks (CEBs), offer a sustainable and cost-effective alternative to concrete in office building construction [19]. Design considerations for earthen walls prioritize the use of locally sourced materials and traditional building techniques to minimize environmental impact and maximize thermal performance [17]. Unlike concrete, which requires elaborate.

In terms of cost analysis, earthen walls present several economic advantages over concrete, including lower material costs, reduced labor requirements, and minimal reliance on heavy equipment. The affordability of earthen materials, coupled with their availability and ease of construction, contributes to significant cost savings compared to conventional building materials [10]. Additionally, the thermal properties of earthen walls contribute to energy efficiency and indoor comfort, potentially reducing heating and cooling expenses over the building's lifespan [4]. From an environmental perspective, earthen construction offers a sustainable solution with minimal carbon footprint, as it utilizes natural materials that are abundant and renewable. The use of earthen walls can also promote local economies and cultural heritage, fostering community engagement and resilience [3]. Despite their many benefits, earthen walls may require additional protection against moisture, erosion, and pests, as well as periodic maintenance to ensure structural integrity and longevity [15]. Overall, earthen walls represent a promising option for load-bearing wall design in office buildings, offering a harmonious blend of sustainability, affordability, and architectural appeal.

2.4 Concrete Wall Design

Concrete walls are renowned for their exceptional structural strength and durability, making them a prevalent choice for load-bearing applications in office buildings. Design considerations for concrete walls often revolve around formwork requirements, as the material needs to be poured into molds and allowed to cure to achieve the desired shape and strength [21]. Additionally, architectural aesthetics and functional requirements play a significant role in concrete wall design, with options for various finishes, textures, and surface treatments to enhance the building's appearance and performance. From a structural perspective, concrete walls boast high compressive strength, providing robust support for vertical loads and resisting deformation under pressure [13]. However, their relatively low tensile strength necessitates the inclusion of steel reinforcement to enhance structural stability and prevent cracking [20]. Despite their impressive strength, concrete walls can be susceptible to environmental degradation over time, especially in corrosive environments or areas prone to seismic activity [6]. Moreover, the production of concrete involves significant energy consumption and carbon emissions, contributing to its environmental impact.

The cost analysis of concrete walls typically includes expenses for materials, labor, equipment, and maintenance. While concrete offers excellent durability and long-term performance, its initial construction costs can be relatively high due to the need for specialized formwork, skilled labor, and heavy machinery [11]. Additionally, ongoing maintenance and repair requirements, such as sealing cracks and addressing corrosion of reinforcement, can add to the lifecycle costs of concrete walls [2]. However, concrete's durability and fire resistance may result in lower long-term maintenance expenses compared to other materials. When evaluating the environmental impact of concrete walls, factors such as embodied carbon emissions, energy consumption during production, and waste generation should be considered [5]. Despite its drawbacks, concrete remains a versatile and widely used material in construction, offering unparalleled strength, durability, and design flexibility for load-bearing wall applications in office buildings.

3 COST ANALYSIS: CONCRETE VS. EARTHEN WALL DESIGN

The cost analysis shown in Table 1 reveals a notable disparity between the expenses associated with constructing load-bearing walls using concrete and earthen materials for office buildings. Concrete walls incur a significantly higher cost, with an average expenditure of 2588 USD, compared to the more economical alternative of earthen walls, which amounts to 1596.5 USD. This finding aligns with the research by Dormohamadi et al.[7].

Table 3. Cost Analysis for Concrete Wall

		Concrete Wall			**Earthen Block**		
		Quantity	Cost ($)/ Unit	Cost	Quantity	Cost / Unit	**Cost**
Slab	concrete	0.9 m³	85/m³	76	0.9 m³	85/m³	**76**
	steel	2 #	50	100	2 #	50	**100**
	formwork	-	-	38	-	-	**38**
	workers	team(2)	50	50	team(2)	50	**50**
walls	concrete	7.2	85/m³	612	-	mortar	**49.5**
	steel	12 #	50	600	-	-	**-**
	formwork	-	-	287	-	-	**-**
	workers	team(2)	50	100	-	50	**200**
	block (0.2*0.15*0.1)	-	-	-	2383	0.15	**358**
footing	concrete	2.88 m³	85/m³	245	2.88 m³	85/m³	**245**
	steel	500 Kg	0.8/ Kg	400	500 Kg	0.8/ Kg	**400**
	formwork	-	-	30	-	-	**30**
	workers	team(2)	50	50	team(2)	50	**50**
Total cost ($)				2588			**1596.5**

This disparity can be attributed to several factors inherent to each construction material. Concrete, a widely utilized building material in modern construction, involves high production costs, transportation expenses, and labor-intensive installation processes [1]. Additionally, the use of reinforcing steel and specialized formwork further contributes to the overall expense of concrete wall construction.

In contrast, earthen materials such as adobe, rammed earth, and compressed earth blocks (CEBs) offer a cost-effective solution characterized by readily available raw materials, simplified construction techniques, and reduced reliance on mechanized processes [16]. The lower cost of earthen wall construction can also be attributed to the minimal processing required for earth-based materials and the potential for on-site sourcing, minimizing transportation costs.

Furthermore, the economic viability of each construction method must be evaluated within the broader context of sustainability and environmental impact. Concrete production is known to contribute significantly to carbon emissions and environmental degradation, necessitating careful consideration of its ecological footprint. In contrast, earthen construction embodies principles of sustainability, offering a renewable and low-impact alternative that aligns with the growing demand for eco-friendly building practices [18].

In conclusion, while concrete walls may initially entail higher costs, the economic benefits of earthen wall construction, coupled with its environmental advantages, underscore its potential as a cost-effective and sustainable solution for load-bearing wall design in office buildings.

4 CONCLUSIONS

In conclusion, the utilization of environmentally friendly materials in the design of load-bearing walls marks a substantial advancement in sustainable construction methodologies. This journey underscores the critical role that material selection plays in mitigating environmental harm and fostering ecological equilibrium. By embracing eco-conscious alternatives for load-bearing wall construction, we not only diminish the carbon footprint inherent in traditional building practices but also actively contribute to the conservation of precious natural resources and the overall health of our planet.

In the design process, selecting sustainable materials stands as a primary consideration. Opting for materials like recycled steel, engineered wood products, bamboo, and rammed earth presents a host of environmental advantages. These options typically boast lower embodied energy, necessitating fewer resources and less energy for production compared to conventional counterparts. Moreover, their renewable or recycled attributes aid in conserving finite resources and reducing waste generation, aligning with the ethos of sustainable construction.

Moreover, the utilization of environmentally friendly materials in the design of load-bearing walls extends their benefits beyond the construction phase. These materials often exhibit superior thermal properties, thereby improving the overall energy efficiency of buildings. By diminishing the need for heating and cooling, sustainable walls facilitate lower energy consumption and reduced greenhouse gas emissions throughout the structure's lifespan. This not only positively impacts the environment but also translates into tangible cost savings for occupants through decreased utility expenses.

Additionally, integrating eco-friendly materials into load-bearing wall design aligns seamlessly with the principles of the circular economy and cradle-to-cradle philosophy. A significant number of these materials are either recyclable or biodegradable, enabling their eventual reuse or safe decomposition at the conclusion of their lifecycle. This closed-loop approach not only reduces waste generation but also fosters a more sustainable and regenerative building industry, embodying a holistic approach to environmental stewardship.

In addition to environmental benefits, incorporating environmentally friendly materials into load-bearing wall design can significantly enhance the aesthetic appeal and occupant comfort of buildings. Sustainable materials frequently feature distinctive textures, colors, and patterns that contribute to a visually appealing environment. Moreover, their inherent properties, such as breathability and moisture regulation, can foster healthier indoor spaces by promoting improved air quality and humidity control, thereby enhancing overall occupant well-being.

In conclusion, the design of load-bearing walls with environmentally friendly materials epitomizes a holistic approach to sustainable construction, encompassing environmental, economic, and social advantages. By emphasizing the adoption of renewable, recycled, and low-impact materials, we have the potential to construct buildings that not only fulfill present needs but also safeguard the well-being of future generations and our planet as a whole. Embracing sustainable practices in construction is not merely an option but a responsibility, and the design of load-bearing walls offers a tangible opportunity to actively contribute to a more sustainable built environment.

5 REFERENCES

[1] Adegun, O. B., & Adedeji, Y. M. D. (2017). Review of economic and environmental benefits of earthen materials for housing in Africa. Frontiers of Architectural Research, 6(4), 519-528.
[2] Barreto, M. M., Timm, J. F. G., Passuello, A., Dal Molin, D. C. C., & Masuero, J. R. (2021). Life cycle costs and impacts of massive slabs with varying concrete cover. *Cleaner Engineering and Technology*, 5, 100256.
[3] Ben-Alon, L., Loftness, V., Harries, K. A., Hameen, E. C., & Bridges, M. (2020). Integrating earthen building materials and methods into mainstream construction. *Journal of Green Building*, 15(1), 87-106.
[4] Chandel, S. S., Sharma, V., & Marwah, B. M. (2016). Review of energy efficient features in vernacular architecture for improving indoor thermal comfort conditions. *Renewable and Sustainable Energy Reviews*, 65, 459-477.
[5] Chamasemani, N. F., Kelishadi, M., Mostafaei, H., Najvani, M. A. D., & Mashayekhi, M. (2023). Environmental Impacts of Reinforced Concrete Buildings: Comparing Common and Sustainable Materials: A Case Study. *Construction Materials*, 4(1), 1-15.
[6] Chen, Z., Feng, D. C., Cao, X. Y., & Wu, G. (2024). Time-variant seismic resilience of reinforced concrete buildings subjected to spatiotemporal random deterioration. *Engineering Structures*, 305, 117759.
[7] Dormohamadi, M., Rahimnia, R., & Bunster, V. (2024). Life cycle assessment and life cycle cost analysis of different walling materials with an environmental approach (comparison between earth-based vs. conventional construction techniques in Iran). *The International Journal of Life Cycle Assessment*, 29(3), 355-379.
[8] Jayasinghe, C., Fonseka, W. M. C. D. J., & Abeygunawardhene, Y. M. (2016). Load bearing properties of composite masonry constructed with recycled building demolition waste and cement stabilized rammed earth. *Construction and building materials*, 102, 471-477.
[9] Klinge, A., Roswag-Klinge, E., Neumann, E., Bojic, D., & Radeljić, L. (2022, September). Earthen construction materials as enabler for circular construction. In IOP Conference Series: *Earth and Environmental Science* (Vol. 1078, No. 1, p. 012065). IOP Publishing.
[10] Kulshreshtha, Y., Mota, N. J., Jagadish, K. S., Bredenoord, J., Vardon, P. J., van Loosdrecht, M. C., & Jonkers, H. M. (2020). The potential and current status of earthen material for low-cost housing in rural India. *Construction and Building Materials*, 247, 118615.
[11] Kurpinska, M., Grzyl, B., & Kristowski, A. (2019). Cost analysis of prefabricated elements of the ordinary and lightweight concrete walls in residential construction. *Materials*, 12(21), 3629.
[12] Makul, N. (2020). Advanced smart concrete-A review of current progress, benefits and challenges. *Journal of Cleaner Production*, 274, 122899.
[13] Martins, R., Carmo, R. D., Costa, H., & Júlio, E. (2023). A review on precast structural concrete walls and connections. *Advances in Structural Engineering*, 26(14), 2600-2620.
[14] Melià, P., Ruggieri, G., Sabbadini, S., & Dotelli, G. (2014). Environmental impacts of natural and conventional building materials: a case study on earth plasters. *Journal of cleaner production*, 80, 179-186.
[15] Morel, J. C., Charef, R., Hamard, E., Fabbri, A., Beckett, C., & Bui, Q. B. (2021). Earth as construction material in the circular economy context: practitioner perspectives on barriers to overcome. *Philosophical Transactions of the Royal Society B*, 376(1834), 20200182.

[16] Nouri, H., Safehian, M., & Mir Mohammad Hosseini, S. M. (2023). Life cycle assessment of earthen materials for low-cost housing a comparison between rammed earth and fired clay bricks. International Journal of Building Pathology and Adaptation, 41(2), 364-377.
[17] Pacheco-Torgal, F., & Jalali, S. (2012). Earth construction: Lessons from the past for future eco-efficient construction. *Construction and building materials*, 29, 512-519.
[18] Pons, J. J., Penadés-Plà, V., Yepes, V., & Martí, J. V. (2018). Life cycle assessment of earth-retaining walls: An environmental comparison. Journal of Cleaner Production, 192, 411-420.
[19] Thompson, D., Augarde, C., & Osorio, J. P. (2022). A review of current construction guidelines to inform the design of rammed earth houses in seismically active zones. *Journal of Building Engineering*, 54, 104666.
[20] Sabouni, A. R. (2023). Advances in Reinforced Concrete Integrity and Failure.
[21] Tierney, L., & Safiuddin, M. (2022). Insights into Concrete Forming, Reinforcing, and Pouring in Building Construction. *Buildings*, 12(9), 1303.
[22] Zhang, Y., Jiang, S., Quan, D., Fang, K., Wang, B., & Ma, Z. (2024). Properties of Sustainable Earth Construction Materials: A State-of-the-Art Review. *Sustainability*, 16(2), 670.

Evaluation of Thermal Performance of Adobe Tandır Houses in Rural Van Province

Berfin Şeker, **Assoc. Prof. Dr. Şefika Ergin**

Faculty of Architecture, Department of Architecture
Dicle University, Diyarbakır

gokdemirb@hotmail.com

ABSTRACT

Adobe is one of the oldest materials produced and used since the emergence of the need for shelter. Just as its traces have surfaced in the architecture of ancient times, adobe continues to exist today, especially in rural architecture. Adobe is widely used as a building material worldwide due to its high thermal insulation properties, indoor moisture control, no need for facilities, sustainability and low cost. As a traditional solution, it provides the comfort and health conditions required in interiors with minimum energy and cost. In this context, it is important to document the original examples and principles of adobe architecture in the literature. The aim of this study is to examine the thermal performance of selected adobe tandır houses in rural settlements of Van province in cold climate. The thermal performance analysis of the adobe house, whose plan was obtained with the photographs and drawings obtained by field study, was carried out with DesignBuilder software. Adobe tandır houses are unique examples of traditional adobe architecture shaped by physical environmental conditions in terms of both their characteristic architecture and the thermal gain they provide to the dwelling. As a result, they should be considered as a cultural architectural value, recorded and preserved in their original form.

Keywords: Thermal performance, adobe, rural architecture, tandoor house.

1 INTRODUCTION

Adobe stands out as an important building material in civil, religious and military structures throughout architectural history. Adobe was the first building material used by humans during the transition to settled life. The materials that form the basis of the arches, vaults and domes used in traditional large covering systems are generally earth-based materials such as adobe and brick. Adobe provides high thermal insulation, moisture control, flexible use and sustainability at low cost. In regions where materials such as wood and stone are not available, adobe is often preferred. The oldest examples of building traditions based on earth-based materials such as adobe and brick are found in Mesopotamia, Iran and Central Asia [1]. Today, studies show that approximately 30% of the world's population lives in buildings made of earth-based materials [2].

Figure 1. New Mexico Taos Native Houses (Pueblos) and Konya Çatalhöyük adobe architecture [3,4].

The place of adobe in traditional architecture in Turkey is often emphasized as a structural and filling material. As a traditional building material, adobe stands out with its advantages such as being easily obtainable, not requiring special facilities for production, and providing both heat and moisture insulation at low cost. Especially in Van province, which has cold climatic conditions, tandır houses built of adobe are used for cooking and water heating as well as a climatic design strategy. Cold climatic conditions require users to spend most of their time indoors. In this context, tandır houses offer users a comfortable space where they communicate and transfer their knowledge and experience. Today, the use of tandır houses, which are an architectural and cultural heritage, is decreasing and disappearing. Tandır houses, which are built from adobe, a natural material, and have an important place in the social life of users, should be recorded and protected with their original quality. In this context, in this study, research was conducted on the thermal gain provided to the neighboring spaces by a housing sample with a adobe tandır house selected from Mollatopuz village of Özalp district of Van province. The house was modeled with DesignBuilder software and thermal performance analysis was performed.

2 RURAL ARCHITECTURE OF VAN PROVINCE

The most important parameter shaping the architecture of rural Van province is the elevation and harsh continental climate of the region. Elevation and harsh winter conditions affect the social, economic, demographic and settlement status of the local people. The Eastern Anatolia Region's Upper Murat-Van Section includes the Van province and the area around Lake Van (Fig. 2). In terms of population, it is the biggest city in the area. Several civilizations have resided in the residential region surrounding Lake Van over the course of history. It contains abundant surface resources in addition to being in a handy location for settlement. In the plains, the human communities who had established here continued to farm, while in the highlands, they raised animals [5].

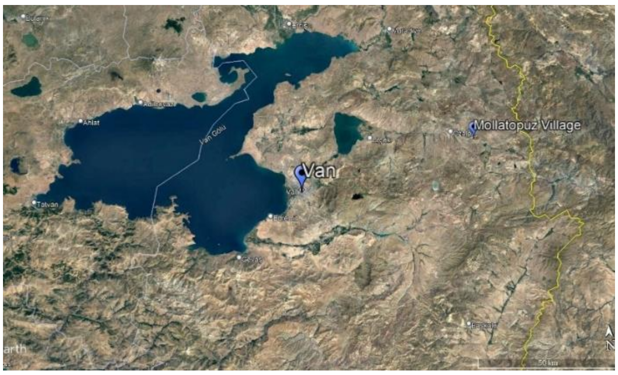


Figure 2. Satellite view of Van province and study area (Google Earth).

The average altitude of the Van region is 2200-2500 m, which is higher than the average altitude of the Eastern Anatolia Region. In the province of Van, where the continental climate is dominant, there are short spring and autumn seasons, a snowy, frosty, rainy, cold and long winter season, and a hot, dry and short summer season [6]. According to measurements made between 1939-2022, the month with the highest average temperature is July with 22.3 °C, and the month with the lowest average temperature is January with -3.1 °C (Fig.3). The average annual total rainfall is 392.7 mm [7].

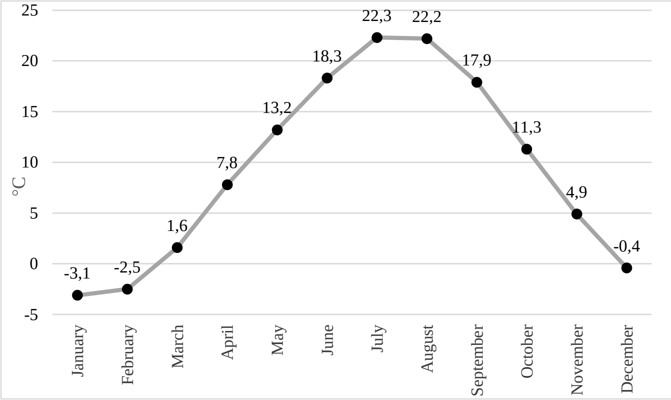


Figure 3. Van province average temperature (1939-2022) [7].

Adobe material was used in the civil, military and religious architecture of the Urartians around Van and in civil architecture in general during the Middle Ages and later (Fig.4) [8]. The adobe material, which is easy to construct and maintain, balances the humidity level in the interior by absorbing the moisture in the air thanks to its porous structure. It protects the building from unwanted hot or cold weather conditions of the external environment with its long-time delay aspect [9].

Figure 4. Examples of adobe houses from the village of Mollatopuz in Van (Şeker Archive).

The single-storey adobe houses in the study area consist of multi-purpose rooms, sofa, storage, corral, barn and tandır house units. Wet units such as kitchens and bathrooms are not planned independently, and activities in these units are carried out on raised floors in tandır houses. The adobe wall thickness of the houses in the region is between 40-65 cm. In Mollatopuz village, the wall thickness of the houses was measured as 50 cm. Compressed soil is generally used as flooring material in adobe houses. Soil, which is the main material of the buildings, is also used in the upper cover system of the houses. In the study area, the upper cover systems can be classified as flat roof and cover systems formed with the corbelling technique. In flat roof coverings, wooden beams ranging in thickness between 10-20 cm are placed at 20-30 cm intervals along the short direction of the space and covered with covering boards and thin branches. The covering is covered with 20-25 cm thick loam and straw (Fig.5).

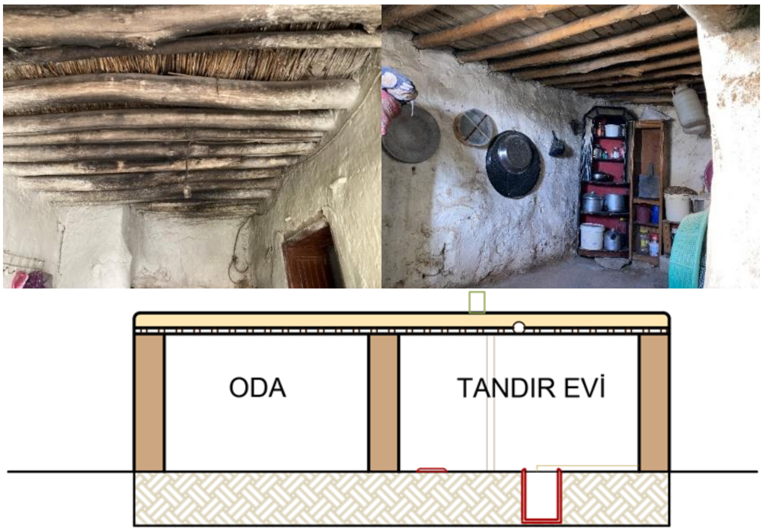


Figure 5. Exterior and interior view of the flat earthen roof from Mollatopuz Village (Şeker Archive).

In the corbelled roof system, rafters with a diameter of 15 cm are placed on 4 wooden posts with a diameter of 15 cm to form the skeleton. The corners of the square pyramid-shaped cover sit on the framework. An opening is left in the center of the pyramid for smoke evacuation from the tandır house. The 7-8 cm diameter rafters are placed at an angle to the framework to form a pyramid (Fig.6) [10].

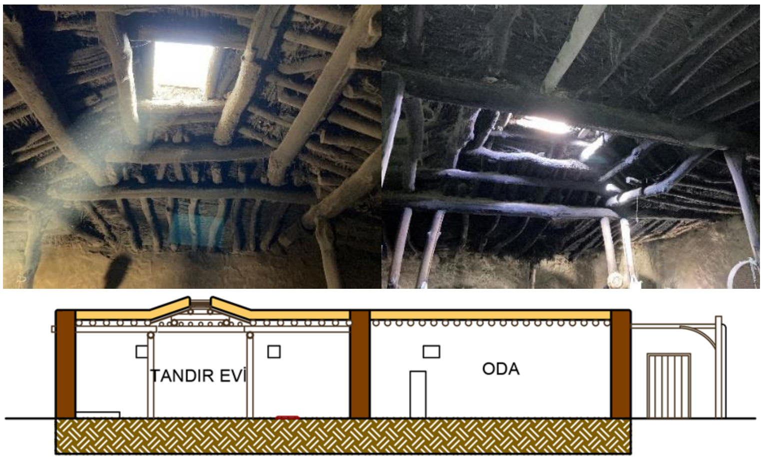


Figure 6. Corbelled roof section, plan and view of tandır houses (Şeker Archive).

3 EVALUATIONS OF THERMAL PERFORMANCE OF ADOBE TANDIR HOUSES IN RURAL VAN PROVINCE

The single-story adobe house selected for analysis from Mollatopuz village consists of a tandır house, a room, and a sofa (Fig.7). Scenarios with and without tandır were created in DesignBuilder software and the indoor and outdoor temperatures of the tandır house and room units of the adobe house were compared for a period of 1 year.

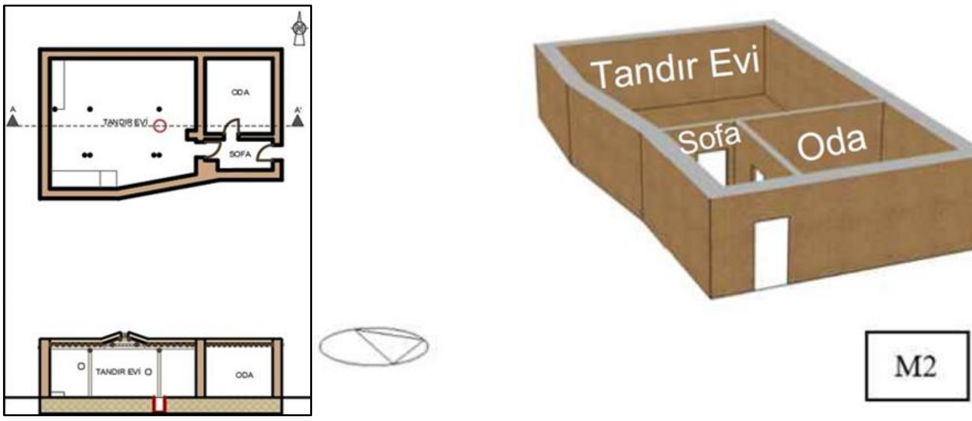


Figure 7. Plan, section and 3D model of the adobe house studied (Şeker Archive).

3.1 Simulation Data Input

Climatic, spatial, structural, user and equipment data entries were made for thermal performance analysis in the software. In the scenario created; the number of users was determined as 2 adults and 2 children, totaling 4 people. In the adobe house, it is assumed that no heating system other than the tandır is used during the heating period. In order to run the simulation; in addition to the building tag, HVAC systems and hot water systems, the dimensional and thermophysical properties of the existing building components and building materials of the houses were defined. The U-values of the building components such as walls, floors and layers of the roofing system are presented (Table 1).

Table 1. Material data of the building components of the analyzed house.

Layers	**Walls**	**Thickness (cm)**	**Thermal Conductivity (W/mK)**	**U** Value **(W/m²K)**
Wall Layers	Adobe Plaster	2,5 cm	**0,40**	**0,674**
	Adobe Brick	55 cm		
	Adobe Plaster	2,5 cm		
Floor Layers	Adobe	20 cm	**0,40**	**2,174**
Top Cover Layers	Clay + Loam Mixture	25 cm	**0,40**	**0,545**
	Covering Board	5 cm	**0,14**	
	Wooden Rafter	10 cm	**0,14**	
Door	Wooden Molding	3,5 cm	**0,19**	**2,832**
Window	Wooden Frame	5 cm	**0,19**	**2,309**

Due to the examination of the thermal performance of the house in the heating period, the indoor air temperature that provides indoor comfort in the winter period was determined as 22 ºC as the comfort degree and the heating setback setting as 12 ºC. The infiltration rate, which is the air infiltration rate, was determined as 0.8 (h^{-1}) with an average value of "nh". It was assumed that the tandır was used only for cooking and water heating during 12:00-15:00 of the day in June, July and August, and for heating purposes in addition to cooking and water heating during 15:00-18:00 and 19:00-22:00 in the remaining months of the heating period.

3.2 Temperature Analysis: Scenario with and without Tandır

In the scenario with tandır, the difference between the indoor and outdoor temperature of the tandır house was 15.84 °C in December, 21.02 °C in January, 18.98 °C in February and 17.97 °C in March, which were higher than the other months of the year. According to January measurements; the average indoor temperature value of the tandır house was 17.16 °C and the average outdoor temperature value was -3.86 °C. The highest monthly average indoor and outdoor temperature difference was 21.02 °C in this month. According to July measurements; the average indoor temperature value of the tandır house was 21.55 °C and the average outdoor temperature value was 21.44 °C. The lowest monthly average indoor and outdoor temperature difference was 0.11 °C in this month.

In the scenario where the tandır is used, the difference between the room indoor and outdoor temperature reached 11.05 °C in December, 14.83 °C in January, 13.34 °C in February and 13.09 °C in March, which are higher than the other months of the year. According to January measurements, the average indoor temperature value of the room was 10.97 °C and the average outdoor temperature value was -3.86 °C. The highest monthly average indoor and outdoor temperature difference was 14.83 °C in this month. According to August measurements; the average indoor temperature value of the room was 21.67 °C and the average outdoor temperature value was 22.44 °C. The lowest monthly average indoor and outdoor temperature difference was 0.75 °C in this month (Fig.8).

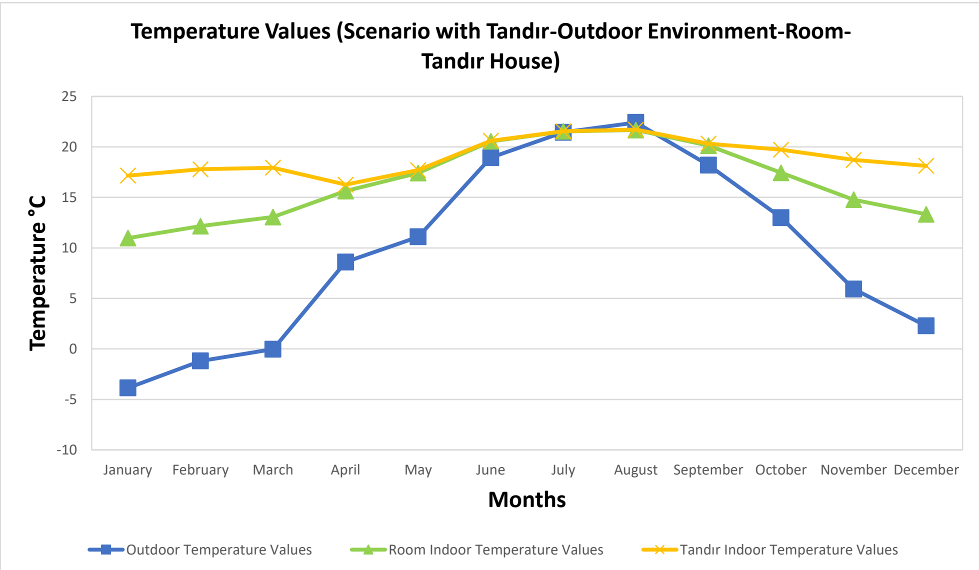


Figure 8. Indoor and outdoor temperature comparison of the tandır house and room unit in the scenario where the tandır is active.

Comparisons of the scenario with and without tandır were carried out for the tandır house and the adjacent room used as living space. The indoor temperature values of the tandır house reached higher temperatures in the scenario with tandır than in the scenario without tandır, with a difference of 3.14 °C in December, 4.68 °C in January, 3.81 °C in February and 3.32 °C in March. In both scenarios, the same temperature values were measured from May to September, when no heating is required. In the annual average, while the outdoor temperature was 9.73 °C, the indoor temperature of the tandır house was 18.96 °C in the scenario with tandır and 17.44 °C in the scenario where the tandır was turned off. The annual average difference between the indoor temperatures of the two scenarios is 1.51 °C. The thermal mass of the building envelope of the adobe dwelling allowed for higher indoor temperatures than the outdoor temperature in both scenarios (Fig.9).

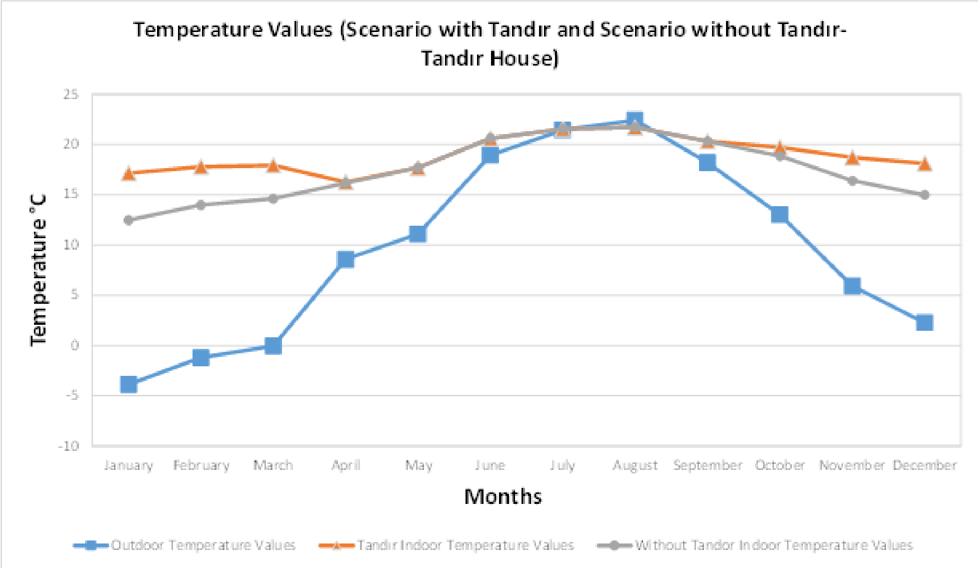


Figure 9. Tandır house, indoor vs. outdoor temperature comparison for the scenario where the tandır is active vs. passive.

The indoor temperature values of the room reached higher temperatures in the scenario with the tandır than in the scenario with the tandır turned off with a difference of 0.25 °C in December, 0.37 °C in January, 0.34 °C in February and 0.27 °C in March. In both scenarios, the same temperature values were measured from May to September, when no heating is required. In the annual average, while the outdoor temperature was 9.73 °C, the indoor temperature of the room was 16.55 °C in the scenario with the tandır and 16.42 °C in the scenario where the tandır was turned off. The annual average difference between the indoor temperatures of the two scenarios is 1.12 °C (Fig.10).

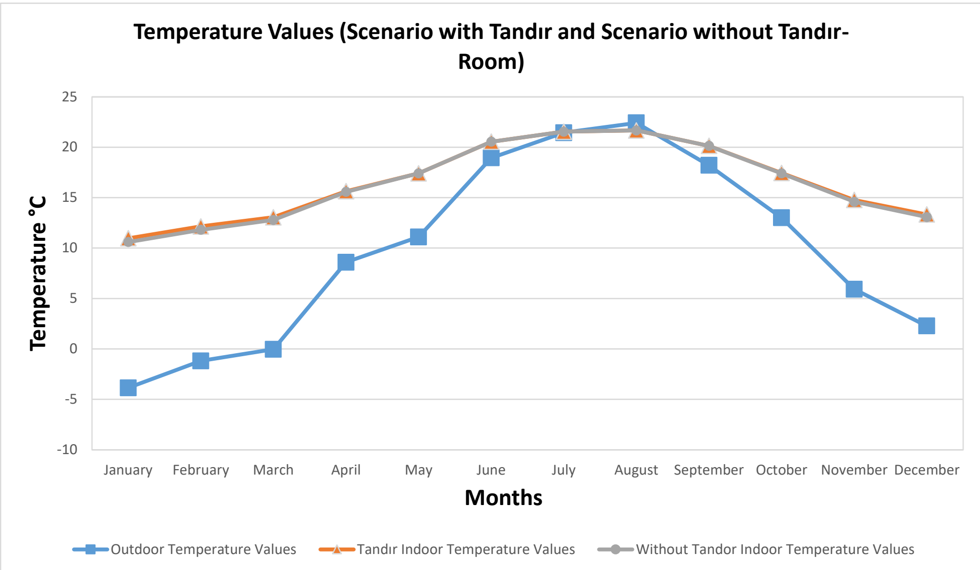


Figure 10. Room, indoor vs. outdoor temperature comparison for the scenario where the tandır is active vs. passive.

4 CONCLUSIONS

Affected by the cold climate of the region, local people spend their daily activities indoors. The fact that tandoori houses provide a comfortable space for daily communication and sharing contributes to its prominence as a cultural value. In addition to the thermal effect provided by the tandoor for the adobe house examined, parameters such as the size of the units, surface areas interacting with the external environment, shared common walls were the parameters affecting the indoor temperature. When the scenarios where the tandoor is active and passive are analyzed, in addition to the thermal effect obtained by using the tandoor, the fact that the houses are built of adobe material has led to high indoor temperatures compared to the cold outside temperature. The thermal mass of the adobe material and the contribution of its U-value, which provides high insulation, to energy efficiency are among the results obtained. Tandoor houses are spaces that increase thermal performance in terms of having a positive effect on the temperature values of adjacent spaces. However, tandoor houses which are abandoned and not repaired, especially due to rural-urban migration, face the danger of vanishing. Within the scope of the results obtained in the study, it should be ensured that rural houses are documented and preserved with their original quality in order to both provide an improvement in thermal performance and to maintain cultural values.

5 REFERENCES

[1] Kuban, D. 1990. Mimarlık Kavramları, YEM Yayınevi, İstanbul.
[2] Vega, P., Juan, A., Guerra M.I., Morán, J. M., Aguado, P.J., Llamas. B., "Mechanical characterisation of traditional adobes from the north of Spain". Construction and Building Materials, 25:3020–23, 2011.
[3] World Monuments Fund. (2012). Conservation at Taos Pueblo, New Mexico, USA. World Monuments Fund,New York, N.Y.
[4] Smalley, I.J., Marshall, J., Fitzsimmons, K.E., Whalley, W.B., Ngambi, S., Desert loess: a selection of relevant topics. Geologos 25, 91–102, 2019.
[5] Gürbüz, O. Van Gölü Çevresinde Kir Yerleşmesi. Coğrafya Dergisi, 0, 6, 1998. Retrieved from https://dergipark.org.tr/tr/pub/iucografya/issue/25055/264523
[6] Kalelioğlu, E., Van Ovasinin İklim Özellikleri. Ankara Üniversitesi Dil ve Tarih-Coğrafya Fakültesi Dergisi, 35 (2), 155-166, 1991. Retrieved from https://dergipark.org.tr/tr/pub/dtcfdergisi/issue/66756/1043906
[7] URL 1: https://mgm.gov.tr/veridegerlendirme/il-ve-ilceler-istatistik.aspx?k=A&m=VAN
[8] Uluçam, A., Ortaçağ ve Sonrasında Van Gölü Çevresi Mimarlığı I Van, Kültür Bakanlığı Yayınları, Ankara, 1, 2000.
[9] Aslan, H. (2019). Van-Başkale Kırsal Yerleşimlerinde Konutların ve Tandır Evlerinin İklimsel Tasarım Yaklaşımlarının Değerlendirilmesi. Yüksek lisans tezi, Dicle Üniversitesi, Fen Bilimleri Enstitüsü, Diyarbakır.
[10] Ergin Oruç Ş., (2015). Diyarbakır İli Kırsal Mimari Çeşitliliğinin İklimsel Konfor Ve Enerji Etkinliği Açısından Değerlendirilmesi. Doktora Tezi. Mimar Sinan Güzel Sanatlar Üniversitesi Fen Bilimleri Enstitüsü. İstanbul.

Post-Earthquake Conservation Problems of Traditional Adobe Houses in Gaziantep, Doğanpınar Village After 2023 Kahramanmaraş Earthquake

Beyza Berfin Aslan, Aynur Çiftçi

Gaziantep University
Yıldız Technical University
aslanbeyzab@gmail.com
cifci@yildiz.edu.tr

ABSTRACT

On February 6, 2023, two separate earthquakes of magnitude Mw 7.7 and Mw 7.6, with the epicenter in Kahramanmaraş, caused large-scale destruction and damage in an area covering 11 provinces in Turkey and the northern settlements of Syria. While more than fifty thousand lives were lost in the collapsed buildings, historical city centers and cultural assets in urban or rural settlements were severely damaged.

Following the earthquake, damage assessment studies were carried out by the Ministry of Environment, Urbanization and Climate Change, and implementations in the following period were carried out according to the results of these assessments. Examples of traditional residential architecture in rural settlements were also affected by these studies.

During these damage assessment studies carried out in a short period of time, it was observed that there were some problems especially in the evaluation of traditional adobe buildings in rural areas. The 'heavily damaged structure' decisions made by the survey teams as a result of not knowing the masonry structures and adobe material properties sufficiently, revealed the necessity of examining the damage reports.

Doğanpınar Village of Gaziantep, which is examined within the scope of a master's thesis being prepared in the field of architectural conservation where these problems are observed, is a rural settlement close to the Syrian border, 42 km away from the city center, consisting of 86 adobe brick houses, the historical past of nearby surrounding dates back to the early bronze age. In the village, 37 buildings were assessed as "heavily damaged" and 8 as "moderately damaged". During the process, 15 buildings were demolished by the teams.

In the study, based on the damage assessment studies carried out within the Ministry of Environment, Urbanization and Climate Change, the reasons for the decision to demolish the adobe buildings will be examined, and evaluations will be made on whether the examined adobe buildings are really 'heavily damaged' or 'moderately damaged'. The change in the traditional village texture after the demolition of the adobe buildings considered 'heavily damaged' will be discussed in terms of universal preservation criteria.

Keywords: 2023 Kahramanmaraş Earthquake, Gaziantep, Traditional Adobe Houses, Damage, Conservation Problems

1 INTRODUCTION

On 6 February 2023, two major earthquakes and many aftershocks occurred in Pazarcık and Elbistan districts of Kahramanmaraş. After the earthquake, various conservation problems emerged in the cultural heritage sites of the region and in the buildings constructed with different techniques and materials with traditional methods. In addition to the specific problems of rural settlements (Kayın, E., 2012), the legal processes experienced after the earthquake have caused various issues. Doğanpınar Village of Gaziantep province in Southeastern Turkey, which is examined in this study within the scope of a master's thesis being prepared in the field of architectural conservation, is a rural area where these conservation problems are identified. Doğanpınar Village is 77 km from Pazarcık, the epicentre of the 7.7 Mw earthquake, and 156 km from Elbistan, the epicentre of the 7.6 Mw earthquake. The traditional adobe buildings in the village were both damaged by the earthquake and faced the risk of extinction due to the lack of legal regulations in the post-earthquake process and problems during damage assessment activities. With the field study conducted between June 2023 and July 2024 for the thesis study, the change occured by the post-earthquake process in the area was observed on site and how the process works for adobe buildings was observed. During the period of the study, demolition decisions were taken and many traditional adobe houses and their original annexes were destroyed in the village. This paper aims to draw attention to the earthquake-oriented conservation problems of adobe buildings and the necessity for the evaluation and legal regulations to be made for adobe buildings to be specific to adobe's negativities in terms of the preservation of this heritage.

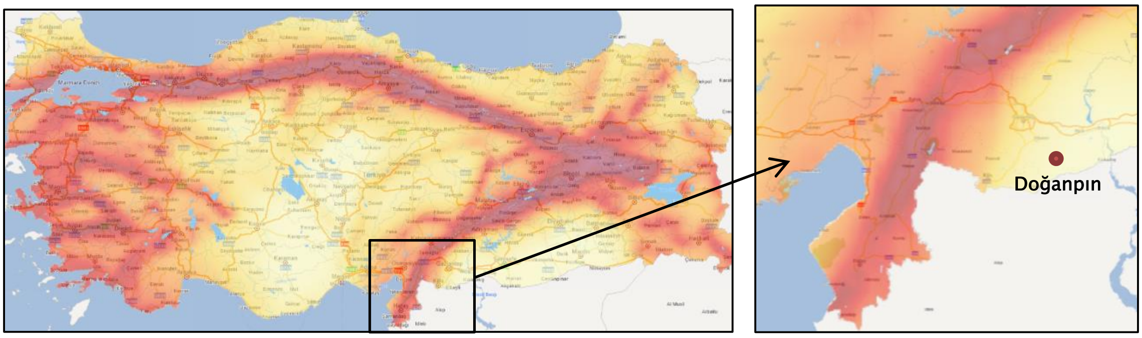


Fig. 1: Location of Doğanpınar village in Turkey's interactive earthquake Map(AFAD, 2024)

2 ARCHITECTURAL CHARACTERISTICS OF ADOBE BUILDINGS IN DOĞANPINAR VILLAGE

In the village where the study was conducted, there are new buildings made of briquette in reinforced concrete and masonry system as well as traditional adobe buildings. The use of new materials has increased over time in the village, which in the past consisted entirely of adobe buildings, and these materials were mostly used in houses and annexes. Some of the existing adobe buildings have reinforced concrete additions or there are both adobe and reinforced concrete or masonry briquette buildings in the same courtyard (named locally "havuş"). The number of adobe houses and annexes in the village is approximately 86 .The annexes are buildings with functions such as stables, storage, furnace, etc., and some of them are independent units that are not part of any residential complex.

Fig. 2: Adobe house with 'havuş' (B.B.A.[1], 2023)

Fig. 3:Adobe House with briquette addition (B.B.A., 2023)

The buildings differ in terms of plan types and street connection. In some of the buildings, an introverted, sheltered living space is provided around a courtyard called 'Havuş', for others, a direct and open relation with the street and its surroundings is established without any courtyard wall.

Fig 4:Timber ceiling beams and timber post (B.B.A.2023)

Fig 5:Two-storey Adobe house (B.B.A. 2023)

The traditional architectural structures in Doğanpınar Village were built using stone, soil and wood, which are the natural materials in the region. The buildings were constructed by blending the soil, which is the most accessible material in the region, with straw and water and drying it in blocks in the sun. These buildings are constructed of adobe blocks and have one or two-storey. The construction of the buildings started with the construction of a rubble stone sub-base wall which is typically 30-40 cm. The mud mortar was used to place rows of adobe blocks on top of the sub-base and the adobe structure was started. Wooden beams, which serve as lintels for door-window openings, were placed and the masonry was completed appropriately. No runner beams are used except lintels. If the building has two-storey, wooden beams obtained from poplar tree were placed for the mezzanine floor and wooden covering boards were placed, followed by branches and mud layer. At the last layer, wooden beams made of poplar trees were placed to form the 'roof' for the upper cover. The beams were covered with branches and mud with or without cladding boards. The construction of the building was completed by compacting the mud layer with 'loğ' stones. The adobe block size used in the buildings was measured as 42x21x10,5 cm. The widest opening measured in the analysed buildings is 615 cm. The maximum height of the spaces is 300 cm and the minimum height is 230 cm.

3 DAMAGE ASSESSMENT PROCESSES AFTER THE 2023 KAHRAMANMARAŞ EARTHQUAKE

In the post-earthquake period, governmental and non-governmental organizations started to create a road map urgently with the fact that the earthquake was not sufficiently prepared for the magnitude of the affected area. While search and rescue operations were continuing, damage assessments were also started. The Ministry of Environment, Urbanisation and Climate Change(MoEUC), which is the

[1] B.B.A.: Beyza Berfin Aslan(1st author)

authorised institution on behalf of AFAD (Disaster and Emergency Management Presidency) , the institution responsible for disasters, has started damage assessment studies. Many volunteer engineers and architects went to the field and participated in studies. Professional chambers also made efforts to organise their members. [9]
The problem emerged that a sufficient number of architects and civil engineers were not trained in damage assessment and there was a lack of experienced staff. Considering the size of the area and the number of buildings, the need for a large number of engineers and architects with the required qualifications for the entire area has brought an urgent search for a solution. To solve this problem, a training video series was published on the online training portal of the MoEUC. Civil engineers and architects who completed this video training series and received their certificates started to work on field. The damage assessment criteria included in this training and the assessments made in a hurry caused some problems and confusion in the later stages of the process. Damages of traditional adobe architectural examples were also evaluated. In addition, the Chamber of Civil Engineers has also published a damage assessment training through its online training platform 'Continuing Education Centre (SEM)' and participation in studies has been provided with this training. However, in this study, an evaluation of the process could only be made through the training of the ministry, which has open access [4,5], since the training published through SEM is not open access. According to the report of the Chamber of Civil Engineers, 2155 civil engineers from the members of the chamber participated in studies.[9]

3.1.Classification in damage assessment and damage assessment criteria for adobe structures

According to the training information provided by the MoEUC, 6 different categories were created while classifying the damage in the assessment studies carried out after the Kahramanmaraş Earthquake in 2023. Classification was made as 'undamaged', 'slightly damaged', 'moderately damaged', 'heavily damaged', 'to be demolished immediately', and 'collapsed'. Buildings that could not be assessed other than these were recorded as 'non-assessment'. For demolished buildings, rubble removal works were carried out during the process.
As for the buildings to be 'urgently demolished', they were planned to be demolished with priority since they could collapse spontaneously with aftershocks and cause loss of life. The process was longer for 'heavy' and 'medium' damaged buildings. After months of proprietor's objection processes, assessments were completed and the defitinitive damage status of the buildings was finalised after the re-evaluation of the objected buildings. In the following months, debris removal and demolition of heavily damaged buildings continued. During the writing of this article, demolition works are still ongoing and there are continuous changes in the traditional village texture. For the 'moderately damaged' buildings, there was first an uncertainty about how to follow a roadmap, and then two options were presented and the decision was left to the property owners. These options are reinforcing or demolishing the building. [3]
In the damage assessment studies of the MoEUC, no special distinction was made for the material, but only for the structural system. According to these evaluation methods, buildings are assessed in two categories as masonry and reinforced concrete. The evaluation system used for masonry structures is basically very similar to the system used for reinforced concrete structures. For masonry structures, damages are classified into two main types as out-of-plane and in-plane. Then, the damage assessment steps are explained.

3.1.1.External inspection: Damage assessment should start with external inspection. If none of the damages in the 3 items listed below are found, the external examination is terminated and the internal examination is started.
*i.*General Inspection of the Building: All facades of the building are observed from outside. If there is a total or regional collapse in the building, it is decided that the building is 'heavily damaged' and the examination is terminated.
*ii.*Investigation of Permanent Displacement Between Floors: If the inter-storey permanent displacement value is greater than 0.01, the structure is considered as heavily damaged.
*iii.*Investigation of the Ground: If there is a tilting/rotation of 3 degrees or more in the building due to different settlements in the foundation, the building is considered to be heavily damaged.

3.1.2.Internal Inspection: If the floor with the most damage can be clearly distinguished, an internal inspection can be carried out on this floor, if it cannot be distinguished, an internal inspection can be carried out on the ground floor or, if necessary, on all floors. During the internal examination, element damages are decided

Table 1. Damage classification of elements

Damage Code	**Damage Class**	**Criteria**
0 Type Damage	No Damage	No cracks or crushing on the wall. There may be cracks/spalling in the plaster.
A Type Damage	Slight damage	Capillary Cracks (1mm)
B Type Damage	Moderate damage	Crack width 5mm, spalling of mortar
C Type Damage	Heavy damage	Crack width 10 mm, crushing of blocks, spalling of mortar
D Type Damage	Very severe damage	Partial or complete disintegration, collapse or overturning of load-bearing walls

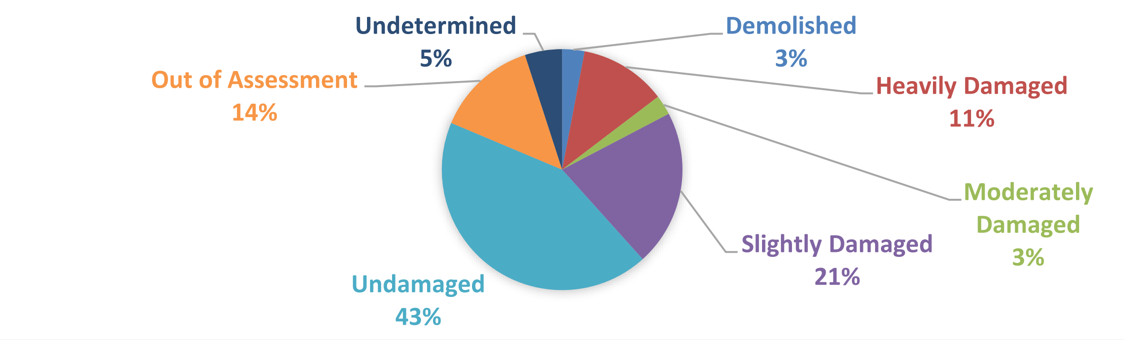
After the element damages are decided, the damage status of the building is decided. After the exterior and interior examinations, if at least one of the load-bearing masonry walls in the building has D-type damage or at least 2 of them have C-type damage, the building is considered 'heavily damaged'. If these are not available, the B-type damaged masonry walls on the floor are examined. If maximum 3 of them are type B damaged and all the rest are undamaged or type A damaged, the building is considered 'slightly damaged', if there are more than 3 type B damaged elements, the building is considered 'moderately damaged' and detailed engineering investigation is deemed necessary. This method is the same as the one used in reinforced concrete.

3.2.Evaluation of the Damage Assessment of the Buildings in Doğanpınar Village after the 2023 Earthquake

In the buildings examined after the earthquake in the village, it was observed that the cracks mostly occurred at the corners of door-window-niche (named locally 'tağa') openings (figure 7) and wall corner joints (figure 6). It was observed that the cracks appeared larger on the earthen or cement plaster, but when the plaster was removed and the adobe blocks were checked, the crack size between the blocks was smaller. It was found that there were more cracks in the buildings that had not been plastered for a long time.In the "kellimbuçuk" (a thick wall built by laying one full and one half brick) buildings where the wall thickness can reach up to 70 cm, fewer cracks were observed compared to the buildings with normal thickness walls.

Fig. 6,7,8: Cracks in the walls of adobe buildings in the village due to earthquake (B.B. A. , 2023)

After the objection processes were completed, when the data for Doğanpınar Village was analysed through the damage assessment query system of the MoEUC , it was determined that there were data entries for a total of 300 structures, including traditional adobe structures and new structures, and that there were 9 'demolished', 35 'heavily damaged', 8 'moderately damaged', 63 'slightly damaged', 129 'undamaged', 41 'out of assessment' and 15 'undetermined' structures. These numbers were counted according to the damage status that became clear after the process were completed. [6]



Graphic: Damage States of Buildings in Doğanpınar Village

There are 4 adobe buildings in the village which are accepted as moderately damaged. While a detailed engineering examination was required for these buildings as a result of the damage assessment decision, demolition and strenghtining options were left to the property owners without this examination. Moderately damaged buildings for which no reinforcement application was made by the property owners were decided to be treated as heavily damaged with the decision of the general regulation [3, article 1] issued by AFAD. When these structures were examined during the field study, it was observed that there was 1 structure that should be considered as heavily damaged according to the damage assessment criteria of the MoEU (Fig. 9), and that the structure had a wall with out-of-plane behaviour. For the other 3 moderately damaged buildings, it was observed that some of the cracks considered in the assessment were earthen plaster cracks.

Fig. 9: Out-of-plane damage in Moderately Damaged (B.B.A. 2023)

Fig 10: C type Damage in Moderately Damaged (B.B.A. 2023)

A significant number of the 35 buildings in the village with heavy damage decision are traditional adobe buildings. Among these, some factors that had a negative effect on the damage assessment were determined. The most important factor is that the earthquake damages could not be distinguished from the damages caused by pre-earthquake deterioration in the structures that did not receive periodic maintenance due to the natural structure of adobe. There are heavily damaged buildings that have been abandoned or not plastered by the users even though they should be plastered routinely every year, and therefore plaster spillage, cracks and various water damages have occurred. This situation is to the extent that it affects the damage decision for some buildings. In addition to this, it was observed that there were no elements with C and D class damage in some buildings with heavy damage decision and it was necessary to examine the demolition decisions taken for these buildings. The building in Figure 11 is an example of these cases. When the building was examined, it was seen that it had not been plastered traditionally for two years, therefore, there were spillages on the exterior plaster and cracks in the plaster, while structural cracks and separation that can be considered as severe damage due to earthquake were not observed. However, the building was treated as heavily damaged and demolished in November 2023.

Fig. 11: The building damaged due to ageing as the plaster was not renewed. (Aslan, B.B., 2023)

All this evaluation system leads to a very superficial examination. Damage to a wall in masonry structures does not always affect the entire structure. Deciding to demolish the entire structure due to damage in a single element, as in reinforced concrete frame structures, is not an appropriate decision for masonry adobe structures. One of the important problems in damage assessment studies is that the architects and engineers working in the field do not have sufficient experience with adobe material and do not know the behaviour of the material and the construction sufficiently. Unfortunately, it was not possible to reach the people specialised in this field among the participants of the assessment studies and to make the assessment in this way due to the unusual conditions and the available facilities during the post-earthquake time.

4 CONCLUSIONS AND PROPOSALS

2023 Kahramanmaraş Earthquakes greatly affected the future of traditional adobe buildings. Due to the panic environment brought by the post-earthquake emergency and the lack of details about adobe in the legal regulations, as well as the fact that adobe is seen as worthless, the preservation of adobe buildings become difficult. Until the preparation of this study, 15 adobe buildings with heavy damage records in Doğanpınar Village were demolished by the authorities. It is thought that some of these buildings may not be demolished if detailed and adobe-concentrated inspection methods are used.

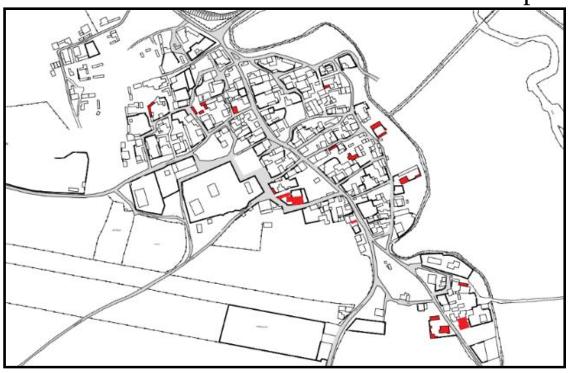


Fig. 12: Map (June 2024) showing the destructed buildings in heavily damaged statues (B.B.A)

Published in 1999, the ICOMOS Charter on the Built Vernacular Heritage addresses the necessity of community participation, support and continuous use for the conservation of traditional buildings within the general principles. The same issue is also addressed in the Nara Authenticity Document (1994) and the responsibility of the community that created the heritage is expressed in the protection of the heritage. In line with the principles stated in these documents, the approach of the users is important in the conservation of traditional adobe buildings as cultural heritage. In the ICOMOS Charter on the Built Vernacular Heritage , it is stated that authorised institutions and administrations are also responsible for the conservation of traditional buildings with legal, administrative and financial means. In this direction, the authorities should make the necessary arrangements, evaluations should be made and decisions should be taken in accordance with the material and structural characteristics of the building for the preservation of traditional buildings. Damage assessment evaluation criteria are also under the responsibility of authorised institutions and administrations. In order to make healthy assessments, damage assessment principles should be reviewed by the authorities, and assessment techniques that take into account the differences in construction system and behavior of the materials should be preferred. There is a need for a regulation for adobe in Turkey as it is for wooden structures and masonry structures [10,11].

While analysing adobe buildings, it should be taken into consideration that adobe is a material requiring periodic maintenance and earthquake damage should not be confused with aging damage. Adobe buildings also have their own methods of strengthening and repair. As stated in the document titled 'Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage' published by ICOMOS in 2003, irreversible interventions should be avoided. In the light of these principles stated in the document, adobe buildings should be strengthened and repaired by experts from various disciplines, and demolition decisions should not be the primary option[12]. Also it is important to train experts who know the material well. Awareness is a quate important point. 'International Conferences on Kerpic' are precious organisations for the understanding and preservation of adobe and increasing the number of such organisations will make a great contribution to the preservation of adobe.

Annotation: This study is based on the master's thesis produced by 1st author at Yıldız Technical University, Graduate School of Science and Engineering, Surveying and Restoration Master's Programme.

5 REFERENCES

[1] AFAD, 2023. 06 Şubat 2023 Pazarcık (Kahramanmaraş) Mw 7.7 Elbistan (Kahramanmaraş) Mw 7.6 Depremlerine İlişkin Ön Değerlendirme Raporu. Retrieved from: https://deprem.afad.gov.tr/assets/pdf/Kahramanmaras%20%20Depremleri_%20On%20Degerlendirme%20Raporu.pdf

[2] AFAD, 2023. 06 Şubat 2023 Pazarcık-Elbistan (Kahramanmaraş) Mw: 7.7 – Mw: 7.6 Depremleri Raporu. Retrieved from: https://deprem.afad.gov.tr/assets/pdf/

[3] AFAD, 2023. 7259 Sayılı Kanunun Geçici 27 nci Maddesi Uygulama Genelgesi , Retrieved from: https://www.afad.gov.tr/kurumlar/afad.gov.tr/Genelge/orta-hasar-gec%CC%A7ici-27-genelgesi-2023_8.pdf

[4] Hasar Tespit Eğitim Dokümanları, İstanbul Valiliği Çevre, Şehircilik ve İklim Değişikliği İl Müdürlüğü. Retrieved from: https://istanbul.csb.gov.tr/hasar-tespit-egitim-dokumanlari-i-95359

[5] LBRQ Hasan, (2020, Aug 13). *Çevre ve Şehircilik Bakanlığı Betonarme ve Yığma Binalarda Deprem Kaynaklı Hasar Tespiti – 4* Retrieved from https://www.youtube.com/watch?v=8zI58BUlus4&list=PLnejttIrdLrKtpPyv4v375m-PptcFUtrH&index=4

[6]T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı Hasar Tespit Sorgulama Sayfası Retrieved from: https://hasartespit.csb.gov.tr/

[7]Türkiye Deprem Tehlike Haritaları, Retrieved from: https://tdth.afad.gov.tr

[8]Emel KAYIN,"Bir "Kültürel Manzara-Kültürel Peyzaj" Öğesi Olarak Kırsal Yerleşimlerin Korunmasına Yönelik Kavramsal ve Yasal İrdelemeler", Mimarlık, 367/46-49, 2012

[9]TMMOB İnşaat Mühendisleri Odası, 2023. 6 Şubat 2023 Kahramanmaraş Depremi Hasar Tespit Çalışmaları Değerlendirme Raporu

[10] ICOMOS Nara Document on Autencity, 1994, ICOMOS. Retrieved from: https://www.icomos.org.tr/Dosyalar/ICOMOSTR_en0756809001536913861.pdf

[11] ICOMOS Charter on the Built Vernacular Heritage, 1999. Retrieved from: https://www.icomos.org.tr/Dosyalar/ICOMOSTR_en0464200001536913566.pdf

[12] ICOMOS, Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage , 2003. Retrieved from: https://www.icomos.org.tr/Dosyalar/ICOMOSTR_en0033912001536913477.pdf

Archaeological Continuity and Urban Evolutione From Çatalhöyük to Develi/Zile - Anatolia's Adobe Building Tradition and its UNESCO World Heritage Potential.

(Prof. Susanna F. Schaller, Urban Studies & Planning, New York
The City College of N ,CUNY sschaller@ccny.cuny.edu, Dr. Bilgehan Köhler, Mustafa Uçdu)
(Chemin d'Archamps, 30, 1257 Croix-de-Rozon, Geneva - Switzerland)

(Dr. Bilgehan Köhler, bilgehan@gmx.de)

ABSTRAC T

The lecture will present selected examples of international earth buildings that have been included in the UNESCO list. In Anatolia, the world's oldest clay buildings were excavated in Çatalhöyük, which is also on the UNESCO list. Their Neolithic construction principles influenced technical construction in Anatolia until the 20th century. After the Battle of Manzikert, the Seljuks immigrated into a Christianized Roman population, resulting in a multicultural urban life. Zile is one such example of this cultural diversity. The Zileli family stories and the listed burial ground of Zile document this impressively. Geopolitically, Zile was closely linked to Istanbul and was even referred to as 'Little Istanbul'. Zile's architectural, historical and traditional diversity make it an important canditate for the UNESCO World Heritage status.

1. Architectural Diversity: The mud houses in Zile are essential for Anatolian's architectural tradition and a living testimony to a culture that is thousands of years old. However, they are threatened because there is a lack of architects, earth building craftsmen, and carpenters. Given the growing importance of clay buildings in the 21st century due to their sustainable construction, it is important to preserve the construction of houses in Zile. We have already built an experimental reconstruction of a clay garden wall to understand the traditional construction method.

2. Historical Significance: Zile's location near the historic Silk Road (Develi) enabled a lively exchange of knowledge and trade, between different civilizations, which contributed to the development of a rich cultural identity of Zile.

3. Cultural Practices and Traditions: Zile's vibrant cultural practices and traditions are maintained beyond its borders. Former residents resettled in Greece (Yanya) under the Lausanne Accords continue to maintain these traditions. A Zile Museum in Greece shows the connection to the Anatolian homeland and presents traditional festivals, crafts, and cultural objects. Every year visitors from Greece come to Zile.

4. Conservation Efforts: The local community shows great commitment to preserving Zile's cultural heritage. Historic buildings are restored, and traditional knowledge (urban development, crafts, clothing, poetry, family history) is documented. There are many private archives that record Zile's tradition.

5. Tourist Potential: The entry of Zile as an example of an Anatolian small town as a UNESCO World Heritage site will celebrate the unique cultural significance of Anatolian Turkish cities and bring international recognition for the Turkish way of life. This will increase the region's tourism potential and contribute to sustainable economic growth and job creation.

Keywords: UNESCO, Develi/Zile, Adobe Building, Sustainable, Architecture

Pilot project for UNESCO World Heritage Status: Zile (Develi) a "Place of Peace"

The project aims to have Zile (Develi) designated as a UNESCO World Heritage site. The research proposal seeks to develop a pilot study that meets the selection criteria of the UNESCO World Heritage Committee. It is also a pilot project for Zile (Develi) in Kayseri, Anatolia, because it has emerged from women's grassroots civic engagement with public sector support.

As a village that presents significant building heritage of clay or adobe structures (Fig.1) and a rich history at the crossroads of many cultures, Zile (Develi) and its exceptional archeological, historically significant architecture as well a multi-ethnic heritage make it a perfect candidate for World Heritage designation. The intention here is to start an interdisciplinary conversation to serve as the basis for a UNESCO proposal. To prepare for such a dialogue, we place Zile (Develi) in a thematic and regional context to begin to make the case that the village has World Heritage potential.

Overview

In the past, UNESCO nominations for Turkey have focused primarily on "elite cultures" such as ancient temples, mosques and other outstanding stone structures. Only a few civil settlements made of mud, such as Çatalhöyük (Fig.2), and the medieval adobe structures in the old city of Istanbul and Safranbolu were included. However, until 10-15 years ago, the medieval heritage, in particular Seljuk and Ottoman buildings, was often demolished without being documented in favor of older settlement layers until the Roman period; newer periods are disregarded. This is shown by the stratigraphy of Kültepe, an Assyrian trading center in Kayseri. Seldschuk and Ottoman settlements were also destroyed despite their thousand-year-old culture. This means a comprehensive historical understanding is foreclosed in the region.

Recent urbanization trends, like the construction surge in Kayseri, resulted in the widespread demolition of traditional earthen structures, including historic Kayseri houses, while stone constructions, as seen in Tavukcu Mahallesi, were preferentially preserved and maintained. This leads to a one-sided representation of stone buildings in the Turkish UNESCO World Heritage List and distorts the historical record.

Anatolia is the cradle of earthen architecture and a crossroads of cultures (Fig.3). Adobe settlements such as those in Kayseri, which existed until very recently, have become victims of urban renewal, erasing are important witnesses to world history. But, Zile (Develi), which is a geographically distant district of Kayseri/Develi has until escaped this dynamic and is largely untouched; it offers a unique concentration of earthen buildings that need to be saved. Moreover, traditional lifestyles, clothing, festivals, and economic practices as well as a history of multi-ethnic coexistence have been preserved in the cultural memory of the population. The Zilelis preserve this heritage at a private level, supported by private archives at home and abroad (e.g. Greece, Yanya). This makes Zile an important piece in the mosaic of world history.

Zile (Develi) reflects the diversity and richness of Anatolia. While the Roman conquest is also part of the history of Zile (Develi), enshrined in the name Zile. Caesar came to Antolia, proclaimed "I came, I saw, I conquered," (Fig.4) and named four places in Anatolia he conquered: Zile (Develi). An underground water reservoir in Zile from Roman times also bears witness to this history. But, a focus on Roman history obscures a richer history. Additionally, the area around Zile exhibits prehistoric caves and boasts the biggest bronze age tumulus of Anatolia made by the Phrygia culture (Fig.5). Indeed, Zile's adobe buildings and construction techniques were influenced by the Neolithic Age (Çatalhöyük); yet, these building techniques are not found in UNESCO cities such as Istanbul and Safranbolu, making Zile unique.

In order to make an argument that Zile (Develi) should be considered a World Heritage site, the multifaceted urban heritage of Zile (Develi) needs to be documented. On the one hand, it is crucial to situate Zile (Develi) in relation to already known archaeological settlements in Anatolia; on the other hand, its development can be explained by the development of medieval and modern cities in Turkey, including their sociocultural and historical aspects.

This project takes its inspiration from the fact that some of the earliest known clay building settlements in Anatolia, such as Çatalhöyük and Hacılar, as well as the medieval clay structures of the old town of Istanbul and Safranbolu, are already on the UNESCO list. In this context, Zile (Develi) with its unique clay houses should be seen as an urban settlement that exhibits a continuity in clay construction, one that evolved over centuries and can be differentiated from those already recognized sites. And, it still exhibits a fairly coherent concentration of these traditional buildings (Fig. 6).

The development of a holistic proposal to support the contemporary development of Zile (Develi), requires an interdisciplinary approach. The focus here then is not solely on the micro-location of individual clay structures and their architecture as this aspect is already being studied by Nuh Naci Yazgan University in Kayseri. Rather, this project seeks to build on and complement this work by focusing on the aspects that situate Zile (Develi) as a clay house urban settlement in historical transformation processes that have shaped and continue to shape the existing urban environment. The aim is also to research and make visible traditional ways of life in Zile (Develi) and place them in a larger historical, political and cultural context. In addition, to tie a potential UNESCO World Heritage designation to the future development of the Zile (Develi) region, the project will also study key socio-demographic and cultural factors that structure its economic life.

Recognition by UNESCO will not only serve to protect the architectural heritage of Zile (Develi) but will help preserve important cultural aspects of its traditional way of life, which are in danger of being lost but still exist. An UNESCO World Heritage designation would also provide the backing necessary to develop and promote educational work in the region, with the goal of strengthening sustainable culturally-focused tourism and with it support an important economic sector in the region.

Background and Context

Zile's (Develi) geographical location at the foot of Mount Erciyes is significant. Its position with its natural water resource (Aci Su) and its elevation has made it a preferred settlement area since prehistoric times. Although of great importance for the region and its development, a lack of surveys and excavations exists with regard to Zile (Develi). Still, oral histories transmitted among families from and in Zile (Develi) confirm the immigration of Turkish residents (Seljuks) into a Romanized Christian community during the past (Köhler Interviews 2018). This is also supported by the existing cemeteries of Seljuks. These burial fields, which are already legally protected

(1960-70) under Historic Preservation laws, suggest that the entire clay settlement, with its several hundred-year-old buildings, should be placed under historic preservation.

Key studies regarding the significance of the houses in Zile (Develi) were presented by the Kayseri Protection, Enforcement and Inspection Branch Directorate Koruma, Uygulama ve Denetim Şube Müdürlüğü (KUDEB) (Banu Küçük, Art Historian, Kayseri Metropolitan Municipality). In 2017, Banu Küçük compiled a list of protected houses to be protected. And, for the first time, the architectural heritage of Zile (Develi), with its historical buildings, monuments, and structures, is being systematically examined and documented, by the architect Caglar Isbilir, to protect the historical integrity of this important site. By 2023 academic institutions, such as Nuh Naci Yazgan University. The university was part of the Kerpic'23 conference "Gain Information From The Traditional Earthen Architecture" Diyarbakir 2023 /23, documenting inner parts of the buildings.

Against this background, the aspect of the research project we want to introduce here, with the intention that it be part of an integrated, larger collaborative research project, aims to situate Zile in its broader regional context, homing in on how the historically significant character of its built environment, specifically its high concentration of historically significant clay buildings, and the continuity of its cultural heritage as evident in water management practices, the revival of clay brick making techniques as well as traditional agricultural and textile production methods, might be mobilized to develop a sustainable future for Zile (Develi) and the region in which it is embedded. The project will build a systematic database of qualitative, archeological and quantitative data that respond to UNESCO World Heritage criteria. The recognition and protection of the architectural, archeological and the cultural heritage of Zile (Develi) by UNESCO is the primary purpose because it would signify a crucial step toward positioning Zile and the region as a site and destination for sustainable tourism.

Projet Aim

Strengthening the economy of Zile (Develi) and the surrounding region, which faces high unemployment, is crucial. The aim of this project is to support the socioeconomic development of Zile and well-being of its population. Should the research indeed lead to gaining recognition from UNESCO and to a plan to effectively promote the cultural heritage of Zile (Develi), new opportunities in tourism will be created, thus stimulating economic growth and creating new jobs. For example, educational and training programs related to specific crafts needed to preserve Zile's traditional building skills as well as agricultural production skills will open up new employment opportunities and markets. These kinds of programs improve the qualifications and job prospects for the local population and help combat poverty, which is a goal of UNESCO and corresponds to the United Nations' Sustainable Development goals. Overall, strengthening the economy of Zile (Develi) by utilizing and promoting its cultural heritage can help improve the quality of life for residents and drive the long-term development of the region away from sectors, such as mining, that threaten the local and regional natural resources base. Therefore, the long term goal of this project to nominate Zile (Develi) as a World Heritage site by UNESCO is of great importance.

Research Agenda

UNESCO has outlined specific selection criteria for the selection of World Heritage sites (27), and a site has to meet at least one of the following selection criteria to be considered by the Committee:

"(i) to represent a masterpiece of human creative genius; (ii) to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design; (iii) to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; (iv) to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; (v) to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; (vi) to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria); (vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; (viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features; (ix) to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; (x) to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation."

Another key aspect UNESCO considers is whether or not local or regional management plans exist to support and maintain the site over the long term.

Zile will likely fulfill aspects of the following criteria, which are worth examining as part of this interdisciplinary research project:

(ii) to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;

(vi) to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance.

(v) to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;

The research project seeks to analyze the tourist appeal of Zile (Develi) analyzed. The development of a specifically tourism focused infrastructure to support local, cultural "slow tourism" (2) is a perspective. The development of a strategic plan requires research to learn from existing places that have successfully implemented such alternative development visions built on preserving a significant architectural and cultural history. Rooted in an appreciation of local traditions and heritage as well as local engagement and management capacity, this kind of tourism focuses on sustainability over the long-term.

UNSECO has also made available case study vignettes from various countries, which can serve as a guide as well (9), and relevant case studies of World Heritage sites, like the following, will be collected and analyzed for comparative value to Zile. Taos Pueblo in New Mexico, USA, is one example. A Native American settlement, dating back to the 13th century, with a local economy, Taos draws heavily on tourism for its economic base and fulfills criterion IV as "a remarkable example of a traditional type of architectural ensemble from the pre-Hispanic period of the Americas unique to this region and one which, because of the living culture of its community, has successfully retained most of its traditional forms up to the present day." (28) The Pueblo also demonstrates "integrity" in that its architectural core reflects the traditional adobe craftsmanship and retains a cohesive historical urban structure. Additionally, Taos claims true authenticity because it has been continuously inhabited by the Pueblo people, who protected their cultural heritage under duress and in the face of colonial violence. Moreover, Taos has a systematic and effective preservation plan, including a sophisticated management structure under local control.

In order to situate Zile (Develi) in the Turkish context, relevant case studies from the Turkish "slow city" network will be assessed to assess best practices in sustainable tourism and place them in the context of World Heritage site designation.

Another crucial aspect is participatory planning, (2) where local communities are involved in the planning process to consider their needs, perspectives, and cultural values. Through these comprehensive methods, a holistic understanding of the urban development of Zile (Develi) is sought, taking into account both historical and contemporary factors.

Research Methods

Accordingly, the study's aim should be to present a comprehensive picture of the urban structure of Zile (Develi) in the rural region surrounding Kayseri, focusing on situating Zile (Develi) in Central Anatolia by investigating, documenting, and reconstructing the historical, cultural, economic, and social significance of the region and Zile as a significant and integrated part thereof. In order to accomplish relevant factors that might support a World Heritage recognition will have to be researched to collect the relevant data for an application.

We know that Zile (Develi) stands as a clay-built settlement in the tradition of the oldest Neolithic, ancient, and medieval Anatolian settlements that have already been included in the UNESCO list (1,9,10,15). With the arrival of the Seljuks, Zile (Develi) remained a multicultural settlement until the Ottoman period (16,17,18,19,20). Later, the settlement, like many other places in Anatolia, became a pawn in world politics. With the Treaties of Lausanne (1923), the living conditions in Zile (Develi) changed. It is crucial that the project reconstruct the complex history of Zile within its regional context in order "to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared." (29)

The research on Zile (Develi), requires methods and approaches from multiple disciplines. Archaeological, urban planning, anthropological and sociological methods must be used to obtain interdisciplinary results. By combining these methods, we could develop a comprehensive understanding of the archaeological, historical, urban planning, and anthropological dimensions of Zile (Develi). The study will contextualize the settlement's significance and underscore its importance to world history. To gain a comprehensive understanding of the socio-cultural practices, traditions, and lifestyles of the residents of Zile (Develi), historical and ethnographic research methods will be applied. This includes archival research, field research and interviews with locals to obtain direct insights. Additionally, oral traditions, stories, and memories of older residents about the history, culture, and traditions of their families and community will be collected. By analyzing family trees and kinship relationships, the social structure and historical development of the local population will also be explored. These ethnographic studies aim to document and preserve the cultural heritage and diversity of Zile (Develi).

Historical archival research to reconstruct the local history will have to draw both on existing scholarship [6] and from local and regional archives. Local collections and private archives already established by Zile residents need to be professionally assessed and recorded:

- Ibrahim Kozanoğlu ARCHIVES, Zile Association Archives, Ibrahim Gönlütok photo collection, Durmuş M. Kuzay Media Archive
- Existing literature needs to be archived, including newspaper articles by investigative Nezir Ötegen documenting the richness of the region, and essays and local monographs (5,7,8) about (Zile) Develi, were written by Mustafa Tas, a local teacher.

Intergenerational exchanges exploring how people experience transformations of local living conditions in Zile (Develi) can be traced through migration histories:

- Oral family histories by Ibrahim Kozanoğlu, Aziz Gedik, Nihal Metin, Seyit Öztepe, Asiye Zilelioglu-Köhler, Filiz Köse - Celik, for example document the significance of Zile in the Middle Ages (crafts, culture, education, poetry, festivals, economy, mills, irrigation, squares, urban development).
- Local knowledge about the cultural importance of Zile (Develi), including traditional lifestyles, craftsmanship, historical sites, and cultural heritage, will be collected and documented by Nimet Balat, Habibe & Hasan Kahraman (Zileli), and Durmuş M. Kuzay.

Existing Revitalization Strategies that Align with UNESCO Objectives

In the 19th and 20th centuries, Zile was renowned for its elevated standard of living and its diverse, multicultural community, which included both Muslims and Orthodox Christians. The economic and socio-cultural decline of Zile, driven by population migration, transformed the area from an urban center to a predominantly agrarian settlement. This is why local youth are departing due to limited job prospects outside of agriculture, while teenagers born elsewhere have minimal connection to their cultural roots and seldom visit Zile. Consequently, the once-flourishing community is experiencing a loss of both economic vitality and cultural vibrancy. However, despite migration to larger cities and Europe, the community has maintained its rich cultural heritage through oral traditions. Emigrants expressed their connection to their hometown by adopting surnames like Zileli or Zilelioglu. And, the Orthodox people from Zile who moved to Greece in 1923 named their new towns after their places of origin such as Yeni Kayseri in Ionia, and continue to celebrate the Cappadocia Festival every year. They also regularly visit Cappadocia, with their most recent visit to the Zile Cultural House in 2024.

Zile's considerable historical and tourist potential, but it has received inadequate attention and support from the relevant authorities. In light of this, it is increasingly crucial for the initiatives to preserve and develop the city to be spearheaded by the local community. The active involvement of residents is essential for regional development, as it contributes to maintaining the city's historical and cultural values and ensuring its long-term appeal and economic viability for future generations.

The Turkish people from Zile started to re-engage with the village in the 1970s and 1980s; the Zile Association (Ankara) began to organize cultural events and trips to maintain community cohesion and cultural identity amidst societal changes. Until today, former residents from Ankara, Istanbul and Europe frequently return to their renovated or new-built family homes mostly during the Kurban Festival. At that time, the population of Zile swells from 400-500 to over 1,500.

2017: Renewal through Civic Engagement from Below

Moreover, civic engagement has accelerated since 2017. To support the preservation and promotion of Zile (Develi) has formally gained momentum. Since 2017, Dr. B. Koehler's (Geneva), an archaeologist and museum educator, and F. Köse Çelik (Ankara), a banker, have worked to advance the development of the project. In this, urban planner and university professor S.F. Schaller (New York) has taken on an advisory role. In 2018, the inaugural Kurban Festival was held in the historic district of Zile (Celebcioğlu Park) with the aim of assessing community engagement among the Zileli residents. The event, attended by the mayor, the imam, and numerous local inhabitants, featured traditional elements such as tea, pastries, and an exhibition showcasing historical artifacts and photographs. This initial event was notably successful given the positive collaboration with the local mayor of Zile.

Collaborating with various partners, the festival has since developed into an annual tradition, enhanced by the inclusion of an art workshop. This workshop fosters social inclusion between rural and urban residents through traditional crafts, including puppet-making and patchwork, as well as through children's interviews, sports demonstrations, and thematic workshops.

The festival has garnered substantial interest from both the local community and the Develi Municipality, while also attracting visitors from neighboring regions. Panel discussions and interviews with prominent local figures facilitate the exchange of knowledge and contribute to a heightened awareness within the community.

A primary focus was placed on the preservation of the historic old town of Zile. In the same year, the Conservation Department of Kayseri (Kudeb Şube Müdürlüğü, Kayseri Büyükşehir Belediyesi, İmar ve Şehircilik Daire Başkanlığı) was integrated into the initiative. An initial assessment of the historic adobe buildings in the city center of Zile (Develi) was undertaken. Under the leadership of Banu Küçük, 17 buildings in the town center were identified for preservation due to their historical and cultural significance. The official evaluations revealed that Zile has remarkably retained a substantial portion of its historical architectural fabric.

2020: Women's Association (Kayseri) for the Sustainable Development of Zile

To promote more sustainable development efforts, the "Avrasya Kayseri Develi Zile Women's Association" was established in 2020, with Filiz Köse Çelik as its President. (Fig.7)

The name "Avrasya" (Eurasia) was chosen to reflect Zile's historical role as a nexus along the Silk Road, bridging Europe and Asia. The significant presence of Orthodox Zile residents in Greece and the Turkish diaspora across various European regions further underscores the relevance of this name.

The Women's Association is committed to documenting Zile's legacy as a "multicultural peace village." It aims to develop collections and archives that preserve the town's cultural heritage. In addition, the association seeks to advance Zile's economic and sustainable development, enhancement of community engagement, and promotion of environmental sustainability, with a particular focus on tourism and local craftsmanship. Empowering women and families remains a central priority for the initiative. (@akdzkadinlardernegi)

2022: A Hub for Experimental Earth Building

Protecting the historical earthen houses in Zile remains a top priority of the Initiative. In 2022, initial experiments with traditional earthen construction were undertaken, including the reconstruction of a garden wall by Mustafa Uctu. By 2024, a small experimental earthen house was constructed in Zile's garden area (Aydan Özkan), attracting local media attention.

However, due to a speculative real estate bubble, companies from Develi acquired and subsequently demolished several historical earthen houses in 2024. Arsu Ata, supported by the women's initiative, will reconstruct one of these demolished houses in a style that merges traditional and contemporary elements.

2023: Inauguration of the Zile Cultural Center "Zile Kültür Evi."

The initiative has effectively engaged the local population and earned the confidence of municipal authorities. This support enabled the Women's Association to take over the dilapidated former mayor's office building in October 2021 (application filed on July 26, 2020). The building was renovated with private contributions and volunteer efforts, also artists like Mustafa Koç, take part of the work (Fig.8). In 2023, the Zile Cultural Center (Zile Kültür Evi) was officially inaugurated for the public. The center features exhibition spaces, a library, kitchen facilities, and rooms for events - and conference hall. The opening of the center has reinforced public trust and spurred additional private initiatives. By opting against large-scale investors, the initiative has emphasized ecological and sustainable principles, promoting a model of "self-help."

This is why the local community is actively involved in the sense of participatory planning in order to preserve their cultural heritage. The cultural center serves as a venue for traditional festivals (Kına gecesi). The community has begun receiving donations of historical artifacts and cultural items from their families. Small-scale fundraising efforts are also underway for various projects.

Through the preservation of cultural heritage, the promotion of social cohesion, and the strengthening of community ties, the initiative plays a significant role in the sustainable development and cultural enrichment of Zile.

2024: Collaboration with Municipal Authorities in Zile (Develi)

In August 2024, our representatives Develi visited the former Orthodox Zileli community in Greece, in Ionia. (Fig.9) Furthermore, the initiative aims to strengthen its existing networks for collaboration with cities in Germany, England, and Switzerland. It also plans to rejuvenate the city partnerships between Develi and France, which have previously existed.

A word from the Women's Association

Our women's association is actively engaged in promoting networks that focus on sustainable building practices, particularly in the field of earth construction. We are building connections and participating in international networks to exchange knowledge and experiences.

Our activities include attending a workshop in London that offers hands-on training in earth construction techniques and facilitates the exchange of ideas with international experts. Additionally, we are taking part in the earth construction fair in Basel, where we network with professionals in the field.

Another key aspect of our work is collaborating with universities. Together with these academic partners, we support experimental earth construction projects and bring scientific research into practice. Additionally, the initiative supports and cooperates with academic institutions, including Nuh Naci Yazgan University (Kayseri), which is organizing the International Earth Building Congress 2024 in Kayseri. This event also provides us with the opportunity to participate in discussions and lectures to gain new insights and inspiration for our work.

Through these initiatives, we aim to empower women in the industry, facilitate the exchange of knowledge, and contribute to the implementation of sustainable building projects.

Also with local researcher and writer Nezir Ötegen. Looking ahead, scholarships will be established to support research on Zile, promoting academic work and enhancing exchange between artists, researchers, students, and the local community through on-site summer academies.

Zile stands out for its historical significance, architectural diversity, and deeply ingrained cultural traditions. The exceptional dedication of the local community, coupled with promising tourism potential, further enhances these attributes. However, Zile faces substantial challenges, notably the unlawful destruction of its natural and cultural heritage due to real estate speculation. Despite these obstacles, new strategies are being explored to safeguard and promote the region's cultural assets.
The continued, committed efforts of the local community, supported by scholarly research and media coverage, underscore the importance of recognizing Zile as a "Place of Peace" and advancing its nomination as a UNESCO World Heritage Site

REFERENCES

[1] Akurgal, E. (1978). Ancient Civilizations and Ruins of Turkey: From Prehistoric Times until the End of the Roman Empire. 4th ed., Istanbul.

[2] Brown, A., & Jeong, B. (2018). International comparison and implementation of slow city success determinants: The case of Damyang Slow City, South Korea, and Seferihisar Slow City, Turkey. Development and Society, 47(4), 613-632. Heitmann,S. and Robinson,P. and Povey,G.,, (114–127), CABI, Slow food, slow cities and slow tourism., (2011)

[3] Çayirdağ, M. (2001) Kayseri Tarihi Arastırmaları, Kayseri.

[4] Çakiroglu, N. (1952). Kayseri Evleri, ITÜ, Istanbul.

[5] Cebeci, O. M. (2018) Develi'de iz bırakanlar, Kayseri. Develi Belediyesi Kultur Yayinlari No:35

[6] Celebi M.R. (2020), Anadolu Kerpic, Istanbul.

[7] Çöteli, M. G.; Akgül B.; Dağlı A. ; Çelik T., (2015). DETOK. Develi`de Örnek Bir Yerel Kalkınma Planlaması.

[8] Devli Belediyesi, (2003) Bütün Yönlerile Develi, Develi.

[9] Deutsche Unesco Kommission (2011) Erstellung von Welterbe - Nominierung - Handbuch, Berlin

[10] Duru, R. (2007), "Göller Bölgesi Neolitiği: Hacılar- Kurucay Höyüğü- Höyücek- Bademağacı Höyüğü", (Özdoğan, M. – Başgelen, N.), Anadolu'da Uygarlığın Doğuşu ve Avrupa'da Yayılımı Türkiye'de Neolitik Dönem Yeni Kazılar- Yeni Bulgular, İstanbul : 331-360.

[11] Dr. Öğretim Üyesi Şükrü Dursun - Arkeolog Gürcan Senem - Özlem Elbustan - Banu Küçük, (2022) 2020 Yılı Kayseri Kızıl Köşk Kazısı, 25. Uluslararası Orta Çağ ve Türk Dönemi Kazıları ve Sanat Tarihi Araştırmaları, Konya 2022 NEÜ Selçuklu Kültür ve Medeniyeti Uygulama ve Araştırma Serisi 3, s. 997-1032.

[12] Faroqhi, S. (2005). Crafts and Craftsmen of the Middle East: Fashioning the Individual in the Muslim Mediterranean, I.B.Tauris.

[13] Häusler, W. (1996). Safranbolu, Leben in einer türkischen Kleinstadt, Graz.

[14] Karaman, A.; Ateş, A.; Sayın, K. (2019). Türkiye'nin UNESCO Değerleri ve Turizm Potansiyeli.

[15] Kemikli, B; (2010). Sehir Hayat ve Dervis, Istanbul.

[16] Mellaart, J. (1970); Excavations at Hacılar I, BIAA Occasional Monograph Series 9, Edinburgh.

[17] Özdoğan, M. (2006). Yeni Veriler Işığında Anadolu Mimarisinin Dünya Mimarisine Katkıları, Fehime Yuttaş (ed.), Gecmişten Geleceğe Anadolu'da Malzeme ve Mimarlık. Sempozyum / UIA 2005 XXII. Dünya Mimarlık Kongresi 4-5 Temmuz 2005, İstanbul: 145-162.

[18] Michell, G. (1978). Architecture of the Islamic World: Ist History and Social Meaning,

[19] Morris, AE.J. (1994) History of Urban Form, London.

[20] Naumann, R. (1975). Eski Anadolu Mimarlıgı, TTK Yayini, no:9, dizi: 4, Ankara.

[21] Reha, G. (1998). Tradition of the Turkish House and Safranbolu Houses, Istanbul.

[22] Rheidt, K. (1990). Byzantinische Wohnhäuser des 11. bis 14. Jahrhunderts in Pergamon, Dumbarton Oaks Papers 44: 195-204.

[23] Rosenberg, M. ; Redding, R. W. (2002), Hallan Cemi and Early Village

Organization in Eastern Anatolia, I. Kuijt, ı. (ed.), Life in Neolithic Farming Communities Social Organization, Identity, and Differentiation, Kluwer Academıc Publıshers, New York-Boston-Dordrecht-London- Moscow: 39-58.

[24] Schmandt-Besserat, D. (1977). The Beginnings of the Use of Clay in Turkey, Anatolian Studies 27: 133-150.

[25] Süme, M. (2018) XIX. Yüzyilda Orta Anadoluda bir osmanli kazasi Develi, Kayseri.

[26] Tolacı, S.S.; Hürümüzlü, B. (2020). Isparta'da Kerpic ve Yasam, Ankara.

[27] UNESCO. (2023) Operational Guidelines for the Implementation of the World Heritage Convention https://whc.unesco.org/en/guidelines/

[28] UNESCO. https://whc.unesco.org/en/list/492/

[29] UNESCO. Criterion iii https://whc.unesco.org/en/criteria/

[30] Yegül, F. ; Favro, D. (2019); Roman Achitecture and Urbanism from the Origins to Late Antiquity, Cambridge.

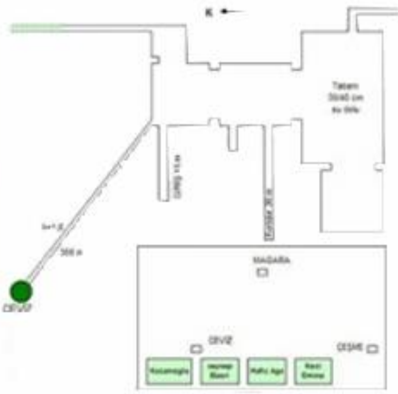
Illustrations: Pilot project for UNESCO World Heritage Status: Zile (Develi) a "Place of Peace."

Fig.1: Zile (Develi) with significant building heritage of adobe structures

Fig.2: Çatal Hüyük 7560 - 4340 BC Neolithic to Chalcolithic (with Reconstruction - Wikipedia)

Fig.3: Çatal Hüyük and Zile (Develi/Kayseri) (googlemap)

Fig.4: Caesar's campaigns from Rome to Zela (modern Zile). Caesar may have used the name Zile up to four times to refer to various small locations.wikipedia



Zile Cave /Drawing plan Ibrahim Kozanoğlu Arcives

" I WENT, I SAW, I WROTE" Nezir Ötegen

Fig.5: The Zile Tumulus, the Anatolian Pyramid. is one of the largest tumuli of Phrygians (nearly 1200 BC). It is 35 meters high and 3000 meters wide. (www.develi.bel.tr)

Fig.6: *A Hub for Experimental Earth Building* in Zile: "Earth architecture cleans the air, protects from radioactivity and is earthquake resistant. Adobe walls keep out the heat in summer and the cold in winter...." N. Ötegen

Fig.7: Women's grassroots civic engagement for World Heritage Status for Zile (Develi).

Fig.8: Inauguration of the Zile Cultural Center "Zile Kültür Evi." and its key initiatives.

Fig.9: Zile (Develi) a "Place of Peace." - in network with former Orthodox Zileli in Greece

Kerpic'24 – Challenges in Earth-Based Interior Architecture;
Current Issue in Earth-Based Materials, Construction Techniques
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Earthquake Resistant Horizontal Flexible Loadbearing Wall

Bilge ISIK[1], Neslihan ISIK[2]

[1] Prof Dr, Istanbul Technical University, TC
[2] Art Center College of Design, Los Angeles, USA
isik.bilge@gmail. com www.kerpic.org
UNESCO ICOMOS ISCEAH
Bilim Kurulu Türkiye temsilcisi

ABSTRACT

The rapid increase in the world population has created a need for multiple housing. With wars and natural disasters increased the demand for housing. With the February 2023 earthquake in Turkey, great destruction occurred in rural and urban settlements. If it is thought that the housing need in rural settlements will be solved by "traditional architecture" It would be useful to examine adobe construction technology today. In the last century, the materials and techniques used in building construction have become industrialized. Reinforced concrete frame and steel frame structures began to be used so that the building could be built faster and with more floors. Although contemporary building technologies were
Included in higher education, "traditional architecture" building technology was not included in architecture and engineering higher education. Considering that **"one third of the world's population"** lives in earthenware architecture, earthenware and masonry construction technology should be included in education.

The reason why the Earth Construction is on the agenda again today: while establishing a healthy internal climate, the structure uses less energy due to the thermal conductivity of the soil wall material. Nowadays, as a result of increasing energy prices, 0-energy buildings are gaining importance. The energy budget of those living in Earth Construction decreases, and environmental pollution decreases as the world uses less energy in the housing sector.

Ankara in 2009 in order to solve the housing needs of the society and to use Earth Construction Earthquake safe technology was obtained with the shaking table experiment at the General Directorate of Disaster Affairs. Research has been carried out in three areas at Istanbul Technical University since 1980: 1. Durability to environmental conditions, 2. Earthquake safety of the Earth Construction and 3. Industrialized Earth Construction technology

In this study, as a result of the information obtained through Earth Construction research at ITU, the construction of fast houses and settlements, using all kinds of industrial machines of construction technology, for those who became homeless and living in containers and tents after the February 2023 earthquake will be briefly summarized.

1. SOLUTION TO THE HOUSING NEED WITH NEW GENERATION EARTH CONSTRUCTION

1/3 of the world's population lives in earthen building (R.1). The most effective issue for architectural decisions is the earthquake safety of buildings. Many parts of the world and many places in Anatolia are affected by earthquakes. A very wide region and a large number of people were affected by the 6 February 2023 Kahramanmaraş earthquake. The post-earthquake housing need in the region is roughly 200 thousand in urban areas and 75 thousand in rural areas (R.2). The results obtained on the subjects will be briefly summarized.

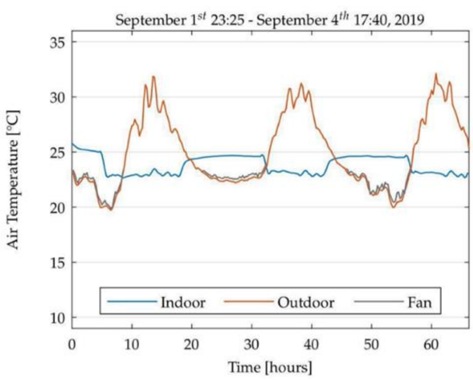
Solution to housing needs with new generation Earth Construction: İTÜ RD

1. **durability technology**
2. **earthquake safe technology**
3. **industrialized new generation Earth Construction technology**

(R.1) World Population in Earth Housing *(R.2) Post Earthquake Housing need*

Healthy and Zero-Energy Housing: Earth Construction

Earth Construction : create a HEALTHY INTERNAL CLIMATE according to the heat transfer resistance and moisture behavior of the soil wall material.
Indoor climate / outdoor climate measurements (R.3) on the Earth Construction built within the scope of TÜBİTAK INTAG TOKİ 622 Project at İTÜ Ayazağa can be seen in the chart.
It shows whether the air inside is hot/cold. The blue inner climate line shows the interior measurements, proves that the Earth Construction naturally provides suitable climatic conditions for humans.



(R.3) Indoor climate / outdoor climate graph *(R.4) TUBITAK Project 622 - 1995*

2. DEFINITION OF TRADITIONAL ADOBE PRODUCTION

Earth Construction production is summarized as follows: Suitable soil with a clay content of approximately 30% is completely mixed with straw and water (R.5) in a mortar pool by crushing it with the foot. (R.6). The obtained adobe mortar is placed in the pool (R.5). It is kept for a week. While the straw was waiting in the pool to ensure the water resistance of the adobe structure, the plant sap passes into the mortar water in the pool. After being given the "block shape" called "adobe cutting" (R.7), it is placed regularly on the threshing floor for drying. If dry in a week, depending on the weather, the adobe bricks should be turned upside down to prevent cracking. If a threshing floor can hold 2 thousand blocks of adobe and the building needs 6 thousand blocks, cutting the adobe + laying it in the mixture + drying the top/bottom is repeated 3 times. After the adobe dries, the sap of the straw (organic matter) sticks the soil particles (inorganic) together. When the Adobe Building sees rain, it is no longer damaged by water. When inorganic and organic are used together, the grains become inseparable and durable. As it is known, historical earthen castles remain intact on top of mountains for thousands of years without melting.



(R.5) Adobe stilling pool *(R.6) Foot Mixing.* *(R.7) Adobe Cutting*

The cost of owning a traditional adobe house in rural areas in ancient times:
Construction Soil and straw material = free in rural areas,
Labor = construction by manual labor of the subject/ neighbor,
Building construction site = own property. In ancient times, one could own a house in rural areas without spending money. Nowadays, traditional adobe 1. It is difficult to obtain materials 2. A lot of daily wages are paid 3. Construction takes a long time.
Today, modern technology that uses: 1.less time, 2.less worker, 3.less materials reduces costs.

3. NEW GENERATION = EARTH CONSTRUCTION-ALKER PRODUCTION

The newly acquired contemporary adobe name is **GYPSUM (ALÇI)+ ADOBE (KERPİÇ)= ALKER .**

Materials	**% kg**	**Practical Scales**
Adobe	100	2 wheelbarrows
Gypsum	10	4 oars
Lime	2 (time)	1 oars
Water	18-20	1 bucket

Plaster + adobe =ALKER, resistant to flood water (Köyceğiz-BKM) and **frost** (VAN mukhtar office)

ALKER construction Technique

1) materials = earth +, 10% gypsum +, 2%lime
2) dry mix the materials, adding very little water
3) transfer the mixture into the concrete curtain mold

4) repeat layers of mixture at a height of 15cm and ram into place,
5) dismantle the mold in about an hour the wall is ready, the mold can be used again.

4. NEW GENERATION EARTH CONSTRUCTION = EARTHQUAKE SAFE TECHNOLOGY

There must be regulations for earthquake-safe construction of masonry buildings. After the meetings held with the ministry and academic members in 2018, Earth Construction material and building rules were removed from the Earthquake regulations. Those who build masonry and traditional Adobe building no longer know and do not use the "earthquake-resistant" rule. Historical masonry structure does not get damaged in an earthquake by showing different strength horizontally (R.8). The masonry wall of equal strength, built recently (R.9), collapses by cracking diagonally under the effect of horizontal load.


(R.8) Stone + brick historical masonry building (R.9) Brick masonry building that broke diagonally during the earthquake

Earthquake Safety Tests Conducted in ITU Construction Laboratory

ITU construction laboratory - earthquake test - <u>different horizontal strength = flexibility</u> results




(R.10) Unguarded wall (R.11) Horizontal shift (R.12) Diagonal crack (R.13) Prj622 Earthquake Pilot House

(R.10) If the masonry wall without precautions is of equal strength, the diagonal cracks.
(R.11) If a flexible horizontal surface is placed at intervals on the masonry wall from bottom to top during the construction phase, the horizontal force fades in the flexible region.
(R.12) If there is a horizontal flexible zone on the wall, the diagonal crack cannot go further than the flexible zone.
(R.13) different strength = flexibility technique obtained in the laboratory was applied in 1995 ITU-TUBITAK prj622 wall construction, in 1999 Istanbul earthquake = no damage in prj622

Research shows Horizontal Flexibility Layers prevents earthquake damage :

Horizontal: different strength or flexibility obtained through experiments is also observed in historical

structures. In the historical social complex (R8), the masonry wall was built with the repetition of stone + brick. Since there is a difference in the strength of stone + brick materials, the horizontal force in an earthquake is extinguished in the horizontal flexible layer and the wall is not damaged.
Horizontal Flexibility Layer : energy quenching technique with different strength - flexibility was determined at ITU lab. 1995- ITU TUBITAK INTAK TOKI 622 (R.13) the wall has different strength and flexibility. The theory applied on the 1995-project622 structure was proven in the Istanbul 1999 earthquake.

Earth Construction Wall: HORIZONTAL FLEXIBILITY TEST WITH SHAKING TABLE



(R.14) Shaking Table (R.15) Horizontal Flexibility Layer (R.16) masonry wall without Flexibility Layer

" HORIZONTAL FLEXIBILITY TECHNIQUE IN WALLS Developed through Research"
It is seen in the form of stone + brick masonry in the historical building. (R.12) Horizontal Flexibility Layers had been applied to test building on shaking table. Test building was shaken 7 times with 7 Richter Earthquake. The shaking table test has proven to withstand this strength. If there is horizontal flexibility , the force does not affect the entire building and its absorbed in the flexible layer.

5. NEW GENERATION EARTH CONSTRUCTION = *industrial rapid construction techniques*

Alker material New Generation Accelerating construction technologies use machinery:

1. rammed earth,
2. block production in the facility,
3. spraying into the mold with shotcrete machine

5.1. New Generation Earth Construction = Rammed Earth

5.1.1. Rammed Earth 1995 TUBITAK INTAG TOKI 622 R&D

A Pilot Building was built according to the findings at ITU Laboratory research developed "horizontally flexible, earthquake safe technology" at ITU Ayazağa in 1995 TÜBITAK INTAG TOKI 622 R&D project. (R19). Not even a plaster crack was visible in the plastered Earth Construction masonry structure during the 1999 Istanbul earthquake.



(R.17) Concrete mixer (R.18) Filling with scoop (R.19) Concrete Mold

5.1.2. Rammed Earth 1997 ALTINOLUK SUMMER HOUSE 280m2


(R.20) Altınoluk Excavation Soil Construction (R.21) Altınoluk Summer House 1997

Altınoluk plastered Earth Construction summer house was built in 1997 as a 180 m2 building. During the project decisions phase when the construction was about to start, the homeowner requested a heating boiler room and radiators in the building because he did not recognize the heat transfer resistance of the Earth Construction wall material. The boiler room has not been operated since 1997, when they used the building. Soil from the excavation was used in the construction of the building.

5.1.3. Rammed Earth 2015 BKM film Shooting Plateau – Köyceğiz

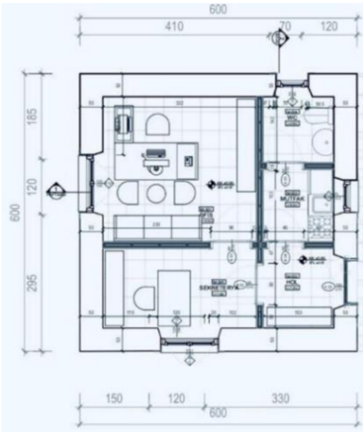


(R.22) Film Plateau (R.23) Rammed earth wall (R.24) Transition between buildings

BKM Film Shooting Plateau in Köyceğiz was built on a very large area in 2015 with a rammed earth wall inside the formwork. The soil used in the building was prepared very quickly at the aggregate facility of the concrete batching plant nearby. Laminated wooden column + beam system was used to span the large span areas of the project. It was completed as a two-story building, including the large filming hall (R.39), a large office building for film preparation, social areas and a dining area. An accommodation facility was built for the artists who will stay during the filming phase. During the winter, the surrounding stream overflowed and the building was submerged in approximately 60 cm of water. After the water receded, there was no damage and no color traces remained on the wall surface. Earth Construction is resistant to time and water.

5.1.4. Rammed Earth - 2019 VAN-Tushba -Municipality Muhtar Office

Earth Construction Wall Construction: The water added to the Earth Construction mortar should be less than dry concrete. If the mortar must be rammed in less then 20 minutes after mixing with water, depending on the setting time, otherwise binding will be impaired. Construction is extremely fast with modern Earth Construction materials. The sample building built with this recipe is the 6x6 m headman's office in VAN. The volume of the soil wall of the Van headman office building is 25m3 and the construction time of the wall by hammering the mold is 3 days. All of construction machines are used in construction (R25, R26, R27). It is proven that the water visible on the surface did not enter the wall section, if it did, below zero temperatures would have burst the wall.

(R.25)Tuşba, Headman's Office (R.26) Headman's Office Plan (R.27) Snow on Earth Construction

5.2. New Generation = Earth-Block Production - 2000 - Urfa GAP

Urfa GAP Administration - Southeastern Anatolia Project - built dams. When the villages that will be under water due to the construction of the Birecik dams were relocated, "soil blocks" produced in the pavement stone facility was used to produce ALKER blocks. The building was built in Load bearing principals with Alker Block in 2000. Horizontal Flexibility Layers were applied. The building has withstand the devastating Kahramanmaras earthquake in 2023.



(R28)GAP Construction Process (R29)Cobble Stone Facility (R.30) GAP Latest Status

5.3. New Generation = Earth Shotcrete - 2012 - Cyprus Dilekkaya

The architectural heritage of Cyprus is adobe. Recently, traditional adobe construction has become obsolete because of high labor and long construction times required. Historical and inhabited Adobe houses were demolished and re-built with industrial materials. Even in Cyprus climate conditions, heating and cooling became necessary in these new buildings. In Cyprus, we built a single-person Earth Construction house in Dilekkaya with the shotcrete technique, which demonstrates the speed of earth construction. Heating and cooling is provided naturally by earth wall insulation properties. (R.31) (R.32)

(R.31) Dilekkaya Shot Pattern

(R.32) Dilekkaya Opening, KTMMOB

6. CONCLUSION

Traditional adobe buildings use the least amount of energy for a healthy internal climate. The buildings use less energy, thus reducing the energy consumption of the residents. If the number of buildings that use low energy increases, the pollution of the world by using energy will be prevented. However, traditional adobe buildings require a long construction time. In the construction industry, increasing time means increasing costs, including the increase in the number of workers.

Today, the research of new generation adobe technology has proven;

Durability; by ALKER material mix against weather and physical conditions.

Earthquake safety; by applying "horizontal flexibility layers" developed in the research.

Industrialized construction; techniques applied by regular construction machinery ensuring safety and speed compared to traditional techniques.

REFERENCES

http://www.kerpic.org/alker%202000%20TR-K%C4%B0TAP.pdf
http://kerpic.org/alker_technology.htm
http://www.kerpic.org/scanscan1920.pdf

IŞIK, B, ÖZDEMİR, P., BODUROĞLU, H., (1999): "Erthquakes Aspects of Proposing Gypsum Stabilized Earth (Alker) Construction for Housing in the Southeast (GAP) Area of Turkey", Workshop on Recent Earthquakes and Disaster Prevention Management, Erthquake Disaster Prevention Research Center Project (JICA), General Directorate of Disaster Affairs (GDDA), Disaster Management Implementation and Research Center (METU). Ankara 10-12 March , http://nisee.berkeley.edu/cgi-bin/texhtml

IŞIK B., (2003), "Case Study on Alker (earth) Shooting Technology" 9th International Conference on the Study and Conservation of Earthen Architecture-Terra 2003, ICHO (Iran Cultural Heritage Organization), Yezd-Iran, 29Nov-5Dec 2003)

IŞIK B., (2003): "Depreme Dayanıklı Yapı Elde Edilmesi için Alker Duvarın Tasarım Kriterlerinin araştırılması", CD Bildiri No: AE-048, Beşinci Ulusal Deprem Mühendisliği Konferansı, 26-30 Mayıs 2003, İstanbul, Ing Poster: Investigating the design criteria of alker wall to achive the earthquake safe structure

The Fringe Architectural Design: Ottoman Adobe Houses in the 19th Century Western Travel Writings and Orientalism


Historian and Writer Dr. Çağdaş L. ÇELEBİ
Asst. Prof. Gözde KUZU DİNÇBAŞ
Nuh Naci Yazgan University, Faculty of Fine Arts and Design, Department of Interior Architecture and Environmental Design

cagdas@alumni.bilkent.edu.tr, gkdincbas@nny.edu.tr

ABSTRACT

The 19th century, which witnessed the emergence of various geographical societies and the increasing influence of Orientalism in historiography, also marked the period when European travellers flocked to the Ottoman lands. Whether consciously or unconsciously, the works written by these travellers provide us with valuable information about the past. Undoubtedly, this holds true for the history of architecture as well.

The issue of describing 'adobe houses,' which were considered one of the cornerstones of architecture in earlier periods, but nowadays exist on the fringe between architectural past and present –because today they are not as popular as before, is essential. When we examine this issue beyond their designs, from a sociological perspective, we see that narratives about adobe houses have the potential to reflect social ties among societies. Therefore, in our study, we will investigate to what extent 19th century travellers viewed adobe houses in the Ottoman lands through an Orientalist lens. To enhance our research, we not only examined travel books but also explored bulletins published by various geographical societies and the writings of Evliya Çelebi, an Ottoman traveller, as well as the works of Europeans, who resided in the Ottoman lands.

Our analysis of archival sources reveals that adobe houses did not hold a prominent place in the narratives of European travellers. However, there were exceptions, and moreover, these structures were not consistently labelled as distinctly Eastern.

Keywords: Adobe house, traveller, 19th century, Ottoman Empire, Orientalism.

1. INTRODUCTION

1.1. Background and Context:

The 19th century travel accounts often delved into the traditional architecture of the regions visited by travellers. Local housing features provided valuable insights not only into regional climate and socio-economic structures but also into human behavior and the lifestyle of inhabitants. Therefore, evaluating "non-verbal" social symbols and values embodied in architectural structures is crucial for us to understand the broader context.[2] While travellers did not necessarily intend to contribute to today's architectural science with their works, the information we glean from their writings significantly

[2] Sharon R. Steadman, "Prehistoric Settlements in Central Anatolia ", *Agency & Identity in the Near East*, Sharon R. Steadman & Jennifer C. Rose, Equinox Publishing, London, 2010, p. 29.

enriches our understanding of the architecture of previous centuries and the societies that shaped them. Undoubtedly travellers, who introduced readers to the socio-architectural features of unfamiliar lands conveyed not only factual information, but also their personal views and tendencies.

In this study, we will examine how 19th century Western travellers perceived "adobe houses," which held a significant place in Eastern architecture and were commonly found in the Ottoman lands. We will explore the criteria they used to present these houses to their readers in their writings. Within this context, we will discuss the extent to which the Orientalist approach, prominent in historiography during the late 19th and early 20th centuries, influenced their descriptions of mud-brick houses.

The adobe houses, which travellers visiting the Ottoman lands in the 19th century came across, had been used in certain regions of Anatolia for thousands of years and are still in use today. Unlike regions with abundant trees where wooden materials were preferred or areas rich in stone, adobe had been used in the rural areas of Anatolia since the Neolithic Age, that is to say since 9,000 B.C. In fact, in addition to being economical and easily accessible –due to its low cost-, because it provides advantages in terms of thermal insulation, and its fire resistant as well as environmental friendly nature, its structural composition has remained largely unchanged up to the present day. [3]

Having these in mind, when we look at travel books and other archival sources of the period, we realize that, despite the comfort they provide and all the above-mentioned benefits, neither today nor in the past was the value of mud brick houses fully understood. So much so that finding traces of earth houses in archival sources, which seem to attract less attention than other traditional building types, is like digging a well with a needle.

1.2. Research Question:

Despite all the limitations, our study examines the 19th century travellers' approach concerning their description of mud brick houses in Anatolia. Within this context, we focused on the question of how much Western travellers were influenced by the Orientalist approach, which had an increasingly significant impact on historiography, especially during the period under investigation.

1.3. Sources:

Since our research is directly limited by the diversity of our sources, we have made use of various materials to evaluate the subject from different angles. Firstly, we analyzed 19th century travel books. However, a significant challenge at this stage was the scarcity of travel books specifically mentioning adobe houses, especially in the eastern regions of Anatolia. Unlike the past, when individual travellers embarked on their journeys independently, this century saw the organization of Oriental trips with the support of geographical societies. As a result, we also scrutinized journals published by societies of this sort. So at this point, we resorted to the travel books, which were written by European people, residing in the Ottoman lands. Apart from this, although written in a different century, another source that helps us understand their tendencies is the *Seyahatnâme* of Evliya Çelebi, who in the 17th century traveled through the Ottoman lands and presented architectural information in his works. By examining the adobe houses depicted by Western travellers through Evliya Çelebi's eyes and comparing their descriptions, we can come closer to answering our question. After evaluating all the available sources, making comparisons using an inductive methodology has allowed us to demonstrate how 19th century travellers influenced historiography regarding mud-brick houses.

2. CONCEPTUALIZING OUR THEORY

2.1. Orientalism:

Before delving into the subject in detail, it is useful to briefly touch upon the meaning of Orientalism and its historical development. Derived from the Latin words for "rising" (*orior*) and "falling" (*occido*), which are based on the movements of the sun in the sky, description of East and West in historical

[3] Çağrı Yalçın, İsmail Emre Kavut and Kadir Bingöl, "Kerpiç Malzemenin Anadolu'da Geleneksel Yapılarda Kullanımı", *8gen-Art* Cilt/Volume: 2 Sayı/Issue: 1, 2022, p. 82, 85.

discourse is actually as old as the first encounters between these two poles. However their meaning had changed in the course of time. During the Medieval times, the term "East" was used to indicate certain climatic terms, such as winds or cardinal directions, rather than referring solely to a "geographical area". Contrary to any negative connotations, the East was –especially until the mid-13th century- also defined as a place where miraculous people lived and wonderful events took place.[4] If we consider the issue from a more formal stance we see that, again during the Middle Ages and even in the early modern period, "religion" formed the foundation of the academic perception of the East. However, with the turn of the 18th century, religion was gradually supplanted by "science". This shift occurred primarily from the 16th century onwards, due to the impact of the Reformation and then the Enlightenment periods. As a result, the world began to be viewed through a more scientific lens, in stark contrast to the past.[5] By the 19th century, Orientalism had established itself as a truly academic discipline.[6]

If we evaluate the impact of Orientalism on historiography from this perspective, we recognize that the geographical and scientific communities, which encouraged and guided travellers to explore the East, did not coincidentally emerge in the same century. In the East-West relationship theory in Orientalism put forward by Edward Said, –who is criticized today for making too much generalization in his view, we come across a combination of Foucault's discourse and Gramsi's understanding of hegemony. As Said underlines the support provided by institutions in the effort to create a perception towards establishing a hegemonic relationship between East and West.[7]

2.2. Western Travellers and Adobe Houses:

As the first of their kind, the *Société de Géographie*, which was founded in Paris in 1821, the *Gesellschaft für Erdkunde zu Berlin* founded in Berlin in 1828, and then *the Royal Geographical Society* founded in London in 1830, sent travellers to various parts of the world, including the Ottoman lands. These travellers, who were often professional geographers, geologists, and sometimes even surgeons, primarily aimed to advance the science of geography. However, their explorations also illuminated the architectural history of today. With support from these institutions, travellers began to systematically examine the inner parts of Anatolia, much like they did with the western regions.

As a consequence, in the traveller books of this era, we encounter more analytical information about the socio-cultural life of societies. This is also accurate for knowledge, related to architectural history. However, an important point that we should keep in mind at this point is that travellers' perception of their environment was directly parallel to their personal tastes and curiosities. That's why sometimes they made different observations about the same city and its architectural structures. For example, unlike William Francis Ainsworth, who openly expressed his liking for Tokat's architecture, William Hamilton gave a completely different descriptions about the very same city[8].

Bearing all these in mind, when we examine specifically the descriptions of adobe houses in traveller accounts, a striking point stands out is that, such houses did not leave a prominent impression in the writings of the travellers. Thus, simplicity prevails in the narratives written about earthen houses, which were often glossed over with short descriptions. The reason behind this, to some extent, can be attributed to the fact that travellers who visited the Ottoman lands in the 19th century were not very familiar with such structures in their homelands. In other words, since they did not know much about the characteristics of adobe buildings, which were foreign to the architectural features of the places they came from, they did not feel the need to talk about and comment at length in their works.

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[4] Kim M. Phillips, *Before Orientalism: Asian Peoples and Cultures in Europe Travel Writing, 1245-1510*, University of Pennsylvania Press, Penn, 2014, p. 18-21.
[5] Mustafa Serdar Palabıyık, "Travel, Civilization and the East: Ottoman Travellers' Perception of "the East" In the Late Ottoman Empire" (P.hD Thesis), Middle East Technical University, Ankara, 2010, p. 32.
[6] Osman Sarı, "Oryantalizm Üzerine Bir Araştırma", (M.A Thesis), Fırat Üniversitesi, Elazığ, 2008, p. 15-17, 44; Oruç Reis, "Oryantalizm", İslam Ansiklopedisi, C. 33, 2007, p. 428-437.
[7] Mustafa Serdar Palabıyık, "Travel, Civilization and the East", p. 27, 29-30.
[8] Aygün Kalınbayrak Ercan and Duygu Kalkan Açıkkapı, "19. Yüzyıl Seyyahlarının Mimarlık Tarihi Yazımına Katkısı: W. J. Hamilton ve W. F. Ainsworth'un Anlatımıyla Tokat ve Amasya", *Beşeri Bilimler Ekseninde Güncel Araştırmalar: Kuramlar, Kavramlar, Uygulamalar*, Kriter Yayınevi, İstanbul, 2020, p. 57-58, 68.

Apart from their frequency of mention, another issue that draws attention in travel writings is that, although these types of houses were not generally found aesthetically and functionally adequate[9], they were not always seen as bad architectural structures. For instance, according to traveller –and in the meantime Levantine missionary- Henry Van Lennep, who was living in İzmir and visited Tokat in 1870, "*The outside of the houses is far from attractive, being plain, uniform mud-wall, pierced at most with a few small and high windows; but when you go in at the gate, you find a paved court, a piazza, and doors and windows opening upon it, or upon the garden in the rear*".[10]

However positive comments, such as those presented by Van Lennep were rare. Nevertheless, while the visual or structural problems of adobe houses were conveyed to the readers, sometimes travellers had mentioned reasons behind the problem. While doing this, -with few exceptions, the deficiencies in adobe houses were mostly associated with the natural resources in the region and sometimes with economic reasons, rather than with the local denizens.[11]

Thus so far it will not be wrong to suggest that, the Western travellers in general had evaluated and wrote about the earthen houses without an explicit prejudice. Apart from all these, directly related to our topic, another important factor that stands out in the traveller writings is the issue of geographical labelling of adobe houses. That is to say, whether or not these houses were categorized under the name of "Eastern" architectural form in particular. If European travellers defined earthen houses as Eastern architecture or considered them solely as Ottoman architectural style, it indicates their inclination toward an Orientalist approach. As it is true that adobe, as a building material, was found in different parts of the world, from Africa to the Far East, and even from South and Central America to Central Europe and certain parts of Australia.[12] However, in the mentioned era, people's travel opportunities were not as common as they are today. Readers mostly confined themselves to what they read from travel books, obtaining indirect information about the outside world. Therefore, it was not unlikely that someone — especially from European or American cities— who did not have much knowledge and experience about adobe houses would read traveller books and mistakenly identify them with Eastern culture. Considering all these factors, when we examine the 19th century traveller books, apart from a few exceptions[13], we discern that earthen houses were not consistently identified as "Eastern" architecture.[14]

In this phase of our research, for a deeper analysis, it would be beneficial to examine Evliya Çelebi's *Seyahatnâme*. As a 17th century traveller from outside of Europe, Çelebi's works serve as a valuable source that can be compared with European travel accounts. Upon reviewing the *Seyahatnâmes* from this perspective, first of all the expressive differences in Çelebi's language become evident. Unlike his European counterparts, he tended to provide more positive and descriptive portrayals of the adobe houses he encountered throughout the Ottoman lands. For instance, in his writings, he described earthen

[9] William Francis Ainsworth, *Travels and Researches in Asia Minor, Mesopotamia, Chaldea and Armenia*, vol. 2, John W. Parker, London, 1842, p. 62; Edwin John Davis, *Life in Asiatic Turkey*, Edward Stanford, London, 1879, p. 200, 240; Charles Fellows, *Travels and Researches in Asia Minor*, John Murray, London, 1852, p. 103; James Morier, *A Second Journey Through Persia, Armenia and Asia Minor*, Longman, London, 1818, p. 136.
[10] Henry J. Van Lennep, *Travels in Little Known Parts of Asia Minor*, vol. 1, John Murray, London, 1870, p. 221.
[11] Ibid., p. 140; Francis Rowdon Chesney, *Narrative of the Euphrates Expedition*, Longmans, London, 1865, p. 424.
[12] Evliya Çelebi, *Tam Metin Seyahatnâme*, vol. 7, Üçdal Neşriyat, İstanbul, 1985, p. 304, 326; Ibid., vol. 9, p. 27, 49, 51, 66; Ibid., vol. 10, p. 449, 463, 469; *The Journal of the American Geographic Society of New York*, vol. 19, N.P, New York, 1887, p. 33, 41, 43; *The Journal of the Royal Society*, vol. 3, John Murray, London, 1834, s. 6, 207, 304, 307; Ibid., vol. 16, p. 38, 61, 111, 170-171, 181-182; Ibid., vol. 47, p. 192; Apostolos Mousourakis, Maria Arakadaki, Sofoklis Kotsopoulos, Iordanis Sinamidis, Tina Mikrou, Evangelia Frangedaki and Nikos D. Lagaros, "Earthen Architecture in Greece: Traditional Techniques and Revaluation", *Heritage*, no: 3, 2020, p. 1237-1238; Seden Acun Özgünler and Erol Gürdal, "Dünden Bugüne Toprak Yapı Malzemesi", *Restorasyon ve Konservasyon Çalışmaları Dergisi*, No. 9, 2012, p. 30, 34; Thomas W. Knox, *The Oriental World*, San Francisco, Hawley, 1879, p. 562.
[13] J. S. Stuart Glennie, *Europe and Asia*, Chapman & Hall, London, 1879, p. 413; John Macdonald Kinneir, *Journey Through Asia Minor, Armenia and Koordistan*, John Murray, London, 1818, p. 35.
[14] William Martin Leake, *A Journal of a Tour in Asia Minor*, John Murray, London, 1824, p. 96.

houses as '… *A house covered with clean soil, with an amber scent*…"[15], "*The doors and roofs are plastered with clean soil*..."[16] or he gave descriptions, which revealed their features like, "*Useful soil houses*... ".[17] On the other hand, despite Çelebi's favourable approach, apparently in his works he did not tended to romanticize the issue a lot. As he underlined the fact that, although such houses were enduring, they might experience structural problems and required maintenance and repairs in time.[18]

CONCLUSION

To sum up our ideas, what we tried to emphasised here is that, undoubtedly the descriptions of adobe houses found in travel accounts were influenced by various factors. These factors include the travellers' educational levels and architectural knowledge, as well as the intellectual tendencies of their time. In addition to these, considering the social atmosphere of the 19th century, we must take into account the potential influence of newly founded geographical societies, which might have affected intellectual trends.

When assessing the information gleaned from archival sources and considering the aforementioned factors, we find that, with some exceptions, the descriptions of adobe houses in 19th century travel books did not exhibit significant biased tendencies that might mislead readers. Surprisingly, the Orientalist approach of that era does not appear prominently in the adobe house portrayals of European travellers. Moreover, the travellers, whose books were examined in our study, did not specifically associate the housing structure of this kind with the East.

Apart from these, the comparison between Evliya Çelebi's house descriptions in his works and the narrations of European travelers revealed a slight contrast. In this respect, the latters' descriptions might appear somewhat plain. One possible explanation for this difference lied not solely in the Orientalist tendencies of European travellers, but also in their level of familiarity. Since, among European travellers too, there were those who provided more favorable and detailed accounts of earthen houses. As we've already seen Henry J. Van Lennep's description. However in this case, Van Lennep's identity played a crucial role. As a Levantine missionary residing in İzmir, he possessed a deeper understanding of the Ottoman lands — perhaps similar to Evliya Çelebi— compared to ordinary European travelers.

REFERENCES

Archival Sources:

Ainsworth William Francis, *Travels and Researches in Asia Minor, Mesopotamia, Chaldea and Armenia*, vol. 2, John W. Parker, London, 1842.

Chesney Francis Rowdon, *Narrative of the Euphrates Expedition*, Longmans, London, 1865.

Çelebi Evliya, *Tam Metin Seyahatnâme*, vols. 7, 9, 10, Üçdal Neşriyat, İstanbul, 1985.

Davis Edwin John, *Life in Asiatic Turkey*, Edward Stanford, London, 1879.

Fellows Charles, *Travels and Researches in Asia Minor*, John Murray, London, 1852.

Glennie J. S. Stuart, *Europe and Asia*, Chapman & Hall, London, 1879.

Kinneir John Macdonald, *Journey Through Asia Minor, Armenia and Koordistan*, John Murray, London, 1818.

Knox Thomas W., *The Oriental World*, San Francisco, Hawley, 1879.

Leake William Martin, *A Journal of a Tour in Asia Minor*, John Murray, London, 1824.

[15] Evliya Çelebi, *Seyahatnâme*, vol. 4, p. 707.
[16] Ibid, p. 708.
[17] Ibid., vol. 5, p. 123.
[18] Ibid., vol. 4, p. 710; Ibid., vol. 9, p. 124.

Lennep Henry J. Van, *Travels in Little Known Parts of Asia Minor*, vol. 1, John Murray, London, 1870.

Morier James, *A Second Journey Through Persia, Armenia and Asia Minor*, , Longman, London, 1818.

The Journal of the Royal Geographic Society, vol. 2, John Murray, London, 1831.

The Journal of the Royal Society, vol. 3, John Murray, London, 1834.

The Journal of the Royal Society, vol. 16, John Murray, London, 1846.

The Journal of the Royal Society, vol. 47, John Murray, London, 1877.

The Journal of the American Geographic Society of New York, vol. 19, N.P, New York, 1887.

Secondary Sources:

Ercan Kalınbayrak Aygün and Kalkan Açıkkapı Duygu, "19. Yüzyıl Seyyahlarının Mimarlık Tarihi Yazımına Katkısı: W. J. Hamilton ve W. F. Ainsworth'un Anlatımıyla Tokat ve Amasya", *Beşeri Bilimler Ekseninde Güncel Araştırmalar: Kuramlar, Kavramlar, Uygulamalar*, Kriter Yayınevi, İstanbul, 2020, s. 57-72.

Palabıyık Mustafa Serdar, "Travel, Civilization and the East: Ottoman Travellers' Perception of "the East" In the Late Ottoman Empire" (P.hD Thesis), Middle East Technical University, Ankara, 2010.

Kim M. Phillips, *Before Orientalism: Asian Peoples and Cultures in Europe Travel Writing, 1245-1510*, University of Pennsylvania Press, Penn, 2014.

Mousourakis Apostolos, Arakadaki Maria, Kotsopoulos Sofoklis, Sinamidis Iordanis, Mikrou Tina, Frangedaki Evangelia and Lagaros Nikos D., "Earthen Architecture in Greece: Traditional Techniques and Revaluation", *Heritage*, no: 3, 2020, 1237–1268; doi:10.3390/heritage3040068.

Özgünler Acun Seden and Gürdal Erol, "Dünden Bugüne Toprak Yapı Malzemesi", *Restorasyon ve Konservasyon Çalışmaları Dergisi*, No. 9, 2012, s. 29-37.

Reis Oruç, "Oryantalizm", *İslam Ansiklopedisi*, C. 33, 2007, s. 428-437.

Sarı Osman, "Oryantalizm Üzerine Bir Araştırma", (M.A Tezi), Fırat Üniversitesi, Elazığ, 2008.

Steadman Sharon R., "Prehistoric Settlements in Central Anatolia ", *Agency & Identity in the Near East, Sharon R. Steadman & Jennifer C. Rose*, Equinox Publishing, London, 2010, s. 27-46.

Yalçın Çağrı, Kavut İsmail Emre and Bingöl Kadir, "Kerpiç Malzemenin Anadolu'da Geleneksel Yapılarda Kullanımı", *8en-Art*, Cilt/Volume: 2 Sayı/Issue: 1, 20222, Sayfa: 82-96, Doi: 10.53463/8genart.202200164

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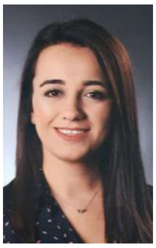
Figures 1, & 2 are obtained from the Municipality of Taşköprü in Kastamonu.

Adobe Structures in Cultural Landscape Areas



Dr. Öğr. Üyesi D. Merve ÇETİNKAYA SÖNMEZ

Ertuğrul Gazi Mahallesi Nuh Naci Yazgan Yerleşkesi Küme Evler 38170 Kocasinan Kayseri

mcsonmez@nny.edu.tr

ABSTRACT

Humanity has always interacted with nature for various reasons such as shelter, eating and drinking, socializing, built structures for various purposes, and shaped nature. As a product of this interaction, cultural landscape areas have emerged. Cultural landscape is defined as the perception of the environment formed as a result of the effects of human activities on the natural environment.

The cultural landscape is used to define areas that reflect the interaction between man and nature. Cultural landscapes are the spatial reflections of the relationship of man with his environment in historical, cultural, traditional settlements. Cultural landscape areas are areas formed as a result of human effects on nature in which local materials and local construction techniques are used. For this reason, they are areas that can be evaluated within the scope of tangible and intangible cultural heritage. For the continuity of tangible and intangible cultural heritage, it is extremely important to document and inventory cultural landscape areas.

It is important for the sustainability of the cultural landscape to determine what the qualities that define an area as a cultural landscape area, to identify and register these areas. Traditional settlements with mud bricks, which emerged as a product of the reflections of the daily lives of societies in the natural environment, are important cultural landscape areas. These settlements should be defined and documented as cultural landscapes and thus gain a conservation status and be passed on to future generations.

Within the scope of the relationship between adobe and cultural landscape, the harmony of these settlements with the natural environment and the reflections of social cultural economic interaction on these settlement textures are discussed. The compatibility of the basic architectural features of adobe structures with the natural environment components and conservation problems were evaluated. It has been determined that the spatial characteristics of the settlements and the structures integrated into the natural environment constitute important cultural landscape areas. The settlements where adobe structures are located have been evaluated as cultural landscape areas that need to be protected in the context of the balance established by the effects of human life on the physical environment with nature.

Keywords: Cultural Landscape, Adobe, Traditional Settlement.

1 INTRODUCTION

Throughout history, humanity has shaped its environment in parallel with the changing and developing living conditions. The materials used in the building culture that shapes the natural environment are easily accessible materials obtained from nature. Soil is one of the main of these materials.

With the Industrial Revolution, building-construction technologies have developed rapidly, as in almost every field. The tradition of earthenware and adobe construction, which has been used for centuries, has also disappeared rapidly since the 1970s. However, the disadvantageous status of adobe structures in the face of natural environmental conditions and natural disasters has been one of the important obstacles to the protection of these structures [11].

Cultural landscape areas emerge when societies shape the natural environments they live in line with their social cultural activities and daily lifestyles. The cultural landscape, which is formed by the interaction between society and the environment, is the areas where natural and cultural features are intertwined. According to UNESCO's definition, cultural landscape areas are areas that emerge as a result of human-nature interactions.

Cultural stratifications created by a settlement throughout history, structures or settlements belonging to different periods of different civilizations can be defined as cultural landscape areas. Settlements with traces of cultural landscapes are living environments where the historical past is preserved and the natural environmental resources are sustainable, and where natural historical and cultural continuity can be monitored. Cultural landscape areas can be urban or rural areas.

Cultural landscape areas are areas designed by human hands for various purposes such as production and housing. It is extremely important in terms of human history to define cultural landscape areas, which are concrete examples of the organic effects of humans on nature, and to include them in conservation processes. However, after the Industrial Revolution, which is one of the important turning points in world history, there have been changes in many issues such as the living spaces and economic activities of societies. Accordingly, natural and cultural heritage sites have been ignored for many years.

It is very important to identify cultural landscape areas under the pressure of rapid urbanization in urban areas, to carry out documentation studies, to monitor their changes in the process, and to develop conservation policies.

Mud-brick settlements, which are a product of human-nature interaction, should be defined with their unique qualities in every area where they are found as cultural landscape areas. These areas are rapidly disappearing due to intense urbanization pressure in urban areas and natural environmental conditions, natural disasters and neglect in rural areas. For this reason, site-specific conservation policies should be developed in adobe-built settlements to be defined as cultural landscape areas.

Residential areas with adobe structures are one of the most concrete examples of the effects of humans on nature. Within the scope of this paper, the definition of built environments built with adobe, a local building material, as cultural landscape areas and the problems related to the sustainability of these areas were evaluated.

2 ADOBE AND CULTURAL LANDSCAPE

Adobe is a building material that can be produced quickly and cost-effectively as a result of a simple process using soil, water and plant parts that can be easily obtained from nature [12]. The use of adobe produced with natural materials as a building material, the use of the right amounts of water, soil and plant parts that make up its content, and the kneading, molding, compaction and drying times require mastery.

The concept of cultural landscape was first defined by the German geographer Friedrich Ratzer in the 1890s as "a landscape shaped by human-nature interaction" [9]. Cultural landscape is the effects of the cultural interactions of the society on natural landscape areas. Culture is a factor, nature is a tool, and the cultural landscape is the result of the interaction of the two [5].

Cultural landscapes are rural or urban areas, including historical settlements. Cultural landscape areas are areas that are formed as a result of a process with human-nature interaction and contain tangible and intangible heritage together [4]. The identity of a cultural landscape area is determined by geographical location, values of the area, historical events, the form of construction created by human hands, aesthetic values and socioeconomic structure [3]. They are areas that develop spontaneously by organizing natural environments according to lifestyles, religious beliefs and economic activities. Mud-brick settlements emerge as a cultural landscape area as a result of the interaction of adobe building material obtained from the natural environment with the cultural structure of the society.

As a result of the interaction of natural and cultural components, the characteristic structure of the cultural landscape emerges. The main characteristics of the cultural landscape can be expressed as follows [6].

- It reflects the characteristics of the residential area and the local life culture.
- It carries the socio-cultural values of the civilizations that lived in the region.
- It reflects the agricultural activities of the local people.
- It reflects the activities of the local people in everyday life.

The cultural landscape reflects people's use of natural resources by adapting to nature [7]. In cultural landscape areas, societies use natural resources in harmony with nature in line with their lifestyles. Adobe structures are structures that respect nature and meet human needs at the highest level within the conditions of the period. A soil-based building material, adobe is a natural resource, and the settlement textures where adobe structures are located are cultural landscape areas. There is an organic link between the cultural landscape and adobe structures.

Adobe bricks were used as part of the local architectural tradition in many settlements in ancient culture. Adobe, which is obtained with local and natural materials, is an environmentally friendly and sustainable building material. Depending on factors such as climate, geography and cultural structure, differences such as plan schemes and façade features of the buildings may occur. With these differences, mud-brick settlements should be considered as cultural landscape areas.

2.1 Adobe Structures in Cultural Landscape Areas and Conservation Problems

Cultural landscape areas are textures where traditional life is maintained with land use forms that are compatible with nature, which have aesthetic, ethnological, anthropological and historical value in harmony with the elements created by human hands in nature. In order for an area to gain the quality of a "cultural landscape area", it must produce important products in the process with nature-human interaction and these products must be in harmony [2]. Settlements with adobe structures are areas that develop and organize according to the lifestyles of the society with local building materials. With these features, they are important cultural landscape areas. Adobe structures are urban identity components that have a place in the urban texture and reflect the history of the settlement texture. The first planned interventions in the urban fabric 18. It has been in question in the Century. Until this period, the settlement textures formed by the effects of the cultural, social and economic activities of the societies on the natural environment in areas that can be defined as "traditional settlement texture" are cultural landscape areas with important heritage value today.

With its technical properties and economic advantages, adobe is a building material that is almost as old as human history [8]. When we look at the history of settlements, it is known that adobe has been used as a building material since 7000 BC. However, with the developing technology and changing lifestyles, rural areas and adobe structures have been abandoned and neglected. These structures, which have low resistance to natural environmental conditions such as rain and wind and natural disasters, are rapidly destroyed and destroyed.

Due to the fact that Anatolia has hosted many civilizations throughout history, there are many multicultural and multi-layered settlements. These settlements can be defined as cultural landscape areas built with local building materials and a product of human-nature interaction. There are no planning and design projects prepared for these settlements, the daily life styles of the society have developed spontaneously in line with the effects of social, cultural and economic activities on the natural environment. The use of local and natural materials in building production contributes greatly to the protection of natural environmental features. Settlements where adobe is used as a building material are environmentally friendly, sustainable residential areas where the material can be mixed back into nature after use. Since these areas are settlements that develop and organize spontaneously according to daily lifestyles, they are the areas where the traces of humans on the natural environment can be observed in the best way. They are cultural landscape areas formed by human-nature interaction.

Adobe structures that have survived to this day with their original quality are generally seen in settlements that can preserve their traditional urban identity. Monumental or civil structures used for various purposes such as housing, trade and education, which have survived to this day in traditional settlements, are cultural landscape areas where the effects of social activities on the natural environment can be monitored in settled life. However, in parallel with the developing technology, the development of new construction techniques has led to the destruction of these cultural heritage sites produced with local materials and traditional construction techniques.

Cultural landscape is becoming a more important concept over the years in terms of understanding and protecting the value of the landscape. Determining the areas that have cultural landscape characteristics in rapidly changing and developing cities, conducting inventory studies, following the change; Decision-making is crucial for creating conservation policies [1]. As in all cultural landscape areas, it is extremely important to protect the cultural landscape areas where adobe structures are located and to transfer them to future generations with their original qualities in order to achieve the goal of a sustainable society. Because cultural landscape areas are areas where both tangible cultural heritage and intangible cultural heritage are represented.

Settlements with mud brick structures are settlements where structures of all sizes such as shelter, education, and religious buildings are built with adobe building materials. Both material and architectural language unity has been achieved between the buildings. The biggest obstacle to the protection of cultural landscape areas is the irresponsible use of natural resources, the inability to manage technological developments correctly and well, and the ignoring of the fact that the natural environment is an exhaustible resource. In order to ensure the sustainability of cultural landscape areas, it is necessary to take the necessary measures to ensure that the integrity of these areas is not deteriorated during their use, that their originality is not lost, and that a high level of sensitivity is provided to the issues of keeping the balance of protection and use under control. Today, adobe structures lose their originality with incompatible additions by users, especially at the point where they cannot respond to contemporary living conditions, or they disappear due to natural environmental conditions such as neglect, rain and wind. When evaluated on a spatial scale, this causes the destruction of organically developing cultural landscape areas.

Especially in traditional settlements, structures built from mud brick materials with local construction techniques constitute cultural landscape areas that can be defined as one of the most concrete examples of the effects of humans on nature. On the scale of historical traditional settlements, there are qualified mud brick structures in many cities in the Eastern and Southeastern Anatolia region of Turkey, especially in Mardin, Diyarbakır, Şanlıurfa and Gaziantep. Adobe is an important building material that respects nature and can be developed and used in the context of sustainability.

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3 CONCLUSION AND EVALUATION

The basic materials used in the production of buildings have been materials obtained from easily accessible nature. Adobe, which has been used as a traditional building material in various parts of the world since 7000 BC , continues to be used as a sustainable material with contemporary adobe applications. It is one of the practices that minimizes the effects of humans on nature in line with the needs of the society that respects nature. Cultural landscape areas have been synthesized for centuries with the reflections of traditional construction materials and construction techniques on the natural environment, shaped as a result of cultural and social interactions, and used as settlements at different scales.

Cultural landscape areas, which emerged as a product of human-nature interaction in the historical process, are under the threat of extinction due to rapidly developing technology and changing lifestyles. Adobe structures and traditional residential areas where these structures are located are disappearing due to problems such as lack of conservation awareness, apathy, neglect, abandonment, natural environmental conditions such as rain and wind, etc.

Adobe, which has been used as a building material for years, has come to the fore again today with the rapid disappearance of natural resources and the increasing greenhouse gas effect, as well as the issues of sustainability and horizontal architecture. In particular, the transfer of adobe structures to future generations as a memorial, symbolic and cultural component in the formation and continuity of the cultural landscape, urban identity and city silhouette should be considered as a necessity for the sustainability of local and national spatial identity. Cultural landscape areas, where the social memory created by human hands in natural environments are embodied, should be protected from the pressure of increasing technological needs on traditional settlements.

All kinds of new construction works carried out under the name of meeting technological needs in living spaces cause damage to qualified cultural landscape areas in traditional settlements. For this reason, in order to ensure the continuity of cultural landscape areas, adobe structures that are examples of monumental or civil architecture in local cultural landscape areas should be protected. These areas should be isolated from new constructions and infrastructure works. These cultural landscape areas should be accepted as the common heritage of humanity and should be preserved and kept alive and transferred to future generations as cultural heritage components.

5 REFERENCES

[1] Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban Planning, 70*(1), 21-34. https://doi.org/10.1016/j.landurbplan.2003.10.002

[2] https://www.tmmob.org.tr/icerik/mimarlar-odasi-kulturel-peyzaj-alanlari-korunmali-ve-toplum-yararina-kullanilmalidir Erişim Tarihi: 15.08.2024

[3] Acun- Özgünler, S., Gürdal, E. (2011). Soil Building Material from Past to Present: Adobe. Journal of Restoration and Conservation Studies. Page:29-37.

[4] Geyik, N. E., Turgut, S. (2023). An Evaluation on the Outstanding Universal Value of the Mardin Cultural Landscape Area and the UNESCO World Heritage List Nomination Process. Journal of Planning. 33(3):393-420.

[5] Sauer, C. O. (1925). The Morphology of Landscape. Publication Geography (Berkeley: University California), (2), 19–53.

[6] Selman, P. H. (2006). Planning at the landscape scale. The RTPI Library Series. Routledge Taylor

&Francis Group, NewYork.

[7] Vos, W. ve Meeks, H. (1999). Trends in european cultural landscape development: perspectives for asustainable future, Landscape and Urban Planning, 46 (1999), 3-14.

[8] Yalçın, Ç., Kavut, İ.E., Bingöl, K., (2022). The Use of Adobe Material in Traditional Buildings in Anatolia. 8Gen-ART. Cilt/Volume:2 Sayı/Issue :1 Page: 82-96 Doi: 10.53463/8genart.20220016 E-ISSN: 2792-0569

[9] Wu, J. (2010). Landscape Of Culture And Culture Of Landscape: Does Landscape Ecology Need Culture?. Landscape Ecology, 25(8): 1147-1150.

[11] Binan-Ulusoy, D., Güler, K., Çobanoğlu, T., (2017). Traditional Adobe Architectural Heritage and Conservation Problems in Anatolia. Soil in every square of life. E-ISBN: 978-605-4303-80-9

[12] Erinç, M., (1980). A Study in the Restoration and Conservation of Adobe Antiquities. Third International Symposium on Adobe Conservation, ICOMOS-ICOM. 79-84. Ankara.

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Traditional Earth-Based Residential Architecture in Countryside of Yozgat


Enes BOSTAN, Ebru Melis ÖZDEMİR
Amasya University, Faculty of Architecture Amasya, Turkey
enes.bostan@amasya.edu.tr
ebru.ozdemir@amasya.edu.tr

ABSTRACT

In the historical process that dates back to 3000 BC, Yozgat and its region have been a mosaic center for many cultures and different civilizations from early times to the present. The city center is 30 km from the capital of the Galatians, Büyüknefes/Tavium; 40 km from the capital of the Hittites, Hattusa; 35 km from the capital of the Medes, Pteria and 77 km from the Roman Imperial Bath city of Basilika Therma. Yozgat, located on the Bozok Plateau, has a rich list in terms of architectural history and cultural heritage. Mosques, building complexes, Ottoman and Roman baths, fountains, public buildings, inns, bridges and especially traditional houses can be mentioned as examples for.

The traditional rural residential architecture of Yozgat shows us features such as one- or two-story houses, rectangular windows, wide eaves and a large garden. Adobe, stone and wood are the most commonly used materials in the houses. In houses built with adobe bricks, the foundations are made of stone to protect them from moisture. Adobe bricks are widely used in the rural residential architecture of Yozgat, especially in the villages in the central district. The people who still live in these villages today prefer clay and stone materials due to the harsh winter conditions in central Anatolia. In addition to the residential function, the barn, the hayloft and the village parlour are also built from mud bricks.

The mud-brick houses of Yozgat show many similarities with traditional building techniques and methods. The aim of researching the traditional adobe houses of Yozgat is to create a 'master model' by examining the similar and different aspects of adobe architecture in the villages of the city center. The basic method is to compare the adobe houses with each other and make certain classifications. In addition, similar and different structural features are identified in these architectural elements. For this reason, the samples are selected from the village settlement line of Büyüknefes/Tavium, which is located between Güneşli and Aydoğan. It was determined that there are no studies in the literature on mud-brick buildings that occupy an important place in the Yozgat landscape. In this sense, it is assumed that filling a large gap will provide an important basis for future research and investigations.

Keywords: Earth-Based, Countryside, Residential Architecture, Yozgat

1. INTRODUCTION

Earth-based architecture, also known as environmentally friendly or sustainable architecture, is about designing buildings that are constructed using materials and techniques that have a minimal impact on the environment [1,2]. Earth-based architecture often uses renewable materials such as clay and straw. It also uses earthen building materials and climate control systems to maximize energy efficiency and reduce energy dependence [2]. Earth-based architecture: The focus is on creating spaces that are compatible with their surroundings, in harmony with the natural landscape and in accordance with the local traditions and materials of the region [3,4]. This approach emphasizes a sense of responsibility for the environment by promoting the connection between people and the land [1].

Earth building, also known as natural building, has become established as a sustainable and efficient construction method, especially in rural areas. This traditional building technique uses materials such as clay, straw, clay bricks and mud, which are locally sourced and readily available in rural areas [5]. In addition, building with earth is generally less expensive, making it an ideal choice for situations with limited financial resources. This construction method also promotes local craftsmanship and gives communities the opportunity to build their own houses, thus preserving cultural traditions and knowledge [6,7]. The thermal properties of natural materials help to regulate the indoor temperature, providing a comfortable living environment without the need for artificial heating and cooling systems. In addition, earth-bound structures are durable and long-lasting, providing resistance to natural disasters such as earthquakes and floods. Overall, the importance of rural construction lies in its ability to address the unique challenges and opportunities of rural communities, promote sustainable development and improve the quality of life for residents [8].

One of the most important factors in the use of earthen architecture, which is an example of earth-based architecture, is geography. The presence of clayey soil, which is the main material for the production of mud bricks, plays an important role in the spread of mud architecture and why it has been a preferred building method for centuries. Another factor that plays a role in the development and spread of this architecture is the climate. It has been shown that adobe bricks made of clay, sand, straw and water can regulate the temperature inside buildings. The thermal mass of clay walls has also been shown to create a more comfortable living environment, as it helps to store heat during the day and release it slowly at night.

One of the regional examples of adobe houses that can be seen and continue to be used in rural settlements in Turkey, especially in Anatolia, are the adobe houses in the Yozgat countryside. The main building material of many buildings in the villages of the central district of Yozgat is earth. The climatic conditions, geographical location, local financial resources and social and cultural structure characterise the earthen architecture in these villages. The aim of this study is to describe the architectural and structural characteristics of the traditional adobe houses in the Yozgat countryside. It is extremely important to document and protect these houses, as they are still used by the people in the villages today and have not yet been scientifically studied. In this context, mud-brick houses in the villages of Gündoğdu, Aydoğan, Derecik, Güneşli, Büyüknefes/Tavium and Musabeyli in the Yozgat countryside were examined and documented on site. As part of the work, knowledge about construction techniques, methods and similar and different aspects of residential architecture in the rural area of Yozgat will be shared in order to preserve the original earthen architecture, the number of which is gradually decreasing, and to ensure its transmission to future generations.

2. STRUCTURAL FEATURES OF TRADITIONAL ADOBE HOUSES IN YOZGAT RURAL

A total of 20 mud-brick houses in 6 villages in the central district of Yozgat province were examined as part of the study. The map of the surveyed villages can be seen in Figure 1.

Figure 1. Surveyed villages

In the villages surveyed, the houses with hipped roofs have one or two storeys (Figure 2). Hall-like floor plans can be found in the settlements. The entrance to the house and the passage to other rooms is from a common place called the 'sofa' (Figure 3). Single-storey houses have rooms, kitchen, bathroom, toilet and storage rooms. Stoves are also used to heat the rooms in winter and to meet the need for hot water in the bathroom. The upper floors of the two-storey buildings contain bedrooms and living rooms. If the family raises livestock, stables for the cattle are planned near the building.

Figure 2. One and two storey adobe house with hipped roof(2024)

Figure 3. Sofa-centered plan, sofa (2024)

Structural features

As a result of extensive interviews with local users living in rural Yozgat, certain structural features and building techniques were identified. In general, these adobe houses are one- or two-story examples. In general, two-storey buildings include rooms with living areas, two different rooms, sofas, pantries and kitchen functions in addition to the one-room examples. Houses, barns, haylofts and mud village rooms were generally observed in the rural areas of Yozgat.

The main building material in the houses, in which wood and stone materials are also used, is clay. In the rural settlements of Anatolia in the villages surveyed, mud buildings with masonry can be seen above all, with walls made of mud cast in brick form (Figure 4). Two different sizes of mud bricks were used in the masonry mud brickwork, which is usually built on a stone foundation at least up to the basement level, referred to as main and lamb bricks, one whole and the other half. The most common clay size used in the studies is 30x30x10 cm. When clay plaster is applied on both sides of the wall, the thickness of the outer walls can generally be 55-60 cm and the thickness of the inner walls 30-40 cm. While clay plaster is applied to the exterior walls, lime plaster is applied over clay plaster on the interior walls.

Figure 4. Stone view down to foundation level

First, the building materials for mud houses are produced. Wooden molds are made for this purpose. Secondly, a mixture of water, earthy materials and fine straw is made and left to stand for 1 day. Then the mixture is poured into the prepared mold and mud bricks are formed. These bricks are left to dry for 2-3 days. And the bricks for the body walls are ready.

Figure 5. Adobe brick

The land is then leveled before the mud-brick houses are built. First, two or four rows of roughly hewn stones are laid on the leveled ground to form the foundation walls, stacked. The stone walls are classified according to their size and use.

The previously formed clay bricks are laid on the stone foundation walls in a strict sequence. Drying and waiting times are allowed for between each stage, which can take up to a week. Once the clay bricks have reached a sufficient height, the earth is sieved and made fine-grained. The fine-grained earth is mixed with water and the outer surface of the houses is covered with clay for plastering. After the clay plastering, the lime is moistened and left to stand for 2 days. It has been observed that the resulting lime plaster was frequently used in Yozgat.

After the body wall is built, knotless trees are used to cover the roof of the rooms. Smooth wooden beams, called refraction, are laid on top of this cladding. Adobe plaster is again applied to the boards to smooth them out. On the upper part of the roof, a unique type of floor called "barren" is used. These saline soils are colloquially referred to as wasteland. The formation of these soils is a process in which water-soluble salts accumulate excessively in the soil, especially in regions with arid and semi-arid climates. When the soil is salinized, Ca++ and Mg++ ions improve the development of aggregates by flocculating clays in the soil and thus have a positive effect on physical properties such as soil aeration and water infiltration.

Figure 6. Roof view

Inside, clay mortar made of straw and earth is poured between the stones to form a floor. After the flooring has dried, it is covered with plaster made from finely sieved sand to create a flat floor. This completes the clay construction.

Common And Different Features

A common method in terms of building systems and construction techniques was observed in the mud-brick houses built on the land of Yozgat. This method is used in all the villages studied. The houses are generally one or two storeys high. In this type of mud houses, units such as barns and haylofts are built in a nearby area separate from the house. Different units are combined with a garden wall to create a complex area. While mud houses are usually covered with lime plaster, structures such as barns and stables do not use lime. In two-storey buildings, the living area of the house is plastered with white lime. The entrances to the house are on the upper level from the outside. A terrace was created in front of the entrance using wooden materials. Access to this terrace is usually via a wooden staircase from the stone base level. Terraces and stairs made of metal and concrete were added later.

Figure 7. Terrace in two-storey buildings

The terrace is also used as an outdoor seating area in summer. There are window openings on both sides of the entrance door on the upper floor. Wooden beams or knotless trees were used as lintels in the window and door openings. Today, the windows are usually tinted with blue paint. Users and builders state that the buildings were built between 1960 and 1970 and are still in use today after repairs. Although clay houses with flat roofs were often used in the past, hipped tiled roofs have been added recently.

Table1. Housing models identified in the villages studied

AYDOĞAN	BÜYÜKNEFES	GÜNEŞLİ
		
DERECİK	GÜNDOĞDU	MUSABEYLİ
		

In one-storey mud houses there is an entrance corridor, a living area and interior rooms with a kitchen/cellar function. In two-storey mud houses, the upper floors are arranged as four separate living rooms on either side of the sofa. The stone-walled part of the lower floor contains a pantry, kitchen and storage rooms.

Figure 8. Interiors

In the landscape of Yozgat we thus encounter two different archetypes built from clay. The first is the large type with a two-storey terrace and the other is the single-storey, simple type.

3. CONCLUSION

Traditional earth-based domestic architecture in countries around the world is seen as an expression of the close relationship between people and the natural environment. These buildings were constructed from materials such as mud, clay, thatch and wood, which are abundant and easily available in the environment. The use of these natural materials has not only contributed to the creation of sustainable and environmentally friendly homes, but has also provided a deep sense of belonging to the rural environment in which they were built.

In countries such as Turkey, Morocco, Iran and India, traditional residential architecture in clay construction has been part of the cultural heritage for centuries. Earthen houses in these countries were not only aesthetically pleasing, but also insulated against extreme temperatures and kept the interior of the houses cool in hot climates and warm in cold regions. The existence of this common cultural base in rural Yozgat can contribute to scientific research as well as provide innovations for modern building techniques. The use of earth-bound materials in the cultural development of Yozgat can allow flexibility and innovation in future designs and promote an understanding that the concept of locality and tradition has always existed, sustained by the creativity and craftsmanship of the people who built them.

The study of adobe houses in the Yozgat landscape is an area where traditional knowledge and modern science combine, with the potential to create sustainable and environmentally friendly habitats. This research can contribute to both the preservation of local cultures and the development of modern architecture and building techniques in Yozgat, a city open to development.

One of the most important advantages of traditional clay construction in Yozgat is its sustainability. These houses have a minimal carbon footprint and are energy efficient. They require less energy to build and maintain. In addition, the use of natural materials such as loam and clay helps to regulate the humidity in the house and creates a healthy living environment without harmful chemicals. This sustainable approach to building not only conserves the region's natural resources, but also promotes a more harmonious relationship between people and the land.

Overall, the traditional earthbound residential architecture in Yozgat is a testament to the creativity and ingenuity of people living in harmony with their natural surroundings. These houses embody a deep connection to the land and respect for the environment, and offer a glimpse into the rich cultural heritage and traditions of the communities that built them. As we continue to face environmental challenges and strive for sustainable living practices in our country and around the world, the lessons from traditional earth-based architecture can provide valuable information on how to build homes that are not only beautiful and functional, but also environmentally friendly and compatible with wildlife.

4. REFERENCES

[1] Ekinci, N. (2019). Modern Toprak Yapı, Kârgir Yapılarda Koruma ve Onarım Semineri XI Bildiri Kitabı, 79–102.
[2] Aktaş, V. (2020). Barak Kerpiç Konut Mimarisinin Sürdürülebilirlik Açısından Değerlendirilmesi, Yüksek Lisans Tezi, Hasan Kalyoncu Üniversitesi, Fen Bilimleri Enstitüsü.
[3] Kuban, D. (1992). Mimarlık Kavramları, Yem Yayınevi, İstanbul.
[4] Hasol, D. (2008). Ansiklopedik Mimarlık Sözlüğü, Yem Yayınevi, İstanbul.
[5] Ay, B.Ö., Azak, T.E. (2021). Türkiye'de Değişen Yapı Özelliklerinin Karşılaştırmalı İncelemesi, Çukurova Üniversitesi Mühendislik Fakültesi Dergisi, 1111–1126.
[6] Öztürk, Ş. (2013) Van Gölü Havzası'nda Bat ve Kerpiçin Mimaride Kullanımı, Güzel Sanatlar Enstitüsü Dergisi, (30): 103-122.
[7] Ekinci, N. (2019). Modern Toprak Yapı, Kârgir Yapılarda Koruma ve Onarım Semineri XI Bildiri Kitabı, 79–102.
[8] Kerpiçle Çağdaş Mimarlık | Yapı, http://www.yapi.com.tr/Haberler/kerpiclecagdas mimarlik_61066.html?ysclid=l43vp2rrr5, Erişim: 7 Mart 2022.
[9] Arpacıoğlu, Ü. (2006). Geçmişten Günümüze Kerpiç Malzeme Üretim Teknikleri ve Güncel Kullanım Olanakları, Ulusal Yapı Malzemesi Kongresi, 15-17.

Alker as a Contemporary Building Material and an Exemplary Project (Perma Doga School Adobe House Workshop)[19]

Esra Nurcin Kara, Assist Prof. Mehmet Nuhoglu

Adress : Esenkent Neighborhood, Kani Pasa Main Street,
Silahlı Kuvvetler Site, Kahraman St., Menekse Apt., Apt. Number : 2, Flat number : 5, Maltepe / ISTANBUL
E-mail : nurcinesra87@gmail.com ,
nuhzademehmet@gmail.com

ABSTRACT

In the article, soil is divided into two main headings as material and building material. Under the title "Soil as a Material", the formation and existence of soil in nature is roughly examined, and under the title "Soil as a Building Material", the traditional building material of Anatolia, mudbrick, its advantages and disadvantages are mentioned. Then, ALKER was discussed as a sub-heading of mudbrick, and its advantages were evaluated in the context of ease of construction, time saving, passive air conditioning and durability. As a sample project, "Perma Nature School Adobe House Workshop" is analyzed.

Keywords: ALKER, adobe, adobe architecture, sustainability

1. INTRODUCTION

Soil is an ancient and widely used building material in the world today. Adobe, on the other hand, is obtained by adding strength to the soil with the sap of fibrous additives such as straw. It is possible to build more reliable and robust structures with more practical methods by stabilizing the soil, which is the main material of adobe, called "adobe" in English literature, with natural components (lime and gypsum). ALKER (Gypsum Reinforced Adobe) is a very valuable building material that makes this possible. In this study, first traditional adobe, then ALKER as a contemporary building material and finally a sample project "Perma Nature School Adobe House Workshop" will be explained.The aim of the study is to expand the place of ALKER as a building material in literature and practice.The adobe workshop at the Perma Nature School was chosen as an example because of the opportunity to examine the material and the construction technique on a small building that can be seen as a sample.

Işık, B. sees the importance of using the word "adobe" when talking about ALKER as "keeping the brand value alive". According to her, ALKER is under the main heading of adobe material [1].For this reason, ALKER is given as a subheading of adobe in this study. By maintaining the use of the word, mudbrick, a traditional building material, should be protected. After all, innovation is possible by keeping the tradition alive. Architectural culture does not emerge all at once; different techniques are passed down and developed over decades and even centuries. Every new generation that knows the traditional construction techniques of their ancestors can easily contribute. Ignoring the experience and knowledge passed down from generation to generation is tantamount to the destruction of architectural culture [2].

[19] This paper is derived from the PHD thesis titled "Housing Design in the Context of Women and Soil Analogy" conducted at Yıldız Technical University, Institute of Social Sciences.

2. SOIL AS MATERIAL

The states of matter are divided into three: solid, liquid and gas. Soil is classified as a solid state of matter.However, it also contains liquids and gases. Aşanlı defines soil as a covering layer formed by the erosion and disintegration of bedrock containing organic and inorganic substances, air and water over a very long period of time.The factors that enable the transformation of bedrock into soil are water, temperature and various living organisms [3]. Soil roughly consists of four horizons (see Figure 1). Of these, the D horizon is the unfragmented bedrock, the C horizon is the fragmented bedrock, the B horizon is the layer rich in salt, iron and various minerals leaking from the earth's surface, and the A horizon is a layer formed by effects such as decay and dissolution, especially in the earth's crust, and agricultural and animal activities.It is very rich in organic matter [4].

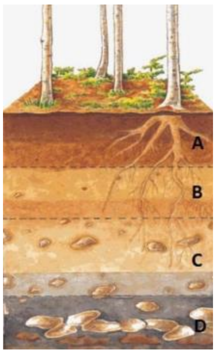

Figure 1. Soil Horizons in Nature, Generally Divided into Four Parts as A, B, C and D **,** Source: "Toprak Katmanları Nelerdir?", 2013, https://eodev.com/gorev/260249

3. SOIL AS A BUILDING MATERIAL

While roughly examining the soil as a material, it was mentioned that the A horizon is rich in organic additives. It is known that the top layer rich in organic wastes is not preferred when obtaining soil from the land for use in construction. In this study, soil as a building material is divided into adobe and ALKER. As a child, Kafescioğlu witnessed masters in Anatolia using lime and gypsum in adobe construction, and years later, when he became an architect, he established a small laboratory at ITU to standardize the proportions of earth, gypsum and lime and named it ALKER [5].

3.1. Adobe

In short, adobe can be defined as a building material produced by blending clay, silt, sand and gravel with the common plant species of the region (straw is generally used in Turkey. In some countries, even cactus is used) can be defined as a building material that is blended and produced especially for use in rural settlements such as barns, houses, etc. Işık B. states that the straw added into the soil does not have any binding properties, but the straw sap that spreads into the mud rested for days is binding [1]. According to some sources, half of the world's population and according to others, one third of the world's population resides in these houses built with traditional materials [2].This is because it is much easier to obtain suitable soil for adobe than other building materials. Construction knowledge is directly proportional to experience and knowledge of the material. Adobe is the most advantageous building material for passive air conditioning. In short, passive air conditioning aims to create optimum ventilation and thermal comfort in spaces with approaches such as the location of the building, the placement of the rooms in the building according to the directions (north, south, east, west), and the strategic positioning of window openings.However, what makes adobe advantageous in passive air conditioning is the structural properties of the soil as a material.Although adobe creates cool indoor air conditions in summer and warm indoor air conditions in winter, it is much more favorable in terms of indoor air quality than many other buildings due to the ventilation of the body walls of the building. Reinforced concrete structures deteriorate the indoor air quality with the construction chemicals used in them, and artificial air conditioning devices used for heating or cooling cause a huge waste of energy (all the insulation materials and chemical components used are certainly not sufficient to maintain heat or coolness).In an adobe building, the energy stored in the walls of a heater that is turned off after a few hours of use helps to utilize this energy throughout the day or night [6]. Reinforced concrete structures are a huge financial burden for the family and the country's budget and a cause of pollution for nature, both with their contribution to carbon emissions during construction (even before construction / during the production of building materials, transportation to the construction site can also be seen as an intermediate process) and the energy consumed during their use.Therefore, adobe as a building material is a very advantageous material in terms of its carbon neutrality and passive air conditioning. The advantages of adobe construction are not limited to this.If the structure is not very complicated, it will not require a great deal of knowledge in the construction process.If the binding of the material is ensured and dimensioning standards are not exceeded in construction (technical details such as determining the maximum number of floors of the building and how many cm the window openings can be, etc.), it can be built easily and safely. The material can be obtained from the location where it will be built or from a point very close to that location. There is no need for any industrial stage for production. It can be easily constructed with conventional techniques. If the structure completes its lifetime, it can be left as it is in nature or demolished and rebuilt. The disadvantages of adobe material can be listed as low compressive strength since it is produced without pressing or firing, lack of water resistance, requiring maintenance every year and having a high unit volume weight, etc. [7]. In addition, if the building is to be constructed with traditional adobe blocks, a large dry area (threshing floor) and time is needed for block construction. Because it is very laborious to produce adobe bricks one by one and to dry them front to back [8].

3.1.1. Alker

Due to the difficulties of building with block adobe (also known as adobe brick), lime and gypsum reinforcements, which are already used in adobe building production even in Anatolia, were standardized by Prof. Dr. Ruhi Kafescioğlu and registered under the name ALKER (Gypsum reinforced adobe) [5]. In the Alker structure, the standards are determined as 10% gypsum and 2% lime of the amount of soil to be used in the mixture. Gypsum accelerates the setting of the soil, lime is added to the gypsum and soil mixture in order to reduce this speed and make it suitable for the construction process of the building. In this way, the setting time of the mixture is increased to twenty minutes. However, the important point here is to make the blocks or walls to be built in the mold rigid by ramming within twenty minutes. Before this stage, gypsum and lime should be mixed homogeneously and homogeneously mixed with the soil and made ready for soaking. Since the drying process will start after soaking, the soaking stage should be carried out at the location where the molding and ramming will be done. In addition, mortar should be poured into the mold in an amount that can be quickly rammed [9]. Wetting here should be neither too wet nor too dry. When the mortar is squeezed in the palm of the hand, it should not drip water, but the sand, silt, clay, gravel, lime and gypsum pieces should stick together (see Figure 2). Of course, complete integration will take place after molding and drying.

Figure 2. Soaked and Palm-integrated ALKER Sample, Source: E. Nurçin Kara Archive

3.1.1.1.1. Perma Nature School Adobe House Workshop

First, a reinforced concrete foundation is built. The foundation can also be constructed using stone, but in this project, it was difficult to obtain suitable stone for the foundation in the city, so a reinforced concrete foundation was decided upon (see Figures 3 and 4).


Figure 3. - 4. Reinforced Concrete Foundation of Perma Nature School Adobe House, Source : Macide Isik Archive

Secondly, just like in reinforced concrete structures, the plywood provided for the walls is used for the formwork system (see Figures 5 - 6).


Figure 5. - 6. Formwork Systems Installed for ALKER Building Walls**,** Source for Figure 5. : Macide Isik Archive, Source for Figure 6. : E. Nurçin Kara Archive

After this stage, the mortar is prepared as described under the heading "Alker" (see Figure 7), and the wetting of the mortar is done as described (see Figure 8).


Figure 7. Mixing the Mortar **/ Figure 8.** Wetting the Mortar, Source for Figure 7. : Macide Isik Archive, Source for Figure 8. : E. Nurçin Kara Archive

In fact, Prof. Dr. Bilge Isik states that it is possible to use reinforced concrete construction systems with all the machines (such as concrete spraying machine) to build an alker structure after this stage (formwork installation stage), but a good operator is needed for this. Generally, if the construction area does not cover a very large area, the mortar poured into the formwork is rammed and the wall construction continues [8]. Ramming can be done with simple tools or with small machines such as compactors that help pressure and pressurization (see Figure 9-10).


Figure 9. Ramming of the Sample Prepared for Adobe House with Compactor
Figure 10. Ramming of Adobe House Walls with Compactor, Source for Figure 9 : Prof. Dr. Bilge Isik Archive, Source for Figure 10 : E. Nurcin Kara Archive

After pressing, the fifteen centimeter thick ALKER mortar for the new layer is laid on the previously rammed surface. When rammed, it reduces to eleven to twelve centimeters. After approximately three layers have been created in this way, a "sliding plane" is created to absorb forces such as earthquakes. This plane can be created with plaster netting or dried pine needles, or it can be created by cutting a lime or plaster sack in the thickness of the wall and laying it on the pressed wall (see Figure 11) [9]. All body walls of the building are constructed with this technique. In this project, concrete, which is preferred in the foundation, is also preferred as a binder at the points where the walls meet the ceiling. In other words: the last stage of wall construction is finalized with the reinforced concrete lintel poured over the walls. After this stage, the molds are removed (Figure 12 - Figure 13). Roof construction begins (Figure 14 - Figure 15).

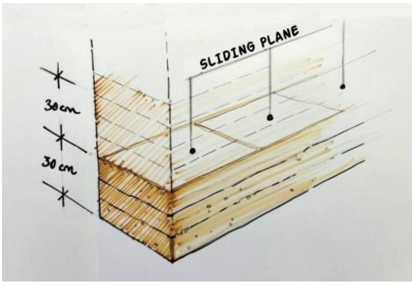

Figure 11. General View of an Adobe Wall with Sliding Planes,Drawing : E. Nurcin Kara


Figure 12. - 13. The Adobe House Whose Molds Were Removed and Made Ready for Roof Construction, Source for Figure 12-13 : Macide Isik Archive


Figure 14 – 15 : Roof Construction after Reinforced Concrete Lintel Construction, Source : E. Nurcin Kara Archive

After the roof construction phase, the floor is laid and doors are installed. After the interior elements are installed, the adobe house workshop is ready for use (Figure 16-17-18-19-20). Since what is important here is the construction of the ALKER walls of the building, issues such as foundation, roof, flooring, door installation, etc. are not discussed in detail.

The advantages of ALKER over adobe are that it can be constructed as a monolithic wall and saves time, especially when constructed with practical tools and equipment. On the other hand, it should be mentioned that the gypsum and lime in it provide sufficient strength and the flexibility provided by the sliding planes placed at certain intervals between the mortar layers increases earthquake safety [9].


Figure 16. - 17. Exterior and Interior Views of the Completed Adobe House Source : Macide Isik Archive


Figure 18 – 19. Diagonal and Front View of the Completed Adobe House
Figure 20. Headmistress Macide Işık and Students of Perma Nature School Source for Figure 18-19-20 : Macide Isik Archive

Conclusion

After the industrial revolution, chemical and industrial building materials became widespread in the sector with the increase in production capacities and the development of production technologies. Thus, traditional building materials and construction techniques have been forgotten. However, it is known that there is a great waste of energy and environmental pollution in the production, construction, use and disposal of industrial building materials such as reinforced concrete. The demand for natural building materials is increasing day by day due to climate changes in the world.

One example of these materials is "ALKER", which was standardized by Prof. Dr. Ruhi Kafescioğlu and is being disseminated through his students. ALKER is not only a response to climate-based problems. It is also a very advantageous building material for the country and family budget. The fact that it can be built using almost all the machines of building technology increases the speed of construction. On the other hand, it can also be constructed by conventional methods if there are no machines and operators to use them. Material procurement and construction of the structure is easy and does not require a great deal of knowledge. Just knowing the material and construction techniques is enough to build a healthy and strong structure. Alker creates optimum indoor climate conditions for human health. Contributes to passive air conditioning. Passive air conditioning is seen as an alternative to artificial air conditioning methods, the use of which is being reduced in the world. For all these reasons, such building materials should be popularized for a sustainable world.

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References

[1] Isik, B., Interview, April 18, 2024.

[2] VBenzeri Blog, *Doğada Doğanın Malzemeleriyle Ekolojik Mimari* [Video], YouTube, https://www.youtube.com/watch?v=HbvxPGiNRJA , September 28, 2021.

[3] Asanli, M., *Geleneksel Yapı Teknikleri,* Yeni İnsan Yayınevi, Istanbul, 2023, p. 63.

[4] Toprak Çeşitleri ve Özellikleri, https://www.derscografya.com/toprak-cesitleri-ve-ozellikleri/ , January 9, 2019.

[5] Kafescioğlu, R., *Çağdaş Yapı Malzemesi Toprak ve Alker,* İTÜ Vakfı Yayınları, Istanbul, 2021, p.190-191.

[6] Kayseri Genç Mimarlar Derneği, *Modern Mimaride Kerpiç ve Çelik Teknolojisi ile Kendi Evini Bir Haftada Yap - Prof. Dr. Bilge Işık* [Video], Youtube, https://www.youtube.com/watch?v=2N0vttCOs94 , April 6, 2022.

[7] Çavuş, M., Dayı, M., Ulusu, H., Aruntaş, Y., 'Sürdürülebilir Bir Yapı Malzemesi Olarak Kerpiç', *2. Uluslararası Sürdürülebilir Yapı Sempozyumu*, Gazi Üniversitesi, Ankara, May 28-30, 2015, p. 190.

[8] Ays_Art_Ays, *KENDİ EVİNİ BİR HAFTADA YAP!! Prof. Dr. Bilge Işık, Prof. Dr. Gültekin Çetiner'in Konuğu* [Video], Youtube, https://www.youtube.com/watch?v=1sdT8bQivC4 , July 17, 2020.

[9] Çakır, A., *Depreme Dayanıklı Sağlıklı Çağdaş Kerpiç Prof. Dr. Bilge Işık ,* [Video], Youtube, https://www.youtube.com/watch?v=heIQy06gYwU , March 13, 2023.

Another source that has been utilized although not directly used in the text of the paper:
Kömürcüoğlu, E. A., *Yapı Malzemesi Olarak Kerpiç ve Kerpiç İnşaat Sistemleri…,* İstanbul Teknik Üniversitesi Matbaası, Istanbul, 1962.

Examination Of Sustainable Construction Management Through the Example of a Kindergarten Which Is Recommended to Use Plastered Adobe Material

Eyüp Salih Elmas

İstanbul Sancaktepe Municipality

eselmas@gmail.com

ABSTRACT

Project construction management envisages the role of the project manager to be completed with the delivery of the structure. Sustainable construction management requires the project manager to take an active role in all steps of the building life cycle - design to demolition phases - through the application of special construction techniques and sustainable materials. Sustainable construction project management requires additional planning and stronger cooperation between actors than traditional project construction management. One of these tasks is to raise awareness and educate users about the operation and maintenance of sustainable buildings. Since it is important to raise user awareness at an early age, the municipal kindergarten project is in the Sancaktepe District of Istanbul Province was used as material in this study. Although the opinions were taken with questionnaire of kindergarten students parents, administrators and teachers were taken; the literature about kindergarten projects was scanned, the decision was made to use plaster adobe and construction technology as materials for the kindergarten project design. With the idea of revealing the contributions of adobe construction technology to sustainable construction management, a SWOT analysis was also made and a kindergarten project design was made by authors design team. The fact that the municipality will build a kindergarten in each neighborhood reveals that this study will be implemented in the field and will contribute to the literature about sustainable construction management.

Keywords: Plaster adobe, Project management, Sustainability, Sustainable construction project management

1 INTRODUCTION AND DEFINITIONS

Adobe is a type of unbaked earth-based brick that has been used as a building material for centuries and is the raw material of rural and historical settlements [1]. Adobe brick creates the most suitable environment for human health with its heat storage, humidity and temperature properties [2]. To benefit from this resource of adobe and make adobe a contemporary and cohesive material, traditional adobe could be reinforced with plaster. Alker literally consists of the abbreviation of the words plaster and adobe [3].

The term sustainability was first introduced into our lives with the report titled "Our Common Future" published by the World Commission on Environment and Development in 1987 [4]. Sustainable formation aims to minimize materials, energy and the built artificial environment that are generally harmful to the ecosystem. Choosing low-energy products that will not negatively affect the performance or endurance of the structure during construction is an ecological and non-aggressive attitude [5]. In order to be an energy-efficient building material, a material project management must consume minimum energy and save money at every stage. Prefering materials that efficiently use energy during their extraction from nature as raw materials, processing, transportation, usage in construction and ultimately at the end of their lifespan, increases the energy efficiency of the building [6,7].

Projects that are unique and implemented on a one-time basis should be managed with a holistic approach using special techniques and methodologies to achieve time, cost, scope, and quality targets [8]. The most significant difference between sustainable construction project management and traditional project management is that sustainable construction focuses on performance throughout all stages of the building's lifecycle, starting from the feasibility phase and ending with the completion of the building's lifespan [9]. Therefore, effective sustainable construction project management can be achieved primarily by involving the project manager in every process of the building's lifecycle [10]. Traditional project management assumes that the project manager's role ends with the delivery of the building. With the implementation of sustainable construction techniques, it is expected that the project manager will play an active role in the use and demolition phases as well. Raising awareness among users about the operation and maintenance of sustainable buildings is one of these tasks. Another innovation is the measurement of user satisfaction, which is becoming more common in developed countries. Recently in some countries, evaluations have begun to determine how satisfied users are with sustainable design and construction six to nine months after the completion of construction. The execution of this task has also been assigned to project managers. As sustainable buildings increase, it is expected that this system will develop in our country as well. Therefore, the responsibilities of project managers which traditionally end with the delivery of the building will extend to the use and demolition phases with sustainable construction [11].

Achieving awareness and a conscious society in terms of sustainability will be realized by providing theoretical knowledge in schools from a young age and applying it throughout rest of life. It is thought that educational buildings themselves should also serve as a laboratory where the theoretical knowledge taught in schools can be experienced [12].

In this study, a kindergarten project built with alker material identified through a survey based on project management principles; is examined in detail in terms of the initial and design phases of sustainable construction management.

2 MATERIAL AND METHOD

In this study, the municipality kindergarten project in the Sancaktepe district of Istanbul was taken as the material. At the beginning of the study a survey was conducted with a sample group consisting of 124 kindergarten teachers, principals and parents in Sancaktepe. A two-round survey method was used as the method for selecting sustainable building materials in building technology preference. In written academic studies survey questions are determined after analyzing related reports, conducting extensive literature reviews, and examining studies related to the topic in the industry [13]. Therefore, the survey questions in this study were also determined by adhering to the same method.

The reliability level of the survey decreases if the candidates are not knowledgeable or interested in the topic [14]. The fact that the implementing institution of the project is the district municipality provided an advantage in selecting individuals to be surveyed and obtaining quick results. In accordance with scientific procedure, interviews were conducted with individuals and in cases where the subject was not fully understood; technical experts provided detailed explanations to obtain responses from the individuals [15].
Before moving on to the design of the alker kindergarten preferred based on the survey results, a SWOT

analysis, shown in Table 1 was conducted. The SWOT analysis report was shared with individuals during the second round of the survey process to provide them with insights. With the obtained results, the design phase was initiated and a literature review was conducted on traditional and modern adobe building technologies and kindergarten functional building projects.

Table 1: Alker Kindergarten SWOT Analysis

Strengths	Weaknesses
Easy access to raw materials The ability to produce on-site and low production costs Strengthened social interaction among students and classrooms due to the absence of multi-story buildings Lower likelihood of harm to human health compared to alternatives Reduced levels of dust, noise and other pollution during demolition A building material that is recyclable	Inability to choose multi-story and wide-span structures Requirement for a large construction site for the blocks to set Preference against using direct adobe surfaces in interior design Difficulty in finding experienced workers and contractors due to the technique not being widely preferred Lack of sufficient example applications Absence of regulations regarding the construction technology in earthquake codes Lack of administrative and managerial incentives
Opportunities	**Threats**
Increasing necessity for creating a sustainable environment Low slope ratio of land plots in the Sancaktepe district The District Municipality's desire to build a nursery in every neighborhood Potential to serve as a model for selecting construction technology for other public buildings	Need for a hybrid construction system on plots with a high slope ratio Requirement for additional measures to address water and humidity issues Acceptance or rejection by parents

3 RESEARCH FINDINGS AND ADOBE KINDERGARTEN DESIGN

The survey was completed with 108 out of 300 parents, 12 out of 20 kindergarten teachers (excluding 8 who were single), and 4 out of 5 school administrators (excluding one who was single).

Table 2. Descriptive statistics of the physical characteristics of the kindergarten

How many floors would you prefer the kindergarten building to have? Please select one of the options.		Single floor	2 and/or 3 floors	3-5 floors	Not important
		%	%	%	%
		78	13	4	5
When choosing a kindergarten, which one would it be in terms of construction technology and materials of the building? List your top 3 choices among the options.	Building materials	Reinforced concrete	Wood	Modern adobe	Masonry
		%	%	%	%
	1st choice	55	10	19	16
	2nd choice	31	17	27	24
	3rd choice	12	22	32	34

Table 3. Descriptive statistics of the kindergarten project in terms of management elements

	X	SS	1	2	3	4	5
			%	%	%	%	%
It is important for parents to choose a school based on whether the school building where education takes place is constructed using ecological and sustainable materials.	3,96	1,18	11,8	0,0	0,0	56,6	31,6
I believe that completing the building construction at a more economical cost will directly reflect on the educational expenses.	4,12	1,03	7,9	0,0	0,0	56,6	35,5
I think that the construction timeline planning during the building phase will directly impact the tuition fees.	3,62	1,28	7,9	19,7	0,00	47,4	25,0
I believe that experiencing and interacting with spaces during kindergarten age will contribute to one's material choices for future life aspects such as housing and work environments.	4,14	1,12	3,9	9,2	3,9	34,2	48,7

1 = Strongly disagree 5 = Strongly agree

In the first round of the survey, it was observed that adobe material was preferred as the second choice after reinforced concrete. Since the goal was to construct a sustainable building, it was decided to conduct a second round of surveys with individuals who did not mark modern adobe as their first choice. Information about adobe material (economic, fast, ecological, sustainable, etc. features) was provided, including examples of alker buildings and the following question was asked again: *"Which kindergarten that will provide the same quality of education would you prefer?"*. Out of 124 participants in the survey, 63 out of 68 who preferred reinforced concrete, 4 out of 20 who preferred masonry and 11 out of 13 who preferred wood. Totaling 101 individuals chose to favor a kindergarten constructed from adobe material.

In accordance with the results of the study, the Municipality of Sancaktepe has tasked the design team under the author's leadership to implement the alker kindergarten project. The project's implementation across every neighborhood in the district restricts the design team in terms of comprehensive planning.

Firstly, suitable areas for constructing kindergartens were identified based on the application 1/1000 scaled zoning plan. Detailed analyses were conducted on the implementation provisions of the plan, plot sizes, topographic values and environmental context. The scope of the project was determined by examining the current and projected population of kindergarten-age children in the neighborhoods.

During scope planning optimization, the goal was to design a building with approximately 80-100 student capacity thus 4 activity rooms. The layout featured an L-shaped symmetrical floor plan to maximize outdoor garden usage in every plot. The needs of the project were solved on a single floor, both in terms of choosing a single-storey building with 78% participation in the survey and increasing energy efficiency.

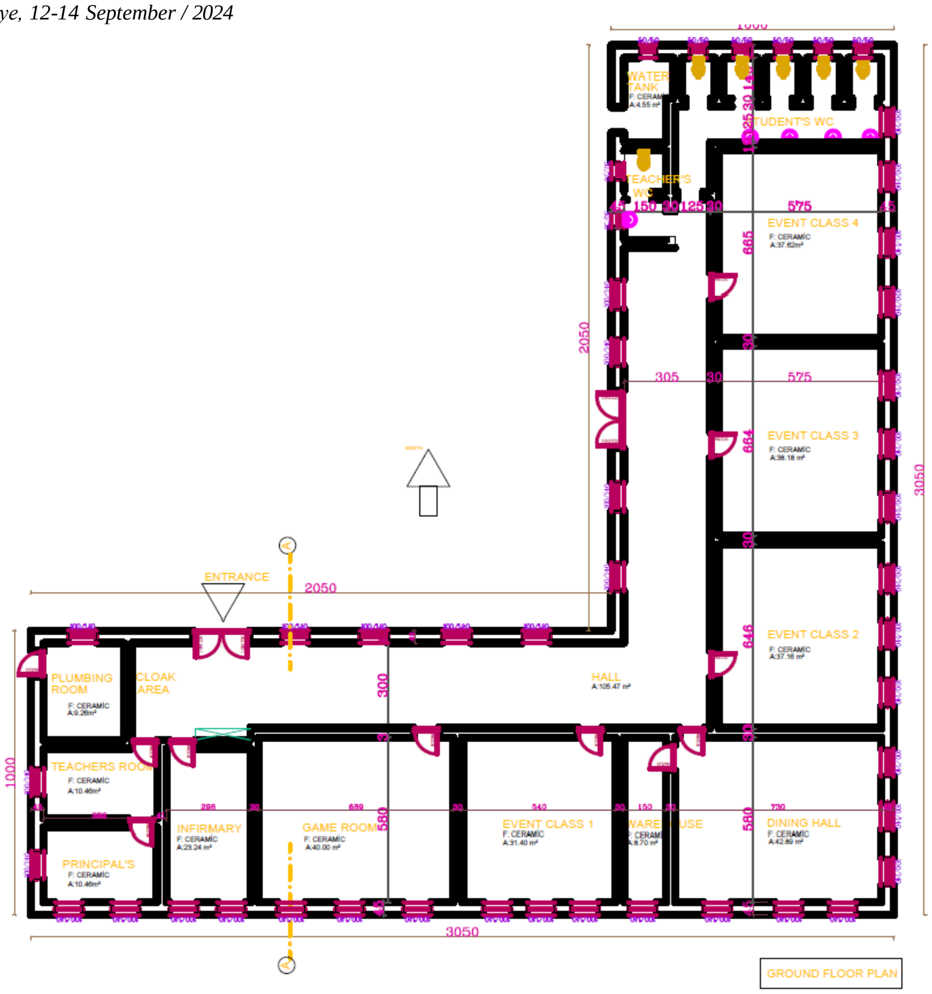

Figure 1: Ground floor plan of kindergarten

The entrance of the kindergarten is located to the north. The cloakroom area placed in this direction serves as a buffer to reduce heat loss in the building. Energy gain is achieved by placing the activity rooms of the school facing south and east. The number of vertical elements where children can grow plants and trees for sustainable agriculture in the outdoor garden can be increased. Alker walls with a thickness of 50cm for exterior walls and 30cm for interior walls as shown in figure 1 floor plan were designed [16]. The building has a closed area of 480m² and a minimum of 610m² of open area. The building height as seen in figure 2, is a minimum of 400cm and due to the flat roof inclination below 10% at the same time the roof inclination can be perceived from the inside of the room.

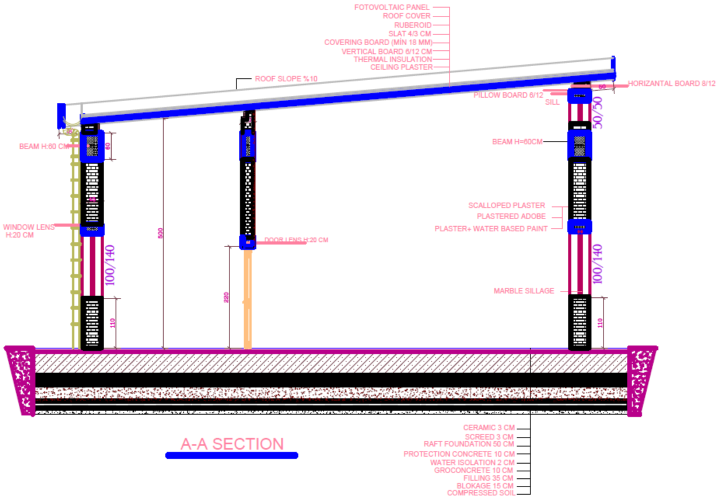

Figure 2: A-A section of kindergarten

The site plan of the kindergarten meets the international sustainability criterion by designing a minimum of 50% of the area as green space. Photovoltaic panels placed on the roof facing south to maximize sunlight convert solar energy into electricity to meet the building's electrical needs. This energy is used for heating, hot water, and electricity requirements within the building. Moveable vertical sunscreens as shown in figure 3 have been added to the facades on the south and east sides of the learning spaces to reduce direct sunlight. Such building technologies provide advantages in terms of cost, comfort and architectural impact.

Figure 3: 3D visual of kindergarten design

Rainwater harvesting is targeted for garden irrigation at the kindergarten. Additionally, water consumption is reduced in wet areas using sensor faucets or graduated flush systems [17]. Another essential factor in spaces where children spend time is natural light, which impacts their physically and physiological health. Skylights in the kindergarten's common hall provide sufficient illumination and natural ventilation. Within the framework of sustainable construction management, attention is given to using recyclable and reusable materials. It is an international standard that at least 55% of the building's structural elements and finishes such as roofs, floors, walls, must be reusable. Furthermore, it anticipates collecting at least 50% of construction waste for recycling and reuse within the building [18]. Design parameters are carefully examined within this framework to generate implementation details for the project.

4 RESULTS

The realization that natural resources are finite has prompted people to reconsider all their activities. Sustainable buildings play a crucial role in promoting environmental awareness within society. In addition to their environmental benefits, sustainable construction project management requires additional planning compared to traditional project construction processes and necessitates stronger collaboration among stakeholders to form a holistic chain throughout the life cycle. Thus, with the discipline of sustainable project construction management, all stakeholders can focus on the same goal; minimizing potential project management issues.

The years when individuals begin to acquire environmental awareness often start in kindergarten. It is essential to equip kindergarten buildings with dimensions, colors, textures, lighting and materials suitable for children's cognitive and perceptual development. The project under study emphasizes preserving ecological balance throughout its life cycle - from design, planning, construction, use to demolition - by optimizing land use, building orientation, efficient use of solar energy and rainwater harvesting with a preference for adobe materials in construction.

The advantages of adobe materials in the sustainable project cycle confirm its preference primarily due to its advantages: minimal or very low energy use in manufacturing, no emission of CO_2 or other harmful gases into the atmosphere, healthiness, economic feasibility, ease of manufacture using local resources and simple tools and quick construction and deconstruction processes. Adobe production does not require dedicated facilities and can be easily manufactured in the local environment. It generates no waste during production or demolition [19, 20].

This study aims to make a significant contribution to individual and societal lives by educating children in sustainable projects from an early age, shaping the future. The Sancaktepe Municipality's plan to implement a standard kindergarten project in every neighborhood will expedite achieving this goal and serve as a pilot application from local to broader contexts.

REFERENCES

[1] Khanzadeh M., Kuzu Dinçbaş G., 'Analyzing Adobe Buildings In The Kayseri, A Study Of Traditional Earthen Architecture In Zile Town', *Gain Information From The Traditional Earthen Architecture*, 10th International Conference Kerpic' 23, pp. 310, Diyarbakır, 2023.
[2] Işık B. & Tülbentçi T., 'Sustainable Housing in Island Conditions Using Alker-Gypsum-Stabilized Earth: A Case Study From Northern Cyprus', *Building and Environment*, vol., 43, iss. 9, pp.1426-1432, September, 2008.
[3] Işık B., 'Türkiye'de Kerpiç Yapı Kültürü ve Alçı İle Stabilize Edilen Kerpiç-Alker Yapılar', *3. Ulusal Alçı Kongresi*, pp. 3-26, 2000.
[4] Bozloğan R., 'Sürdürülebilir Gelişme Düşüncesinin Tarihsel Arka Planı', *Journal of Social Policy Conferences*, iss. 50, pp. 1011, 2010.
[5] Bayır E., 'Sürdürülebilirlik Kavramının İç mimari Tasarım Sürecine Manipülatif Etkileri', *Uluslararası Sanat, Tasarım ve Manipülasyon Sempozyumu* , Sakarya, Turkey, pp.131-136, 2013.
[6] Akbaş, M. F., Aslan M. & Arpacıoğlu, Ü., 'Yeşil Malzeme Bağlamında Kerpiç', *Eksen Dokuz Eylül Üniversitesi Mimarlık Fakültesi Dergisi*, vol. 3, iss. 2, pp.72-88, 2022.
[7]https://www.academia.edu/15442985/Kerpiç_Yapılar_Depreme_Dayanıksız_Mıdır_Avantajları_ve_Dezavantajları_Nelerdir?, erişim tarihi: 23 Nisan 2024.
[8] Kömürlü R. & Toltar L., 'İnşaatta Proje Yönetimi; Projenin Başarısına Etkisi', *Mimarlık ve Yaşam Dergisi Journal of Architecture and Life*, vol. 3, iss. 2., pp. 249-258, 2018.
[9] Atkinson R., 'Project management: cost, time and quality, two best guesses and a phenomenon, its

time to accept other success criteria', *International Journal of Project Management*, vol. 17, iss. 6, pp. 337-342, December, 1999.
[10] Kömürlü R., 'Yeşil Bina Kavramı ve Proje Yönetimi (Green Building Concept and Project Management)', *Yapı Dergisi (Building Journal),* pp. 48-51, 2018.
[11] Gündes, S. & Ergönül S., 'Sürdürülebilir Yapımın Gelişim Süreci ve Proje Yönetimi', *Mimarlıkta Malzeme*, vol. 3, pp. 68-72, 2011.
[12] Kaya P. & Kaya B., 'Sürdürülebilir Mimarlık Anlayışının Bahriye Üçok Anaokulu Örneklem Alanı Üzerinden Analizi', *The Turkish Online Journal of Design, Art and Communication*, vol. 9, iss. 1, pp. 28-41, 2019.
[13] Öztemel E. & Gürsev S., 'Türkiye'de Lojistik Yönetiminde Endüstri 4.0 Etkileri ve Yatırım İmkanlarına Bakış Üzerine Anket Uygulaması', Marmara Fen Bilimleri Dergisi, vol. 30, iss. 2, pp. 145-154, 2018.
[14] Altun A. & Kovancı A., 'Personel Seçiminde Mülakat ve Mülakat Yöntemleri', *Havacılık ve Uzay Teknolojileri Dergisi*, vol. 1, iss. 3, pp. 55-61, January 2004.
[15] Yaşar O., 'Sanayi Coğrafyası Öğretiminde Araştırma Yöntemlerinden "Anket ve Mülakat"ın Kullanılması', *Doğu Coğrafya Dergisi*, vol. 10, iss. 13, pp. 86, 2011.
[16] https://dergipark.org.tr/en/download/article-file/209205, erişim tarihi: 10 Mayıs 2024.
[17] Tavşan F., Bahar Z., & Tavşan C., 'Sürdürülebilirlik Kapsamında Yağmur Suyu Toplama Sistemli Pavilyonlar', *Kent Akademisi*, vol. 15 iss. 2, pp. 896-915, 2022.
[18] Şahin, B. E. & Dostoğlu, N., 'Okul Binaları Tasarımında Sürdürülebilirlik', *Uludağ Üniversitesi Mühendislik Fakültesi Dergisi*, vol. 20, iss. 1, pp. 75-91, 2015.
[19] Bozyel M. E., 'Betonarme Kullanıcılarının Kerpiç Yapılar Hakkındaki Görüşlerinin Bilimsel Veriler Doğrultusunda İncelenmesi', *Fatih Sultan Mehmet Vakıf Üniversitesi*, Yüksek Lisans Tezi, pp. 112, İstanbul, 2021.
[20] Güner A. F., Benli G., Karaçar P. & Kasapseçkin M. A., 'Adobe Use in the Eco-village of Büyükkonuk on the Karpaz Peninsula', *Kerpic'18 – Back to Earthen Architecture: Industrialized, Injected, Rammed, Stabilized 6th International Conference,* Hasan Kalyoncu University, Turkey, 1-2 June, 2018.

A Systematic Review on the Construction and Demolition (C&D) Material Waste and Waste Management in the Context of Brick

Gizem Can[1]
(Assist.Prof.Dr., Istanbul Medipol University, gizem.can@medipol.edu.tr)

Saniye Karaman Öztaş[2]
(Assoc.Prof.Dr., Gebze Technical University, saniyekaraman@gtu.edu.tr)

Elçin Filiz Taş[3]
(Prof.Dr., Istanbul Technical University, tase@itu.edu.tr)

ABSTRACT

The construction industry consumes over 37% part of material waste during the construction and demolition processes. In many countries, material wastes, one of the physical wastes, generation increased by 342% in the last years. While waste is fast becoming an environmental and economic agenda for global urban development, there are still substantial knowledge gaps in the possible construction management strategies to speed up this waste management transition. Well organized and implemented material waste management in the construction industry provides reduced demand for landfill spaces, improved resource management, productivity, and quality improvement as well as economic benefits.

Material waste management, planning, identifying, assessing, responding, and monitoring material wastes, is a vital principle to figure out and manage the wastes during the construction project life cycle. Identify material wastes is important to classify materials to plan how could be managed these each type of material according to their own characteristics. In recent years, because of limited resources and large volume of material waste production such as woods, steel, glass, brick companies in many countries, which one of them Türkiye have started to explore new waste management strategies to manage construction wastes to contribute circular economy and environment. Natural and sustainable materials started to be researched and preferred in the construction industry to reach the low-carbon emission and zero-waste target, too. Therefore, in this study it is aimed to determine studies of the C&D material waste in context of brick to figure out current waste management strategies and potential sustainability because of having a widespread usage area of brick as a natural and sustainable material.

This study undertakes a systematic review of C&D material waste in context of brick, one of most used natural material in the construction industry. The general scope of the literature is limited to last 20 years publications in the Scopus and Web of Science. It adopts a five-stage procedure as a systematic approach for the review which are formulation of the research question(s), locating and identifying relevant and repetitive studies in both databases, selection and evaluation of studies, meta-analysis of selected studies and results reporting. It is thought that the findings of this study will provide evidence of current C&D material waste management strategies to improve and manage material wastes in the construction industry.

Keywords: Brick waste, circular economy, construction and demolition process, construction material waste, waste management.

1 INTRODUCTION

Construction and demolition wastes are generally generated because of the new construction, repair, renovation, demolition of the sub and super structures such as buildings, roads. Both of controlled process in the construction project life cycle and catastrophic results of natural disasters, it is important and necessary to manage waste in an effective way due to limited resources and today's world need.

The material waste type and volume changes according to the type of structure. In the buildings, the material wastes vary depending on the type of materials used, but generally include reinforced concrete, steel, concrete, brick, wood, glass, metals, natural stones, tiles, plastic etc. In Loch, Stocker & Bertolini [1]'s research, the building material wastes are subdivided into four classes. These classes are named as A (reusable or recyclable wastes such as metals, glass, cardboard), B (recyclable waste for other purposes such as plastics, paper, cardboard, metals, glass, wood, empty packaging of paints), C (waste for no economically viable technologies or applications have been developed to enable its recycling such as gypsum waste) and D (hazardous waste from the construction process such as paints, solvents, oils and others). Similarly, building material wastes were classified with waste status and waste code by Government of United Kingdom [2]. This classification has 10 groups such as Group 1 (insulation and asbestos materials), Group 2 (concrete, bricks, tiles, and ceramics) and Group 3 (wood, glass, and plastic). To manage the material waste, classification the materials and improving management scenarios are essential for providing circularity in the construction industry instead of only disposal option.

EPA's report emphasizes that more than 75% of all construction waste from wood, drywall, asphalt shingles, bricks and clay tiles ends up in landfills [3]. Concrete and metals, relatively cost-effective to recycle, and brick, clay, gypsum boards, much less reusable, are the basic material wastes which ends up in landfills in plenty of quantities [4]. So, it is important for sustainability that such wastes can be used as raw material input in either the construction industry or the different industry. As a result of such a waste management, the damage to nature during waste storage processes will also be reduced while saving natural resources to be used for production activities.

This paper aims to determine studies of the C&D material waste in context of brick to figure out current waste management strategies and potential sustainability because of having a widespread usage area of brick as a natural and sustainable material.

2 DATA COLLECTION AND METHODOLOGY

To make new research and improve suggestions, it is essential to know evaluating existing knowledge and determining the studies which have been completed up to that time is necessary. This determining step could be realized with different ways like literature review in a systematic way. To understand the focus of research on C&D material waste to compose brick in the construction industry, a systematic literature review was conducted using relevant and available scholarly studies. A five-stage procedure was suggested to realize a systematic literature review by Denyer and Tranfield [5]. This procedure includes the formulation of question(s), locating and identifying relevant studies and evaluation of studies, analysis or synthesis and results reporting.

In this study, a systematic review of C&D material waste in context of brick was preferred to figure out how the recent 20 years (2005-2024) focused to C&D material waste regarding brick production. This study was composed by five main steps as below:

Step 1

- Defining the research question.

Step 2

- Keyword search in the *Scopus* and *Web of Science* database using the keyword "*brick& material waste& construction& demolition.*"
- Selection of only articles in English language, published/article in press between 2005-2024.

- Exporting the data with *Plain Text format* to analyze in the *Microsoft Excel.*
- Determining the total records from two databases to remove duplicated records before screening the studies to select according to the research aim and question.
- Removing the duplicated records.

Step 3
- Title Screening.
- Basic classification of the research according to the C&D material waste.
- Defining records sought for retrieval.

Step 4
- Analyzing the articles focused on "*brick production with construction and demolition waste*" using the "*Meta-Analyses Method*".

Step 5
- Synthesizing the articles focused on "*brick production with construction and demolition waste*" to reach answer to the research question of this study.

3 FINDINGS

Keywords were searched in *Scopus and Web of Science* considering article title & abstract & keywords by 2005 to 2024. Then related articles were filtered in English language and they were explored with *Plain Text Format for Microsoft Excel.* Findings were analyzed with *Meta-Analysis.*
In Figure 1, the systematic literature review steps are seen as 5 basic steps.

Step 1: Research Question
In the first step, the research question is determined according to the preliminary literature review in scope of C&D material waste & waste management and preferring and analyzing a specific material like brick which is one of the most widely used materials with low embodied energy. The research question is "*what the focus and content of the recent research in the literature about the management is the C&D material waste to produce brick?".*

Step 2: Identification
In the second step, "*brick& material waste& construction& demolition*" keywords were searched in *Scopus* and *Web of Science* considering article title & abstract & keywords by 2005 to 2024 (Figure 1). The total 838 articles (369 in Scopus and 471 in Web of Science), in English language, were selected and explored with *Plain Format.* Findings were listed with *Microsoft Excel* to determine duplicated records for removing. In total, 262 duplicated records were removed from Web of Science database list before screening step.

Step 3: Screening
In the third step, 369 articles in Scopus and 209 articles in Web of Science were screened according to the title. 276 articles and 167 articles were removed from Scopus and Web of Science database list before second screening step to sort articles according to material waste management. After sorting step, 26 articles in Scopus and 7 articles in Web of Science were determined according to "*brick production with construction and demolition wastes*."

1.STEP: RESEARCH QUESTION		
2.STEP: IDENTIFICATION	**1**	Keywords: "brick& material waste& construction& demolition" Database: SCOPUS & WOS Research within: Article title, abstract, keywords Document type: Article Publication Years: 2005-2024 (last 20 years) Language: English
	2	Total records identified from databases: (n=838) ,including: SCOPUS: (n: 369) WOS: (n: 471)
	3	Record removed before screening: Duplicate records removed (n=262)
3.STEP: SCREENING	**4**	Records Screened - title: SCOPUS: (n: 369) WOS: (n: 209)
	5	Record removed before second screening (excluded): SCOPUS: (n: 276) WOS: (n: 167)
	6	Records Screened - second screening for sorting: SCOPUS: (n: 93) WOS: (n: 42)
	6	Records sought for retrieval (*records sorted according to brick production with construction and demolition wastes*): SCOPUS: (n: 26) WOS: (n: 7)
	7	Records not assesed for eligebility: SCOPUS: (n: 0) WOS: (n: 0)
4.STEP: ANALYZING	**8**	Records included for meta-analyses: SCOPUS: (n: 26) WOS: (n: 7)
5.STEP: SYNTHESIZING		

Figure 1. Systematic literature review of the C&D material waste in brick context.

Step 4: Analyzing

In the analyzing step, Meta-Analysis was preferred to see the basic information of each article of total 34 articles. In Meta-Analysis, the journal information, article name, publication year, keywords, authors and author information, article's aim, scope and methodology, level of analyses, industry, sources of information, research output and limitations of the research were determined to reach out a common synthesis.

Table 1. First part of the Meta-Analysis for 1-17 articles.

Article Code	Reference	Database	Journal Info	Article Name	Publication Year	Keywords	Author	Author(s) Background	Author(s) Country	Citiation
A1	[6]	SCOPUS	Journal of the Air and Waste Management Association , 73(8), pp. 625–637	Effect of biowaste and construction waste additives on mechanical dewaterability of lake sediment for brick production	2023	_	Huyen T.T. Dang, Lan T.N. Pham, Thuy T. Pham, Huan X. Nguyen, Nga T.H.Tran & Khai M.Nguyen	Faculty of Environmental Engineering, Faculty of Chemistry and Environment, Faculty of Environmental Sciences	Vietnam	0
A2	[7]	SCOPUS	Innovative Infrastructure Solutions , 8(11), 306	Influence of mud waste and straw grass addition in fired bricks production: technical properties evaluation	2023	Pennisetum purpureum straw grass, Ecological materials, Fired clay bricks, Mud rubbles, Brick buildingmaterials	Adazabra, A.N., Viruthagiri, G., Tiose, C.	School of Physical Sciences, Faculty of Science	Ghana, India	0
A3	[8]	SCOPUS	Waste Management , 159, pp. 114–124	Investigation of agro-forestry and construction demolition wastes in alkali-activated fly ash bricks as sustainable building materials	2023	Alkali-activated fly ash, Agro-forestry wastes, Sound transmission loss, Wallette units, Thermal conductivity	Siddharth S., Mickey M. D., Soumitra M., Ravindra S. B., Nagesh B. B., Soraj K. P.	Acoustics Instrumentation and Mechanical Systems Group, Structural Engineering Group, Environmental Science and Technology Group, Efficiency of Buildings Group	India	16
A4	[9]	SCOPUS	Journal of Environmental Management , 357, 120720	Assessment of the mechanical and physical characteristics of PET bricks with different aggregates	2024	PET, Expanded polystyrene Construction and demolition wastes, Bricks, Low-cost, Social housing	Lucas E.P., Maria del M.B.B., Clara B. G.C., Jeronimo K., Rosana G.	Experimental Center for Economic Housing, School of Architecture	Argentina, Spain	0
A5	[10]	SCOPUS	International Journal of Advanced and Applied Sciences , 10(6), pp. 150–157	Valorization and reuse of construction and demolition waste for its transformation into ecological bricks	2023	Construction and demolition waste, Environmentally-friendly bricks, Analytical and evaluative investigation, Suitable proportions, Sustainable culture	Ñañez-Silva, M., Sánchez-Cárdenas, L., Yactayo-Carrión, E.	Faculty of Business Sciences	Peru	0
A6	[11]	SCOPUS	Construction and Building Materials , 385, 131517	Analysis of two processing techniques applied on powders from recycling of clay bricks and concrete, in terms of efficiency, energy consumption, and cost	2023	Powder processing, Construction and demolition wastes (CDW), Grinding, Calcination, Extra power consumptionCost performance	Zhang, H., Zhang, B., Tang, L., Zeng, W.	School of Advanced Manufacturing, College of Civil Engineering, China State Construction Hailong Technology	China	4
A7	[12]	SCOPUS	Construction and Building Materials , 370, 130655	Design development of sustainable brick-waste geopolymer brick using full factorial design methodology	2023	Brick waste powder, Construction & demolition waste, Molarity, Alkaline solution ratio, Geopolymer bricks	Rihan Maaze, M., Shrivastava S.	Department of Civil Engineering	India	23
A8	[13]	SCOPUS	Open Ceramics, 18, 100569	Alkaline activation of brick waste with partial addition of ordinary Portland cement (OPC) for reducing brick industry pollution and developing a feasible and competitive construction material	2024	Alkaline activated cement, Brick waste, Geopolymer, Building material, Construction and demolition waste, Ordinary portland cement	Angelica C., Henry A. C.	CCComposites Laboratory (Faculty of Engineering)	Colombia	1
A9	[14]	SCOPUS	Case Studies in Construction Materials , 18, e02024	Utilization of construction spoil and recycled powder in fired bricks	2023	Construction spoil(CS), Fired bricks, Sustainability, Mechanical property, Recycled powder(RP)	Bai, M., Xiao, J., Gao, Q., Shen, J.	Department of Structural Engineering, Xuchang Jinke Resource Recycling CO.	China	5
A10	[15]	SCOPUS	Case Studies in Construction Materials , 20, e02780	Taguchi-optimized triple-aluminosilicate geopolymer bricks with recycled sand: A sustainable construction solution	2024	Triple-Aluminosilicate, Geopolymer Bricks, Taguchi Method, Recycled Washed Sand, Heat Map	MZU Haq, H Sood, R Kumar, I Merta	Department of Civil Engineering NITTTR Sector, Department of Civil Engineering CCET Sector, Faculty of Civil and Environmental Engineering	India, Austria	18
A11	[16]	SCOPUS	Materials, 16(1), 262	Utilization of Construction and Demolition Mix Waste in the Fired Brick Production: The Impact on Mechanical Properties	2023	Mixed C&Dwaste, Clay brick, Fired brick quality, Laterite soil, Alluvial soil, Firing temperature	M Dubale, MV Vasić, G Goel, A Kalamdhad, LB Singh	Department of Civil Engineering, Institute for Testing of Materials IMS, School of Energy and Environment	India, Serbia	5
A12	[17]	SCOPUS	Journal of Industrial Ecology , 26(2)	Tracking the material cycle of Italian bricks with the aid of building information modeling	2022	C&D waste, Circular economy, Direct emissions, Fired bricks, Industrial ecology, Recycling	A Miatto, C Sartori, M Bianchi, P Borin, A Giordano, S Saxe, TE Graedel	School of the Environment, Department of Civil, Architectural, and Environmental Engineering, Department of Civil and Mineral Engineering	USA, Italy, Canada	2
A13	[18]	SCOPUS	Materialstoday:Proceedings 60	Clay bricks using building debris	2022	Construction and demolition waste, Fired and unfired bricks, FlyashCompressive strength, Water absorption, Aggregate crushing value	Harikumar, M., Mohamed, F., Mohammed, A., Ashraf, I., Shahansha, M., & Anand, A. G.	NIT Goa, College of Engineeirng Vatakara	India	2
A14	[19]	SCOPUS	Journal of Cleaner Production , 368, 133118	Mine waste as a sustainable resource for facing bricks	2022	Building ceramics, Circular economy, Facing bricks, LCA, Mining waste, Valorisation	Simão, F. V., Chambart, H., Vandemeulebroeke, L., Nielsen, P., Adrianto, L. R., Pfister, S., & Cappuyns, V.	Central Laboratory for Clay Roof Tiles, Research Centre for Economics and Corporate Sustainability, Department of Earth and Environmental Sciences, Laboratory of Waste and Recycling Technologies, Institute of Environmental Engineering	Belgium, Switzerland	17
A15	[20]	SCOPUS	Applied Sciences (Switzerland) , 11(19), 8918	Recycling construction and demolition residues in clay bricks	2021	Construction and demolition residues, Clay bricks, Technological properties	Zanelli, C., Marrocchino, E., Guarini, G., Toffano, A., Vaccaro, C., & Dondi, M.	Institute of Science and Technology for Ceramics, Department of Chemical, Department of Physics and Earth Sciences	Italy	6
A16	[21]	SCOPUS	Archives of Civil and Mechanical Engineering , 22(2), 78	Manufacturing of fired bricks derived from wastes: utilization of water treatment sludge and concrete demolition waste	2022	Sustainability, Construction materials, Recycling, Waste, Firing, Circular economy	Gencel, O., Kizinievic, O., Erdogmus, E., Kizinievic, V., Sutcu, M., & Muñoz, P.	Civil Engineering Department, Laboratory of Composite Materials, Environmental Engineering Department, Materials Science and Engineering Department, School of Engineering,	Türkiye, Lithuania, Chile, Spain	6
A17	[22]	SCOPUS	Journal of Cleaner Production , 376, 134139	Life cycle assessment of three typical recycled products from construction and demolition waste	2022	Recycled aggregates, Environmental impact assessment, Life cycle cost, Carbon account, Process optimisation	Qiao, L., Tang, Y., Li, Y., Liu, M., Yuan, X., Wang, Q., & Ma, Q.	School of Energy and Power Engineering, Shandong Construction and Development Research Institute, School of Mechanical Engineering	China, UK	16

Table 2. First part of the Meta-Analysis for 18-33 articles.

Article Code	Reference	Database	Journal Info	Article Name	Publication Year	Keywords	Author	Author(s) Background	Author(s) Country	Citiation
A18	[23]	SCOPUS	Environmental Science and Pollution Research, 29, pages 72528–72544	Study on preparation of brick blocks by using construction waste and sludge	2022	brick, mix optimization, construction and demolition waste, sludge waste, leaching, firing temperature, microstructure analysis	Raguraman Vaithiyasubramanian, Deepasree Srinivasan, Arul Kumar Kanagarajan	Department of Civil Engineering,	India	4
A19	[24]	SCOPUS	Materials Today: Proceedings, 77, Part 3, Pages 879-886	Application of recycled soil and sand in brick production over conventional clay Brick: A sustainable alternative	2023	Recycled soil, Recycled sand, Bagasse ash, Bricks	M Desai, N Yadav, N Desai	Civil Engineering Department	India	2
A20	[25]	SCOPUS	International Journal of Nanoelectronics and MaterialsVolume 14, Issue Special Issue	The Determination of Optimum Ratio by using Recycled Concrete Aggregate and Crumb Rubber as Partial Sand Replacement Material in Sand Cement Brick Production	2021	Brick, Crumb Rubber, Durability, Recycled Concrete Aggregate, Strength	Khalid F.S, minuddin M.Y.A., Abdullah Al-Jaberi A.N.,Zaki Z., Irwan J.M., Ayob S., Tayeh, Bassam A.	Faculty of Civil Engineering and Built Environment, Civil Engineering Department	Malaysia	0
A21	[26]	SCOPUS	Construction and Building Materials, 167, Pages 154-165	Sustainable unfired bricks manufacturing from construction and demolition wastes	2018	Unfired bricks, Construction and demolition wastes, Pozzolanic reactions, Mechanical properties, Durability,,Life Cycle Analysis	A. Seco, J. Omer, S. Marcelino, S. Espuelas, E. Prieto	Dept. of Projects and Rural Engineering, Faculty of SEC	Spain	74
A22	[27]	SCOPUS	Applied Sciences, 7(10), p.1012.	Physicochemical, mineralogical and microscopic evaluation of sustainable bricks manufactured with construction wastes	2017	Bricks, Construction waste; Mineralogical; Physical properties; Thermogravimetric analyses	Aguilar-Penagos, A.; Rojas-Valencia, M.N.; Gómez-Soberón, J.M.	Institute of Engineering, Department of Construction Technology	Mexico	27
A23	[28]	SCOPUS	Journal of Cleaner Production, 258	Fabrication, microstructure, and properties of fired clay bricks using construction and demolition waste sludge as the main additive	2020	Bricks production, Construction and demolition waste sludge, Insulation properties, Mechanical properties, Recycling and valorization	dos Reis, G.S.; Sampaio, C.H.; Lima, E.C.; Cazacliu, B.G.; Cothenet, A.; Poullain, P.; Wilhelm, M.; Ambros, W.;	Graduate Program in Metallurgical, Mine, and Materials Engineering, Research Institute in Civil Engineering and Mechanics, Industrial and ICT Engineering, Metallurgical Engineering Department, Institute of Chemistry	Brazil	94
A24	[29]	SCOPUS	Journal of the Balkan Tribological Association, 25 Issue 4, p941-950.	Comparative study of bricks made with various waste materials to conventional clay brick	2019	bricks, clay, waste materials.	GUNASEKAR, S.; RAMESH, N.	Department of Civil Engineering	India	0
A25	[30]	SCOPUS	Waste Management, 85:396-404	Separation studies of concrete and brick from construction and demolition waste	2019	Construction and demolition waste (CDW), Recycling technology, Concrete/brick separation, Air jigging	Hu, Kui; Chen, Yujing; Naz, Falak; Zeng, Changnv; Cao, Shihao.	College of Civil Engineering and Architecture	China	48
A26	[31]	SCOPUS	Waste management & research, 1–7	Recycling waste brick from construction and demolition of buildings as pozzolanic materials	2010	pozzolic characteristic, waste brick, hydration product, compressive strength, construction and demolition waste, linear polysilicate anions	KL Lin, HH Wu, JL Shie, CL Hwang, A Cheng	Department of Environmental Engineering, Department of Construction Engineering, Department of Civil Engineering	Taiwan	85
A27	[32]	WEB OF SCIENCE	Construction and Building Materials, 412, 134727	The recycling of demolition roof tile waste as a resource in the manufacturing of fired bricks: A scale-up to the industry	2024	Waste-to-resource , Roof tile waste , Construction a	M Dubale, MV Vasić, G Goel, A Kalamdhad, B Laishram	Collage of Engineering and Technology, Institute for Testing of Materials IMS, School of Energy and Environment, Institute of Engineering and Technology, Department of Civil Engineering	India	0
A28	[33]	WEB OF SCIENCE	Construction and Building Materials, 255	Effects of concrete waste on characteristics of structural fired clay bricks	2020	Construction demolition wastes, Recycling, Clay brick, Sustainability	O Gencel, E Erdugmus, M Sutcu, OH Oren	Civil Engineering Department, Environmental Engineering Department, Bartin University, Materials Science and Engineering Department, Construction Department, Vocational of Higher Education	Türkiye	92
A29	[34]	WEB OF SCIENCE	Journal of Building Engineering, 75	Design optimization of a recycled concrete waste-based brick through alkali activation using Box- Behnken design methodology	2023	Construction and demolition waste, Concrete waste, Alkali-activation, Box- Behnken design, Concrete waste bricks	MR Maaze, S Shrivastava	Department of Civil Engineering	India	11
A30	[35]	WEB OF SCIENCE	Proceedings of the Institution of Civil Engineers - construction materials, 172 Issue 1,	Recycling of construction wastes for manufacturing sustainable bricks	2019	conservation, demolition, environment	MN Rojas-Valencia, E Aquino	Instituto de Ingeniería	Mexico	14
A31	[36]	WEB OF SCIENCE	Environmental Technology & Innovation, 25, 102228	An investigation of demolished floor and wall ceramic tile waste utilization in fired brick production	2022	C&D waste, Floor and wall tile waste, Fired brick, Laterite soil, Alluvial soil	Mandefrot Dubale, Gaurav Goel, A jay Kalamdhad, Laishram Boeing Singh	Department of Civil Engineering, School of Energy and Environment	India	13
A32	[37]	WEB OF SCIENCE	Construction and Building Materials, 411,134385	Production of sustainable lime-based brick using carbonated recycled concrete fines: Mechanical, mineralogical and microstructure properties	2024	Recycled cement powder, CarbonationCalcium hydroxide, Recycled brick, Hydration products	Xiaowei Ouyang, Jiongqi Chen, Jia ming Li, Kai Wu, Yuwei Ma, Jiyan g Fu	Research Center for Wind Engineering and Engineering Vibration, Key Laboratory of Advanced Civil Engineering Materials of Ministry of Education	China	1
A33	[38]	WEB OF SCIENCE	Case Studies in Construction Materials,	Experimental investigation on physical and mechanical properties of excavated soil- and fine recycled concrete aggregate-based unfired clay bricks containing compound additives	2023	Unfired clay bricks, Excavated soil-waste, Fine recycled concrete aggregate, Compressive strength, Flexural strength	W Xiong, H Zhu, J Xu, J Ma, C Luo	IC-IPRES, College of Civil Engineering, Hexian Feijun New Building Materials Co.	China	5

Table 3. Second part of the Meta-Analysis for 1-17 articles.

Article Code	Aim	Scope	Method	Research Output
A1	to evaluate the effect of using fourbio-wastes as organic additives and two construction wastes	to evaluate four kinds of bio-wastes and two kinds of construction wastes in which the sludges would then be reused for brick production	sludge for testing, sludge dewatering test, data analysis (ANOVA), the software StatPlus:mac LE v7.3.31	The results have revealed a potentially green route for brick production with lake sediment and bio-waste/construction wastes
A2	to report the preliminary findings on powdered mud C&D and straw grass material on the technological properties of fired clay bricks	geared towards optimizing the sustainable development of enhanced fired clay building material utilizing MCD and rubble and SGM	brick precursors, ultimate analysis, sample preparation	bricks containing 15 wt% MCD and 7.5 wt% SGM were the most optimized samples as these bricks exhibited compressive strength values of 10 MPa for load-bearing structural construction application
A3	investigate the effect of treated rice straw and forestry leaves in alkali-activated fly ash bricks with CDW for non-load bearing partitions walls	agro-forestry and CDW utilisation in AA-FA bricks for non-load bearing application (Mechanical, thermal, acoustic and high temperature behaviour)	Brick casting, characterization analysis	shows a potential green solution toward sustainable building materials in construction sector leading to reduced depletion of fertile soil used in production of burnt clay bricks
A4	the evaluation of the impact of larger particle sizes of PET and the inclusion of other aggregates, and CDW on the mechanical and physical properties of bricks.	evaluating the performance of cement mortar in conjunction with sand, CDW, and lightweight expanded polystyrene aggregates	Granulometry curves, Bulk density, Water absorption coefficient, Flexural resistance, Compressive resistance	the inclusion of fine construction and demolition waste has proven effective in achieving mechanical and physical properties that meet standard requirements
A5	to improve and propose costeffective and structurally sound construction units by manufacturing bricks using CDW	incorporating CDW, cement, coarse sand, fine sand, crushed stone, confitillo, and polystyrene for the relevant tests	Preliminary study of aggregates, Specific weight (NTP 400. 022), Unit weight (NTP 400 017), Absorption, Resistance tests, Control	the produced bricks meet the necessary technical and economic requirements for use in the construction of perimeter fences for low-cost housing
A6	to investigate the effects of the two processing methods to clarify the mechanism for such effects	grinding and calcination taken on fine powders from RCP/RBP as CDW were evaluated in terms of their efficiency, energy consumption, and cost	Processing of recycled powder, Preparation of the blended mortar, Water demand and setting time, Hydration features and the micro-structure of blended paste/mortar	two processing techniques were evaluated in terms of the fluidity, compressive strength, and flexural strength of the blended cement mortar with the incorporation of 20 % RCP/RBP
A7	to use the brick waste powder as a precursormaterial, create a unique alternative sustainable brick	BWP obtained from CDW was used as a precursor material	Full factorial design, Preparation of alkaline solution, Mixing and manufacturing of bricks, Physio-mechanical properties evaluation, Sample preparation for microstructural studies	BWP has a good proportion of alumina and silica and can be used as a precursor material in geopolymer applications
A8	to provide knowledge for the development through the synthesis of an alkaline activated hybrid cement (CDWOPC) with mechanical properties adhered to the regulations	cement will be made up of a CDW material from brick waste and eliminate the limitation of thermal curing, a limitation	sample preparation, mixed mechanically for 10 min, X-ray diffraction (XRD) tests	the great property that brick waste has to be a precursor for the synthesis of AAC under specific conditions, such as particle size, the liquid/solid ratios, and SiO_2/Al_2O_3 and Na_2O/SiO_2
A9	the feasibility of brick making with CS and RP derived from CDW	using RP to prepare fired CS brick	Chemical composition, Physical properties, Mechanical properties, Microstructure	there is an apparent positive correlation between the weight loss on ignition and the RP content
A10	to determine the optimal SiO_2/Al_2O_3 ratio and increase the strength of a red mud-based geopolymer by mechanical activation.	utilization of different industrial by product which are a source of alumina and silica for the formation of geopolymer binder like RHA, GGBS and Red Mud	conventional method	the proportion and kind of aluminosilicate material used in the preparation of the geopolymer bricks is the most important component
A11	use the mixed CDW, analyze the influence of firing temperature, limit the usage of natural resources	a partial replacement of the natural clay soil that is normally utilized in the manufacturing of fired brick was substituted by mixed CDW	ball-rolling grinder and sieved	based on raw materials and fired brick characterization, mixed C&D waste can be incorporated in a quantity of 10% in the fired brick making
A12	integrates MFA and BIM to assess the quantity and use cases of clay bricks and terracotta tiles	material flows for these products were traced from the supply of raw materials to manufacturing, use, demolition, and waste management	expert data and site data collection and BIM integration	the integration of MFAandBIMapproaches markedly improves the detail, speed, and realism of quantifying the material flows within the urban environment
A13	the feasibility of using CDW as a partial replacement of red earth or clay in conventional clay brick	a replacement for clay, red earth, and water materials using building debris	a novel method	to ensure economy and eco-friendliness clay shall be replaced by flyash in small amounts
A14	to evaluate the sustainable use of sulphidic mining waste materials in facing bricks	a company-specific blend for facing bricks has been modified on a lab scale, by partly replacing primary raw materials with mining waste materials	LCA	the suitability of using the untreated Plombi`eres tailings material in facing brick blends, giving satisfactory technical and aesthetical properties, and complying with environmental regulations for service, 2nd life, and end-of-life stages
A15	to assess the effect of fine-grained fractions of C&D residues on the technological behavior and technical performance of clay bricks	the sampling of the residues studied took place in a CDR processing plant	Simulating the brickmaking process on a laboratory scale	the use of CDR is technologically feasible
A16	WTS for replacing natural clay in brick industry, to evaluate the impact of adding concrete waste	bricks containing sludge and CW have been successfully manufactured by firing at 1000 °C and tested	WTS and CW were subjected, grinding up	water absorption and apparent porosity values increase while bulk density, compressive strength and thermal conductivity values decrease by depending on the increment in CW content
A17	to find out the environmental impact, economic cost, and carbon emissions of various CDW recycling methods	conducts a life cycle assessment on three typical recycled products manufactured from CDW	LCA	the use of cement is a key impact material in the production of masonry bricks and thermal isolation blocks

Table 4. Second part of the Meta-Analysis for 18-33 articles.

Article Code	Aim	Scope	Method	Research Output
A18	to eliminate the natural resources like clay and utilization of waste additives effectively in making brick blocks	The mix proportions are maintained at 30% sludge with 3:2:2, 2:3:2, and 2:2:3, 40% sludge with 1:3:2, 2:3:1,and 3:2:1 and 50% sludge with 2:1:2, 2:2:1, and 1.5:1.5:2	laboratory tests, the physicochemical properties assessment	the waste additives provide a significant strength within the standard limits
A19	to utilize CDW for manufacturing of bricks as an alternative to a conventional brick	20%, 40%, 60%, 80% of recycled soil and recycled sand are utilized as an alternative to conventional soil along with bagasse ash	Physical and mechanical test of bricks	brick requires a larger quantity of soil for the manufacturing process of bricks but recycled soil and recycled sand potentially reduce the use of natural soil by up to 20 %.
A20	to establish the sustainable properties for sand cement bricks using RCA and CR, to determine the optimum cement-sand ratio	the brick specimens were prepared using 15%, 30%, 45%, and 60% of RCA and 1.5%, 3.0%, 4.5%, and 6.0% of CR by volume of sand with a water-cement ratio of 0.6	density, compressive strength, and water absorption tests	the average density of sand cement bricks is lower than the control bricks
A21	examining the suitability of using the fine fraction of CDW in the production of unfired bricks	tests were conducted using fine materials resulting from crushed old concrete and clay bricks	bricks were tested for mechanical strength, water absorption freeze-thaw resistance, LCA	CDWs can replace natural soils for the unfired brick manufacturing
A22	to manufacture a sustainable brick combining	four different types of secondary materials for the composition of the brick matrix	Mixtures Design, Sustainable Brick Manufacturing Process, compressive strength tests, TGA	construction wastes could be used as an alternative in the manufacture of sustainable bricks
A23	to investigate sludge from the inert mineral part of the CDW use in the fabrication of fired bricks for building purposes	different dosages of RA-S and earth material were prepared and evaluated in terms of their physical-chemical properties	XRD analysis, The compressive strength, The thermal conductivity	RA-S generated from recycling inert mineral part of construction and demolition waste plant is an excellent raw material to prepare efficient fired bricks
A24	make a comparative study of bricks made with various waste materials to conventional clay brick	steel slag, saw dust and construction and demolition waste for the partial replacement to clay	compression test, water absorption test and efflorescence test	selecting 20% of steel slag and using 50% of C&D will produce maximum of strength and reuse of waste production to save the environment
A25	air jigging separation for removing brick particles from recycled construction and demolition waste aggregates	the constituents of the recycled CDW included brick, concrete and a small amount of gypsum, tile, and dust	the separation studies performed based on the theoretical approach at a laboratory scale	the proposed air jigging separation method was effective at reducing brick particle content and producing significant recycled concrete aggregates
A26	to investigate the pozzolic characteristics of pastes that contain waste brick from building CDW	some of the cement was replaced with waste brick, in pro-portions of 10%, 20%, 30%, 40% and 50% by mass	the chemical composition and physical characteristics of the cement and waste brick	waste brick has potential as a pozzolanic material in the partial replacement of cement
A27	the utilization of roof tile waste as a resource in the manufacturing of fired bricks	two types of soil and demolition RTW to create a fired clay brick at three peak firing temperatures	Characterization of the raw materials, laboratory-scale analysis and a commercial-scale assessment of the bricks	the minimum acceptable quality for the produced bricks was achieved with an addition of 35 wt% waste
A28	evaluation of concrete waste in the production of fired clay brick	ground concrete waste powder was replaced with the clay up to 15% by weight	Loss on ignition, bulk density, apparent porosity, water absorption capacity, compressive strength, thermal conductivity, dilatometric, leach analysis and efflorescence analysis	loss on ignition, porosity and water absorption values slightly increase while compressive strength and thermal conductivity values decrease by depending on the increment in concrete waste content
A29	the utilization of recycled concrete waste powder as a precursor in geopolymer to design eco-friendly bricks	three-factor and three-levels designs were considered	an experimental mix was generated based on the RSM-BBD methodology	12 Molarity of NaOH Solution, 2.32 Alkaline mix ratio (Na_2SiO_3:NaOH), and 50 °C curing temperature were the optimum factors.
A30	to manufacture sustainable bricks	9 mixtures were prepared using 62% excavation wastes, 5% wood-cutting residues and 33% RA	compressive strength and water absorption parameters	ecological bricks manufactured with the mixture of cementing RA only of 3/8 and 1/4 inch to fines meet the standard requirements, providing compressive strength values of up to 8 Mpa
A31	to utilize DFWT waste into fired brick production with two types of soils	the soil and demolished building floor and wall tile waste were mixed in different ratios ranging from 5wt% to 45wt%	Raw material characterization, techniques like XRF, XRD, FTIR, TGA, proximate & ultimate analysis were used	the higher the firing temperature, the more the compressive strength and the lower the water absorption
A32	reusing CW and simultaneously sequestering CO_2 in the form of mineral carbon	waste concrete is crushed and ground into RCF	the production of construction bricks using waste concrete fines treated with carbonation	the results indicate that bricks made with CRCF exhibit mechanical properties exceeding those of RCF-based bricks by more than two-fold
A34	to use the excavated soil waste and the demolished concrete as the source of natural aggregates' replacement in concrete	the ordinary Portland cement of grade C42.5 was employed as the binding material	two orthogonal experiments	excavated soil & FRCA-based UCBs exhibit the favourable water absorption, bulk density, compressive strength and flexural strength

Step 5: Synthesizing

In the first step, the research question was determined according to the preliminary literature review in the scope of C&D material waste & waste management and preferring and analyzing a specific material like brick, which is one of the most widely used materials with low embodied energy. The research question was "what the focus and content of the recent research in the literature about the management is the C&D material waste to produce brick?".

The 2010s have marked a significant era in the realm of circular economy and construction material studies. Our study indicated a surge in scientific inquiries focusing on the reduction of raw material consumption and the utilization of C&D material waste in brick production from 2010 to 2024. Prior to 2010, there were no documented studies regarding the utilization of waste materials in brick production within the scope of the examined databases. Seven studies were identified in 2022, followed by eleven studies in 2023, and currently, there are five ongoing studies in 2024. Researchers addressed the examined studies in countries where brick production is prevalent, such as India, China, Spain, and Vietnam. In Türkiye, there were two studies on this subject [16, 33]. The studies aimed to evaluate C&D material waste's impact on bricks' mechanical, physical, and thermal properties and chemical composition. While some studies assessed the cost, only two studies investigated the environmental impacts of brick production with C&D material waste using the Life Cycle Assessment (LCA) [19, 22]. The mixing procedure represented the pivotal influencing stage. Cement emerged as a critical influencing material in the manufacturing of masonry bricks and thermal insulation blocks, whereas adhesive glue assumed significance as a key influencing material in permeable brick manufacturing [22].

A variety of materials, including bio-wastes (such as corn core powder, rice husk powder, sugarcane bagasse powder, and peanut shell powders), sludge, recycled soil, recycled sand, autoclaved aerated concrete, pavement stone waste, mud construction and demolition, rubble, brick waste powder, recycled concrete aggregate, steel slag, and sawdust were used in brick production alongside mixed C&D material waste residue (all in one waste). Among these wastes, brick waste powder demonstrated a favorable content of alumina and silica, qualifying it as a potential base material for integration into geopolymer bricks [12]. Except for one study focusing on material flow analysis and BIM integration, all other studies encompassed laboratory experiments. For laboratory studies, the maximum replacement ratio of C&D material waste varied depending on the waste material and the components of the mixture. Some studies highlighted that workability limited each CDW's maximum replacement ratio [27, 35]. Waste-derived brick materials that meet the required performance in terms of comprehensive strength were proposed for structural purposes [7, 23, 33]. In contrast, brick materials obtained from wastes were recommended for non-load-bearing building elements [27].

4 CONCLUSION

Effective material waste management provides cost savings, reduced demand for landfills, improved resource management, profit, and quality maximization. As a result of today's limited resources and sustainable development, it is believed that waste management in the construction industry should has priority. Waste management is closely associated with the almost whole project life cycle, considering material life cycle, too. In this study, it is emphasised the importance of C&D material waste management in terms of life cycle of brick as a sample.

The studies stated the significance of utilizing C&D waste in reducing raw material consumption in brick manufacturing and effectively minimizing waste generation, thus contributing to sustainable material production. In this context, the bricks produced by C&D waste should meet the necessary technical and standard specifications. The chemical and physical properties of C&D waste differ depending on its source, exhibiting varying compositions. Therefore, laboratory and environmental analysis is required to test the new material's properties. In addition, the development of a process-based waste management plan, from waste sources to the transportation to the production site, waste segregation, and material incorporation of waste to produce new materials, will serve as a guiding framework in introducing the material to the industry.

5 REFERENCES

[1] Loch, P., Stocker, S. M., & Bertolini, G. R. (2019). Civil Construction Waste Management Plan: A Systematic Review of The Brazilian Scientific Production From 2003 To 2016. Rev. Gest. Ambient. Sustentabilidade, São Paulo (8)1, 100-122.

[2] Gov.UK. (2022). Classify different types of waste: https://www.gov.uk/how-to-classify-different-types-of-waste/construction-and-demolition-waste adresinden alındı

[3] EPA. (2022). Construction and Demolition Debris: Material-Specific Data: https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/construction-and-demolition-debris-material adresinden alındı

[4] BigRentz, I. (2021). 23 Construction Waste Statistics & Tips to Reduce Landfill Debris. Big Rentz: https://www.bigrentz.com/blog/construction-waste-statistics adresinden alındı

[5] Denyer, D., & Tranfield, D. (2009). Producing a systematic review.

[6] Dang, H. T., Pham, L. T., Pham, T. T., Nguyen, H. X., Tran, N. T., & Nguyen, K. M. (2023). Effect of biowaste and construction waste additives on mechanical dewaterability of lake sediment for brick production. Journal of the Air & Waste Management Association, 73(8), 625-637.

[7] Adazabra, A. N., Viruthagiri, G., & Tiose, C. (2023). Influence of mud waste and straw grass addition in fired bricks production: technical properties evaluation. Innovative Infrastructure Solutions, 8(11), 306.

[8] Singh, S., Dalbehera, M. M., Maiti, S., Bisht, R. S., Balam, N. B., & Panigrahi, S. K. (2023). Investigation of agro-forestry and construction demolition wastes in alkali-activated fly ash bricks as sustainable building materials. Waste Management, 159, 114-124.

[9] Peisino, L. E., del Mar Barbero-Barrera, M., García-Castro, C. B., Kreiker, J., & Gaggino, R. (2024). Assessment of the mechanical and physical characteristics of PET bricks with different aggregates. Journal of Environmental Management, 357, 120720.

[10] Ñañez-Silva, M., Sánchez-Cárdenas, L., Yactayo-Carrión, E. (2023). Valorization and reuse of construction and demolition waste for its transformation into ecological bricks. International Journal of Advanced and Applied Sciences, 10(6), pp. 150–157

[11] Zhang, H., Zhang, B., Tang, L., & Zeng, W. (2023). Analysis of two processing techniques applied on powders from recycling of clay bricks and concrete, in terms of efficiency, energy consumption, and cost. Construction and Building Materials, 385, 131517.

[12] Maaze, M. R., & Shrivastava, S. (2023). Design development of sustainable brick-waste geopolymer brick using full factorial design methodology. Construction and Building Materials, 370, 130655.

[13] Cardoza, A., & Colorado, H. A. (2024). Alkaline activation of brick waste with partial addition of ordinary Portland cement (OPC) for reducing brick industry pollution and developing a feasible and competitive construction material. Open Ceramics, 18, 100569.

[14] Bai, M., Xiao, J., Gao, Q., & Shen, J. (2023). Utilization of construction spoil and recycled powder in fired bricks. Case Studies in Construction Materials, 18, e02024.

[15] Haq, M. Z. U., Sood, H., Kumar, R., & Merta, I. (2024). Taguchi-optimized triple-aluminosilicate geopolymer bricks with recycled sand: a sustainable construction solution. Case Studies in Construction Materials, 20, e02780.

[16] Dubale, M., Vasić, M. V., Goel, G., Kalamdhad, A., & Singh, L. B. (2022). Utilization of construction and demolition mix waste in the fired brick production: the impact on mechanical properties. Materials, 16(1), 262.

[17] Miatto, A., Sartori, C., Bianchi, M., Borin, P., Giordano, A., Saxe, S., & Graedel, T. E. (2022). Tracking the material cycle of Italian bricks with the aid of building information modeling. Journal of Industrial Ecology, 26(2), 609-626.
[18] Harikumar, M., Mohamed, F., Mohammed, A., Ashraf, I., Shahansha, M., & Anand, A. G. (2022). Clay bricks using building debris. Materials Today: Proceedings, 60, 746-752.
[19] Simão, F. V., Chambart, H., Vandemeulebroeke, L., Nielsen, P., Adrianto, L. R., Pfister, S., & Cappuyns, V. (2022). Mine waste as a sustainable resource for facing bricks. Journal of Cleaner Production, 368, 133118.
[20] Zanelli, C., Marrocchino, E., Guarini, G., Toffano, A., Vaccaro, C., & Dondi, M. (2021). Recycling construction and demolition residues in clay bricks. Applied Sciences, 11(19), 8918.
[21] Gencel, O., Kizinievic, O., Erdogmus, E., Kizinievic, V., Sutcu, M., & Muñoz, P. (2022). Manufacturing of fired bricks derived from wastes: utilization of water treatment sludge and concrete demolition waste. Archives of Civil and Mechanical Engineering, 22(2), 78.
[22] Qiao, L., Tang, Y., Li, Y., Liu, M., Yuan, X., Wang, Q., & Ma, Q. (2022). Life cycle assessment of three typical recycled products from construction and demolition waste. Journal of Cleaner Production, 376, 134139.
[23] Vaithiyasubramanian, R., Srinivasan, D., & Kanagarajan, A. K. (2022). Study on preparation of brick blocks by using construction waste and sludge. Environmental Science and Pollution Research, 29(48), 72528-72544.
[24] Desai, M., Yadav, N., & Desai, N. (2023). Application of recycled soil and sand in brick production over conventional clay Brick: A sustainable alternative. Materials Today: Proceedings, 77, 879-886.
[25] Khalid F.S., Aminuddin M. Y. A., Abdullah Al-Jaberi A. N., Zaki1 Z., Irwan J.M., Ayob S., Bassam Tayeh A. (2021). The determination of optimum ratio by using recycled concrete aggregate and crumb rubber as partial sand replacement material in sand cement brick production. International Journal of Nanoelectronics and Materials, 14, 29-42.
[26] Seco, A., Omer, J., Marcelino, S., Espuelas, S., & Prieto, E. (2018). Sustainable unfired bricks manufacturing from construction and demolition wastes. Construction and Building Materials, 167, 154-165.
[27] Aguilar-Penagos, A., Gómez-Soberón, J. M., & Rojas-Valencia, M. N. (2017). Physicochemical, mineralogical and microscopic evaluation of sustainable bricks manufactured with construction wastes. Applied Sciences, 7(10), 1012.
[28] Dos Reis, G. S., Cazacliu, B. G., Cothenet, A., Poullain, P., Wilhelm, M., Sampaio, C. H., ... & Torrenti, J. M. (2020). Fabrication, microstructure, and properties of fired clay bricks using construction and demolition waste sludge as the main additive. Journal of cleaner production, 258, 120733.
[29] GUNASEKAR, S., & RAMESH, N. (2019). COMPARATIVE STUDY OF BRICKS MADE WITH VARIOUS WASTE MATERIALS TO CONVENTIONAL CLAY BRICK. Journal of the Balkan Tribological Association, 25(4).
[30] Hu, K., Chen, Y., Naz, F., Zeng, C., & Cao, S. (2019). Separation studies of concrete and brick from construction and demolition waste. Waste Management, 85, 396-404.
[31] Lin, K. L., Wu, H. H., Shie, J. L., Hwang, C. L., & Cheng, A. (2010). Recycling waste brick from construction and demolition of buildings as pozzolanic materials. Waste management & research, 28(7), 653-659.
[32] Dubale, M., Vasić, M. V., Goel, G., Kalamdhad, A., & Laishram, B. (2024). The recycling of demolition roof tile waste as a resource in the manufacturing of fired bricks: A scale-up to the industry. Construction and Building Materials, 412, 134727.
[33] Gencel, O., Erdugmus, E., Sutcu, M., & Oren, O. H. (2020). Effects of concrete waste on characteristics of structural fired clay bricks. Construction and Building Materials, 255, 119362.

[34] Maaze, M. R., & Shrivastava, S. (2023). Design optimization of a recycled concrete waste-based brick through alkali activation using Box-Behnken design methodology. Journal of Building Engineering, 75, 106863.
[35] Rojas-Valencia, M. N., & Aquino, E. (2019). Recycling of construction wastes for manufacturing sustainable bricks. Proceedings of the Institution of Civil Engineers-Construction Materials, 172(1), 29-36.
[36] Dubale, M., Goel, G., Kalamdhad, A., & Singh, L. B. (2022). An investigation of demolished floor and wall ceramic tile waste utilization in fired brick production. Environmental Technology & Innovation, 25, 102228.
[37] Ouyang, X., Chen, J., Li, J., Wu, K., Ma, Y., & Fu, J. (2024). Production of sustainable lime-based brick using carbonated recycled concrete fines: Mechanical, mineralogical and microstructure properties. Construction and Building Materials, 411, 134385.
[38] Xiong, W., Zhu, H., Xu, J., Ma, J., & Luo, C. (2023). Experimental investigation on physical and mechanical properties of excavated soil-and fine recycled concrete aggregate-based unfired clay bricks containing compound additives. Case Studies in Construction Materials, 18, e02057.

Traditional Adobe House Architecture in Yeşilyurt, Darende, Battalgazi Regions in Malatya

Gülhan BENLİ,
Istanbul Medipol University, Istanbul/TURKIYE

gbenli@medipol.edu.tr

ABSTRACT

In this study, the adobe houses that shape the architectural formation in the Battalgazi, Darende and Yeşilyurt settlements of Malatya Province are discussed, and the architectural with structural features of the houses will be examined. Simplicity prevails in the architecture of the houses planned in harmony with the topography. In the interiors, very rare examples of wood craftsmanship attract attention. Generally, the ground floors of two-storey houses are reserved for service spaces and the upper floors are reserved for living spaces. Almost all of the houses, whose long facades form a street silhouette, have large gardens. Since the gardens are included in the private life of the house, they are surrounded by high walls so that the life inside cannot be perceived from the outside.

Within the scope of the study, research on the region will be shared based on findings made in the field and on-site in 2022. The extensive use of adobe architecture in the region is an indication that the art of soil-based construction has been widespread for many years. It is believed that understanding the earthen construction techniques produced in the past will provide a different perspective on today's construction techniques. For this reason, it is important to share the examples of adobe buildings that were damaged and some of them collapsed due to the devastating February 6, 2023 earthquake in the region, on the occasion of the Kerpic'24 conference, and to document them as written documents.

Examples of adobe houses, determined to prevent the region from remaining only in memories, will be presented under the title of "Cultural Preservation", one of the themes of the conference.

Keywords: adobe houses, earthen construction technique, malatya, darende, yeşilyurt

1 LOCATION, GEOGRAPHICAL FEATURES AND BRIEF HISTORY OF MALATYA PROVINCE

Malatya is located at the intersection of Central Anatolia, Mediterranean, Eastern Anatolia and Southeastern Anatolia Regions. Since the province is located on the second largest fault zone in Turkey in terms of earthquake zone, earthquakes occur frequently. There is mountainous terrain throughout the province, the vegetation is steppe, the center of the province is approximately 960 meters above sea level and the province has a continental climate. Malatya's surface area is 12.259 km2, population: 742,725 people and according to this determination, the most densely populated districts are Battalgazi and Yeşilyurt (URL 1).

Figure 1. Location of Malatya province and Darende, Balaban, Yeşilyurt districts in Türkiye (URL 2).

Although it is known in historical sources that there were settlements in the Chalcolithic period (5500-3000 BC) during the excavations in Malatya and its surroundings, it is known that there are Hittite city ruins from the 13th century BC in the 4th cultural layer of the Arslantepe mound. Malatya, which has names such as Maldiya and Melitene in historical sources, was shaped over the centuries by the influences of the Hittite, Assyrian, Urartian, Roman, Byzantine, Turkish Principalities and the Ottoman Empire. The most comprehensive settlement and increase in the settled population occurred in 1839 during World War II. It is attributed to Hafız Mehmet Pasha establishing his headquarters in Malatya by the order of Mahmud. After the declaration of the Republic, it became a province [1, 2].

2 EXAMPLES OF TRADITIONAL ADOBE HOUSES IN MALATYA

The building materials of houses in Malatya districts and villages are stone, adobe and wood. Stone material is used in the foundation part and rises up to 1-2 meters from the ground. The walls of the houses were built in the wooden ("hımış" in Turkish) construction system, in the mudbrick brick knitting method between the wooden construction. The wall, which is thicker on the ground floor, becomes thinner when you go upstairs. The houses are plastered externally and internally. The mezzanine floor has wooden beams.

Although there are single-storey examples in the region, many mudbrick houses have two storeys. Houses with large residential areas usually have gardens or courtyards. The garden or courtyard entrance doors of mudbrick houses, which can be defined as mansions in the districts and aga houses in the villages, have double wings and are big enough for a horse cart or camel to pass through easily. The garden walls are high and the inside cannot be seen. In houses with haremlik-selamlık (separated for women and men) or large programs, the garden is opened to several other buildings with different functions such as barns, haystacks, latrines, and baths in addition to the house.

In the adobe houses of Malatya, the ground floors are usually occupied by cellars, warehouses, kitchens and winter rooms, which are called service spaces. Locally, the cellar is called "zahirelik" and the kitchen is called "hızna" and is one of the most valuable parts of the house. In the zahirelik or hızna space, foods such as cereals, cheeses pressed in tins, grape juice filled in cubes, pickles, grape paste, butter, etc. are stored to meet the winter needs of the house.

There are no windows in some examples to prevent animals from entering and to keep the interior dark and cool, while in other examples there are very small windows opened at the top of the wall. The winter room on the ground floor is the common place where the family sits together during the cold season and where the fireplace is located. There is also another space, locally called "limseki", located on the ground floor. The limseki is located adjacent to the winter room in some examples and the kitchen in others. This elevation, which is accessed by 2-3 steps from the ground, is an area for communal sitting or chatting, sometimes responding to activities such as rolling out dough. It is covered with rugs and carpets and cannot be climbed with shoes.

The upper floors, which are reached by a wooden staircase, have a sofa, head room and rooms. The simple façade of the ground floor is enriched by the projection from the upper floor. In some examples, there is an open sofa called "hayat" in front of the rooms. The open sofa leads to the garden or courtyard and is not visible from the street. Fireplaces were built to sit in the open sofa on cold days. Adobe houses are covered with wooden beams and flat earthen roofs.

2.1 Adobe Houses in Yeşilyurt

In Yeşilyurt district of Malatya, it is possible to see the houses collectively built using adobe, wood and stone, which date back 350 years and reflect the architectural features of the region, in Hıroğlu Neighborhood. A total of 19 historical houses on Adıyaman Street in Hıroğlu Neighborhood of Yeşilyurt District were maintained, repaired and restored in 2010-2011 by the Provincial Special Provincial Administration Protection and Implementation Supervision Bureau (KUDEB) of Malatya Governorship.

Two of the 13 historic houses were converted into accommodation and four into nostalgic places where local food and products are sold. At the same time, a cinema museum was opened in the region with a private entrepreneur (Fig. 2). It has become a meeting and socializing area adopted by the local people and where both Malatian and other visitors can spend their summer evenings cooling off due to its geography. After 2011, Yeşilyurt has developed to become not only Turkey's but also the world's gastronomy center, and other houses have also been functionalized in accordance with the region. It is a positive and successful example that Yeşilyurt mansions are put into service not only as museums, but also as living mansions with service areas with different functions, where life flows inside (Fig. 2).

Figure 2. Examples of adobe houses from Yeşilyurt Mansions, which have been renovated as accommodation (left photo) and Cinema Museum (right photo) (author's archive, 2022).

However, the 7.7 magnitude earthquake centered in Pazarcık District of Kahramanmaraş on February 06, 2022 and the 7.6 magnitude earthquake centered in Elbistan on the same date caused great destruction in all the surrounding provinces and negatively affected Malatya as well. Researches conducted in the region revealed that many adobe houses survived after the first earthquake. In the first earthquake, it was learned that just the roofs of many adobe buildings were damaged the most. People living in the region shared the information that the biggest damage and destruction of adobe houses occurred during the second earthquake or aftershocks. Most likely, the collapse of the roofs connecting the adobe walls in the 1st earthquake caused the adobe walls to collapse and decompose due to the dislocation of some wooden construction (Fig. 3).

Figure 3. Examples of adobe houses destroyed in the second earthquake in Hıroğlu neighborhood of Yeşilyurt district (URL 3).

It is seen that the damage is much less in buildings that have been repaired and maintained in a certain way, such as the mansions in the Hıroğlu Neighborhood of Yeşilyurt District. It can be seen in figures 5, 6 that the destruction in Yeşilyurt Mansions, which were repaired and restored with the support of local administration and the state, can be eliminated much faster and with less intervention (Figs. 4, 5).

Figure 4. Examples of collapse and cracking of mudbrick walls in Yeşilyurt Mansions (author's archive, 2023).

Figure 5. Partial collapse of the roof, eaves and walls of Yeşilyurt Mansions (author's archive, 2023).

2.2 Adobe Houses in Darende

The neighborhoods where adobe houses are located in Darende are Gökyar, İbrahimpaşa, Hacı Derviş, Heyiketeği, Beybağı, Günpınar, Aşağıulupınar and Balaban. The 19th and 20th century adobe houses, which can be dated to the last quarter of the 19th century and the first quarter of the 20th century, are mostly two-story, street-facing with courtyard or gardens [2, 3]. The materials used in the construction of the houses in Darende also are stone, adobe and wood. Stone material was used for the garden walls and the foundations of the houses, and was generally raised until the connection of the building with the ground level was finished. The roof cover of the houses is a flat roof made of compressed soil on wooden beams. However, due to the difficulty of maintenance over the years, the roofs of many houses have been covered with sheet metal or zinc roofing that slopes in one or both directions.

Stables, haystacks and toilets are located in the courtyard. The ground floors of the two-storey houses are reserved for various services (grain storage, warehouses, winter rooms, etc.), while the first floor has a sofa and rooms. In the Gökyar neighborhood, mudbrick houses with a larger residential area are seen compared to other neighborhoods. Since the houses are positioned according to the slope of the land, they do not block each other's view. In some examples, there are no windows in the basement or ground floors due to the slope. These sections are mostly used as barns or haystacks. The windows of the cellars, kitchens, tandoori houses and winter rooms on the ground floors are generally small in size and on the upper level (Fig. 6, 7). On the upper floor, where the living areas of the houses are located, there are rooms with windows facing the view. There are many examples where overhangs are applied to enlarge the room on the upper floors and to see the street more easily. The overhangs are formed by extending the wooden floor beams and supporting them with wooden brackets (Figs. 6, 7). The upstairs rooms have elements such as couches, load-bags, cupboards, and firecase.

In the adobe house examples located in the center of the neighborhood, commercial spaces (workshops, shops) are also seen on the ground floor. Open bay windows are also applied on the upper floors in the examples that were first built as commercial + residential or transformed after they were built (Fig. 8).

Figure 6. Examples of large adobe houses in Gökyar Neighborhood (author's archive, 2022).

Figure 7. Located on a corner parcel in Hacıderviş Neighborhood, the adobe house has as many spaces and an inner courtyard as a mansion structure. It has double overhang and balcony facing the street. The flat adobe roof was covered with sheet metal in the later period (author's archive, 2022).

Figure 8. Ibrahimpasa Neighborhood, examples with ground floors as workshops and upper floors as residences (author's archive, 2022).

After the February 06, 2023 earthquake, many damaged houses, even in the area declared as a protected site, were turned into plots of land before they could be fully and clearly identified. As can be seen in Figure 9, adobe structures that are still standing in the area. These special examples should be carefully preserved as they represent culture, history and experiences rather than being a physical product (Fig.9).

Figure 9. In Darende, the three-storey adobe house that survived the earthquake and the adjacent adobe house, which was completely demolished due to damage and turned into a plot of land, can be seen (URL 4).

2.3 Adobe Houses in Battalgazi

It is known that the oldest city center of Malatya, where heroes such as Battal Gazi grew up, is today's Battalgazi District and its surroundings. Located on the historical Silk Road route, the district continued to be the city center until 1938 [4]. In addition to the Roman walls, mosques, madrasahs, baths, kumbets, there are also archaeological settlements in the district [5].

Battalgazi adobe house examples, most of which are two-storeyed, have a warehouse or pantry, kitchen and winter room serving basic needs on the ground floor, and a sofa and rooms on the upper floors [4]. Depending on the fact that the majority of the people living in the region are engaged in agriculture and animal husbandry, there are "corrals" for animals and "roofs" for drying vegetables and fruits in the gardens of the houses [4].

The most magnificent adobe house of the district that has survived to the present day is the Poyraz Mansion (Ertunan House) located in Meydanbaşı Neighborhood. The mansion was brought back to life as the "Neighborhood Life Museum" after extensive restoration. The two-storey mansion has a rectangular plan and reflects the haremlik-selamlik living tradition. On the first floor, which is reached by a wooden staircase from the ground floor, there is an open sofa called "hayat" in Turkish in addition to the rooms. The woodwork in the mansion is eye-catching even today (Fig. 10).

The original street texture of the houses on Çukurpınar Street in Alacakapı Neighborhood of Battalgazi District, Alacakapı Neighborhood, is a positive example as the original street texture of the architectural structures such as the facades of the houses facing the street and the courtyard walls have been documented and transferred to the future with the sanitization practices (Fig.11).

Figure 10. Battalgazi Meydanbaşı Neighborhood Poyraz Mansion (Ertunan House) exterior facade, hayat (open sofa) and kitchen (author's archive, 2022).

Figure 11. Examples of adobe houses from Battalgazi (anonymous).

4 CONCLUSION

As in many regions of Anatolia, the adobe houses of Malatya were built in a way to respond to vital needs, using natural building materials (stone, wood, soil) obtained from the immediate surroundings and learned through the master-apprentice relationship.

On February 06, 2023, in the devastating earthquakes of magnitude 7.7 and 7.6 centered in the province of Kahramanmaraş, many houses were destroyed in Malatya as in other provinces. The mudbrick row houses, which were brought to tourism under the name of "Beş Konaklar" in Saray Mahallesi Cinema Street in the center of Malatya, survived the earthquake without any damage. The fact that they were low-rise and had wooden construction as a construction system allowed them to oscillate in the earthquake and absorb the earthquake load. Although there are many reinforced concrete houses adjacent to, opposite and in the immediate vicinity of Beş Konaklar, which were built 120 years ago, they were able to survive (Fig. 12). Yeşilyurt mansions also survived the earthquake with little damage. One of the most common misconceptions in the region is that low-rise buildings with reinforced concrete slab floors built on pile or masonry walls are characterized as adobe buildings. By generalizing, adobe buildings are discredited in the press.

However, the structures built by stacking random materials on top of each other without taking any precautions and without considering the load-bearing system have no relation with the adobe building tradition. In the mudbrick building tradition, wooden carcass is used as a carrier construction or there are wooden beams that are repeated every 90-100 cm. in height and surround the structure. The soil material, which is the raw material of adobe, should be reconsidered and evaluated with today's techniques and technology. It is important for future generations that adobe material, which is sustainable, recyclable and very favorable for human health, finds a place in today's architecture.

Figure 12. Beş Konaklar (Five Mansions in English) in the center of Malatya; traditional adobe Malatya houses that survived the devastating earthquakes of magnitude 7.7 and 7.6 in 2022 (URL 5).

5 REFERENCES

[1] Akyıldız, N., Olğun, T., 'Geleneksel Yapılarda Yaşlı ve Engelli Erişilebilirliğinin İrdelenmesi: Malatya-Balaban Geleneksel Evleri Örneği', *Sosyal Politika Çalışmaları Dergisi, "Erişilebilirlik" special issue*, 1, 31-48. DOI: 10.21560/spcd.vi.817603, 2020.

[2] Aytaç, İ., *Geleneksel Malatya Evleri Envanteri*, Malatya: Diltemizler Reklam ve Matbaa San. Tic. Ltd.Şti., 2015.

[3] Bahçeci, F. ve Aytaç, İ., 'Kırsal Mimaride Malatya-Darende Aşağıulupınar Evlerinin Karakteristik Özellikleri', *Social Sciences (NWSASOS)*, 12 (2), 118-139, DOI:10.12739/NWSA.2017.12.2.3C0161, 2017.

[4] Baran M., Aykal F.D., Kocaman M., 'Battalgazi ve Geleneksel Evlerinin Analizi', *Elektronik Sosyal Bilimler Dergisi*, 17 (67), 1302-1316, ISSN:1304-0278, 2018.

[5] Şentürk, A., Malatya, (II. Baskı), İstanbul, 1985.

URL 1: http://www.malatya.gov.tr/nufus-ve-idari-yapi. Date of access: June 15, 2024.

URL 2: http://cografyaharita.com/haritalarim/4l_malatya_ili_haritasi.png. Date of access: June 16, 2024.

URL 3: https://m.haberturk.com/yesilyurt-ta-depremin-tarihi-yapilara-hasari-havadan-goruntulendi-3568681. Date of access: June 15, 2024.

URL 4: https://www.cumhuriyet.com.tr/turkiye/depremde-agir-hasar-alan-2-kerpic-ev-kendiliginden-yikildi-2154440. Date of access: June 15, 2024.

URL 5: https://www.malatyagundemozel.com/haber/3-yillik-binalarin-yikildigi-malatya-da-120-yillik-tarihi-kerpic-evler-ayakta-kaldi-25725.html. Date of access: June 15, 2024.

Kerpic'24 – Challenges in Earth-Based Interior Architecture; Current Issue in Earth-Based Materials, Construction Techniques and Approaches
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Sustainable Settlements and Adobe Structures

Authors: Associate Professor Gülru Koca

Address: Işık Üniversitesi Meşrutiyet Mahallesi,
Üniversite Sokak No: 2
E-Mail: gulru.koca@isikun.edu.tr

ABSTRACT

"Adobe", which was one of the most preferred traditional building materials due to its advantageous properties, began to be abandoned in both urban and rural areas after the significant increase in the use of modern construction techniques. Traditional construction techniques were naturally abandoned in urban areas to build modern settlements during the modernization period. Nevertheless, they were also abandoned in rural areas because they could not meet the modern needs of the community. Abandoning traditional construction techniques, within this context particularly adobe, leads to the deterioration of urban texture and cultural heritage in rural areas.

The abandonment of traditional construction techniques and accordingly the deterioration of urban texture decrease the attractiveness of rural areas. This primarily results with migration from rural to urban areas and then the desolation of these settlements. In addition to this, the growing population in urban areas results with an increase in the demand for new constructions. These interconnected developments make it difficult to build earthquake-resilient and sustainable settlements.

Buildings which are constructed to respond to the needs of increasing population in urban areas usually result with dense vertical architectural solutions and with a decrease in green areas. In some cases, it also shows itself with negative consequences such as illegal housing. Especially in building earthquake-resilient and sustainable cities it is an important requirement to preserve, to modernize and to encourage the use of traditional construction techniques in rural areas.

Keywords: Adobe, cultural preservation, earthquake resilience, sustainable settlements, traditional construction techniques

1. INTRODUCTION

The population of cities is increasing due to various social and economic reasons, and rural areas are becoming deserted as a result of migration. Migrations do not only lead to population growth in cities but also become the source of many different problems. Migrations cause an increase in building density and illegal construction in urban areas. These problems negatively affect urban sustainability.
The increase in building density and illegal construction due to population growth causes both an increase in unsafe areas in cities and an increase in earthquake damage in earthquake prone areas. Rural sustainability must be ensured to prevent these negative outcomes. The rural population should be preserved

while ensuring the rural sustainability.
One of the most crucial requirements in ensuring rural sustainability is to prevent the migration from rural areas. The most significant reason of migration is the business and social opportunities available in cities. Therefore, achieving economic development in rural areas should be the main target. Highlighting the strengths of the region and developing activities such as agriculture, animal husbandry, and tourism, as well as maintaining active transportation networks with nearby settlements, are essential needs.
Another important factor in ensuring rural sustainability is the preservation of the region's architectural and cultural heritage. Preserving the cultural heritage significantly contributes to the region's tourism activities. Maintaining traditional construction techniques can also be effective in increasing the earthquake resistance of settlements.
The most commonly preferred traditional construction technique in many parts of Anatolia is adobe. Adobe is an advantageous construction technique due to its ease of manufacturing and thermal properties. However, adobe has significant disadvantages as well, such as physical degradation against environmental factors, reduction in indoor air quality and low earthquake resistance. A significant part of Türkiye's surface area is under earthquake risk. Therefore, developing practices for the use of earthquake-resistant adobe will be beneficial for both the sustainability of rural areas and the improvement of the earthquake resistance of settlements.

2. SUSTAINABLE and EARTQUAKE RESILIENT SETTLEMENTS

The high building density and illegal construction resulting from rapid urbanization create significant problems, especially in regions with high earthquake risk, and thus must be prevented. Migration from rural areas should also be prevented for economic, touristic, and social reasons. Measures should be taken to ensure rural sustainability.
Various practices can be used to ensure rural sustainability. Strengthening the connection between urban and rural areas and highlighting the advantageous features of rural areas are among the most effective practices in preventing migration. Strengthening the transportation link between rural and urban areas is also an effective measure to prevent residents working in urban areas from abandoning the rural region. Emphasizing the strengths of the region in agriculture and animal husbandry is another important factor which supports economic development. This approach can also improve tourism activities related to agriculture and animal husbandry in rural areas. The activities of entrepreneurs with significant connections in major cities can also be effective in this context.
Preserving and maintaining sustainable construction techniques in rural areas is also effective in the preservation of the region's authenticity and urban fabric. Preserving the cultural heritage by taking advantage of traditional construction techniques also enhance the tourism potential and prevent migration. The preservation of traditional constrıction techniques plays an active role in supporting sustainability practices and reducing threats related to global warming. Instead of modern building materials and construction techniques that require high energy consumption, the use of low-energy-consuming materials with low carbon emissions is an important step in constructing sustainable settlements.

3. USING ADOBE in ENSURING RURAL SUSTAINABILITY

One of the most important objectives in the urbanization practices of the modern world is to ensure sustainability. The primary requirement within this scope is the preservation of the population in urban and rural areas. The idea of preserving traditional construction techniques emerges as a significant factor in controlling population growth in cities and preventing the depopulation of rural areas.
Although there are many different traditional techniques used in construction worldwide, the most common one is adobe. Despite its broad use since prehistoric times, adobe has been mostly abandoned in urban areas nowadays. However, it is also mentioned that approximately 30% of the world's population, especially in

rural areas, lived in adobe structures by the end of the twentieth century. Earth-based materials are still widely used in construction in many parts of the world as shown in Figure 1 [1].

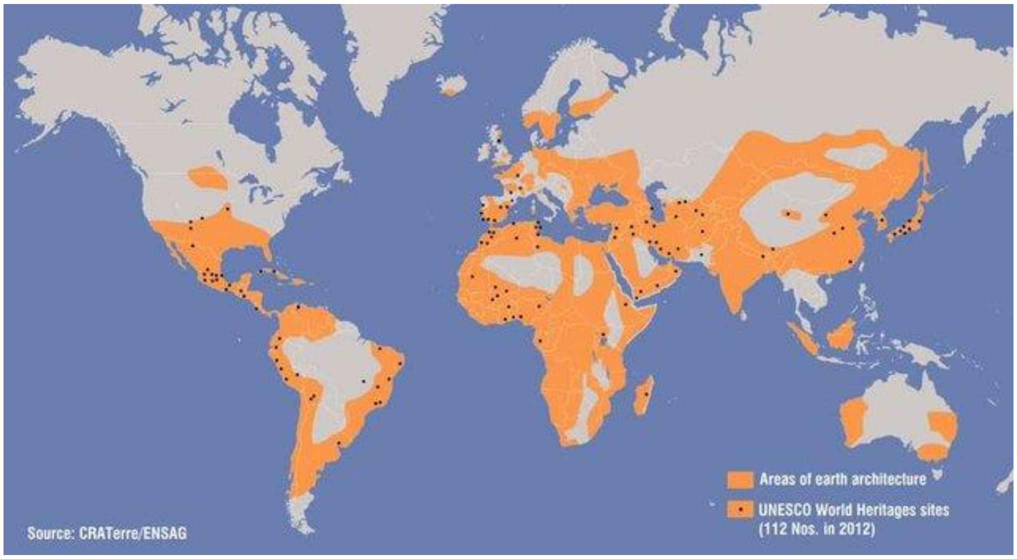

Figure 1. The worldwide use of earth-based construction [2]

Despite its many advantages, adobe also has some significant disadvantages. The advantageous properties of the material should be highlighted, while measures should be taken to mitigate its disadvantages in urban planning practices which aim achieving rural sustainability. In this context, adopting practices to modernize the material is also important.

3.1. Earthen Construction and Properties of Adobe

Adobe is being used in two different ways in today's world. The first is traditional and local use of the material. In traditional use, the material is utilized as it has been learned over centuries. This method is common in developing countries [1].

The second use combines traditional and modern construction techniques for adobe manufacturing. The second practice is mainly carried out within the scope of sustainability and include the practices of developed countries [1].

Earth-based materials are usually produced with a mixture which contain clay, silt, sand, and sometimes larger aggregates. Fibres and stabilizers (such as cement or lime) may occasionally be added to this mixture to improve the properties of the material. The manufacturing process of the material can be seen in Figure 2. [1, 3, 4].

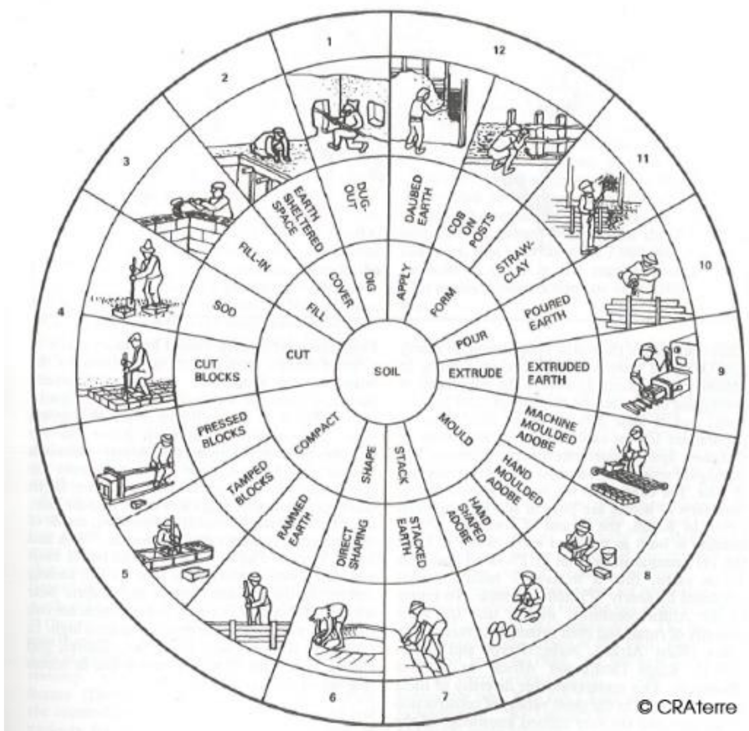

Figure 2. Techniques of earth-based building materials [5]

Earth-based materials are being used in different types in construction. Accordingly, they can be used in structures as rammed earth, adobe, cob, and compressed earth block. In rammed earth, the material is compacted and single-piece structural elements are manufactured. In adobe, the mixture is moulded and dried under the sun to create prismatic blocks. In cob, a clay mixture is mixed with a significant amount of straw and often applied by hand to form monolithic structural elements. Compressed earth block (CEB) is a new method where mechanical methods are used to compress the material, and lime and cement are added to strengthen the mixture [3, 6].

There are many advantages that make adobe a frequently preferred material in construction. The most important advantages include the abundant availability of raw materials, ease of manufacturing, economic feasibility, local availability, recyclability, good thermal properties, acoustic insulation, and fire resistance [1, 3, 7, 8].

Modern building materials which are predominantly used in the construction industry is responsible for 23-40% of global greenhouse gas emissions in the world and a significant portion of countries' total energy consumption. Besides, adobe has the advantage of causing much lower greenhouse gas emissions [7, 8].

In addition to these advantages, adobe has some disadvantages as well. One of the main disadvantages of adobe construction is the thickness of the walls. Thick walls reduce the efficient useful area in the structure. Additionally, as adobe is produced without any chemical changes (without being fired), it is a material with low resistance to environmental factors. Temperature changes, precipitation, wind, and other atmospheric elements cause mass loss in adobe. Mass losses in the material affect both its strength values and the indoor air quality. Another disadvantage is about the material's thermal properties. When adobe gets wet due to atmospheric factors, its thermal conductivity coefficient increases. Therefore, while the thermal performance of the material is better during the dry summer season (meaning no additional cooling is needed indoors), its thermal performance decreases during the humid winter season, increasing heating costs indoors [1, 7].

The most significant disadvantage of adobe is its structural behaviour during earthquakes. Adobe is a building material with low earthquake resistance, low tensile strength, and brittle structure. Therefore, adobe buildings experience brittle fractures under earthquake effects, can suffer severe structural damage, and may collapse, causing loss of life and property [1, 9].

There is a growing interest in earthen construction in recent years, advanced research and applications are being carried out in some developed countries. However, earthen construction is often inhabited by rural communities from low-income groups. These structures are mostly built by non-specialized staff using empirical knowledge without proper methods. In Türkiye, where 99% of the land area is at risk of earthquakes, adobe is still the most preferred construction material in rural areas. The use of insufficiently produced adobe construction in rural areas and the abandonment of them for different reasons decrease the seismic resistance of those regions and prevent the rural sustainability.

The authenticity and existing urban texture of rural regions should be preserved to ensure rural sustainability. Adobe structures, which have cultural heritage value should be protected, the proper production and maintenance of adobe structures should be supported. For this purpose, researches should be carried out to improve the seismic behaviour of adobe structures, codes related to mitigate the seismic risk should be developed and implemented.

3.2. Improving the Seismic Response of Adobe

Adobe, produced by non-specialized staff using locally available soil, result with highly variable compositions and mechanical properties. The properties of adobe are directly dependent on the properties of the soil as there is not a quality control mechanism during the production stage. This variability affects the material's strength. Experiments on adobe specimens with similar strength values have shown a 300% difference in shear strength. Various factors, such as granulometric distribution, volumetric drying crack values, and density, influence the strength values of the material [1].

Adobe walls have low tensile strength and a brittle nature, leading to poor structural performance during earthquakes. The typical damage observed in adobe constructions include:

- diagonal in-plane cracks,
- cracks near openings,
- vertical cracking at intersection points,
- seperation of walls at corners,
- out-of-plane damage or collapse in gable-end and other walls,
- seperation between roof and walls [1].

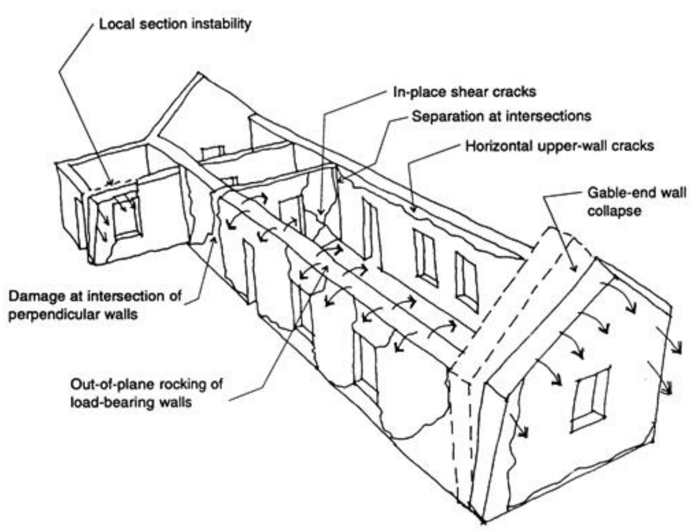

Figure 3. Failure mechanism of adobe [1]

The most prevalent damage in adobe structures during earthquakes is out-of-plane movement following vertical cracks at wall intersections. After the walls are damaged and collapse, the roof loses its support and may also collapse (Figure 4). Cities such as El Salvador, Bam, Pisco, Maule, and Gorkha have suffered severe damage due to the earthquake sensitivity of adobe [1].

Figure 4. Failure of roof due to out-of-plane wall collapse [9]

The earthquake resistance of adobe structures can be increased by retrofitting the structure before or after an earthquake, or by constructing new earthquake-resistant adobe buildings. The improvement process should include the soil properties of the construction site, the features of the other building materials which will be used together with adobe in the construction and the function of the structure [1].
In the improvement process of adobe structures the following aspects are emphasized:

- ***Improvement of strength:*** This approach focuses on the geometry of the structure, including wall thickness and the number of walls.
- ***Improvement of stability:*** It focuses on the strength of the connections such as wall-to-wall, wall-to-floor, and wall-to-roof connections.
- ***Improvement of structural behaviour:*** This approach focuses on the application of specific strengthening techniques. This include tying walls that are likely to crack, reinforcing wall-roof connections, controlling the displacement of structural elements and using high tensile strength materials to prevent partial and total collapses [1].

Although adobe is still being produced by using traditional and empirical methods, there are numerous researches which have been carried out in order to mitigate the risks of the material. Initial improvements started at 1970's. The researches focused on strengthening adobe by using materials such as wood, wire, and bamboo. In the following years, light and thin materials like metal, synthetic, and wood-based (bamboo, reed, etc.) meshes were added (Figure 5) to wall surfaces to prevent brittle fractures. These meshes were applied horizontally and vertically. In some cases, wooden posts were added to the corners of the walls to increase the stability. Other applications to increase wall strength include adding centre-core rods, bond beams, and ring beams [1, 10].

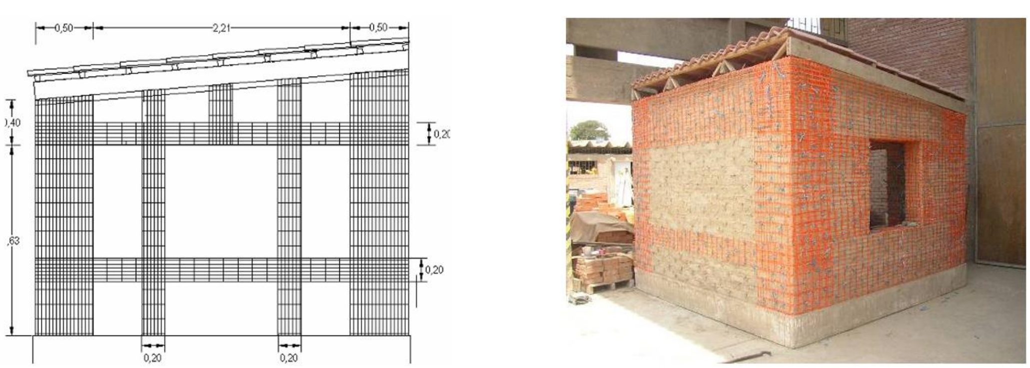

Figure 5. Reinforcement with polymer mesh [11]

There are also repair methods for adobe buildings which are damaged during the earthquakes. Hydraulic lime gum injection used for repairing cracks is mentioned as a highly effective solution. The repairment application for small openings includes filling the crack with liquid mortar. However, the existing mortar should be completely removed and should be refilled with new mortar for large openings [1].

Global research on strengthening and repair techniques has proved that the improvement applications yield successful results when they are used together. The main purposes of these applications are:

- to prevent sudden collapse of previously damaged structures during new earthquakes,
- to increase the tensile strength of newly constructed buildings and prevent out-of-plane deformation,
- to use affordable and easily available materials for adobe structures.

4. CONCLUSION

It is necessary to highlight the region's advantageous features such as agriculture and animal husbandry, enhance its tourism potential, and preserve its authentic character to ensure rural sustainability. Another crucial goal is to increase earthquake resistance in contemporary urban planning practices. Consequently, in the context of our country, preserving adobe structures in rural areas and making them earthquake-resistant is a significant objective.

Important research has been conducted worldwide for the improvement of the seismic resistance of adobe structures. During the improvement process it is essential to initially repair and then strengthen adobe buildings that have been damaged in previous earthquakes. Repair mortars are predominantly used for this purpose. Hydraulic lime gum is one of the most effective material for repair purposes.

Affordable and easily available materials that are suitable for the profile of the local population should be used for strengthening purposes. Frequently used materials include metal, synthetic, and wood-based (bamboo, reed, etc.) meshes applied horizontally or vertically, wooden posts added to wall corners, and centre core rods, bond beams, and ring beams integrated into the walls.

Research demonstrates that the simple repair and strengthening applications give highly effective results when they are used together. Proper implementation of these techniques not only helps to save lives but also contributes to the construction of sustainable cities.

5. REFERENCES

[1] Vargas-Neumann, J., Oliveira, C., Silveira, D., & Varum, H. (2018). Seismic Retrofit of Adobe Constructions. *Strengthening and retrofitting of existing structures*, 85-111.

[2] Vyncke, J., Kupers, L., & Denies, N. (2018). Earth as Building Material–an overview of RILEM activities and recent Innovations in Geotechnics. In *MATEC web of conferences* (Vol. 149, p. 02001). EDP Sciences.

[3] Niroumand, H., Zain, M. F. M., & Jamil, M. (2013). Various types of earth buildings. *Procedia-Social and Behavioural Sciences*, *89*, 226-230.

[4] Fernandes, M. (2013). Adobe architecture in Portugal: Differences and analogies between vernacular and 'designed' architecture. *Vernacular Heritage and Earthen Architecture*, 111-116.

[5] CRATerre (Carnet de Recherche Craterre), *La Roue des Techniques.* Access date (23.06.2024). https://craterre.hypotheses.org/3917

[6] Costa, C., Cerqueira, Â., Rocha, F., & Velosa, A. (2018). The sustainability of adobe construction: past to future. *International Journal of Architectural Heritage*.

[7] Obafemi, A. O., & Kurt, S. (2016). Environmental impacts of adobe as a building material: The north Cyprus traditional building case. *Case Studies in Construction Materials*, *4*, 32-41.

[8] Illampas, R., Ioannou, I., & Charmpis, D. C. (2009). Adobe: an environmentally friendly construction material. *WIT Transactions on Ecology and the Environment*, *120*, 245-256.

[9] Rafi, M. M., & Varum, H. (2017). Seismic performance of adobe construction. *Sustainable and Resilient Infrastructure*, *2*(1), 8-21.
[10] Tarque, N., Blondet, M., Vargas-Neumann, J., & Yallico-Luque, R. (2022). Rope mesh as a seismic reinforcement for two-storey adobe buildings. *Bulletin of Earthquake Engineering*, *20*(8), 3863-3888.
[11] Blondet, M., Torrealva, D., Vargas, J., Velasquez, J., & Tarque, N. (2006, September). Seismic reinforcement of adobe houses using external polymer mesh. In *First European Conference on Earthquake Engineering and Seismology*. *Geneva, Switzerland*.

Adobe in Iranian Architecture: Examining the Use of Earth-Based Materials in Tabriz's Traditional Dwellings for Climate Responsiveness

Masoumeh KHANZADEH

Nuh Naci Yazgan University, Department of Interior Architecture and Environmental Design

mkhanzadeh@nny.edu.tr

Abstract
In Iranian architecture, adobe functions as a fundamental material, akin to how bricks (terracotta) are used in modern construction, offering both structural stability and aesthetic richness through its traditional and contemporary applications. In the craft of bricks, discriminating architects have developed elaborately beautiful and long-lasting patterns that are still a treasured heritage of architectural arts today. These patterns and designs, rich in movement and artistic techniques, offer numerous options for modern building facades. This shift is deeply rooted in the evolution of Iran's distinctive architectural culture.
This research examines the production techniques and varieties of bricks and their decorative applications in Islamic architecture in Iran. The study uses qualitative descriptive methods and content analysis, drawing on library research, field observations, material investigations, and traditional building materials' creative approaches. Furthermore, it incorporates empirical insights from both theoretical and practical fields, particularly from the teachings of past masters, to collect data and elucidate the aesthetic principles of Iranian Islamic architecture related to brickwork decoration, aiming to enhance the understanding of the physical and decorative aspects of Islamic Iran's architectural heritage. In recent years, the ornamental role of bricks, whether bricks, plaques, or bricks, has become more vibrant in Iranian architecture. It is usually known as postmodern architecture. In this essay, we first analyze the nature of postmodern architecture and postmodern ideas, followed by a brief history of bricks in Iranian architecture and an examination of modern features' utility.
Keywords: Terracotta bricks, Islamic architecture, contemporary architecture, architectural decoration, and postmodernism.

Definition
The name Tabriz is thought to be derived from the Persian terms tab (meaning "fever") and riz (meaning "shedding"), resulting in "Tabriz" or "fever-shedding." The origin of this term may be traced back to 791, when Zubayda Hatun, wife of Abbasid Caliph Harun al-Rashid, recovered from an illness by swimming in Tabriz's hot springs. The city's precise founding date is uncertain, although archeological evidence implies a 5,000-year existence. Tabriz, formerly known as Gazaca and subsequently as Atropatene's capital, came to prominence under numerous rulers, notably the Seljuks and Atabegs, and is known as "the Mother of Azerbaijan" due to its large Turkish population. This research looks at Tabriz's architectural legacy and Turkish cultural influences from the early Seljuk era (11th century) until the end of the Qajar dynasty(1925).

Figure 1. Şarden's illustration of Tabriz (Tabriz Ministry of Culture and Tourism, Tabriz, 2003)

Geography and Architecture

Tabriz is surrounded by the Sahand Mountains to the south and the Eynali Mountains to the northeast.The Mehranrud River runs through the city center, while the Aji Chay River flows from the north and northw est to Lake Urmia.Travelers, historians, and older locals remember Tabriz as a developed city with beautiful vineyards. Due to the colder environment, a specific architectural style emerges. Buildings face inward, having central courtyards that serve as a focal point for other rooms. The southern side of the structure is rarely used, whereas the main design emphasizes the northern side. Because of the chilly weather, everyday activities are carried out indoors, resulting in a smaller courtyard than other places. The city plan is more compact, reducing the impact of chilly winds.

Tabriz's architecture integrates a strong historical legacy with contemporary development. The city's prominent buildings, like as the Blue Mosque and Grand Bazaar, have traditional elements such as vaulted ceilings, elaborate tile work, and arches, demonstrating centuries of brick and ceramic skill. The city's layout blends ancient structures with new neighborhoods such as Parvaz and Golshahr, where modern skyscrapers contrast with older mud brick and stone structures. Public places like Shah Goli Park combine modern design with traditional Iranian garden aesthetics. Tabriz's urban growth honors its architectural heritage while balancing preservation with modern infrastructure and development.

Purpose of the Study

The research goal for this study is to investigate the climate-responsive characteristics of adobe in Tabriz's traditional building, which has a unique and demanding environment. Adobe, an earth-based substance with inherent insulating characteristics, is frequently employed in Iranian architecture due to its thermal efficacy and durability. Adobe construction has played an important role in controlling internal temperatures and increasing comfort in Tabriz's traditional homes, even in the face of severe weather. However, as technology changes construction practices away from traditional techniques, there is an urgent need to investigate and document the usefulness of adobe in Tabriz's climate. This study will examine how adobe was historically used to build sustainable, climate-responsive dwellings, providing ideas for modern design that attempts to reconcile cultural legacy with environmental adaptation. The goal of this study is to look at the usage of earth-based materials, notably adobe, in Tabriz's traditional buildings and evaluate their usefulness in solving the region's climate concerns. Adobe, noted for its thermal insulation and capacity to adjust inside temperatures, has long been used in Tabriz architecture as a natural answer to harsh weather, notably cold winters and scorching summers. This study aims to better understand how historic construction methods supported sustainable, comfortable living conditions by examining the architectural strategies and material features that allow adobe to manage interior climate. The findings are intended to give useful insights for current architectural practices, encouraging climate-responsive, eco-friendly solutions that respect cultural heritage.

Significance of the Study

The relevance of this work stems from its ability to further our understanding of sustainable design and vernacular construction methods in dry regions, with an emphasis on Tabriz's historic adobe structures. Adobe, a material long chosen for its local availability, thermal efficiency, and minimal environmental impact, is a prime example of how indigenous design can efficiently adjust to climate change while reducing resource use. By investigating adobe's specialized uses in Tabriz's traditional buildings, this research not only shows the material's virtues, but also provides insights into the construction processes and design tactics used by local builders to maintain comfort in a harsh climate. These vernacular solutions have stood the test of time, demonstrating concepts that current sustainable architecture frequently strives to emulate. The study's documentation and analysis of these practices contributes to broader discussions about adapting ancient building methods to contemporary contexts, particularly as architects and urban planners strive to create energy-efficient, environmentally responsible buildings in arid and semi-arid regions around the world. Finally, this study emphasizes the importance of traditional knowledge systems in sustainable development, proposing for an architectural approach that values cultural heritage while achieving current sustainability requirements.

Brickwork's Timeless Legacy

Throughout Iranian architectural history, the use of brick as a key construction material has undergone significant evolution in terms of structure, form, and size. This remarkable element of Iranian architecture reached its pinnacle of development over time, becoming a cornerstone of architectural practices across all eras. In Iranian architecture, brick serves not only as a filler material but also as a structural element, demonstrating its dual functionality (Racabi, 2001). The Chogha Zanbil ziggurat exhibits two construction phases: the first features ground-floor rooms surrounding a central courtyard, while the second incorporates upper-floor volumes built around the courtyard. Buildings in the city were constructed primarily with mudbrick and fired brick, the latter often used as a protective layer against environmental conditions. Remarkably, many structures have endured the test of time with minimal damage. Architectural techniques included the use of glazed bricks, natural bitumen mortar, glass decorations, and plaster coatings. Excavations have also revealed clay cow statues believed to have been placed at temple entrances as protective symbols.

Among these, the Seljuk period stands out as a golden age for brickwork, marked by an unprecedented level of creativity and artistry. During this time, Seljuk architects showcased their mastery by crafting unparalleled architectural masterpieces through intricate brickwork techniques. Brick became a versatile material, used in various architectural elements, including walls, facades, domes, arches, and minarets, exemplifying the era's ingenuity. The enduring beauty of Seljuk-era structures is a testament to the era's advanced brickwork artistry.

Figure 2. The historical monument of Robat Sharaf (Abgineh) is the most luxurious residence of the Seljuk period, located on the edge of the Silk Road.(Esfahan Ministry of Culture and Tourism, Esfahan, 2000)

The primary aim of studying Seljuk brickwork is to explore the craftsmanship and innovative techniques that defined this period. The Seljuk Empire's political stability and prosperity provided fertile ground for architectural advancements, fostering the growth and refinement of brick-based construction. This study examines the interplay between the political context of the Seljuk era and the flourishing of architectural art forms, particularly brickwork. By understanding these dynamics, the research sheds light on how the Seljuks' centralized governance and cultural policies influenced the aesthetic and functional aspects of architecture, culminating in some of the most iconic structures in Iranian history.

Furthermore, analyzing Seljuk brickwork offers insights into the evolutionary journey of this architectural technique and its profound impact on Iranian architecture. The Seljuk period not only refined traditional methods but also introduced innovative applications of brick, paving the way for its extensive use in various architectural components. By documenting these advancements, this research highlights the enduring legacy of Seljuk brickwork, emphasizing its role in shaping architectural practices and inspiring future generations of architects. This exploration contributes to a broader understanding of the Seljuk Empire's cultural and artistic heritage, cementing its place as a transformative period in Iranian architectural history.

Figure 3. The grand porch of Tabriz Blue Mosque, showcasing intricate and unique brickwork. (Tabriz Ministry of Culture and Tourism, Tabriz, 2003)

Brick has been a staple of Iranian construction for millennia, prized for its durability, versatility, and aesthetic appeal. Its resilience to external forces such as earthquakes, as well as its capacity to manage temperature in Iran's each climate, making it an attractive option for construction. Beyond necessity, brick has been used as an artistic medium, with complex designs and decoration demonstrating Iranian builders' craftsmanship. Brick has been used to build walls, domes, minarets, and courtyards from antiquity to the present day, with famous examples such as muqarnas and geometric patterns characterizing Persian architecture. The material's affordability, thermal qualities, recyclability, and environmental sustainability add to its significance in both historical and contemporary architecture, combining tradition and innovation while retaining a symbol of cultural identity and workmanship.

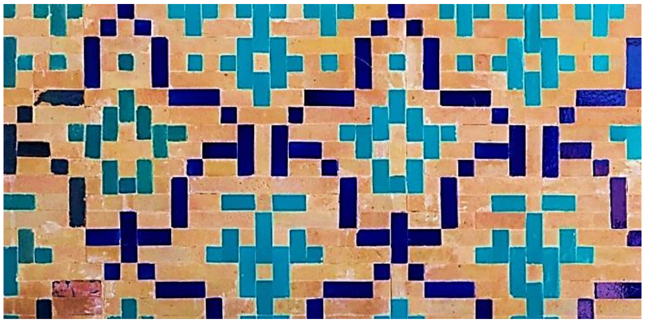

Figure 4. Iranian brickwork of the Moqgali type with a floral design

Results and Discussion

Bricks play an important part in architectural design in cold areas because of their thermal bulk, durability, and energy efficiency. Bricks can absorb, store, and gradually release heat, which helps to manage indoor temperatures. Bricks absorb heat from sunlight and warmth generated within the house during the day, then release this stored heat at night, minimizing the need for ongoing heating. This thermal buffering effect contributes to a steady indoor climate, making buildings more energy efficient and comfortable under cold situations.

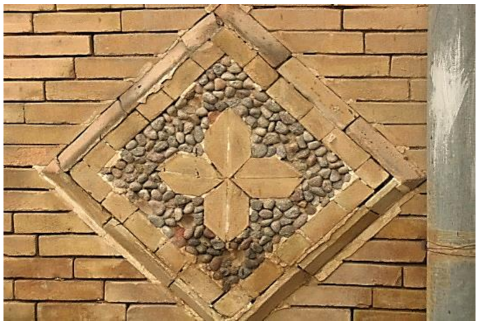

Figure 5. Gogani House and brickwork

Bricks are also particularly resistant to the harsh weather conditions common in cold climates, such as snow, frost, and freeze/thaw cycles. Their endurance guarantees that structures can endure the stress of freezing and thawing, which can destroy other materials over time. Bricks' density also makes them a good wind barrier, reducing heat loss and enhancing insulation.

Figure 6. Gogani House and brickwork (author, Tabriz, 2010)

In cold climates, brick can be utilized to produce visually appealing façades, courtyards, and interiors, in addition to its functional applications. Its adaptability allows it to be shaped into elaborate designs, enhancing both functionality and beauty in constructions. Overall, bricks help to increase the lifetime and energy efficiency of buildings in cold areas, making them a crucial material for sustainable and resilient construction.

Figure 7. Pool room and ceiling decorations of Heyderzadeh House (author, Tabriz, 2010)

The architectural identity of Tabriz is greatly influenced by Adobe, which also shapes the aesthetic and cultural values of the city. Adobe is not only a useful building material in traditional Tabriz homes, but it is also a fundamental component of the local architectural style. These homes' natural texture and character are defined by adobe, thick earth walls, graceful arches, and elaborate embellishments. The inhabitants of Tabriz have been able to establish a sustainable building culture that maintains their cultural history while continuing to be economically viable thanks to the local availability of adobe. Adobe buildings display Tabriz's distinctive architectural style while also symbolizing the area's rich history and environmentally conscious way of life. These structures show how natural materials and regional identity are entwined, demonstrating how Tabriz's architecture reflects the local way of life.

Conclusion

In Tabriz, adobe has been a fundamental building material, deeply embedded in the region's architectural heritage. Known for its practical and aesthetic qualities, adobe has shaped the city's traditional and modern urban landscape, especially in older districts and residential structures. The role of adobe in Tabriz's architecture can be explored through several key dimensions:

Figure 8. Bulurchiyan House(author, Tabriz, 2010)

Climate Adaptation: Tabriz is located in a cold climate zone, which presents unique challenges for residential construction. Adobe's natural thermal properties make it an excellent material for such environments. With its high thermal mass, adobe absorbs heat from the sun during the day, and slowly releases it during the colder night hours. This ability to regulate temperature naturally reduces the reliance on heating systems, maintaining a warm and consistent indoor environment during the harsh winter months. The thermal efficiency of adobe also helps keep interiors cool in summer, contributing to the comfort of Tabriz's residents year-round. As such, adobe has long been a practical and sustainable choice for homes in the region, mitigating the extremes of the local climate.

Figure 9. Genceyizadeh (Yung Brother)House(author, Tabriz, 2010)

Cultural and Aesthetic Value: Adobe's earthy and natural appearance makes it an ideal material for blending with the landscape of Tabriz, which is characterized by its proximity to the Sahand mountains. The color and texture of adobe complement the surrounding natural environment, creating a harmonious relationship between built structures and the landscape. This aesthetic value is particularly evident in the historic districts of Tabriz, where adobe is used to create intricate facades, courtyards, and interior spaces that reflect the city's rich cultural heritage. Traditional adobe homes in Tabriz often feature ornamental details and craftsmanship, such as carved wooden doors, ornamental brickwork, and decorative arches, showcasing the material's versatility in achieving both beauty and function.

Figure 10. Ganceyizadeh(Old Brother) (author, Tabriz, 2010)

Sustainability and Eco-friendliness: One of the key benefits of adobe is its sustainability. Made from locally sourced materials such as clay, straw, and water, adobe has a minimal environmental footprint compared to more industrialized building materials. The production process of adobe requires little energy and does not produce harmful emissions, making it an environmentally friendly option for construction. In Tabriz, where the natural resources for adobe are readily available, this sustainable material has been used for centuries, reflecting a tradition of eco-conscious construction practices. The widespread use of adobe aligns with the region's long-standing values of resource conservation and respect for the environment, long before modern sustainability practices became a global concern.
Structural and Seismic Considerations: While adobe is an ideal material for regulating temperature, it does have certain structural limitations, particularly in earthquake-prone areas like Tabriz. Adobe walls, if not properly reinforced, can crack or collapse during seismic activity. However, traditional building methods in Tabriz have adapted to these challenges. Adobe structures were often reinforced with wooden beams, known locally as "chahar-sou," which provided additional support and flexibility, allowing the buildings to absorb and dissipate seismic energy. This hybrid approach of combining adobe with timber framing helped improve the earthquake resistance of traditional homes in Tabriz, ensuring their survival in a region with a history of seismic activity. Moreover, thick adobe walls contributed to the overall structural integrity of homes, adding to the durability of buildings in the region.

Figure 11. Fakher House (author, Tabriz, 2010)

Symbolism and Social Function: Beyond its practical qualities, adobe has symbolic value in Iranian architecture, representing a connection to the land and a deep cultural significance. In Tabriz, adobe walls were not only structural elements but also cultural symbols. Adobe construction often marked the distinction between private and public spaces within traditional homes. Thick adobe walls provided privacy, which was crucial in Iranian society, where family life and social interactions were traditionally separated by gender and function. The use of adobe in the construction of courtyards, rooms, and living spaces helped maintain this division of space, supporting the social and cultural norms of the time. Additionally, adobe's use in the region reflects a lifestyle rooted in simplicity, sustainability, and a deep respect for nature, qualities that have been central to Tabriz's cultural identity.

Figure 12. Galichi House (author, Tabriz, 2010)

Cost-effectiveness: One of the key reasons adobe became the material of choice for construction in Tabriz is its affordability. Adobe is a low-cost material, easily accessible and requiring minimal financial investment compared to other building materials like brick or stone. This made it an ideal choice for a wide range of socioeconomic groups, from rural farmers to urban dwellers. The ease of construction also contributed to its widespread use, as adobe homes could be built with limited resources and labor. In Tabriz, adobe homes were not limited to rural or lower-income areas; even large, elaborate homes for the wealthy were constructed using adobe, demonstrating the material's versatility and cost-effectiveness across different social classes.

Integration with Modern Architecture: Despite the development of more contemporary building materials, adobe still plays a role in Tabriz's modern architecture. In some cases, newer buildings incorporate adobe alongside materials like concrete, brick, and steel to blend modern design with traditional craftsmanship. In addition, there is growing interest in revitalizing and preserving adobe architecture as a part of Tabriz's cultural heritage, with some historic adobe buildings being restored to maintain the city's architectural diversity. These efforts not only celebrate the city's architectural past but also promote the use of sustainable materials in modern construction.

In conclusion, adobe is a vital and integral material in Tabriz's architectural history and continues to influence the city's building practices. Its adaptability to climate, aesthetic appeal, sustainability, and cost-effectiveness make it an enduring part of the region's architectural identity. Whether in traditional houses, courtyards, or modern buildings, adobe's influence on Tabriz's urban landscape remains strong, providing a tangible connection to the city's past while offering practical solutions

References

Badr, K. (1390). *Civilization of the Achaemenid Empire* (2nd ed.). Tehran, Iran: Badr System Publishing.

Falāmaki, M. (n.d.). *Revisiting an Environmental Link: Physical Space and Living Space*. Tehran, Iran: Unknown Publisher.

Gheiasabadi, M. R. (1390). *What is Iran? An Investigation into the Name of the Aryans and Persia*. Tehran, Iran: Navid Publishing.

Habibi, M. (1366). Conceptual and Mental Images of Place. *Journal of Fine Arts*, University of Tehran, 35, 55–61. Tehran, Iran.

Hasani, M. (1386). *Conceptual and Mental Images of Place*. Tehran, Iran: Fine Arts Publishing.

Hashemian, F., Etemad, J., & Haeri, M. (1362). *Urbanization in Iran* (1st ed.). Tehran, Iran: Aghah Publishing.

Kazalbash, A. (n.d.). *The Alphabet of Traditional Houses in Yazd*. Tehran, Iran: Unknown Publisher.

Mashhadi Nejad, A. (1371). *Analysis and Features of Planning in Iran* (3rd ed.). Tehran, Iran: Iran University of Science and Technology Press.

Mousavi, E. A. (1382). Tabriz under the Seljuk Rule. *Journal of Oriental Studies*, 4(13), Tehran, Iran.
Nehzadeh Ahmadi, H. (1388). *Essence of Architecture*. Isfahan, Iran: Khak Publishing.
Pirnia, M. (1373). *Islamic Architecture of Iran*. Tehran, Iran: Iran University of Science and Technology Press.
Pop, A. (1369). *Architecture of Iran* (2nd ed., Vol. 2). Tehran, Iran: Jahannaghsh Publishing.
Racabi, P. (2001, 2004). *Lost Millennia: The Achaemenids as Narrated* (Vol. 2).
Tofan, M. (1384). Recognizing the Role of Water in the Life of Traditional Iranian Houses. *Bāgh-e Nazar Journal*, 3(6). Tehran, Iran.
Umō Zineddini, M. (1382). Tabriz during the Seljuk Dynasty. *Journal of Oriental Studies*, 4(13), Tehran, Iran.

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The Tale of an Adobe House: Memories Through the Language of Objects

Melike Şerbet

Nuh Naci Yazgan University, Faculty of Fine Arts and Design,
Department of Interior Architecture and Environmental Design

milayk1903@gmail.com

ABSTRACT

The focus of the research is the house where I was born and lived until I was seven years old. This house does not have a documented narrative. It is known to have stood for approximately 60 years in the Lüleburgaz district of Kırklareli. The house consists of two separate dwellings where an extended family shares a common courtyard, with both immediate family members and relatives living independently. In this context, although the term "group of dwellings" might be more appropriate, I consciously use the term "house." Moreover, despite each household having different domestic scenarios, the presence of everyday household objects tends to connect the stories of these two households.

In the research, only the narrative of the adobe house is addressed. This adobe house, where my paternal grandmother, grandfather, and uncle lived, and where I witnessed domestic rituals, is examined in the context of its interior and the everyday household objects that constitute the home. I convey my personal testimonies of the home, which no longer exists today, through an autoethnographic writing experience in my own voice. By utilizing illustrations, I aim to employ autobiographical material in this context and contribute to the research methodology while revitalizing the adobe house. The adoption of methods that reference personal narratives in place-oriented research in recent years offers an opportunity to evaluate how the subject is approached in writing an alternative spatial history.

Keywords: Autoethnography, adobe house, interior space, everyday objects, illustration.

*The full text of this paper has been derived from topics currently being explored in my ongoing doctoral thesis.

1. INTRODUCTION

> *Okula gitmek için evden çıkmıştım. Kafa kulaklığım takılı, muhtemelen çalan şarkı, Rocoberry'den Goodbye, fall (o sıralar malum şarkıya takılmış durumdayım). Çisentili bir yağmur vardı ve henüz irileşmemiş yağmur damlaları kulaklığımı ıslatıyordu; ama benim umrumda değil. Sonrasında bedenim hiç tanımadığı bir hale büründü; peş peşe birçok duygu ve düşünce aynı anda bedenime hücum etmiş gibiydi. El ayak titremesi, kafa bulanıklığı derken ağlamaklı bir hal ve peşi sıra gelen bir huşu hali. Ne oldu ki o sıra… Yaşadığım şehirle tokalaşırken buldum kendimi, ama bu bir veda değil tabi. Yeni tanıştığım birinin elini sıkar gibiydi biraz. Bu şehri ve yaşadığım evi aldım, kabul*

> *ettim gibi bir rıza durumu; ancak yine de kararsız kalmış bir kabul. Anlık gelen bu duygulanımın biraz daha devam etmesi arzusundayım ki asfalt yoldan mıcırlı bozuk zemine geçişimde nasıl sendelediğimi ayaklarım şimdi hatırlıyor. Buluşma noktasında okul servisini bekleyen mesai arkadaşlarımla nezaketen selamlaştım ama nafile… Aklım, kendimde ve olup bitende. Kürdan gibi cılız boynumun taşıdığı 33 yıllık ağırlığı evvela göğe kaldırıp bulutların dolaştığı yere doğrulttum, güneşi selamlayan gündöndüler misali. Yağmur bu sefer yüzümü ıslattı, burnum toprak kokusunu aradı hemen, ama yerden biten beton blokların arasında ne arasın. Uyanmak istemediğim bir rüyada gibiydim, kafası gereksiz meselelerle dolu benim gibilerine nadir uğrar böyle anlar. Bambaşka bir bilinç haliydi. Şoför gelince servise bindim tabi, bende bir müddet –ki evden okula mesafe, yaklaşık 5 dakika- devam etti bu şuurlu şuursuzluk hali (April 27, 2023).*

So, what is this *personal narrative* doing here? In fact, this passage, in which we witness a moment of epiphany[20], is essentially woven with informative codes that point to person's search for her/his home on the earth; it is none other than the person in this story who is trying to discover and shape "that first shelter that she/he always carries in the depths of her/his own meaning" [1], (pp. 4).

In my research, I start with the story of the house where I spent my childhood until the age of 7. I also incorporate the household rituals I witnessed when visiting my elder family members in adulthood after we moved from that house. The theoretical framework of the research is defined through the statement "personal testimonies turning into spatial knowledge sources" [2], (pp. 52). Additionally, recent years have seen the emergence of spatial research methodologies such as oral history, autobiography, and autoethnography, creating a research field where different disciplines collaborate [2], (Bektaş Ata, 2021; Bahloul, 1996; Marcus, 1994; Skeggs, 1995; as cited in Aykaç, 2022). Drawing inspiration from this, I construct the research text using the possibilities of autoethnography and complement it with my own hand-drawn illustrations. I approach autoethnography based on the principle of doing and writing research, essentially performing it, guided solely by my personal experiences.

2. POSSIBILITIES OF AUTOETHNOGRAPHY

Autoethnography is recognized as an intriguing and hopeful qualitative research method. It challenges the dominance of traditional social sciences and research paradigms, legitimizing diverse ways of knowing and questioning, rooted in postmodern philosophies that emphasize listening to the researcher's personal experience to understand culture [3]. It creates an experience of conducting research and writing that inherently speaks from "within". Many of my readings on autoethnography emphasize learning multiple paths of inquiry and knowledge production (self-narrative), structuring the research text systematically, and most critically, providing optimal tools for "writing." "Autoethnography is an approach to *research* and *writing* that seeks to *describe* and *systematically analyze personal experience* in order to understand cultural experience." [4], (pp. 273, italics added). In autoethnographic studies, topics considered taboo in society, human stories, and even the representation and transmission of these stories become visible and gain legitimacy [5]. Additionally, ethnographic and autoethnographic texts, while a form of personal narrative, go beyond storytelling within these research traditions. They rely on evidence-based scientific and justifiable interpretations. Methods used include participant observation, reflective writing experiences, interviews, and document collection for data gathering. As a result, the resulting texts are not solely

[20] I preferred to write the personal narrative in my native language for the example of epiphany because I think and communicate in my own language.

composed of the researcher's own views; these views are also supported by data that can substantiate them [6].

I will explore what autoethnography is, how it structures and conducts research writing, and how I will continue to narrate "in my own voice" throughout the research. Understanding and explaining the literature and terminology of autoethnography in one go is not easy. Moreover, besides literature reviews, there are also ethnographic data collection techniques such as field notes, memoirs, diaries, photographs, and audio recordings. In addition to its academic expression, autoethnographic texts often lend themselves to artistic interpretation (I use my own drawings in the research) or literary expression. Nonetheless, drawing from both exemplary academic texts and *my own experiences*, I can demonstrate the extent to which autoethnography contributes to the concepts addressed specifically in the research. As "Autoethnography is a genre of writing and research that connects the personal to the cultural, placing the self within a social context" [7], (Reed-Danahay, 1997; as cited in Holt, 2003, pp. 18). Autoethnographic texts are typically written in the first-person voice. Influenced by history, social structure, and culture, these texts consist of relational and institutional stories where dialogue, emotion, embodiment, spirituality, and self-awareness are prominent [8].

Considering the research, I can say that "a researcher uses tenets of *autobiography* and *ethnography* to *do* and *write* autoethnography. Thus, as a method, autoethnography is both process and product" [4], (pp. 273). This means that autoethnography is an ethnographic inquiry that uses the researcher's autobiographical material as primary data [9]. Naturally, in fact, as I use autoethnography:

> *As someone who has lived in and witnessed the home within its social context (auto), I will draw upon my own experiences to understand my past home and my relationship with it (ethno). In doing so, I will focus on everyday household objects, the foundational elements of the home, to facilitate the process of describing, writing about, and reconstructing (graphy) the home.*

When considering the foundational elements of the home, I don't just see them as mere household items. At this point, memories, images of home that flood the mind while drawing, the interactions and positions of household members within the action-space, sounds, meals, the mulberry tree, swing, chickens... These are all objects that portray my home, together. On the other hand, the research also aims to treat objects without glorification and to value all inhabitants of the home on an equal plane.

Object, despite being at the heart of interior design, is a neglected, almost undiscussed, overlooked issue (thesis committee meeting, February 1, 2023). In fact, alongside the neglected and overlooked objects, it signifies the personal life of the space user -its biographical traces, symbolic, and emotional values. Without these objects, neither the space nor the home exists, of course. A home is where we live... but beyond all, it is an image imbued with the thoughts and emotions of its inhabitant [10]. In this sense, a home is both a physical space and a cluster of emotions and cultural meanings; it emerges from the interaction of these two aspects [10], (Blunt and Dowling, 2006; as cited in Bici Nasır, 2016). Exploring this cluster of cultural meanings and emotions is made possible through the opportunities offered by autoethnography. Therefore, the main aim of this study is to present an imaginative reconstruction of a home, navigating between reality and fiction, based on a story from the past.

3. ADOBE HOUSE AND EVERYDAY OBJECTS

The first place where a person settles is their mother's mind. It is the first space opened to them, the first door they enter from within [11]. The mother's mind, perhaps even before her womb, is where an individual's unique dreams and designs first take shape. Thus, with the innate instinct for refuge and protection that humans bring from birth, it can be considered that the first place of residence is within the mind and body of one's mother. The cluster of experiences lived there transforms into a narrative later discovered, perceived, felt, and designed [1].

Throughout history, the course of civilizations, cultures, beliefs, and aesthetic pursuits has consistently involved the production of homes, both physically and intellectually. Due to the inseparable relationship between humans and homes, the home serves not only as a physical structure within urban scales but also as a transmitter of multi-layered human-specific meanings. Home possesses the greatest unifying power, housing human thoughts, memories, and dreams, protecting them [12]. Describing architecture (or unarchitected architecture) so familiar and close to humanity as "a perpetually popular and current research field" would not be incorrect, because home is an arena for confrontation and, metaphorically speaking, life itself [13], (pp. xii, emphasis added). Philosophical perspectives on home, personal stories, and expressions in autoethnographies thus make it possible to narrate even my mudbrick house at this point.

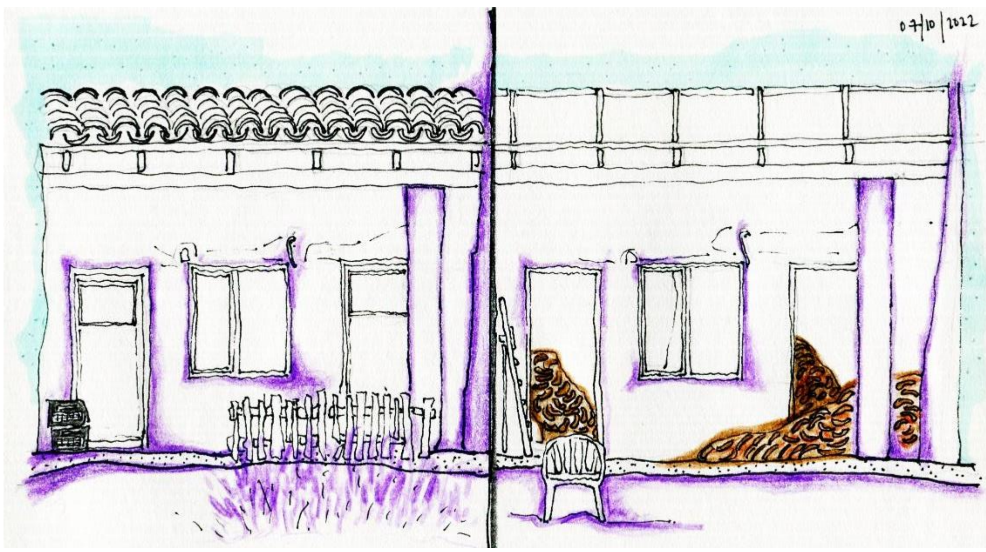


Figure 1. Before 2022 and after the demolition of adobe house

Since I can remember, my grandmother, grandfather, and uncle lived in the adobe house; today, although the house no longer exists, it continues to live vividly in my mind along with the objects that brought it together in that neighborhood. According to what my elders have recounted, my grandmother, upon becoming a bride, constructed this house herself, with other workers assisting in the roofing. Often referred to *fakirhane*, *aşağı(da)ki ev*, *koliba*, and occasionally *yer evi*, this dwelling (see Fig. 1), with its *sundurma* (a kind of porch), offered its residents the sweet pleasure of being half in the garden and half inside the house. The two mulberry trees growing right next to the house provide shade for the sundurma; they not only satisfy the residents with their fruit but also keep the house cool during the summer months. The adobe house consists of two separate sleeping rooms and a combined cooking and sitting area. Each of these three rooms has independent wooden doors opening onto the sundurma. *Ardiye* to the house is a storage room, also made of adobe, which was added later. Due to its adobe construction, the house possesses bioclimatic features that provide warmth in winter and a cool environment in summer. The women of the home -my grandmother and mother- are occupied with daily chores and childcare, such as sweeping the courtyard/garden, cleaning, cooking, setting up the stove, making noodles for winter preparation, pickling, washing clothes, and more. Periodically, maintenance and repairs of the house, such as whitewashing the walls *(duvarlara kireç badanası vurmak)* and applying putty to the windows *(camlara macun çekmek)*, are exclusively managed by my grandmother's efforts. She uses improvised stilts to reach places her height cannot, which she refers to as "donkey" (*eşek* in Turkish).

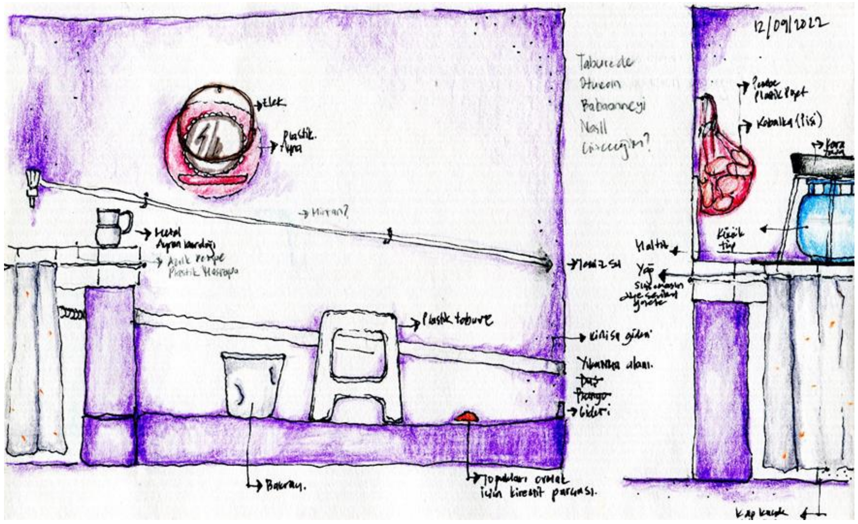


Figure 2. The kitchen space and the section where the washing ritual takes place.

Some everyday objects of the adobe house are both the creator and the narrator of the spatial story. These objects, which represent a primitive and ordinary daily life, when read one by one, create a narrative that tends to imagine the inhabitant of the house. In Figure 2, the coming together of the objects that represent how the washing-cleaning ritual takes place, also provides a series of spatial clues about domesticity. The plastic stool on the *yunak taşı* (generally the stone platform where the laundry and residents are washed) is used to sit on while washing, while the *bakraç* (like a metal jug) next to it is in close proximity to where water is carried by hand. The piece of tile on the floor serves to remove dead skin from the body during washing. In this ongoing ritual, objects, which are the neglected heroes of the house, help to restore meaning within the house.

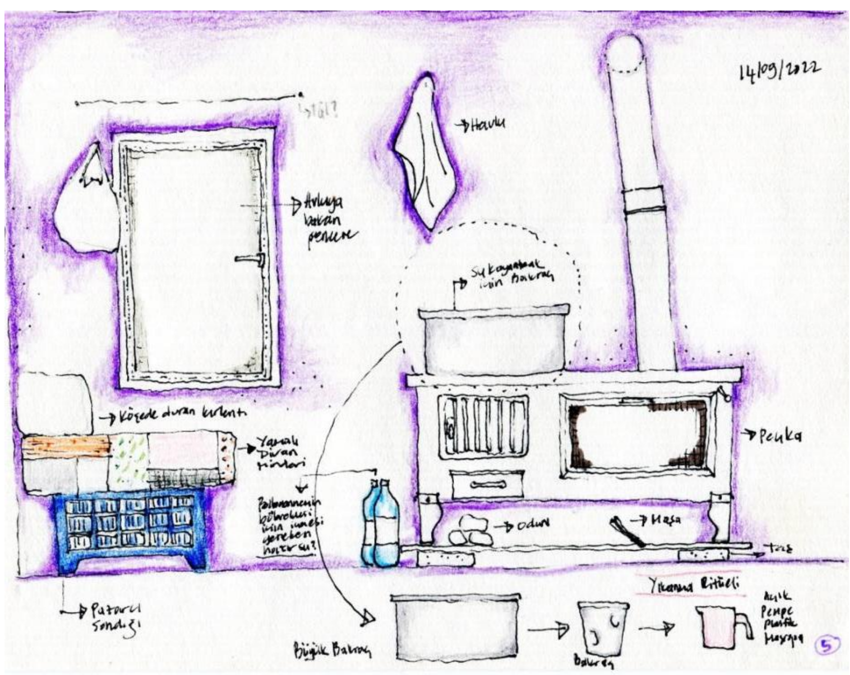


Figure 3. *Peçka* (a stove for both cooking and heating); *sele* or *pazar sandığı* (a kind of basket) is used as a seating element in the home.

The part of the house where food is cooked and preserved, i.e. used as a kind of kitchen space (see Fig. 2) and the *peçka* (pronounced in Thracian accent, originally *kuzine;* meaning a stove for both cooking and heating) in Fig. 3, together with other objects that reinforce the imagery, provide an authentic, cultural and socio-economic background. In fact, some of the objects in the house are an extension of the routine work of the men in the household - as my grandfather and uncle were market vendors/tradesmen - in their working life; the market chest (In Turkish it can be called *pazar/pazarcı sandığı*), known as *sele* (the fruit and vegetable basket), is used as an auxiliary item in practical furniture solutions in the house. The basket in question is used as a seating element in the home, serving a purpose other than its current function. It is not incorporated into the home as an accessory or any other decorative element, as is the case with today's popular DIY trends. It transforms into the supporting structure of a sofa (in our words, *divan*) used as a seating element and is utilized for storing and stacking plates and dishes under the kitchen counter. There are no unnecessary objects in the house. Everything, including the inhabitants of the house, is in its proper place (see Fig. 4). Almost none of the objects are designed items; there is no interior decor element that aligns with the furniture and home decoration trends of those years. The house is actually filled with these ordinary, mass-produced, and easily accessible objects for the masses. However, they are no longer merely possessions but have become entities that are cherished and protected as "carriers of moment"; they are irreplaceable and non-transferable. Despite being ordinary objects produced for the masses, when their material existence is lost and replaced, they transform into something different from their replicas [14].

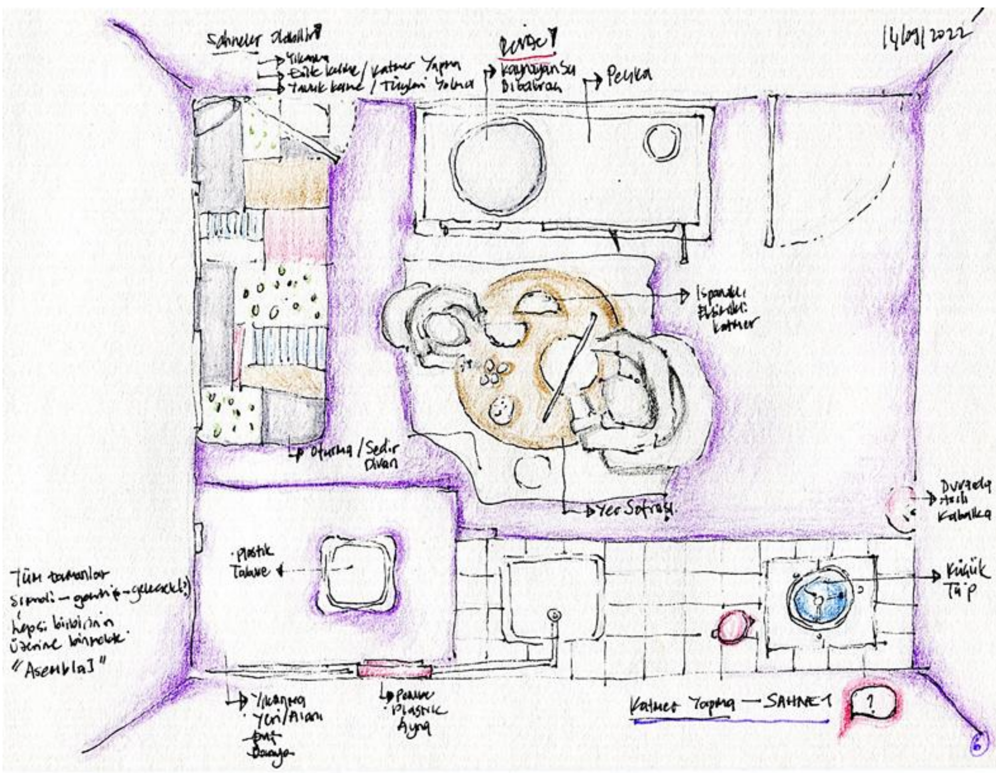


Figure 4. The impact of objects in the process of establishing meaning at home.

Orhon states, "The home is built on familiarity. The moment when the inhabitant can find their way in the dark is perhaps the most visible instance of this familiarity" [15], (pp. 54). In my relationship with the home, I seek this familiarity elsewhere as well. The images of objects greatly assist in this search and in re-establishing meaning. When images are included in the drawing, new connections form among the object - connections that I know but which the viewer witnesses for the first time through my perspective. When rebuilding the home, fiction and reality walk the same tightrope; the identities of objects familiar from the past and the objects reflecting the house's own natural culture acquire a memory of the present moment and keep a record of it [16], by "carrying moments within them" [17], (pp. 269). For example, a flour sieve (see Fig. 1) hangs on the mirror just above the kitchen counter. This may seem unusual, but not to me; a few nails driven into the wall can be used as hanging elements. This is not a kitchen that dictates "action according to its space." The plastic bags hanging on the nails in the wall, the fried dough (*pişi* or *kabalka*; This is how it is expressed in Thracian accent) in the bag, medicine boxes, headscarves, and towels create a scene that is very familiar to me in this adobe house. Authenticity, culture, and the house's unique everyday objects have also influenced the formation of the jargon related to the home.

4. CONCLUSION

Autoethnography's effort to understand a personal experience within its social context keeps the researcher's participatory role and performative receptors active. The research and writing process, along with the act of drawing, have revealed the "things" felt but not fully grasped in the lost home-space. The drawings, which serve as a means to materialize an intellectual and conceptual journey, sometimes seem to freeze the relationships, flow, and permeability between objects, yet searching for lost space stories within the objects encourages creative thinking. Each image of an object emerging from my memory re-embodies as the invisible but true protagonists of the house's identity. As the object images are revealed through representations, this moment of expression also questions new ways of knowing and researching. The autoethnographic approach enriches the researcher's individual and academic journey while providing a deep understanding of cultural experiences. Through autoethnography, the story of a lost home and the everyday objects responsible for this story enable the rediscovery of cultural memory and personal history.

5. REFERENCES

[1] Şerbet, M., *Mimari Karakterli İnşai Seramik Çalışmalar.* Ankara, Hacettepe Üniversitesi, Güzel Sanatlar Enstitüsü, Seramik ve Cam Anasanat Dalı, Yüksek Lisans Sanat Çalışması Raporu, 2019.

[2] Aykaç, G., "Annemin Hayatlı Evi: Eviçi Emeğin Mekansal Halleri", *İnceleme: Ege Mimarlık,* (115), 52-55, 2022. (Accessed: November 16, 2022).

[3] Wall, S., "Easier said than done: Writing an autoethnography", *International journal of qualitative methods,* 7(1), 38-53, 2008. (Accessed: May 11, 2024)

[4] Ellis, C., Adams, T. E., & Bochner, A. P., "Autoethnography: an overview", *Historical social research/Historische sozialforschung,* pp. 273-290, 2011. (Accessed: May 1, 2024)

[5] Muncey, T., "Doing autoethnography", *International journal of qualitative methods,* 4(1), 69-86, 2005. (Accessed: May 11, 2024)

[6] Duncan, M., "Autoethnography: Critical appreciation of an emerging art", *International journal of qualitative methods,* 3(4), 28-39, 2004. (Accessed: May 12, 2024)

[7] Holt, N. L., "Representation, legitimation, and autoethnography: An autoethnographic writing story", *International journal of qualitative methods,* 2(1), 18-28, 2003. (Accessed: May 12, 2024)

[8] Ellis, C., & Bochner, A. P., "Autoethnography, personal narrative, reflexivity", In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 733-768). Thousand Oaks, CA: Sage, 2000.

[9] Çelik, H., "Kültür ve Kişisel Deneyim: Bir Araştırma Yöntemi Olarak Oto-etnografi", *İstanbul Sosyal Bilimler Dergisi,* (6), 1-14, 2013. (Accessed: December 17, 2022)

[10] Bici Nasır, E., "Salonun Çelişkili Niteliğine Dair Güncel Bir Kesit", *in Spaces/Times/Peoples: Domesticity, Dwelling and Architectural History* (Mekânlar/Zamanlar/İnsanlar: Evsellik, Ev, Barınma ve Mimarlık Tarihi), ODTÜ Basım İşliği, Ankara, pp. 7-21, 2016.

[11] Keskinöz Bilen, N., *İlk Ev,* TMMOB Mimarlar Odası Ankara Şubesi Dosya Dergisi, (41), pp. 84-88, 2018, Eylül. http://www.mimarlarodasiankara.org

[12] Bachelard, G., *Mekânın Poetikası*, Alp Tümertekin (Çev.)., İthaki Yayınları, İstanbul, 2017.

[13] Özgenel, L., "Ev'in Halleri; Cases of the House", in *Space/Times/Peoples: Domesticity, Dwelling and Architectural History.* (Mekânlar/Zamanlar/İnsanlar: Evsellik, Ev, Barınma ve Mimarlık Tarihi), ODTÜ Basım İşliği, Ankara, pp. xi-xii, 2016.

[14] Sağdıç, K., *Keepsake: Meanings, Practices and Tactics of Making and Preserving Memory*, Ankara, Bilkent Üniversitesi, Grafik Tasarım Yükseklisans Programı, Yüksek Lisans Tezi, 2010. (Accessed: September 12, 2022)

[15] Orhon, G., "Cisimleşmiş Bellek, Yaşayan Nesne: Eşya, Ev, Müze", in *Gökcisimleri Üzerine,* prepared by Kevser Güler & Süreyyya Evren, Arter Yayınları, İstanbul, pp. 51-58, 2021.

[16] Korkmaz, G. Nurseli, "Orhan Pamuk'un Masumiyet Müzesi Romanında Nesneler Arası İlişkiler; Posthümanizm ve Nesne Yönelimli Ontoloji Çerçevesinde Bir Çözümleme", in *Edebiyatta Posthümanizm* e-book (Chapter 15), Sümeyra Buran (Ed.), Transnational Press, London, pp. 285-310, 2020. (Accessed: December 7, 2022)

[17] Pamuk, O., *Masumiyet Müzesi*, Yapıkredi Yayınları, İstanbul, 2023.

Study on Properties and Uses of Clay Burnt Bricks as a Popular Construction Material: A Case Study of Bhaktapur Nepal

Nischal Thapaliya[1], Niwesh Karki[1], Lalit Badu[1], Rejina Karki[1], Utsav Bagale[1], Ishan Timalsina[1], Yahir Ali[1], Shishir Thapa[1], Mahesh Raj Bhatt[1]

[1] Department of Civil Engineering, Kathmandu University, Nepal
nischal.thapaliya138@gmail.com
mahesh.bhatt@ku.edu.np

ABSTRACT

This study aims to review the use of clay bricks in history and the current scenario of Nepal's traditional constructions particularly focusing on the Bhaktapur City. Clay and bricks are essential in creating structures, particularly houses, temples, stupas and other structures starting from the Malla period or even prehistoric. This study is divided into two parts: a literature study of the history and the use of clay-fired bricks in Bhaktapur city and the physical properties and mechanical property characterization of first-class clay-burnt bricks collected from the Bhaktapur area.

In this study, clay burnt bricks are investigated in accordance with Indian Standard IS 3495 and Nepal Building Code NBC 109:1994, in different aspects such as shape, size, colour, density, water absorption, impact-resistance, efflorescence, texture and compressive strength. Experimental results of the brick samples demonstrated that the water absorption ranges between 6% to 25% while their compressive strengths ranged from 8.6 MPa to 15 MPa respectively.

The study concludes that, there are issues regarding the quality of bricks in commercial production and distribution, where some do not even comply with NBC standards. This calls for quality consistency in construction materials in the determination of safety and workability of masonry structures especially in areas experiencing earthquakes.

Keywords: Clay brunt bricks, Compressive strength, Nepal Building code (NBC), Traditional bricks in Bhaktapur, Building materials testing

INTRODUCTION

As one of the most abundant and durable materials in human history, brick has been used for more than 10,000 years, demonstrating its status as among the oldest and most extensively used earth materials in civilization [1]. In Nepal, masonry construction has a lengthy history spanning several centuries. Rural building was mostly dependent on the local resources and labour of the local populace. Nepalese rural

masonry building construction was dependent on skills of local masons and available local construction material [2].
Building practices in Nepal have evolved due to extensive use of bricks over thousands of years ago in historical periods including the Lichhavi, Kirat, Malla, Shah, and Rana eras, demonstrate changes in vernacular masonry construction methods and the development of brick usage [3].

Brick is still a common choice for building materials in Nepal. Nepal hosts approximately 1000 brick kilns, contributing to the annual production of around six billion bricks [4]. Additionally, the Terai and the Kathmandu Valley are home to Nepal's main brick industries. The Kathmandu Valley is home to an estimated 110 brick kilns, of which 15 are located in the Kathmandu District, 32 in Lalitpur, and 63 in Bhaktapur [5].

Bhaktapur: A City in Red

The first thing anyone notices in Bhaktapur is the abundance of bricks. A lot of structures are made of bricks: temples, walkways, passages, houses, hotels, etc. As a Newari community, Bhaktapur's architecture prominently features intricate wood carvings, stone carvings, and distinctive bricks.

a) Brick-paved Bhaktapur Durbar Square

b) Ancient stone tap housed in brick structure

c) Nyatapola temple of Bhaktapur

Figure 13: Pictures highlighting the wide use of bricks in the Bhaktapur Area

The valley has various clay types ranging from white, black, yellow, red and brown, which are utilized in different construction sectors based on their properties and quality. Grey and black clays are used for common bricks and tiles, similarly, grey and brown clays are ideal for high-quality plaster and mortar and red clay is used in paving and pure kaolin (white clay) for internal and external paintings. Past research shows that these clays are rich in quartz, feldspar and clay minerals like kaolinite, and have a varying clay content from 42% to 77%. The suitability of Bhaktapur's clay for brick production is enhanced by its mineral composition and the traditional method of extracting and
processing the clay further ensures the production of high-quality bricks [6].

During the Malla period (1200-1768 AD), bricks used in temples were categorized into two types: ***'dachi appa***' (veneer bricks) and ***'ma appa'*** (structural bricks). ***Dachi appa*** bricks are fired at high temperatures, giving them a glossy finish. These bricks have a smooth side and are tapered along the width to prevent mortar leakage and maintain aesthetics, contributing to the polished look of Newari temples and palaces. Whereas, ***Ma appa*** bricks ensure structural integrity. Traditionally, the Newars used a special mortar called ***'silay'***, made from pine resins, red clay, and vermillion, giving the bricks a dark red colour [7].

The ***ma appa*** and ***dachi appa*** bricks are different in width and thickness, but they are the same length. The ***dachi appa*** brick has dimensions of 8 inches long by 4 inches wide by 2 inches thick, and the ma appa brick has dimensions of 8 inches long by 5 inches wide by 1¾ inches thick. By comparison, a typical local red brick used in the construction of modern homes has dimensions of 9 inches in length, 4 inches in width, and 2 inches in thickness [7].

a) Structure of ***Dachi appa*** Brick

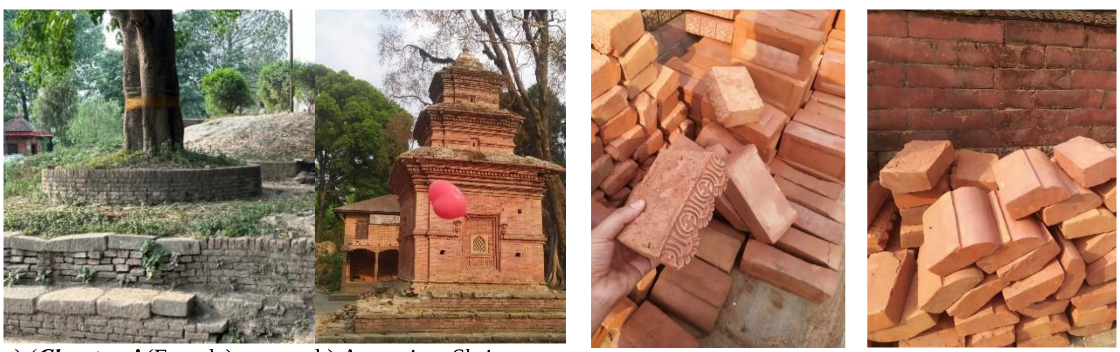
b) Lime mortar as a binding material in Pashupatinath area

c) Newari-style boutique hotel at Surya Binayak

d) Restoration Work in progress at Bhaktapur

Figure 14: Dachi appa, Lime Mortar, and construction and restoration of structures.

Ornamental bricks, featuring symbolic elements and are created using negative mould, are also prevalent in the Newar community. They are used as frames in the walls of Newari houses. The 'jhigati' or 'djigati' tile is a traditional Nepalese tile with grooves for interlocking, made using a mould and finished by hand. Apart from wall facades, plainer bricks are used in various shapes for pavements and in local 'chautara' and 'paati' (slightly raised platforms for sitting or resting in shaded areas) *[6]*.



a) ***'Chautara'*** (Estrade) A sitting space or gathering space (Bhaktapur).

b) An ancient Shrine with ornamental bricks in Bhaktapur area

c) Ornamental bricks used at Pashupati temple premises.

d) Typical bricks used in the construction of 'paati' at Pashupati temple premises.

Figure 15: Use of bricks in different types of construction in Bhaktapur and Kathmandu.

a) Traditional style load-bearing residential houses made up of bricks.

b) RCC framed buildings with bricks infill.

c) Traditional brick house destroyed in the 2015 Gorkha Earthquake

d) Walls Supported by wooden logs after the 2015 Gorkha earthquake

Figure 16: Highlighting the use of bricks in residential areas of Bhaktapur.

The extensive use of fair-faced bricks with their intense colour visually unifies and characterizes Bhaktapur's urban spaces, including palaces, temples, roofs, pavements, narrow lanes, streets, and squares. As per locals, Bhaktapur metropolis has taken the initiative to provide grants to locals for constructing their houses in traditional styles by fulfilling building codes to promote the preservation and construction of cultural heritages. They also receive assistance and discounts if they purchase traditional bricks, hand-carved windows and doors from the government.

LITERATURE REVIEW

Numerous research has been carried out to examine the mechanical and physical characteristics of bricks in various settings. In a study, the ideal firing temperatures for clay bricks from Lalitpur, Nepal were found to be between 700°C and 1100°C. The water absorptivity ranged from 11% to 23%, the apparent porosity from 19% to 37%, and the bulk density from 1.50 to 1.65 gm/cm^3. The compressive strengths of bricks fired between 950°C and 1000°C ranged from 15.6 to 17.1 MPa. The composition of minerals and their absorption of water determine their properties; strength increases with decreasing temperature and porosity [8].

In a study on the properties of brick manufactured in Bhaktapur, it was observed that the properties of bricks made in Bhaktapur city varied widely, with many samples falling short of the Nepal Building Code's requirements. Notable examples of these shortcomings include variations in water absorption between 8.80% and 23.93%, porosity between 19.28% and 53.99%, and crushing strength between 7.83 MPa and 22.10 MPa [9].

Another study on brick properties aimed to enhance understanding of the mechanical properties of Nepali monumental masonry. They found substantial differences in compressive and shear strengths through in-situ testing, lab investigations, and computational validation using Discrete Element Models. The results of the study highlight how crucial precise experimental data are to improving structural studies of Nepali masonry construction [10].

Tests conducted on historical buildings in Nepal following the 2015 Gorkha earthquake revealed that the average compressive strengths of the bricks, mud mortar, and masonry prisms were 5.05 N/mm^2, 1.40 N/mm^2, and 1.70 N/mm^2, respectively, and Young's moduli were 4.30×10^3 N/mm^2, 1.17×10^3 N/mm^2, and 3.10×10^2 N/mm^2. Brick walls had a shear strength of 0.054 N/mm^2. These findings contribute to the understanding of Nepal's past brick masonry [11].

As per Nepal Building Code NBC 109: 1994, the dimensions of a Nepal Standard Brick are 240 mm in length, 115 mm in breadth, and 57 mm in height for a 10 mm mortar joint [12]. Even though first-class bricks are frequently used in buildings, it is not clear from the available data whether or not these bricks satisfy the requirements outlined in Nepal Building Code 109: 1994. Furthermore, there is a lack of pertinent research on the application of brick in a variety of fields as a building material.

MATERIALS AND METHOD

Materials

Samples of bricks were collected from multiple brick kilns located in Bhaktapur, Nepal. These specimens were gathered and then brought to the Kathmandu University construction material laboratory for experimental investigation.

Methods

The study initiated with on-site inspections and photographic documentation of existing and under-construction brick structures, temples, houses, and public spaces, with a motive to analyze their construction processes and materials. After some informal discussion with locals and elderly members, insights were gained about the history of traditional brickmaking and its current status.

As the second part of this study, tests were conducted aiming to analyze and investigate both the physical and mechanical properties of the manufactured bricks. Brick testing was done in the lab using samples that were collected from various locations for various physical and mechanical properties using IS 1077: 1992 [13]

Physical Properties

Physical tests conducted on the brick sample include physical observation, dimension tolerance, soundness, impact and water absorption.

- Six randomly chosen brick samples were measured for the dimension tolerance test, and the results were compared to the standard dimensions of 240 mm by 115 mm by 57 mm as stated in NBC 109: 1994.
- The soundness test checks the bricks' ability to withstand sudden impacts. Two bricks are chosen at random and struck together for this test. A good brick should sound clear and ring like a bell upon hit, meaning it should not break.
- A good brick should be able to withstand scratches from sharp objects. Therefore, a sharp object was utilized to scuff the brick in this test. Brick is referred to as hard if there are no scratches on it.
- During the impact test, bricks are let to fall from a height of one meter on the ground. High-quality brick ought to be unbreakable.

The density of brick is determined using the following relation.

$$Density = \frac{Dry\ weight\ of\ brick}{Volume\ of\ Brick}$$

- A dry specimen is obtained for a water absorption test and dried in an oven between 105°C and 115°C until it reaches a consistent mass. After being immersed in clean water at 27±2°C for 24 hours, the specimen is weighed again. Water absorption is determined using the following relation as per IS 3495 (Parts 1 to 4): 1992,

$$Water\ absorption = \frac{Saturated\ weight\ of\ brick\ - Dry\ weight\ of\ brick}{Dry\ weight\ of\ brick} X\ 100\%$$

Mechanical Properties

The brick's crushing strength can be used to assess its quality and durability before it is utilized to build a structure. The compressive strength of bricks was determined using IS 3495 (Parts 1- 4): 1992 using the following formula.

$$Compressive\ Strength = \frac{Maximum\ Load\ at\ Failure\ (N)}{Average\ area\ of\ bed\ face\ (mm2)}$$

RESULT AND DISCUSSION

Physical Properties

Water Absorption Test on Brick

Bricks were subjected to a water absorption test in order to evaluate their durability, taking into account variables like degree of burning and behaviour during weathering. This test measures the quantity of moisture that bricks can absorb in extreme conditions. Low water absorption is a sign of preferred brick quality, durability, and compressive strength.

The majority of bricks (14 out of 30) exhibited a water absorption percentage ranging from 6% to 10%. Additionally, 11 bricks had a water absorption percentage between 10% and 15%, while 3 bricks fell within the range of 20% to 25%. Notably, no bricks were observed to have a water absorption percentage between 15% and 20%.

Density

While the density of bricks can vary from region to region, IS 875 (Part 1) – 1987 offers recommendations, suggesting an ideal range between 1600.00 kg/m³ and 1920.00 kg/m³. This study revealed deviations from this standard: 8 bricks fell within the 1000 kg/m³ to 1500 kg/m³ range, while 22 bricks ranged from 1500 kg/m³ to 2000 kg/m³. It showed that 73.33% of brick samples are within the range provided by IS 875 (Part 1)-1987.

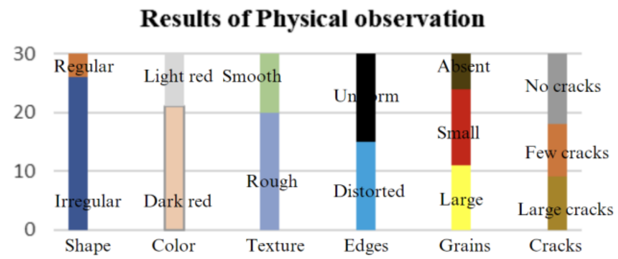


Figure 5: Physical observation of brick result.

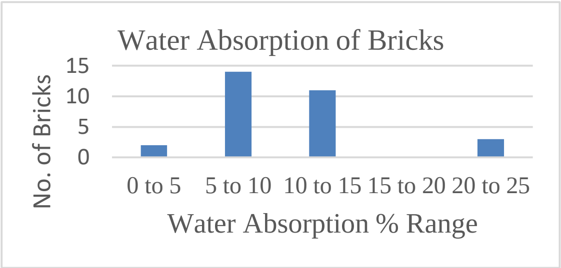


Figure 6: Water absorption test

Dimension Tolerance Test

When the dimensions of the brick samples were compared to the standard size specified by NBC 109:1994, it was observed that no samples matched the specified dimensions. Specifically, while the length of certain bricks fell below the standard requirement, the height of others surpassed the specified limit.

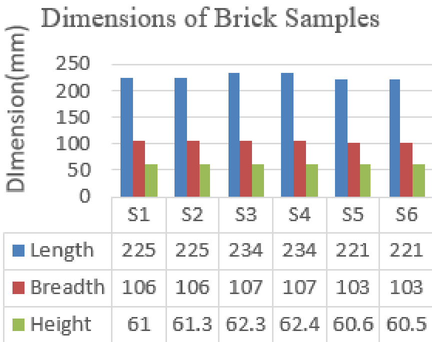


Figure 7: Dimensions of Brick Samples

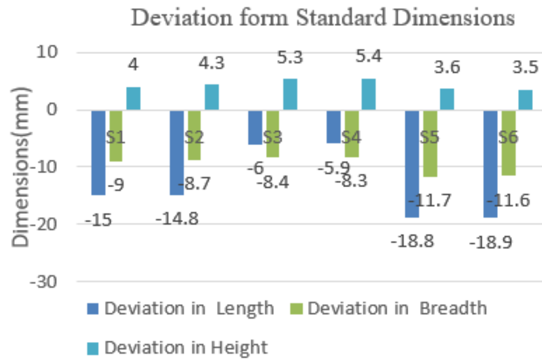


Figure 8: Deviation of Brick Sample dimensions from Standard Brick

Impact Test

In the impact test, conducted by dropping bricks from a height of 1 meter, 8 out of 10 samples fractured upon impact, rendering them unsuitable for construction use.

Soundness Test

Among the 30 samples examined, 21 demonstrated attributes indicative of good-quality bricks, characterized by their ability to resist breakage and produce a metallic sound.

Mechanical Properties

The compressive strength of bricks is a crucial indicator of their suitability for construction, reflecting their ability to withstand applied loads. The compressive strength of 15 samples of bricks has been tested for mechanical properties as shown in Figure 9. As per NBC 109:1994 standards, first-class bricks are expected to have a minimum compressive strength of 10 MPa, with no bricks falling below the critical threshold of 3.50 MPa. In the analysis of 15 brick samples, the compressive strengths varied significantly. Nine samples exhibited compressive strengths meeting or exceeding the minimum requirement, ranging from 11.47 MPa to 16.97 MPa. However, six samples fell short of the specified standard, with compressive strengths below 10 MPa, which showed unsatisfactory results.

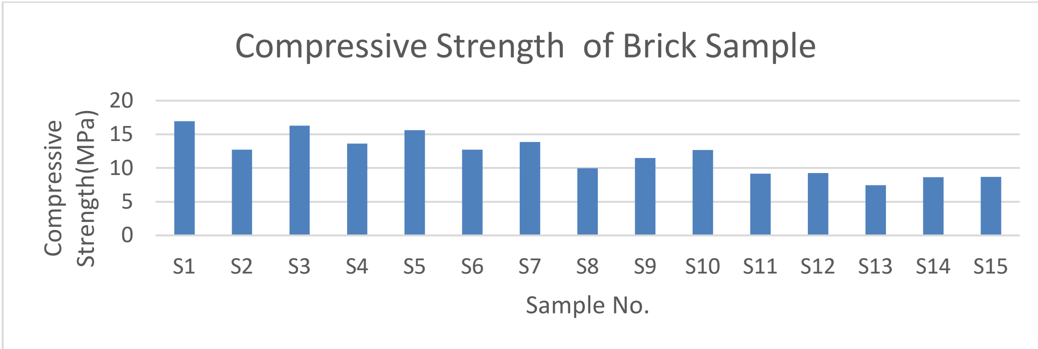


Figure 9: Compressive strength test results


a) Frog filling for compressive strength test


b) Dimension Tolerance Test of Bricks


c) Physical Observation of grains and organic matters


d) Water Absorption Test of Bricks


e) Compressive Strength Test of Bricks


f) Impact Test of Bricks

Figure 10: Works performed during the Laboratory tests of bricks

CONCLUSION

The Bhaktapur region is rich in clay with abundant minerals, which has been extensively used to construct various structures such as walls, buildings, and temples. As a result of this historical practice, it is essential for the contemporary government to prioritize the preservation, construction, and reconstruction of these structures. Traditional bricks made from this clay are not only used for construction purposes, but also for pavements, tombs, decorations, roofs, and more.

The traditional method of making bricks is different from today's factory-made bricks. This study evaluated the quality of first-class bricks made in Bhaktapur for construction. Tests showed variations in dimension tolerance, hardness, impact, soundness, water absorption, compressive strength, and density among the samples. Some bricks met the specifications, while others did not. The bricks exhibited an average compressive strength of 11.95 MPa, water absorption of 9.88%, and density of 1558.547 kg/m³. Eight out of ten samples fractured during the impact test, raising concerns about quality. Despite this, the majority of bricks met or surpassed the NBC 109:1994 minimum compressive strength standard of 10 MPa. The impact test raises concerns about quality. Despite this, the majority of bricks met or surpassed the NBC 109:1994 minimum compressive strength standard of 10 MPa.

ACKNOWLEDGMENTS`

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REFERENCES

[1] J. Fiala, M. Mikolas, K. Krejsova, "Full Brick, History and Future," in *IOP conference series: Earth and Environmental Science*, Prague, Czech Republic, 2019.

[2] M.R. Bhatt and P. M. Pradhan, "Behaviour of Stone Masonry Buildings at Ramechhap District During 2015 Gorkha Earthquake: A Case Study," in *Kerpiç'19 – Earthen Heritage, New Technology, Management 7th International Conference Köycegiz*, Muğla Turkey, 2019.

[3] D. Gautam, H. Chaulagain, R. Rupakhety, R. Adhikari, P. Neupane, and H. Rodrigues,, Vernacular masonry construction in Nepal: History, dynamics, vulnerability and sustainability, New York: Nova Science Publishers Inc., 2018.

[4] E. Baum and C. A. T. Force, "Present Status of Brick Production in Asia," in *INE Proceedings*, Guanajuato, Mexico, 2012.

[5] S.P. Vista and B. Gautam, "Influence of brick processing on changes in soil physicochemical properties of Bhaktapur District, Nepal," *International Journal of chemical studies,* pp. SP4: 146-150, 2018.

[6] V. Sestini and C.Bonapace, Traditional Materials and Construction Technologies used in Kathmandu Valley, France: Paragraphic for the United Nations Educational, Scientific and Cultural Organization, 2003.

[7] S. L. Pande, "The history of dachi appa and Ma appa Bricks," The Kathmandu Post, 18 Feb 2018. [Online]. Available: https://kathmandupost.com/art-entertainment/2018/02/18/the-history-of-dachi-appa-and-ma-appa-bricks. [Accessed 29 5 2024].

[8] N. Bohara, D. Ghale, Y. Chapagain, N. Duwal, and J. Bhattarai, "Effect of firing temperature on physico-mechanical properties of contemporary clay brick productions in Lalitpur, Nepal," *Bangladesh Journal of Scientific and Industrial Research,* vol. 55(I), pp. 43-52, 2020.

[9] S. Shrestha, "A Case Study of Brick Properties Manufacture in Bhaktapur," *Journal of Science and Engineering,* vol. Vol. 7 (2019), pp. 27-33, 2019-12-22.

[10] R. R. Parajuli, A. Furukawa, and D. Gautam, "Experimental characterization of monumental brick masonry in Nepal," *Structures,* vol. 28, no. December 2020, pp. 1314-1321, 2020.

[11] C. Mishra, K. Yamaguchi, Y. Endo, and T. Hanazato, "Mechanical Properties of Components of Nepalese Historical Masonry Buildings.," in *International exchange and innovation conference on engineering and sciences.*, Fukuoka, Japan, 2018.

[12] Ministry of Physical Planning and works, "Nepal National Building Code (NBC)," Ministry of Physical Planning and Works, Kathmandu, 1994.

[13] Bureau of Indian Standards, "IS 3495 : 1992 Methods of Tests of Burnt Clay Building Bricks," Bureu of Indian Standards, 1992.

Rebuilding with Earth in Seismic Zone: Case study of Nepal

Author: Nripal Adhikary
Address: nripal@abari.earth
ABARI, Kathmandu, Nepal

ABSTRACT
Nepal lies in a seismically active and subtropical climactic zone with average rainfall as high as 1 meters a year. Yet according to Nepal's Living Standard Survey 74% of the Nepali houses are made of earthen material. In 2015, there were multiple earthquakes with over 7.5 rector-scale. All the structures, that the author designed using materials like earth and survived unscathed- including structures built at the epicenter.

Those structures gave lots of confidence to local population who were told that earthen structures are not stable. Aftermath of the earthquakes, author has designed and build over a dozen school, public spaces, monasteries, temples, hotel and homes. In this paper, the author will share his experience of rebuilding using the local resources. Author will discuss building an enterprise, creating a supply chain, involving university for research, lobbying for policy change and the process of building using rammed earth, adobe, compressed earth blocks, wattle and daub, lime bricks and bamboo trusses.

Keywords: Earthquake reconstruction, earth construction, rammed earth, bamboo, Nepal, Gorkha Earthquake.

Background:
Two-thirds of Nepal's terrain is mountains including the Himalayas. Mountains are hard to navigate, therefore in earlier times, communities separated by mountains had very limited exchange. Such conditions gave rise to hyper-local, context specific indigenous knowledge systems within a few square miles. It is for this reason the small county of Nepal, that is only 1400 km wide and in average 300 km wide, has more than 100 languages and corresponding means of articulating their worldviews through arts, crafts, agricultural systems and architecture.

The materials available at their disposal- mostly timber, stones, bamboo and earth are utilized by the communities to design and build extraordinary structures. Some of them are multi storied structures designed to be earthquake resistant and cope with the harsh winter. Some of the wood joineries and stone carvings embedded in the walls or structural members are among the most extraordinary in the world (Tiwari, 2023, Tiwari, 2009, Bernier 1997).

The materials for these houses were locally sourced from the commons, so they were virtually free. Timber was typically sourced and managed from local forests, stones were harvested from local quarries (which were abundant in the mountains) and soil procured from their own site. Labor was bartered, in other words if A helped in construction of B's house for 10 days then B would have to reciprocate in construction of A's house by working for same amount of days. This system of barter of labor is called "*parma*". If the owner is disabled or old, the neighbors would help in the spirit of community.

As 'development' creeped in the 1950's, these independent communities began to be regulated. The common resources like the local forest, quarries, rivers became state property (Regmi,2000). In other words, the government started monetizing materials which were hitherto free. The communities were left with no other choice but to buy industrial materials for construction and maintenance.

When the government began to regulate the commons and imposing building codes even in rural and remote Nepal, the vernacular architecture of yesteryears began to diminish in numbers. Many of the building traditions that were thousands of years old were also deemed unfit in the light of renewed building codes.

Earthquake of 2015

In 2015, there were two massive earthquakes on April 12th and May 22nd of Richter scale 7.8 and 7.3 magnitude. It claimed casualties of over 8856 people (NDRRIP, 2015). Considering the magnitude of the earthquake, the casualty was considered to be low. Earthquake of similar magnitude in Pakistan and Turkey killed more than 80,000 people. Despite media and the government claiming that vernacular houses are weak and unsafe, it was observed that properly built traditional structures survived the earthquake even at the epicenter (Adhikary, 2017).

In a country where majority of the buildings are made with earth and stone, the new regulation from the government, in the light of the natural disaster, made it very difficult to rebuild with the existing materials and skills. Hundreds of high paying consultants from abroad flew in with different agendas for reconstruction. Even after a year of the devastation and the lack of initial disaster response, the government did not lean towards the ideas of rebuilding homes, schools and communal spaces which were needed urgently using local materials. They supplanted a renewed building code, uninspired by the possibilities with natural materials and local craftsmanship. Interestingly, the older code allowed for vernacular construction. The new government approved designs had no resemblance to any traditional building style (see DUDBC 2015). The government engineers seemed to have been inspired by foreign laws, codes, materials and designs. They lacked the creativity and finesse to contemporize vernacular buildings. Even in the odd case that some designs that utilized natural materials and traditional aesthetic were assessed and selected to be passed by law, the criteria for legally executing such a construction were that it be reinforced heavily with the usage of cement and steel.

The average cost of building a house before the earthquake was around 5000 USD but with the new building laws of the government (with the mandate to reinforce every room using RCC), a similar house would cost more than 20,000 USD.

Many home-owners emigrated to middle eastern countries to work in a very harsh conditions to earn the money necessary to rebuild their homes destroyed by the earthquake. In a short span of less than a few decades, owing to modernization and hastened by the earthquake, a previously self-sufficient common man in Nepal, who could build using resources from the commons, was forced to work in foreign lands (with very poor working rights) to pay for their shelter.

Not building back better.

In many instances the Government turned very authentic villages with a unique vernacular architecture into a cookie cutter design that looked very trite and non-functional. One such example in Barpak, which was the epicenter of the earthquake. The village had beautiful cobble stone streets with intimate stone structures roofed with stone slates (Fig. 1). The new rebuilt houses, built with lots of government and foreign help, are bereft of any authenticity to the place. There are many such government rebuilt settlement which are abandoned, wasting billions of tax-payers money (NepaliTimes, 2016).

Photo of Barpak before the earthquake Photo Source: Nepali Times

Barpak after the earthquake. Photosource: Nepalitimes


Government implement cookie cutter design, which is now abandoned. Photo: Nepali times.

By forcing cement and steel down peoples throat with their earthquake reconstruction effort, the government managed to reduce the amount of vernacular Nepali architecture that used locally available materials from 74% in 2011 down to In 2021. (CBS 2011 and 2021)

ABARI

In 2006, after returning from Northern New Mexico college with specialization in Adobe Earth Construction, the author set up a private social enterprise called ABARI, that would reappropriate earth based traditional materials into contemporary architecture. Author was inspired by Northern New Mexican architecture which celebrated the ancient adobe techniques in the modern context.

In 2007 author met a group of Norwegians who wanted to build a learning center based on the Scandinavian *folkschule*, where they would demonstrate different sustainability techniques. Author led ABARI to design and built adobe domes, two story dormitory with rammed earth, office space with compressed earth blocks, canteens and training halls which had to house 100 people each with bamboo and adobe. In the process, the team trained hundreds of builders both men and women in sourcing, processing and finishing. The communal projects led to economic opportunities for the local communities who not only shared a beautiful space, but also subsequently generated income by hosting tourists in these buildings. People from different parts of the countries came there to learn about sustainability when programs were organized at community, municipality and national and international level. They offered courses on natural earth construction, permaculture, social mobilization, women empowerment etc.

The public infrastructure cost lots of money and generally always uses modern industrial material, which have to be imported. The government schools, however limited they are, are not satisfactory. They are made of cinder blocks, metal trusses and tin sheet. They are basic without any insulation whatsoever. These schools would close if the weather is too hot or cold or when it rained because the tin roof would make so much noise that it is impossible to hear what the teachers were saying.

ABARI's second project was construction of small pre-primary school. It was designed a demonstration so it could be replicated across the country. Fortunately, Justin Wickham, an English builder and a friend of ABARI, had already started building a school with stone in a remote village of Gorkha. It was so remote that the closest hardware store was five hours away. ABARI team volunteered to build the roof with bamboo and stone. With limited budget and it took almost three years to build the school. Just after ABARI had finished the building, a huge earthquake hit Nepal. The school was only 12 km from the epicenter. The devastation was very intense and our school was one of the very few schools that survived the tremor.

Though it was a tragic event, it was a vindication that buildings that are built with earth bamboo and stone can survive big tremors. It proved that using local resources one can build beautiful spaces that can meet the needs of the local people with its own vernacular flavor. Furthermore, it demonstrated that one does not need imported industrial technologies or materials to make safe, comfortable and beautiful structures.

After the earthquake, around 40,000 schools had to be rebuilt. It was a perfect opportunity to pitch a new idea to the government. Government immediately approved ABARI's prototype design of a modular school that would work in Nepali terrain. It was one of the rare moments, even internationally, where government had approved earth and bamboo as construction materials for public schools. The designs were very popular and the team got so many offers to build schools all over the country. ABARI did not have the bandwidth to build all those schools, therefore they put the design on their website as opensource documents. Over thirty schools were built using the documents and there were almost a million downloads.

Politics of Construction.
After the earthquake people were scared that the government would come up with prescriptive design that would create cookie cutter structure all over the country, undermining thousands of years of vernacular architectural tradition. Unfortunately, that is what happened. Government, funded by World Bank, made construction with natural buildings very difficult. Even if it was allowed, it had to be done by adding tons of cement and steel in the mixture. Even though so many people wanted to build in ABARI style, the regulations made it difficult to do so. The building codes which were pretty favorable to natural construction before the earthquake was changed in order to prioritize concrete and steel. 10 years after the earthquake, one can see traditional vernacular architecture being cannibalized by modern cookie cutter concrete and

steel construction.

Nevertheless, there were some pockets of opportunities that open up among a small group of alternative thinking individuals and organizations. A big commission after the earthquake was an immediate reconstruction of a public archive. It was a public building right at the center of Kathmandu Valley. A public building out of earth and bamboo in an urban area would have been almost impossible before the earthquake. ABARI finished the library in 9 months using rammed earth, wattle and daub and bamboo trusses. The two story structure exposed all the bamboo members that form a complex spider web like trusses. It was instantly embraced by the public. The slender, lightweight and ductile bamboo roof was psychologically comforting to the public who had witness heavy concrete structure come down like house of cards.

The building is now reaching its 10 years and is now a public attraction, where many tourists come just to see the building. Instead of doing mass housing projects ABARI does small projects that can redefine the earth and bamboo construction in modern context. ABARI get clients from various spectrums of life, they have designed public halls, monasteries, schools, residence, house of worships. One of the biggest achievement so far has to been to challenge the biases that people had regarding vernacular materials.

References:

Adhikary, 2016. *Vernacular architecture in post-earthquake Nepal*. International Journal of Environmental Studies Volume 73, 2016 - Issue 4: South Asian Vernacular Architecture

Bernier, M. R., 1997, *Himalayan Architecture*. Madison: Fairleigh Dickinson University Press.

CBS, 2011, *National Population and Housing Census.* Central Bureau of Statistics, Kathmandu, Nepal.

CBS, 2021, *National Population and Housing Census.* Central Bureau of Statistics, Kathmandu, Nepal.

DUDBC, 2015. *Design catalogue for reconstruction of earthquake resistant houses, Volume 1*. Department of Urban Development and Building

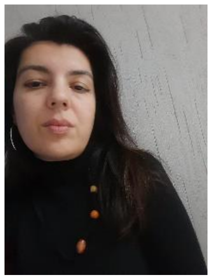
NDRRIP, 2015. *Nepal Earthquake 2015*. National Disaster Relief and Recovery Information Platform. Website: http://www.drrportal.gov.np/

Regmi, 2000. Thatched Huts & Stucco Palaces. Delhi: Adroit Publishers.

Tiwari, 2009, *Temples of Nepal Valley*. Kathmandu: Himal Books.

Tiwari, 2023. Bhaktapur, *The Capital of the Malla Nepal Mandala*. Kathmandu: Rich Publishers.

Conservation works in adobe traditional buildings: Afyon Sandıklı Yesildirek Street Rehabilitation Example

Ömer Tavacıgil[1], Eda Tavacıgil[2]
[1]Nuh Naci Yazgan University, Kayseri, Turkey
[1]tavacigilomer@hotmail.com
[2]mimareda@hotmail.com

The transfer of our historical cities, which have witnessed many periods from the past to the present, to the present day with their tangible or intangible values is important for the preservation of their urban identities. Afyon Sandıklı Houses, which were built with adobe construction system and have survived to the present day, have been able to preserve their original identity, but have been worn out due to atmospheric conditions and lack of maintenance under the influence of time. It has become a necessity to take protection measures to transfer the street texture to future generations. Yeşildirek Street, located in the southwest direction of Hisartepe Mound in the 1st Archaeological Site in Hisar Neighborhood of Sandıklı District, was determined as the study area. The silhouettes of registered and unregistered buildings, courtyard walls facing the road, outbuildings, etc. are included in the project. The aim of the study is to document the architectural elements in order to integrate them into contemporary life by preserving their original street texture. Street facades were scanned with a local laser scanner and documented in CAD environment. The architectural features, qualities and damages of the building facades were determined with the building analyzes made on the street and a basis for the restoration work was created.

Keywords: Adobe Housing, Sandıklı Houses, Historical urban texture, Historical building conservation, Street rehabilitation

1 STREET SANITATION

"Rehabilitation", which is a concept within the process of conservation and restoration, is an intervention method for buildings or building groups that are inadequate for use in their current state [1].

Rehabilitation is the restoration of a cultural asset by preserving the features that give it historical, cultural and architectural value and making it meet today's needs [1].

Ahunbay (2008) defines street rehabilitation as the restoration of neglected, dilapidated, idle and abandoned historical buildings and environments in a way to meet the changing and transforming needs of the society, ensuring their adaptation to today's life, making their various equipment complete, making those that are inadequate much better, removing later additions that are incompatible with the structure, and, if necessary, renewing the living conditions with new additions in and around the building by paying attention to the unity of living conditions with historical and architectural values [2].

Since the 1990s, street sanitization practices have started to take place intensively in the national cultural heritage literature and discussions on how to protect this heritage, and have become one of the methods frequently used by local governments [3].

2 WORKSPACES

Sandıklı, a district of Afyonkarahisar province, is located in the Inner West Anatolia Department of the Aegean Region, on the Antalya-Ankara highway. Yeşildirek Street, located in the southwest direction of Hisartepe Mound, which is located in the 1st Archaeological Site Area in Hisar Neighborhood in Sandıklı district, was determined as the study area.

Figure 17 Satellite view of the area (CBS)

The project area covers the building facades of registered and unregistered buildings facing the road in the area between Güldalı Street to the north and Ekmekçi Street to the south.

There are 38 buildings on a total of 39 parcels within the area. Of these, 4 are registered and 34 are unregistered buildings. It is the registered religious building on Yeşildirek Mosque Street. The other three registered buildings are registered residential buildings owned by Sandıklı Municipality. The other buildings on the street are unregistered and the majority of them were built with masonry system with wooden roof and mudbrick filling, which is the traditional building texture of the region.

Table 1. Registered Buildings on Yesildirek Street

Building No	Image	Building	Function	Number of

Block/Plot		**system**		**Floors**
Building No. 1 195/6		Wooden construction	Housing+ workplace	Ground floor+1
Building No. 18 494/7		Adobe building with wooden structure	Housing	Ground floor+2
Building No. 30 247/1 Yesildirek Mosque		Adobe building with wooden structure	Housing	Ground floor +1
Building No.31 238/25		Adobe building with wooden structure	Housing	Ground floor+1

Figure 18 Examples of adobe buildings with wooden construction on Yesildirek Street

Figure 19 Examples of adobe buildings with wooden construction on Yesildirek Street

3 DOCUMENTATION STUDIES

A local laser scanner was used in the documentation of the existing building stock. Homogeneous data were obtained from the measurement data by scanning at certain distances on Yeşildirek Street, and these data were combined in the software program of the scanner on the computer. A total of 77 installations were made at certain intervals along the street. Each installation took approximately 15 minutes with the installation of the instrument setup. The data was recorded and stored on a portable hard disk. By processing the point cloud obtained with the scanner, orthophotos of all building facades were taken. CAD program was used to convert the data from the orthophotos into technical drawings.

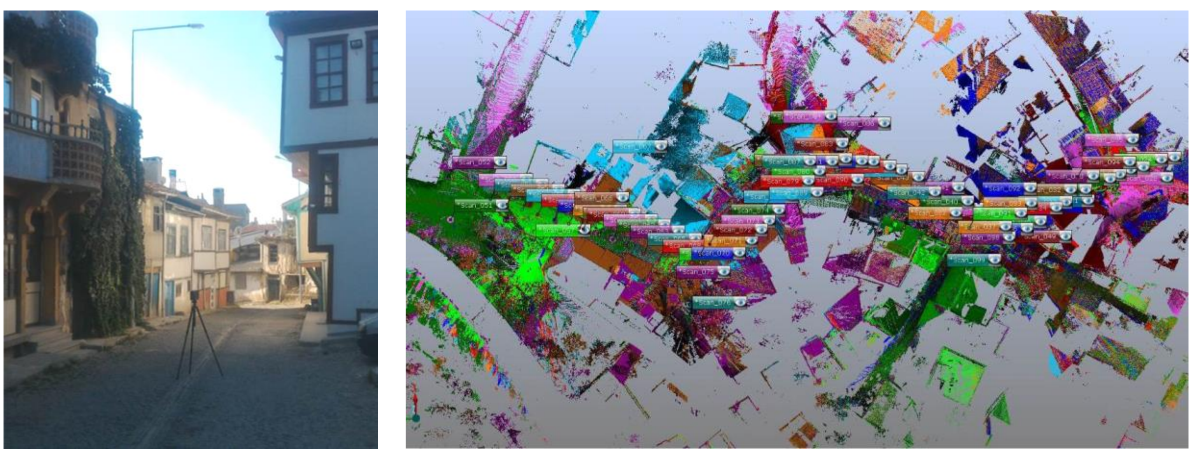


Figure 20 Correspondence view showing the location of laser scanner installations

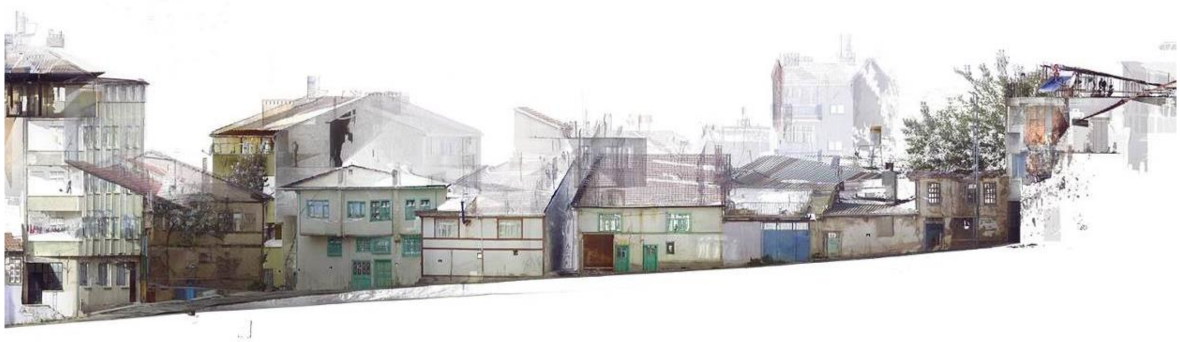


Figure 21 Yesildirek Street orthophoto image 1

Figure 22 Yesildirek Street orthophoto image 2

The survey drawings of Yesildirek Street from both sides were prepared and the buildings were revealed in their current state with all their additions, add-ons, deterioration and even deformations.

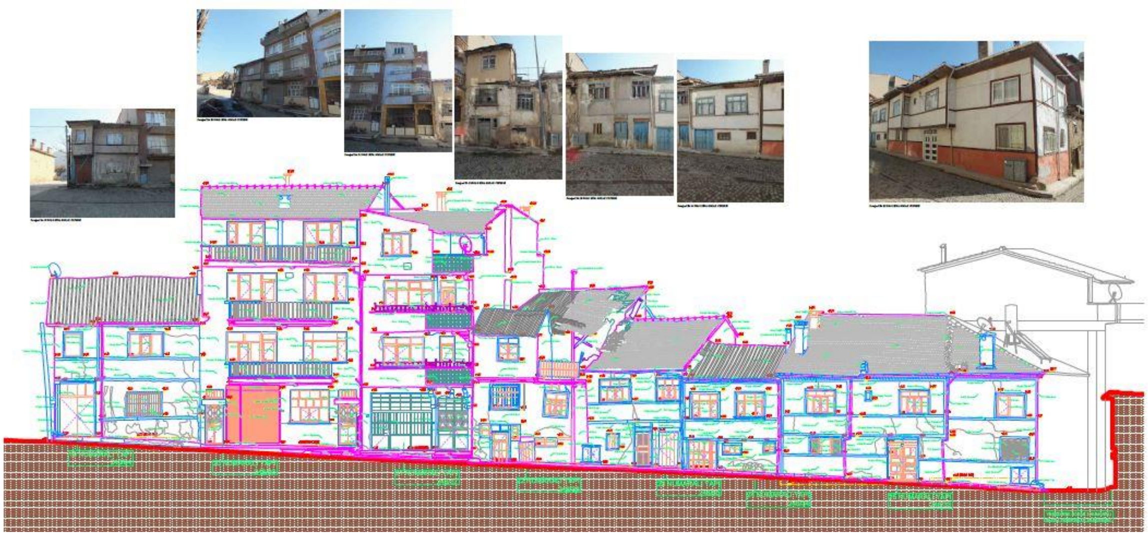


Figure 23 Part of rolove drawing of Yesildirek Street

4 ANALYSIS STUDIES

With this study, it is aimed to document all the elements that define the street texture and to prepare a survey project to be the basis for restoration in order to preserve the architectural elements such as courtyard walls, outbuildings, etc. together with the facade silhouettes facing the road of the registered and unregistered buildings on the street called Yeşildirek, to preserve them with their original street texture, to keep them alive by sanitizing them and to participate in contemporary life.

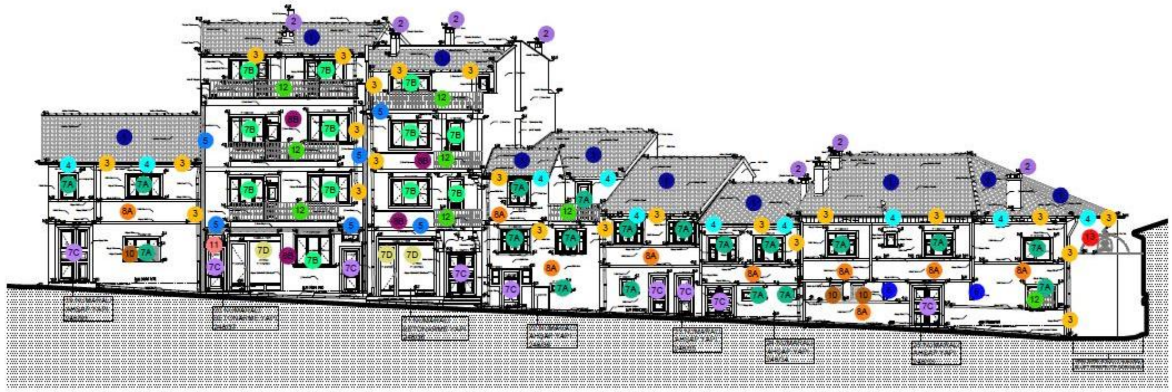


Figure 8 Damage assessment project of a section of Yesildirek Street

Analysis sheets were prepared and the data of the buildings were evaluated. In the analysis sheets; land use sheet (ownership status), land use sheet (function), structural (physical) status sheet, construction system, number of floors and building grouping sheet were prepared (Figure 10-15)

By creating numbered legends on the damage assessment sheets, damages to the architectural elements of the building such as roof, eaves, facade, windows, doors, balconies and walls were revealed (Figure 8)

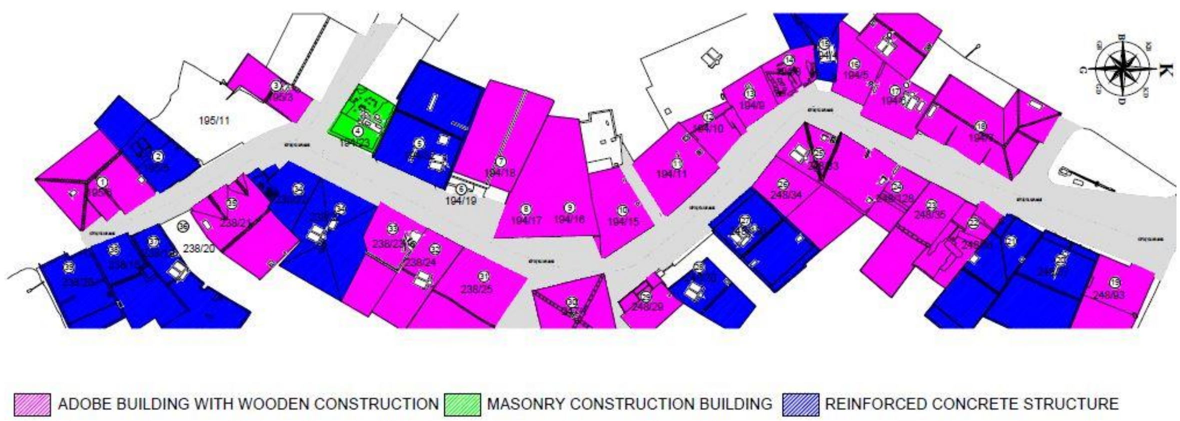


Figure 24 Building system analysis of Yesildirek Street

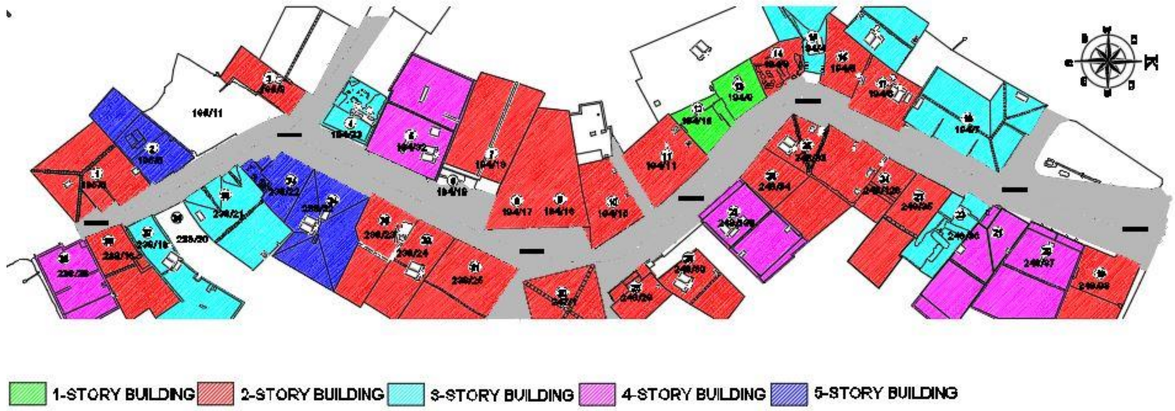


Figure 25 Analysis of the number of floors of buildings on Yesildirek Street

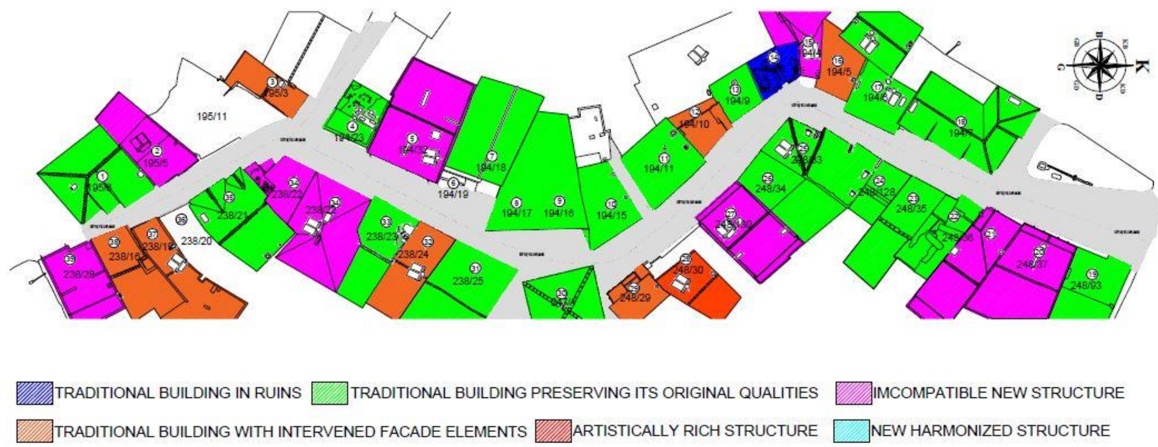


Figure 26 Grouping of buildings on Yesildirek Street

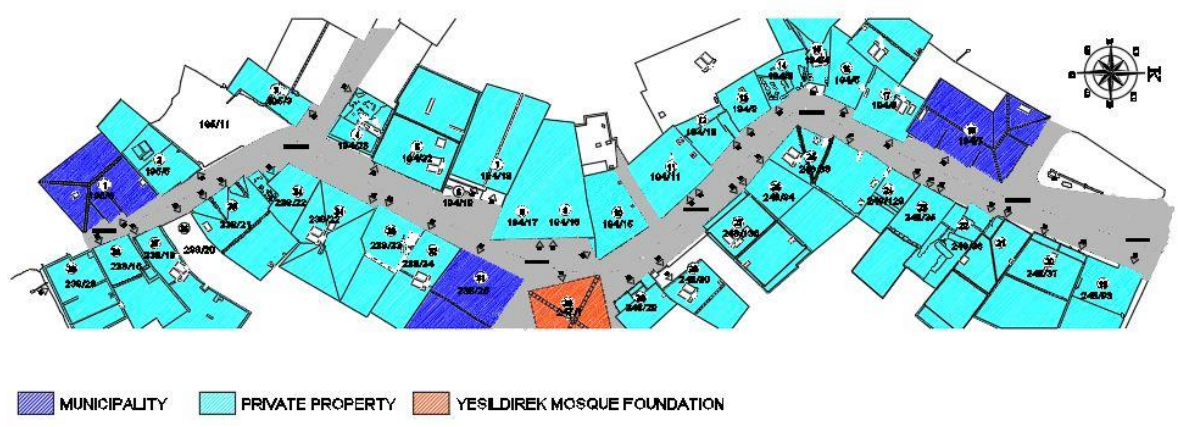


Figure 27 Land use on Yesildirek Street (ownership)

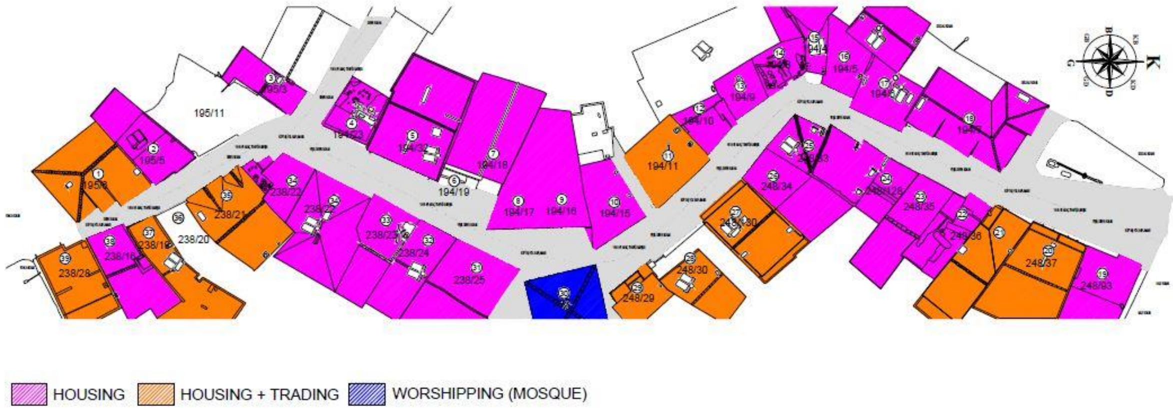


Figure 28 Land use on Yesildirek Street (function)

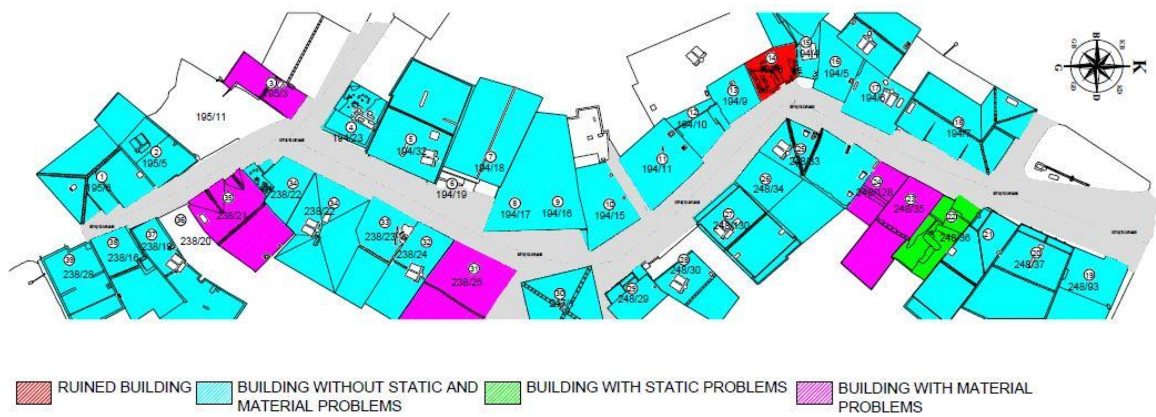


Figure 29 Physical structural situation

5 CONCLUSION

With the documentation, survey, analysis and damage assessment studies, the existing building stock and problems on Yeşildirek Street were revealed and a basis for restoration works was created.

The interventions for the protection of the buildings were evaluated within the framework of restoration principles and planned as cleaning, consolidation and completion of missing parts, if any. The original building components will be preserved and protected in line with these principles. It is important to raise the conservation awareness of property owners and users.

It will be possible to ensure a sustainable conservation by preserving the traditional materials and textures of the buildings, re-functioning them when necessary, increasing the technical comfort of the buildings, and bringing the street to tourism.

REFERENCES

[1] Zakar, L., Eyüpgiller, K.K., '*Mimari Restorasyon Koruma Teknik ve Yöntemleri*', Ömür Matbaacılık, İstanbul, 35-40,2015

[2] Ahunbay, Z., 'Rehabilitasyon', *Eczacıbaşı Sanat Ansiklopedisi*, YEM Yayınevi, İstanbul, 2008

[3] Güner vd., 'Sokak Sağlıklaştırma Proje Deneyimi; Kayseri-Talas Kazım Paşa Caddesi', *Online Journal of Art and Design*, volume 7, Issue 1, pp 184, January 2019.

Adobe Material, Sustainability, and Anatolian Heritage

Authors **Özlem Atalan**, Ecem Uğurlu.
Address Manisa Celal Bayar University,
Department of Architecture

E-Mail ozlem.atalan@cbu.edu.tr

ABSTRACT

In today's world, sustainability holds an increasingly significant role in the construction sector. In this context, the use of traditional and environmentally friendly materials is crucial for preserving natural resources and enhancing energy efficiency. Adobe, in this regard, stands out as a noteworthy material in sustainable architectural practices. Adobe is a natural building material obtained from a mixture of earth, water, and organic materials. The eco-friendly properties of this material form the foundation of sustainable construction. During the production process, adobe, often sourced from non-industrial, local resources, minimizes its carbon footprint, contributing to the sustainable utilization of natural resources.
The energy efficiency of adobe material is further highlighted by its ability to retain and radiate heat. These characteristics help balance indoor temperatures, reducing energy consumption and creating a positive impact on the environment. Additionally, adobe structures are designed to align with natural climatic conditions, minimizing their energy needs. The use of adobe in sustainable architecture also contributes to the local economy. The utilization of local materials and craftsmanship supports regional economies and empowers communities. Moreover, the maintenance and repair of adobe structures often rely on local skills, creating a sustainable employment sector.
Especially in Anatolia, adobe material has been utilized as an infill material in timber frame architecture, particularly in the inner and western regions of Anatolia. In this study, an investigation will be conducted into the context of sustainability and the use of adobe material in the inner and western regions of Anatolia, exploring its applications and areas of implementation.

Keywords: Sustainability, Adobe Material, Anatolian Traditional Houses

1 INTRODUCTION

Anatolian cities and towns symbolize an important culture. One of the important criteria that forms the identities of these settlements is traditional architecture. The most important factors in the development and design of vernacular and rural architecture in Anatolia have been environment, topography and climate data. During the Ottoman Empire, the environment, topography and climate conditions were evaluated by the local people and unique construction techniques and architecture were developed. However, what we can learn from the Ottoman housing heritage and local techniques does not go back much further, as no traditional housing older than the 17th century has survived. Cities, which are large residential areas in our country, are affected by changes very quickly and are losing their original qualities day by day. Traditional architecture, which is the building blocks of your cities, was formed in the historical process within the harmonious relationships that people established with nature.

Adobe brick has been an indispensable material of traditional residential architecture for centuries. This natural building material, obtained from a mixture of soil, water and organic materials, has been preferred in many cultures due to its durability, economy and environmentally friendly properties. Especially in Anatolia, mud brick houses are common in both rural and urban areas and form an important part of the region's cultural heritage. As the importance of sustainability and environmentally friendly materials increases in modern architecture, adobe is gaining popularity again. Today's architects and builders combine the advantages of adobe with modern techniques to build both environmentally friendly and aesthetically rich structures.

2 SUSTAINABILITY AND ADOBE MATERIAL

2.1. Adobe Material

Adobe is a building material obtained as a result of mixing and kneading suitable soil with additives such as straw and water, then shaping it and drying it in the open air. It has been a building material used since the transition to settled life due to its easy availability, easy shaping and adaptability to climatic conditions. In addition to being traditional and natural, it is an ecological material. It is economical, easy to produce, does not require energy for its production, does not harm the environment during/after the production process, and has a high thermal insulation value. [1] In addition to these features, thanks to its porous structure, it provides a healthy environment by maintaining the heat and humidity balance in the space [2]. Apart from all these advantages, it also has disadvantages such as its lack of water resistance.

The earliest examples of adobe material used since the Neolithic Age are found in Mesopotamia, Anatolia, Iran and the Mediterranean region [3]. Excavations at Çatalhöyük, Acemhöyük, Beycesultan, Hacılar, Kültepe and Norşuntepe in Anatolia revealed mudbrick walls over three meters high with or without beams. It was observed that the walls in these settlements were used in religious, military and civilian structures. [4].

3 ADOBE MATERIAL IN ANATOLIAN HERITAGE

3.1. The Use of Adobe in Anatolian Heritage

Since the first settlements; adobe material has been one of the main elements of building designs for reasons such as geography, climate and easy accessibility. Although ecological sustainability is not considered in the production of settlements with adobe material, it is said to contribute to social sustainability as it provides unity [5]. In this context, concepts such as the division of labor and cooperation required by living together have also enabled the growth and development of settlement production.

The first settlements in human history were seen in Anatolia during the Neolithic period. Çayönü, Çatalhöyük, Aşıklı Höyük are among the first settlements. In the following periods, mud-wall material was preferred and became a traditional building material due to its important features such as ease of use and accessibility. The productions of this local understanding of architecture can be seen in Anatolia.

3.1.1. Çayönü

Çayönü, dated to 8200-6000 BC, is located in the vicinity of present-day Diyarbakır. The settlement has an architectural approach that starts with simple huts with round plans and gradually develops into complex structures with stone foundations and mud-walls, and carries the first examples of mud- walls. (Fig. 1) The roofs are as remarkable as the houses in the settlement. The roofs are mostly flat and produced with adobe material and are generally designed in such a way that daylight can be utilized. [6].

Figure 30: Çayönü House [7]

3.1.2. Çatalhöyük

Çatalhöyük, dated to 6200-5200 BC, located near present-day Konya, has a regular city plan. It is known that the adjoining buildings were built with adobe and reed materials, and adobe access was provided by utilizing the swamps in the region. (Fig. 2, Fig.3) The residential buildings have wooden posts between the walls. With this feature, it is reminiscent of adobe housing designs in Anatolia [8]. The construction of the city with unified plans; as in Çayönü; enabled the inhabitants to work together and to engage in production.

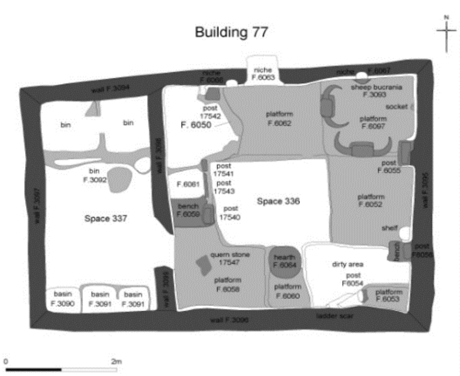


Figure 31: Çatalhöyük Houses Plan [9]

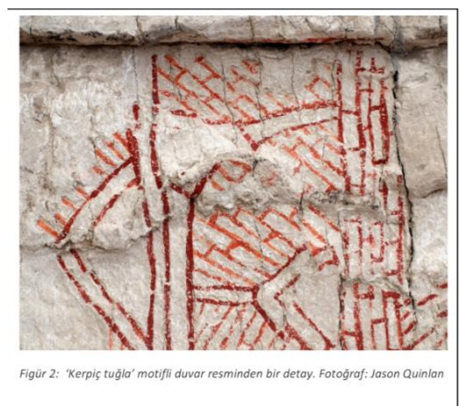


Figure 32: Mud-wall drawings at Çatalhöyük [9]

3.1.3. Aşıklı höyük

The settlement located in today's Aksaray province is dated between 8000-7500 BC. It is a settlement with dwellings in the north and public buildings in the south with a gravel road between them. There is a dense settlement texture in the residential area. Building groups are separated by narrow intervals or 0.7-1.0 m wide streets [10].

The important information on the architecture of Aşıklı Höyük, such as the honeycomb-like settlement layout, mud-wall dwelling architecture, and the continuity of use in buildings and open spaces, is also observed in other Neolithic settlements of Central Anatolia such as Çatalhöyük. (Fig.4) The mud-wall dwellings did not have doors opening to the outside, but were entered by means of a wooden staircase through a gap in the roof; the roof level was another living space and some houses had under-floor burials.

(Fig. 5) The finds in the south of the settlement indicate that this area housed buildings with special functions that were shared in accordance with the beliefs of the community [11].

Figure 33: Aşıklı Höyük Houses [12]

Figure 34: Aşıklı Höyük Houses [13]

3.1.4. Harran Houses

The houses of Şanlıurfa Harran in southeastern Anatolia are remarkable for their interconnectedness and conical domed roofs. The first examples were implemented about 260 years ago. These domes are about four meters high and have openings for ventilation at the top. They are also built on stone foundations, but the masonry system was used for the walls and roof covering, using stone, brick and adobe, and the surfaces were plastered with adobe. Kumbet houses are connected to each other through the rooms inside, and thanks to this feature and the thermal insulation of the material, the houses are more easily heated.(Fig 8., Fig 9.)

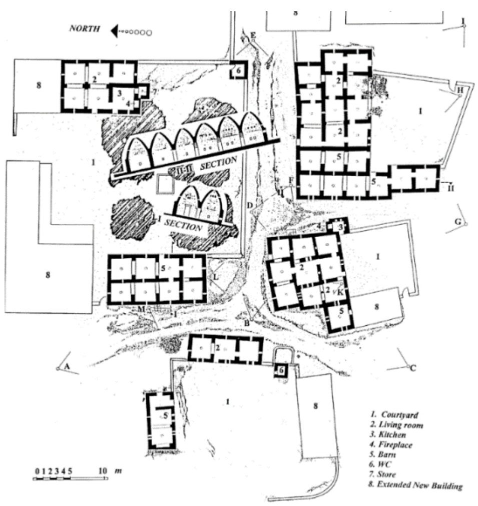


Figure 6: Plans of a typical Harran neighbourhood. [14**]**

Figure 7: Harran Houses [15]

3.1.5. Examples from Inner- Western Anatolia: Afyonkarahisar Houses

As civilizations developed, new construction techniques and skills were developed. Climatic differences have led to the formation of different architectural approaches. When we look at the adobe houses in Turkish traditional architecture in general, it is seen that they are built on a stone foundation with adobe walls and flat roofs. The mudbrick houses applied in different regions of Anatolia are characterized by may show differences. For example, in Afyon in Inner Western Anatolia, stone, adobe and wood materials are used together. While stone is used up to the flood level, the walls are filled with mudbrick between the wooden frame system in the building using the "hımış" construction technique and plastered over. (Fig. 8-9-10)

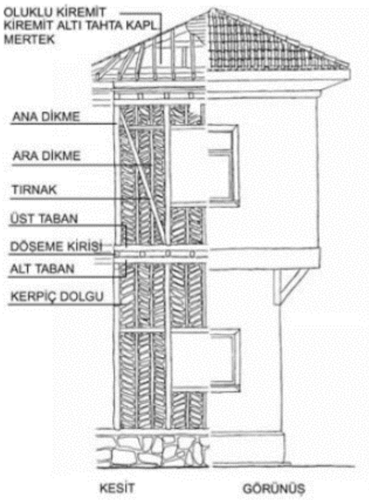


Figure 8: cross-section of a "hımış" structure [16] **Figure 9**: An Afyonkarahisar House [17]

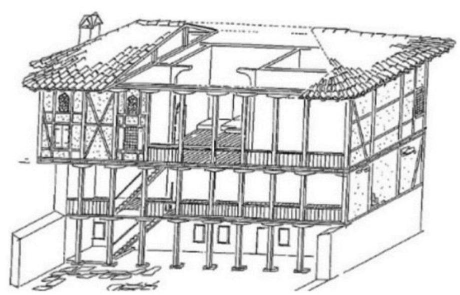


Figure 10: Kula- Manisa House [18]

3.2. Sustainability in Adobe Applications in Anatolian Heritage

Adobe is not only a building material in traditional architecture, but also a cultural symbol. Adobe houses in Anatolia were designed to adapt to the climate, topography and cultural characteristics of the region. The mud brick building material used in Anatolian traditional houses is adapted to the local climate. Adobe houses stay cool in the hot summer months and retain heat in the winter, making them very suitable from a climatic point of view. Adobe houses are built using traditional construction techniques and manual skills of the local people. This helps communities preserve their cultural heritage. At the same time, adobe offers a natural and warm aesthetic. Additionally, adobe buildings often reflect local architectural styles, making them compatible with the cultural and historical fabric of the region.

Since adobe is a natural building material obtained from the mixture of soil, water and organic materials, it has a great potential in terms of urban sustainability today. Adobe, which can contribute to both environmental, economic and social sustainability goals, is gaining value again in modern urban life.

3.2.1. Environmental Sustainability

Low Carbon Footprint: Since adobe is produced with natural materials obtained from local resources, it consumes low energy in the production process. This minimizes the carbon footprint and reduces environmental impacts in the construction industry.
Energy Efficiency: Adobe buildings increase energy efficiency thanks to their excellent thermal insulation properties. Their ability to keep cool in summer and warm in winter reduces energy consumption by reducing heating and cooling needs.
Use of Natural and Local Materials: Since adobe is generally made from local soil and organic materials, it saves energy in transportation and production processes. This contributes to the conservation of natural resources and environmental sustainability.

3.2.2. Economic Sustainability

Cost Effectiveness: Adobe is an economical building material because it is made from local and cheap materials. It reduces construction costs and provides greater access to affordable housing.
Contribution to the Local Economy: Adobe production and construction uses local labor and local resources. This supports the local economy and strengthens communities.

3.2.3. Social and Cultural Sustainability

Preservation of Cultural Heritage: Adobe buildings help preserve traditional construction techniques and cultural heritage. This helps communities keep their identities and histories alive.
Healthy Living Spaces: Since adobe is made of natural materials, it does not contain chemicals and provides healthy indoor environments. This improves the health and comfort of people living in cities.

3.3. Use of Adobe Adobe in Modern Urban Sustainability

The reintroduction of adobe in modern cities is a big step in terms of sustainable architecture and urban planning. When adobe is combined with modern building techniques and materials, both aesthetically rich and environmentally friendly structures can be built.
Green Buildings and Eco-Architecture: Adobe is an ideal material for building energy efficient and environmentally friendly structures that comply with green building standards. Adobe buildings built with an eco-architecture approach can play an important role in achieving urban sustainability goals.
Social Housing Projects: The fact that adobe is economical and easily accessible makes it attractive to use it in social housing projects. This can offer affordable and healthy living spaces for low-income families.
Revitalization of Cultural and Historical Areas: Adobe can also be used in restoration projects in historical and cultural areas. This both supports sustainable tourism and preserves cultural heritage.

4 CONCLUSION

Today, both in the world and in our country, the importance of historical buildings, urban texture and culture has been understood with the development of historical environmental awareness. For this reason, the decisions taken by the city for conservation purposes must be valid for the entire historical urban fabric. Keeping the historical environments of cities alive by integrating them with today's living conditions will make a significant contribution to the sustainability of the urban identity and culture. In Anatolia, approximately BC. Adobe material, which has been used since the 5000s until today, has provided healthy, economical and safe environments to its users in all processes in which it is used. The use of mud brick and various architectural space structures can be seen in the mud brick residential buildings in the archaeological areas of Çayönü, Çatal Höyük and Aşıklı Höyük, Şanlıurfa Harran local houses and Afyon Traditional Turkish houses, which are mentioned with examples within the scope of the article.

Houses with stone foundations and flat roofs with adobe bricks were built in Çayönü, which has the first examples of adobe material application. In Çatalhöyük, it was seen that it was a contiguous settlement and its materials were adobe and reed together, and sometimes its walls were supported by wooden pillars. An adjacent settlement with a flat roof was also provided in Aşıklı Höyük. As the ages progressed, the use of adobe materials continued, as seen in examples from Anatolia. The adobe material, which was mostly used with wooden pillars in the West, was used together with wood and adobe in the east and southeast. In traditional Turkish architecture, adobe was used as filling material in the wooden frame architectural structure system.

Considering the advantages of using adobe material in modern architecture, adobe can last for many years if made correctly and with regular maintenance. The fact that adobe houses have survived for centuries shows how durable the material is. Adobe brick has thermal insulation properties. Its ability to keep cool in summer and warm in winter saves energy and increases living comfort. Adobe buildings have a low carbon footprint. The materials used in its production and construction are completely natural and sourced from local sources, minimizing its environmental impact. Since adobe is generally made from local soil and materials, its cost is low. This makes adobe houses an affordable housing option. As a result, adobe has an important place in Anatolian cultural heritage and traditional residential architecture. Its durability, thermal insulation properties, environmentally friendly structure and economy make it a valuable building material today as in the past. While mud brick houses built with traditional methods contribute to the preservation of our cultural heritage, they continue to be a part of sustainable architecture with modern applications.

5 REFERENCES

[1] Leblebicier, E., Akıncı, A. (2021), Ecological New Generation Adobe. Bilim Armonisi Dergisi, 4 (2): 12-19. doi: 10.37215/bilar.827628
[2] Şimşek Tolacı S., Hürmüzlü B. (2020), Adobe and life in Isparta, SDÜ Publications, Ankara.
[3] Kafesçioğlu, R. (2017), Contemporary Building Material Soil and Alker, ITU Foundation Publications, İstanbul.
[4]Naumann, R. (1975), Eski Anatolian Architecture, Türk Tarih Kurumu Publications.
[5] Akbaş, M. F., Aslan M. and Arpacıoğlu, Ü. (2022). Adobe in the context of green material. Eksen Journal of Dokuz Eylul University Faculty of Architecture, 3(2), 72-88.Volume 3, Issue 2, Year 2022, 72-88
[6] Özdemir M., A Section from the Neolithic Period Anatolian Architecture: Çayönü, Journal of History and Future, December 2017, Volume 3, Issue 3,2017.
[7] https://worldarkeoloji.blogspot.com/2016/02/cayonu-hoyuk.html
[8] Uyanık,N. , Berk, F.M., Çatalhöyük Within the Context of Space-City and Civilization, ÇATALHÖYÜK International Journal of Tourism and Social Research Year: 2016, Issue: 16 Page: 1-16 ,2016.
[9] Çatalhöyük Research Project 2011 Season Excavatıon Report - A New Wall Painting Found at Çatalhöyük - Ian Hodder
[10] Harmankaya, E., Aşıklı (Esin, U. , S. Harmankaya, 1999 Neolithic İn Turkey, The Cradle Of Civilisation, New Discoveries, Istanbul, Yay. Haz. M. Özdoğan, N. Başgelen) 1999.
[11] Özbaşaran, M., Güneş D.,Teksöz D. Omacan S.,The Living Past: Aşıklı Höyük, TÜBA-KED 8/2010.
[12] https://tr.advisor.travel/poi/Asikli-Hoyuk-7714
[13] https://tr.wikipedia.org/wiki/Aşıklı_Höyük

[14] Özdeniz M.B. v.d, 1998, Vernacular domed houses of Harran, Turkey, Habitat InternationalVolume 22, Issue 4, December 1998, Pages 477-485
[15] https://www.trthaber.com/foto-galeri/manastir-vadisi-ziyaretcilerini-tarihte-yolculuga-cikariyor/36028/sayfa-1.html
[16] Tuztaşı, U.,Çobancıoğlu T. (2006), The Tradition of Adobe Use in Anatolia and Comparison of Adobe Housing Construction Systems, Journal of Tasarım + Kuram, 5.
[17] Kunduracı, O., Bahargülü N. (2018), Façade Desıgns In Tradıtıonal Afyonkarahısar Houses, SUTAD, Spring 2018; (43): 491-522.
[18] Kuban, Doğan, Türk Hayatlı Evi, Eren Yayınları, İstanbul 1995

The Assessment of Chronological Evolution of The Use of Earth-Based Building Materials In Traditional Architecture In Anatolia

Authors Özlem Karakul, Ömür Bakırer
Address Selçuk University, Middle East Technical University
E-Mail karakulozlem@gmail.com, obakirer@gmail.com

Abstract

From very early times, man has used the materials found in his vicinity and shaped them according to his needs. Building in brick shows a chronological evolution from the first primitive huts built in the Neolithic period to the later constructions. The process starts with the preparation of the clay to be used as the raw material, first used as mud smeared on reeds and followed by forming mud brick units, drying and later firing the units to form burnt or fired brick. There is a chronological evolution. In all times, man has manufactured mudbrick and brick in sizes and forms designated according to his own needs, which brings varieties dependent on time and geography.

Earth-based materials have been used for centuries in Anatolian traditional residential architecture, both as a building material within the building culture, specifically, mud brick and brick, and in the construction of tools, equipment, and objects necessary for the implementation of cultural practices reflecting the culture of living. The conservation of earth-based materials in traditional architecture, depending on the way it is used, is included in the discussions on the protection of both tangible and intangible cultural heritage and requires different conservation methods in different aspects.

Recent years have seen a noticeable increase in the amount of research on the use of local construction materials in new building design, as well as a rise in the prominence of traditional building methods, notably earthen architecture, in talks on sustainability. The use of adobe building materials and techniques in new construction, along with the rising body of study on the subject, has created concerns about ecological architecture and sustainability. This paper will cover the chronological evolution of earth-based building materials by investigating first the beginnings of the use of mud brick in Anatolia during the Neolithic period and second its use in recent times.

Keywords: earth-based materials, mud-brick, brick, traditional architecture, Anatolia

1 INTRODUCTION

From early times, man has used the materials found in his vicinity and handled them according to his immediate needs, for constructing dwellings. Earth-based materials, with their easy availability from riverbeds and the reeds coming from the same source, had a priority, as they made a good duo. Examples of such dwellings are not recovered in Anatolia but, the next step when clay was shaped by like bread and turned into mudbrick units was abundant in the Neolithic settlements of Anatolia, from ca. 8000 -7000 BC on. Özdoğan (1999: 9-12), considers the production of mudbrick together with farming and raising grains for making bread, as a revolution that marks the beginning of the Neolithic period.[21]

The material for mudbrick or brick does not occur in nature. It is found in nature as clay, and it must be prepared, therefore, mudbrick is the first material that man has produced and used for different. purposes. Starting with finding suitable clay as the raw material, preparing it by kneading and adding straw if needed, forming, drying, and using it with mud mortar for building, making figurines with ritual practices and making hand-built pottery designated for everyday use. Examples of all these practices are recorded in Egypt, Mesopotamia, the Levant, and in the Neolithic settlements in Anatolia with Çatalhöyük and Hacılar coming first (Lloyd, 1973: 456-462; Frankfort: 1951: 2 ; Mellaart, 1965 : 13 ; Hodges, 1970: 30, Kuban 1973, 27).[22]

After around 3000 BC firing began first in Egypt and Mesopotamia, then in Anatolia. Firing the mudbrick units converted them to fired or burnt brick, much stronger for building but costly because firing needed fuel and appropriate facilities, like open-air fires or furnaces, for the process. Throughout history, the same manufacturing steps were followed. It was possible to change its properties only according to current needs, according to geological conditions that brought varieties to the properties of the raw material, according to current manufacturing technologies etc[23].

Even today the basic materials and basic production steps have not changed much. However, the evolution of mechanization has affected the quality of the end product on the good side and sped up the production cycle. However, in small villages and primitive societies, the old traditional process is still followed. The steps followed can be summarized as:

Choosing the appropriate soil → sifting the soil and cleaning the impurities in it, → mixing it with water, to turn it into a soft workable condition and kneading it to a plastic consistency → forming mudbrick/adobe units by hand, → molding, in later years forming in wooden molds →drying in the open air, in a shaded area → using the units in the construction of shelters after drying → turning mudbrick units into bricks by firing → using brick units as cladding on mudbrick walls in large sized buildings → using brick units alone in large sized structures → hiding brick surfaces behind coating materials of different qualities → using brick surfaces on their own without coating material→ hiding brick surfaces behind different materials once more. In these surface coatings, a series of chronological developments can be traced to our time.

Yet it can be stated that the basic steps for preparation have not changed, but there are differences in product qualities in parallel with technological developments.

[21] The beginning of farming, of growing grains and mudbrick production is the beginning of the Neolithic era which also marks a climatic change.

[22] In Egypt, Mesopotamia, Anatolia and Syria, houses are made of mudbricks. Although there are suitable building stones in the Nile valley, mud bricks were used for residences when the use of stone was taken under state control in early history. The scarcity of stone and brick in the northern Mesopotamia and Iraqi plateau ensured the longevity of the use of mud bricks and bricks. They produced adobe bricks in the dimensions of 20x40x3-4. In Anatolia, starting from 7000 BC, mud brick wall technique with wooden beams is seen on stone foundations in dwellings.

[23] Today, in the production of bricks and similar building materials with earthen building materials, suitable soil types are prepared, by adding the necessary elements, if the clay lacks them, according to the results of laboratory studies. The use of well-equipped production machines, rather than human labor at every stage, are at the forefront, but the steps followed are still the same.

2 MUDBRICK IN NEOLITHIC SETTLEMENTS IN ANATOLIA

Ufuk Esin stated that around 13.000 BC human communities in Antolia and in the south-west of Asia began to establish small villages. This early period, when pottery production had not yet begun, is called "aceramic neolithic" or PPN (Pre-Pottery Neolithic**).** These small communities gradually developed in the following 3000 years and flourished into cultural communities named as Neolithic. The transition to fully settled life and the beginning of agriculture, beginning of Adobe / Mudbrick and pottery production are dated between 11,000-8.000 BC.

Özdoğan, Braidwood and some others call this the "neolithic revolution" and consider its beginnings of agriculture, pottery and mudbrick production, to the middle of the period. Özdoğan describes this progression as "Neolithic is not a chronological period, but a period in which living conditions and cultural characteristics changed with climate changes. Agriculture began to be made by using local seeds and animals were domesticated. It is defined as showing the technological development of people" (Özdoğan, 1999), [24]According to researchers, Neolithic culture began around 9500–9000 BC in the Jericho/Jericho settlement of the Levant, near the Jordan River, and spread to Anatolia through Egypt and North Africa.

In recent years, Göbekli Tepe, Nevali Çori, Hallan Çemi, Karahan Tepe, and many early settlements in Urfa region has contributed to the region's history being pushed back to an earlier date, around 10,000 – 11.000 BC. However, due to the geological structure of the region around Urfa, the use of earthen building materials is not found in Göbekli Tepe and the surrounding settlements. The use of earthen materials, thus mudbrick is recovered in Çayönü, Norşuntepe, Arslantepe a little further north, and then in Central and Western Anatolia around 7000 BC.

In Central Anatolia, the use of Mudbrick starts in the settlements of Çatalhöyük in the Konya Plain and Hacılar near Burdur. These were retrieved in excavations as well-established villages, that could be studied both for their house plans and the materials used in their construction. In a short time, the following sites flourished altogether announcing the importance of Anatolia for the Neolithic Period (Lloyd, L and Rice D.S, 1973: 457).

In the Çatalhöyük West mound, and Hacılar archaeological excavations were carried out by James Mellart between 1950 and 1957, where the houses recovered on stone foundations in the early and later layers allow to determine differences in house plans and the materials used for their construction (Mellart, 1962, 41-65; Mellart, 1963, 43-103; Mellart, 1967).In these multi-layered villages, mud-brick units have turned into bricks, because of fires and, this way they provide information on their sizes and the method of construction.

In Çatalhöyük West, it was disclosed that the mud-brick wall structure with wooden tie beams was covered with mud mortar, followed by white earthen plaster. On this plastered background, symbolic depictions of the animals they hunted or those that were around them and, most importantly a city panorama were painted with red ochre on the plaster.[25] The best information about Çatalhöyük is the Çatalhöyük East site, which was excavated, researched, and published by Ian Hodder for twenty-five years starting in 1999.

[24] In the Neolithic period there were climatic changes. The beginning of farming is perhaps related to these. The manufacture and use of pottery is also at the same time.
[25] These wall paintings were transferred from the original walls to the Museum of Anatolian Civilizations in Ankara, where they are exhibited within the context of reconstructed Neolithic huts or installed on the walls.

Figure 1. (left) Çatalhöyük excavation site (Source: Ömür Bakırer Archive); **(right)** Wall paintings from Çatalhöyük (Source: Ömür Bakırer Archive).

3 THE CONTINUITY OF THE ADOBE BUILDING TRADITION IN TRADITIONAL ARCHITECTURE IN ANATOLIA

The adobe building tradition is still maintained throughout the construction process of Anatolian traditional dwellings. Within the scope of this study, two rural settlements where this tradition continues, the application process of the mudbrick construction system today, the knowledge and techniques, materials and tools used by the local craftsmen and people are selected to be investigated.

The fieldwork was carried out in two rural settlements in Kazan district of Ankara and Hüyük district of Konya where mudbrick construction culture is continued today. Because they preserve their authenticity, two villages in each settlement, with traditional buildings constructed using the mudbrick construction technique, were chosen for field study. The traditional buildings in Çavuş Village in Hüyük District and Fethiye Village in Kazan District are densely built, and their continued use of mudbrick construction makes them worthy of analysis. The mudbrick building tradition has mainly been maintained in terms of maintenance and decoration practices today.

3.1 Adobe Building Tradition in Çavuş Village in Konya/Konya's Rural Settlements

Konya, which has been the settlement area of different civilizations in Anatolia since ancient times, offers a rich architectural diversity formed by the interaction of different cultures. Çatalhöyük, whose settlement dates to 7200 BC, also contains early examples of flat earth-roofed houses built with mudbrick masonry technique (Human, 2016: 301). In Konya, which was the capital city during the Seljuk Period, traditional residential architecture has been constructed mostly with mudbrick masonry walls and earth roofs since that period (Arseven, 1952: 2078). In rural settlements in Konya and its immediate surroundings, traditional dwellings were built with stone masonry or mudbrick masonry technique, which has been widely used in Anatolia since the Hittites, depending on the material possibilities available in the region (Karakul, 2023:93).

Çatalhöyük also includes early examples of wall paintings that people applied for decoration by reflecting their cultural and religious symbols. The history of wall painting, which is stated to date back to the Roman Period in Central Anatolia, literally begins with the pictures in the traditional houses in Çatalhöyük, a

Neolithic Period settlement (Hodder and Meskell, 2010). In the production of the wall paintings in Çatalhöyük Houses, using red, pink, brown, white, and black colors on dirty beige adobe plaster, plain painted panels, single or multicolored geometric decorations, symbolic motifs such as flowers, stars, and circles, as well as the depictions on different themes have been made. The murals depicting wild animals, human shapes, hunting scenes, landscape and settlement paintings, and geometric designs represent the first examples of prehistoric wall paintings. The wall painting tradition that emerged in Çatalhöyük has still been continued by peasant women in the Hüyük district as a part of the decoration practices.

Hüyük is a district center located on the west and 96 km away from Konya. Hüyük District shows similar settlement and architectural features due to its proximity to Beyşehir District (Karakul, 2019, 67). Çavuş and Değirmenaltı Villages, where the studies were carried out, are rural settlements of Hüyük District of Konya, containing traditional dwellings with similar characteristics in architectural and building tradition. In Çavuş and Değirmenaltı villages of Hüyük district, traditional houses are built as single or two stories, mostly mudbrick masonry walls connected with wooden beams on the stone water basin level, closed covered wooden beams on the roof and finished with packed earth.

The building masters of earthen architecture construct adobe masonry walls using mudbrick blocks as construction materials and earth and mortar mixtures as binder materials after digging the foundation pit. Adobe is formed by mixing soil with an organic binder material, such as hay or animal hair, to form blocks that are then dried in the sun. The process of making adobe blocks is divided into three stages: sludge preparation, molding-cutting-casting, and drying.

The external walls of traditional adobe buildings are usually constructed by the stone masonry technique up to 50–60 cm height from the ground level. While building the mudbrick walls, the large blocks and small blocks are placed side by side and the gaps between them are filled with mud mixed with the fragments of mud bricks. The wall thicknesses are generally 60 cm, consisting of a main and two small adobe blocks and an air gap, and the inner walls are 40 cm with a main and a small adobe block. During the construction of the mudbrick walls, the main and small blocks are placed side by side and the gaps between them are filled with mud mixed with mud bricks. Mud mortar mixed with mud-brick fragments ensures that the mudbrick blocks are 'welded', in the words of the craftsmen, that is, they are joined together solidly. Pulling the rope at the corners ensures that the masonry is smooth. The wooden beams are 10 × 15 cm above the windows and 10 × 10 cm or 5 × 10 cm under the floor beams, usually made of poplar wood, rarely juniper or pine wood. They are usually used in the same regions and called '*palastır*'.

In Hüyük district and its immediate surroundings, especially in two-story buildings, many building examples in which the adobe masonry system is supported by wooden pillars, called *'çelen ağacı'* or *'direk'*, 15, 18, or 30 cm thick, depending on the beam thickness, under the wooden beams are also seen. According to what the masters say, these pillars hidden inside the wall ensure that the structures are resistant to earthquakes.

Women, who are the practitioners of the maintenance and decoration tradition that starts after the completion of the traditional house-building process by the building masters, are important for the protection and maintenance of intangible cultural heritage in terms of the materials, tools, and techniques they use.

The tradition of mural painting in the Neolithic Period in Çatalhöyük settlement in Konya and its immediate vicinity, despite the variations in the motifs and symbolic meanings, has continued in the building tradition of Çavuş and Değirmenaltı (Karakul, 2023:93). The decoration practices examined in this study have shown the process of applying different patterns and motifs made by using plaster and paint on the wall surfaces of the peasant women by using different tools and techniques.

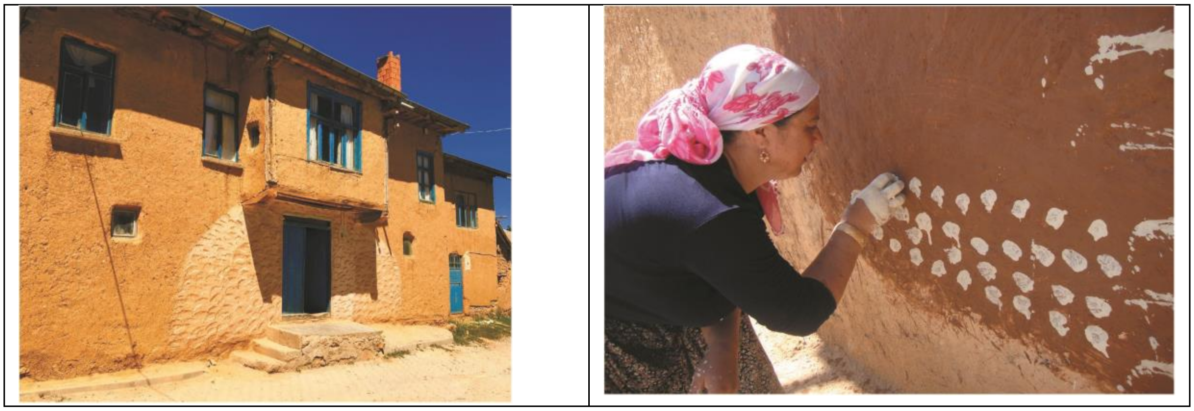


Figure 2. (left) The earth-based patterns around the main entrance door of a traditional building in Hüyük (Source: Cüneyd Ülvan Archive); **(right)** Finger-pressing technique carried out by a peasant woman (Source: Cüneyd Ülvan Archive).

3.2 Adobe Building Tradition in Fethiye Village in Ankara/Ankara's Rural Settlements

The traditional houses in Fethiye Village were built with the mudbrick masonry technique, which has been widely used in Anatolia since the Hittites. As in rural Ankara, where wood is scarce, traditional houses in Fethiye Village are constructed with one or two stories with mudbrick masonry walls connected with wooden beams on the stone flood level, covered with wooden beams on the roof, and covered with soil (Karakul, Şahin-Güçhan, 2022; Karakul, Şahin-Güçhan, 2016). The construction process is carried out by local building masons, also known as *dülger*, who are known to have built houses in the neighborhood or nearby provinces and by teams of at most 4-5 people working together. Before starting the construction, the master meets with the house owner, designs the structure, and calculates the required materials. If desired, he would provide the material to be used or buy it from the owner and wait for it to be ready before the construction season. After the materials were procured and work started at the beginning of summer, when the rough construction of the house reached a certain point, an order was placed with a carpenter in the region for architectural elements such as cabinets, doors, and windows to be used in the building.

Adobe is obtained by mixing soil with organic binding material such as straw or animal hair and drying it in blocks in the sun. However, not all soils are suitable for adobe construction. Clay soil that can turn into loam is preferred for mudbrick construction. Therefore, the soil suitable for this purpose is selected in each region and used in the production of adobe blocks.

Adobe production, which consists of three stages: mud preparation, molding, cutting, and drying, is usually carried out in May and June, and the construction process usually starts in July. To prepare the mud for mudbrick construction, straw, and water are added to the transported soil suitable for mudbrick construction and mixed until it becomes viscous and left for a day for it to thicken. Adding straw to the mud prevents or minimizes the cracking of the adobe during drying. The next day, the mud was poured one by one into wooden molds of the desired size and left to dry overnight. According to the information obtained from local people, adobe cutting was carried out using wooden molds prepared in four compartments to produce two main and two lamb adobe blocks at a time. Adobe cutting was carried out by mobile cutting teams consisting of a master with his wooden molds and several laborers.

In the houses in Fethiye village, the dimensions of the large unit called the main unit are generally 12x25x38 cm or 12x 29x 35 cm, while the lambs, which are half of the main unit, are narrower in width and their dimensions are 12x 14x 35 cm. The wooden molds used for cutting mudbrick are mostly made of resinous pine wood with interlocking joints; their inner surfaces are grated and oiled and their corners are rounded to ensure that the mudbrick can be easily removed from them (Kömürcüoğlu, 1962, 42).

The wall thickness of traditional houses in Fethiye Village is generally 60 cm in adobe and stone walls. Wall thickness provides resistance to climatic conditions, heat, and cold, and allows the interior to retain heat. Two different-sized blocks called mother and lamb are used in adobe walls. When the wall is built, care is taken to ensure that the main and lamb block joints do not overlap both horizontally and vertically.

As in the mudbrick houses in the villages around Ankara, the binding material used in the stone and mudbrick walls of the houses in Fethiye Village is almost always earth mortar. While preparing the plaster in Fethiye Village, unlike mortar, the clay is sieved, and fine straw is added to it. The mixture, which turns into a slurry, is applied as a thin layer on the wall surface with soaked rags (cotton cloth). Clay plaster or mud plaster should be renewed at least once a year to maintain its durability. Renovation of earth plaster is usually the work of women in the village.

4 CONCLUSIONS

Adobe is the most widely used building material in the world and in our country with its heat retention and storage capacity and thermal insulation properties (Kömürcüoğlu, 1962: 13). Contrary to popular belief, adobe is not limited to traditional buildings but is also used in modern buildings, especially in ecological designs based on local materials (Minke, 2006: 52). In recent years, earth-based materials have regained importance in sustainability discussions and the number of studies on their use in new buildings has increased.

The tradition of mudbrick construction has been continued in Anatolia since the Neolithic period. The rural settlements in Konya and Ankara and its immediate surroundings are important sources of information for the knowledge and understanding of the rapidly dying rural architectural tradition with both their architecture and the mudbrick architectural construction technique that still exists. The preservation of the rural building tradition and not forgetting the building tradition of the region is very important for the cultural history of Konya and Ankara. In addition, understanding the ways of using the soil in the building tradition is important in terms of drawing lessons for sustainability in today's architecture. In this context, it is necessary to increase the number of similar studies and to document and evaluate the information about Konya's rural building tradition in order to be transferred to future generations.

5 REFERENCES

Arseven, C. E. *Sanat Ansiklopedisi*. İstanbul: Maarif Matbaası, p.2078, 1952.

Briggs, M.S. 'Building Construction', *History of Technology* (ed. Singer, Holmyard,Hall), Oxford Clarendon Press, 1954-58.

Hodges, H., *Technology in the Ancient World*, New York, Knopf. 1970.

Hodges, *Artifacts: an Introduction to PrimitiveTechnology*, New York, Praeger. 1964.

Hodder, I., and Meskell, L. 'The Symbolism of Çatalhöyük in Its Regional Context', In *Religion in the Emergence of Civilization: Çatalhöyük as a Case Study,* Ed. Ian Hodder, New York: Cambridge University Press, pp., 32–72., 2010.

Human, H. "Neolithic Site of Çatalhöyük". Unesco World Heritage in Turkey 2016, Ed. Nevra Ertürk, Özlem Karakul, Ankara: Grafiker Ltd.Şti., p. 301, 2016.

Karakul, Ö. 'Traditional Earthen Architecture: Konya, a Case Study of Intangible Heritage and Local Building Practice', *The Historic Environment: Policy & Practice*, 14:1, 87-111, 2023.

Karakul, Ö. 'Ornament in Adobe Architecture (Kerpiç Mimaride Bezeme)', *Yapı Dergisi*, Yapı Endüstri Merkezi, 447, 64-71, 2019.

Karakul, Ö., Şahin-Güçhan, N. 'Ankara kırsalında geleneksel konutların yapım tekniklerine bir örnek: Fethiye Köyü-Kazan', IV. Uluslararası Halk Kültürü Sempozyumu, 29 Eylül- 1 Ekim, Kazan, Ankara, 2016.

Karakul, Ö., Şahin-Güçhan, N. *Dört Usta Dört Yapı: Ankara ve Yakın Çevresinde Geleneksel Konut*, Vehbi Koç Ankara Araştırmaları Uygulama ve Araştırma Merkezi, Koç Üniversitesi Yayınları. 2022.

Kömürcüoğlu, E.*Yapı Malzemesi Olarak Kerpiç ve Kerpiç İnşaat Sistemleri*, İstanbul: Teknik Üniversitesi Matbaası. 1962.

Kuban D. *Mimarlık Kavramları*, İstanbul, Yapı Endüstri Merkezi (3.baskı), 1990.

Lloyd, S. 'Building in Brick and Stone', *History of Technology*, (ed.Singer, Holmyard,Hall). Oxford Clarendon Press. 1954-56.

Mellart, J., Excavations at Çatal Höyük, First Preliminary Report, *Anatolian Studies*,12, 41-65, 1962.

Mellart, J., Excavations at Çatal Höyük, First Preliminary Report, *Anatolian Studies*, 13, 43-103, 1963.

Mellart, J., *Çatal Höyük a Neolithic Town in Anatolia*, London, Thames and Hudson, 1967.

Mellaart, J., *Excavations at Hacılar*, Edinbourg, University Press, 1970.

Minke, G., *Building with Earth| Design and Technology of a Sustainable Architecture*, Birkhäuser – Publishers for Architecture, Boston, p.52, 2006.

Özdoğan, M. *Neolithic in Turkey,* Arkeoloji ve Sanat Yayınları, İstanbul, 9-12.,1999.

A Case Study on Environmental Degradation, Conservation Methods and Sustainability in Adobe Buildings

Penbegül Öztürk

pgl.mimarlik@gmail.com

ABSTRACT

Adobe is known as one of the oldest building materials used by many civilizations throughout history to meet the need for shelter. In recent years, increasing environmental awareness and the need for sustainability have revitalized interest in traditional building materials. In this direction, adobe responds to these needs with its local material, harmony with nature and low energy consumption. However, various deterioration can occur over time in the buildings where this natural building material is used. In this study, environmental factors affecting the sustainability of adobe buildings, common types of deterioration in adobe buildings and conservation measures that can be taken to prevent or repair these deterioration are emphasized. Thus, it is aimed to draw attention to the protection of existing mudbrick buildings and to take these issues into consideration in new mudbrick buildings. In this direction, structural improvements, regular maintenance and repair methods are examined in order to increase the sustainability of adobe buildings until today with the literature review method. In the light of the data obtained, the environmental resistance of the mudbrick structures of Kayseri Zile settlement determined within the scope of the study is evaluated and strategies are proposed to increase this resistance.

Keywords: Adobe building, Alker, Conservation methods, Sustainable material

INTRODUCTION

Today, with the efforts to reduce environmental impacts and increase energy efficiency, interest in sustainable building materials such as adobe is increasing.

Thanks to this growing interest, traditional materials such as adobe are back on the agenda. Adobe buildings offer sustainable advantages in ecological, economic and social terms. However, the sustainability of adobe structures can be affected by environmental factors. Major impacts include climate changes, water exposure and poor maintenance. Temperature differences, heavy rainfall, high humidity, lack of maintenance and improper practices can reduce the durability of adobe material. To solve these problems, it is important to carefully analyze environmental factors and take measures to mitigate negative effects.

1. Sustainability of Adobe Buildings

1.1. Definition and Historical Development of Adobe Buildings

Adobe is a building material obtained by mixing water, clay, straw and sometimes other organic materials. Molded and sun-dried into bricks, adobe is used in building construction. Adobe, which is the basic building material of many civilizations such as Mesopotamia, Egypt and Anatolia, has been shaped according to local climatic conditions and material availability from past to present, and traditional techniques have developed over the centuries with the experiences gained. In today's search for sustainable building materials, it draws attention with its locality and low energy requirement.

1.2. Sustainability Concept and Adobe Buildings

Sustainability is the ability to exist and develop without depleting natural resources for future generations **[1]**. Accordingly, sustainability in buildings aims to minimize environmental, economic and social impacts **[2]**. Since adobe buildings are built with local materials, they provide energy savings in transportation and production processes. In addition, it makes significant contributions to the sustainable building concept with its features such as recyclability, low carbon emission, proper moisture, heat and sound insulation provided by its thick walls.

However, this natural building material may be subject to various deterioration over time. Therefore, the sustainability of adobe buildings may vary depending on various environmental conditions such as climate, exposure to water and wind. Precautions against such environmental factors and regular maintenance ensure the longevity of these structures and minimize their environmental impact.

2. Environmental Factors and Their Effects on Adobe Buildings

Adobe buildings are an important part of historical and cultural heritage and have a special place among sustainable building materials. However, their preservation requires regular maintenance, proper restoration techniques and careful management of environmental impacts **[3]**. Adobe structures may deteriorate over time as a result of natural processes and human activities. These deteriorations can be caused by physical, chemical and biological factors.

2.1. Physical Deterioration

Climate is the environmental factor that has the primary influence on physical deterioration affecting the sustainability and durability of adobe structures. Variable temperature conditions, humidity, wind effect and amount of precipitation to which the adobe structure is exposed can affect the life of the structure. Fluctuations in temperatures and extreme heat can cause expansion and contraction of the adobe material and subsequent cracking. In regions with high rainfall, rainwater can penetrate into the adobe material and disrupt its integrity, causing disintegration and structural damage by erosion. Wind effect is another factor that causes erosion on adobe surfaces. In addition, high humidity can prolong the evaporation process inside the mudbrick walls, causing the structure to remain damp, and dampness can cause the straw and organic fibers in the mudbrick to rot. Walls exposed to sunlight are more likely to freeze and thaw due to faster cooling in overcast and cold weather, and crack formation accelerates in these areas (Figure 1).

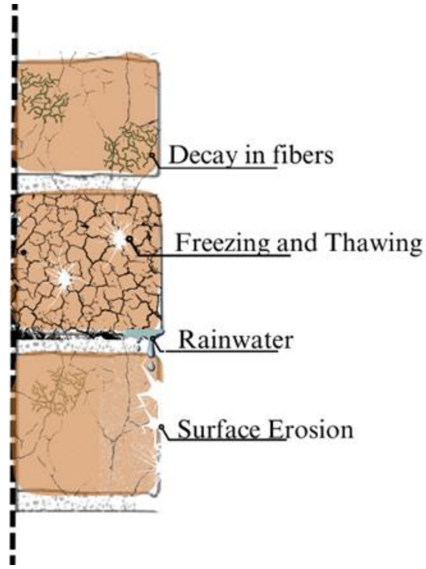


Figure 1: Physical deterioration of a wall built with traditional adobe blocks.

The weakest aspect of adobe material is its sensitivity to water. Water penetrating into the material, salty water causing chemical reactions and erosion cause deterioration in adobe structures. The contact of water with adobe surfaces in stream beds, flood zones or areas with heavy rainfall can cause major damage to the structure and collapse of the walls. In addition, moisture originating from the ground is drawn into the adobe material with the effect of capillarity and reduces its strength (Figure 2).

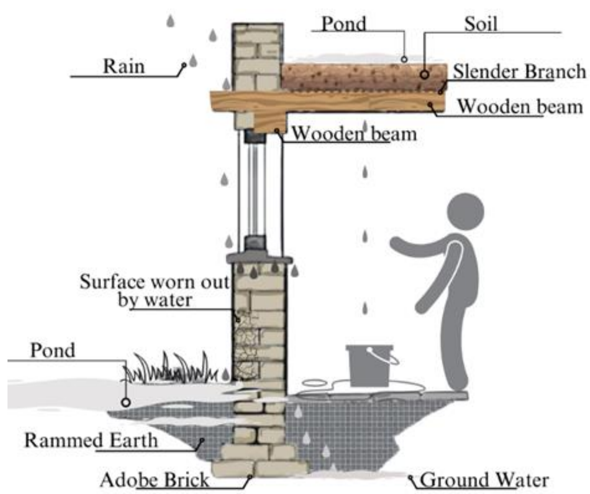


Figure 2: Structural and climatic deterioration of an adobe structure built with traditional methods.
Earthquakes and other seismic activities can also cause serious damage to adobe structures.

2.2. Chemical Degradation

Another important factor affecting the durability of adobe structures is chemical deterioration. Salt accumulation, acid rain and pollutants in the air weaken the structure of adobe **[4]**. When the water absorbed into the adobe material evaporates, chemicals such as lime, sulfate and chloride are deposited on the surface of the adobe material, causing salt crystals to form. These crystals create tensions in the adobe structure over time and cause the material to crack and disintegrate.

2.3. Biological Degradation

The deterioration of adobe structures due to biological factors such as plant roots, insects and microorganisms is characterized as biological deterioration **[5]**. Plant roots weaken adobe walls and jeopardize structural integrity. In particular, insects such as ants can create cavities in mudbrick structures and greatly damage the durability of the structure. Microorganisms such as fungus and mold, caused by moisture, can multiply rapidly in adobe structures and cause the material to deteriorate. Such biological deterioration shortens the life of the structures.

2.4. Lack of Maintenance and Improper Intervention

Adobe buildings built with traditional methods can survive as long as they are lived in and regularly maintained. Although necessary precautions are taken in consideration of local climatic conditions and the special conditions of the location, the material and construction technique require maintenance and protection. Stresses caused by rain, wind or soil movements, as well as earthquakes, can cause cracks and even collapse in mudbrick walls. Improper repair, lack of maintenance and intervention to the structure can be listed as other issues that cause the deterioration of mudbrick structures. The lack of maintenance of roof formations and the lack of an eaves solution to remove rainwater from the building facade are other reasons that cause damage to the structure. In addition, wall and foundation damages may occur as a result of the splashing of water puddles originating from the foundation and on the ground.

3. Case Study: Adobe Buildings in Zile Region

With the study conducted for the sustainability of the mudbrick structures located in the Zile settlement area of Develi District of Kayseri city, it is aimed to show how environmental factors have an impact on these structures and to evaluate how the structures can be protected by preventing these effects.
The town, known as "West Shamiya" during the Sumerian period and "Zela" during the Roman period, has a historical importance as it is located at the intersection of important trade routes such as the King's Road and the Silk Road. Zile was originally a village, but it was elevated to municipality status. The healing water source known as "Acı Su" in the region is approved by the Ministry of Health. Zile has archaeological remains from Roman and earlier civilizations and was one of the important religious centers of Greek settlers before the Ottoman Empire. Turks and Greeks have lived together since the Seljuk conquests and created a rich cultural heritage. As a result of the population exchange, the Greeks migrated to Greece. The population of the town is approximately 1,500 and reaches up to 3,000 in the summer months (Figure 3) **[6]**.

Figure 3: Location of Kayseri Zile Campus **[7]**.

3.1. Climate and Geographical Conditions of the Region

The effects of continental climate are evident in Develi and Zile regions. While the summer season is generally hot and dry, cold and snowfall is common in the winter months. Precipitation is mostly experienced in spring and fall. During the clear days of these transition seasons, frost and frost are common, which can have negative impacts on agricultural activities and existing mudbrick structures. Steppe vegetation is widespread in the region. The prevailing wind direction is generally north and south and wind erosion is experienced.

3.2. Condition of Structures and Environmental Impacts

The observations made on the mudbrick buildings in Zile reveal how environmental factors affect the condition of the buildings. The investigations on the structures include the following findings:

- **Cracks and Damages in Walls**: Cracks and damages observed in buildings are caused by temperature differences, rain, wind, humidity, earthquake effects, soil movements and settlements (Figure 4).

Figure 4: Cracks and damages on mudbrick walls, Zile.

- **Water Erosion:** Damages due to water erosion were observed on the foundations, lower walls, windowsills and roof sections of the buildings. Although the building in Figure 5 is an example of a well-maintained adobe building, water damage was observed at the corners where the roof eaves were insufficient.

Figure 5: Water damage observed in mudbrick structure, Zile.

- **Efflorescence Problem:** The deterioration of interior and exterior wall surfaces in buildings due to efflorescence is noteworthy. Water penetrating the exterior walls dissolves salts in the wall cross-section and these salts crystallize on the inner and outer surfaces of the wall during drying. This is called "efflorescence" and as a result of efflorescence, damages such as plaster cracks, blistering, paint flaking occur (Figure 6) **[8]**.

Figure 6: Damage caused by efflorescence on adobe structure, Zile.

- **Wind Erosion:** Wind erosion caused by the prevailing wind due to the effect of water erosion was observed on the surfaces of the buildings. As a result of these effects, it is seen that the plaster on the façade of the sample building in Figure 7 has disappeared and the mudbrick blocks have eroded.

Figure 7: Damage caused by wind and rain erosion on mudbrick building, Zile.

- **Roof Problems:** The biggest problems seen in the buildings are caused by incorrect roof solutions. The application of metal sheet covering on the mudbrick structures, which were originally built as earth roofs, or the roofs with insufficient eaves overhangs did not provide a solution. Rain gutters were not considered in some places and left as free dripping or not transferred to the ground with rain downpipes, especially in buildings with insufficient eaves overhangs, causing rainwater-induced facade damages (Figure 8).

Figure 8: Roof damage to adobe structure, Zile.

- **Foundation Problems:** In some buildings, it was observed that the integrity of the structure was disrupted and collapses occurred as a result of the foundation being buried in the soil over time due to earthquake, soil movement or ground water effect (Figure 9).

Figure 9: Damage to adobe structure caused by foundation, Zile.

- **Lack of Maintenance:** It was determined that most of the buildings were not regularly maintained and therefore deteriorated rapidly. Especially the abandoned and uninhabited buildings are not only affected by climatic factors, but also the interior has been damaged to a great extent (Figure 10).

Figure 10: Damage to mudbrick structure due to lack of maintenance, Zile.

- **Wrong Practices:** Structural interventions and wrong repairs were also observed to have damaged some of the buildings. In the building examples in Figure 11, it is seen that the roofs were added later and the eaves are inadequate. In addition, the gable walls and roof formation put extra load on the structure, especially in the first example.

Figure 11: Faulty practices in mudbrick construction, Zile.

4. Improvements that can be made for the Sustainability of Adobe Buildings

4.1. Structural Improvements

Various structural improvements can be made to increase the durability of adobe structures against environmental impacts. The first step in the conservation and restoration of adobe structures is to accurately identify existing deterioration and decide what to conserve and how **[9]**. This process requires a detailed examination of all elements of the adobe structure. In a method that has been practiced in Anatolia for thousands of years, mudbrick ruins and still-used village houses can be preserved by regularly plastering them with mud mortar. This renewable plaster increases the weather resistance of mudbrick structures and prevents them from melting away over time. Through continuous maintenance, these structures can be made long-lasting **[10]**. Since adobe is a material that can be affected by water, climatic conditions should be taken into consideration during construction. Damp insulation should be made where necessary and wall surfaces inside and outside should be protected with plaster **[11]**. For maintenance; cracks in the walls should be repaired without delay and possible problems such as water leakage should be prevented. In an adobe building built with traditional methods, plaster should be used to protect the adobe blocks that make up the walls, and if possible, it should be water resistant. Protective roofs and eaves should also be considered to prevent the facade of the building from being damaged by rain. These improvements can be explained under the following headings.

- **Repair of Spilled Plasters:** In order to eliminate the deformations and damages caused by wind and water over time on the facades, as well as to prevent the destruction of the wall structure, plasters should be repaired. Before starting the plaster repair process, adobe walls should be cleaned from dust and dirt. Dust can be removed with a soft brush or broom. Also, plants growing on the walls can damage the structure. The plants should be carefully cleaned with special brushes or by hand and the roots should be completely removed. After these operations, the cracks should be cleaned and made ready for repair. Water repellent insulation material can be used inside or on the surface of the plaster to prevent rain and similar water damage. Although the buildings in the region were built with traditional methods and plastered with traditional straw and clay mixture plaster, the use of a plaster mixture consisting of an up-to-date alker mixture will be a longer-lasting solution to correct the plaster damage. "Alker is a type of adobe in which 10-20% gypsum is added to suitable adobe soil" **[12, 13]**. While 10-15 kg/cm2 compressive strength is measured in normal adobe, this reaches 30-50 kg/cm2 in alker. Thus, more durability is obtained **[14, 13]**. In addition, since there is very little water in alker, shrinkage formation in the material that sets in 20 minutes is reduced to 1-1.5% **[15]**.
- **Reinforcement of Walls:** Where collapse and weakening of mudbrick walls are observed; strengthening can be achieved by methods such as supporting with wooden elements, adding support beams to the walls, reinforcing the walls with steel mesh and applying a protective layer on the outside of the walls. Adding steel wire mesh or rods to the walls will also make the structure more resistant to earthquake and wind effects (Figure 12).

Figure 12: Geo-grid providing horizontal movement of the wall **[16, 17]**.

In addition, damaged walls in adobe structures can be renovated by creating a work joint and using the ramming method (Figure 13, Figure 14).

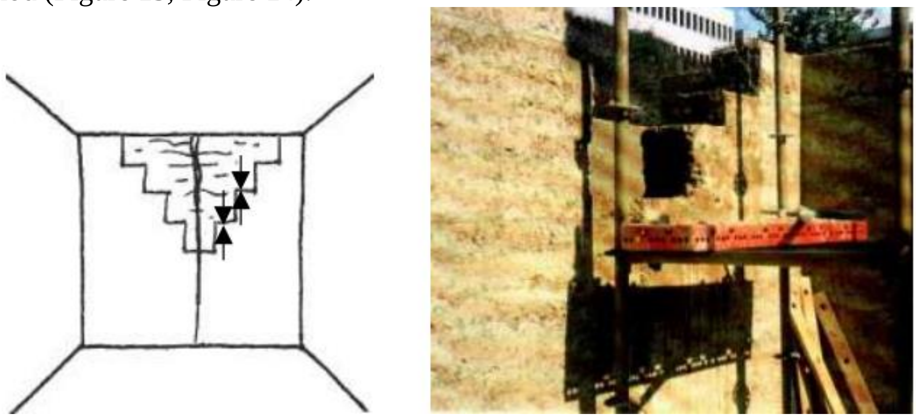


Figure 13: Renovation of the adobe wall by creating a work joint **[15]**.

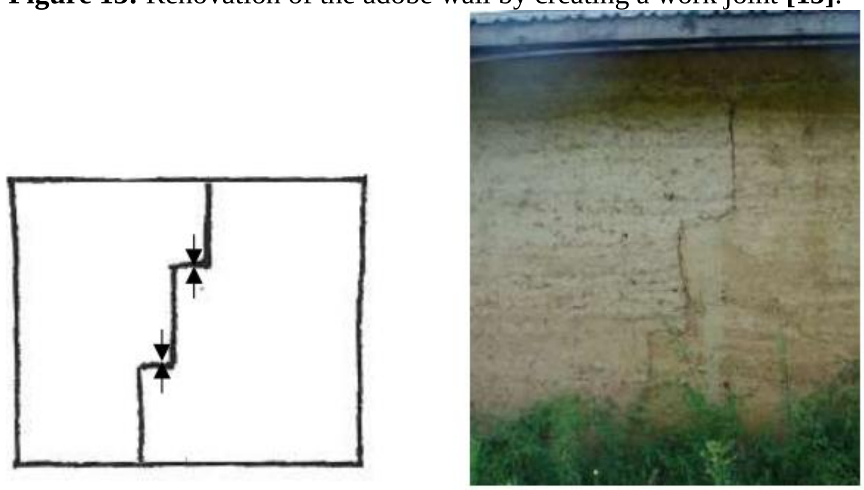


Figure 14: Renovation of the adobe wall by creating stepped work joints **[15]**.

"The principle of the work joint is to create horizontal steps that can be rammed on top of the old wall piece in new castings. These horizontal ramming surfaces connect the new and the previous wall piece. The greater the number of these steps, the better the connectivity between the two work periods will be achieved" **[15]**.

Traditional methods used in Anatolia in the past can be applied in order to prevent the energy coming from the earthquake effect from forcing the wall to move and causing damage. First of all, cavities are created at certain intervals on the surface of the adobe wall and wooden elements are placed in these cavities with the prepared mud (Figure 15). Thus, at the points where the section is thinned, linear cracks can be formed horizontally, thus preventing diagonal cracking and damage **[1]**.

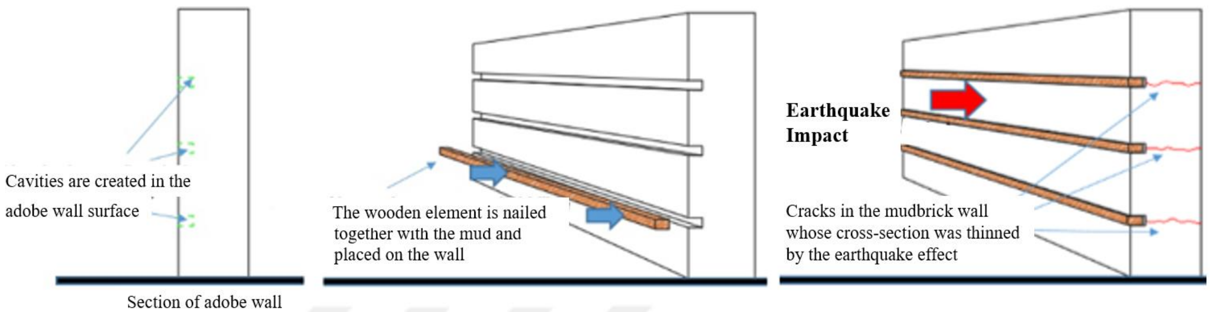


Figure 15: Extinguishing earthquake energy in an adobe wall as desired **[1]**.

- **Waterproofing:** In adobe structures, water (solid, liquid, gas) can have a corrosive and even destructive effect in all cases where it is present. Insulation with waterproof materials can increase the water resistance of adobe structures in order to prevent damages that may occur due to inadequate waterproofing of foundations, groundwater and surface water. "Rainwater causes solvent, carrier, physical and chemical deformations on the surfaces it affects" **[15]**. While waterproof coatings prevent water from seeping into the structure, the moisture balance within the structure is maintained by using breathable materials. Measures can be taken to prevent rainwater affecting the spaces between the adobe blocks with materials such as waterproof mastic (Figure 16).

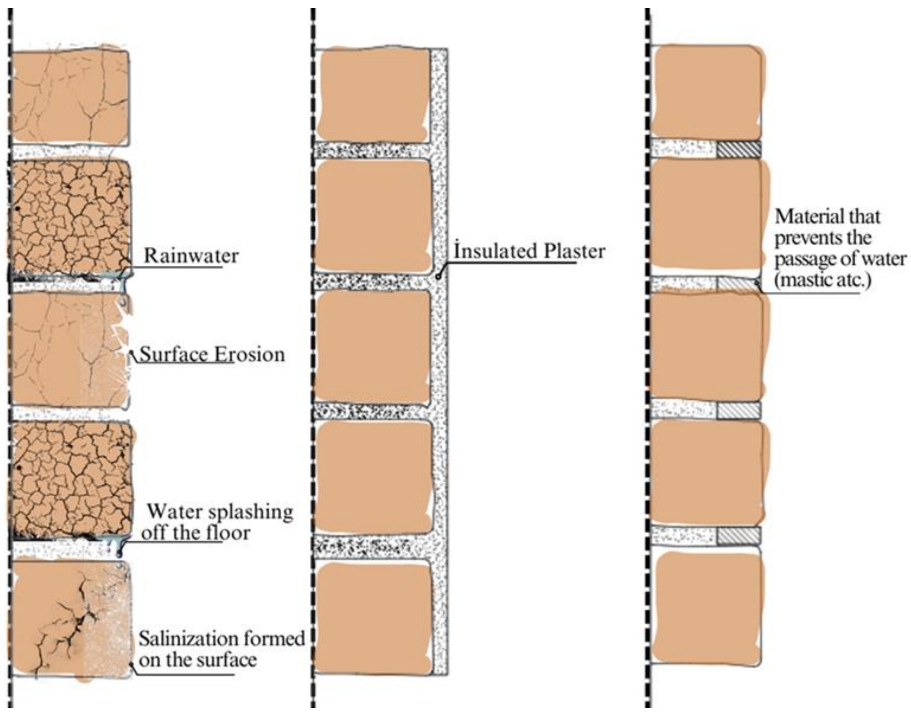


Figure 16: Precautions against water damage in a wall built with adobe blocks.

In order to prevent puddles or rainwater from splashing from the ground and eroding the mudbrick wall, it would be appropriate to make the lower part of the mudbrick wall with stone or a water-resistant material or to cover the surface of the mudbrick. In addition, the foundation and the wall as a whole can be improved with a drainage system that can be applied around the building against ground water. Drainage systems prevent rainwater from reaching the structure and prevent the soil from being saturated with water. At the same time, it also prevents the formation of mold and fungus that may occur as a result of water seeping into the structure. Removing and insulating the soil on a clay-roofed roof and reducing the amount of soil on it will also reduce the roof load on the structure. Creating a parapet, gargoyle or rain downpipe to prevent the free flow of rainwater is also among the measures. Applying waterproof coatings such as limewash to the walls prevents water from seeping into the building, while using breathable materials is another measure that can be taken to maintain the moisture balance in the building (Figure 17).

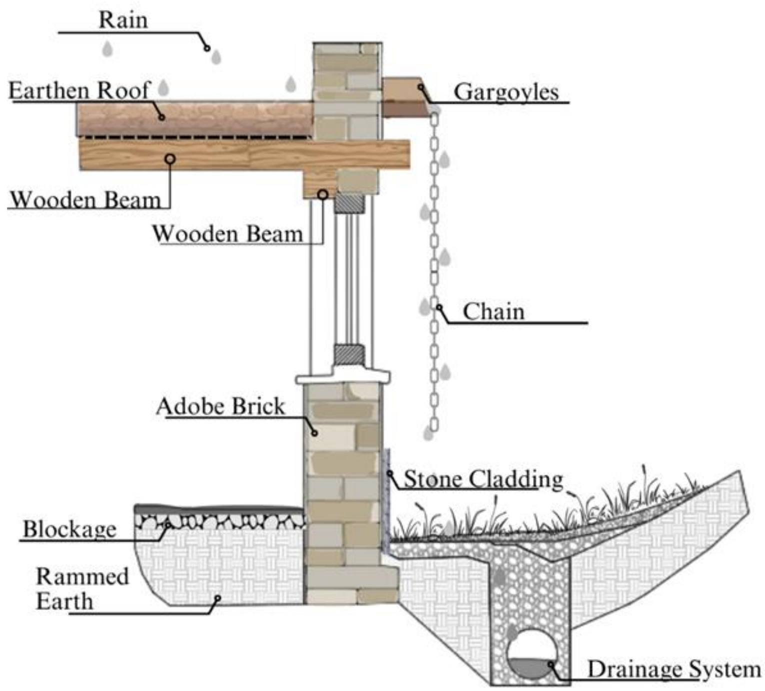


Figure 17: Measures that can be taken against water in adobe structure.

- **Wind Precautions:** In order to make the structure more resistant to wind, windbreaker elements can be placed on the walls, broad-leaved trees can be planted in the prevailing wind direction of the structure or a wind-breaking barrier can be built.
- **Sun Protection:** Planting plants to provide shade on adobe building facades where the sun is very active in hot weather and using insulation materials to regulate the indoor temperature can be listed as measures that can reduce thermal stress on the walls. Thus, possible expansion and contraction effects with heat effect can be reduced.
- **Improved Roof Systems:** The earthen roof coverings observed in traditional adobe buildings are damaged by rain, snow and frost over time and cause water leakage problems. For this reason, it is necessary to take measures with waterproofing materials on the roofs. In addition, since rainwater affecting the building surface from the roof edges erodes the wall surface, the roofs of adobe buildings should be designed with wide eaves to remove rainwater and protect the walls. In order to regulate the flow of rainwater in existing buildings and remove it from the building, measures should be taken to collect rainwater and convey it to the ground (Figure 18).

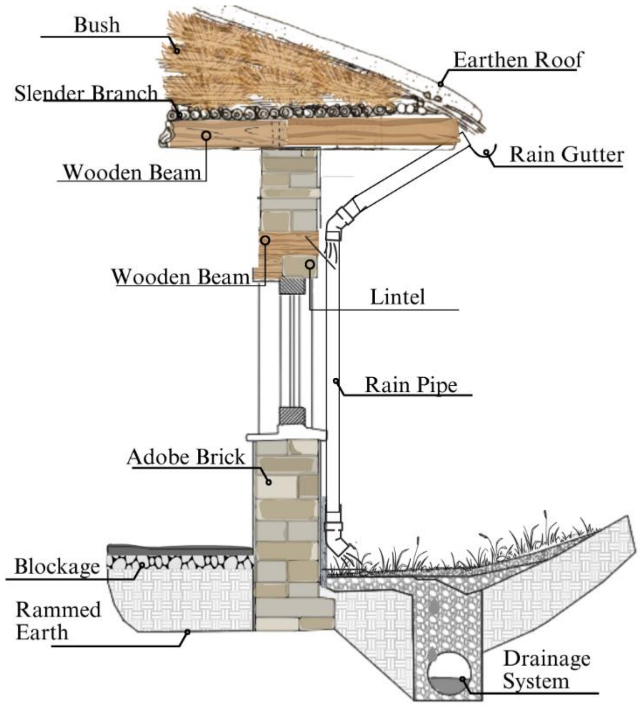


Figure 18: Improvements that can be made to roofs built with traditional methods

In addition, in buildings with earthen roofs, the flow of rainwater flowing from the gargoyles should be planned so as not to damage the facade. If possible, roof formations should be provided to prevent ceiling and facade damage (Figure 19).

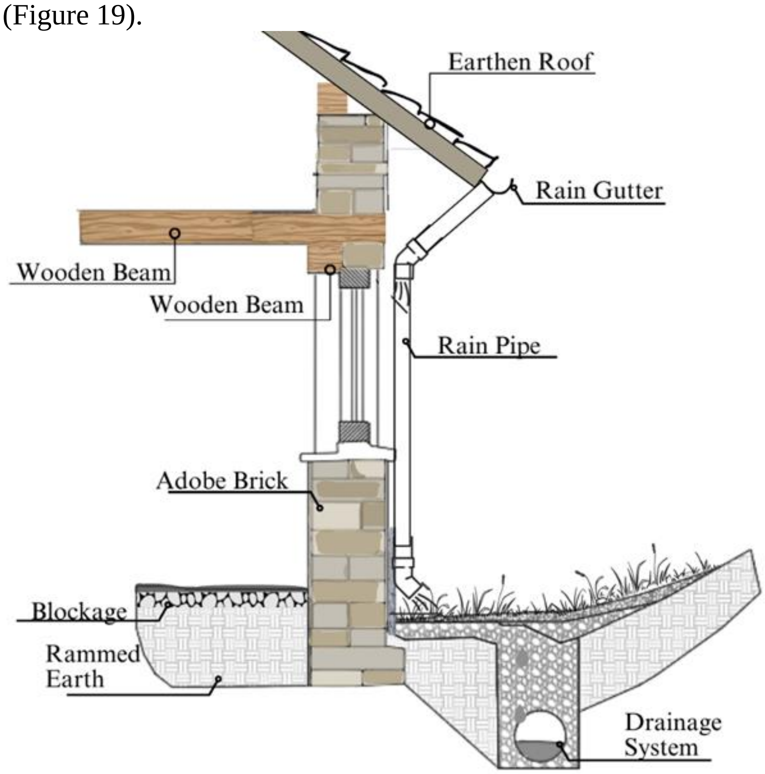


Figure 19: Roof solution instead of the existing earth roof in adobe building.

- **Strengthening Foundations:** Stone foundations and body walls, which are frequently observed in traditional buildings, prevent damage to the mudbrick material and make it last longer. Reinforcing damaged foundations in the region with stone or concrete, and covering the damaged parts of the mudbrick wall surfaces with stone, especially the flood level, increases the stability of the structure and increases its resistance to water.

Although reinforcement is usually thought of as the strengthening of the structural system of a building, this concept also includes the strengthening of both the material and the ground on which the building is located. Among the strengthening techniques in terms of the structural system, cross-sectional widening, bracing, metal element supports in the form of tension and strapping, foundation reinforcement, stitching and injection methods can also be used for adobe structures. Micro injections and clamp reinforcements can be used for reinforcement on element basis, and injection and soil replacement methods can be used in relation to the soil. These techniques offer a solution for saving old structures such as adobe from demolition **[9]**.

4.2. Regular Maintenance and Repair

Regular maintenance and repair is of great importance for the longevity of Zile adobe structures. In this context

- **Regular Inspections:** Regular inspections include checking the roof and rain downpour systems, inspecting for insects such as ants, checking the walls of the building and carrying out repair work where necessary. In addition, regular pruning of plants close to the structure and preventing their roots from damaging the structure are among the issues that should be followed regularly. By inspecting buildings at least once a year, small problems can be solved before they become large.
- **Repair Guides:** Documenting traditional repair techniques and current solution techniques used by local craftsmen, easily accessible to building users, and passing them on to new generations can ensure the longevity of adobe structures.
- **Community Engagement:** Raising awareness and educating local people through community activities in the region can increase community engagement in the maintenance and conservation of mudbrick structures. Collective interventions rather than individual efforts will lead to better results.

4.3. Use of Local Materials and Contemporary Techniques

In order to increase the sustainability of adobe buildings in Zile, it is important to support the use of local materials with contemporary techniques. In this context, the following measures can be taken:

- **Use of Local Soil and Fiber:** In all of the existing buildings that are maintained and repaired and new buildings produced with traditional methods, obtaining the soil used as building material from local sources will be effective in better adaptation of the material to environmental conditions. In addition, fibers obtained from local plants that grow in accordance with the climatic conditions of the region will increase the durability of the adobe material.
- **Use of Modern Construction Techniques:** The transformation of traditional construction techniques to modern construction methods in earthen buildings is preferable in terms of time and ease of application in today's conditions where speed and efficiency are often prioritized. Current adobe mixtures such as Alker and new generation solutions such as the ramming method make adobe structures more resistant to environmental factors.

In addition, mixing 2% lime in the stabilization of adobe with gypsum allows the material to be used with construction machinery. Thus, speed and ease of production are provided both in the ramming method and in the method of construction by spraying into the mold **[12, 13]**. The new formwork systems, in which the disadvantages of traditional formwork systems are eliminated, do not contain intermediate partition elements and the mold surfaces can move easily in vertical lines, allow curved surfaces and rounded corners to be formed easily **[18]**.

CONCLUSION

Adobe has an important place in today's construction world as a low-cost and sustainable building material that is compatible with nature. This study emphasizes the structural improvements, maintenance and repair requirements and the importance of local materials and contemporary techniques to increase the sustainability of adobe buildings in Zile region with continental climate. The study provides data on the interaction between environmental factors and the lifespan of traditional building materials. It has been observed that these buildings are faced with various deterioration caused by the characteristic climatic conditions of the region over time. These deteriorations can be listed as thermal fluctuations, erosion of adobe material due to rainfall, wind and meteorological effects, and structural weakening.

In order to maintain the sustainability of adobe buildings in the face of environmental factors, careful planning, regular maintenance and improvements in accordance with local conditions are required. In this context, sustainability requires not only the use of locally sourced and environmentally friendly materials, but also the use of construction techniques and maintenance practices that extend the life of these buildings. In this direction, revisiting traditional knowledge and integrating it with modern scientific developments would be the best step towards preserving existing adobe structures and increasing the durability of newly built adobe structures against harsh climatic conditions. Techniques such as the addition of protective additives, retrofitting, surface treatments, strategic architectural designs that reduce the effects of water, wind and thermal fluctuations can yield more sustainable, resilient and durable results.

In summary, the study emphasizes the importance of a multifaceted approach to conservation. This approach encourages not only the physical preservation of adobe buildings, but also the maintenance of the cultural heritage and traditional practices associated with the area and structures. The findings support the idea that although these ancient building techniques are highly adapted to environmental contexts, combining traditional methods with modern techniques can effectively utilize adobe buildings in today's construction industry. Further research and further studies on the subject are essential to develop more effective conservation techniques going forward. By delving deeper into the myriad of factors that contribute to the deterioration of adobe buildings and exploring a range of conservation methods, the study aims to raise awareness for our community and all those interested in the preservation of our built heritage. In parallel, community awareness raising, up-to-date techniques, regular monitoring, use of compatible materials, timely repairs and interventions that protect structures from environmental damage can ensure the sustainability of existing and new adobe structures.

REFERENCES

[1] Öztürk, P., (2020). Yapı Biyolojisi Açısından Kerpiç Kullanımının Etkileri, Hasan Kalyoncu Üniversitesi Fen Bilimleri Yüksek Lisans Tezi, Gaziantep.
[2] Miller, T., & Scott, R. (2013). Sustainability in building design. London: Routledge.
[3] Eires, R., Camões, A., Jajali, S., (2015). Key Engineering Materials Vol. 634 pp 357-366 Trans Tech Publications, Switzerland
[4] Calabria, J. A., Vasconcelos, W. L., Boccaccini, A. R., (2009). Microstructure and chemical degradation of adobe and clay bricks. Ceramics International.
[5] Ma, X., (2006). Deterioration of Earthen Building Materials. The Encyclopedia of Archaeological Sciences. Publisher: Wiley
[6]https://www.cagdasdeveli.com.tr/kose-yazarlari/yrd-doc-dr-kadir-ozdamarlar-kose-yazarlari/mustafa-tan-zilesi. html
[7] https://www.haritamap.com/yer/zile-belediyesi-develi
[8] Doğan, A., (2004). Adana' nın Sıcak-Nemli İkliminde Dış Duvarlarda Oluşan Hasarların İrdelenmesi ve Yapısal Çözüm Önerileri, İTÜ Yüksek Lisans Tezi.
[9] Tellioğlu, S., Satıcı, B., (2023). Tarihi Yapılarda Restorasyon Tekniklerine Göre Uygulanacak Malzemelerin Belirlenmesi. Teknoloji ve Uygulamalı Bilimler Dergisi, Cilt 6, No 1, s. 37-49.

[10] Ahunbay, Z., (2019). Tarihi Çevre Koruma ve Restorasyon, Yem Yayınları.
[11] Gür, V., Deniz, Ö. ve Ekinci, S., (2012). Kagir Yığma Duvarlarda Taşıyıcı Malzeme ve Bileşenler, 6. Ulusal Çatı & Cephe Sempozyumu, Uludağ Üniversitesi Mühendislik ve Mimarlık Fakültesi.
[12] Işık, B., Akın, A., Kuş, H., Çetiner, İ., Göçer, C., Arıoğlu, N. (1995). Alçı Katkılı Yapı Malzemesinde Uygun Mekanize İnşaat Teknolojisinin ve Standartlarının Belirlenmesi. Tübitak Araştırma Raporu. Proje No: İNTAG TOKİ 622.
[13] Gündüz, G. N., (1999). Deprem Bölgelerinde Yığma Yapı Tasarımın Yönetmeliğe Göre İncelenmesi, İTÜ Fen Bilimleri Enstitüsü Yüksek Lisans Tezi, İstanbul.
[14] Eriç M., Koçu K., 1992, Konya Ve Çevresinde Kerpiç Malzemede Eskime ve Yenileme Sorunları (Ders Notu), MSÜ Fen Bilimleri Enstitüsü, İstanbul.
[15] Kuşaslan D., (2002). Yapıda durabilite ve Hasar Analizi Alçılı Kerpiç Yapıda Hasar Oluşumunun İncelenmesi, İTÜ Fen Bilimleri Enstitüsü Yüksek Lisans Tezi, İstanbul.
[16] Işık, B., (2003). "Depreme Dayanıklı Yapı Elde Edilmesi için Alker Duvarın Tasarım Kriterlerinin araştırılması", CD Bildiri No: AE-048, Beşinci Ulusal Deprem Mühendisliği Konferansı, 26-30 Mayıs 2003, İstanbul - Ing Poster: Investigating the design criteria of alker wall to achive the earthquake safe structure.
[17] Işık, B., (2005). "Investigating the Earthquake Safety of Alker Wall",Earth Building 2005, University of Technology, Sydney, 19-20 January.
[18] King, B., Tanaçan, L, (2010), Toprak Mimarisinin Yeniden Doğuşu-Kil Kökenli İnşaata Taze ve Güncellenmiş Bir Bakış, Mimarlıkta Malzeme Dergisi, Yıl:5, Sayı:17, Güz 2010, sf 61-80.

Earthen Buildings' Thermal Performance and its Indoor Impact in a Different Regions.

Authors: Rasha Elborgy Architect Ph.D

Address: rasha.borgy@gmail.com

Abstract

Earth buildings have a long history in the construction field in architecture. It is a natural material that is environmentally friendly and has proven its positive effect. In recent years, the advantages of earthen buildings, such as environmental protection, low or zero carbon buildings, low cost, and recyclability, have attracted considerable attention, many different researches and papers have been shown the importance of this material. This paper presents the thermal comfort impact of earthen building, whereas the topic is important in reducing the affecting problem of global climate change. The literature was collected, reviewed, analyzed and filtered based on: What is related to moisture absorbed and evaporated or emitted in earthen building, and the thermal insulation performance. The environmental impact of the temperature's ratio inside the building and its impact on the comfort for users. This paper intends to increase the knowledge of the thermal behavior of this type of construction. The aim is to enhance the recent researches in this field and show proof of the efficiency of this material, which has been used for thousands of years in different civilizations, and that it is an important architectural element in contributing to reducing environmental problems. All results gave the same positive conclusion for earthen buildings, whether on the environmental, economic and human comfort level inside the building.

Keywords: Earthen architecture, thermal behavior, passive building, indoor environment.

1. Introduction

Due to greenhouse gas emissions linked to human activities (deforestation, industry, agriculture, residential, commercial and public buildings, electricity production, transport, waste), climate change can already be observed and will increase in the future: In order to limit these devastating and irreversible impacts, the increase in global temperatures needs to be limited to +2°C. For this, it is essential to reduce our CO_2 emissions by 50% by the year 2050 and 90% by the year 2100. [1].
buildings account for 40% of world energy use and 33% of global greenhouse gas emissions. [2], It is estimated at European level that up to 97% (i.e. all buildings built before 2010) require partial or total intervention to improve their energy performance by 2050 [3], Research has shown that, compared to materials produced in industry, rammed–earth materials have more environmentally friendly advantages, lower carbon emissions, and consume less energy [4].
Indeed, buildings consume 30% to 40% of the primary energy on the global scale for maintaining a comfortable indoor climate [5], so that we must work on reducing the heat transfer coefficient of the envelope. In regard to buildings without air conditioning and a mechanical ventilation system, a naturally ventilated building, which is the case of most dwellings in the bioclimatic approach presents the thermal

mass as a suitable method to reduce thermal discomfort due to disturbing temperatures in a hot climate [5], These materials absorb heat from solar radiation at a slower rate and are very active in countering rapid heat transfer. However, providing the walls with a thermal resistance layer or using passive design can allow for reducing the energy demand for cooling and therefore has an impact on the thermal comfort of the occupants [5].

Despite centuries of human habitation in earthen structures, the principles of sustainable construction and thermal comfort using earth materials remain relatively not widespread compared to alternative methods. Scientific documentation of the thermal performance of earthen buildings is limited, and further research is necessary to optimize solutions for contemporary applications. In the regions that characterized with dry summer climate, indoor climate moderation is based on traditional and vernacular architectural approaches such as high thermal mass materials, thick walls and others, hence, the earth construction is known for their large walls and their nice inside temperatures during very hot summers days and warmed indoor atmosphere in winter which explain the use of this material in hot climates. As a benefit of the large thickness, the earth's walls have a high thermal inertia which is responsible for the delay of the heat conduction throughout the walls, contributing for nice inside temperatures. Also, their large mass can collect the heat inside the walls and, so, it can reduce the use of energy.

Research consistently demonstrates that earthen construction is well-suited for hot, dry climates. This natural building method effectively maintains comfortable interior temperatures, often eliminating the need for active cooling systems. Furthermore, earthen materials have been shown to contribute to a healthy indoor environment by regulating both temperature and humidity. The inherent thermal and moisture-regulating properties of earth walls result in enhanced indoor comfort for occupants.

This paper is discussing and show the thermal comfort effect of earthen buildings, through analyzing different studies in different regions and countries that characterized by hot climate. The literature was collected and analyzed based on the nature of the prevailing climate in each country or region. The method used to measure the temperature and thermal comfort inside the earthen building. and if it is a direct measurement method in the building, or have simulation software programs been used to measure temperatures, which can help architects more in reach accurate thermal reading of the building, results, discussions and recommendations in the final conclusion of each experiment were analyzed.

2. The Physical Thermal Proprieties of Earthen Building (*The Impact of Earthen Walls in Thermal Comfort*).

A report from the International Energy Agency (IEA) states that, in 2019, the building sector causes two-fifths of the total CO2 emissions, being responsible for over one-third of the global final energy consumption, having risen in the last years. 11% of these CO2 emissions resulted from manufacturing building materials like steel, cement, and glass [6]. To quantify the influence of materials on the energy efficiency of buildings it is also necessary to consider the methodology that is employed to determine the physical parameters that define those materials.

Rammed earth houses are featured to be thermally efficient because they are able to maintain a reasonably comfortable indoor temperatures year around without external heating and cooling energy, This is because rammed earth constructions are characteristically built with thick earthen walls for stability (typically 30 cm–60 cm thick) and more sometimes, and the thermal mass of these thick walls can delay the transmission of heat from the outside to the inside due to the wall's long time lateness in hot summer days (typical 30 cm thick rammed earth walls can provide a thermal time lateness of about 10 h. [7], In cold winter days, the thermal mass stores much of the heat it absorbs during daytime and the stored heat will be released to the inside of the house at night and help to warm the spaces.

Therefore, Among the characteristics that distinguish the earthen buildings are:

- Thermal Mass: Earthen materials have high thermal mass, meaning they can absorb, store, and release heat over time. This helps to stabilize indoor temperatures, moderating both daytime heat and nighttime cold.
- Thermal Conductivity: Earthen materials generally have low thermal conductivity, meaning they are not good conductors of heat. This property helps to slow down the transfer of heat through the walls, floors, and roofs of earthen buildings, contributing to their thermal efficiency.
- Specific Heat Capacity: Earthen materials typically have a relatively high specific heat capacity, which is the amount of heat required to raise the temperature of a unit mass of the material by one degree Celsius. This property enables earthen buildings to store large amounts of heat energy.
- Insulation: While earthen materials may not have the same insulation properties as synthetic materials, their thermal mass and low conductivity can provide some insulation against temperature extremes. Additionally, earthen buildings can be designed with added insulation layers to enhance thermal performance and using a passive design.
- Hygroscopicity: Earthen materials have the ability to absorb and release moisture from the surrounding environment. This property can help regulate indoor humidity levels, contributing to occupant comfort and indoor air quality. However, excessive moisture absorption can lead to structural issues, so proper design and maintenance are important.

It is also characterized as a durable and long-lasting building material if maintained regularly, and good fire resistance.
Some studies say that, inappropriate use of thermal mass may cause negative impacts on thermal comfort, hence it is recommended that the integration of thermal mass and other design parameters be optimized and this optimization be conducted using thermal performance tools [7].
Because thermal comfort is "that condition of mind that expresses satisfaction, Rammed earth walls alone cannot guarantee thermal comfort or energy conservation and the building performance generally improves when other design strategies, such as insulation, glazing, shading and ventilation, are implemented [7]. Some studies find that thermal comfort in naturally ventilated rammed earth houses can be improved by appropriate control of a set of design parameters relating to external walls, in particular by adding insulation. In order to achieve high level of occupant satisfaction on thermal comfort, these parameters should be wisely optimized by taking into account the influence of local climates [7].
Previous research on earthen buildings has explored the extent to which thermal comfort can be achieved within them. By measuring thermal properties, hygroscopicity, and thermal insulation efficiency, researchers have employed simulation programs or by direct practical recording to assess the ability of earthen buildings to provide thermal comfort to users. This has led to insights into energy conservation potential, contributing to environmental preservation. This will be clarified through analyzing of the following studies.

3. The Previous Studies Analysis.

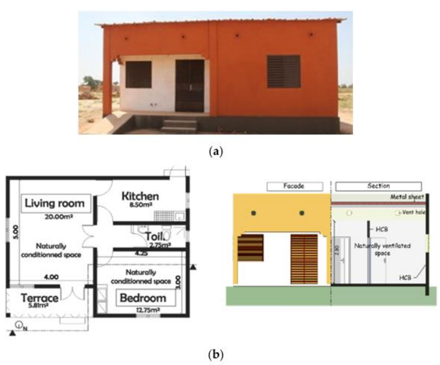
3.1. Case 1

3.1.1 Region and Climate: Burkina Faso's hot, dry climate, characterized by soaring temperatures exceeding 40°C during the November to May dry season, presents a significant challenge for building thermal comfort. Effective passive design strategies, including insulation, shade, and natural ventilation, are essential for mitigating heat gain in this low-humidity environment. This study sought to improve the thermal performance of buildings in Burkina Faso by investigating the impact of wall designs incorporating compressed earth blocks.
3.1.2 Simulation software: To evaluate the influence of diverse wall designs on indoor thermal comfort, the study employed the WUFI® Plus v2.5.1.0 simulation software. Developed by the Fraunhofer Institute for Building Physics in Stuttgart, Germany, WUFI® Plus specializes in modeling heat and moisture transfer and storage within building components. Its ability to simulate indoor thermal

environments makes it a valuable tool for examining thermal comfort and energy consumption in buildings.

3.1.3 Case study: In the case study presented, six different wall constructions incorporating Compressed Earth Blocks (CEB) and locally sourced materials were subjected to simulations and comparative analyses against standard hollow concrete block walls. Figures 1 and 2 show the model of the study and the wall construction system.

The building's design incorporates traditional urban construction practices, featuring a steel roof, ventilated attic, plywood ceiling, and metal louvers for doors and windows. To improve indoor comfort, the study investigated the thermal performance of different wall types, using an adaptive discomfort index. The aim was to identify wall designs that effectively enhance thermal comfort in urban buildings in Burkina Faso, compared to traditional hollow concrete block walls



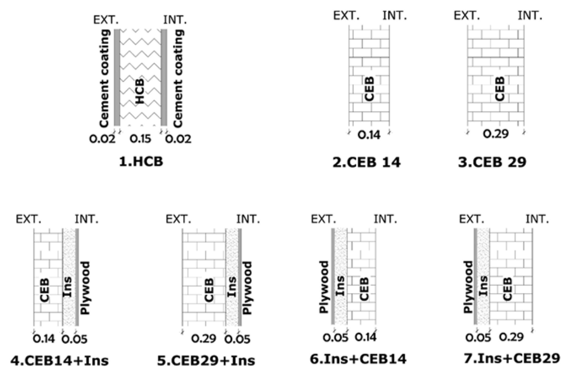


Figure 1: model of the case study [4]. Figure 2: constructive system of the walls [4]

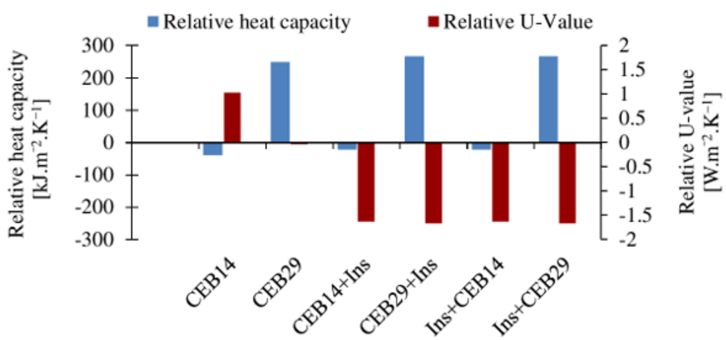


Figure 3: relative heat capacity and heat transmittance of the walls [4].

3.1.4 The Case Results, Discussion: During representative days of the experiment, the simulated temperatures were meticulously compared against their measured counterparts. The results demonstrated a remarkable convergence between the simulated and measured temperatures, underscoring the fidelity of the thermal model in representing the actual data. Despite a marginal elevation in the predicted temperatures, the overall contours of the temperature curves exhibited a striking resemblance, further validating the accuracy of the model. To assess the accuracy and reliability of the thermal model, statistical metrics were employed, including the normal mean bias error (NMBE), coefficient of variation of the root mean squared error (CVRMSE), and correlation coefficient R^2. These metrics indicated that the model was capable of differentiating and evaluating the thermal performance of various wall systems, demonstrating its effectiveness in assessing thermal efficiency.

3.1.5 The Case Conclusion: In summary, a study simulating a Burkina Faso house's thermal performance using WUFI® Plus software revealed important findings. It showed that sustainable materials like compressed earth blocks could improve thermal comfort more effectively than traditional hollow concrete blocks. The study highlights the critical role of selecting appropriate wall materials and designs in enhancing indoor thermal conditions. By considering such factors, we can create sustainable and comfortable living spaces in hot climates like Burkina Faso, where thermal comfort is a prevalent concern, figure 3 shows the relative heat capacity and heat transmittance of the walls, and in figure 4

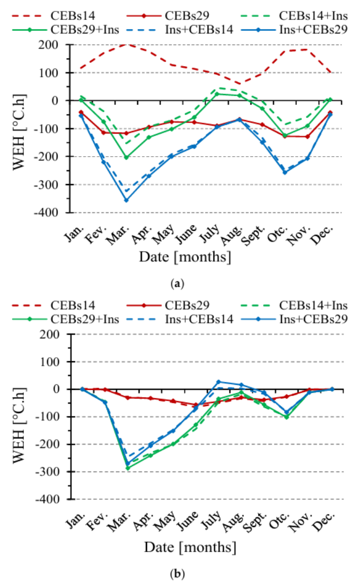


Figure 4: the thermal discomfort of 6 construction system and the building made of hollow blocks.

3.2 Case 2:

3.2.1 Climate and Region: In a semi-arid region of Morocco, this case examines the thermal energy performance of buildings situated in two distinct cities: Ben Guerir and Beni Mellal. Ben Guerir, classified as Csa (Hot Mediterranean climate) under the Köppen-Geiger system, experiences extremely dry summers and sporadic winter precipitation. Conversely, Beni Mellal is distinguished by sweltering, arid summers marked by exceedingly high daytime temperatures and tepid nights.
3.2.2 Simulation software: To evaluate the thermal performance of the buildings, the researchers employed the widely recognized EnergyPlus modeling tool. This comprehensive building energy simulation software enables detailed analysis of energy consumption, thermal comfort, and the effectiveness of HVAC systems. Using EnergyPlus, the researchers were able to investigate the influence of various design strategies and materials on energy consumption and indoor comfort levels.
3.2.3 The monitoring and validation process: The monitoring and verification process were carried out through a structured methodology involved multiple phases.

1. Empirical Validation: it carried out by comparing the predicted temperatures generated by the model with the actual measured values obtained. **2**. Data Collection: data collected in June 2021, which is identified as the warmest month in the region. Measurements are taken every 5 minutes in the absence of precipitation and under clear skies, with irradiance values rising to 800 W/m^2 by mid-day. **3**. Monitoring Setup: byusing sensors that measure indoor air temperature and relative humidity in different zones (Z1 and Z7) *that shown in figure kk*. The sensors collect data continuously, generating over 17,000 measurements per day during the monitoring period. **4**. Data Management: it involves storing real-time data streams on customized Raspberry Pi devices and uploading them locally at the end of the monitoring period. **5**. Comparison and Analysis: The simulation results from the EnergyPlus model are compared with the monitored data to assess the accuracy and reliability of the model. **6**. Uncertainty Analysis: The comparison between the simulation results and the monitored data includes an assessment of uncertainty using indices proposed by relevant guidelines or standards, such as the AS 14 guide, to determine the reliability of the building energy model.

3.2.4 The Case Results and Conclusion:

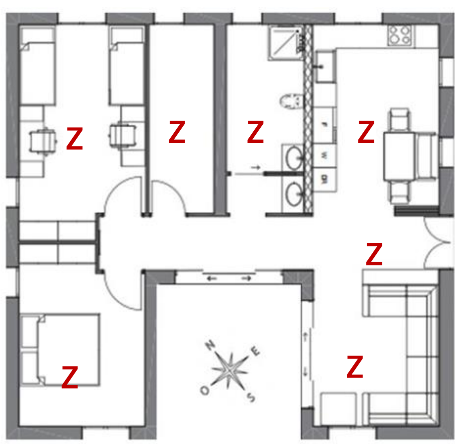


Figure 5: 2D architectural plan [2].

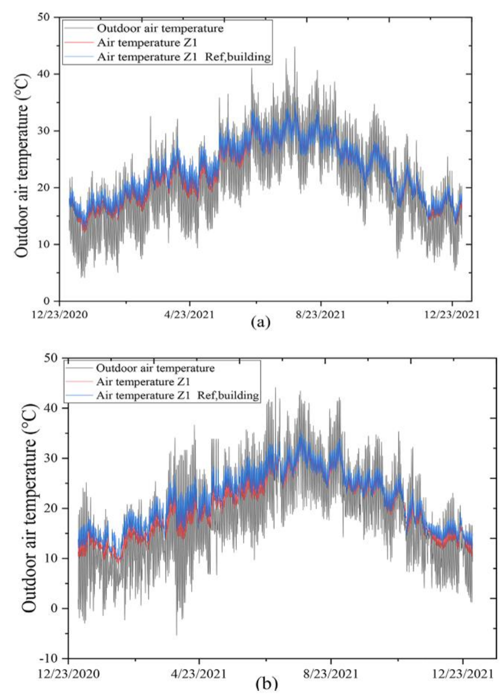


Figure 6: Hourly air temperature of outdoor and the monitored zones during all the year: (a) Ben Guerir; (b) Beni Mellal city [2].

The study found that the use of compressed earth blocks coupled with passive design strategies led to improved indoor thermal comfort and greater sustainability in the buildings compared to conventional construction methods. Specifically, the researchers observed a reduction of about 12% in summer discomfort hours. Additionally, the combination of semi-arid climate-responsive passive design techniques resulted in a reduction in thermal energy intensity ranging from 20 to 65 kWh.m^−2.y^−1.
Furthermore, the comparison of the thermal performance of buildings constructed with compressed earth blocks and traditional materials showed significant improvements in thermal

comfort. For instance, the thermal discomfort hours in buildings made of compressed earth blocks were reduced by about 20% compared to those made of cement-based masonry. Moreover, the combination of earthen building technique with passive design led to almost total elimination of thermal discomfort during the year, with only 209 hours not meeting the set point.

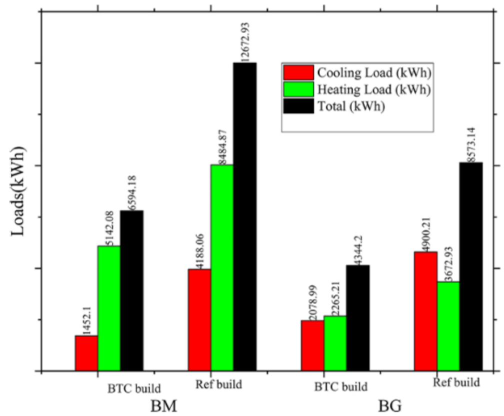


Figure 7: Annual cooling and heating loads in both cities.

and significantly improve indoor thermal comfort and sustainability compared to conventional building materials.
By leveraging passive design techniques tailored to the semi-arid climate, such as thick external walls, roof insulation, solar shadings, and double glazing, the study demonstrated the potential for enhancing building efficiency and occupant comfort. Both of figures 6 and 7 show the hourly air temperature of outdoor and the monitored zones during all the year, and the Annual cooling and heating loads.

3.3 Case 3:
3.3.1 Climate: *Serpa*: located in southern Portugal. in winter, the average temperatures ranging from 5°C to 18°C, in summer, the maximum temperatures above 30°C and minimum is around 18°C. *Odemira*: in summer the average maximum temperatures above 27°C. in winter the maximum temperatures below 18°C.
3.3.2 Simulation: This study utilizes Autodesk Ecotect, a digital modeling software, to conduct comparative simulations of three buildings with varying functions in different climate zones. The simulations aim to assess the thermal performance, user comfort, and energy efficiency of each building, ultimately validating the methodology employed in the study.
3.3.3 Case studies: The study presents three buildings; these buildings demonstrate the effectiveness of the design and materials strategies for achieving thermal comfort:
1. *Office Building*, raw earth walls (REW), Building orientation and solar exposure were critical factors in achieving good thermal behavior, highlighting the importance of passive design strategies, **2**. *Kindergarten*, constructed with reinforced concrete (RC) structures and raw earth walls (REW), had an active air conditioning system that was not needed due to the passive performance of the building, **3.** *Rural Hotel*, features raw earth walls (REW) with a thickness of 50 cm, providing thermal comfort.

Figure 8: The three buildings. (a) The architectural office, (b) The hotel, (c) The Odemira kindergarten [1]

3.3.4 The Case Results and Discussions:

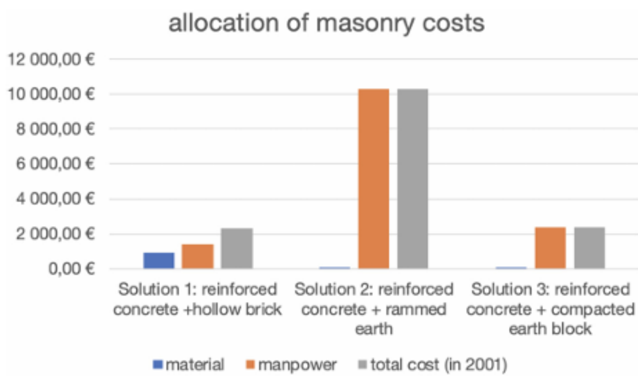


Figure 9: the case studies construction costs [1].

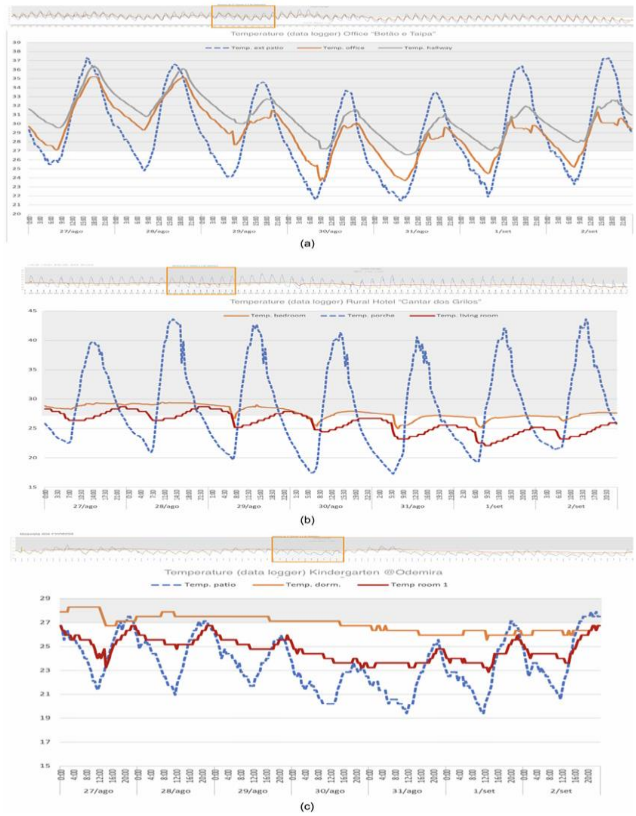
The study utilizing the Autodesk Ecotect simulation software and data loggers in buildings within the Serpa and Odemira regions yielded the following results:

1. Thermal Comfort: Acceptable thermal comfort conditions were achieved inside the three buildings where sun exposure was minimized, demonstrated thermal comfort without the need for air conditioning, figure 10 shows the measurement recorded temperature by data logger devices, with representative week analysis of each building.

2. Energy Efficiency: The passive performance of buildings with REW resulted in significant energy savings by not requiring active air conditioning systems.

3. Cost Analysis: The construction cost comparison showed that the REW production costs were higher compared to masonry blocks. Despite higher initial costs for REW, the long-term energy savings and sustainability benefits make it a viable and cost-effective construction solution as shown in figure 9.

beside the Thermal Performance, Energy Efficiency and Sustainability and the Cost-Effectiveness the study proved, also showed the Tradition and Adaptation: Technicians and builders have successfully adapted raw earth construction to modern requirements, emphasizing passive design strategies for climate adaptation.



The office

The hotel

Odemira Kindergarten

Figure 10: Measurement recorded temperature by data logger devices, with representative week analysis. (a) The architectural office "Betão e Taipa", (b) The rural hotel "Cantar dos Grilos", (c) Odemira Kindergarten buildings.

3.3.5 The Case conclusion: In conclusion, the study demonstrates that raw earth construction systems, when properly designed and implemented, offer effective solutions for achieving thermal comfort, energy efficiency, and sustainability in buildings in Portugal. The adaptation of traditional techniques to modern requirements showcases the potential of raw earth construction as a viable and environmentally friendly building solution.

3.4 Case 4:

3.4.1 Climate and region: Vojvodina is a region located in northern Serbia, known for its continental climate with hot summers and cold winters.

3.4.2 Simulation software**:** This study focuses on the thermal properties of earthen walls through a combination of theoretical analysis and on-site measurements.

3.4.3 Case study: The case study analysis focuses on a traditional house in Vojvodina where in situ measurements were conducted to evaluate the thermal behavior of rammed earth walls. The selected house met specific criteria, including the use of rammed earth as the construction material for load-bearing walls, average wall thickness. Measurements were conducted on two distinct house walls. One wall, constructed around 1800, utilized rammed earth as its primary material. The second wall, added as an extension between 1850 and 1900. Comprehensive analysis involved utilizing sensors and a measuring device to quantify parameters such as external air temperature, external surface wall temperature, internal air temperature, and internal surface wall temperature.

The study's methodology combined theoretical analyses and on-site measurements. This approach entailed the following steps:

1. Theoretical Analysis: The study included analyses of theoretical values such as wall heat transmittance (U), thermal resistance (R), and thermal conductivity (λ) based on available literature data. Theoretical

estimations indicated relatively poor thermal characteristics of rammed earth walls, which were considered in steady-state calculation methods. **2.** In Situ Measurements: On-site evaluations of 60 cm thick rammed earth walls demonstrated their enhanced thermal characteristics. Contrary to theoretical predictions, the experimental measurements indicated a notable improvement in thermal performance. **3.** Evaluation of Thermal Mass: The study emphasized the importance of the high thermal mass of rammed earth walls in maintaining thermal stability and comfort within the buildings. **4.** Future Research Directions.
Where: **U** is the heat transfer coefficient, U for a rammed earth wall 50 cm thick without mud mortar was estimated to be 0.87 W/(m²·K). The thermal resistance **R** of a building material is indirectly proportional to the value of the heat transfer coefficient (U-value). For example, for a 30 cm thick rammed earth wall with an estimated heat transfer coefficient U of 2.0 W/(m²·K), the thermal resistance R would be expected to be around 0.5 (m²·K/W). **λ** is the thermal conductivity, it is a thermophysical characteristic of a building material that represents the amount of heat transferred by conduction through the material per unit time, area, and temperature difference. In the context of rammed earth walls, the estimated thermal conductivity values vary based on different sources. For example, the thermal conductivity for compacted earth is reported as λ = 1.2 W/(m·K) in some Serbian and international standards. Additionally, the thermal conductivity for mud mortar (mud plaster) is estimated to be λ = 0.8 W/(m·K).
3.4.4 The Case Results and Conclusion: In situ measurements of 60 cm thick rammed earth walls have shown significantly better thermal properties, leading to stable indoor conditions with minimal temperature fluctuations (around ±0.5°C) even when outdoor temperatures vary greatly (up to ±16°C). The study's findings corroborate theoretical models and prior research, underscoring the significance of rammed earth walls' high thermal mass in dynamic thermal simulations. The walls' ability to absorb, store, and release heat gradually minimizes energy requirements for heating and cooling. This results in a thermally stable indoor environment characterized by consistent temperatures hovering around 23°C, promoting occupant comfort.
overall, Rammed earth walls in traditional Vojvodinian houses exhibit remarkable thermal stability, energy efficiency, and occupant comfort. Their thermal mass effectively regulates indoor temperatures. The study underscores the need for further research to fully understand the energy performance of rammed earth buildings. Diverse in situ measurements of walls with varying materials, thicknesses, and structures are crucial to guide potential rehabilitation and upgrades, ensuring compliance with contemporary building regulations.

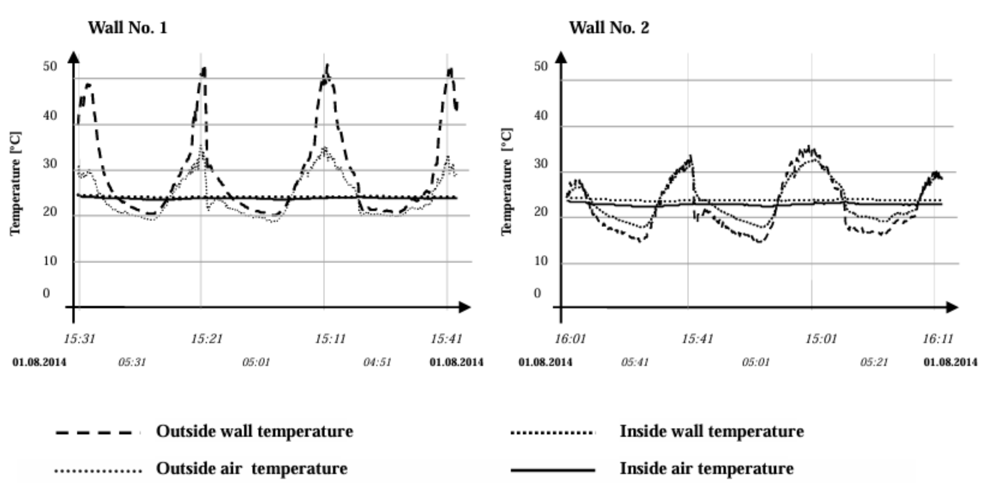


Figure 8: Diagram of the parameters measured *in situ*.

Figure 11: diagram of the outside wall and outside air temperature [8]

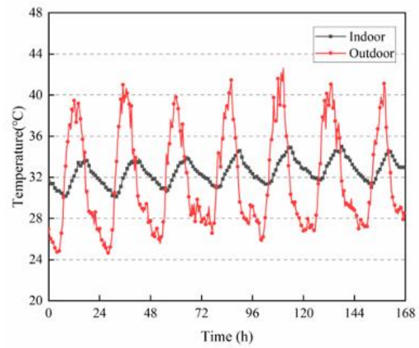
3.5 Case 5:

3.5.1 Climate and region: Northwest Sichuan, China features a subtropical monsoon humid climate with warm winters and hot, humid summers.

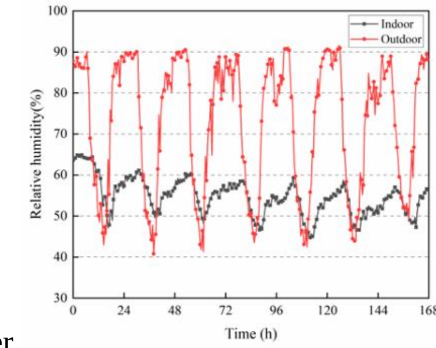
3.5.2 Simulation software: The study employed a multifaceted approach to assess the thermal and moisture performance of rammed-earth walls in typical climates. This included field testing, theoretical analysis, and other methods. The research primarily relied on empirical data collection, theoretical modeling, and analytical techniques to evaluate the thermal and humidity characteristics of these walls.

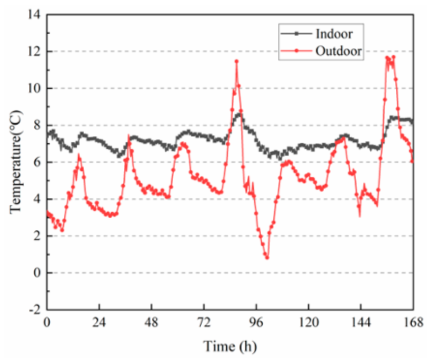
3.5.3 The study focuses on: The study focuses on several key aspects related to the properties and behavior of rammed-earth materials in different climatic conditions, as following:
- This case investigate the thermal and physical characteristics of rammed-earth materials, scrutinizing how these properties fluctuate in response to variations in moisture content.
- This case delves into the complex interplay of heat and moisture transfer within rammed-earth walls, known as hygrothermal performance. the study highlights their impact on indoor temperatures and humidity levels.
- the moisture absorption and desorption properties of rammed earth, emphasizing its effectiveness in controlling moisture levels. it notes that, rammed earth exhibits superior moisture absorption capabilities compared to its moisture release capacity within certain relative humidity ranges.
- Environmental Benefits: The study underscores the environmental advantages of rammed-earth construction, such as sustainability, low cost, recyclability, and energy efficiency. It emphasizes the potential of rammed-earth materials to provide thermal comfort and stable indoor environments in the context of sustainable building practices.

3.5.4 The Case Results: (Heat & Moisture transfer) the daily temperature fluctuation of the outer surface of the wall was approximately 7.5C. in the middle and inner surfaces of the walls were approximately 3C and 1.5 C, respectively. the moisture content was highest in the middle of the wall. the larger the temperature fluctuation, and the greater the moisture content fluctuation at the corresponding position inside the wall.
While outdoor temperatures fluctuated significantly, averaging above 14°C, indoor temperatures remained more stable, varying by no more than 4°C. This difference in temperature fluctuation is attributed to a thermal lag, with an average delay of 5.07 hours and a maximum delay of up to 8 hours between outdoor and indoor temperature changes.
Due to elevated outdoor temperatures and rapid moisture evaporation, the relative humidity outdoors exhibited a low range of 40% to 50%. Conversely, at night, humidity soared to nearly 90%. This disparity is attributed to the building's hillside location. In comparison, the indoor relative humidity displayed a milder fluctuation, ranging from 40% to 70%, highlighting the building's ability to regulate humidity more effectively than its outdoor surroundings.
Indoor relative humidity is regulated within a range of 50-60% for 72.6% of the time, while outdoor humidity exceeds 80% for 48.5% of the time. Both indoor and outdoor humidity levels exhibit more dispersed periods between 40-80%. These findings demonstrate the ability of rammed-earth buildings to moderate indoor relative humidity. The stable indoor humidity environment supports comfortable living conditions by reducing the occurrence of extreme humidity levels, the final result shown in figure 12 and 13.



in summer





in winter

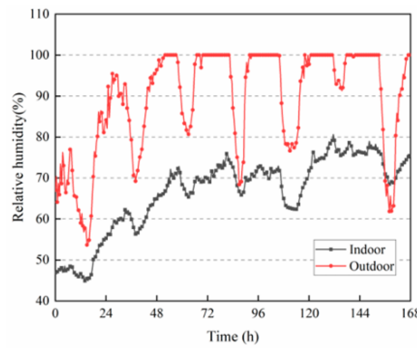


Figure 12, 13: the change in indoor an outdoor temperature and humidity, in summer and winter [3]

3.5.5 The Case Conclusion: During summer and winter, the coupled heat and moisture transfer processes of rammed-earth walls and changes in the indoor environment of buildings were analyzed. The main findings of this study were:
- the study proved that the higher the moisture content of the rammed–earth materials, the larger the related thermal physical parameters,
- the earthen wall had good moisture absorption and discharge characteristics, and that the moisture absorption performance was better than the moisture discharge performance.
- Rammed-earth buildings demonstrate exceptional thermal insulation and buffering capabilities, particularly in high-temperature climates. Their ability to create comfortable indoor environments extends beyond temperature regulation. These walls can absorb and release moisture in response to changes in indoor relative humidity, effectively regulating the humidity level. This dual function, coupled with their thermal insulation properties, makes rammed-earth buildings highly effective in maintaining comfortable conditions even during winter months.

Conclusion: A comparative analysis of earthen building previous cases across diverse regions and countries with hot, dry climates revealed consistent findings, regardless of whether thermal comfort was assessed directly or through advanced simulation programs, they agreed on:

- earthen buildings have a high ability to enhance thermal comfort inside the building compared to other building materials.

- Integrating sustainable earthen building materials with passive design principles can enhance indoor thermal comfort, minimizing discomfort hours and eliminating the reliance on air conditioning. This approach promotes environmental conservation, reducing energy consumption.
- the earthen wall had good moisture absorption and discharge characteristics, effectively regulating the humidity level and in addition to thermal insulation properties.
- One case demonstrated that the long-term energy savings and sustainability benefits make earthen buildings a real cost-effective solution.

References:

1. B. Marques, 2021, H. Varum, H. Corvacho, et al., "Using Raw Earth Construction Systems on Contemporary Buildings: Reflections on Sustainability and Thermal Efficiency", Renew. Energy Environ. Sustain. 6, 46 (2021), https://doi.org/10.1051/rees/2021041
2. M. Wakil, H. El Mghari, S. Idrissi Kaitouni et al., Thermal energy performance of compressed earth building in two different cities in Moroccan semi-arid climate, Energy and Built Environment, https://doi.org/10.1016/j.enbenv.2023.06.008
3. M. Jiang, 2023, B. Jiang, R. Lu et al., "Thermal and Humidity Performance Test of Rammed-Earth Dwellings in Northwest Sichuan during Summer and Winter" https://doi.org/10.3390/ma16186283, Materials 2023, 16, 6283.
4. C. Hema, 2020, A. Messan, A. Lawane et al., "Impact of the Design of Walls Made of Compressed Earth Blocks on the Thermal Comfort of Housing in Hot Climate", http://dx.doi.org/10.3390/buildings10090157, Buildings 2020, 10, 157
5. X. Dong, 2014, V. Soebarto, M. Griffith, "Achieving thermal comfort in naturally ventilated rammed earth houses", Building and Environment, Volume 82, December 2014, Pages 588-598, https://doi.org/10.1016/j.buildenv.2014.09.029.
6. L. Ben-Alon, A. R. Rempel, "Thermal comfort and passive survivability in earthen buildings", Building and Environment, Volume 238, 15 June 2023, 110339, https://doi.org/10.1016/j.buildenv.2023.110339.
7. M. Ángel Mellado Mascaraque,F. Javier Castilla Pascual, V. Pérez Andreu and G. Adrián Gosalbo Guenot, "Evaluation of the Thermal Comfort and Energy Demand in a Building with Rammed Earth Walls in Spain: Influence of the Use of In Situ Measured Thermal Conductivity and Estimated Values", Buildings 2021, 11(12), 635; https://doi.org/10.3390/buildings11120635.
8. Vesna B. LOVEC, Milica Đ. JOVANOVIC–POPOVIC, Branislav D. ZIVKOVIC, "THE THERMAL BEHAVIOR OF RAMMED EARTH WALL IN TRADITIONAL HOUSE IN VOJVODINA: THERMAL MASS AS A KEY ELEMENT FOR THERMAL COMFORT", Faculty of Architecture, University of Belgrade, Serbia. Bulevar kralja Aleksandra 73/II, Belgrade, Faculty of Architecture, University of Belgrade, Serbia. University of Belgrade, Faculty of Mechanical Engineering, Serbia.
9. Sofia Sampaio, M. Glória Gomes, António Borges Abel, "ANALYSIS OF THE EARTH CONSTRUCTION'S THERMAL BEHAVIOR – IN SITU MEASUREMENT AND EVALUATION OF THERMAL PERFORMANCE OF THREE RAMMED EARTH CASE STUDIES", Instituto Superior Técnico, DECivil/ICIST, UTL, Av. Rovisco Pais, Lisboa, Portuga, Universidade de Évora, Largo dos Colegiais, Évora, Portugal.
10. O. Ali Mahmoud Bayoumi, "Nubian Vernacular architecture & contemporary Aswan buildings' enhancement", Alexandria Engineering Journal, Volume 57, Issue 2, June 2018, Pages 875-883, https://doi.org/10.1016/j.aej.2016.01.002.

11. Kathryn J McCartney, J Fergus Nico, "Developing an adaptive control algorithm for Europe", Energy and Buildings, Volume 34, Issue 6, July 2002, Pages 623-635, https://doi.org/10.1016/S0378-7788(02)00013-0
12. J. Tinsley, S. Pavía, "Thermal performance and fitness of glacial till for rammed earth construction", Journal of Building Engineering, Volume 24, July 2019, 100727, https://doi.org/10.1016/j.jobe.2019.02.019
13. A. Carrobé, L. Rincón and I. Martorell, "Thermal Monitoring and Simulation of Earthen Buildings. A Review", Energies 2021, 14(8), 2080; https://doi.org/10.3390/en14082080
14. P. Gupta, D. Cupkova, L. Ben-Alon, "EVALUATION OF RAMMED EARTH ASSEMBLIES AS THERMAL MASS THROUGH WHOLE-BUILDING SIMULATION", 2020 Building Performance Analysis Conference and SimBuild co-organized by ASHRAE and IBPSA-USA.

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Comparison of traditional finish materials from the Himalayan region (Nepal) to the deltaic plane (Bangladesh)

Renu Maharjan,
Conservation Architect, Hanumandhoka museum, Nepal
renu.renumaharjan@gmail.com
Fatiha Polin
Founder & Executive Director, Perceive Research & Design, Bangladesh
fatiha.polin@gmail.com

ABSTRACT
Vernacular or traditional buildings demonstrate the best use of environment-friendly and locally available materials such as mud, timber, and stones in various forms and shapes. But, unfortunately, these structures are predominantly found in rural or peri-urban areas. In urban settings, they have been largely replaced by concrete or brick structures, and there seems to be little inclination to revive or preserve them.
The primary aim of this paper is to investigate the traditional construction material, especially in the case of indoor finishes like floor or wall surface. The focus is on examining how this particular material is utilized with minor variations in different geographic locations; such as the Himalayan region, mid hill region-Tarai region of Nepal, and also in the deltaic plane of Bangladesh covering from the highest region to the lowest possible place of human settlement.
The initial phase of the research involves extensive literature review from various previously published papers on the subject and then a thorough examination of artists utilizing mud for diverse purposes across the region.
While various articles and other sources contribute to the study, they are predominantly concentrated in one location. This particular intention of this paper is to broaden the scope by examining and comparing the material itself and the processes involved in its usage in multiple location to understand its behavior in different humidity, temperature and soil type.
The anticipated result could be the innovative utilization of mud. Given that mud houses are on the brink of disappearance, research in this domain encourages the continued use of such structures. Additionally, the paper could serve as a comprehensive compilation of documents pertaining to earthen architecture in both Nepal and Bangladesh.

Keywords:
Earthen architecture, mud plaster, traditional materials, natural building.

1. INTRODUCTION

Throughout history, humanity has relied on the Earth as one of its most ancient construction resources. Locally available materials like stones, timber, and bricks were utilized in the creation of structures. However, the ascent of industrially manufactured materials such as concrete, brick, and steel led to a decline in the prominence of earthen architecture, gradually relegating it to obscurity. Yet, in recent times, the surge in demand for eco-friendly building materials has heralded a resurgence of interest in earthen architecture in different part of the globe. İn this paper, two distint geographical area – Nepal on the high altitude and Bangladesh on the lower deltaic plane has been selected for study.
Nepal, nestled in the heart of the Himalayas, is a land of diverse landscapes and cultures. It can be broadly

divided into three distinct regions: the Himalayan region, the Mid-hill region, and the Tarai region. Each of these regions contributes to the rich tapestry of Nepalese culture and heritage, art, and architecture. This architecture depends on the geological composition of different regions and the availability of various types of mud in it.

On the otherhand, Bangladesh is located at the lowermost deltaic plane of three mighty river systems - the ganges-padma river system, brahmaputra-jamuna river system and surma-meghna river system. Based on altitude and relief, the land can be divided into three major categories of physical units: Tertiary hills, Pleistocene uplands and Recent plains (formed in recent epoch). The low altitude of the major areas of the country and heavy monsoon rainfall make floods a frequent annual phenomenon in Bangladesh. However, those regional variations molded the distinct earthen architectural practics spreading all over the country.

2. REGIONS OF NEPAL AND CORRESPONDING STRUCTURES:

a. Himalayan region (Lomangthang)
b. Mid hill region (Kathmandu)
c. Tarai region (Chitwan)

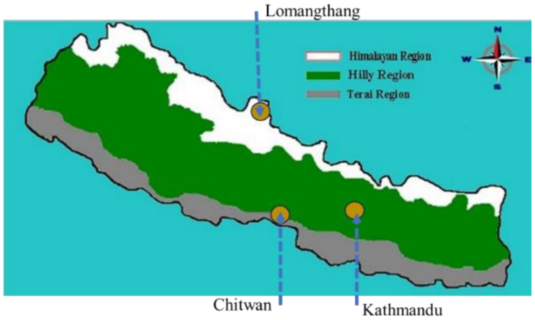


Figure 36: Three main regions of Nepal and the study area

The Himalayan region of Nepal is a highest-altitude landscape and Lomangthang is chosen for the study of the mud construction of this region.

Lomangthang, nestled in the Mustang district of western Nepal, is a rural municipality deeply infused with the cultural and linguistic essence of Tibet. Perched at an elevation of 3,840 meters (12,598 feet) above sea level, inside its ancient walls lie a treasure trove of wonders: royal residences, *chortens*, traditional settlements, Buddhist monasteries, and a wealth of artifacts and art, all are of either complete mud structure of partially mud architecture.

The mid-hill regions of Nepal, also known as the Middle Hills, are an integral part of the country's diverse geographical landscape. These regions lie between the lowland Terai plains and the high Himalayan mountains. It typically range from about 700 to 3,000 meters above sea level. This elevation results in a moderate climate, making it suitable for habitation and agriculture.

The style and techniques of mud architecture in Kathmandu are influenced by various ethnic groups and their respective building traditions. The Newars, the indigenous people of the Kathmandu Valley, have a rich tradition of using local materials, including mud, for construction.

The Terai region of Nepal, also known as the Tarai or the Madhesh, is a lowland area that forms the southernmost part of the country, bordering India. It is a significant geographical, cultural, and economic region of Nepal.

Chitwan, a district in the Terai region of Nepal, is renowned not only for its national park and rich biodiversity but also for its traditional mud architecture. This form of architecture is integral to the cultural heritage of the local communities, particularly the Tharu people, who are indigenous to the region.

Location	Type of Mud	Preparation	Construction
Lomangthang	Soft and light black mud is used for the mud structures.	Mud is extracted from a selected spot on the ground. It is sun dried and sieved and soak in water for 2/3 days. A wooden mold is filled with this soaked mud and rammed from top.	For rectangular mud bricks, they are layed and binded with mud mortar. These walls are plasters with mud again. The mixture of the mud plaster is straw/rice husk, cow dunk, mud and water
Kathmandu	Soft and yellow mud is used.	Mud is extracted from a selected spot on the ground (as deep as possible). It is sun-dried sieved and soaked in water for 2/3 days.	Bricks, are laid and bound with mud mortar. These walls are plastered with mud again. The mixture of the mud plaster is straw/rice husk, cow dunk, lintels, mud and water
Chitwan	Soft and light-yellow mud is used.	Clay from the pond is extracted and mixed with cow dung, rice bran, and straw. The yellow ochre clayey soil is also mixed with the rice husk forms cohesive cement.	The walls are made up of thatch thickly coated with cow dung and mud on wooden frames. A coating of clayey soil and cow dung is applied on the cob walls, the floors, and the household equipment: silos, fire etc.

Table 1: Use of Mud in different regions of Nepal

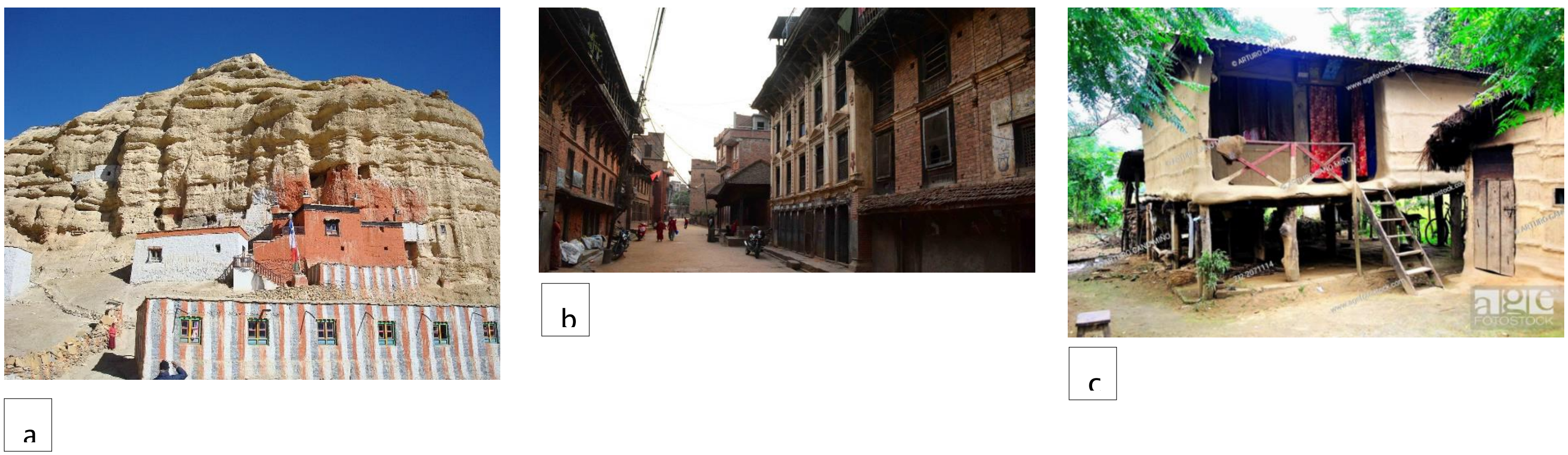


Figure 2: Earthen architecture in Lomangthang (a), Kathmandu (b), and Chitwan (c)

Location	Most common problem	Common solution
Lomangthang	I. Erosion of mud due to rain and wind. II. Lack of maintenance of the structure on time.	I. A layer of Pang/Moss is put on the roof. It absorbs water and keeps the walls dry. II. Stacking of firewood on the roof does not allow the water to directly penetrate the mud structures. III. Use of stones breaking the moisture path rising from the ground to the walls.
Kathmandu	I. Erosion of mud structures due to rain. II. A thick layer of mud and tiles makes the top of the structure heavier than the rest of the building.	I. A large projection of the roof protects a good wall area even in the rainy season. II. Using stones breaks the moisture path from the ground to the walls above. III. Use of a special tapered brick (*Dachi appa*) cover the mortar
Chitwan	I. Erosion of mud due to rain in monsoon ruining the external surface of the walls. II. Short life span of the structure. III. Shortage of timber, tiles, *khariya* grass, and alluvial clay found in ponds which are used to build a traditional house.	I. Spread the awareness of the value of vernacular architecture. II. Repair the structure frequently.

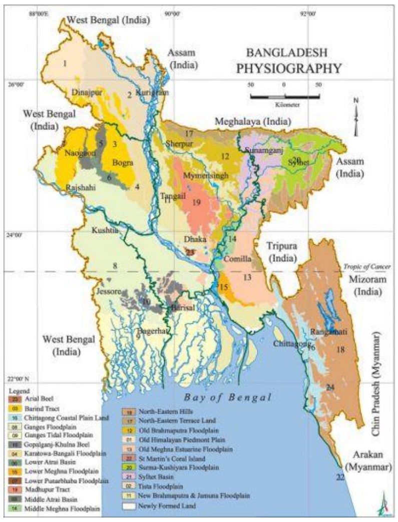
Table2: Problems and their solution while using mud

a b c

Figure 3: fire wood stacks on the roofs of houses (a), wedged brick (b), and Tharu house (c)

3. REGIONS OF BANGLADESH AND CORRESPONDING STRUCTURES:

a. Tertiary hills
b. Pleistocene uplands
c. Recent plains (formed in recent epoch)



Hillocks and hills are confined to a narrow strip along the southern spur of the shillong plateau, to the eastern and southern portions of the Sylhet district, and to the chittagong hill tracts (CHT) in the southeast of the country bordering upon the Indian states of Tripura and Mizoram and Myanmar. People used to live in houses made on bamboo stilts. Ocasionally the bamboo mats used as wall were daubed in mud to get protection from the cold winter. Mud houses can be seen on low hills with beautiful floral or pattern decoration created by women with soaked rice paste.

Pleistocene uplands comprising the lalmai hills of Comilla district together with the low hills in the east through Dhaka and Rajshahi divisions to West Bengal of India. The river systems of the Meghna and the Jamuna trisect the Pleistocene upland giving rise to three blocks of high lands that exhibit smooth rolling topography. The Barind Tract, the Madhupur Tract, and the Tippera Surface form three individual blocks. This terrace consists of reddish and yellowish and partially mottled clays and is characterised morphologically by a dendritic drainage pattern, which is typical of all older and makes earthen structures of even two/three storied height.

The physiography and the drainage pattern of the vast alluvial plains in the central, northern and western regions have gone under considerable alterations in Recent times. The deposition of Quaternary sediments was influenced and controlled by structural activities. The eastward shift of the Ganges and tista as well as the significant westward shift of the Brahmaputra during the last 200 years gives evidence of epeirogenic movements even in recent days. The high amount of clay and silt with the lower elevation makes it difficult to build only with mud. Traditionally they used to build with reeds, timber and nipa pulm. In the case of mud wall the plinth has to be very high; above the flood level.

In the context of physiography,these three distinct regions; each having distinguishing characteristics of its own, has been furher divided into 24 sub-regions and 54 units. From the climatic perspective, Bangaldesh used to have three seasons: the hot and humid pre-monsoon season (March-May), the monsoon (June-October) and the cold dry season (November-February); but due to climate change, there is often prolonged rainy season or heavy shower within a short period. Therefore, this climatic condition, geography, complex soil structure and socio-economic condition has generated an even diveresd traditional construction systems.

Location	Type of Mud	Preparation	Construction
Tertiary hills	Red, brown, pink, green and yellow mud is used.	Bamboo structures on stilts are seen on the high slopes and mud structures are seen on the lower level.	Mostly bamboo columns are used as a stilt and timber planks are used make the platform. Walls are made either with bamboo mats or wooden planks.

		Mud is extracted from the hill, sieved and mixed with straws to make cob structures.	Roofs are typically made of reeds or iron sheets. Sometimes structures on the lower hill has mud wall.
Pleistocene uplands	Red and yellow mud is used.	Mud is extracted from the highland. Sometimes built with cob wall or a chunk of mud is placed one after another to build the structure and sun-dried.	Chunk of mud are laid and bound with mud mortar. These walls are plastered with mud again. The mixture of the mud plaster is straw/rice husk, cow dung, extract from boiled goat-skin mud and water.
Recent plains	Soft-light yellow and black mud is used for the mud structures.	Clay from the river basin, pond is extracted and mixed with cow dung, rice bran, and straw. The yellow ochre clayey soil is also mixed with the rice husk for cohesion.	The walls are made up of thatch thickly coated with cow dung and mud on wooden frames. A coating of clayey soil and cow dung is applied on the cob walls and floors.

a b c

Figure 3: Earthen architecture on hills (a), Pleistocene uplands (b), and recent plains (c)

Location	Most common problem	Common solution
Tertiary hills	I. Landslide II. Erosion of materials due to rain and wind. III. Lack of maintenance of the structure on time.	I. Buttressing with bamboo and planting of deep-rooted trees II. Use of seasoned bamboo and timber III. Use of Neem oil to protection from insect
Pleistocene uplands	I. Erosion of mud structures due to rain. II. Direct water forced displacement during flood III. Melting down of wall during water logging for a long period	I. Extended roof to protect the mud wall II. Using combing pattern to break the water channel on the wall surface and reduce erosion III. Securing plinth with burnt brick or timber to avoid melting
Recent plains	I. Erosion of mud due to rain in monsoon ruining the external surface of the walls. II. Short life span of the structure due to flood. III. River bank erosion	I. Frequent repairing with mud, cow dung and water mixture II. Increase the height of plinth and securing from flood III. Awareness rising on the comfort and health benefit of traditional houses

	IV. Socio-economic status and prestige

a b c

Figure 3: land slide (a), cob construction (b), and repairing wattle-daub house (c)

4. MUD WORK - NEW CONSTRUCTION OF NEPAL -BANGLADESH

Mud work in new construction in Nepal and Bangladeshis a growing trend that blends traditional knowledge with modern innovation. It offers sustainable, cost-effective, and culturally significant alternatives to conventional construction methods, contributing to environmentally friendly and resilient architecture in the region. Few examples are:

Madan Puraskar Pustakalay, Kathmandu
Madan Puraskar Pustakalay Library building was the first large-scale public building to be built with bamboo and earth, the building hosts the largest archive of Nepali literature in the country. The weight of earthen walls would breathe creating a perfect environment to protect the old documents. This building has been transformational in its treatment of traditional materials and is now a tourist attraction. It has used rammed earth for the building's walls, a material with a high thermal mass that slowly releases heat over time. this results in cool interiors in summer and warmer conditions in winter.

Figure 4: External wall of Madan Purskar Library

Bayalpata Hospital, Accham
In the far west of Nepal, a hospital was built which introduced rammed earth as a locally available material and low-tech construction method. Soil from the site was mixed with a 6% cement content to stabilize the earth for better durability and seismic resistance. Reusable, plastic lock-in-place formwork facilitated faster construction was maintained. The local stone was used for foundations, pathways, and retaining walls.

Figure 5: Exterior of Bayalpata hospital

Kopila Valley School, Surkhet

A school in Surkhet was built for underprivileged children and was an example of using locally available construction materials. The colorful soils for rammed earth walls are borrowed from the surrounding mountains. There is no cement stabilization, because that would inhibit the walls breathing capacity and it will not make the materials reusable in future (Abari).

Figure 6: Kopilla Valley School premises

METI School, Dinajpur

Rudrapur lies in the north of the most densely populated country on the earth. Poverty and the lack of an infrastructure drive many people from the countryside into the cities. The local NGO Dipshikha attempts to follow new paths with its development programme: the intention is to give the rural population perspectives and to help people learn about the value of the village in all its complexity. Part of this is a special school concept that instils in the children self-confidence and independence with the aim of strengthening their sense of identity. İt won the Aga Khan Award for Architecture, 10th Circle.

Figure 7: METI School, Dinajpur

Rupgaon-A Knowledge Exchange Center, Narayanagnj

Rupgaon is a learning center situated at rupganj, Narayanganj about an hour drive from the capital of Bangladesh. The main idea was to make an eco friendly place where everyone can exchange their ideas beign close to nature. There is a multipurpose room, dining, kitchen, wash room and a room for administrative work at the ground floor. On the upper floor there is a meditation room and some accomodations for residential trainings. The ramp from the road side gives access to both upper and lower level ensuring universal accessibility.

Figure 8: Rupgaon learning center, Narayanganj.

5. CONCLUSION

Although there are many benefits of traditional buildings and construction methods, there are always many misconception that earthen buildings cannot provide dust free surface, it is difficult to maintain, it needs frequent repairing, it takes long to build etc. But good things take time to happen and serves better. It just need more awareness to change the mindset from permanence to comfort, from environmental damage to a sustainable future. More research, hands on training, design build workshop, community engagement can offer some strong moral support to tackle the wide spreading construction industries and new materials that are liable to 40 percent of the total environmental polutions. This paper sharing insights from the high altitude to the lower basin would generate wider research scope and solution to improve millions of people still dreaming for a better way of life.

6. REFERENCES

I. *Early childhood school,* Abari

II. *Bayalpata Hospital in Nepal wins global design award,* 2019

III. Madan Puraskar Pustakalaya (MPP), Abari

IV. Rastriya Samachar Samiti,*Traditional Tharu houses on the verge of disappearance,* 2019

V. Er-Rashid, Haroun. 1991. Geography of Bangladesh, Dhaka: University Press Ltd.

VI. Paul, B. Kanti. 2003. Asia's old dwellings, et al. Ronald G.K, New York: Oxford University Press Ltd.

VII. Khalili, Nader. 1983. Racing Along. California: Cal-Earth Press.

VIII. Sing, Rajmoni. 2000. Eco-adaptiveness of Monipuri Housing Technology,(Unpublished Research Paper, Department of Anthropology, University of Dhaka)

IX. Anthony D. King. 1984. The Bungalow. Boston, Mass. : Routledge and Kegan Paul.

X. Ahmed, K. Iftekhar. 1994. *Up to the Waist in Mud*. Dhaka: University Press Ltd.

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We Come from Adobe, We Will Return to Adobe

Author Rümeysa AYDIN-Research Assistant-NNY

Address Ertuğrul Gazi Neighborhood, Nuh Naci Yazgan Campus, Cluster Houses, 38170 Kocasinan / KAYSERİ

E-Mail raydin@nny.edu.tr or rumeysayd07@gmail.com

ABSTRACT

The relationship between humanity and soil dates back to ancient times. People have produced various materials directly and indirectly from soil for centuries. One such material is adobe, which is made from bricks created by mixing soil with clay. This traditional construction method has decreased significantly with the increase in reinforced concrete structures. Reinforced concrete structures, which are increasing day by day, consume the human soul and contribute to the pollution of the world. In contrast, adobe is one of the most suitable building materials for human nature. Indeed, many mythologies and sacred texts indicate that humans were created from soil. For instance, the 55th verse of Surah Taha in the Quran states: "From the earth We created you, and into it We will return you, and from it We will bring you back again." This verse emphasizes that humans were made from soil, that when their lifespan ends, they will return to it, and that they will be resurrected from it. It also highlights the deep connection between the human soul and soil, suggesting that the relationship between humans and soil has never been broken. While this connection is clear, it is further supported by scientific studies that demonstrate the benefits of "earthing." Researchers, designers, and manufacturers have a significant responsibility to promote the reuse of this traditional construction method, whose use has diminished in modern life. If we are all created from soil and will eventually return to it, it follows that we came from adobe and must return to adobe.

Keywords: Adobe, Soil, Human

1. INTRODUCTION

Humans and soil are an inseparable whole. This relationship dates back to humanity's earliest written sources. In the Epic of Gilgamesh, it is stated that man was created from soil and clay. In the sacred texts of monotheistic religions, it is also mentioned that soil is the origin and source of creation. The human-soil relationship is very important and must be well understood. Universal culture has a great need for the insights that can be gained through this analysis [1]. In the Middle Ages, the story of humanity was viewed as a return from soil to soil. The importance that people of this period attributed to soil was shaped by the value they placed on the intermediate time spent coming from and going to it. This situation, which Âşık Veysel likened to a two-door inn, summarizes the story of humanity. Until recently, being without soil was equated with being rootless, and soillessness was regarded as misfortune. Since almost everything was shaped by soil, its role in the lives of humans during ancient and medieval times holds significant importance [2]. People utilized soil in many areas, creating various kitchenware, ornaments, pottery, graves, and structures. Adobe brick, made from soil, is also a natural building material that has provided living space for people for many years.

The study consists of three stages in the order of research and expression. In the first stage of the study, a literature review was conducted using various sources to explain the human-soil relationship, including statements about humans being created from soil. In the second stage, the products humans have made from soil since ancient times were listed, highlighting that adobe construction is among these products, and adobe was examined as a building material. After explaining the relationship between humans and soil in these two stages, in the study finally expressed the benefits of adobe construction for human health due to its soil content. Additionally, the benefits of soil for human health were discussed, emphasizing that adobe construction should be utilized more today.

2. HUMAN AND SOIL

2.1 Creation of Human from Soil by God

When literature is examined, there are many expressions, narratives, and verses indicating that man was created from soil. Whether in pre-Islamic monotheistic religions or Islam, various sources state that man was created from soil. In all Mesopotamian narratives, soil was used in the creation of man. Analyzing various mythologies and sacred texts reveals that the information about man being created from soil overlaps and shows significant parallelism.

In the Epic of Gilgamesh, it is stated that creation and design were made with soil (clay), similar to the teachings of religions based on revelation [3]. In the Altai legends, although a large ocean and water are fundamental, it is believed that man was not created from water; rather, man was originally made from soil. According to the narrative, God Ulgen sees a piece of land floating on the sea while walking. As he approaches, he notices mud on the soil. He thinks this is a human being, and as he contemplates this, the mud takes on a human form. In Iranian mythology, the first man was made of sticky soil, which we refer to as clay. For this reason, the Iranians called the first man Kil Shah. The Turks, on the other hand, focused more on clay [4]. Again, there are statements in Greek mythology indicating that women were created from soil. In *Works and Days*, the creation of women is described in detail as follows:

"...Then he called the famous Hephaestus. He said to him, 'Mix some soil with water. Let there be a human voice and strength in it, so that its face resembles that of goddesses and its body resembles that of young girls.' Then he told Athena, 'Teach her to embroider and weave colorful fabrics.' He told Aphrodite, 'Envelop her with your spells. Let desires and wishes remain in her.' He told Hermes, who had killed the hundred-eyed giant, 'Let there be a dog's heart and a fox's temperament.' They all did what Zeus commanded. The lame craftsman Hephaestus created a human from soil..." [5].

The First of the Ancient Roman Foundation Epics: In the *Aeneid*, when the hero of the epic visits his father in Elysium, he sees people walking around in a peaceful landscape. When he asks who these people are, his father explains that they are spirits who have not yet found a body, and then he describes the "plan of creation." According to this plan, "...The Creator first created the substance from which the four elements that constitute the soul—fire, air, earth, and water—were formed. When all of these were combined, they took the form of the most perfect element, fire, and became flame. This substance was scattered among the celestial beings—the sun, the moon, and the stars—like seeds. The secondary gods created man and all other animals from this seed by adding clay in various proportions. The mixture corrupted and reduced the purity of the substance. Therefore, the more clay there is in a person's composition, the less pure that person is..." [5].

There are statements in mythology that indicate man was created from soil, as well as verses in various holy books that affirm this belief. In Genesis 2:7 of the Torah, it is written: "And the LORD God formed man of the dust of the ground and breathed into his nostrils the breath of life and man became a living soul " [6]. While this is stated, there are multiple verses in the Holy Quran that also mention that man was created from soil. The 55th verse of Surah Taha states: “From the earth We created you, and into it We will return you, and from it We will bring you back again.” [7]. The 14th verse of Surah Ar-Rahman states: “He created humankind from ˹sounding˺ clay like pottery.” [8]. The 12th verse of Surah Al-Mu’minun states: “And indeed, We created humankind from an extract of clay.” [9].

2.2 Creation of things from Soil by Human

For years, humans have used soil indirectly and directly to produce something. They have obtained crops through agriculture, shaped the soil and directly produced various household and kitchen tools such as pottery. They have also continued to use soil for after-death purposes as cube graves found in ancient excavations. Adobe brick construction is the method of shaping soil into bricks by humans and using it as a building material. Today, humans still continue to produce from soil. Soil continues to be used in pottery production, as a burial place after death, and in various building materials (glass, adobe, ceramic, brick and tile). It is more accurate to describe the soil used here as clay. Clay is defined as an impermeable fine-grained soil originally made of aluminum silicate. Clay is a plastic soil that shrinks when dry, increases its volume when wet and gives off its water when compressed [10]. Adobe, ceramic, brick and tile are clay-based building materials [11].

2.2.1. Various Kitchenware and Ornaments Made of Soil

Humanity has always used tools to meet its basic needs since its existence. The auxiliary tools required within the scope of the first steps of the hierarchy of needs in the struggle for life of man were created with his intelligence along with his existence. The production of baked clay, which is accepted as the most important invention of the Neolithic Period, the first revolution of humanity, continued its production in a more practical and aesthetic way with the potter's wheel, the first industrial production tool, evolving towards the Bronze Age [12].

Although it is not known exactly when pottery, one of the oldest arts in human history, was first discovered, it is proven by sources that Hz. Ibrahim, who is called the father of society, made his living by making pottery and dealing with agriculture and that it has been made ever since. Pottery, which is included in our dictionary as "earthenware pot made of dissolved mud", is produced by turning soil, the oldest known and most useful raw material, into mud, and sometimes mixing it with clay and shaping it by hand or with a device called a potter's wheel [13].

Figure 1. Antalya Museum, from Left to Right; Archaic Classical Period, Geometric Period, Various Perfume, Oil Bottles, Kitchenware and Ornaments, Photo Source: Author Photo Archive

In the Neolithic Period, which is considered the first revolutionary period of humanity, a very important stage was reached in agriculture with the cultivation of plants, and in parallel, the development of many tools that needed to be used began in this period. Another important development of the period was pottery, which divided the Neolithic period into two and started the Ceramic Neolithic Period. Pottery, which can be considered the first industrial production with a zeitgeist approach, was also the starting point of today's ceramic industry and modern ceramic art [14].

2.2.2 Earthenware Jar Tombs (Cube Tombs)

Earthenware jar tombs: A type of grave in which a ceramic container such as a jar, pot or cooking pot is used as a coffin. Although some were used for single burials, there are also those with multiple burials [15].

Figure 2. Antalya Museum Earthenware Jar Tomb Example, Photo Source: Author Photo Archive

In the excavations carried out by Prof. Machteld Mellik since 1963 and determined by the American Bryn Mawr College, the existence of an Early Bronze Age settlement dated from the middle of the 3rd millennium to the beginning of the 2nd millennium BC was determined. A quadrangular palace surrounded by moats and the ruins of houses around it and to the west of these, the Cube Tombs (Pithoi) exhibited today in the Antalya Museum were unearthed. Other archaeological findings unearthed in the excavations include pithoi, ceramics, bronze needles, mirrors, spindle whorls, seals, bracelets belonging to young girls, beak-mouthed jugs, necklaces and spearheads exhibited today in the Antalya Museum [16]. When we look at all these, it can be seen that man's production from soil dates back to very ancient times.

2.2.3 Adobe

Adobe brick is defined as a primitive brick made of straw and clay that is poured into molds and dried in the sun to be used in wall construction [17]. When one of Hz. Mevlana's seven pieces of advice, "Be like soil in modesty and humility..." is considered, adobe is a modest material due to its soil content. The definition of adobe given in TS 2514 is as follows; "Adobe is a building material obtained by mixing straw or other plant fibers (reeds, coarse grass, hemp fibers, leftover straw collected from barn mangers, dry heather, pine needles, tree branches, sawdust, planer shavings, etc.) into clayey and suitable soil, kneading it with water, then pouring it into molds, shaping it and drying it in the open air." [18].

Figure 3. Adobe Brick Making, Photo Source from Left to Right: [18-19-19]

- Cheap, easy to obtain and can be produced quickly.
- When the effects on the structure's ecology and human health are taken into account, there is no harm.
- Balances in humidity.
- Cleans the air.
- It is an environmentally friendly material that consumes the least energy compared to other features during production and also requires less energy for heating and cooling.
- It has no radioactivity.
- It does not pollute nature, it is due to its nature.
- Since it is produced on site, there is no transportation cost.
- It protects the wood.
- It is resistant to pressure, if not protected, it becomes less.
- It can be reused and recycled.
- When produced according to the right architecture and engineering policies, it is twice as resistant to earthquakes as reinforced concrete structures [20].

In addition to all these positive features of adobe buildings, they require constant maintenance and repair. However, they can be built in dry conditions. They cannot be built in rainy and rainy weather conditions. They are sensitive to moisture and water. Disintegration and deterioration occur due to water and moisture. Water, especially rain, can cause adobe blocks and therefore walls to disintegrate. Heavy rain on adobe wall surfaces can cause wear and tear on adobe walls and breakage of parts. Extremely high temperatures cause cracks during the drying of bricks wet from rain.
Small animals such as reptiles, rodents and insects and plants growing in the soil and their roots can also cause adobe buildings to rot and deteriorate. Its compressive strength, especially tensile strength, is low [18].

The material, which is seen as primitive and outdated in our country, actually has many advantages over other building materials. At the same time, adobe continues to be integrated with many different construction technologies in America and European countries [20].

Certain rules must be followed for the correct use of naturally produced adobe material in construction. First of all, the timing of the construction should be done well. Since adobe is a material that can be affected by water, the climate conditions should be taken into consideration. Moisture insulation should be done in necessary places, and the wall surfaces inside and outside should be covered with plaster. Things to consider in construction: Selection of the building location (in regions with little rainfall, arid areas, regions with low earthquake effects*) Selection of the building type (residence, farm buildings, workplaces, service buildings, etc.) Selection of the building plan type (square, rectangular) * In earthquake zones, it is useful to reinforce adobe with a wooden frame [21].

3. BENEFITS OF SOIL MATERIAL TO HUMAN HEALTH

When you go on a village vacation for a while, you may have noticed that you wake up earlier than you do in the city. Although there are various factors such as air and water in this situation, the fact that the living space material is natural also affects our biological clock and the body feels more vigorous and healthy. In general, village houses are made by the local people themselves, using natural building materials found in the region, which can be interpreted as changing our biological clock and making us feel more vigorous.

Frequently used natural building materials include: Soil, Wood, Straw, Stone, Clay, Bamboo, Sand, Adobe can be counted as [22]. Indeed, various studies have revealed that natural construction materials are beneficial to human health. Soil is one of these materials. Therefore, adobe is also a building material beneficial to human health due to the soil it contains. You may have heard experts talk about the importance of keeping our feet on the ground and transferring the negative energy accumulated in the body from time to time. The study below proves this sentiment.

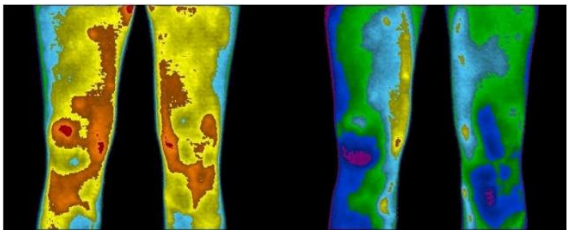

Figure 4. These thermal images, of a patient with pain in the area of both knees, were taken a half-hour apart before (left) and after Earthing (right). Tissue damage generates heat, represented by the hot colors on the left. The difference shows a clear and rapid resolution of inflammation [23].

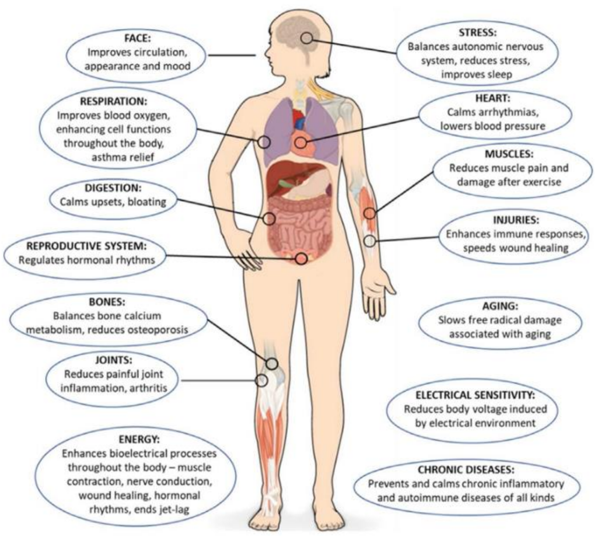

Figure 5. Systemic benefits of Earthing, Photo Source: [23]

When we examine the figure above, it is clearly seen what benefits grounding has on which areas of our body. Ongoing research shows that Earthing augments the physiology's infrastructure from the foundation up. As the burden of global disease and pain conditions grow increasingly larger, it is more necessary than ever to promote effective prevention and lifestyle practices. Such practices should include Earthing. Earthing means a return to a forgotten and vital aspect of Nature Earth's healing properties that has great potential to both prevent and treat common disorders afflicting modern society [23].

4. CONCLUSIONS

When we examine the literature, we see that soil is in constant communication and transformation with humans. Humanity has maintained its connection with the soil for centuries, continuously producing and consuming items derived from it, both directly and indirectly. People have made pottery from soil, engaged in agriculture to obtain products, consumed those products, and returned the seeds from those products back to the soil. This cycle has been ongoing for many years. This interaction was not limited to agriculture and pottery; soil has also been used as a building material. A human being, who has been in contact with the soil throughout life, is buried in the soil like a seed when he dies, and according to the Holy Quran, he is created from the soil once again. Taking all of this into account, the following cycle emerges: a human being is created from soil, creates from soil throughout his life, and when he dies, he and his products return to the soil.

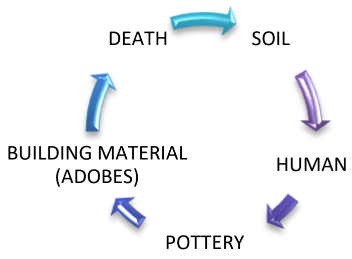

Figure 6. Life Cycle of Human and Soil, Created by the Author

When we remove the soil from this unique cycle, there is neither a human being nor pottery nor adobe. When we remove the adobe, a human being does not become a human being and continues to struggle with various troubles. Now, let's consider two separate lives. One is a weary life cycle that we all experience, living inside concrete structures. We wake up in the morning without even seeing the sunrise due to the surrounding buildings. We go to work out of necessity and shop at the market after work without seeing the sunset. We eat our meals in front of the television. We fill up with stress and electricity in traffic and in front of the computer. And we end the day without touching the ground. The other life is a primitive life cycle compared to modern life, consisting of natural materials (stone, soil, adobe, etc.), where we grow our own fruits and vegetables on our own land when necessary, earthining ourselves while living and growing products. The second life, which is romanticized by popular culture today, is, of course, a life that has its difficulties but is healthy and necessary for human nature.

Figure 7. Urban Life in a Reinforced Concrete Building - Life in an Adobe Building, Photo Source from Left to Right: [24-25].

The important point here is to include adobe, which consists of soil, into our lives and benefit from its advantages. However, there are difficulties in incorporating this material into modern life. If the disadvantages of the material are addressed and these problems are solved, this material can indeed keep up with modern life.

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6. REFERENCES

[1] Güner, G., On the human-soil relationship, Turkish Journal of Agriculture and Forestry, 116-117, May-June 2019 http://www.turktarim.gov.tr/Haber/274/insan-toprak-iliskisi-uzerine
[2] Arifoğlu, Y. AÇÜ International Journal of Social Sciences, Volume: 5, Issue:1, pp. 53-60, 2019.
[3] Yılter, S. 'Comparison of the Concepts of "God" and "Creation" in the Epic of Gilgamesh (Enome Eniş) and the "Creation Myth" of the Altay Turks', Mecmua International Journal of Social Sciences, 2 (4), 29-40, 2017.
[4] https://tr.wikipedia.org/wiki/Yaratılış_Destanı_(Altay) Last Access Date: 11.08.2024
[5] Kurşun Cengiz, P., 'Myths in the Ancient Age in the Light of Written Sources', Master's Thesis, 2014
[6] https://biblehub.com/text/genesis/2-7.htm Last Access Date: 11.08.2024
[7] https://quran.com/taha/55 Last Access Date: 11.08.2024
[8] https://quran.com/55?startingVerse=14 Last Access Date: 11.08.2024
[9] https://quran.com/23?startingVerse=12 Last Access Date: 11.08.2024
[10] Hasol, D., 2010. "Encyclopedic Architecture Dictionary", YEM Publications, Istanbul
[11]https://www.santiye.com.tr/kil-esasli-yapi-malzemelerinin-cati-ve-cephelerde-gecmisten-gunumuze-surdurulebilir-kullanimi-623.html#:~:text=Adobe%2C%20ceramic%2C%20brick%20and%20tile,gereçlere%20given%20isimdir%20%5B2%5D.
[12] Ünal, S. and Hasekioğlu, U., Use of Lake District clays in ceramic forms with three-dimensional printing technology. 7th International Zeugma Conference On Scientific Researches, (ed.: M. Kotuk), 225-234, Gaziantep: Iksad, 2022
[13] Doğan, H., An art as old as human history: Pottery Turkish Journal of Agriculture and Forestry, 74-77, May-June 2018 http://turktarim.gov.tr/Haber/82/insanlik-tarihi-kadar-eski-bir-sanat-comlekcilik
[14] Ünal, S. and Hasekioğlu, U. Ceramic Production with 3D Printers from the First Type of Neolithic Pottery to the Present Motif Academy Journal of Folklore, 2023, Volume: 16, Issue: 42, 821-835.
[15] Mutlu, G. AÇÜ International Journal of Social Sciences, Volume: 4, Issue: 2, pp. 71-101, 2018.
[16] https://www.ktb.gov.tr/yazdir?CFDABF2C39F377F3B7D4805CD9915408 Last Access Date: 11.08.2024
[17] TDK https://sozluk.gov.tr Last Access Date: 11.08.2024
[18] https://insaatt.com/kerpic-nedir-ozellikleri-ve-avantajlari-kerpic-evler/
[19] https://commons.wikimedia.org/wiki/User:Soare
[20]https://gaiadergi.com/doga-dostu-kerpicin-faydalari-ve-dunyadaki-kerpic-yapilar/#google_vignette
[21] Özgünler Acun, S., Gürdal, E., From Yesterday to Today Earth Building Material: Adobe
[22] https://www.uksyapi.com/tr/blog/yapi-malzemeleri Last Access Date: 14.08.2024
[23] Menigoz, W., Latz, T. T., Ely, A. R., Kamei, C., Melvin, G., Sinatra, D., Integrative And Lifestyle Medicine Strategies Should Include Earthing (Grounding): Review Of Research Evidence And Clinical Observations, Explore 16 (2020) 152-160.
[24] https://tr.wikipedia.org/wiki/Kentleşme
[25] Photo: AA/Muhammed Ali Akman https://www.aa.com.tr/tr/yasam/sonsuz-sukran-koyunun-kerpic-evleri-betona-alternatif-oldu-/1256704

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The Remains of the Demolished Piece of City: Çolak House

Dr. Architect Saadet Mutlu KAYTAN

Pamukkale University Kınıklı Campus, Faculty of Architecture and Design, Department of Architecture, Denizli, Türkiye

smkaytan@gmail.com

ABSTRACT

Due to its geographical location and living conditions, Denizli is an important transition and settlement center from past periods to the present. In the city, which was affected by urbanization and industrialization policies, the construction of apartments and slums started to become widespread since the 1950s and has continued increasingly since the 1980s.
Çolak House, located in Zümrüt district, is a unique building in its immediate vicinity with its adobe construction system and traditional architectural features. It is surrounded by reinforced concrete apartments and office buildings. The road axis passing right in front of the building connects the Denizli-Antalya highway to Vatan Street, and threatens the authenticity of the building with intensified vehicle traffic.
Within the scope of the study; spatial transformations at the urban scale in Türkiye and Denizli were analysed and the current status of the building was tried to be explained. For this purpose, it is aimed to document the building with photographs and to analyse the plan scheme. The aim of this study is to determine the original architectural features of a building surrounded by high blocks in today's urban texture and to draw attention to the adobe texture which is in danger of extinction.

Keywords: Adobe, Earth architecture, Denizli traditional housing texture, Vernacular architecture, Adobe construction.

1 INTRODUCTION

The principles of modern urbanism were put forward in the studies of the International Congress of Modern Architecture (C.I.A.M.) organized in Athens in 1932. In this study, called the "Athens Card", sub-headings such as the city, the urban region, the current state of cities, housing, transportation, recreation and work were discussed. It was stated that the city is a part of the political, social and economic whole that creates the region, and it was concluded that the reasons that cause urban developments depend on continuous changes [1].
In the 1998 Athens Charter, it was emphasized that cities should be organized to meet the social and cultural needs of current and future generations and that civic actors and professional groups should participate in urban developments [1].
In the 2003 revision, the definition of "Harmonious City" was added. The issue of cohesion is addressed in areas such as the harmony of visual elements and the harmony between different urban functions, infrastructure networks, new information and communication technologies [1].
Academic, sociological, economic and political studies and decisions on urbanization, which

have affected the whole world, and the transformation process that has spread over many years have also been effective in Türkiye.
İlhan Tekeli states that it is generally said that urban planning developed as a reaction to the problems of the industrial city caused by industrialization that emerged within the market mechanism and in accordance with the liberalist understanding of property [2].
Tekeli, refers to the period from 1950 to 1980 as one of the stages of the modernization project in urban planning in Türkiye. He states that the rapid urbanization in the country was effective in the modernization project [2].
The transition to the multi-storey reinforced concrete block housing model in Türkiye began after the 1950s with the activities of Emlak Kredi Bank. Levent and Ataköy are among the first examples in this context. These early examples are sensitive to issues such as solar orientation, use of green space and ventilation. In the apartment building examples of later years, however, examples that do not show sensitivity to the relationship between environment and design have multiplied. Architectural concerns were replaced by concerns of material gain [3].
According to Sibel Bozdoğan, after the 1980s, there is a building boom and rapidly changing urban landscapes [3]. The change in the silhouettes of streets, avenues and neighborhoods has accelerated.
Migratory movements that began to accelerate from rural areas to urban centers in the Republic of Türkiye in 1950, were accelerated by industrial reforms, transportation and also planning policies. It also continued to resume in as a result of intensified privatization and urbanization policies in the 1980s. The traditional housing texture has given up its place to apartments and slums over time.

2 URBAN CHANGE IN DENİZLİ

Denizli, located in the Aegean Region of Türkiye, has been affected by the industrialization and urbanization policies in the country and is one of the important industrial cities of the region. Especially the acceleration of industrialization has increased migration to the city.
The city has experienced many disasters throughout history due to its location in an earthquake zone, and the zoning plans and architectural typology have also been affected by this situation.
Starting from the 1950s, the industrialization process in Denizli has developed from small independent producers oriented towards the domestic market to a large, organized production structure. Denizli, which was included in the scope of "Priority Regions for Development" between 1973-1981, gained privileges in the implementation of incentive measures and its industrialization was supported. The increase in industrialization and exports led to intensive migration to the city and an increase in the number of factories on the highways. The preparation of zoning plans accelerated in this period. As the industry developed in Denizli, the old city silhouette was lost due to rapid urbanization, concretization, increase in the number of floors and unplanned, irregular and dense construction that emerged due to rent concerns. Industrial facilities covering the city center and its surroundings have surrounded the city. Since the sectors where labor force is used in Denizli are located in the city, the city has turned into a place of production. Along with this, squatting and dense apartment building started [4].
After 1980, increasing privatization movements and industrialization in relation to politics further accelerated the change in the urban structure. Increasing migration has accelerated the need for housing. The need for housing has increased even more, and in parallel, unplanned urbanization has accelerated.
In the 1990s, Denizli started to become one of the important cities of the country, especially in the field of textile. Production spaces have spread from specialized factories and workshops to the ground floor spaces of residences. Agriculture and animal husbandry activities, which continue in parallel with industrialization, are intertwined with residences.
The city center has started to expand towards the periphery since the 1990s. The traditional housing pattern was demolished and roads, apartment blocks and industrial structures were built in its place. Agricultural areas have also been affected by these renewal movements, and new

construction is common in both urban and rural areas.

3 THE REMAINS OF THE DEMOLISHED PIECE OF CITY: ÇOLAK HOUSE

Çolak House is located on the border of Bağbaşı and Zümrüt neighborhoods of Pamukkale District of Denizli (Figure 1). The building is reached from a sloping road connecting to the Antalya highway. Since this road is not located on a straight axis, the facade of the building is reached directly from the road.

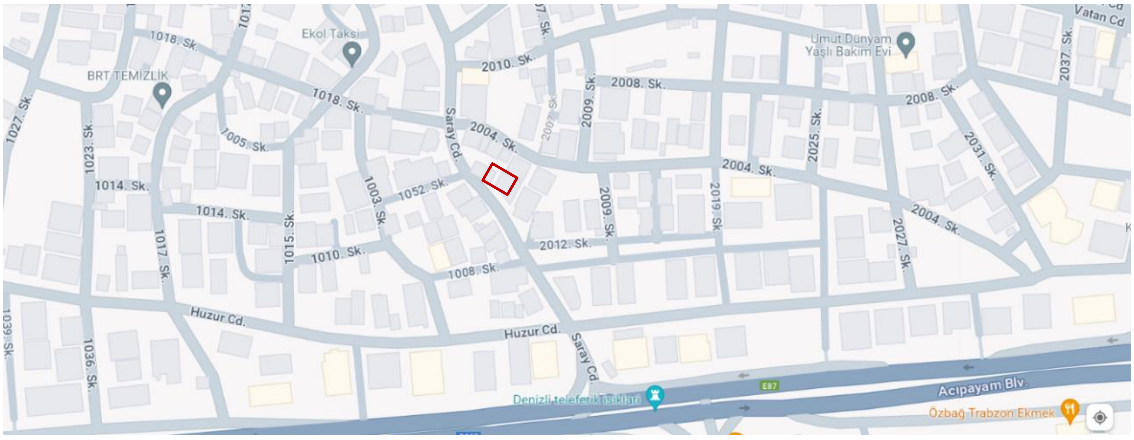

Figure 1. Çolak House location [5].

The building is mostly surrounded by high-rise apartment blocks (Figure 2-3). The property owners live in the reinforced concrete building they built right next to the building, and Çolak House is idle and dilapidated.
The neighborhood where Çolak House is located is a region where industry, agriculture and animal husbandry activities are intertwined. There are many industrial structures such as fattening farms, furniture production areas and agricultural areas in the immediate vicinity of the residential settlements.

Figure 2. Close vicinity of Çolak House

Figure 3. Close vicinity of Çolak House

Çolak House was built on two floors. Rubble stone and adobe blocks were placed between the wooden carrier system. On the rubble stone blocks seen in several rows on the ground floor, wooden carriers are integrated from the end level of the window opening. On the upper floor, after the use of several rows of rubble stone filling from the floor level, the structure extends to the roof with adobe filling (Figure 4). The hipped roof structure is covered with Marseille tiles. On some facades of the building, the ground floor filling material is also seen as firebrick.

Figure 4. Çolak House street facade view

The rooms are located around the sofa (Figure 5). The upper floor of the building is reached by a wooden staircase. On the ground floor there is storage and rooms, while on the upper floor there are only rooms. An additional space was added to the building in the later period. A toilet was added to a room on the upper floor. It is observed that some door and window openings were opened in later periods and plumbing was added to the building later. It is understood that the adobe filling was emptied in places due to the applications made for this purpose (Figure 6-7).
A reinforced concrete addition was made to the wooden staircase reaching the upper floor at the ground floor level in the following period. The ceilings on the upper floor are in original condition and the ceiling coverings on the ground floor have been replaced. It is possible to see the original

cabinets on the upper floor (Figure 8).

Figure 5-6. Entrance facade

Figure 7. Ground floor entrance facade **Figure 8.** Original cabinets on the upper floor

4 EVALUATION AND CONCLUSION

Experiencing an industrial revolution in which the leading sector in the globalization process is the textile industry, Denizli has become a large manufacturing industry region by shifting from traditional production relations to factory-scale production. In this process of social and economic transformation, Denizli has also transformed at the level of urban and rural settlements. The transformation of Denizli, which was a medium-sized Anatolian city among the priority provinces for development in the 1970s, continued after 1980 [6].

As a result of the expansion of Denizli city center, many buildings belonging to the traditional housing typology of the city, located in many neighborhoods such as Bağbaşı and Zümrüt neighborhoods, have been demolished today.

In the immediate vicinity of Çolak House, there are traditional houses with similar architectural features. These buildings, which are made of adobe, are surrounded by apartment blocks like Çolak House (Figure 9-10). These buildings are generally in a state of disrepair.

Figure 9. Housing texture using adobe materials in the immediate vicinity.

Figure 10. Housing texture using adobe materials in the immediate vicinity.

Urbanization policies, irregular construction decisions, and the lack of control mechanisms have led to a decrease in the number of adobe structures in Denizli's traditional housing typology. Originally built with adobe blocks, modern building materials were added to some parts of the building over time. Despite all these additions, the original plan scheme of the building has been preserved and the adobe construction technique has largely survived. This building, which preserves its visibility despite the high-rise reinforced concrete blocks surrounding it, should be protected and repaired.

5 REFERENCES

[1] Gökgür, P. '1933'den 2003'e Atina Kartasındaki Değişimler, CIAM'dan CEU'ya', Planlama, 35-41, 2005/1.
[2] Tekeli, İ. (2014). "Bir Modernleşme Projesi Olarak Türkiye'de Kent Planlaması". Türkiye'de Modernleşme ve Ulusal Kimlik. Editors: Bozdoğan, S., Kasaba, R. İstanbul: Tarih Vakfı.
[3] Bozdoğan, S. (2014). "Türk Mimari Kültüründe Modernizm: Genel Bir Bakış". Türkiye'de Modernleşme ve Ulusal Kimlik. Editors: Bozdoğan, S., Kasaba, R., 135-154. İstanbul: Tarih Vakfı Yurt Yayınları.
[4] Yavuzçehre, P. S. (2017) Denizli Kentsel Mekanında Değişim, Arkitera, https://www.arkitera.com/gorus/denizli-kentsel-mekaninda-degisim/
[5] Google Maps, https://www.google.com/maps/place/Z%C3%BCmr%C3%BCt,+Saray+Cd.+No:28,+20160+Denizli+Merkez%2FDenizli/@37.7345317,29.1343132,18.09z/data=!4m6!3m5!1s0x14c73ea198a7b8f7:0xa6485c3cd4c26674!8m2!3d37.7345508!4d29.1346951!16s%2Fg%2F11v0cwnnzg?entry=ttu
[6] Arlı, A. (2009). "Sosyal Mekânda Farklılaşma: Denizli'de Kırsal/Kentsel Dönüşüm (1990–2000)". PhD Thesis, Istanbul: Istanbul University.

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The Earthen Architectural Heritage of The Ankara Style: A Case Study Of Örtmeli, Sabuni, and Molla Büyük Masjids

Authors (Dr. Öğretim. Üyesi Serap Sevgi)
Address (Karabük Üniversitesi, Başak Cengiz Mimarlık Fakültesi)
E-Mail (serapsevgi@karabuk.edu.tr)

ABSTRACT

The mosques built in Ankara during the 14th-15th and 17th-18th centuries represent an architectural style known as the Ankara style, which brought a new identity to the wooden mosque tradition of the Seljuk period. Due to the rarity of structures commissioned by palace members or prominent individuals during the Ottoman period, the mosques and chapels of this period in Ankara exhibit local characteristics distinct from the Ottoman's established architecture seen in Istanbul, Bursa, and Edirne.The traditional use of the earthen material, commonly preferred in rural areas for the construction of lower floors in rubble stone masonry or infill material in upper floors, became the main building material for mosques and masjids in Ankara starting from earlier periods. Mosques and masjids built during the 14th-15th centuries typically feature the earthen material in a timber-framed rubble wall technique, elevated on a stone foundation, with some exhibiting longitudinal rectangular plans, occasionally asymmetric depending on the terrain. Some have a wooden-roofed last assembly area supported by wooden legs located on the side or north (main entrance). Despite their simple exterior appearance, they boast magnificent ceilings supported by wooden legs with Romanesque column capitals in the interior. In relatively larger mosques built during the 17th-18th centuries, some are entirely constructed using the earthen or timber-framed rubble techniques, while others feature stone or brick masonry on the front façade. The last assembly areas on the north side of the rectangular-plan sanctuaries are formed by three pointed arches. In these mosques and masjıds, wooden columns are no longer present in the sanctuary, and the load of the wooden roof and roof is directly supported by the walls. Despite the wear and tear seen in traditional the earthen-built houses, the eathen mosques and masjids built in Ankara during the 14th-15th centuries have stood for centuries and have been in uninterrupted use for approximately 600 years thanks to continuous maintenance and repairs. In this regard, the earthen material, being a natural and easily obtainable material, can withstand the test of time when constructed with appropriate building mass, proportions, and construction techniques, and when necessary maintenance is carried out.This study examines the architecture of Örtmeli (Hoca Hundi) and Sabuni (Karanlık) Mosques, as well as Molla Büyük Mosque, which represent the characteristics of the period and the earthen architecture heritage in Ankara, and discusses the repairs they have undergone, based on archival research.

Keywords: The Earthen Architectural Heritage, Ankara Style, Örtmeli (Hoca Hundi), Masjid, Sabuni (Karanlık) Masjid, Molla Büyük Masjid.

INTRODUCTION

Following Ankara's transition to Turkish sovereignty in 1073, small-scale modest structures were constructed under the influence of the Ahilik administration in the 13th century [17]. The city came under Ottoman rule in 1403, leading to the production of sof from mohair goats, which attracted European merchants and initiated exports to countries such as Poland and Venice [2],

[8]. During the Ottoman period, Ankara was strategically important commercially and regarding the Ahilik administration. It is observed that mosques and masjids were constructed in honor of local community leaders rather than prominent palace members [4]. Few public buildings, such as mosques and masjids, were built during Anatolian Seljuk. According to travelers in the 16th century, Ankara Castle was established on a high hill and surrounded by walls. The city extended irregularly around the hill into a plain, with large gardens surrounding it. As one approached the city, narrow dirt roads and primitive-looking, irregular houses with earth roofs could be seen. These houses, constructed from unfired dried bricks (the earthen), were likened to barns. In the 18th century, according to Lucas, Tournefort, and Montarye, the earthen was used in the repair of the city walls, while Pococke noted that the houses within the walls were made of the earthen and all makeshift houses had earth roofs. He also reported that only twelve of the approximately one hundred mosques had minarets [3], [16]. Evliya Çelebi, who visited Ankara in 1848, described the houses as having earthen roofs without tile coverings and mentioned that seventy mansions with adjacent gardens were constructed from the earthen and were two to three stories high. He remarked on the fame of Ankara's kerpic, noting its strength, smoothness, and molded shape [16].

In the 14th and 15th centuries, various mosques and masjids were built, including Ahi Elvan (14th century), Eyüp Masjid (14th-15th centuries), Geneği Masjid (14th-15th centuries), Hacı İvaz Masjid (15th century), Kulderviş Masjid, Molla Büyük Masjid (15th century), Örtmeli (Hoca Hundi) Masjid (15th century), Poyracı Masjid (14th-15th centuries), and Sabuni Masjid (14th-15th centuries). Additionally, Ahi Yakup (1392), Direkli Masjid (15th century), Hacettepe Mosque (15th century), Ahi Tura Masjid (15th century), Balaban Masjid (14th-15th centuries), Boyacı Ali Masjid (1317), Gecik Masjid (1443), Hacı Arap Masjid (14th-15th centuries), Hacı Doğan Masjid (14th-15th centuries), Hacı Seyid Masjid (14th-15th centuries), Hemhüm Masjid (15th century), Rüstem Nail Masjid (15th century), and Şeyh İzzettin Masjid (14th century) were established [14].During the 13th to 15th centuries, a unique architectural style specific to Ankara emerged under the Ahi administration, and this style continued in subsequent periods. These mosques and masjids typically featured square or rectangular plans, with base sections made of stone/rubble stone, walls constructed of wooden-reinforced adobe bricks, and interiors supported by wooden columns carrying wooden ceilings. They also included plaster mihrabs and had an area for latecomers with wooden columns and ceilings.

Despite their superficial exterior appearances, the interiors of these structures feature magnificent ceilings supported by wooden columns with Roman-era capitals. These columns help reduce the structural load on the walls. Karacabey and Aldulkadir Isfani masjids, 15th-century structures made of a mix of stone and brick, and the 16th-century Cenabı Ahmet Mosque with its lead-covered dome, and the Kurşunlu Mosque, constructed of brick, do not reflect the typical Ottoman architecture and fall outside the Ankara style [4]. Relatively larger structures built in the 17th and 18th centuries include the two-balcony Resul Efendi Mosque (1674-75) and the Ramazan Şemseddin (Kale Pazarı) Mosque (17th century). These were entirely constructed using adobe or wooden-reinforced adobe techniques, with some featuring stone or brick walls on their front facades. The rectangular prayer halls have an area for latecomers on the north side, formed by three pointed arches. In these mosques and masjids, wooden columns are no longer present in the prayer halls, and the walls directly support the wooden ceiling and roof loads.

Molla Büyük Mosque (Masjid)

Located on a rocky hill in the Bend Deresi area, across from Ankara Castle in Altındağ District, Kayabaşı Neighborhood, the Molla Büyük Mosque is situated on parcel 4. To its west, parcel 5 houses another madrasa, currently used as a private residence under the ownership of the Ahmet Necmettin Foundation. Parcel 2, under the ownership of the Governorship, contains a madrasa. According to a foundation record in the 1522 Ankara Evkaf Register, various shop revenues were endowed to the "Mevlana Büyük Masjids" [15], [11]. As a mosque, Molla Büyük Mosque belongs to the typology of wooden-columned mosques.

The mosque, whose courtyard is accessed from the south, is surrounded by high walls on this side. The nearly square rectangular plan of the mosque is oriented east-west. The prayer area on the east side has been enclosed and transformed. Access to the mosque is through this area, with wooden stairs attached to the north wall leading to the minaret and a room above the prayer area where Quran courses are held. The wooden minaret rises in the northeast corner. The prayer hall features two aisles parallel to the qibla, supported by three wooden columns in the center, with a thick beam running parallel to the qibla. The central column among these three has a reused marble capital. The wooden beam resting on a wooden pillow forms the structure's framework. Wooden brackets placed along the mosque's walls serve as supports and decorative elements. The wooden ceiling is supported by wooden columns, reducing the load transferred to the walls.

The qibla wall has symmetrically placed windows, with two at the top and two at the bottom. The north wall has one window at the top and two at the bottom, while the east wall has one window. The plaster mihrab, extending to the ceiling, showcases the classical Ankara style and features Millet-style ceramic bowls (Bacini), a rare example in Ankara found in the Molla Büyük Mosque, Ahi Yakup Mosque, and Örtmeli Mosque [12], [14], [16]. A wooden women's section was added later, supported by wooden columns in the mosque's center. The doors have been renewed and are of a simple design (Fig. 1).The primary support of the wooden minaret is a circular wooden post with a diameter of 25 cm. This wooden post is anchored onto a concrete base on the ground and is supported by the upper-level floor above the mosque's prayer area. The circular wooden minaret has an entrance door facing east. The staircase steps are composed of slats placed horizontally and vertically on the minaret's body, attached to covering boards. The minaret's balcony floor and railings are wooden, with simple wooden drops at the level of the balcony floor. The section connecting the balcony and the minaret's body is formed by combining horizontal and oval wooden rods to create concave and convex shapes. The wooden-hipped roof is covered with Marseille tiles. The mosque's foundation consists of rubble stone walls—about one meter above the ground; the construction transitions to a wooden-reinforced earthen wall technique. Wooden columns support the interior. Straw-reinforced mud mortar was used as a binder for the rubble stone and the earthen walls. This mixture was also used for plastering, and the walls were painted with lime wash.

Figure. 1. olla Grand Mosque exterior and view from the harim, 1970s and 1988 [14], [18].

As a result of the repairs it has undergone from its construction to the present, the structure has assumed a transverse rectangular plan. It has significantly deviated from its original state. Over time, repairs have involved reinforcing the walls with internal and external bricks.

In 1941, the building was converted into a mosque with a pulpit, and a wooden minaret was added during the same period. Due to the addition of rows of windows on both the north and south sides, the upper windows on the north side were blocked when a gallery was added, and a new window was opened on the east side. During these renovations, the final prayer space, characteristic of traditional Ankara mosques, was enclosed with a rubble stone wall and covered with a porch-like roof. Windows were opened on the entrance facade. The wooden ceiling was also renewed. The structure underwent further repairs in 1952, 1988, and 2014. The earliest record of the building as a historic monument dates back to 1941. Upon examining the repairs carried out up to the present, it is evident that the mosque, with its double-aisled wooden columned prayer hall and open final congregation area, is an example of the Ankara style, featuring a flat earthen roof. Due to the altered load distribution from the enclosure of the final congregation area, the main walls were reinforced in 1986 by thinning the earthen walls to 20 cm and constructing brick walls in front and behind them. The windows in the thick main walls of the prayer hall narrow from the inside to the outside in the upper row. In contrast, the lower-row windows are rectangular and accommodate double internal and external windows. The joints were re-pointed with cement mortar, and the walls were plastered with cement-based plaster and painted with plastic paint. During the 2014 renovations, the mosque's high courtyard walls were removed and replaced with lower walls to enhance the visibility of the structure. The walls and windows on the upper floor of the final congregation area, which had been enclosed and included substandard alterations, were removed and replaced with glass panels. Maintenance and cleaning of the wooden materials were cleaned, and non-original paint and repairs were removed to reveal the original wooden decorations (Fig.2)[11]. It can be said that the mosque, which lost its original form due to the window arrangement and the modern additions to the entrance section, has benefited from the preservation of its original prayer hall, the uninterrupted continuation of its use, and the interventions made within the framework of the conservation understanding of the period.

Figure. 2. Molla Grand Mosque exterior and view from the harim, in 2024

Sabuni (Karanlık) Masjid

Sabuni Mosque is located at the corner of Uzunkavak and Cevizaltı Streets in Turan (Sabuni) Neighborhood, Hamamönü District, Altındağ, Ankara. The mosque lacks an inscription or a foundation deed. Based on the original parts of the mihrab, its wooden door, and the craftsmanship of the wooden ceiling, it is dated to the late 14th or early 15th century[5][10]. The only information about the mosque's founder is in the inscription above the wooden main door, now in the Ankara Ethnography Museum: "Hacı Hasan / May Allah build this blessed mosque; forgive him, his parents, and all Muslims."

The mosque has a square plan, with two wooden columns and a final congregation area. A wooden prayer tower with a square body was later added to the northeast. The northern part of the mosque features a final congregation area with closed sides. The columns of this area support the ceiling beam with profiled corbels. Above the beam, there are wooden brackets. Enclosed by a wooden lattice, two windows open from the final congregation area and enter the prayer hall. The west facade of the mosque has two lower and one upper window; the south and east facades each have two lower and two upper windows, all with simple wooden window shutters. The prayer hall, accessible through a plain door from the final congregation area, has a longitudinal rectangular plan. Two large beams extending perpendicular to the mihrab divide the prayer hall into three naves with the help of two central wooden columns. These columns have reused capitals and profiled corbels. The ceiling is supported by beams parallel to the mihrab, which connect the beams to the walls. Slats have been nailed to the ceiling to create triangular patterns. The central nave is slightly higher than the side naves, with its end supported by profiled brackets. The ceiling is adorned with red ochre and hand-painted decorations between the brackets and the beams' sides. The lower part of the renewed wooden gallery at the back is divided by glass panels on the west side. A staircase on the east side leads to the prayer tower. The mosque's wooden pulpit is new. The wooden gallery for women is accessed via a wooden staircase on the west side. It is believed that the original flooring of the mosque was brick, later covered with wood[14].

The plaster mihrab features a rectangular niche. The niche's edges and the space's upper part beside the muqarnas hood are adorned with intricate geometric interlaced decorations. Simpler interlaced patterns are seen in the lower part. Externally, a thin braided molding runs around the mihrab, and a row of palmettes is at the top. The mosque has two lower and one upper window on the west facade, two lower and two upper windows on the south and east facades, and windows opening to the final congregation area on the north side. Two windows are positioned on the qibla wall and the west, while the east wall features two lower and one upper window. A square wooden prayer tower rises from the northeast corner of the roof, covered with traditional Turkish tiles. The prayer tower is made of wood, and its roof is covered with zinc. The mosque, built with adobe walls supported by wooden beams on a stone foundation, has walls constructed up to the lower row of windows with stone and above that with adobe reinforced by wooden beams (Fig. 3).

Figure 3. Sabuni (Karanlık) Masjid exterior and view from the harem in 2008 [18].

During the 1920s restoration of the Sabuni Mosque, its roof, and load-bearing walls were elevated, and a sloped wooden roof with tile covering was installed[18]. Konyalı noted that the mosque was closed in the early 1940s[13]. In the 2008 renovations, interventions were made to reveal and preserve the mosque's original architecture. Unauthorized additions on the south facade were removed, and the window openings on this side were newly arranged. The concrete fill placed over the original stone flooring of the final congregation area due to the raised road level was removed. A replica of the main door exhibited in the museum, was created and installed at the entrance to the prayer hall. Inferior plaster and paints applied to the facade during previous restorations were removed and replastered with the original plaster. Paints on wooden architectural elements were cleaned to reveal the original decorations, and surface protection was applied after maintenance (Fig. 4).

Figure 4. Sabuni (Karanlık) Masjid exterior and view from the harem in 2024

Örtmeli (Hoca Hundi) Masjids

In the 1924 Ankara map, the neighborhood where Örtmeli Mosque is located is called Hoca Hundi Müslim Mahallesi. This neighborhood is listed as "Hucendi" in the 1522 records, "Hacendi" between 1785 and 1830, and "Hoca Hundi" in 1830, situated in the Yeğenbey neighborhood. It is part of the Ankara Jewish Quarter, where Jews and Muslims lived together[11]. The mosque is located at the intersection of Örtmeli and Kalyoncu streets in the Samanpazarı area. Sources suggest that the mosque might be named Örtmeli due to the large porch above its main entrance[13]. The mosque, which lacks an inscription, is dated to the late 14th to early 15th century[14] and the first half of the 15th century[10].

The mosque is surrounded to the north by Sakalar Primary School and to the east by buildings adjoining its small courtyard. Initially, the mosque had a flat roof and an elongated rectangular plan and was topped with a row of cornices at the eaves level. It is covered with a wooden roof and traditional Turkish tiles. Externally quite simple, the mosque's main entrance is unusually located on the east side. The main beams, supported by two wooden columns and perpendicular to the mihrab, divide the prayer hall into three naves. The central nave is arranged to be higher and broader than the side naves. The main wooden beams are adorned with slats, creating decorative patterns between the parallel beams and the mihrab. The wooden columns supporting the ceiling have reused capitals: Doric on the west and Corinthian with acanthus leaves on the east. There are two windows to the east and one to the west of the mihrab. Wooden columns support the women's gallery on the north side and feature two rectangular windows at this level[14]. The mihrab, reaching up to the ceiling, is adorned with Miletus-style bowls crafted using plaster molding. The minaret is located in the northeast corner. The cylindrical minaret can be accessed from the women's gallery (Fig. 5).

Figure 5. Exterior view of the Örtmeli (Hoca Hundi) Masjid in 1970 and 2006 [18].

During the 1951 restoration of the mosque, the load-bearing walls were repaired, and the exterior facade was covered with cement-based plaster instead of the original hımış plaster. The interior walls were also replastered with cement-based plaster. All walls and the plaster mihrab were painted with acrylic and oil-based paint[7]. It is known that the mosque was painted with oil paint in the 1970s[14]. Sources indicate that the decrease in ceiling height may be due to the flooring being raised during previous restorations[1]. A room for the imam's use was added later to the west of the women's section. In the 2006 and 2007 restorations of Örtmeli Mosque, Aktan and Aktan (2004) removed the cement-based interior and exterior plasters and replastered them with a clay-based plaster. The oil paints on the wooden elements were cleaned to reveal the original decorations. The roof, minaret, and drainage system were repaired to protect the mosque from water damage. Rotten wooden beams and deteriorated bricks in the load-bearing walls were replaced. Restoration work was carried out on the painted decorations, and the plaster mihrab was also restored using cast stucco and similar geometric and floral patterns (Fig. 6)[7].

Figure 6. Örtmeli (Hoca Hundi) Masjid, view from the harim and mihrab in 2006 [18] and 2024

3 CONCLUSION

The tradition of using earthen in monumental and public buildings and residential architecture has continued in Ankara from the Anatolian beyliks to the present day. The earthen, still used in rural residential architecture, traditionally consists of a mixture of clayey soil, coarse rock salt, wood ash, and straw[5].Three mosques were converted into mosques by placing pulpits inside. In both Sabuni Mosque and Molla Büyük Mosque, the original final congregation area was an open entrance, which is absent in Örtmeli Mosque. Each of these mosques has a women's gallery that was added later. The approximately 1-meter thick earthen load-bearing walls provide insulation against summer heat and winter cold. The wooden ceilings were initially flat roofs, known as "kara dam," a method sometimes seen in adobe structures in Central Anatolia. The flooring above the wooden beams was plastered with mud and covered with about 30-40 cm of clayey soil called "çorak." These flat roofs must be compressed annually with a cylindrical roller called a "loğ taşı." Due to the inability to perform such maintenance, the flat roofs were covered with wooden saddle roofs and tiles[8].The three mosques were constructed with a rubble stone foundation up to the height of the lower windows, above which earthen material with wooden beams was used. The load-bearing system consists of the main body walls and centrally placed wooden columns in the prayer hall. The load of the flat roof, supported by two parallel to the mihrab and two to three perpendicular wooden columns forming naves, is thus reduced on the walls. The average prayer hall sections measure 10 x 10 meters externally and 8 x 8 meters internally, with spans of about 4.00 meters between wooden columns and walls. These span measurements (3-4 meters) were used in the layout of the final congregation areas. To protect the earthen from external weather conditions, especially water, it was plastered with clay both internally and externally (Fig. 7).

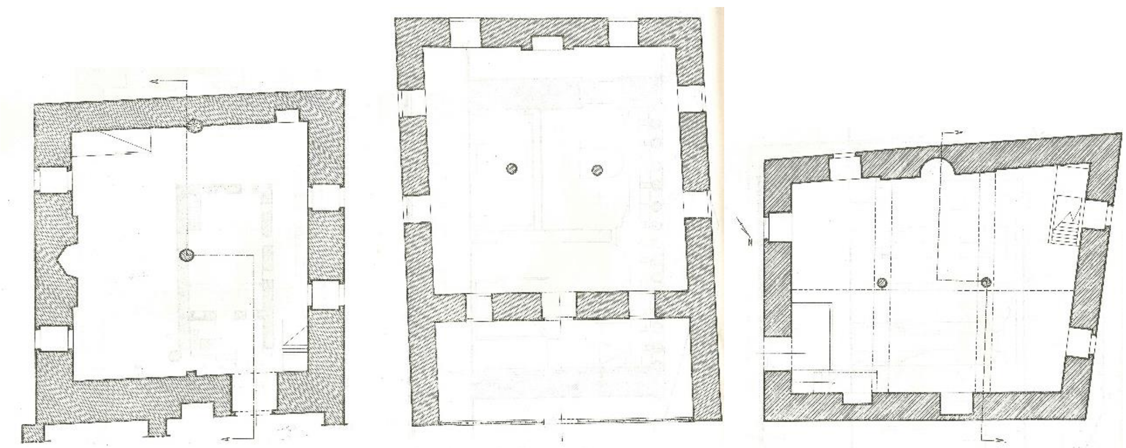

Figure 7. Plan scheme of Molla Büyük Mosque, Sabuni (Karanlık) and Örtmeli (Hoca Hundi) Masjids [14]

It can be said that it was used and developed in the interior spaces of mosques with wooden pillars, which were widely used in the Anatolian Seljuks, and in small-sized Ankara-style masjid buildings with adobe masonry walls in terms of the carrying system, material, and details of wooden ceilings.

As a result, Ankara's famous stone-solid earthen masjid buildings were built by the masters of the period, not only as a building material but also by considering the construction technique and carrying capacity. Thanks to the building size and forms used, it has maintained its strength for approximately 600 centuries. Thanks to their constant care and use, they can survive for centuries.

4 ACKNOWLEDGMENTS

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5 REFERENCES

[1] Aktan, K.K. & M. F. Aktan, Örtmeli mesjidi, Hoca Hundi, 14. Yüzyıl, *Unpublished report, Vakıflar Genel Müdürlüğü,* Ankara, 2004.
[2] Akpolat, M. S. & Eser, E., *Ankara Başkentin Tarihi, Arkeolojisi ve Mimarisi,* (Birinci Baskı), Ankara, 2004, 24
[3] Alemdar, K., Seyahatnamelerde Ankara, *Tarih İçinde Ankara-Eylül 1981 Seminer Bildirileri*, pp. 97-105, 1984.
[4] Ceylan, C., & Aydın, Ö., 18.-19. Yüzyıl Ankara Camileri Üzerine Bir Değerlendirme, *Sosyal Ve Beşeri Bilimler Dergisi*, 2(2), 1-21, 2018.
[5] Çavuş, M., Dayı, M., Aruntaş, H.Y. & Ulusu H., Sürdürülebilir Bir Yapı Malzemesi Olarak Kerpic. *Conference: ISBS2015 - International Sustainable Buildings Symposium At: Ankara/Turkey*, pp. 184-192, 2015.
[6] Demiriz Y., *Osmanlı Mimarisinde Süsleme I, Erken Devir (1300-1453*), Kültür Bakanlığı Yayın, 1979.
[7] Erder, E., *Ahi Elvan Mosque, Örtmelđ Mesjid, Sabunî Mesjid And Poyrajı Mesiđd—Four 14th And 15th Century Mosques In Ankara—A Re-Evaluatıon Their Sustainable Conservaıon* (Yayımlanmamış Doktora Tezi), ODTÜ, 2008.
[8] Erder, E. 2010, Sustaınable Conservatıon Issues Of Four 14th And 15th Century Mosques In Ankara: Ahi Elvan Mosque, Örtmeli, Sabunî And Poyrajı Mesjıds, *METU JFA* 2010/1 (27:1) 45-66. DOI: 10.4305/METU.JFA.2010.1.3, 2010.
[9] Ergenç Ö., *16. yüzyılda Ankara ve Konya*, Tarih Vakfı Yurt Yayınları, 2012, 55-57.
[10] Eskici, B., *Ankara Mihrapları*. Ankara, Kültür Bakanlığı Yayınları, 2001.
[11] İşçen İ.Y., *Cumhuriyet Öncesi Ankara'da Cami Ve Mescitler*, Sincan Matbaası, Ankara, 2019.
[12] Karasu, Y. E., Ankara yapılarında Bacini uygulamaları, *Anadolu Üniversitesi Sosyal Bilimler Dergisi, 22(1), pp.349-384, 2022.*
[13] Konyalı, İ. H., *Ankara Camiileri*, Kültür Matbaacılık, Ankara, pp. 63-64, 1978.
[14] Öney, G., *Ankara'da Türk Devri Yapıları,* Ankara Üniversitesi DTCF Yayınları, 1971.
[15] *Şehr-i Kadim Ankara*, Cilt 3, Ankara Büyükşehir Belediyesi Yayını, 2015.
[16] Tezcan, N., Evliye Çelebi'nin Ankara'sı, *Evliyâ Çelebi: doğumunun 400. Yılında, Kültür ve Turizm Bakanlığı yayınları*, Kütüphaneler ve Yayımlar Genel Müdürlüğü anma ve armağan kitaplar dizisi. ss.148-158, 2011.
[17] Tunç, G.,*Şehrin Zulası:Ankara Kalesi,* (Vol. 8). İstanbul, 2004.87-89,
[18] Vakıflar Genel Müdürlüğü arşivi

An extra curriculum workshop for Earth-based Construction Techniques ”From Tradition to Future: Applied Training on Earth Construction Techniques"

Authors **Dr. Öğr. Üyesi Sinan Akyüz**, Dr. Sümeyra Ayık

Address Barbaros, Sümer Kampüsü, Erkilet Blv., 38080 /Kayseri

E-Mail sinan.akyuz@agu.edu.tr / sümeyra.ayik@agu.edu.tr

ABSTRACT

Supported within the scope of the TÜBİTAK Scientific Education Activities Support Program, the "From Tradition to Future: Applied Training on Earth Construction Techniques" took place at Abdullah Gül University Sumer Campus between January 29th and February 3rd, 2024. Led by Dr. Sinan Akyüz and Dr. Sümeyra Ayık, along with graduate students Ece Sultan Karacık and Mustafa Burak Köroğlu, this project aimed to introduce earth-based building materials and application techniques to students studying architecture and civil engineering and to explore the potential use of these materials and techniques through practical and theoretical courses.

Over 6 days, practical training sessions on earth construction techniques including rammed earth, adobe bricks, and earth plaster were supplemented with theoretical education in conservation, design, and building knowledge, resulting in a multidimensional approach to earth construction techniques. This comprehensive training, the first of its kind in Turkey focusing on traditional earth construction techniques, was attended by 20 undergraduate (3rd and 4th year) and graduate students from Kayseri and nearby provinces (Sivas, Yozgat, Niğde, Nevşehir), as well as from earthquake-prone regions (11 provinces). During the training program, we implemented pre and final tests for students about their knowledge and experience about earth-based construction techniques. We implemented a thematic analysis method for analyzing the data from the students. The results show a significant increase in students' knowledge of earth-based material even though the workshop lasts a week. We also observed a significant increase in their interest in earth-based material after the workshop based on the feedback provided.

Keywords: Earth construction techniques, Rammed earth, Adobe bricks, Earth plaster, Architecture education

1 INTRODUCTION

This project is a multidisciplinary endeavor aimed at introducing architecture and construction students to earth-based building materials and application techniques (Rammed Earth, Earth Plaster, Adobe). Through both theoretical and practical courses, the project seeks to explore the potential uses of these materials and techniques.

"This workshop is designed to introduce earth-based building materials and teach construction techniques. Architecture programs should cultivate creative, ecologically sensitive, and socially responsible students by referencing various models and schools of thought. To identify these different models and practices, the curricula of six architecture schools in Turkey were examined and compared [1]. This review revealed that, outside of structure and materials courses, there were limited courses specifically dedicated to earth-based building materials and application techniques [1]. A regional review of the curricula of universities today shows that while theoretical education in natural building materials and application techniques has increased in architecture and engineering faculties, it would be more beneficial if these faculties provided more hands-on training. For this reason, the workshop is organized in two stages: theoretical and practical.

Within the scope of this project, theoretical and practical courses were conducted on how soil, based on its particle size, can be categorized into three different classes and how these three classes of soil can be used as three different structural elements. In this context, participants were encouraged to discover the potential uses of soil, a readily available material, in construction through theoretical and practical courses.

Soils with varying particle sizes can be transformed into structural elements with different functions within a building. Within the project, three different usage proposals were made for three different categories created according to particle size. Clayey soils, with the smallest particle size and high binding potential among other types, were produced using the rammed earth technique and used as load-bearing elements in the building's structural system. It was not recommended to use silty soils, the second group of soils, as fill material in walls within frame-bearing systems or to produce them using the adobe technique. The third group, coarse-grained sandy soils, due to their relatively low binding properties, was suggested to be used as a surface coating material.

2 IMPLEMENTATİON OF THE WORKSHOP

2.1. The Aim of the Training Module

This project is a multidisciplinary endeavor aimed at introducing architecture and construction students to earth-based building materials and techniques, such as rammed earth, earth plaster, and adobe. Through both theoretical and practical lessons, the project seeks to explore the potential applications of these materials.

Earth has been one of the primary building materials since humans began settling. While earth-based structures once constituted a significant portion of the built environment in Anatolia and worldwide, technological advancements, urbanization, and evolving human needs have led to a decline in the use of this material. Initially associated with rural areas, the reduced use of earth has resulted in significant changes in rural landscapes, leading to an increase in structures that are disconnected from their surroundings. In today's era of ecological design and sustainable architecture, earth, as an environmentally friendly material, can provide healthier living spaces in urban areas and contribute to sustainable cities. As an organic material, earth is recyclable and can be produced by hand, reducing waste and energy consumption. Its high thermal performance ensures indoor comfort without the need for artificial ventilation or heating. Given these properties, increased use of earth-based materials has the potential to be a beneficial step towards recyclable and contextually-connected built environments, both in rural and urban areas.

As a building material, earth possesses remarkable properties. According to [2], earth is moist but impermeable to water, breathable, and provides insulation. As a living material, it responds to external factors by flexing while maintaining its shape. Despite its flexibility, structures made from earth are surprisingly durable. Its natural properties make it easy to understand and work with. The construction process is relatively quick and can be done collaboratively. These advantages have contributed to the centuries-long use of earth as a building material.

While reinforced concrete offers certain advantages, its drawbacks have become evident, particularly after the 2023 Kahramanmaraş earthquake. The collapse of many reinforced concrete buildings has shaken public confidence in this material. However, the problem lies not in the material itself but in factors such as the building's resistance to water and moisture and the quality of construction. Earth-based structures, when constructed correctly, can be earthquake-resistant. Therefore, it is essential to learn not only about the material itself but also about the correct construction techniques.

This workshop is designed to introduce participants to earth-based building materials and teach construction techniques. Architecture programs should cultivate creative, ecologically sensitive, and socially responsible students. A review of curricula from six Turkish architecture schools revealed a limited focus on earth-based materials and techniques. While there has been an increase in theoretical courses on natural building materials in recent years, there is a need for more practical education. This workshop addresses this gap by combining theoretical and practical learning[3].

2.2. The Content of the Training Module

Within the scope of this project, theoretical and practical lessons were conducted on classifying soil materials into three categories based on particle size and exploring how these three categories can be used as different structural elements. In this context, participants were encouraged to discover the potential uses of soil, a readily available material, in construction through theoretical and practical courses.

Soils with varying particle sizes can be transformed into building elements to serve different functions within a structure.The project proposed three different usage suggestions for the three soil categories based on particle size. Clayey soils,with their relatively small particle size and high binding potential, were used to create load-bearing elements through the rammed earth technique. Silty soils, the second group, were not recommended for use as a filling material in frame-bearing systems or for producing adobe bricks. The third group, coarse-grained sandy soils, with their relatively low binding properties, was suggested for use as a surface coating material."

2.3. Implementation of the Training Module

After a thorough evaluation of applications based on specific criteria and interviews conducted by the project coordinator,a total of 20 participants were selected. These participants were drawn from both undergraduate and graduate programs in architecture and civil engineering. Out of the 20, six students were from universities outside the city, including three from Yozgat Bozok University, two from Iskenderun Technical University, and one from Istanbul Technical University.Notably, the participant from Istanbul Technical University was included due to their residence in Malatya, a region significantly impacted by earthquakes.
To facilitate communication and provide necessary information, a WhatsApp group was established on January 26, 2024, exclusively for project participants. This platform was used to discuss project details, execution plans, instructor information, accommodation arrangements, transportation logistics, and to address any queries from the students.

For the project, which was scheduled from January 29 to February 3, 2024, six participants from outside Kayseri arrived a day earlier on January 28th to ensure their readiness for the early start of the workshop. To aid their orientation, maps and directions to the accommodation and local transportation routes, particularly the tram lines, were provided a day prior.

Preparations for the project, including material procurement, commenced a week before the workshop's start date. A significant challenge was sourcing the specific type of soil required for the project. After consulting with construction companies and the university's facilities department and failing to find the necessary soil, the team turned to the Kültepe Archaeological Site. With the support of Prof. Dr. Fikri Kulakoğlu, the head of the Kültepe Kaniş-Karum Mound Excavation, the required quantity and quality of clay soil were successfully obtained. Using a university-provided van, the project team transported the soil to the AGÜ Sumer Campus Architecture workshop, where it was stored in sacks.

In addition to the soil, various other materials were gathered and stored in the university's large warehouse, including gravel, straw, gypsum board, heavy-duty work gloves, adobe molds, wooden planks, buckets, shovels of different sizes,bolts, and screws. Tools such as drills, hammers, and screwdrivers, which were necessary for constructing the molds, were obtained from the university's construction department and architecture department's model-making workshop.

The program officially started on Monday, January 29, 2024, at 10:00 AM with an opening speech by Dr. Sinan Akyüz,the project coordinator. Participants were introduced to the facilities that would be used throughout the program, including the school buildings and architecture studios. Before diving into the practical sessions, pre-tests were conducted to assess the participants' existing knowledge of traditional construction techniques.

The workshop's theoretical component was structured to provide a comprehensive overview of the subject, starting from broad concepts and gradually delving into specific topics. Additionally, social activities were integrated into the program to foster a sense of teamwork among participants.

A "Warm-up" session led by psychologist Ceyda Cihan Aydoğdu initiated the program with ice-breaking activities and the establishment of group and collaborative work rules. This was followed by a "Trust Workshop" conducted by drama trainer Şebnem Soylu. These sessions aimed to strengthen social bonds among participants. Furthermore, a theoretical lecture titled "Sustainable Development Goals (SDGs) with a Focus on Sustainable Cities and Communities" was delivered by Dr. Sümeyra Ayık. This lecture, aligned with the SDGs, discussed the roles and responsibilities of urban built environment producers in achieving sustainable cities and communities, setting the foundation for the practical sessions and the entire program.

Subsequently, a two-hour theoretical lecture titled "Traditional Residential Architecture and the Use of Earth" was delivered by Assoc. Prof. Dr. Hayriye Nisa Semiz. This lecture helped participants establish a connection between cultural values and architecture. It formed the basis of a theoretical framework that focused on traditional architectural regulations from the perspectives of preservation, design, and construction—a novel approach in workshop programs.

Dr. Sinan Akyüz presented a theoretical lecture titled "An Examination of the Turkish Construction Sector Through Housing," which delved into the reasons behind the invisibility of cultural values in modern-day cities. This lecture explored the relationship between rapid urbanization after 1950 and changes in housing construction practices, as well as the institutionalization of housing construction systems. Prof. Dr. Burak Asiliskender delivered a theoretical lecture titled "Modernism and Earth Structures," which examined the current state of the construction sector and its relationship with earth-based structures.

Within the framework of the program, which combines theoretical and practical training in the fields of conservation, design, and construction, some adjustments were made to the course schedule to accommodate the instructors' availability while adhering to the initially planned course hours. Due to scheduling conflicts, the lectures by architects Can Cumalı and Çağla İşbilir from the Monoearth team began on January 30, 2024. A full-day of theoretical and practical training on the rammed earth technique was conducted.

Figure 1. Training Material Preparation by Participants

Meanwhile, videos and images from the soil workshop, prepared by the support staff, were shared through the school's and event's social media accounts and by the participants, increasing the visibility of the event. Participants actively engaged in all stages of the process, including moistening the soil, mixing it, preparing molds, mixing soils with different properties, and compacting the soil using various tools. To create a lasting legacy of the activity, a 35x35x90 cm soil base was designed and constructed in the workshop for use in future university events. Thus, the production carried out throughout the workshop was transformed into a permanent artifact for the university, extending beyond the theoretical realm.

On January 31, 2024, architects Can Cumalı and Çağla İşbilir from the Monoearth team successfully completed their theoretical sessions, ending the 10-hour rammed earth workshop, as initially planned with five-hour sessions each day. In addition, Assoc. Prof. Dr. Fulya Akipek's lecture titled "Computational Design and Earth Structure Production" provided participants with insights into creating designs that align with contemporary aesthetics and production methods, combining traditional materials with modern design practices. Subsequently, architect Ece Sultan Karacık delivered a lecture titled "Soil as a Building Material," delving into the details of soil and its components. Following this, Mustafa Burak Köroğlu's theoretical lecture on "Alternative Construction Techniques" elaborated on various applications of soil. While these lectures were ongoing in the architecture studios, architects Betül Ergün, Mina Öner, and Ceren Yıldırım from the Poçolana team were simultaneously preparing for the earth plaster workshop.

Figure 2. The Result of the Monoearth Team Rammed Earth Workshop

A theoretical lecture titled "Innovative Uses of Earth Materials" delivered by Dr. Buket Metin established a connection between the traditional and innovative uses of earthen materials. This was followed by another theoretical lecture on "Rammed Earth Construction Techniques," paving the way for a practical workshop on the same topic. The practical session allowed participants to explore the potential of earthen materials. The participants were involved in preparing for the traditional rammed earth construction process. Each stage of the process was examined from an experiential perspective, ensuring active participation from all attendees. Participants were informed about mold design and manufacturing, and they created a 35x40x12 cm rammed earth mold as part of the workshop.

Experiments were conducted to understand the characteristics of soil suitable for rammed earth construction, including tests to determine soil properties and the effects of different additives on the mixture. Two sizes of rammed earth samples were produced: standard (35x40x12 cm) and smaller ones (35x20x12 cm). These samples were numbered and their compositions recorded. Discussions were held on the potential of soil and rammed earth, application methods, and mixture ratios based on the results. After examining the 12 produced samples and exchanging ideas, the optimal mixture ratio for rammed earth bricks using the tested soil was determined. Finally, Assoc. Prof. Dr. Müge Akın from the Civil Engineering Department of AGÜ delivered a theoretical lecture on "Natural Stones.
On February 2, 2024, architects Betül Ergün, Mina Öner, and Ceren Yıldırım delivered theoretical lectures on earth plastering techniques. The focus of both the theoretical and practical sessions was on the "mural" technique, which transforms earth plaster into a work of art. Prior to the workshop, participants had been involved in various preparatory tasks, including presentations and other workshops. In preparation for the earth plaster painting day, participants, together with the student team, sifted two different types of soil and sand into various particle sizes. They also mixed different materials such as soil, sand, and water; and soil, sand, straw, and water in varying proportions and recipes. These different plaster mortars were then tested on a panel.

On the day of the workshop, participants prepared the earth plaster according to the agreed-upon recipe and mixed it with different colors to create small-scale samples. These earth plaster paints were then applied to a pre-prepared picture composition on a wall. In addition to the practical training, theoretical presentations were given throughout the workshop on various natural construction sites and processes, wall construction techniques using different ecological materials, and the use of earth plaster as a protective and finishing material for creating artistic murals.

As a result of the one-and-a-half-day workshop, a collective mural was created, reflecting the region's culture and history. This permanent artwork was installed in the university's large warehouse building.

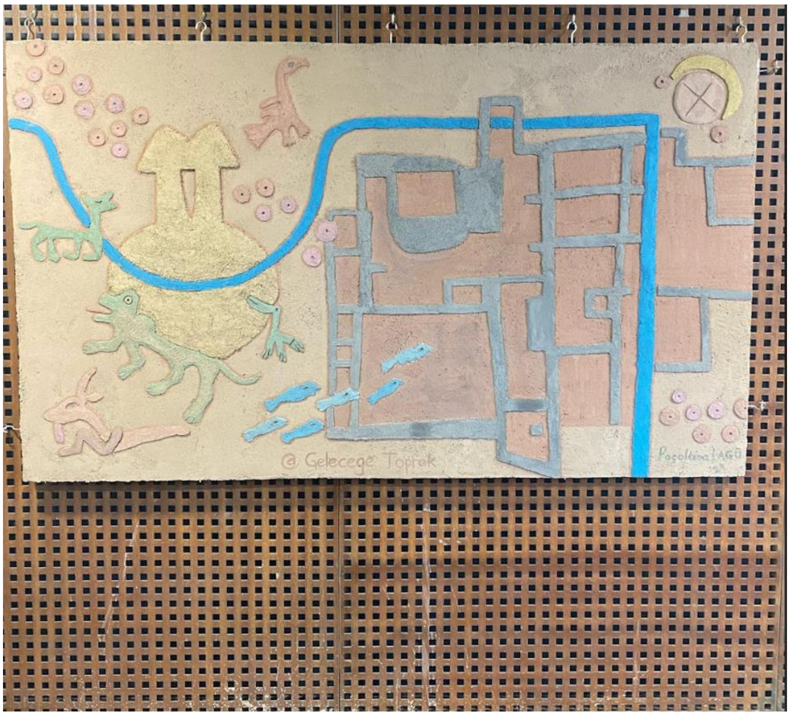

Figure 3. The Result of the one-and-a-half-day workshop, a collective mural

The primary objective of this project was to explore the potential of various soil types as building materials by integrating them into different construction systems. The idea was to enhance the utilization of all types of soil as a building material by employing them in diverse structural elements. Within the scope of this project, theoretical and practical training was successfully conducted on three primary soil types and their corresponding construction techniques: rammed earth, adobe, and earth plaster.

The event featured 16 expert instructors from various fields, including architecture, urban and regional planning, education, psychology, geology, civil engineering, economics, ceramics, and glass art, as well as practitioners of earth building techniques. The project comprised a total of 48 lessons, including 20 hours of theory and 28 hours of practical sessions, delivered in a hybrid format over six days.

Throughout the event, theoretical training covering 20 hours focused on topics such as sustainable development goals, traditional residential architecture and soil use, Turkey's construction sector and housing production, modernism and earth structures, natural stones, innovative uses of earth materials, and architectural design with earth. Additionally, during this phase of the event, participants were introduced to real-world "best practice" examples, presented firsthand by designers and practitioners, to provide concrete examples of the concepts and topics they had learned. This aimed to enhance participants' awareness of traditional earth building techniques. Pre- and post-training tests were conducted to measure the progress of participants' knowledge and skills in this area. The 28 hours of practical training allowed participants to gain hands-on experience in earth plaster, rammed earth, and adobe construction under the guidance of experienced instructors

2.4. İmpact and Value of the Module

It has been observed that architecture and civil engineering students receive very limited hours of instruction on earth-based materials and application techniques during their undergraduate and graduate studies. Learning about traditional construction techniques such as earth construction and its application techniques has both increased awareness of sustainable building practices among architecture students and their knowledge of traditional construction techniques and materials.

This event provided participants with both theoretical and practical training on three earth-based building material techniques: rammed earth, adobe brick, and earth plaster. This is the first study of its kind in Turkey where these three techniques were taught simultaneously and where the applications of these techniques were supported by conservation, design, and construction knowledge courses and conveyed to the participants. Therefore, the event has been reported in local and national media.

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5 REFERENCES

References should be numbered in the text. Use consecutive Arabic numerals in parenthesis.

[1] Nalçakan, H. and Polatoğlu, Ç.,. *Education Of Architectural In World And Turkey With Comparison Analyses And The Effect Of The Globalisation To The Architectural Education//Türkiye'deki Ve Dünyadaki Mimarlik Eğitiminin Karşilaştirmali Analizi İle Küreselleşmenin Mimarlik Eğitimine Etkisinin İrdelenmesi*. *Megaron*, *3*(1), p.79, 2008
[2] Aşanlı, Melih. *Geleneksel yapı teknikleri: doğal ve ekolojik yapı rehberi*. Vol. 33. Yeni İnsan Yayınevi, 2021.
[3] Alibeyoğlu, R. N., & Ökten, M. S.. *Sıkıştırılmış Toprak Yapılar Üzerine Bir İnceleme.* Turkish Online Journal of Design Art and Communication, 11(3), 1036-1057, 2021

Kerpic'24 – Challenges in Earth-Based Interior Architecture; Current Issue in Earth-Based Materials, Construction Techniques and Approaches
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Visual Analysis of Stone Deterioration in The Ulu Mosque Of Mardin

Şefika ERGİN[1], İlhami AY[2], Ayşe BİÇEN ÇELİK[1]
[1]Dicle University, Diyarbakır
[2]Hakkari University, Hakkari

erginsefika@gmail.com
ilhamiay@hakkari.edu.tr
ayse.bicen@outlook.com

ABSTRACT

The province of Mardin has been occupied by various civilizations and states throughout history. Traces of these cultures are evident throughout the city, which has hosted diverse groups over the centuries. Historical structures such as inns, baths, mosques, madrasas, and churches display influences from different eras. One such structure is the Ulu Cami, located in the Artuklu district of Mardin.

The use of stone material in Mardin's traditional structures, which hold cultural heritage significance, is crucial for the durability of these buildings and their preservation for future generations. Stone material is commonly seen in the walls, columns, floors, and facades of these traditional buildings. It is preferred over other primary building materials due to its ease of carving, drilling, processing, and use with sharp tools. The durability of the stone used is the most significant factor contributing to the longevity of traditional buildings. Considering the petrological properties and the climatic conditions of the region, changes can occur on the stone surfaces over time. These changes are referred to as decay or alteration. Identifying, classifying, and taking preventive measures against such decay in traditional buildings of cultural heritage is vital for their prolonged preservation. If the factors causing decay on stone surfaces are not identified in a timely manner, it can lead to increased damage and new deteriorations.

This study aims to examine the decays occurring in the Ulu Cami located in the Artuklu district of Mardin and to investigate the factors contributing to these decays. The decays in the structure have been categorized and examined as physical, chemical, biological, and anthropogenic deteriorations. Visual analysis was employed in the study, and the decays in the structure were documented through photographs. The study aims to identify the decays in the Mardin Ulu Cami, provide suggestions, and contribute to the preservation of the structure's authenticity for future generations. Additionally, it is proposed that the results obtained from this study be utilized in future restoration efforts, providing data-based solutions.

Keywords: Stone deterioration, Mardin Ulu Mosque, Visual Analysis, Cultural Heritage

1 INTRODUCTION

Natural stones, which are the main construction material of historical buildings that are cultural heritage, have been used in different areas throughout history. In addition to their use as columns, load-bearing walls, flooring, stairs and facade elements in traditional buildings, natural stone is also used in areas such as construction, cladding and sculpture [1, 2]. Stone material is preferred more than other materials. The ease of stone processing, drilling, chipping and the use of sharp materials such as nails and screws are effective in this [3, 4]. The fact that the amount of stone is high, its accessibility is high, it can be processed and its cost is less than other materials has been effective in the use of stone material more [5, 6]. Physical, chemical and biological degradation is observed in stone structures exposed to atmospheric conditions along with natural factors. In addition to these, anthropogenic degradation by humans is also observed and these degradations rapidly destroy the structures over time [7, 8]. Destruction and damages on the stone surfaces cause the strength of the stone to decrease over time and the bonds between the stones to break [9]. Taking measures against the deterioration of historical buildings is important in terms of transferring the buildings to future years [10]. Detection and classification of deterioration in cultural heritage buildings and early and accurate detection of deterioration play an important role in the survival of buildings for a longer period of time [11]. In this context, it is important to identify the deterioration observed in cultural heritage buildings and to take precautions in order for people to be aware of history and to take appropriate protection actions by authorised persons or institutions.

2 MATERIALS AND METHODS

In this study, the deterioration of the stone surfaces of Mardin Ulu Mosque was examined by visual analysis method. Stone surfaces have deteriorated over time due to unfavourable climatic conditions, traffic intensity, user error, internal and external factors [12]. Alterations in the structure were classified and analysed as physical, chemical, biological and anthropogenic alterations [11]. These changes are called degradation. This degradation occurring in buildings is not singular, but in some cases it causes the formation and acceleration of other degradation. For this reason, it is important to determine the degradation of the structures, to investigate the causes and to take precautions in order to transfer the structures to future generations.

2.1 Characteristics of the Study Area

The fact that Mardin is located on the historical road and has hosted different civilisations has played an effective role in the high number of madrasah buildings in the city. When the first settlements of Mardin are examined historically, it is observed that there are artefacts dating back to 3000 BC. [13]. When we look at the later years, there are also artefacts belonging to different civilisations, civilisations and states [14]. However, it is seen that the Artuqid state had an influence in determining the architectural identity of the city [15].

Mardin is a city in the Southeastern Anatolia Region of Turkey, located at 36o 54' and 37o 47' north latitude and 39o 55' and 42o 41' east longitude, with a surface area of 8891 km2 and an altitude of 1100 metres. It borders the provinces of Şanlıurfa, Diyarbakır, Batman, Şırnak and Siirt as well as Syria (Figure 1). The settlements in the city are shaped around Mardin Castle [16]. Since the city has sloping lands due to its geographical location, the buildings were built on these lands and access to the buildings is provided by steep ramps and stairs [17, 18].

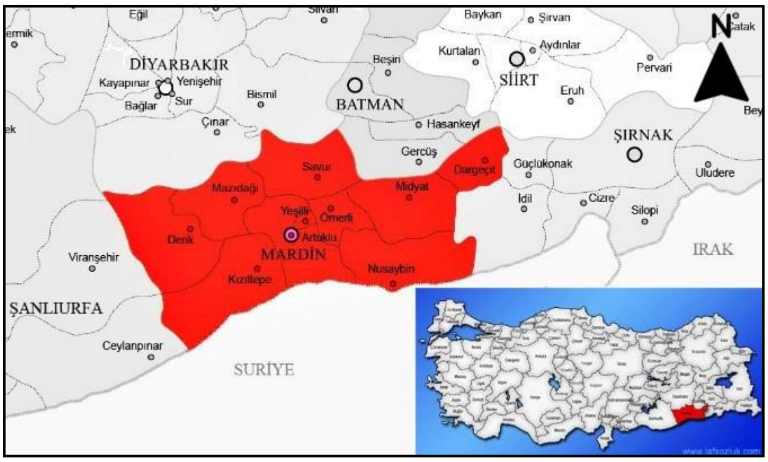

Figure 1. Location of Mardin in Turkey

When the climate of Mardin is examined; continental climate is observed in the centre and Mediterranean climate is observed in the districts. The winter months are cold and the summer months are dry and hot due to the pressure and wind coming from the desert. When the average temperature values are analysed, it is observed that July has the highest temperature value (29.8 ºC) and January has the lowest temperature value (3.0 ºC). Table 1 shows the average temperature values between 1942 and 2022. In the light of the data obtained, it was observed that the maximum sunshine duration was in July (12.4 hours) and the minimum in December (4.5 hours). Due to the climatic characteristics of Mardin, stone alterations are frequently encountered [19, 20].

Table 1. According to meteorological data, average temperature and precipitation values of Mardin province

MARDİN	Average Temperature (ºC)	Average Highest Temperature (ºC)	Average Lowest Temperature (ºC)	Average Sunbathing Time (hours)	Average Number of Rainy Days	Average Monthly Precipitation (mm)
January	3.0	5.8	0.6	4.5	12.11	115.9
February	4.2	7.4	1.4	5.1	10.61	103.2
March	7.9	11.6	4.6	5.9	11.70	97.7
April	13.5	17.4	9.8	7.3	10.28	81.1
May	19.5	24.0	15.1	9.7	7.35	47.3
June	25.6	30.6	20.3	12.1	1.54	6.5
July	29.8	35.0	24.6	12.4	0.48	3.2
August	29.6	34.7	24.7	11.4	0.24	2.3
September	25.3	30.1	20.8	10.3	0.70	4.0
October	18.6	22.9	14.7	7.7	5.12	33.8
November	11.1	14.5	8.1	5.9	7.66	71.9
December	5.4	8.2	2.9	4.4	10.80	108.7
Annual	16.1	20.2	12.3	8.1	78.6	675.6

3 RESEARCH AND FINDINGS

It is important to determine the factors causing the deterioration of stone surfaces in historical buildings with cultural heritage characteristics and to take appropriate measures [21]. When the stone material is exposed to climatic factors such as pressure, temperature, wind and precipitation over time, degradation occurs on the stone surfaces [22]. These degradations on stone surfaces reduce the durability of the stone over time, prepare the environment for new degradations and accelerate the process. Failure to take precautions against deterioration or wrong interventions cause serious damage to the structures [23]. The deterioration observed in Mardin Ulu Cami was identified, classified, photographed, documented and analysed by visual analysis method. The deterioration of the buildings were classified as physical, chemical, biological and anthropogenic deterioration [24, 25]. In this study, the stone deterioration seen in Mardin Ulu Mosque is examined under the title of visual analysis method.

Physical degradation; atmospheric conditions and mechanical effects due to the weakening of the minerals in the stone due to the weakening of the minerals in the stone as a result of the breakage of the bonds between the stones on the stone surfaces such as fracture, joint discharge, crack formation, abrasion [26–28]. Physical deterioration in Mardin Ulu Cami was observed as abrasion, joint discharge and capillary crack formation. The physical deterioration of Mardin Ulu Cami is shown in Figure 2.

Figure 2. Physical deterioration observed in the Mardin Ulu Mosque

Chemical degradation is defined as the changes on stone surfaces due to climate and atmospheric events. Effects such as colour changes, salting, crystallisation and encrusting on stone surfaces are caused by chemical degradation [29–31]. Colour change and salting were observed as chemical degradation types in Mardin Ulu Mosque. Chemical degradation in Mardin Ulu Mosque is shown in Figure 3.

Figure 3. Chemical deterioration observed in the Mardin Ulu Mosque

Biological degradation; It is called as the changes formed by organic substances occurring on stone surfaces. Moss, lichen, plant formations and biological accumulations are formed as a result of biological degradation. [32, 33]. Plant formation and microorganism formation were observed as biodegradation types in Mardin Ulu Mosque. Biodegradation in Mardin Ulu Mosque is shown in Figure 4.

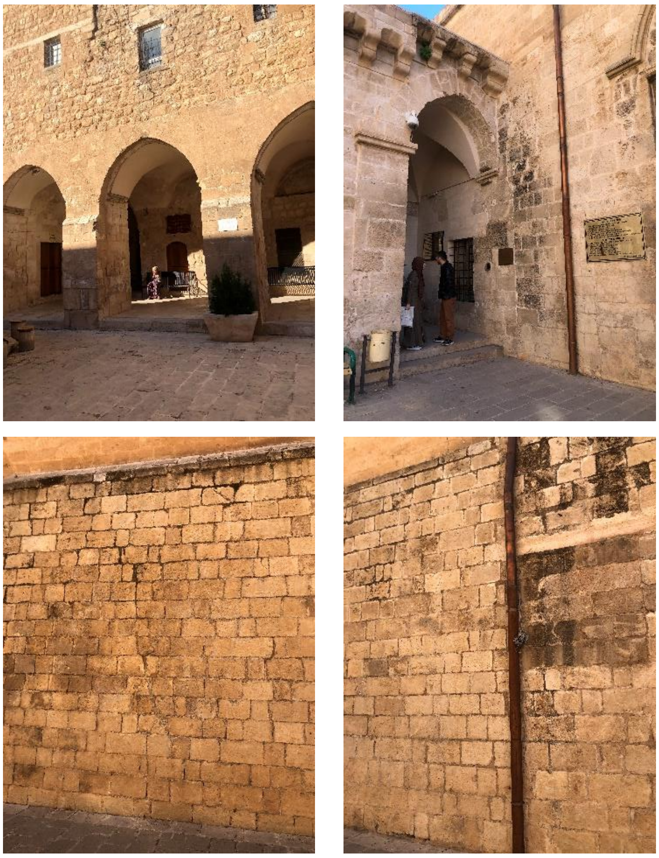

Figure 4. Biological deterioration observed in the Mardin Ulu Mosque

Anthropogenic degradation is the changes that occur as a result of conscious or unconscious damage caused by humans to stone surfaces. Misuse, periodic wear and tear and lack of maintenance occur as a result of anthropogenic deterioration. Periodic wear and tear due to use were observed as anthropogenic deterioration types in Mardin Ulu Mosque. The anthropogenic deterioration of the Mardin Ulu Mosque is shown in Figure 5.

Figure 5. Anthropogenic deterioration observed in the Mardin Ulu Mosque

4 RESULTS

Stone, which is one of the main construction materials of cultural heritage buildings, is used in different areas of human life for different functions and purposes. In Mardin Ulu Cami, one of the cultural heritage buildings in Mardin, natural stone was used as the main construction material. Due to the petrographic properties of natural stones, changes are observed on the stone surfaces when exposed to climate and external factors. In this study, stone deterioration observed in Mardin Ulu Cami was analysed. In the study, stone deterioration seen on the facades of the buildings were identified, classified and documented by photographing. The deterioration of the building was determined by visual analysis method and classified as physical, chemical, biological and anthropogenic deterioration. While physical and chemical degradation were the most observed degradation, biological and anthropogenic degradation were observed less.

As a result of the observations made in the structure, abrasion, joint discharge and capillary cracks were observed as physical degradation. Colour change and salting were observed as chemical degradation. While microorganism and plant formations were observed as biological degradation, usage-related damages were observed as anthropogenic degradation.

Mardin Ulu Mosque is one of the important cultural heritage buildings in Mardin province. The first step required for the preservation of the building is to determine the deterioration of the structure. The determinations obtained are important in terms of solving the problems occurring in the structure and preventing damages. If measures are not taken against the deterioration of traditional historical buildings, the deterioration of the building over time will increase and the functionality of the building will decrease. Measures to be taken against deterioration in traditional buildings, which are cultural heritage, are important in terms of transferring the building to future generations.

5 REFERENCES

[1] Hasbay, U., & Hattap, S. (2017). Doğal Taşlardaki Bozunma (Ayrışma) Türleri ve Nedenleri. *Bilim ve Gençlik Dergisi*, *5*(1), 23–45.

[2] Fitzner, B., & Heinrichs, K. (2001). Damage Diagnosis on Stone Monuments – Weathering Forms, Damage Categories And Damage Indices, 1–49.

[3] Biçen Çelik, A., Ergin, Ş., Dal, M., & Ay, İ. (2023). Analysis of Stone Deterioration on the Facades of Hatuniye Madrasah. *Mimarlık Bilimleri ve Uygulamaları Dergisi (MBUD)*. https://doi.org/10.30785/mbud.1302007

[4] Ay, İ., Ergin, Ş., & Dal, M. (2023). Geleneksel Taş Yapılarda Meydana Gelen Taş Alterasyonları: Gaziantep Hamam Müzesi Örneği. In *UMTEB - XIII International Scientific Research Congress* (pp. 515–523). IKSAD Yayınevi.

[5] Adin, H. (2007). Mardin ve Midyat'ta Kullanılan Bina Yapı Taşlarının Bazı Fiziksel Özellikleri. *Mühendis ve Makina*, *48*(570), 13–17.

[6] Ay, İ., Ergin, Ş., & Dal, M. (2023). Geleneksel Taş Yapılarda Meydana Gelen Taş Alterasyonları: Gaziantep Millet Hanı Örneği. In *UMTEB - XIII International Scientific Research Congress* (pp. 507–514). IKSAD Yayınevi.

[7] Dal, M., & Öcal, A. D. (2013). Limestone In Islamic Religious Architecture: İstanbul And Turkish Thrace. *METU Journal Of The Faculty Of Architecture*, *30*(01). https://doi.org/10.4305/METU.JFA.2013.1.2

[8] Dal, M., & Öcal, A. D. (2013). Investigations on Stone Weathering of Ottoman Architecture: A Kirklareli Hizirbey Kulliye Case Study. *Paripex- Indian Journal Of Research*, *2*(13), 1–6.

[9] Ergin, Ş., Gökdemir, B., Yardımlı, S., & Dal, M. (2022). Deterioration On The Stone Surfaces Of The Diyarbakır Nebi Mosque. *International Refereed Journal of Design And Architecture*, (27), 1–32. https://doi.org/10.17365/TMD.2022.TURKEY.27.01

[10] Biçen Çelik, A., Ergin, Ş., Dal, M., & Ay, İ. (2023). Analysis of Deterioration on Stone Surfaces: The Case of Kasimiye Madrasah. *Journal of Architectural Sciences and Applications (JASA)*, *8*(2), 696–712. https://doi.org/10.30785/mbud.1341005
[11] Öcal, A. D., & Dal, M. (2012). *Doğal Taşlardaki Bozunmalar* (Müka Matba.). İstanbul: Mimarlık Vakfı İktisadi İşletmesi.
[12] Öcal, A. D. (2010). *Kayaçtan Yapılmış Eski Eser Koruma Çalışmalarına Arkeometrik Bir Yaklaşım: Ayrışma Durumu Haritası. Türkiye ve Kolombiya'daki Anıt Eserlerin Bozunma Analizi*. Çukurova Üniversitesi, Adana, Adana.
[13] Aydın, S., Emiroğlu, K., Özel, O., & Ünsal, S. (2000). *Mardin: Aşiret-Cemaat-Devlet*. Türkiye Ekonomik ve Toplumsal Tarih Vakfı.
[14] Biçen Çelik, A. (2021). *Mardin İlindeki Medrese Yapılarının Cephelerinde Oluşan Taş Bozunmalarının İncelenmesi ve XRF Spektrometresi İle Analizi*. Dicle Üniversitesi.
[15] Dal, M., & Öcal, A. D. (2017). Mardin Şehrindeki Taştan Yapılmış Eserlerde Görülen Bozunmalar. *Balıkesir Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *19*(1), 60–74. https://doi.org/10.25092/baunfbed.321027
[16] Karataş, L. (2018). *Mardin Kenti İbadet Yapılarında Malzeme Kullanımı ve Sorunları Üzerine Bir Araştırma*. Uludağ Üniversitesi.
[17] Bekleyen, A., Dalkılıç, N., & Özen, N. (2014). Geleneksel Mardin Evi'nin Mekânsal ve Isısal Konfor Özellikleri, *7*(4), 28–44.
[18] Kejanli, D. T., Aykal, F. D., & Koç, C. (2023). Eski Mardin'de Sokak-Cephe İlişkisinin Değişimi Üzerine Değerlendirme. *Uluslararası Hakemli Tasarım ve Mimarlık Dergisi*, (18), 77–100. https://doi.org/10.17365/TMD.2019.3.4
[19] Ergin, Ş., Biçen Çelik, A., & Dal, M. (2019). Technical Characteristics of Kasimiye Madrasa Building Stones and Analysis of Stone Decay Problems. Köycegiz, Muğla Turkey.
[20] Biçen Çelik, A., Ay, İ., Ergin, Ş., & Dal, M. (2023). Mardin Medreselerinde Görülen Taş Alterasyonları: Şehidiye ve Hatuniye Medreseleri Örneği. *Kültürel Miras Araştırmaları*, *4*(2), 79–90. https://doi.org/10.59127/kulmira.1381600
[21] Karataş, L., & Perker, Z. S. (2023). An Observational Research for the Determination of Stone Material Problems in Mardin Kasımiye Madrasa. In M. Dal & L. Karataş (Eds.), *Architectural Sciences and Theory, Practice and New Approaches-1* (pp. 199–228). Iksad Publications.
[22] Dal, M. (2021). The Deterioration Problems Observed in the Natural Building Blocks of Saint George Church in Diyarbakır Province. *Online Journal of Art and Design*, *9*(1), 254–262.
[23] Khooshroo, S., Javadi, N., Yardimli, S., & Hattap, S. (2017). İstanbul Süleymaniye Camii Taş Yüzeylerinde Tespit Edilen Bozunmalar (pp. 227–235). Antalya.
[24] Ay, İ., & Ergin, Ş. (2023). Geleneksel Taş Yapılarda Meydana Gelen Bozunmalar: Hakkari Meydan Medresesi Örneği. In A. Biçen (Ed.), *Mimari İncelemeler ve Güncel Yaklaşımlar* (pp. 151–168). Ankara: Atlas Akademik.
[25] Ay, İ., & Ergin, Ş. (2023). Geleneksel Taş Yapılardaki Alterasyoınlar: Gaziantep Kürkçü Hanı Örneği. In H. Demir Kayan (Ed.), *Mekan/Çevre/Kültür* (pp. 164–178). Ankara: Atlas Akademik.
[26] Yılmaz Erten, Ş., & Mısırlı, A. (2023). Yığma Yapılarda Gözleme Dayalı Bozulma/Hasar Tespiti: Eski Harbiye Kışlası. *Bayburt Üniversitesi Fen Bilimleri Dergisi*, *6*(1), 39–51. https://doi.org/10.55117/bufbd.1265734
[27] Dal, M., & Yardımlı, S. (2021). Taş Duvarlarda Yüzey Bozunmaları. *Kent Akademisi*, *14*(2), 428–451. https://doi.org/10.35674/kent.922313
[28] Tosunlar, M. B., Hatır, M. E., İnce, İ., Bozdağ, A., & Korkanç, M. (2018). The Determination of Deteriorations on the Mısırlıoğlu Bridge (Konya, Turkey) by Non-Destructive Techniques (NDT). *ICONARP International Journal of Architecture and Planning*, *6*(2), 399–412. https://doi.org/10.15320/ICONARP.2018.60
[29] Biçen Çelik, A., Ergin, Ş., Dal, M., & Ay, İ. (2023). Analyzes of Stone Deterioration on the Facades of the Şehidiye Madrasah in the Central District of Mardin Province. *Uluslararası*

Doğu Anadolu Fen Mühendislik ve Tasarım Dergisi, 248–271. https://doi.org/10.47898/ijeased.1342472

[30] Ergin, Ş., Karahan, B., & Dal, M. (2021). Sultan Hamza-i Kebir Camii'nde Görülen Taş Bozunmaları. *Kent Akademisi*, *14*(2), 414–427. https://doi.org/10.35674/kent.931428

[31] Karkaş, Z. S., & Acun Özgünler, S. (2022). A Survey About the Determination of Essential Parameters of Surface Treatment Application Decisions. *Mimarlık Bilimleri ve Uygulamaları Dergisi (MBUD)*, 364–382. https://doi.org/10.30785/mbud.1090550

[32] Dolar, A., & Yardımlı, S. (2017). Tarihi Yapı Taşarlındaki Alg ve Bakteri Alterasyonları. In *Uluslararası Katılımlı 6. Tarihi Yapıların Korunması ve Güçlendirilmesi Sempozyumu* (pp. 143–152).

[33] Dal, M., Zülfikar, H. C., & Dolar, A. (2020). Mimari Taş Yapılarda Görülen Biyolojik Bozunmalar. In *Geleneksel ve Çağdaş Mimari Yapılar Üzerine Akademik Çalışmalar* (pp. 29–62). Ankara: İksad Yayınevi.

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Properties of soil bricks containing Agro-wastes

Taghried Abdel-Magid, Pete Walker, Kevin Paine, Stephen Allen

Department of Architecture and Civil Engineering, Faculty of Engineering and Design, University of Bath

timam20@bath.ac.uk

ABSTRACT

Soil bricks used in masonry are one of the oldest forms of construction. The material is low-cost and readily available around the world. Stabilisation techniques and additives, including agricultural wastes (agro-wastes), are commonly used to improve their mechanical properties. In this study, sorghum stalk, groundnut husk, and corncob (with different surface treatments) were used in the production of soil bricks. Characterisation tests of the agro-wastes were performed as well as mechanical tests for the soil bricks. Properties of soil used for brick production were characterised through laboratory tests. Following a pilot study to optimise production, the main experimental study focused on assessing the strength and thermal conductivity of the bricks. The compressive strength, flexural strength and thermal conductivity properties of prototype blocks incorporating agro-wastes were evaluated, including the influence of corn cob surface treatments.

Keywords: Compressed soil bricks; Agro-waste; Earthen construction; Sorghum stalk; Groundnut husk; Corncob.

1 INTRODUCTION

Soil suitable for masonry units is widely available, and as such masonry remains one of the most favoured and widely used construction techniques. This is particularly relevant in rural areas of low- and medium-income countries for its low cost, ease of construction, and relatively durable life [1]. Despite these advantages, masonry units, especially unfired ones, are susceptible to water damage [2]. While the dry compressive strength of unfired soil masonry units can reach 4 MPa, or higher, their strength when saturated often approaches zero [3], rendering them susceptible to damage during wet seasons.

Additives may be used as chemical and physical stimulators to improve the strength and drying shrinkage; these can be industrial wastes, such as fly ash, plastic fibres, recycled papers, granulated blast furnace slag, and others [4], [5]. Numerous agricultural wastes (agro-wastes) were tested as well to provide additional strength. These include cereal crop straw and other fibrous materials [4].

In this paper, the effect of agro-wastes on the properties of soil bricks is studied with the objectives of: 1) studying the effect of different agro-waste percentages on flexural and compressive strength of the soil bricks, 2) assessing the effect of different agro-waste percentages on the thermal conductivity of the bricks, and 3) studying the effect of different corncob coating methods on their contribution to physical properties of the soil bricks.

2 MATERIALS AND METHODS

2.1 Agro-wastes

For this study, three agro-wastes were used in their raw state: sorghum stalk (SS), groundnut husk (GN), and corncob (CC). Two were also treated: corncob covered with cement paste (CCem), and corncob covered with acacia gum (gum Arabic) (CGum). The agro-wastes were sourced as follows:

1. Sorghum stalks (SS) from Al-Gadarif state in eastern Sudan.
2. Groundnut husks (GN) from North Kurdufan in central Sudan.
3. Corncobs (CC) were sourced from the company 'Oberflächentechnik Seelmann e.K.' with a grain size ranging between 200 and 400 μm.

Corncobs were not sourced locally due to travel restrictions between the countries during the time of research. Leaves were initially removed from SS. The SS and GN were cleaned, washed, and sun-dried before shipping to the UK. They underwent another washing upon arrival at the University of Bath, then were dried in a 105°C oven until constant mass. CC was sourced in a sealed container and dried. Agro-wastes were then stored in vacuum plastic bags, to ensure they did not absorb moisture from the surrounding environment until the time of use.

2.2 Soil Characterisation Tests

A set of characterisation tests was conducted to confirm the soil properties, including: 1) compaction test performed on soil and soil containing different percentages of agro-wastes following BS 1377-4, 2) Atterberg limits test following BS 1377-2, and 3) particle size distribtuion following by dry sieving and wet sieving as per BS 933-4 and hydrometer test on clay particles following the BS EN ISO 17892-4:2016.

2.3 Agro-Waste Characterisation Tests

2.3.1 Physical characterisation tests

A set of characterisation tests was conducted including 1) bulk and particle density measured using an AccuPyc 1330 Pycnometer, 2) sorption kinetics using Dynamic vapour sorption (DVS) Intrinsic equipment under RH up to 95% using water as sorbent, 3) pore size distribution using a mercury intrusion porosimeter, 4) water absorption determined by weighing the agro-waste in a dry state and saturated state, and 5) morphology, using optical and scanning electron microscopes.

2.3.2 Chemical characterisation tests

Tests conducted included 1) thermogravimetric analysis using a High-Temperature Platform 400 STA 449 F1 Jupiter and 2) energy dispersive x-rays using a scanning electron microscope.

2.4 Mechanical Properties Tests

2.4.1 Flexural strength

Flexural strength tests were conducted on 40 mm × 40 mm × 160 mm prisms of soil bricks following BS EN 196-1. Tests were performed in a universal testing machine Instron 3369 test frame with a load rate of 0.2 mm/min. The test terminated when the maximum load dropped by 75%.

2.4.2 Compressive strength

Compressive strength tests were conducted on a 40 mm × 40 mm square area of the soil bricks specimens following BS EN 196-1. These were performed on both halves following the flexural tests in a universal testing machine Instron 3369 test frame with a load rate of 0.5 mm/min. The test terminated when the maximum load dropped by 75%. Compressive strength was normalised using a shape factor of 0.82 as recommended by the BS EN 772-1.

2.4.3 Thermal conductivity

Thermal conductivity was measured for the soil bricks using a Transient Plane Source technique with a TPS 3500 Hot Disk thermal constants analyser. A Kapton sensor of a diameter of 6.403 mm was sandwiched between the two halves of a soil brick produced after flexural testing. Measuring time was set as what gives a total characteristic time between 0.3 and 1, and was concluded to be 40 seconds. Output power was adjusted for each sample to sustain a total temperature increase between 3 Kelvin and 5 Kelvin for all specimens. Tests were scheduled for the same sample with 20-minute time laps between each reading to avoid heat storage affecting the results. Initial measurements are removed from each transient graph to revoke the influence of the contact resistance between the sensor and the sample. Further points were cut from the start of the transient as needed to maintain a mean deviation between 1E-04 to 3E-04.

2.5 Bricks Preparation

Dry soil and the agro-wastes were mixed thoroughly before adding water content to achieve the Proctor optimum moisture content. The moisture contents were 15%, 16% and 17% for the 1%, 2% and 3% of agro-waste addition, respectively. Mixing was initially carried out manually; subsequently, the damp soil was added to the mixer, with automatic mixing continued for 2 to 4 minutes. The soil mixture was then covered with plastic wrap to limit drying before compaction.

A fabricated mould accompanying six brick specimens with the dimensions of 40 mm × 40 mm × 140 mm each was lubricated for ease of extraction, and parchment paper was laid to prevent contamination of the soil with the grease. Each chamber of the mould was filled with a mass determined from the compaction test. A manual 'constant volume' block compaction press was used. A load cell was installed to assure consistency in compaction force between 25-30 kN. The load cell was subsequently removed for ease of compaction after the procedure was optimised.

3 RESULTS AND DISCUSSION

3.1 Agro-waste Properties

Particle density is a fundamental characteristic which influences the density of the construction material, and its mechanical behaviour. It is also used to estimate the porosity and air-filled voids in a matrix. The particle density of the agro-wastes, 120, 300, and 410 kg/m^3 for SS, GN and CC, respectively, are within the range recorded in literature: 600 – 1600 kg/m^3 for fibres extracted from the bast of the crop such as abaca, jute, hemp and bamboo [6], [7]. These values are for fibres extracted from agro-wastes, rather than raw stalks or husks. Thus, the wastes studied here are considered low-density.

The water absorption capacity of a brick can affect its durability and the shrinkage cracks formation. The 24-hour water absorption capacity is a way to identify the susceptibility of a brick to water damage in wet seasons. This was high for the tested bricks when compared to other synthetic fibres as expected, due to the hydroxyl groups in natural materials. Although high water absorption can be amended by chemical treatments or coating of the wastes [8], [9], this study focused on the use of agro-wastes with the least possible interference to minimise the cost.

All sorption isotherms extracted from the DVS test of agro-wastes were a Type III isotherm as per Sing et al. [10], which indicates a macroporous surface with no monolayer sorption and can also indicate a cluster of vapour on the surface. For these materials, both suggestions are valid when put together with the WA behaviour and the SEM imaging. Having a hysteresis across the entire humidity range shows that the moisture is absorbed into the bulk of the material, not merely adsorbed on the surface, and the desorption is diffusion-limited [11] which can be seen by the slow initial slope in the desorption curve. The process is reversible though, as evident by the return to zero in the desorption curve. Low sorption at low RH indicates low water affinity which is more prominent in the CC and GN samples possibly due to the wax layer covering the particles. Breaking the SS by shredding them might have broken that layer hence increasing the initial water uptake. The sorption capacity associated with the hygroscopic quality of the natural materials and apparent in these results can be beneficial when using the material as a moisture buffer to control the indoor quality in a building [12].

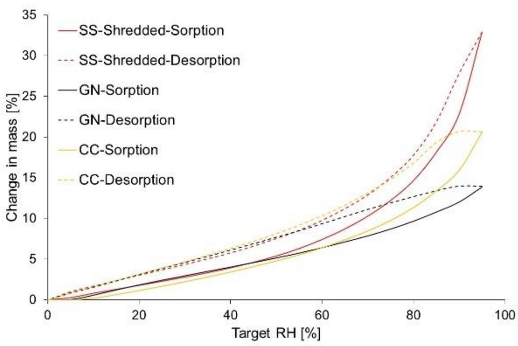


Figure 1*:* Sorption/desorption isotherms for agro-wastes

3.2 Agro-waste Soil Bricks

3.2.1 Strength testing

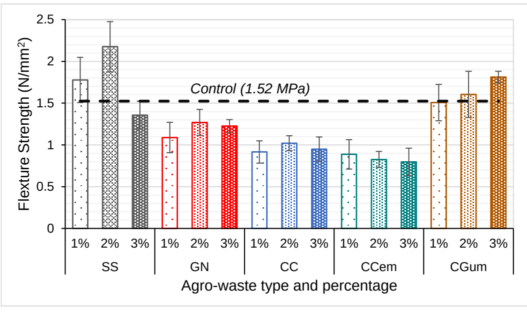
The average and standard deviation (SD) of the flexural strength and strain of the bricks containing SS were calculated and presented in Table 1.

Compared to the control sample, the flexural strength of GN, CC and CCem (Fig. 3) decreased with the increase in agro-wastes, while that of SS and CGum increased. Compressive strength (Fig. 4) generally increased with the addition of agro-wastes. İn CGum bricks, the increase might be attributed to the glueing effect of acacia gum.

All sets exhibited flexural strength higher than that required by the Masonry Structure Joint Committee [13].

Table 1. Mean and standard deviation values for brick samples containing SS

	Flexure strength [N/mm^2]	*Strain at displacement:*							
		Max stress	1 mm	1.5 mm	2 mm	2.5 mm	2.8 mm	3 mm	3.5 mm
Mean	1.7007	1.6%	2.4%	3.7%	4.9%	6.2%	7.0%	7.5%	8.7%
SD	0.3633	0.88	0.02	0.04	0.06	0.07	0.08	0.07	0.09



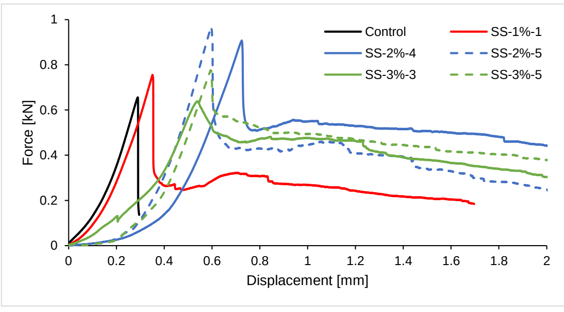


Figure 3: Flexural strength of agro-waste bricks (left), Examples of force-displacement curves of soil bricks, control and containing SS (right)
there is a general trend of decreasing compressive strength with the increase in percentage agro-waste content. That was expected as the fibre-fibre bond can weaken the matrix integrity. For up to 3% of all types of agro-waste used here improved the compressive strength. CCem bricks showed a strength increase with the percentage increase, attributed to the cement's role in stabilising the soil.

An increase in compressive strength accompanied by a decrease in the density (Fig.4) gives way to the use of these agro-wastes with higher percentages. All tested specimens meet the O-2 designation by the African Regional Standards [14] for compressed earth blocks in terms of compressive strength (≥ 4 N/mm^2) for use in a dry environment.

SS bricks had a higher flexural strength (1.4 to 2.2 N/mm^2) than that recorded by other types of fibres in literature such as jute and straw [15], [16]. The compressive strength of SS bricks (5.2 to 5.8 N/mm^2) was also higher than those recorded in the literature for jute, hibiscus fibres and straw [15]–[18]. The compressive strength exhibited by all three types of corncob granules (5.1 to 5.8 N/mm^2) was higher than that recorded in the literature [19].

A two-tailed Student's t-test was performed testing the null hypothesis of no significant difference between the strengths of the control and the other tested bricks. The degree of freedom used was 10 and 22 and the associated probability value (p-value) for a significance level of 5% was 2.228 and 2.074 for flexural and compressive strength, respectively. As the specimens had higher t-values than their respective p-value, this gave strong evidence to reject the null hypothesis, thus concluding there is a significant difference between the mean strengths of the sets. It can be concluded that the agro-wastes contributed to this difference.

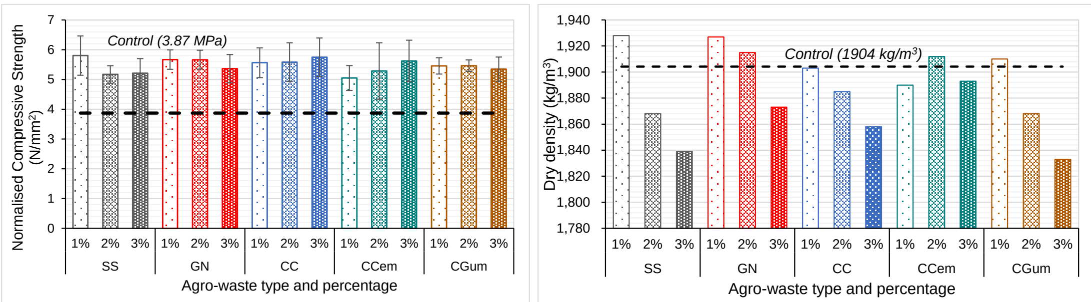


Figure 4: Normalised dry compressive strength of agro-waste bricks (left), Dry density of agro-waste bricks (right)

A reliability function helps determine the probability of a failure-free operation of a unit. This could help identify the reproducibility of the formed bricks. Here, a Weibull distribution was chosen for its flexibility in accommodating different data distributions. The two-parameter Weibull distribution is identified by the shape parameter and the scale parameter. The shape parameter, the slope of Weibull distribution, provides information on the failure rate change over time. The scale parameter, the time by which 63.2% of the sample fails, gives information on how wide is the distribution curve and how varied are the data [20], [21].

For the failure data provided from the compressive strength test of the different sets, a cumulative density function of Weibull distribution was plotted and the 95% certainty indices (CI) borders as shown in Fig. 5 by the two boundary lines surrounding the dotted best-fit line. All the data points are within the 95% CI showing a good fit with the Weibull distribution. Which gives good level of confidence on the reproducibility of the brick units.

All of the 2% and 3% agro-waste samples (except CGum-3%) data were plotted in a curve or an s-shape around the best-fit line. This indicates that the failure rate of the tested specimens fluctuated between increasing and decreasing, which reflects infant mortality meaning that the specimens failed as if they were in the early stages of production and did not undergo stresses due to load carrying, while others failed in a more brittle phenomenon, representing the end-of-life behaviour. This discrepancy can be attributed to the random distribution of the agro-waste within the specimen.

The shape parameter of the control was 20.2, which is the highest value compared to the agro-waste bricks, other than GN-1% and CGum-3%. This shows a higher failure rate and less variability between specimens. The other samples with variability within individual specimens can be justified by the arbitrary agro-waste distribution within the matrix. CCem and CGum samples were shown to be less variable than the other samples, which can be related to their granular shapes. The scale factor is higher than the control for all the agro-waste bricks, especially the ones containing SS and GN, which indicates more energy absorption than the control. This was clearly shown with the slower propagation of cracks the SS bricks displayed.

For low-cost, affordable structural elements, all units tested in this study exhibited normalised compressive strength higher than those set by the different design standards (British, Indian, Mexican and African standards).

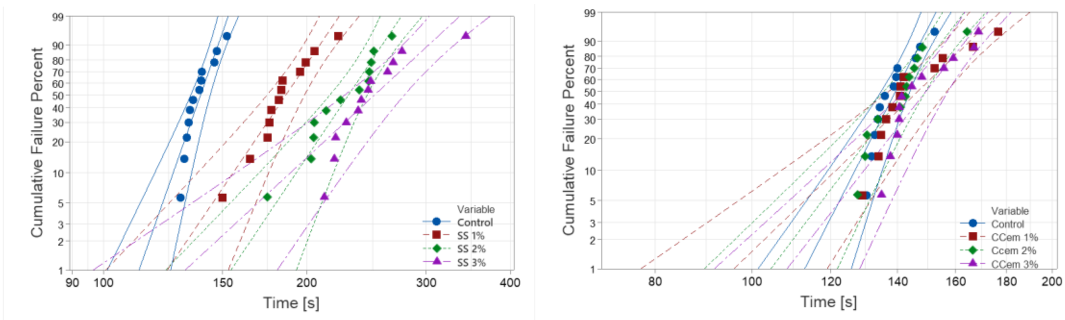


Figure 5: Cumulative probability plot - Weibull distribution with 95% certainty for bricks containing SS (left) and CCem (right)

3.2.2 Thermal conductivity

The average thermal conductivity of agro-waste bricks is shown in Fig. 6. The conductivity is mainly influenced by the density and porosity of the specimen, along with the pores sizes and the mineralogical composition [22]. A decrease in thermal conductivity was expected with the increased percentage of waste as a more porous material. The increase in thermal conductivity in CCem samples was expected due to the use of cement. GN have less porous shells than SS and they contain chunks of stalks which can be the reason behind the relatively higher value. In general, the effect of agro-waste on thermal conductivity did not follow a specific pattern. This can be attributed to the random agro-waste distribution in the soil matrix and their individual variations. All values here were higher than other agro-wastes recorded in the literature [15], [19], [23].

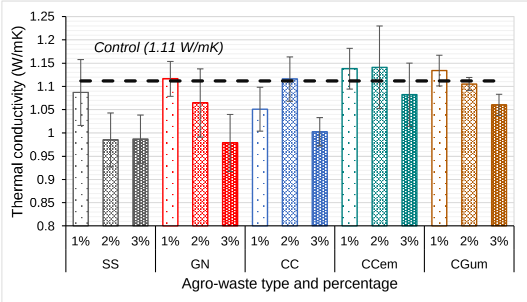


Figure 6: Thermal conductivity of agro-waste soil bricks

4 CONCLUSIONS

The use of sorghum stalk, groundnut husk, and corncob in the production of pressed earth bricks was studied. The brick preparation method was optimised through a pilot study, then the main study focused on assessing the strength and thermal conductivity of the different bricks. The following conclusions and recommendations are drawn from this part of the research study:

1- Incorporating the five agro-waste types in the production of HG Matthews soil bricks showed promising mechanical behaviours in terms of compressive strength and thermal conductivity.
2- The use of sorghum stalk positively impacted the flexural and compressive strengths of the soil bricks and had a promising influence when compared to other fibres and straws in literature.
3- Groundnut husk with the least treatment can be used in the preparation of soil bricks with promising physical properties. Caution must be exercised while leaving it in a damp environment.
4- Corncob can be used treated or untreated to strengthen the soil bricks and improve their thermal properties. Acacia gum and cement slurry improved the bond within the soil matrix resulting in higher strengths.

5 REFERENCES

[1] B. V. Venkatarama Reddy *et al.*, "Codes and Standards on Earth Construction," in *Testing and Characterisation of Earth-based Building Materials and Elements. RILEM State-of-the-Art Reports*, A. Fabbri, J. Morel, J. Aubert, Q. Bui, D. Gallipoli, and B. V. Reddy, Eds., Springer, 2021. doi: https://doi.org/10.1007/978-3-030-83297-1_7.

[2] J. C. Morel, A. Pkla, and P. Walker, "Compressive strength testing of compressed earth blocks," *Constr. Build. Mater.*, vol. 21, no. 2, pp. 303–309, 2007, doi: 10.1016/j.conbuildmat.2005.08.021.

[3] K. Dao, M. Ouedraogo, Y. Millogo, J. E. Aubert, and M. Gomina, "Thermal, hydric and mechanical behaviours of adobes stabilized with cement," *Constr. Build. Mater.*, vol. 158, pp. 84–96, 2018, doi: 10.1016/j.conbuildmat.2017.10.001.

[4] S. P. Raut, R. V. Ralegaonkar, and S. A. Mandavgane, "Development of sustainable construction material using industrial and agricultural solid waste: A review of waste-create bricks," *Constr. Build. Mater.*, vol. 25, no. 10, pp. 4037–4042, 2011, doi: 10.1016/j.conbuildmat.2011.04.038.

[5] M. Sutcu and S. Akkurt, "The use of recycled paper processing residues in making porous brick with reduced thermal conductivity," *Ceram. Int.*, vol. 35, pp. 2625–2631, 2009, doi: 10.1016/j.ceramint.2009.02.027.

[6] O. Faruk, A. K. Bledzki, H. P. Fink, and M. Sain, "Biocomposites reinforced with natural

fibers: 2000-2010," *Prog. Polym. Sci.*, vol. 37, no. 11, pp. 1552–1596, 2012, doi: 10.1016/j.progpolymsci.2012.04.003.

[7] O. Onuaguluchi and N. Banthia, "Plant-based natural fibre reinforced cement composites: A review," *Cem. Concr. Compos.*, vol. 68, pp. 96–108, Apr. 2016, doi: 10.1016/j.cemconcomp.2016.02.014.

[8] J. A. Rabi, S. F. Santos, G. H. D. Tonoli, and H. S. Jr, "Agricultural Wastes as Building Materials: Properties , Performance and Applications," in *Building Materials: Properties, Performance and Applications*, D. N. Cornejo and J. L. Haro, Eds., Nova Science Publishers, 2009, pp. 1–44.

[9] N. Stevulova *et al.*, "Properties characterization of chemically modified hemp hurds," *Materials (Basel).*, vol. 7, pp. 8131–8150, 2014, doi: 10.3390/ma7128131.

[10] K. S. W. SING *et al.*, "REPORTING PHYSISORPTION DATA FOR GAS/SOLID SYSTEMS with Special Reference to the Determination of Surface Area and Porosity (Recommendations 1984)," *Pure Appl. Chem.*, vol. 57, no. 603, 1985.

[11] N. Hunter, "Dynamic Vapour Sorption," in *Principles of Thermal Analysis and Calorimetry: 2nd Edition*, S. Gaisford, V. Kett, and P. Haines, Eds., The Royal Society of Chemistry, 2016, pp. 47–66. [Online]. Available: http://www.micromeritics.com/repository/files/Dynamic_vapor_sorption.pdf

[12] M. Palumbo, A. M. Lacasta, N. Holcroft, A. Shea, and P. Walker, "Determination of hygrothermal parameters of experimental and commercial bio-based insulation materials," *Constr. Build. Mater.*, vol. 124, pp. 269–275, 2016, doi: 10.1016/j.conbuildmat.2016.07.106.

[13] MSJC, "Building code requirements and specification for masonry structures," 2012.

[14] ARS, "ARS 670 African Regional Standards for Compressed Earth Blocks," 1998.

[15] G. Araya-Letelier *et al.*, "Experimental evaluation of adobe mixtures reinforced with jute fibers," *Constr. Build. Mater.*, vol. 276, p. 122127, 2021, doi: 10.1016/j.conbuildmat.2020.122127.

[16] K. F. Abdulla, L. S. Cunningham, and M. Gillie, "Experimental Study on the Mechanical Properties of Straw Fiber–Reinforced Adobe Masonry," *J. Mater. Civ. Eng.*, vol. 32, no. 11, pp. 1–15, 2020, doi: 10.1061/(asce)mt.1943-5533.0003410.

[17] F. F. Khorasani and M. Z. Kabir, "Experimental study on the effectiveness of short fiber reinforced clay mortars and plasters on the mechanical behavior of adobe masonry walls," *Case Stud. Constr. Mater.*, vol. 16, no. September 2021, p. e00918, 2022, doi: 10.1016/j.cscm.2022.e00918.

[18] Y. Millogo, J. C. Morel, J. E. Aubert, and K. Ghavami, "Experimental analysis of Pressed Adobe Blocks reinforced with Hibiscus cannabinus fibers," *Constr. Build. Mater.*, vol. 52, pp. 71–78, 2014, doi: 10.1016/j.conbuildmat.2013.10.094.

[19] A. Laborel-préneron, J. Aubert, and C. Magniont, "Corn cob influence on unfired earth bricks' properties," *Terra Lyon 2016*, pp. 1–8, 2018.

[20] P. D. T. O'Connor and A. Kleyner, "Life Data Analysis and Probability Plotting," *Pract. Reliab. Eng.*, pp. 70–107, 2011, doi: 10.1002/9781119961260.ch3.

[21] C. Lai, "Weibull Distributions and Their Applications," in *Springer Handbook of Engineering Statistics*, 2006. doi: 10.1007/978-1-84628-288-1.

[22] S. M. S. Kazmi, M. J. Munir, I. Patnaikuni, Y. F. Wu, and U. Fawad, "Thermal performance enhancement of eco-friendly bricks incorporating agro-wastes," *Energy Build.*, vol. 158, pp. 1117–1129, 2018, doi: 10.1016/j.enbuild.2017.10.056.

[23] T. Ashour, A. Korjenic, S. Korjenic, and W. Wu, "Thermal conductivity of unfired earth bricks reinforced by agricultural wastes with cement and gypsum," *Energy Build.*, vol. 104, pp. 139–146, 2015, doi: 10.1016/j.enbuild.2015.07.016.

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Influences of Substrate Sorptivity and Straw Incorporation on the Moisture Management of Earth-Lime Mixtures in Earthen Construction

Authors Tugce Busra Su-Cadirci

Address Barbaros, Sümer Kampüsü, Erkilet Blv., 38080 Kocasinan/Kayseri

E-Mail tugcebusra.su@agu.edu.tr

ABSTRACT

This study explores the impact of substrate sorptivity and straw incorporation on the transfer sorptivity of earth-lime mixtures in earthen construction. There is a direct correlation between the sorptivity of substrate materials and the transfer sorptivity of the mixtures, highlighting how substrates with higher sorptivity (S=3 mm/min$^{1/2}$) significantly enhance the water-release capabilities of the mixtures, as evidenced in comparisons between the two different bricks. Additionally, the straw addition into the mixtures was observed to increase their water-releasing properties, which is crucial for applications requiring rapid drying and reduced water retention. The experiments demonstrated that mixtures containing straw (Mix 2) exhibited higher transfer sorptivity compared to those consisting only of lime and earth (Mix 1). Furthermore, an increase in the lime content relative to the earth decreased transfer sorptivity, underscoring lime's role in improving water retention a beneficial property in moisture-sensitive environments.

These findings provide essential insights into the design of earth-lime mixtures, suggesting that adjusting the sorptivity of the substrate and the ratio of straw and lime can significantly influence the hygrothermal performance of earthen constructions. This knowledge advances our understanding of moisture management in earthen materials and offers practical guidelines for optimizing construction mixes to meet specific environmental and functional demands. Further research into the complex interplay of material composition and environmental factors is recommended to further enhance the performance and sustainability of earthen architecture.

Keywords: Earth blocks, lime, transfer sorptivity, breathability

1 INTRODUCTION

In sustainable architecture, the hygrothermal performance of earthen constructions is a key factor influencing the building performance that affects both their durability and comfort levels of their users[1]. Traditional earthen building techniques, which incorporate natural materials like soil and lime, have been revived and adapted in sustainable architecture due to their low environmental impact and thermal performances.

Understanding the hydric performance of earth-based masonry is essential for ensuring their durability regarding their breathability mechanisms which has a main role on the degradation processes of the materials in the buildings. Therefore dewatering, a critical process in masonry construction, involves the water from freshly mixed properties to a dry porous substrate [2], [3], [4]. The extent of dewatering is governed by the water retention characteristics of the mixtures and the sorptivity of the substrate. When high-water-releasing mixtures are applied to substrates with high sorptivity, a substantial amount of water can be absorbed by the substrate from the mixes. The high-water retaining ability of these mixtures gives changes in optimisations between materials used in constructions, especially when this high-water retaining mixture contacted with the low sorptivity substrates in the hybrid systems used in masonry buildings.

During dewatering, transfer sorptivity, a key parameter reflecting the rate of water absorption and transmission in porous materials, offers valuable insights into the moisture management characteristics of these structures. Not only do the physio-chemical characteristics of the mixtures including pore size, pore distribution, surface roughness, and material composition, affect the moisture management, but also do the sorptivity of a porous substrate and the transfer sorptivity of the mixtures. Therefore, these are critical parameters for durability, and resistance to weathering.

The purpose of this study is to examine the hydric performance of earth-based masonry, with a special emphasis on the impact of transfer sorptivity in blocks that have been treated with lime and straw. In order to evaluate the hydric behaviour of various block kinds, such as earth blocks and earth-lime blocks, laboratory tests will be carried out. Measurements of transfer sorptivity will monitor the rates of water absorption and transmission over time, giving information on the flow of moisture inside the blocks. With these discussions, the breathability mechanism and moisture management capacities of earth blocks will be clarified.

This study attempts to distinguish the influence of lime and straw additions on moisture behaviour of the earth-based mixtures by analysing the transfer sorptivity of two different compositions in contact with two different substrate sorptivities. Therefore, the influence of sorptivity of porous substrate and the straw addition on lime-earth mixes are discussed. Substrate sorptivity, the ability of the underlying material to absorb and transmit water, is a significant factor that can influence the overall moisture management of the construction[1]. Similarly, straw has been traditionally used in earthen mixes to enhance mechanical properties[5], [6], [7], but its role in influencing moisture dynamics is less understood. By analysing the transfer sorptivity of various earth-lime mixtures, this research aims to clarify how these factors interact to affect the moisture management capabilities of earthen materials. Understanding these interactions can lead to more informed choices in material selection and construction practices. The results will advance knowledge of earth-based masonry's moisture management and building envelope performance.

2 MIXTURES AND EXPERIMENTAL PROCEDURES

2.1 Mixtures

The soil is from Kultepe archaeological excavation site; lime is hydrated lime, which conforms to EN 459–1[8]. The ingredients and proportions of fresh mixtures are shown in Table 1. Mix 1 and Mix 2 compared the effect of straw on transfer sorptivity of mixtures, while the influence of substrate sorptivity variability were highlighted using different subsrates for each mixes.

Table 1. The ingredients and proportion (gr) of mixtures

Types	*Soil(gr)*	*Lime(gr)*	*Straw(gr)*	*Water(gr)*	*Total Mix (gr)*	*Flow*
Mix 1	960	150		450	1560	17.5
Mix 2	960	120	30	500	1610	16

2.2 Experimental Procedures

Two different bricks are used for the effect of sorptivity of bricks on mixtures. The sorptivity (S) of bricks are 1 (Buyukdere) and 3 (AGU campus) mm/min1/2. The mix designs used in this study were based on lime (CL90), soil in Table 1**Hata! Başvuru kaynağı bulunamadı.**. Then, approximately half of the required water content was added and mixed for 2 minutes, followed by 1 minute by hand. The remaining water required was then carefully added in increments until a flow of 170±5 mm was achieved across all mortars [9]. Freshly earth based mixtures were measured using the Flow test according to ASTM C230 Standard [10].

The measurement of sorptivity (S) was determined by placing the substrate bricks in contact with wet earth-based mixes. The two types of bricks were used as substrate to see the effect of sorptivity of substrates on transfer sorptivity of earth-based mixes. The bricks are dried to a constant weight at 1200C. The mixtures divided into two and each brick placed on wet mixtures, removing from wet fresh mixes consecutively at increasing time intervals and weighted. Desorptivity, R, defines the water retaining ability of a wet mix such as an earth-based mixtures in this study. A low R value indicates a high-water retaining characteristic of the mix. The sorptivity, S, defines the ability of a porous material (brick) to absorb water by capillarity. The transfer sorptivity, A, is a function of both R and S and characterises the ability of a porous material to absorb water from a wet mix.

Transfer sorptivity and time to dewater were determined from a plot of cumulative absorbed volume of water per unit area (i) versus time to dewater (tdw). While three data points for the first stage where the gradient of this data defines the transfer sorptivity, the second stage was determined with the two data points which total dewatering was seen.

3 RESULTS AND DISCUSSION

3.1 The influence of sorptivity of brick unit on transfer sorptivity of earth-based mixtures

The sorptivity of bricks were used to substrate the water included in mixture. S=1 mm/min1/2 for Buyukdere brick and S=3 mm/min$^{1/2}$ for AGU brick were determined. Desorptivity (R) and sorptivity (S) and transfer sorptivity (A) are the three parameters of dewatering process at fresh stage, explained in Su-Cadirci et al., 2021 [3]. One of these parameters was the sorptivty of substrate units. The influence of sorptivity of brick unit on transfer sorptivity of earth-based mixtures was shown in Figure 37. It is clearly seen that Mix 2 with S=1 mm/min$^{1/2}$ and Mix 2 with S=1 mm/min$^{1/2}$ indicated the similar trends and transfer sorptivity values, in the similar way, Mix 1 with S=3 mm/min$^{1/2}$ and Mix 2 with S=3 mm/min$^{1/2}$ mixtures showed the nearly alike results. This is an indication of the influence of sorptivity of brick on the transfer sorptivity of the mixtures. Due to the high sorptivity increases the transfer sorptivity, the values determined with the mixtures (seen in Table 2) with S=3 mm/min$^{1/2}$ are higher than the one with S=1 mm/min$^{1/2}$.

Table 2. Transfer Sorptivity (i (mm)) and the amount of water removed.

Mixtures	*A (S=1)*	*A (S=3)*	*Dewatered water (g) S=1*	*Dewatered water (g) S=3*	*% of Additions*	*Water(gr)*
Mix 1	0.77	0.90	39.31	57.25	%12,5 lime	450
Mix 2	0.86	1.27	45.26	62.07	%10 lime+%2,5 straw	500

3.2 The influence of straw use on transfer sorptivity of earth-based mixtures

The influence of straw use in earth-based mixtures on transfer sorptivity is determined with the comparison the transfer sorptivities of Mix 2 and Mix 3. The transfer sorptivity of the mixtures are increased with the straw use in mixtures, seen in Table 2 and Figure 37 that The transfer sorptivity of straw including mix (Mix 2) is lower than lime-earth mix (Mix1). This means that Mix 2 has a more Mix 2 become more water releasing than Mix1. Secondly, the lime amount increases with the same amount of earth in mixtures caused the decrease in transfer sorptivity. This is because high water retaining character of lime.

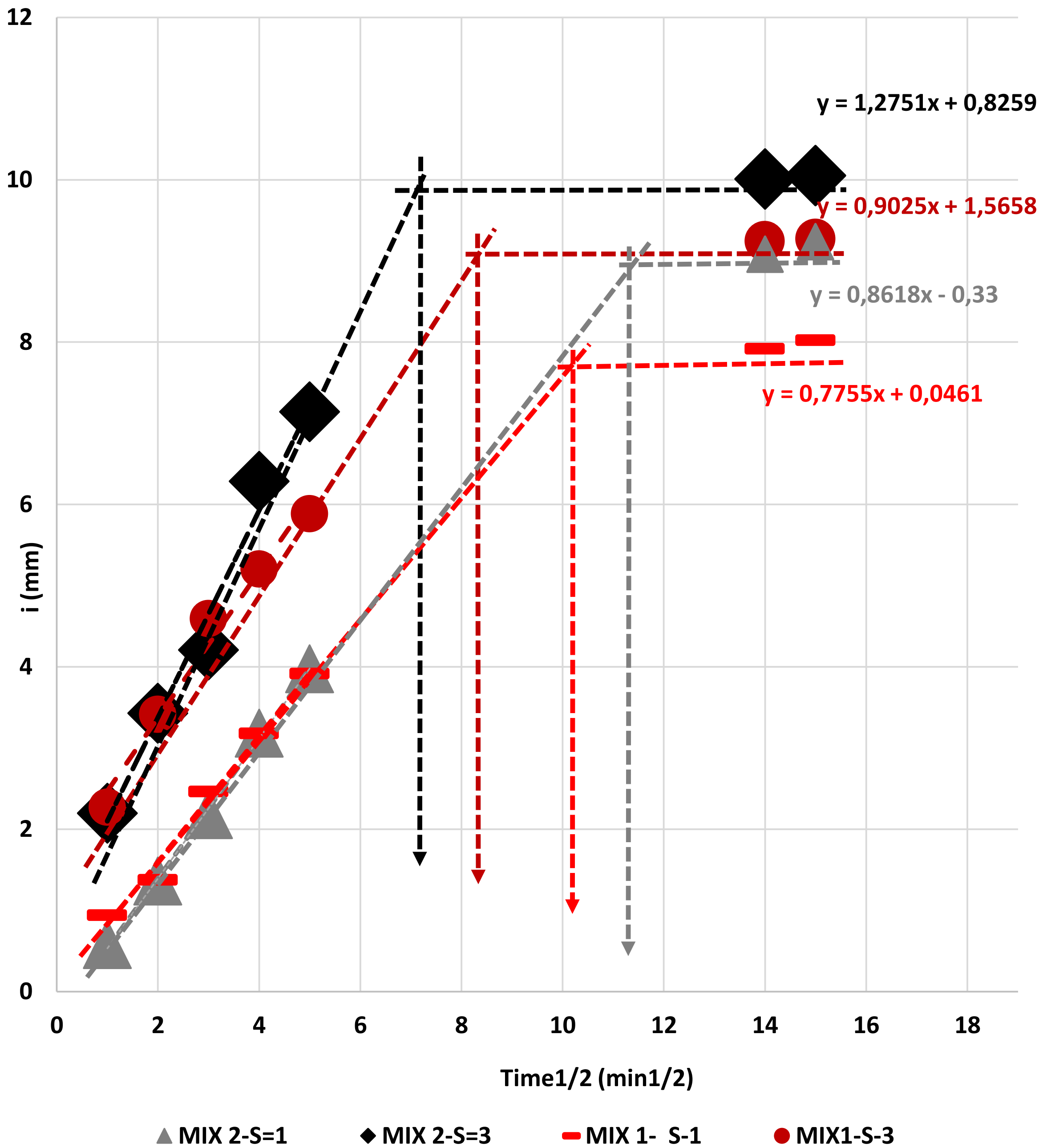

Figure 37. transfer sorptivity (A) and t_{dw} of earth-based mixtures

5 CONCLUSION

This study investigated the impact of substrate sorptivity and straw incorporation on the transfer sorptivity of earth-lime mixtures used in earthen construction. The results depicted show a clear relationship between the mixes' transfer sorptivity and the substrate materials' sorptivity. Specifically, bricks with higher sorptivity (S=3 mm/min$^{1/2}$) led to higher transfer sorptivity values in the corresponding mixtures, as demonstrated in our experiments with AGU brick (S=3 mm/min$^{1/2}$) compared to Büyükdere brick (S=1 mm/min$^{1/2}$). This outcome underscores the significance of substrate sorptivity in influencing the moisture transfer characteristics of earthen constructions, where higher substrate sorptivity enhances the mixture's ability to release water.

The addition of straw changed the transfer sorptivity of mixtures. Straw-lime-earth mixture (Mix2) showed improved water releasing qualities, which is important for applications that need reduced water retention and faster drying times. When comparing transfer sorptivities measured with S=1 mm/min$^{1/2}$ substrate, Mix 2, which incorporated straw, had a greater transfer sorptivity than Mix 1, which contained lime and earth (Mix1). This suggests that straw not only reinforces the structural integrity but also modifies the hygrothermal behaviour of the mixtures.

Furthermore, increasing the lime content relative to the earth in the mixtures resulted in a decrease in transfer sorptivity, highlighting lime's role in enhancing water retention. This characteristic can be particularly advantageous in environments where moisture control is critical.

These findings contribute valuable insights into the design of earth-lime mixtures for sustainable construction, offering guidelines on how to tailor material properties to meet specific environmental and functional demands. Future research should continue to explore the complex interactions between various compositional adjustments and their effects on the physical properties of earthen materials to optimize their performance in diverse construction contexts.

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5 REFERENCES

[1] Torres I., R. Veiga and V. Freitas, 'Influence of Substrate Characteristics on Behavior of Applied Mortar', J. Mater. Civ. Eng., vol. 30, no. 10, 1–13, (2018) doi: 10.1061/(asce)mt.1943-5533.0002339.
[2] Su-Cadirci T. B., C. Ince, J. Calabria Holley and R. J. Ball, 'Use of brick dust to optimise the dewatering process of hydrated lime mortars for conservation applications', Mater. Struct. Constr., vol. 56, no. 3, 1–19, (2023) doi: 10.1617/s11527-023-02128-6.
[3] Su-Cadirci T. B., C. Ince, J. Calabria Holley, R. Kurchania and R. J. Ball, 'Use of brick waste for mortar-substrate optimisation of mortar-masonry systems', Constr. Build. Mater., vol. 301, no. February, 124256, (2021) doi: 10.1016/j.conbuildmat.2021.124256.
[4] Ayasgil D., C. Ince, S. Derogar and R. James, 'The long-term engineering properties and sustainability indices of dewatering hydrated lime mortars through Jacaranda seed pods', Sustain. Mater. Technol., vol. 32, no. February, e00435, (2022) doi: 10.1016/j.susmat.2022.e00435.
[5] Kaluđer J., I. Kraus, A. Perić and L. Kraus, 'Shear Strength of Reproduced Soil Mixtures

Based on Samples from Rammed Earth Walls from Eastern Croatia', Appl. Sci., vol. 12, no. 22, (2022) doi: 10.3390/app122211708.
[6] Stefanidou M., M. Papachristoforou and F. Kesikidou, 'Fiber-reinforced lime mortars', 4th Hist. Mortars Conf., no. October, 422–430, (2016).
[7] Appels F. V. W. et al., 'Fabrication factors influencing mechanical, moisture- and water-related properties of mycelium-based composites', Mater. Des., vol. 161, 64–71, (2019) doi: 10.1016/j.matdes.2018.11.027.
[8] British Standards Institution, 'BS EN 459-2: 2010 Building lime Part 2: Test methods', 2010
[9] Rogers S. B., 'Evaluation and Testing of Brick Dust as a Pozzolanic Additive to Lime Mortars for Architectural Conservation', University of Pennsylvania, 2011. [Online]. Available: http://repository.upenn.edu/hp_theses/162
[10]ASTM C230, 'Standard Specification for Flow Table for Use in Tests of Hydraulic Cement 1', Annu. B. ASTM Stand., (2010).

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Suggestions on Material-Based Models Inspired by Nature in Adobe Structures

Zehra Taştan Korkut

Nevşehir Hacı Bektaş Veli Üniversitesi Güzel Sanatlar Fakültesi İç Mimarlık Bölümü

ztastan@nevsehir.edu.tr

ABSTRACT

Since the existence of humanity, materials have been a tool for meeting basic needs. In the early ages, human beings solved their sheltering needs by using natural formations and used the material as it is found in nature. In the following periods, with the developing ideas and perceptions of people, the chipping of stones, the production of adobe, the processing of wood and the development of molding techniques with the help of binding technologies, it has developed with mutual interaction. Adobe is made from a material obtained by mixing clay soil, straw and water. Adobe is not only used in arid regimes, it can be used in buildings that are not exposed to flooding and excessive humidity, but can also be used in moderately humid climates by protecting the walls from moisture. This study aims to make the sustainability of the material sustainable without disrupting its relationship with nature by combining the adobe material with new formations consisting of design products inspired by nature that can offer more durable, flexible in use, strengthened with various protection methods and color alternatives. As a result of the study, it is aimed to bring new suggestions for the material in terms of long and flexible use, creating original designs with original colors, reducing material and moral loss by protecting it from some components such as wind, snow and fire by incorporating the properties of new components obtained from products inspired by nature into the adobe material.

Keywords: Adobe, Natura, Material, Place

INTRODUCTION

The use of adobe is found in the Mesopotamia region in the X. millennium BC. As a result of the abundant rainfall in the Mesopotamia region, it became compulsory to construct building floors with stone material due to the wetness of the ground. In case there was insufficient stone in the rural areas of the region, the need for stone was met through the procurement process from neighboring regions. The construction process was continued by using adobe in the wall components of the houses . The first use of adobe material in the European continent was in the German region in the VIth century BC. The first use in Anatolian civilizations was found in the settlements in Çayönü in Diyarbakır province in 8500 BC during the polished stone age known as the Neolithic Age. It is known that hut-shaped and round-planned structures were built in Çayönü since the early Neolithic Age. With the continuation of the age, it is seen that people who developed with the continuation of the age continued similar construction techniques and geometric rectangular place plans were determined . In the first stage of the place construction process, the buildings were in geometric form with circular and oval plans and small, hollow bases. With the changing perception of mankind, the buildings have transitioned to a rectangular plan system with a grid plan. In the following period, channeled structures were built using mudbrick blocks on stone blocks [17].

In the Middle Eastern civilizations, the use of mudbrick is seen during the Neolithic Period with the transition to settled life. The same remains were traced in the city of Jericho in Israel in the 8000s BC, and it was found that there were structures built with mudbrick on the lower part of the stone foundation. Again in the Middle East around 2000 BC, it was observed that the Median Kingdom was built with unbaked mudbrick blocks during the construction of administrative and religious buildings (Aktaş 2020: 16). Buildings made of mudbrick are also found in Palestine, Syria, Crete and the Aegean Islands. Here, the use of mudbrick has started to be seen in city walls, bridges, religious buildings, educational centers and castles. The Great Wall of China in the world and the castle of Van in our country are examples of these structures [2].

In the settlements near Egypt and in the Nile Delta, houses made of clay, desert sand and straw were found in the settlements found in 5000 BC. In the first construction phase of the houses in this settlement, it is known that the materials were applied by people by shaping them with their hands, and in later times, the material was placed in molds and dried in the sun.

METHODS AND PURPOSE OF THE STUDY

The study presents component suggestions to make the durability and sustainability process of the works constructed with adobe material longer. It aims to create longer lasting and sustainable structures by combining products inspired by nature with adobe construction. The study provides alternative suggestions for extending the durability and duration of use of these examples by giving examples of building elements made with adobe. Selected examples of interior building elements used in adobe structures are examined in combination with sustainable product designs inspired by nature and their reflections on the place. In this context, the study focuses on the process of making adobe buildings more sustainable. In the last part of the current article, how the material is processed in adobe structures and reinforcement solutions, what kind of problems are encountered after use, how the problems are solved and how the problems are solved; Spatial suggestions are presented to these problems and problems are proposed to be eliminated. In the study, qualitative research and logical method are used.

THE PLACE OF ADOBE IN NATURE

With the developing industrialization and increase in the use of technology, there is a significant increase in the use of energy resources. The excess in the amount of this increase has been seen at a high rate in energy use in construction, informatics, industry and commercial areas. This reason has led to serious reductions in energy resources, leading to awareness among individuals and designers. As a result of this awareness, the primary goal of individuals and designers has been to continue on the road by protecting the environment and nature. The concepts of protecting nature and energy have become important not only to reduce the rate of consumption, but also to minimize the damage in new designs and to feed nature in terms of energy. In this regard, they have accepted the concepts of re-functioning, sustainability and feeding from nature as pioneers. As a result of the awareness created, the damage to the environment has been minimized, efficient product use and conscious user components have worked together in new designs. The fact that they were inspired by nature while they were putting them forward was a serious reference for the design and the designer, and environmentally friendly products that facilitated the production process were put forward [3].

While the rate of use of new, up-to-date and contemporary building materials has increased in place of the use of established materials, the effects of these materials on the environment and human health have begun to be taken into consideration. Adobe, which is one of the most traditional and traditionally accepted materials, is an ecological building material that is sensitive to the environment and ecosystem with minimum energy use from the construction and production process to the consumption process. This material, created with clay soil that meets all material and mixture requirements from nature, is a nature, environment and human-friendly breathable product that can be used both as a carrier and plastering material. Adobe, which has been used for centuries and continues to be used in the 21st century, has an important place in rural areas due to its low cost level, without the need for production facilities, and being a material with high thermal insulation value. Especially due to its high efficiency in thermal insulation, it protects the heat balance in the interior places in the most efficient way by minimizing the heat exchange within the building [16].

Adobe material has been presented to us by using it in many forms. In Anatolia and Mesopotamia, the use of the material has been differentiated with the excessive use in the region and it has been both strengthened and its durability has been increased by using many different techniques. In addition to the fact that it does not require the establishment of a facility during production, it has provided an important comfort to the users with its thermal insulation material and moisture balancing feature. In this respect, it provides lifetime economy without the need for an extra thermal insulation material in the building. Due to its material content, it is possible to recycle the kerpic, which has expired, back into nature by re-mixing it with water and allowing it to be used in a short period of time. In some application systems, if there is no good adobe soil, it is possible to reuse the adobe obtained from old buildings by breaking and soaking [4].

The way the material is put together is produced by molding clay-based soil, straw or fiber by blending them with water and drying them with natural heat from the sun. A weather condition without rain and not too hot is preferred for the adobe material to dry in a sighing manner. The area where the adobe is molded is properly leveled and corrected, wooden molds are formed, mortar is poured and left to dry and a thin layer of sand should be laid on the ground surface for easy demolding [5].
The adobe molds created from wooden molds are completely cleaned with the help of a cloth in water pools before each use, ensuring that there is no debris on the edge components. For this reason, it is aimed to ensure that the adobe is properly shaped before it is poured and removed. In the general production phase, 4-cavity rectangular molds are preferred. Although it varies between regions, the length of an adobe plate is 30-40 cm, the width is between 18-19-25-30 cm and the height is 12 cm.

The basic components of the main material are known as clay and sand. The clay, which has the task of combining the sand, determines the properties of the adobe mortar in which it is added. The most suitable clay and sand ratio is known as clay/sand=1/5. Adobe, which varies from region to region, is usually produced in 2 different sizes. The larger sizes of adobe are called mother and the smaller ones are called lamb. According to TS 2514, the dimensions of adobe to be used in load-bearing walls should be 120×300×400 (main) and 120×190×400 (lamb), or 120×250×300 (main) and 120×180×300 (lamb) in mm (Çavuş et al., 2015). The average unit weight of adobe building material is 1.2-1.6 g/cm2, the compressive strength is 3-20 kgf/cm2, the heat permeability coefficient is 0.4 kcal/mhoC and the dissolution time in water varies between 20-45 minutes. However, the properties of adobe material may vary depending on the type of soil, the amount of water entering the mixture, the amount of fiber and drying methods and times [6].

EXAMPLES OF ADOBE BUILDINGS IN THE WORLD AND TURKEY

The earliest use of adobe was found in Mesopotamia in the Xth century BC [20]. In the European continent, the first use of adobe was found in Germany in the VI century BC. In Anatolia, the first use of mudbrick was observed in the Çayönü settlement in Diyarbakır around 8500 BC [5].

Figure 1. Yemen Shibam Town [11].

In the town built in the 16th century, which is on the Unesco World Cultural Heritage list, all buildings are made of adobe and vary between 5 and 11 floors. The town, consisting of 30-meter blocks with the world's highest adobe structure, is known as the oldest skyscraper city in history. The outer surfaces of the buildings are covered with a thick sheathing system. In order to prevent damage from rain and wind, maintenance and repair of the facades is required at regular intervals**.**

Figure 2. Exterior facade view of Shibam town, inner courtyard [12].

The fact that the lower floors are designed without windows in the interior design is used by the women of the house for tasks such as storage space and food storage. The 2nd and 3rd floors are used separately by men and women, while the last floors are considered as a common area for the whole family (Url 1).

Figure 3. Shibam town houses interior door detail [12].

As shown in the interior visuals of the building, all the elements of the building such as walls, columns and beams, door and window openings were built with adobe. In the positioning of the buildings, care was taken to ensure that all the light is inside the house until sunrise and sunset. With this design system, it was possible to protect from the cold of the Yemeni air at night and the scorching heat during the day. Ventilation on the upper floors is done with the help of larger-scale windows, and on the lower floors through the stairwell and ducts built into the wall [11].

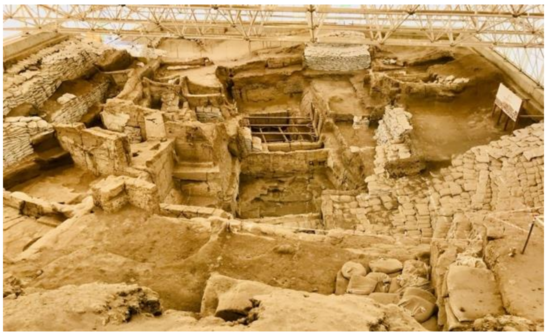

Figure 4. Çatalhöyük House settlement [13].

Çatalhöyük dates between 3000 and 8000 BC (Hodder, 2019). Çatalhöyük settlement is located on the alluvial soils that emerged as a result of the drying of the Old Konya Lake, which intersects with the Çarşamba River in Konya province. During seasonal transitions, settlements can be surrounded by water with the increase of snow and rainwater in the existing area.

When we look at the historical background of Çatalhöyük settlement, we can see that there is a rectangular building system, which is close to each other in terms of layout and scale, and which is created by adding new buildings side by side and building a new one on top of it every 80 years. Mellart, who discovered Çatalhöyük, described the spaces between these rectangular, bee-comb-like houses as courtyards, and Hodder described them as open spaces due to the lack of use and passage and the presence of garbage remains. In this closed settlement system, the city was built with deaf mudbrick walls and terraces with different elevation differences between them. In the settlement where there is no street system, it is thought that the houses are accessed from the roof. It is estimated that the individuals living in the terrace ledges they created continued their daily lives there. The settlement, which has no geometric angles, has an organic development plan scheme [7].

MATERIALS AND PRODUCTS INSPIRED BY NATURE

Velcro, which is among the designs inspired by nature, designed by a Swiss engineer in 1941; Although it is seen as the first premise in the category of products inspired by nature, it is not known exactly which design is the first in this regard. During this design process, engineer George de Mestral, who continued his life in Switzerland in 1940, came across burdock sticking to his dog's feet during a walk in the Alps with his dog. The engineer, who wanted to break his dog from this process, was inspired while cleaning the burdock, which he could hardly remove from his feet, and produced and put on sale the "Velcro tape", which is frequently used today in the textile, clothing and fashion industry. The component, which is still up to date and is called velcro tape among the people, is included in the sales market as velcro tape. With the product, which is used in a wide variety of fields from textiles to clothing, Mestral manages to print his name in the literature by patenting this idea and design and becomes well-known [9].

Brown seaweed sea mussel, on the other hand, in order to bond two different products together, the adhesive needs to cure and harden by contacting the surface boundary layers on the opposite side. This situation causes adhesives developed for dry applications to not perform as well as desired in wet areas and surfaces. Some algae species, algae and sea mussels in nature have developed their own system to adhere to wet surfaces. Brown algae provide cohesion by producing various secretions to increase the adhesive surface. With this cohesion, it binds to the counter product by forming cross-links. Based on this fiction, scientists have produced a waterproof adhesive system by copying the adhesion systems and some cells of algae, which have intense adhesive properties under the sea [10].

Approximately 1.2 billion tons of CO2 is produced annually in the field of textile in the 21st century period in which human beings have continued their lives. In the coloring process of textile products and designed products, 20% of the waste water is composed of dyes. In order to reduce this high rate of increase with the increase in global warming and the formation of human awareness, they created textile dye by being affected by discosoma coral. It has been investigated that in order for the discosoma coral to maintain its life span, it must maintain its relationship with algae and the structure of RFP, which is the colorant source in it, depends on the continuous secretion of RFP [14].

The designer has created a special synthetic mixture with the protein taken from this coral species, which contains high functional properties and forms structurally separable fibers. With this blend, the product was realized by counteracting synthetic dyes, petroleum-based components and high damage to the environment. Breathable designs have been created with the product group, which is frequently used in the clothing textile and fabric sector and has no environmental damage rate [14].

The lotus flower leaf is woven with a thin wax secretion on it. With this secretion, the leaf has a hydrophobic feature. With this feature, it can clean itself by trapping the dirt on the entire surface with the incoming water without containing dust and dirt on it. With this system it has created, the lotus flower can actually fulfill the necessary conditions for photosynthesis by protecting itself against infections. Based on this feature of the lotus flower, scientists have produced self-cleaning paint containing nano particles containing hirophobic silica for use indoors and outdoors [10].

The components that make up mother-of-pearls are internal components that change color as they move. With the force applied on it, movements are realized by shifting to the right and left.Thanks to these movements, a flexible and strong strength is created in the mother-of-pearl.Based on this feature of mother-of-pearl, designers have designed polymer matrices consisting of nano layers.In this product group designed as an exterior coating, polymers are placed on the plates that make up the coating and it is aimed to provide a fiction that will create the movement of the plates among themselves.This material forms the lower form of the component in which it is placed and provides 60% durability and is minimally affected by fire and moisture caused by water [15].

CONCLUSION

The adobe material is composed of clay, sand, water and straw, shaped by the specified molding materials and left to dry in the sun to dry in such a way that no moisture remains inside.This building material, which is obtained without being exposed to any additives other than products obtained from nature, has a very important place in human life with its ability to trap moisture in the area where it is used, not allowing moisture and not providing permeability by maintaining the balance between outside and inside air.Considering the labor and loss of time given by human beings in terms of protecting and maintaining the continuity of this building material, which is frequently seen in the world and in our country from the first settlements to the present day, serious values can be obtained.In order to protect the traces of the past, to keep historical artifacts away from wind, moisture and weather events, and to minimize the damage caused during the restoration process, we designers have serious work to do.In designs inspired by nature, which are involved in this process, and in designs that copy nature, the minimum damage to the design and the environment offers equivalence in some aspects, just as in adobe.Issues such as environmental awareness and sustainability, breathable product design, nature-friendly products and human health have emerged as a result of this study.

In order to lighten the workload of the adobe material in the process of continuous renewal and renovation and to extend its usage period, we can obtain a more durable tightly bonded clay, sand and straw component by including the product produced from the brown algae sea mussel mentioned above, which does not lose its adhesive properties even under water, into the mortar created during the construction process of the adobe material. In this case, it can become a more resistant material against weather conditions and human impact.

In this component created with the natural colors of Discosoma coral material, it can be included in the adobe mortar to create original designs with unique colors. It can be aimed to provide originality by providing liveliness in the space and providing different color alternatives by being realized in the components used indoors and outdoors.

With the aforementioned secretion given by the lotus flower, the outer surface of the adobe material can be painted with this system or by including this mixture in the adobe mortar, it can be ensured that the surface is not affected by storms, wind, snow and humidity, preventing the surface from staining, dirt and soil retention and allowing clean and smooth use for a long time. Its use indiscriminately indoors and outdoors can be aimed to shorten the work process of the user audience.

With this coating system produced from mother of pearl, it can be aimed to protect the structure from external factors (wind, snow, rain, forest fires, etc.) and to keep the user away from material and moral damage by keeping the service life long by preventing the adobe materials from being frequently affected by fire and wind, shortening their life and causing heavy damage.

REFERENCES

[1] Arpacıoğlu, Ü. (2006). Geçmişten günümüze kerpiç malzeme üretim teknikleri ve güncel kullanım olanakları. Ulusal Yapı Malzemesi Kongresi, 15–17.
[2] Aghazadeh Ebrahim (2011), *Kireç ve Alçı İçeren Toprak Yapı Elemanlarının*

Fiziksel ve Mekanik Özellikleri (Yayımlanmamış Yüksek Lisans Tezi), İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü, İstanbul.
[3] Benyus, J.M., (1997). Biomimicry: Innovation Inspired by Nature. New York: HarpenCollins.
[4] Binici, H., Durgun, M.Y. ve Yardım, Y., "Kerpiç Yapılar Depreme Dayanıksız Mıdır? Avantajları ve Dezavantajları Nelerdir?", KSÜ Mühendislik Bilimleri Dergisi, 13(2), (2010).
[5] Çavuş, M., Dayı, M., Ulusu, H. ve Aruntaş, Y. (2015). Sürdürülebilir bir yapı malzemesi olarak kerpiç-Adobe as a sustainable building material, 2nd International Sustainable Buildings Symposium, 28-30 May 2015, Turkey, Ankara.
[6] Eriç, M., "Kerpiç Eserlerin Onarımı ve Kullanılmasında Bir Araştırma", 3.Uluslararası Kerpiç Koruma Sempozyumu, Ankara, (1980).
[7] Hamilton, N., Bones, Stones, Paint and Clay-Writing History from the Finds of Çatalhöyük, *I. Uluslararası Çatalhöyük'ten Günümüze Çumra Kongresi Bildiriler Kitabı,* 15-16 Eylül 2000, Çumra: Özgü Ciltevi, s.281-289, 2000.
[8] Hodder, I., *Religion in the Emergence of Civilization Çatalhöyük as a Case Study*, Cambridge University Press, New York, 2010.
[9] https://biomimicry.org/ourmission/).
[10] https://biomimicry.org/what-is-biomimicry/
[11] https://onedio.com/haber/sibam-colun-manhattan-i-454768
[12] https://www.aa.com.tr/tr/pg/foto-galeri/seh9irlerin-atasi-sibam/0
[13] https://irmakozer.com/2019/02/03/9400-yillik-macera-catalhoyuk/
[14] https://www.nature.com/articles/s41467-017-02451-x
[15] https://asknature.org/innovation/fireproof-coatingmaterialinspired-by-nacre/
[16] Özgünler, A., Gürdal, E. (2012). Dünden bugüne toprak yapı malzemesi: Kerpiç. Restorasyon ve Konservasyon Çalışmaları Dergisi, (9), 29–37.
[17] Ölmez, B., (2022) Geleneksel Kerpiç Mimarisinin Korunması: Van İli Erciş İlçesi Tekler Mahallesi Örneği (Yayımlanmış Yüksek Lisans Tezi). Çankaya Üniversitesi, Fen Bilimleri Ens titüsü, Mimarlık Anabilim Dalı.

The Use of Mycelium in Architecture

Zulal Nurdan KORUR[1], Esra BAYIR[1]
Aysun F. GUNER[1], Pelin KARACAR[1]

[1]Istanbul Medipol University, Istanbul/Turkey

znkorur@medipol.edu.tr, ebayir@medipol.edu.tr
afguner@medipol.edu.tr, pkaracar@medipol.edu.tr

ABSTRACT

The mycelium of fungus refers to the fragile root-like fibres of fungus that live underneath the ground. Mycelium is 100% organic, compostable, and biodegradable. When combined with natural products such as the stems of agricultural by-products, mycelium can form by acting as a self-generating glue. Mycelium, which is considered as a binding mediate element by allowing the fungus to hold on soil due to its fibrous structure, becomes incredibly resistant to water, mold and fire when it is dried. Mycelium is one of the sustainable materials that is gaining importance in the construction industry today in terms of reducing environmental degradation, protecting natural resources and minimising energy consumption. Mycelium-based materials, which can be produced naturally in a short time at low costs without requiring long and costly fabrication processes and without producing waste, have high sound and thermal insulation capacity and show high performance during fire. In order to expand the application range of the material, which can be applied in areas such as wall and floor covering, panels, furniture etc., it is necessary to increase the tensile and compressive strength as well as the hardness of the material.

In this study, research on mycelium and its results, as well as application examples in architecture, will be discussed.

Key words: mycelium, earthen architecture, sustainability, adobe, construction

1.INTRODUCTION

The construction industry is one of those that causes the greatest damage to ecosystem. Most conventional materials produced industrially lead to significant energy consumption and greenhouse gas emissions. As a result of the gradual decrease of natural resources, the search for alternative ways to use existing resources in order to develop renewable and recyclable products is one of the greatest responsibilities of humankind today. [1] Therefore, it is frequently expressed that it is necessary to develop policies to transfer the existing economic systems, energy resources used, technological products developed, production and planning of countries globally and regionally to future generations. [2] [3] Materials that are economically viable as well as producing less pollution and waste during the production, transportation, use and destruction processes are considered sustainable. Sustainable building materials are the type that minimize energy consumption during the production and use stages and the waste that may arise during the raw material production, processing, use, maintenance and repair stages, does not have any harmful effects on the environment and human health. [2]

Fungi play an active role in the recycling of substances and nutrients in terrestrial ecosystems by recycling carbon after splitting cellulosic biomass. Mycelium is an environmentally and economically sustainable material obtained from fungus, which has become increasingly recognised in recent years. [2] [4] The mycelium of fungus refers to the fragile root-like fibres of fungus that live underneath the ground. Mycelium is 100% organic, compostable, and biodegradable. When combined with natural products such as the stems of agricultural by-products, mycelium can form by acting as self-generating glue. Mycelium, which is considered as a binding mediate element by allowing the fungus to hold on soil due to its fibrous structure, becomes incredibly resistant to water, mold and fire when it is dried.

Mycelium bio-composites are grown using various growth media, mainly agricultural wastes. They have high sound and thermal insulation capacity and show high performance during fire. With their favourable insulation properties, mycelium-based composite materials are shown as ideal bio-based alternative materials to conventional insulation materials. If stored under appropriate and stable conditions, the lifespan of mycelium bricks can be approximately 20 years. [5] [6] In order to expand the application range of the material, which can be applied in wall and floor covering, panels, furniture etc., it is necessary to increase the tensile and compressive strength as well as the hardness of the material.

Designers and architects have started to use mycelium-based products such as packaging materials, wall and floor coverings, panels, various furniture, blocks and masonry units as an alternative to conventional materials since 2000s. [7] [8] Since mycelium, which is formed naturally in a short time without long and costly fabrication processes, is 100% biodegradable, it can be easily and at very low costs returned to nature without producing waste. Mycelium of fungus has become a promising research topic in recent years with its porous structure and lightness, high sound and thermal insulation capacity, fire resistance and non-toxicity. In this study, research on mycelium and its results, as well as application examples in architecture, will be discussed.

2.MYCELIUM AS A SUSTAINABLE BUILDING MATERIAL

Mycelium is a branched fungal structure composed of hyphae that is typically found in soil and the fruiting body of the fungus. [9] It is a combination of filamentous hyphae that form the root structures of fibrous fungi and enable them to cling to their environment, spread and feed. [10] Mycelium is more like an underground network system. Network density and network topology are largely controlled by nutritional and environmental conditions. [7] [11] Figure 1 shows a schematic view of the mycelium at different scales.

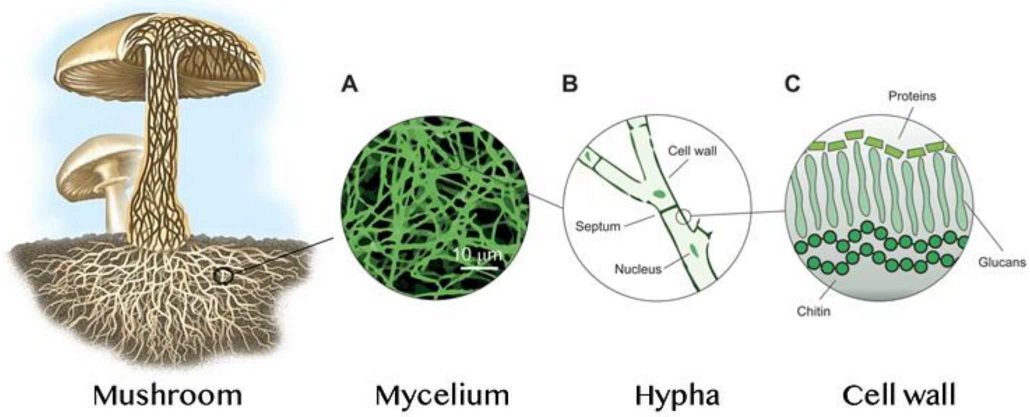

Figure 1. Schematic view of the mycelium at different scales [12] [13]

(A) Optical microscopy image of a mycelium film showing a branched network of micro-filaments (hyphae) **(B)** Schematic representation of a hypha that is formed by cells separated by cross walls (septa), all enclosed within a cell wall. **(C)** Schematic representation of the cell wall that is composed of a layer of chitin on the cell membrane, a layer of glucans (whose composition varies between species) and a layer of proteins on the surface. [12] [13]

Mycelium has been described as the largest living organism in the world. A mycelium network in the Blue Mountains of Oregon is approximately 10 km^2. [10] Fungi colonise the substrate they are in, with hyphae ranging from 1-10 μm in width and 1-10 mm in length. While the hyphae grow from their tips and branch in different directions, forming a three-dimensional hyphae network, that is, mycelium, the diameter of a mycelium that develops in this way can vary from millimetres to kilometres in length. [14] [15] These networks appear as a white material with a very thick consistency. Mycelium production is denser and richer if the nutrient source is rich in their environment, while mycelium is occured in the form of sparser, porous and open branches in areas where the nutrient source is less. [14] [16]

Mycelium, which can grow in soil and many other substrates, turns into a root network if combined with the stems of agricultural by-products and kept in a dark room for a few days. [10] Mycelium grows most efficiently when the materials on which it grows (waste from agriculture and forestry, etc.) are cut into small pieces of 0.6-5 cm and diluted 60%-80% with water. Mixing finely and coarsely processed materials generally provides a more favourable environment for mycelium development. Some of the alternative materials in which mycelium can grow include; bamboo, brewery waste, cocoa pods, cacti, poppies, leaves, manure, paper products, weaving and textiles, coconut and coir, corn, corn cobs and cornstalks, cotton and cotton waste, garden waste, mown grass, nutshells and seed shells, (plant and petroleum) oils, tea, tea waste, leaves and trimmings, tobacco and tobacco stems, trees, shrubs and wood structure waste, crop stalks (wheat, rye, rice, oats, barley, etc.). Many fungi can grow on cereal stalks (especially wheat, barley, rye and rice, etc.) through their powerful enzymes that can break down plant fibres. Straws can be processed by cold incubation, peroxide treatment and heat pasteurization methods so that the fungi can grow on them. Although other frequently used methods are effective against mold and pests, they pose a danger to human and environmental health both during and after the process due to the toxicity they create due to the substances used in their applications. [14] [17]

The substrate necessary for mycelium production is moisturised to ensure the healthy development of the fungus. The substrate provides nutrients for the growth of the mycelium network. In nature, these organic substances come from the remains of organisms such as plants and animals and from waste products in the environment. [18] After the humidification process, the substrates are subjected to grinding to the required size. Sterilisation of the substrate is carried out at high temperature values or with the help of pressurised devices. [2] [19] Mycelium spores are then homogenously distributed into the moulds as the most preferred method and left to grow under suitable conditions. The incubation period is approximately 7 to 14 days. (Image 1)

(a) (b) (c)

Image 1. Close-up of the growth process of oyster mushroom mycelium on beech sawdust: **(a)** after 3 days; **(b)** after 5 days; **(c)** after 19 days [20]

After the growth reaches a sufficient level, drying is carried out at the appropriate temperature.

Room temperature (24-25°C) with high humidity (98% relative humidity) and fresh air provides an excellent environment for growing mycelium. [18] The growth of mycelium and the production process of mycelium-based composite materials are shown schematically in Figure 2.

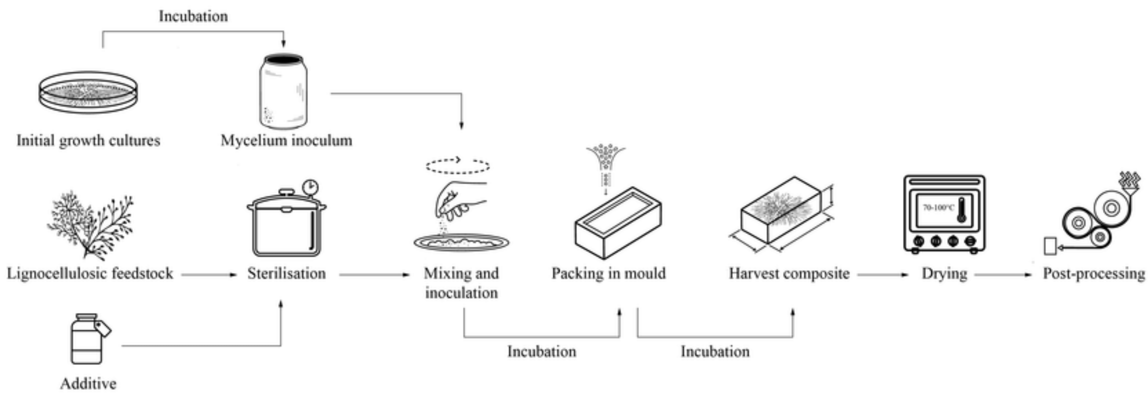

Figure 2. **Process flow chart showing the production process of mycelium-based composites [21]**

Since the physical structure of mycelium shows self-binding properties, it is at the forefront with this binding feature in material production. [1] Factors such as fungus type, substrate, press conditions and growth time, growth conditions, material drying methods, etc. affect the properties of mycelium-based composite material. [7] [22]

Mycelium, which forms naturally in a short time without requiring long and costly fabrication processes, can be returned to nature easily and at very low costs, without producing waste. It is noteworthy that mycelium bio-composites with their porous structure have high sound and thermal insulation capacity, show high performance by extending the flashover time, which is a critical threshold during fire and do not release toxic gases during combustion. Despite their advantages, it is stated that the application of mycelium-based materials as load-bearing structural elements is limited primarily due to their low mechanical properties, the tensile and compressive strength of mycelium composites is not sufficient and the water absorption capacity is high due to its porous structure. [7]

Substrate selection is very important in mycelium composite materials. In the studies carried out, moisture-resistant composites were obtained by using substrates such as cotton buds, rice straw, corn stalks and applying processes such as hot pressing. [23] In addition to all its benefits, mycelium can acquire new, more advanced properties as it can be customized with different growth conditions. Thus, it can be predicted that it will be a popular product with different usage areas in many sectors in the future. [7]

3. APPLICATIONS

Mycelium-based materials are used in areas such as packaging, textiles and furniture. There are examples of use as insulation material, wall and floor covering, brick in the construction sector. (Image 2-5) Mycelium-based foam (MBF) and sandwich composites (MBSC) have been actively developed for the construction sector to show mechanical strength compared to EPS (expanded polystyrene) foams. [7] [18]

Image 2. **A mycelium-based composite consists of a lignocellulose reinforced fungal mycelium [24]**

(a) **(b)**

Image 3. Packaging foam (EcoCradle) produced by Ecovative company from buckwheat hulls and fungal mycelium **(a)** and insulation material (Greensulate) produced using agricultural by-products such as seed hulls and fungal mycelium as a binder **(b)** [25]

(a) **(b)** **(c)**

Image 4. Mycelium floor covering produced from selected fungal mycelium, cotton residues and low-value biomasses such as corn crops, rice straw, used coffee grounds, discarded seaweed and clam shells **(a)** [26], examples of various mycelium-based panel products **(b)** [27], examples of mycelium bricks **(c)** [28]

(a) **(b)**

Image 5. Sound-absorbing modular acoustic MYX tiles using the natural absorbency of hemp fiber in combination with fungal mycelium, 2017 **(a)** MYX chair made from several layers of hemp and mycelium fiber matts, molded and folded into shape, and then grown into a solid shape, 2020 **(b)** [29]

In recent years, many architects and designers have tried using mycelium as a building material. Some sample applications are mentioned below.

Mushroom Tiny House

In the project carried out by Ecovative company, in order to create an insulation material that can replace plastic foam, mycelium was used to bind loose agricultural plant particles together and the insulation material produced from corn stalks and mycelium was placed in the space between the two wooden panels in the outer shell. (Image 6) The product, which naturally completes the drying process in a month, is fire resistant, has good thermal performance and is environmentally friendly. [10]

Image 6. Mushroom Tiny House, 2013 [30]

The Hy-Fi Tower

The Hy-Fi Tower, an example of a structure made of mycelium bricks, is a temporary installation that was built in 2014 in the courtyard of the Museum of Modern Art (MoMa) in New York, where visitors could use it as a resting place during a music festival. 'Hy-Fi' is a reference to "hypha", the type of living organism used to produce the building blocks of the project. The structure, which is over 12 m high, consists of 10.000 mycelium bricks. Designed by David Benjamin, the bricks are formed by combining chopped waste corn stalks and mycelium, which are fungal roots used to fuse these stalks together. The bricks made by Ecovative company, were grown as moulds in 5 days. The chimney-shaped design provides coolness in the shaded interior of the building by taking the cold air from the lower part of the building and discharging the hot air from the upper part. The building was constructed by stacking mycelium bricks on top of each other. (Image 7-8) After the building completed its function, the dismantled bricks were left on the soil and observed to dissolve in nature within 60 days. [2] [4] [5] [31]

Image 7. The Hy-Fi Tower, compostable mycelium brick structure with zero carbon emissions, 2014 [31] [32]

Image 8. Mycelium bricks grown form shredded corn stalks and mushroom mycelium [31]

Shell Mycelium Pavilion

Within the scope of the Kochi Muziris Biennial in Southwest India, it was aimed to draw attention to the waste materials generated during the dismantling of buildings designed for short-term events and using wooden skeleton, plywood and mycelium of fungus, a structure was constructed that grows in the habitat provided by wood, becoming one with it and transforming it. (Image 9) Triangular wooden profiles and plywood are assembled with steel fasteners in the construction, which is demountable and very light. The fungi placed on the upper surface of the pavilion are mixed with coconut extract. Over time, the top layer formed a protective shell. As the substrate continues to develop, it breaks down the surface of the wooden structure and over time the pavilion transforms itself. [1] [10] [33]

Image 9. **Shell Mycelium Pavilion, 2016 [33]**

Grown Structures

In 2017, architecture student Aleksi Vesaluoma developed a living and alternative building material from the mycelium of the oyster fungus in his project 'Grown Structures' with Astudio architecture office. The project worked on a technique that mixes cardboard and mycelium in tubes (mushroom sausages) made with cotton bandages. Mycelium can be grown with organic waste such as straw and cardboard within 2-4 weeks and can hold these materials together like glue. These tubes solidify and stick together when left in a ventilated greenhouse for four weeks. Mushrooms that grow on living building material are edible. (Image 10) [10] [34]

Image 10. Grown Structure, 2017 [34]

The Growing Pavilion

The Growing Pavilion is a temporary event space at Dutch Design Week, constructed with panels grown from mushroom mycelium on a wooden frame. The pavilion design focuses on reducing the use of fossil resources and CO_2 emissions, as well as drawing attention to the increasing impact of climate change. Five bio-based raw materials including mycelium, wood, hemp, reed and cotton were used together in the study. The pavilion consists of 88 mycelium panels on the outer surface. These panels, which are placed on a wooden frame, are obtained from a mixture of Reishi mushrooms and plant residues. Mycelium panels are very light, robust, fire resistant and waterproof coated. Besides, heat and sound insulation properties are high. It has a unique visual identity with the stains and reliefs formed over time by mycelium, a bio-based material, on the facade consisting of an organic texture and colour. On the other hand, the design creates a dynamic effect with wavy window openings. (Image 11-12) [1] [35]

Image 11. The Growing Pavilion, 2019 [35]

Image 12. The Growing Pavilion, mycelium panels [35]

Research on the use of mycelium in architecture continues. In a study on the improvement of the structural performance of compressed adobe blocks by using mycorrhizal fungi, it was found that the compressed adobe block to which mycorrhiza was added was 25% more resistant to pressure than the block without it. [36] The Shape Lab research group at the Institute of Architecture and Media at Graz University of Technology, developed a new material called MyCera, composed of clay, wood sawdust and mycelium, on the use of mycelium to strengthen 3D printed clay structures. (Image 13) The hypothesis of the research is that **mycelium could be used as an intelligently oriented fiber reinforcement** to increase the structural performance of 3D printed clay structures. This assumption was based on the examination of mycelium acting as an additional binding agent that connects between printed layers. [37]

Image 13. 3D printed mycelium-added structures [37]

NASA is also exploring the potentials and challenges of using mycelium to build habitable structures on Mars. It is planned to perform a series of experiments (compressive, tensile and flexural strength, drilling resistance, dynamic modulus of elasticity) to understand the mechanical properties in the study proving that mycelium can be a binder in inorganic soil. (Image14) [38]

Image 14. Mycelium growing in regolith-like sand structures on Mars [38]

4.CONCLUSION

Materials that are economically viable as well as producing less pollution and waste during the production, transportation, use and destruction processes are considered sustainable. Mycelium is one of the sustainable materials that is gaining importance in the construction industry today in terms of reducing environmental degradation, protecting natural resources and minimising energy consumption. Mycelium-based materials, which can be produced naturally in a short time at low costs without requiring long and costly fabrication processes and without producing waste, have high sound and heat insulation capacity and show high performance during fire. However, it is stated that the application of mycelium-based materials as load-bearing structural elements is limited primarily due to their low mechanical properties, the tensile and compressive strength of mycelium composites is not sufficient and the water absorption capacity is high due to its porous structure. It is remarked that the water resistance capacity of mycelium bricks also decreases over time, they become unstable against mold and moisture and therefore cannot be used in long-term structures. For all that, it has been determined in studies that moisture resistant composites can be obtained by selecting the appropriate substrate and applying processes such as hot pressing. Since mycelium is customisable with different growth conditions, it can acquire new and more advanced properties. In this respect, there is a need to focus research on improving the mechanical properties, which vary depending on the substrate, fungus type, growth state and processing method.

5.REFERENCES

[1] Eyüboğlu, H., Yanılmaz, Zeynep, Yaşayan Yapılar: Bir Yapı Malzemesi Olarak Miselyum, *Ege 10. Uluslararası Uygulamalı Bilimler Kongresi*, İzmir, 22 - 24 Aralık, 2023.
[2] Çüçen, A., Solak, A., Sürdürülebilir Yapı Malzemeleri Üzerine Bir Araştırma, *Teknik Bilimler Dergisi*, Cilt 13, Sayı 1, S. 1-8, Ocak 2023.
[3] Hoşkara, E., Ülkesel Koşullara Uygun Sürdürülebilir Yapım İçin Stratejik Yönetim Modeli. İstanbul Teknik Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi, 2007.
[4] Sertkaya, S. N., Tokuç, A., Yaşayan Yapılar: Miselyum ve Mimarlık. M. Dal içinde, Geleneksel ve Çağdaş Mimari Yapılar Üzerine Akademik Çalışmalar, İksad Yayınevi, 2020.
[5] Yıldız, B., Sürdürülebilir Yapımda Alternatif Yapı Malzemeleri Kullanımı, Dokuz Eylül Üniversitesi, Fen Bilimleri Enstitüsü, Mimarlık Anabilim Dalı, Yapı Bilgisi Programı, Yüksek Lisans Tezi, 2023.
[6] Mangukiya, J., An emerging sustainable construction material - Mycelium bricks. https://happho.com/an-emerging-sustainable-construction-material-mycelium-bricks/ (date of access: 20.05.2024).
[7] Sarıay, E., Cörüt, A., Büyükakıncı, B.Y., Miselyum Kompozitlerinin Sürdürülebilir Yapı Malzemesi Olarak Kullanımı, *Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 14(1): 196-207, 2023.
[8] Alemu, D., Tafesse, M, Mondal, A. K., Mycelium-Based Composite: The Future Sustainable Biomaterial. *International Journal of Biomaterials*, 2022.
[9] Crawford, A., Designer's Guide to Lab Practice, Bio Design Series, Routledge, 2024.
[10] Ateş, S.C., Çetiner, M., Miselyumun Mimari Tasarım ve Uygulamalarda Sürdürülebilir Kullanım Olasılıkları, *3. Uluslararası Bilimsel Çalışmalar Kongresi*, 01.12.2019.
[11] Islam, M. R., Tudryn, G., Bucinell, R., Schadler, L., Picu, R. C., Morphology and Mechanics of Fungal Mycelium, Scientific Reports, 7(1): 1-12; 2017.
[12] Haneef, M., Ceseracciu, L., Canale, C., Bayer, I.S., Heredia-Guerrero, J.A. & Athanassiou, A. , Advanced Materials from Fungal Mycelium: Fabrication and Tuning of Physical Properties, *Scientific Reports* volume 7, 2017.
[13] Tonevitskaya, S., When mushrooms go in the lab: growing design, 2018. https://medium.com/@stonev/when-mushrooms-go-in-the-lab-growing-design-882bff633aa8 (date of access: 20.05.2024).
[14] Kutbay, N.H., Miselyum ile Geliştirilen Biyokompozit Malzemelerin Analizi ve Kullanım Alanlarının Değerlendirilmesi, Gazi Üniversitesi, Fen Bilimleri Enstitüsü, Endüstriyel Tasarım Ana Bilim Dalı, Doktora Tezi, 2022.
[15] Appels, F. V. W., Wosten, H., Mycelium Materials.Encyclopedia of Mycology. Elsevier. pp. 710–718, 2021.
[16] Kavanagh, K., Mantarlar: Biyoloji ve Uygulamalar, Nobel Akademik Yayıncılık, 2014.
[17] Stamets, P., Mycelium Running: How Mushrooms Can Help Save The World. New York: Ten Speed Press, 160-161, 2005.
[18] Yang, L., Park, D., Qin, Z., Material Function of Mycelium-Based Bio-Composite: A Review. *Frontiers in Material*, 374, 2021.
[19] Jones, M., Waste-Derived Mycelium Materials for Non-Structural and Semi-Structural Applications. Doctoral Dissertation, RMIT University, 2019.
[20] Hana Vašatko, H., Gosch, L., Jauk, J., Stavric, M., Basic Research of Material Properties of

Mycelium-Based Composites, *Biomimetics, 7*(2), 51, 2022.
[21] Elsacker, E., Vandelook, S., Van Wylick, A., Ruytinx, J., De Laet, L., Peeters, E., A Comprehensive Framework for The Production of Mycelium-Based Lignocellulosic Composites, *Science of the Total Environment*, April 2020.
[22] Manan, S., Ullah, M. W., Ul-Islam, M., Atta, O. M., Yang, G., Synthesis and Applications of Fungal Mycelium-Based Advanced Functional Materials. *Journal of Bioresources and Bioproducts*, 6(1), 2021.
[23] Ghazvinian, A., Gursoy, B., Basics of Building with Mycelium-Based Bio-Composites, A Review of Built Projects and Related Material Reearch. *Journal of Green Building*. 37-69, 2022.
[24] Angelova, G.V., Brazkova, M.S., Krastanov, A.I., Renewable Mycelium-Based Composite Sustainable Approach for Lignocellulose Waste Recovery and Alternative to Synthetic Materials A Review, *De Gruyter*, 2021.
[25] Greensulate-A fungus-based insulation material that's grown rather than manufactured https://www.buildinggreen.com/blog/greensulate---fungus-based-insulation-material-thats-grown-rather-manufactured (date of access: 10.05.2024).
[26] Resilient Mycelium Flooring. https://theexplodedview.com/materialbb/resilient-mycelium-flooring/ (date of access: 20.05.2024).
[27] McGaw, J., Andrianopoulos, A., Liuti, A., Tangled Tales of Mycelium and Architecture: Learning From Failure, *Frontiers in Built Environment*, Volume 8, 2022
[28] An Emerging Sustainable Construction Material – Mycelium Bricks, https://happho.com/an-emerging-sustainable-construction-material-mycelium-bricks/ (date of access: 20.05.2024).
[29] Edvard, J., https://mindcraftproject.com/designer/jonas-edvard/ (date of access: 20.05.2024).
[30] Mushroom Tiny House, https://mushroomtinyhouse.com/ (date of access: 20.05.2024).
[31] Hy-Fi Zero carbon emissions compostable structure, 2015. https://www.holcimfoundation.org/projects/hy-fi (date of access: 20.05.2024).
[32] Frearson, A., Tower of "grown" bio-bricks by The Living opens at MoMA PS1, 2014. https://www.dezeen.com/2014/07/01/tower-of-grown-bio-bricks-by-the-living-opens-at-moma-ps1-gallery/ (date of access: 20.05.2024).
[33] Frearson, A., Fungus used to build arching pavilion in Kerala, 2017. https://www.dezeen.com/2017/08/26/shell-mycelium-fungus-pavilion-beetles-3-3-yassin-arredia-design-kerala-india/ (date of access: 10.05.2024).
[34] Doğa dostu bir yapı malzemesi olarak mantar, 2017. https://bigumigu.com/haber/doga-dostu-bir-yapi-malzemesi-olarak-mantar/ (date of access: 31.05.2024).
[35] Pownall, A., Pavilion grown from mycelium acts as pop-up performance space at Dutch Design Week, 2019. https://www.dezeen.com/2019/10/29/growing-pavilion-mycelium-dutch-design-week/ (date of access: 30.05.2024).
[36] Ataç, A., Mimarlıkta Biyomalzemelerin Kullanımı: Sıkıştırılmış Toprak Blokların Performansının Mikorizal Mantar Kullanılarak Geliştirilmesi, İstanbul Bilgi Üniversitesi, Yüksek Lisans Tezi, 2019.
[37] Severi, A., MyCera 3D printing mycelium reinforced structures, 2023. https://www.3dwasp.com/en/mycera-3d-printing-mycelium-reinforced-structures/ (date of access: 20.06.2024).
[38] Lipińska, M.B., Maurer, C., Cadogan, D., Head, J., Dade-Robertson, M., Paulino-Lima, I.G., Liu, C., Morrow, R., Senesky, D.G., Theodoridou, M., Rheinstädter, M.C., Zhang, M., Rothschild, L.J, Biological Growth As An Alternative Approach to on and off-Earth

DEAR COLLEAGUES;

We are pleased to announce the call for the 11th International Conference on kerpic2024 “Challenges in Earth-Based Interior Architecture; Current Issue in Earth-Based Materials, Construction Techniques and Approaches”. The Conference will be held on 12 – 14 September 2024 and organized by Kerpic Akademi, Kerpic Network and Nuh Naci Yazgan University, Interior Architecture and Environmental Design Department.

The aim of the conference is to gather the findings and knowledge regarding the theme “Challenges in Earth-Based Interior Architecture; Current Issue in Earth-Based Materials, Construction Techniques and Approaches”.

The conference will focus on using earth as a building material and the event will include graduate students, academics and professionals exchanging their findings and experiences. The conference will provide for an opportunity to understand the strategies involved, advantages of and advances made in the contemporary construction technology of earth-based material.

Since 1978, Kerpic Network has been conducting research on seismic response and comtemporary production techniques of earthen construction. The durability research is based on gypsum stabilized earth (alker); the seismic response research is based on horizontal energy dissipating surfaces on the load bearing walls and additional research has been conducted on production techniques of earthen materials and walls.

Prof. Dr. Bilge IŞIK