

# The importance of local materials in sustainable rural planning: Case of Gelemiş

Figen Altiner\*   
Ayşegül Ağan\*\* 

## Abstract

Studies carried out for sustainable and low carbon emission rural area design and planning are important in minimising the effects of climate change and protecting the ecology. Especially in rural areas, the choice of local materials plays an important role in ensuring environmental sustainability within the scope of landscape planning studies, creating the identity and aesthetic values of the region. In recent years, the traditional building materials used in traditional buildings in rural settlements and the fact that the structures in which these materials are applied do not harm the nature and are suitable for user comfort have been effective in bringing these structures back to the agenda. Traditional buildings were constructed with the most appropriate materials and components depending on the climatic characteristics. In addition, designing and planning studies by taking into consideration the natural, climatic, cultural, social and economic factors of rural settlements contributes to the success of the low carbon target in these areas. In this study, adobe buildings in village settlements within the scope of low carbon rural areas in Gelemiş rural settlement within the borders of Bursa province were evaluated in terms of sustainability and also examined within the scope of climatic and ecological parameters. The construction technique of traditional architectural structures was observed and analytical methods were used to analyse adobe, which is the original and local building material. In addition, the climatic characteristics (precipitation and temperature data between 2004-2024) and geological structure (seismicity, rock structure and soil structure) of the study area were examined and maps were produced using Geographic Information Systems. In line with the information on the produced maps, construction techniques and material properties used in traditional buildings were analysed. As a result of the study, the adobe building material used in traditional houses in Gelemiş rural settlements adapts to the climatic and ecological structure of the region and contributes to the sustainability of the cultural landscape. According to the laboratory tests, the strengths of adobe, which is the main building material used in the timber frame system in the study area, are similar to the values specified in the literature. In addition, the intensive use of adobe material in the study area, the fact that the raw material used in adobe production is supplied from the location close to the settlement, the CO<sub>2</sub> emission that may occur in the logistics process is low and the adobe material used is suitable in terms of sustainability.

**Keywords:** adobe, geographic information systems, rural architectural heritage, rural landscape planning, sustainable planning

## 1. Introduction

Climate change is defined as ‘changes in the average state and/or variability of the climate over decades or longer, regardless of the cause’. According to the Intergovernmental Panel on Climate Change (IPCC) reports, excessive use of fossil fuels is shown as the first degree responsible for the increase in the amount of carbon emissions in the atmosphere (Koçak & Bozyurt, 2021). It is accepted that most of the fossil fuel-based energy use, which causes the rapidly increasing greenhouse gas emission rate in Turkey, originates from residential buildings, which constitute 75% of the existing buildings. For this reason, it is predicted that making the existing construction energy efficient and using sustainable building materials will be effective in reducing carbon emissions (Kocabaş, 2012; Bostan, 2014; Koçak & Bozyurt 2021; Chen et al., 2021).

\* (Corresponding author), Department of Architecture, Balıkesir University, Balıkesir, Türkiye ✉ [altinerfigen@gmail.com](mailto:altinerfigen@gmail.com)

\*\* Department of Architecture, Balıkesir University, Balıkesir, Türkiye ✉ [aysegul.agan@balikesir.edu.tr](mailto:aysegul.agan@balikesir.edu.tr)

Article history: Received 20 June 2025, Revised 16 January 2026, Accepted 10 February 2026, Published 30 April 2026

Copyright: © The Author(s). Distributed under the terms of the Creative Commons Attribution 4.0 International License



The selection of local and low-energy building materials is an important issue in landscape planning studies, as well as supporting environmental sustainability and protecting the identity and aesthetic values of the region (Morel et al., 2001; Şahin, 2006; Görmüş & Oğuz, 2013; Balta & Atik, 2019; Wang & Prominski, 2020; Elagöz Timur & Asiliskender, 2024). Despite being locally producible, concrete is the most widely manufactured man-made material globally, exceeding 1 m<sup>3</sup> per capita annually, and its cradle-to-gate CO<sub>2</sub> emissions vary significantly by region (Orhon, 2012; Hammond & Jones, 2008; Nielsen, 2008; Purnell, 2013). In this context, Çümen and Sarıkaya (2023) reported that a ready-mixed concrete plant in Uşak, Turkey emitted 250.891 tCO<sub>2</sub>e annually, with CO<sub>2</sub> accounting for 98.611% of total greenhouse gas emissions, highlighting the substantial carbon footprint of conventional construction materials. These findings indicate that the environmental impact of building materials extends beyond the construction phase and must be evaluated through a comprehensive perspective encompassing production, transportation, and use. Materials reliant on energy-intensive and industrialized production processes, such as concrete, represent a substantial share of carbon emissions within the building sector. This situation has prompted a critical reassessment of material choices and increased interest in alternatives that require significantly lower energy inputs.

Within this context, traditional and locally sourced building materials have regained importance due to their minimal production energy, local availability, and capacity to provide thermal comfort largely through passive means. Materials commonly employed in traditional architecture—including timber, stone, brick, adobe, lime plaster, plant-based materials, and glass—are therefore increasingly recognized as key components of sustainable and energy-efficient building practices (Damluji, 1999; Varum et al., 2015).

Within this framework, earthen construction materials—particularly adobe—have emerged as a critical focus in sustainable building research. Among traditional materials, adobe occupies a distinctive position due to its widespread historical use, low embodied energy requirements, and strong compatibility with local environmental conditions (Fathy, 1986; Morel et al., 2001).

Adobe material is an environmentally friendly and important material for human health that has been used globally since the Neolithic period. According to some international reports, hundreds of millions of people worldwide still live in earth and mud-brick structures (Houben & Guillaud, 1994; Minke, 2022).

The widespread preference for adobe can primarily be attributed to its economic affordability, ease of access, and reliance on locally available raw materials. Its low embodied energy, high energy and cost efficiency during use, and biodegradability make adobe particularly advantageous in achieving low-carbon construction targets (Ziegler et al., 1998; Bui et al., 2009; Christoforou et al., 2016; Reyes et al., 2018; Costa et al., 2019; Salih et al., 2020; Akbaş et al., 2022). Due to these characteristics, adobe has maintained its significance over centuries, especially in rural areas where the absence of industrial production facilities, low construction costs, and favourable thermal performance support passive indoor comfort conditions (Silveira et al., 2007; Özgünler & Gürdal, 2012; Illampas et al., 2023; Christoforou et al., 2016; Yue et al., 2022). In this respect, promoting the use of low-carbon building materials within the existing building stock necessitates comprehensive investigations that extend beyond urban contexts to include rural settlements. Understanding the natural, climatic, and cultural characteristics of rural environments and aligning material selection accordingly is therefore essential for achieving long-term sustainability goals (Royer, 2011; Christoforou et al., 2016; Cavé et al., 2022; Aras Gaudry et al., 2023).

Within the Turkish context, a significant portion of academic research on adobe structures has focused primarily on the physical and mechanical properties of the material, its energy performance, and its environmental impacts. The low embodied energy of adobe, its compatibility with locally sourced raw materials, and its evaluation as a climate-responsive building material are among the key attributes frequently emphasised in the literature on sustainable and low-carbon construction (Acun & Gürdal, 2003; Çavuş et al., 2015; Akbaş et al., 2022; İsak, 2023). However,

most existing studies tend to confine their assessments to the material or building-component scale; the role of adobe structures within broader low-carbon cycles and their relationship with climatic and environmental parameters remain insufficiently addressed in a holistic manner.

In this context, there is a need for holistic studies that evaluate the sustainability of adobe buildings not only at the material or individual building scale, but also within the framework of settlement patterns and environmental and climatic relationships. In this study, it is aimed to evaluate the adobe structures in village settlements within the scope of low carbon rural areas in Gelemiç rural settlement located within the borders of Bursa province, which is among the important industrial centres of Turkey, in terms of sustainability. The ecological sustainability of the adobe material was investigated by examining the relationship of the traditional settlement texture of Gelemiç settlement with the climatic and geographical structure. In addition, traditional construction technique and material properties were analysed.

The originality of this study lies in its holistic evaluation approach, which assesses the sustainability of adobe structures in rural Turkey not solely through architectural or material characteristics, but by considering climatic, geological, and spatial parameters together. The literature review conducted reveals that mudbrick and other earth-based structures have mostly been examined through individual analysis layers in the context of architectural typology, material performance, or environmental impacts. In this context, the study conducted on the example of the Gelemiç rural settlement aims to reveal the multi-layered ecological adaptation potential of traditional building knowledge by evaluating geographical information system-supported climatic and geological data, on-site architectural observations, and limited laboratory analyses together.

## 2. Material and Methods

The Gelemiç rural settlement was selected as the study area due to its high representational value, as it allows for the interpretation of the compatibility between adobe production techniques based on local soil resources and the prevailing climatic and geological conditions, while enabling the integrated evaluation of different stages of the low-carbon building cycle.

Gelemiç, a village of Keles district within the borders of Bursa province, is located between 39°53'28"-39°53'36" north parallels and 29°16'45"-29°16'74" east meridians. Gelemiç (Figure 1) is located 70 km from Bursa city centre and 10 km from Keles district centre and has an altitude of 780. According to Turkish Statistical Institute (TSI) 2024 population data, 378 people live in the village. The main source of livelihood of the people is agriculture and animal husbandry (Yıldız & Çobancaoğlu, 2019).

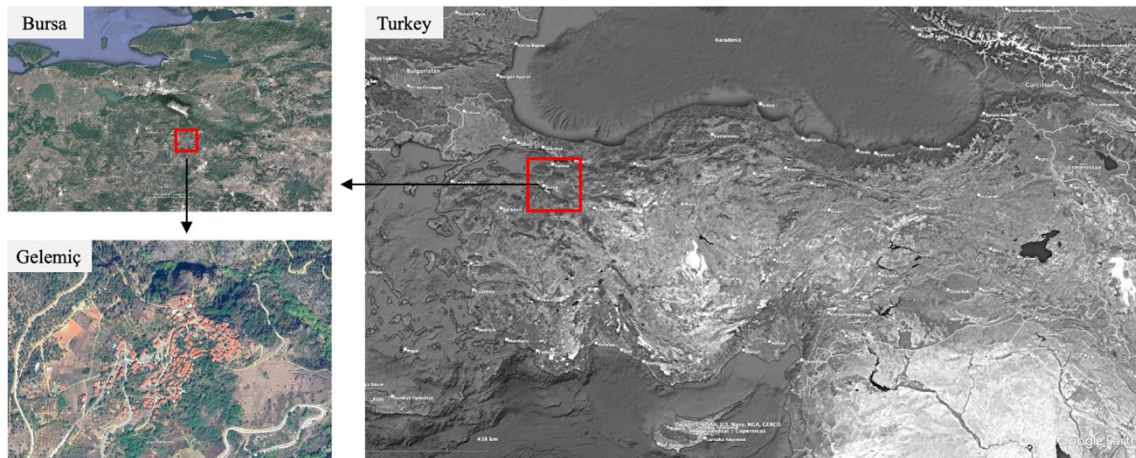


Figure 1 Location of Gelemiç (Google Earth, accessed on 25 December 2024)

### 2.1. Physical Characteristics of Settlement Fabric

Gelemiş has an organic settlement pattern that closely harmonises with the local topography. Within the settlement, approximately 330 parcels contain buildings serving various functions, excluding gardens and agricultural fields. The settlement has largely preserved its traditional character, with residential buildings constituting the dominant architectural typology rather than monumental structures. Haylofts and storage buildings also form integral components of the settlement fabric.

The housing layout follows the natural slope of the valley, with buildings generally oriented in response to topographic conditions. While recent development has expanded towards the south and southwest, the historic core remains largely intact. Due to the sloping terrain, most buildings benefit from open views towards surrounding forested and mountainous areas.

A defining characteristic of the settlement is the extensive use of adobe as the primary building material. The majority of traditional dwellings and ancillary structures are constructed using adobe, predominantly within timber-framed systems. Importantly, these adobe buildings are not abandoned heritage remnants; rather, many continue to be actively used for residential and agricultural purposes, demonstrating the material's ongoing functional relevance.

The street network has developed organically under the combined influence of topography, climate, and socio-cultural practices. Narrow streets, stone-paved surfaces with central drainage channels, and soil-stabilised paths are characteristic of the historic core, while newer areas feature asphalted main roads and concrete-paved side streets. The settlement includes three main communal spaces: the village square at the southwestern entrance, the threshing floor along the northern boundary, and a large open area at the eastern edge of the settlement (Figure 2).

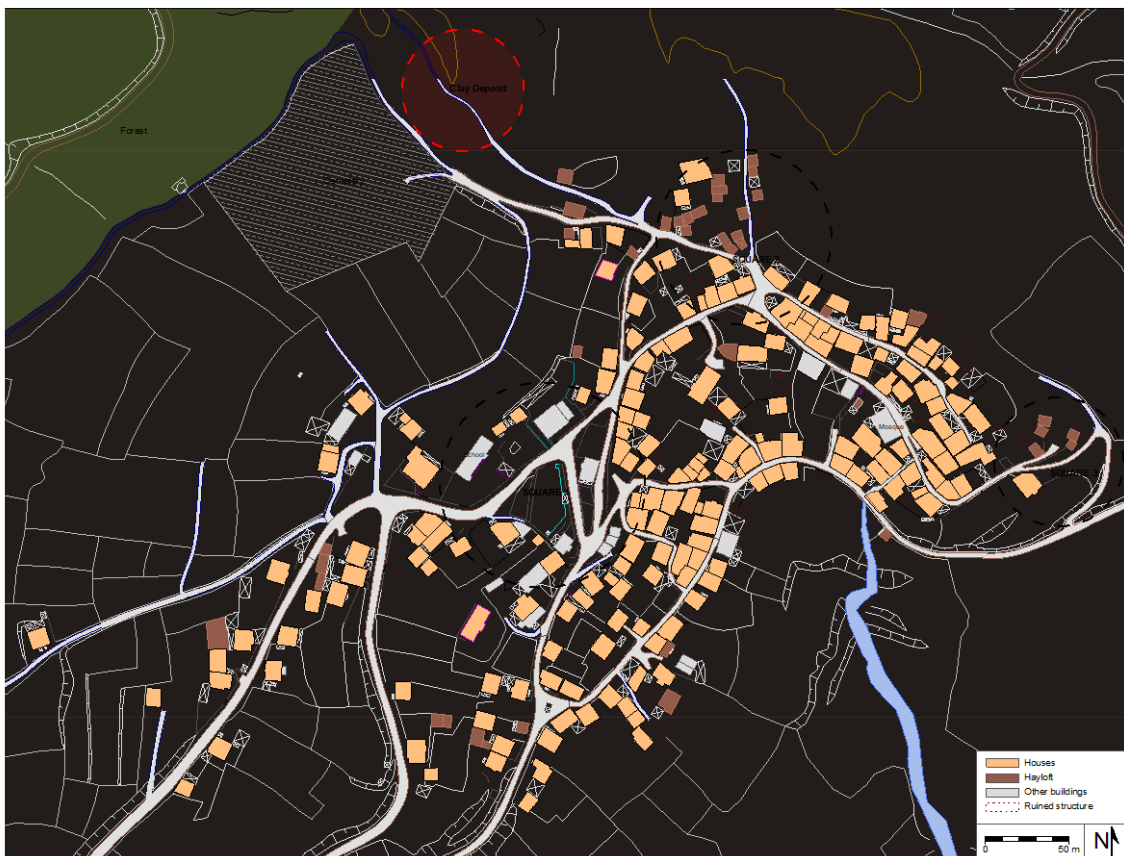


Figure 2 Gelemiş settlement pattern map (Developed by authors)

## 2.2. Methods

The methodology of this study is structured within an integrated mixed-methods framework designed to evaluate the sustainability of adobe structures in the Gelemiş rural settlement by relating architectural, environmental, and material dimensions within a unified analytical structure (Figure 3). Rather than treating each analytical step independently, all methods are systematically linked to the central research objective: to assess ecological sustainability potential of adobe in its local context. The methodological framework consists of four interrelated stages, each addressing a specific research dimension while informing and supporting the others.

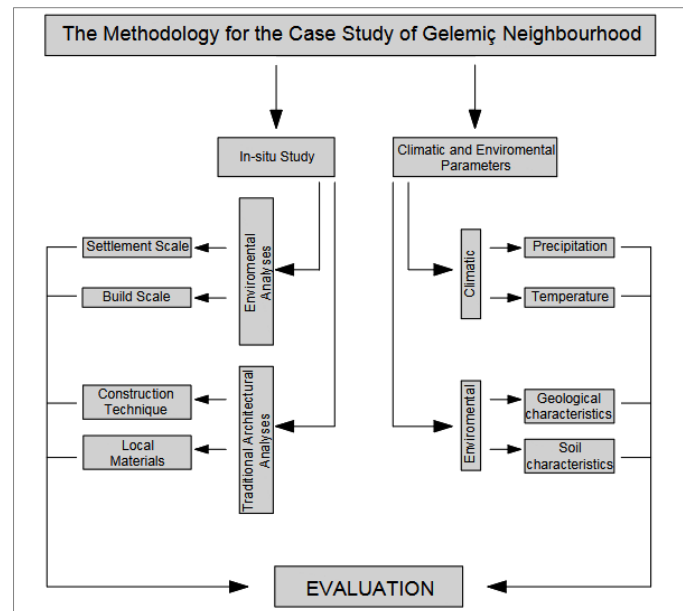


Figure 3 Method flow chart

The first stage comprises fieldwork, which forms the empirical basis of the study and supports all subsequent analyses. Certain examinations and observations were made in order to realise the environmental, socio-cultural, economic and architectural structure of Gelemiş rural settlement in detail. In addition, interviews with local people, public institutions and organisations constitute the first stage of the study.

The second stage focuses on the physical and architectural analysis of the settlement and its traditional building stock, directly addressing the research question related to how adobe is spatially and structurally embedded within the rural fabric. The construction technique of the traditional architectural structures was observed and the principle of the carrier system was schematised by on-site measurements. In addition, adobe, which is the original and local building material, was analysed using analytical methods. The adobe brick samples taken on site were tested in the laboratory. After macroscopic observations, mechanical and mineralogical properties were determined. TS EN 2514 standard was used to determine the mechanical properties. Before the compressive strength test, the brick samples were cut into 7x7x7 cm cubes as specified in the standard. ZWICK /Roell compression test device was used to measure the compressive strength of the cube samples. XRD (X-ray diffraction) was used to characterise the clay and other mineral phases used in adobe brick production and to obtain semi-quantitative data. Philips X'Pert Pro was used for this analysis. The analyses were performed on finely ground samples with grain size <125 µm. Scans were performed in the range of 5-80°2θ at a scan rate of 0.04° per second. The data were interpreted using the 'highscore plus' software and the International Centre of Diffraction Data database.

The third stage investigates climatic and environmental parameters to examine the ecological compatibility of adobe material with its natural context, addressing the question of environmental suitability and climatic adaptation. Using Geographic Information Systems (GIS), rainfall,

temperature, geology, and soil maps were produced to analyze the relationship between local environmental conditions and the use of adobe. ArcGis 10.8 programme was used to produce these maps. In the study, after the necessary coordinating process of the data obtained from the Earth Sciences Database of the General Directorate of Mineral Research and Exploration of Turkey, geological times and stratigraphy information were processed and a geological map was created. The data obtained from Bursa Provincial Directorate of Agriculture and Forestry were used to create the soil map. In the creation of the temperature and precipitation map, the average temperature and precipitation data obtained from the General Directorate of Meteorology Station Data Database were used and the Inverse Distance Weighting (IDW) method was applied. Digital Elevation Model (DEM) data used in obtaining temperature and precipitation maps were downloaded from the USGS- Earthexplorer programme.

In the IDW method, cell values are determined for each non-sampled point according to the distance increase. It is an interpolation technique used to determine the cell values of non-sampled points with the help of the values of known sample points. The cell value is calculated by considering various points moving away from the cell of interest and depending on the increase in distance. The estimated values are a function of the distance and size of the points in the neighbourhood, and the importance and impact on the cell to be estimated decreases with increasing distance (Chen & Liu, 2012; Ajaj et al., 2018; Khouni et al., 2021). In this method, properties such as general distribution, trend, anisotropy and clustering are examined. In recent years, its usage areas have expanded with Geographic Information Systems. The role of Geographic Information Systems in scientific studies on increasing the resolution of meteorological parameter maps and climate model outputs is quite large (Daly et al., 2002; Demircan et al., 2011; Altiner & Kelkit, 2021; Huang et al., 2023; Bingöl et al., 2023).

At the final stage of the methodology, the architectural, material, and environmental data obtained within the scope of the study were synthesized; through these data, the potential of adobe as a low-carbon, climate-responsive, and sustainable building material was discussed from a holistic perspective, specifically in the context of the rural settlement of Gelemiş.

### 3. Results and Discussions

#### 3.1. Finding of the Traditional Settlement Texture

The functions of the buildings in Gelemiş can be listed as residential, haystack, warehouse, shop-commerce, residential, religious and public buildings. The most dominant building types of the settlement texture are dwellings and haylofts that preserve their original character (Figure 4). Of the buildings in the settlement, 60 per cent are residential buildings, 20 per cent are haystacks and 17 per cent are other buildings. The other 3% are the ruins of the houses in ruins (Graph 1a).

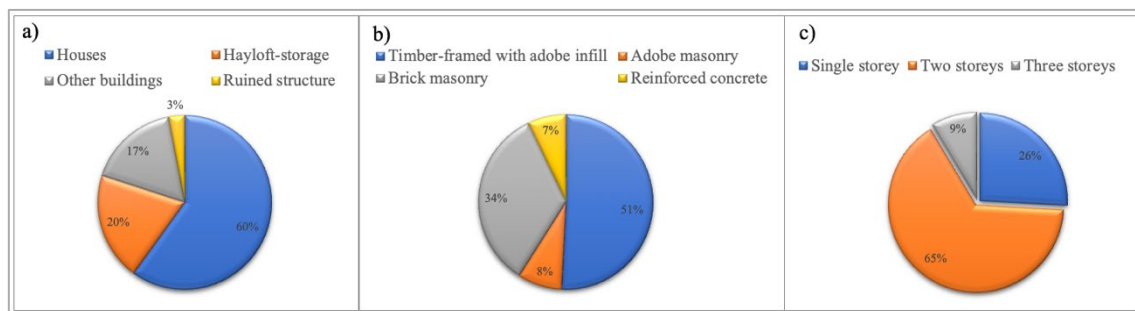


Figure 4 Traditional houses and haylofts

The traditional construction systems in the settlement and the use of adobe as the main building material stand out. Almost all of the traditional residential buildings were constructed with adobe-filled timber frame construction system on rough masonry rubble stone body walls with wooden

beams on the ground floor. There are also buildings constructed with masonry adobe technique. Until the 1980s, traditional building craftsmen continued to produce adobe and carried out repairs and new building construction. However, in the last 40 years, since the knowledge and skills of the craftsmen could not be transferred to the new generations, the masonry brick system has been mostly preferred in the partial repair of traditional buildings or in the construction of another building completely. Reinforced concrete system is preferred in today's constructions. As for the haystacks, which are one of the important elements of the settlement texture, it is possible to see examples with adobe filling or adobe masonry technique in the wooden frame system on rough masonry rubble stone body walls with wooden beams. Of the buildings analysed in the settlement, 51% were built with infilled timber frame, 34% with masonry brick, 8% with masonry adobe and 7% with reinforced concrete construction system (Graph 1b).

The majority of the wooden carcass buildings built with the traditional method within the settlement texture of Gelemiş have two storeys. The masonry residential buildings built after the 1960s were generally built as three storeys. When the haystack structures, which are one of the remarkable features of the settlement, are examined, almost all of them were built as two storeys on sloping slopes in order to provide loading from the upper level and access from the lower level when necessary. The buildings built in reinforced concrete or masonry brick system with concrete beams have 3 storeys. Buildings with more than 3 storeys are rarely seen. Sixty-five per cent of the buildings in the settlement are two-storey, 26 per cent are one-storey and 9 per cent are three-storey (Graph 1c).



**Graph 1** a) Percentages of building types in the settlement; b) Percentages of buildings in the settlement according to their construction systems; c) Percentages of buildings in the settlement according to the number of storeys

### 3.1.1. Construction Techniques and Material Properties

The environmental compatibility of traditional adobe structures is not limited to their location or number of storeys, but is closely related to material properties, production methods, and construction techniques. In rural settlements, the sustainability potential of such structures can only be assessed through an integrated evaluation of material performance, structural configuration, and adaptation to local environmental conditions.

The settlement of Gelemiş exhibits a hillside settlement pattern shaped by sloping topography, where buildings are constructed with different level solutions in response to terrain conditions. Within this context, the traditional construction system is predominantly based on adobe-filled timber-framed structures erected on rubble stone foundations and load-bearing walls. According to local master builders, construction begins with rubble stone foundations and body walls, followed by the placement of timber beams and the erection of a timber frame composed of vertical posts and diagonal braces. The spaces between the timber elements are then filled with adobe blocks, and wall surfaces are finished with earthen plaster.

On-site investigations indicate that the ground floors of buildings are formed by rubble stone walls with a thickness of approximately 60–70 cm, reinforced with timber beams. Above these walls, timber-framed systems are installed on wooden bases with cross-sections ranging between 10×10 cm and 15×15 cm. Main posts are carefully positioned on larger stones, particularly at the corners, and in some cases supported by diagonal braces placed at angles of 30° and 45° (Figure 5-

6). The infill of the timber frame consists of adobe bricks measuring 15×7×27 cm, 16×8×28 cm, and 17×8×30 cm. While upper-storey surfaces are generally covered with earthen plaster, the stone masonry surfaces of ground floors are mostly left unplastered.



Figure 5 In-situ measurements

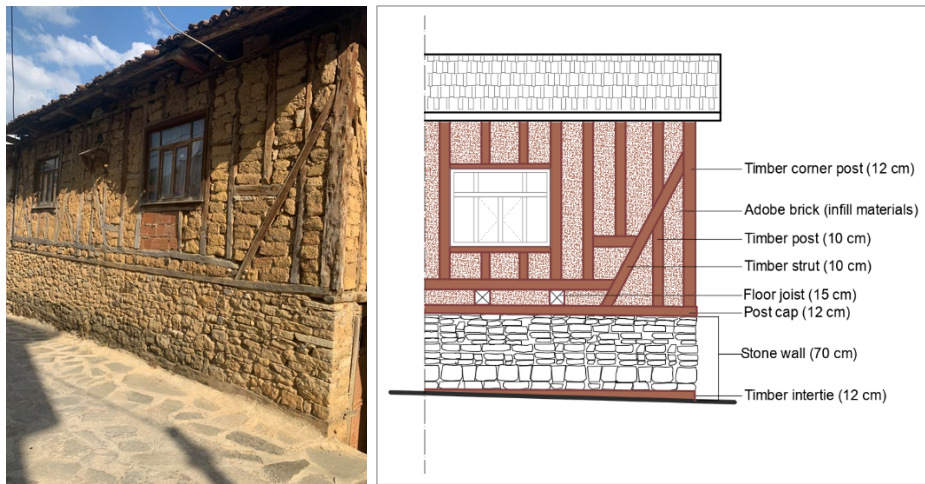


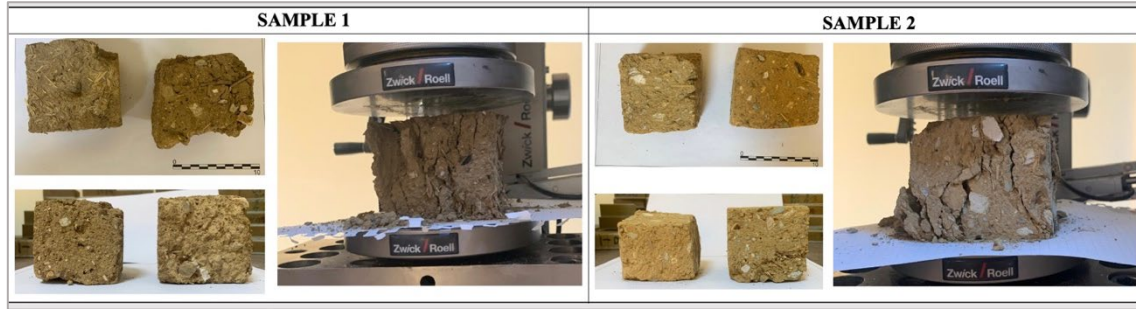
Figure 6 Construction technique-principle of load-bearing system

Adobe is the principal building material used in the settlement, functioning both as an infill material within the timber-framed system and as a plaster on wall surfaces. The clay and soil used for adobe production were sourced locally, primarily from the area surrounding the cemetery located to the north of the settlement. The material analyses conducted in this study were carried out for empirical reasons, aiming to evaluate the mechanical performance of adobe structures based on experimental data and to obtain results comparable with those reported in the literature. For this purpose, two adobe brick samples taken from different traditional houses were subjected to laboratory analyses. The bricks were produced by pouring a mixture of clay, sand, and water into wooden moulds and drying them under the sun, and they contain organic fibres such as straw to enhance strength.

Compression tests (Figure 7) revealed strength values ranging between 0.58 and 0.81 MPa for sample 1 and between 0.50 and 0.69 MPa for sample 2. These values fall within the range of compressive strength values for adobe bricks reported in the literature, which generally vary between 0.6 and 8.3 MPa (Walker et al., 2005; Corrado et al., 2010; Miccoli et al., 2014; Illampas

et al., 2011; Scalisi & Sposito, 2015). Variations in the measured values are considered to be related to the heterogeneous distribution of aggregates and fibre inclusions within the samples.

XRD analyses indicated that freitalite, quartz, and calcite are the dominant minerals in sample 1, while luogufengite, quartz, kaolin, and calcite are predominant in sample 2. This mineralogical composition demonstrates a strong relationship between adobe material and local soil characteristics and shows clear similarities with findings reported for traditional adobe structures in Anatolia and the Mediterranean Basin (Heathcote, 2011; Hall & Djerbib, 2004).



**Figure 7** Adobe brick samples and compressive strength test

### 3.2. Investigation of Gelemiş Houses in Terms of Climatic and Ecological Parameters

#### 3.2.1. Climatic Parameters

The shape of the building envelope, the ratio of transparent and deaf surfaces, material, orientation directly depend on climatic factors. In this context, the comfort environment in buildings should be provided as naturally as possible through climatic effects (Yüceer, 2011). The most important feature of adobe, one of the traditional materials, is that it is natural and healthy. With the help of the additives it contains, it provides thermal insulation without using an external thermal insulation material. Therefore, it keeps the environment warm by keeping the cold air inside in winter and keeps the environment cool by keeping the hot air outside in summer. Adobe, which is a soil-based material, is resistant to fire as it hardens at high temperatures. Walls made of adobe material, which are also used in humid climate zones, should be protected from moisture (Özgünler, 2017; Yalçın et al., 2022).

Gelemiş has a climate with hot summers and cold and rainy winters. Climatic factors, as an important design criterion, also guided the plan schemes during the design phase of the houses. In Gelemiş houses, space organisation, use of direction (orientation towards south), use of building elements and materials were planned and detailed according to the climatic parameters of the region. The houses, which are generally located close to the parcel boundary and/or forming the boundary of large gardens, are generally located in the north-south direction.

##### 3.2.1.1. Material Properties Average Annual Precipitation

Site selection is very important for adobe structures. It is suitable for use in arid regions with little rainfall (Acun & Gürdal, 2003). One of the negative effects of climatic conditions on earthen houses is the destruction of adobe by rainwater and physical dissolution (Şahinalp, 2012). As can be seen in Figure 8, Gelemiş receives a high rate of precipitation (605-626 mm) in terms of annual precipitation averages.

Considering the rainfall conditions based on the last 20 years of data given in Table 1 and Table 2, it is seen that Gelemiş receives rainfall in an amount that can destroy the mud obtained by the addition of straw and salt used as adobe and plaster material in a short time and the monthly total rainfall average is highest in December and lowest in August. In Table 1, the long years (2004-2024) annual average of total monthly precipitation in millimetres is given in Table 2.

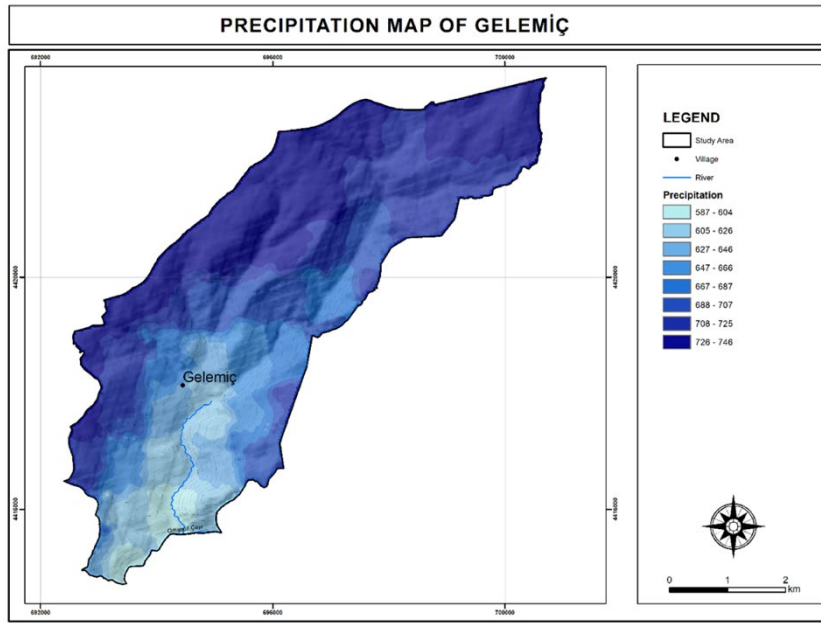


Figure 8 Annual average precipitation map of Gelemiş

Adobe can be quickly affected by moisture and water and may disintegrate after a while. Buildings should be protected especially in areas with flood risk and areas that may be exposed to ground water, and materials such as stone that are less affected by water should be preferred until the sub-base level. When the houses in Gelemiş are evaluated in terms of precipitation, although the precipitation rate is above the average of Turkey, the rate of negative impact is low because the foundations, foundation and basement walls of the buildings are stone up to the subbasement level. In adobe buildings, elements such as foundation, subbasement or basement floor below the ground level are made of suitable sized and durable stones. Stones that are large enough to exceed the thickness of the wall to be built or small enough to cause collapses in the foundation were not used. The construction was carried out below the minimum frost level of the ground.

Table 1 Long Years (2004-2024) of Gelemiş Rural Settlement Area (General Directorate of Meteorology Bursa Branch, 2024)

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Average precipitation	846.3	815.4	488.6	575.4	587.4	783.2	1121.8	619.6	745	709.6	802	670.6	766.6	591.2	788.2	527.6	552.6	821.8	577.0	986.2	488.4

Table 2 Monthly Average Total Precipitation (mm=kg-m<sup>2</sup>) of Gelemiş Rural Settlement Area (General Directorate of Meteorology Bursa Branch, 2024)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Average total precipitation	96.5	69.7	85.2	61.1	67.4	51.7	16	11.7	30.8	56.8	73.8	80

### 3.2.1.2. Average Annual Temperature

According to Goldstein et al. (2010), temperature, like other climatic factors, is one of the factors that contain versatile solutions in architectural design. According to Yezioro (2009), temperature, like other climatic factors (wind, humidity, etc.), creates a temperature difference between indoor and outdoor spaces, causing heat transfer and accumulation in building components and materials

such as windows, walls and roofs. Undesirable temperature increase or heat loss in buildings adversely affects both indoor comfort. Based on temperature maps with the help of Geographical Information Systems, the average temperature of the village (Figure 9) is between 10.8 °C - 11.10 °C. Table 3, the monthly average temperature values of Gelemiş rural settlement area between 2004 and 2024, the annual average temperature values between 2004 and 2024 in Table 4, the monthly average maximum and minimum temperature values between 2004 and 2024, the highest and lowest temperature values are shown in Table 5.

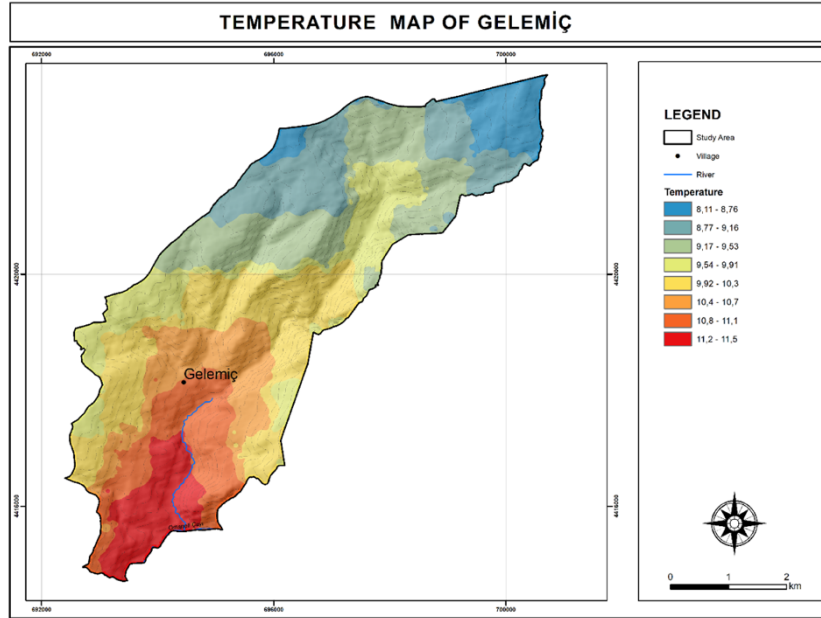


Figure 9 Annual average temperature map of Gelemiş

Adobe reacts slowly to temperature changes but does not heat up or cool down quickly, which helps to buffer sudden temperature changes. Adobe structures are generally used in hot and dry climates. Adobe has a high thermal mass. This allows the material to absorb heat and then release it slowly, absorbing heat from the sun during the day and keeping the interior cool, and releasing it back at night, stabilising the temperature of the interior. Adobe generally retains its structural properties at outdoor temperatures up to a maximum of 45-50°C. At higher temperatures, especially if exposed to direct sunlight for a long time, water loss and cracking may occur. When the monthly average maximum temperature values of Gelemiş were analysed, the average of July was measured as 41 °C, indicating that the adobe is ideal for maintaining its structural properties at outdoor temperatures.

When the monthly rainfall and temperature averages for the rural settlement of Gelemiş are evaluated together, it is concluded that the moisture formed in the wall during the winter period increases the possibility of freezing. However, it was determined that the void ratios on the wall surface in the building envelope in Gelemiş houses were not too high.

Table 3 Monthly Average Temperature Values (°C) of Gelemiş Rural Settlement Area Between 2004-2024 (General Directorate of Meteorology Bursa Branch, 2024)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Average total precipitation	0.65	2.2	4.6	9.4	13.8	17.9	21	21.5	17.2	12	7.4	3.2

**Table 4** Annual Mean Temperature Values (°C) of Gelemiş Rural Settlement Area Between 2004 and 2024 (General Directorate of Meteorology Bursa Branch, 2024)

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Average precipitation	9.5	9.1	9.5	10	10	9.9	10.9	9.2	10.4	10.4	11.1	10.3	10.7	10.3	11.4	11.5	11.1	10.5	11.1	11.2	12

**Table 5** Monthly Average Maximum and Minimum Temperature Values and Highest and Lowest Temperature Values (°C) of Gelemiş Rural Settlement Area Between 2004 and 2024 (General Directorate of Meteorology Bursa Branch, 2024)

Years	January	February	March	April	May	June	July	August	September	October	November	December
Average Maksimum temperature	9.6	10.9	13.8	19	24.9	31.9	32	28	22.1	16.6	11.7	3.2
Average Minimum temperature	1.7	2.2	3.6	7.2	11.4	15	17.3	17.3	13.8	10.2	6.4	3.6
Highest temperature	8.4	21.3	27.8	31.6	34.4	37	41	40.5	39.1	33.2	24.7	41
Lowest temperature	-24.9	-24.2	-19.1	-7.2	-1.6	3.8	4.4	5.5	-1.5	-9.8	-17.5	-24.9

### 3.2.2. Ecological Parameters

In addition to many positive aspects of adobe material, it also has negative aspects such as low compressive strength and weak resistance to earthquake effects. The lack of earthquake resistance of the structures produced with adobe material is not only due to material defects, but also due to problems related to the structure of the structure as a result of not applying the necessary details. In this study, geological factors and soil structure are examined.

#### 3.2.2.1. Seismicity and Rock Structure

The major faults of Bursa, the province to which Gelemiş rural settlement is connected, are Iznik-Mekece, Gemlik, Gençali, Zeytinbağı, Inegol, Oylat, Bursa, Uludağ, Mustafakemalpaşa, Orhaneli, Karacabey, Barakfaki, Sogukpinar and Kaymakoba. Among these fault lines, Soğukpinar at a distance of 7.1 km and Orhaneli at a distance of 11.9 km are the closest live fault lines to Gelemiş.

When the destructive earthquakes in the region are examined, the earthquake centred in Mustafakemalpaşa on 28 February 1855 occurred with a magnitude of 7.5 and caused great destruction all over Bursa and neighbouring provinces. In 1964, Manyas earthquake occurred with a magnitude of 7.0 and caused loss of life and property. The most recent earthquake centred in Gölcük on 17 August 1999 occurred with a magnitude of 7.6 and caused many damages. The information received from public institutions and organisations as well as the people living in Gelemiş emphasised that Gelemiş and its immediate surroundings were not affected by the major earthquakes that occurred in Bursa province (Bursa Provincial Directorate of Disaster and Emergency-AFAD, 2024).

Considering the regulation on adobe buildings to be built in earthquake zones, the walls should be continuous and the axis directions should follow each other and forms that do not have too many recesses and protrusions should be used. The void ratios in the building envelope of the houses in Gelemiş are as stipulated in the earthquake regulations as required by the construction technique of adobe material. In order to ensure horizontal stability, the use of beams in the

masonry is very important. Wooden material was used as beams in the houses in the village. The local thatch covering material used in the ceiling coverings is a natural and ecological material other than adobe used in Gelemiş houses. It also provides a lightness on the roof. As seen in the map in Figure 10 produced with the help of Geographical Information Systems, the geological infrastructure of Gelemiş, which has an altitude of 780 m, consists of rocks such as schist, granitoid, marble, sandstone, alluvium. When Gelemiş is analysed in terms of soil properties, rocks such as sandstone, marble and granite are found in places where settlements are dense. Since hard rocks such as granite transmit earthquake waves with less magnification, it increases the possibility of less damage to the structures on them. Marble and sandstone, on the other hand, are earthquake resistant because they have a good bearing capacity. Although there has not been a devastating earthquake in recent years, since the region is an earthquake zone, a number of suggestions for improving the adobe used in buildings have been brought by various studies. The use of stabilisers and additives to improve the properties of the soil against earthquakes is suggested in some studies. Various substances added to the soil in order to improve and develop the adobe are cement, lime, gypsum or lime + gypsum, bitumen, binding industrial wastes, straw, flax fibre, cotton stalks etc. (Binici et al., 2010).

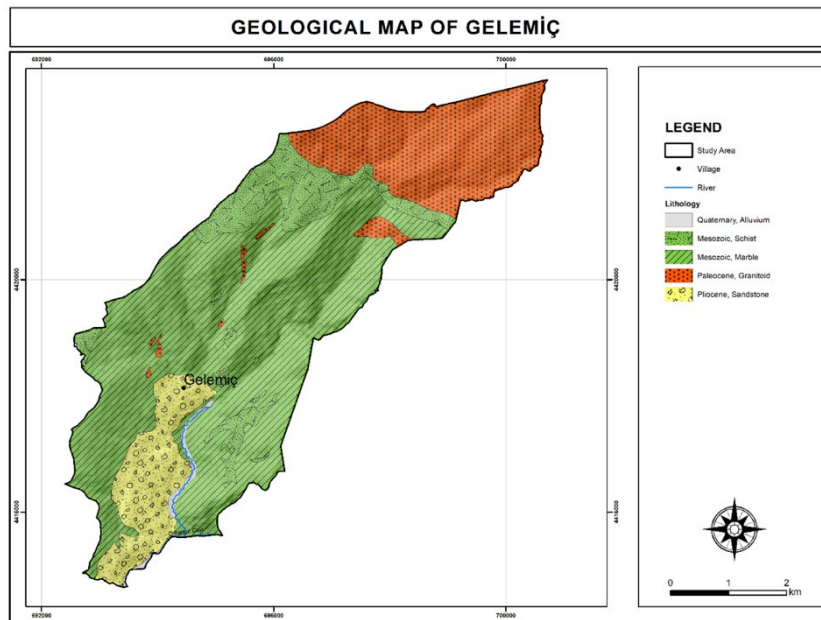


Figure 10 Geological map of Gelemiş

### 3.2.2.2. Soil Structure

In order to produce good adobe as a building material, it is important to select the appropriate soil type for this work. It is possible to find sufficient and good quality soil for adobe in many regions of our country (Koçu & Korkmaz, 2004). When the soil structure in Gelemiş was analysed, it was seen that it has brown forest soil, alluvium and non-calcerous brown forest soil structure (Figure 11).

Brown forest soils, which are among the large soil groups, consist of clays with calcareous clay or shale clay and limestone interlayers. Thanks to the clay contained in the brown forest soil group, the clay, which is one of the main components of the adobe material, is obtained from the foundation land called 'Clay deposit' (Figure 2) located in the village area, which provides certain advantages for the local people. These advantages are;

- Economic advantage: Elimination of the costly transport element for the supply of clay material
- Temporal advantage: The short supply of material provides advantages in terms of time in adobe structures to be built or requiring certain restorations and

- Spatial advantage: Providing clay material from an area belonging to the same ecosystem increases the resistance capacity of the material to environmental conditions.

The fact that the building material can be obtained from the immediate surroundings provides an advantage as it reduces the transport costs that may occur and accelerates the production process of the buildings (Ağan, 2024). The clay soil, which is the main material of the adobe buildings in Gelemic, is obtained from the village and its immediate surroundings. The people living in the village stated that they supply the clay soil, which is the main material of the adobe structures they have built, and that they do not have any problems in transport.

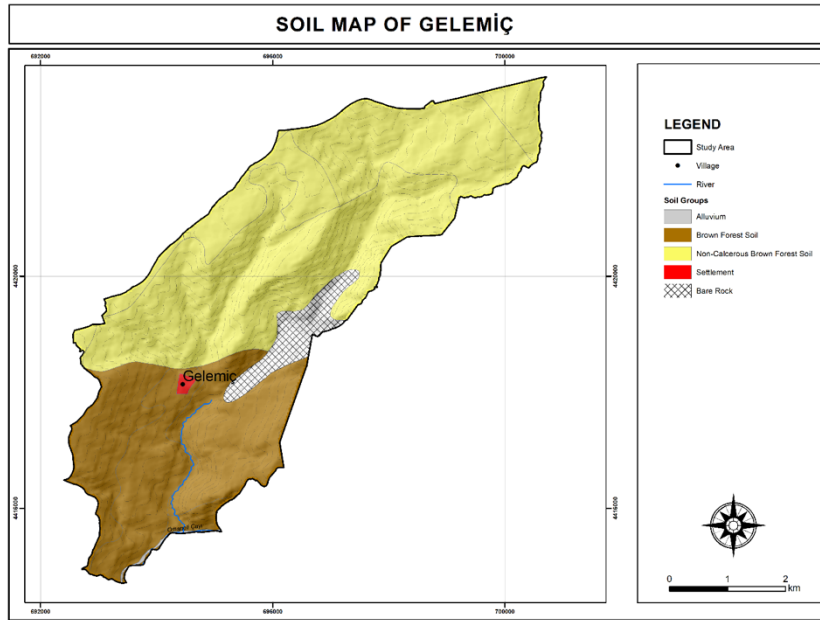


Figure 11 Soil map of Gelemic

#### 4. Conclusions

The World Bank states that if carbon dioxide emissions continue at the current rate of increase, the average temperature increase in the world will reach 4 °C in 2060 (World Health Organization, 2025). Climate change, which has become one of the most important problems of the whole world in recent years, shows its effects at an increasing rate. When analysed in the case of Gelemic, the fact that the buildings are made of adobe releases less CO<sub>2</sub> into the atmosphere compared to concrete and brick structures in terms of climate change. When the issue of materials is examined within the scope of sustainable design and planning, the role of materials in climate change is known by everyone.

In this study, the physical characteristics of the rural settlement of Gelemic and the architectural features of traditional buildings were investigated. In addition, adobe, which is an original and local building material, was analysed using analytical methods. As a result of laboratory tests, the compressive strength of adobe brick samples was found to be within the ranges specified in the literature. In order to ensure the ecological sustainability of the adobe material, the climatic characteristics of the study area (long years monthly average precipitation and temperature) and geological structure (seismicity, rock structure and soil structure) were examined. It has been observed that heavy rainfall, which is perhaps the most important of the climatic factors in the region, affects the spatial organisation and development of these structures and some measures have been taken by the local people against this.

When the 20-year monthly and annual average maximum and minimum temperature values are analysed, it is concluded that the adobe structures in the region are ideal for maintaining their structural properties at outdoor temperatures. Thanks to the clay contained in the brown soil group, which constitutes a large part of the area, the use of adobe material has become easier. This

situation provides economic, temporal and spatial benefits to the users. The void ratios in the building envelope of the houses in Gelemiş are made as stipulated in the earthquake regulations as required by the construction technique of the adobe material and the construction on a geologically earthquake-resistant ground reduces the risk of earthquake damage. However, despite all these, since the region is an earthquake zone, more scientific studies on the improvement of adobe used in buildings should be increased. In this regard, the studies to be carried out by public institutions together with scientists are very important. In rural dwellings where local materials are used, measures or suggestions to ensure the sustainability of these structures should be developed by taking into account the climatic and geological conditions of the environment.

Adobe is used as the building material with the least energy consumption during the manufacturing phase. In addition, since they also act as insulation, the energy consumption required for heating the space is low. In other words, adobe structures are a material that has been used for many years in terms of economic, functional, healthy and thermal comfort. Adobe material has a great role in the emergence of ecologically sustainable planning in rural settlements in harmony with nature. At the same time, the use of adobe and other local, renewable building materials necessitates an interdisciplinary collaboration in rural planning among landscape architecture, architecture, urban and regional planning, civil engineering, environmental engineering, and sociology, thereby enabling the development of holistic and sustainable settlement models that integrate ecological sensitivity with cultural continuity.

#### CRediT Authorship Contribution Statement

*Figen Altiner: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization. Ayşegül Ağan: Writing – review & editing, Writing – original draft, Methodology, Investigation, Analysis, Data curation, Conceptualization, Data visualization.*

#### Declaration of Competing Interest

*The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.*

#### Data Availability

*Data will be made available on request.*

#### Ethics Committee Approval

*Ethics committee permission is not required.*

#### References

- Acun, S., & Gürdal, E. (2003). Yenilenebilir bir malzeme: Kerpiç ve alçılı kerpiç. *Türkiye Mühendislik Haberleri*, 427, 71-77.
- Ağan, A. (2024). Investigation of the use of local materials in historical buildings: The case of Ayvalık. In Ö. Parlak Biçer (Ed.), *Researches and evaluations in the field of architecture*, (pp. 26-39). Gece Kitaplığı.
- Ajaj, Q. M., Shareef, M. A., Hassan, N. D., Hasan, S. F., & Noori, A. M. (2018). GIS based spatial modeling to mapping and estimation relative risk of different diseases using inverse distance weighting (idw) interpolation algorithm and evidential belief function (EBF) (Case study: minor part of Kirkuk City, Iraq). *International Journal of Engineering and Technology*, 7(4), 185-191.
- Akbaş, M. F., Aslan, M., & Arpacioğlu, Ü. (2022). Yeşil malzeme bağlamında kerpiç. *Eksen Dokuz Eylül Üniversitesi Mimarlık Fakültesi Dergisi*, 3(2), 72-88.
- Altiner, F., & Kelkit, A. (2021). Land use cover change analysis (1985-2020) of Ayvalık district Balıkesir Turkey using geographic information systems and remote sensing. *Fresenius Environmental Bulletin*, 10(11), 8275-8290.
- Aras Gaudry, A., Fronteau, G., & Hamard, E. (2023). Rediscovering raw earth heritage of champagne area (France): Cartography and typology of a specific adobe vernacular architecture. *Materials Today: Proceedings*. <https://doi.org/10.1016/j.matpr.2023.08.310>

- Balta, S., & Atik, M. (2019). Köy tasarım rehberlerinin hazırlanmasında kırsal peyzaj karakterlerinin yeri: Antalya Elmalı örneği. *Mediterranean Agricultural Sciences*, 32(1), 1\_9. <https://doi.org/10.29136/mediterranean.475220>
- Bingöl, F., Altiner, F., & Kelkit, A. (2023). Analyzing the most eligible site selection for biomass energy facilities through weighted overlay analysis: Case of Balıkesir (Turkey) province. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 60(1), 19-35. <https://doi.org/10.20289/zfdergi.1136651>
- Binici, H., Durgun, M. Y., & Yardım, Y. (2010). Kerpiç yapılar depreme dayanıksız mıdır? Avantajları ve dezavantajları nedir? *KSÜ Mühendislik Bilimleri Dergisi*, 13(2), 1-10.
- Bostan, Z. (2014). *Düşük karbonlu kentsel gelişme bağlamında korunacak kültür varlıklarının yeniden ele alınması* [Unpublished master dissertation]. Mimar Sinan Güzel Sanatlar Üniversitesi.
- Bui, Q. B., Morel J. C., Venkatarama Reddy, B. V., & Ghayad, W. (2009). Durability of rammed earth walls exposed for 20 years to natural weathering. *Built Environment*, 44(5), 912-919.
- Bursa Provincial Directorate of Disaster and Emergency-AFAD. (2024). (Retrieved January, 20, 2025) <https://bursa.afad.gov.tr/bursa-ilinin-afet-tehlike-ve-riskleri>
- Cavé, M., Sindonino, S., & Groetembril, S. (2022). Exemples d'habitats aristocratiques sur les sites des rues Eugène Desteuque et Ponsardin à Reims/Durocortorum. *Gallia*, 79(1), 169\_194. <https://doi.org/10.4000/gallia.6589>
- Chen, F. W., & Liu, C. W. (2012). Estimation of the spatial rainfall distribution using inverse distance weighting (idw) in the middle of Taiwan. *Paddy and Water Environment*, 10, 209\_222. <https://doi.org/10.1007/s10333-012-0319-1>
- Chen, R., Zhang, R., & Han, H. (2021). Where has carbon footprint research gone? *Ecological Indicators*, 120, 106882. <https://doi.org/10.1016/j.ecolind.2020.106882>
- Christoforou, E., Kylii, A., Fokaidis, P. A., & Ioannou, I. (2016). Cradle to site life cycle assessment (LCA) of adobe bricks. *Journal of Cleaner Production*, 112, 443\_452. <https://doi.org/10.1016/j.jclepro.2015.09.016>
- Coroado, J., et al. (2010). Mechanical characterization of adobe bricks. *Materials and Structures*, 43, 1183-93.
- Costa, C., Cerqueira, Â., Rocha, F., & Velosa, A. (2019). The sustainability of adobe construction: Past to future. *International Journal of Architectural Heritage*, 13(5), 639\_647. <https://doi.org/10.1080/15583058.2018.1459954>
- Çavuş, M., Dayı, M., Ulusu, H., & Aruntaş, H. Y. (2015). Sürdürülebilir bir yapı malzemesi olarak kerpiç. In *II. Uluslararası Sürdürülebilir Yapılar Sempozyumu bildiriler kitabı* (pp. 10-15).
- Çümen, U., & Sarıkaya, H. (2023). Hazır beton santralinin karbon emisyonlarının belirlenmesi. *Bingöl Üniversitesi Teknik Bilimler Dergisi*, 4(2), 27-36.
- Daly, J. W., Kaneko, T., William, J., Garratto, H. M., Spander, T. F., Espinosa, A., & Donnel, M. A. (2002). Bioactive alkaloids of frog skin: Combinatorial bioprospecting reveals that pumiliotoxins have an arthropod source. *Proceedings of the National Academy of Sciences of the United States of America*, 99 (22), 13996-14001
- Damluji, S. A. (1999). *Yemen Reality-Architecture sculptured in mud and stone*. Garnet Publishing.
- Demircan, M., Alan, İ., & Şensoy, S. (2011). Coğrafi bilgi sistemleri kullanarak sıcaklık haritalarının çözünürlüğünün artırılması. *TMMOB Harita ve Kadastro Mühendisleri Odası Yayını*, 13, 18-22.
- Elagöz Timur, B., & Asiliskender, B. (2024). Kırsal peyzaj mirası çalışmalarının habitus üzerinden değerlendirilmesi. *Milli Folklor*, 36(141). <https://doi.org/10.58242/millifolklor.1129209>
- Fathy, H. (1986). *Natural energy and vernacular architecture: Principles and examples with reference to hot arid climates*. University of Chicago Press.
- General Directorate of Meteorology Bursa Branch. (2024). (Retrieved March, 20, 2025). <https://eskisehir.mgm.gov.tr/>
- Goldstein, E. R., Ziegenfuss, T., Kalman, D., Kreider, R., Campbell, B., Wilborn, C., Taylor, L., Willoughby, D., Stout, J., Graves, B., Wildman, R., Ivy, J. L., Spano, M., Smith, A. E., & Antonio, J. (2010). International society of sports nutrition position stand: Caffeine and performance. *Journal of the International Society of Sports Nutrition*, 7, 5. <https://doi.org/10.1186/1550-2783-7-5>
- Google Earth. (2024). (Retrieved December, 25, 2024). <https://earth.google.com/web/>
- Görmüş, S., & Oğuz, D. (2013). Kırsal yerleşim ve korunmuş alan arasındaki etkileşimin değerlendirilmesinde peyzaj karakter analizinin rolü: Kapısıyü Havzası örneği. *Tarım Bilimleri Dergisi*, 19(4), 310-322.
- Hall, M., & Djerbib, Y. (2004). Moisture ingress in rammed earth: Part 1-The effect of soil particle size distribution on the rate of capillary suction. *Construction and Building Materials*, 18(4), 269-280.
- Hammond, G. & Jones C. (2008). *Inventory of carbon & energy (ICE), version 1.6a*. University of Bath.
- Heathcote, K. (2011). *The thermal performance of earth buildings*. Routledge.

- Houben, H., & Guillaud, H. (1994). *Earth construction: A comprehensive guide*. Intermediate Technology Publications.
- Huang, F., Jiang, S., Zhan, W., Bechtel, B., Liu, Z., Demuzere, M., ... & Chen, J. (2023). Mapping local climate zones for cities: A large review. *Remote Sensing of Environment*, 292, 113573. <https://doi.org/10.1016/j.rse.2023.113573>
- Illampas, R., Ioannou, I., & Charmpis, D. C. (2011). A study of the mechanical behaviour of adobe masonry. *Construction and Building Materials*, 40, 105-116.
- Illampas, R., Ioannou, I., & Charmpis, D. C. (2023). Overview of the pathology, repair and strengthening of adobe structures. *International Journal of Architectural Heritage*, 7, 165\_188. <https://doi.org/10.1080/15583058.2011.624254>
- İsak, S. (2023). *Pişmemiş toprak (kerpiç) duvarların enerji korunumuna etkisi ve çağdaş uygulama örneklerinin incelenmesi* [Yüksek lisans tezi, Karadeniz Teknik Üniversitesi].
- Khouni, I., Louhichi, G., & Ghrabi, A. (2021). Use of GIS based inverse distance weighted interpolation to assess surface water quality: Case of Wadi El Bey, Tunisia. *Environmental Technology and Innovation*, 24, 101892. <https://doi.org/10.1016/j.eti.2021.101892>
- Kocabaş, A. (2012). The transition to low carbon urbanisation in Turkey: Emerging policies and initial action. *Habitat International*, 37, 80-87. <https://doi.org/10.1016/j.habitatint.2011.12.016>
- Koçak, H., & Bozyurt, O. (2021). Küresel iklim değişikliğine yönelik çözüm odaklı yaklaşımlar. *Journal of Social, Humanities and Administrative Sciences*, 7(47), 2468-2479. <http://dx.doi.org/10.31589/JOSHAS.831>
- Koçu, N., & Korkmaz, Z. (2004). Kerpiç malzeme ile üretilen yapılarda deprem etkilerinin tespiti. In 2. *Ulusal Yapı Malzemesi Kongresi bildirileri*. TMMOB Mimarlar Odası İstanbul Büyükşehir Şubesi.
- Miccoli, L., Müller, U., & Fontana, P. (2014). Mechanical behaviour of earthen materials: A comparison between earth block masonry, rammed earth and cob. *Construction and Building Materials*, 61, 327-339. <https://doi.org/10.1016/j.conbuildmat.2014.03.009>
- Minke, G. (2022). *Building with earth: Design and technology of sustainable architecture* (2nd ed.). Birkhäuser.
- Morel, J. C., Mesbah, A., Oggero, M., & Walker, P. (2001). Building houses with local materials: Means to drastically reduce the environmental impact of construction. *Building and Environment*, 36(10), 1119-1126.
- Nielsen, C. V. (2008). Carbon footprint of concrete buildings seen in the life cycle perspective. In *NRMCA 2008 Concrete Technology Forum: Proceedings*.
- Orhon, A. V. (2012). Tasarımdan yapıma, sürdürülebilir beton yaklaşımları. 2. *Proje ve Yapım Yönetimi Kongresi bildiriler kitabı* (pp. 700-706).
- Özgünler, M. (2017). Kırsal sürdürülebilirlik bağlamında geleneksel köy evlerinde kullanılan toprak esaslı yapı malzemelerinin incelenmesi. *Journal of Architectural Sciences and Applications*, 2, 33-41.
- Özgünler, S., & Gürdal, E. (2012). Dünden bugüne toprak yapı malzemesi: Kerpiç. *Restorasyon ve Konservasyon Çalışmaları Dergisi*, 9, 29-37. <https://izlik.org/JA49DF52GM>
- Purnell, P. (2013). The carbon footprint of reinforced concrete. *Advances in Cement Research*, 25(6), 362-368. <https://doi.org/10.1680/adcr.13.00013>
- Reyes, J. C., Yamin, L. E., Hassan, W. M., Sandoval, J. D., Gonzalez, C. D., & Galvis, F. A. (2018). Shear behavior of adobe and rammed earth walls of heritage structures. *Engineering Structures*, 174, 526-537. <https://doi.org/10.1016/j.engstruct.2018.07.061>
- Royer, C. (2011). Les carreaux de terre crue en champagne-ardenne. In *Les cultures constructives de la brique crue: Échanges transdisciplinaires* (Vol. 3). Éditions Espérou, ENSAM.
- Salih, M. M., Osofero, A. I., & Imbabi, M. S. (2020). Critical review of recent development in fiber reinforced adobe bricks for sustainable construction. *Frontiers of Structural and Civil Engineering*, 14, 839-854.
- Scalisi, F., & Sposito, C. (2015). Earth construction: The mechanical properties of adobe with the addition of laponite.
- Silveira, D., Varum, H., & Costa, A. (2007). Rehabilitation of an important cultural and architectural heritage: The traditional adobe constructions in aveiro district. *WIT Transactions on Ecology and the Environment*, 102.
- Şahin, Ş. (2006). Kırsal peyzaj: Peyzaj karakter analizi, peyzaj planlama ve peyzaj yönetimi, Türkiye'deki peyzaj uygulamaları ve avrupa peyzaj sözleşmesi. *Eğitim uygulama programı*.
- Şahinalp, M. S. A. (2012). Type of rural houses or a cultural heritage that tending to disappear: Beehive houses of Suruç. *Gaziantep University Journal of Social Sciences*, 11(3), 881-916.
- Turkish Statistical Institute. (2024). *Population and demography*. (Retrieved January, 3, 2025) <https://data.tuik.gov.tr/Kategori/GetKategori?p=Nufus-ve-Demografi-109>

- Varum, H., Costa, A., Fonseca, J., & Furtado, A. (2015). Behaviour characterization and rehabilitation of adobe construction. *Procedia Engineering*, 114, 714-721. <https://doi.org/10.1016/j.proeng.2015.08.015>
- Walker, P., Keable, R., Martin, J., & Maniatidis, V. (2005). *Rammed earth: Design and construction guidelines*. BRE Press.
- Wang, F., & Prominski, M. (2020). Landscapes with locality in urban or rural areas. *Indoor and Built Environment*, 29(8), 1047-1052. <https://doi.org/10.1177/1420326X209383>
- World Health Organization. (2025). (Retrieved January, 3, 2025) <https://www.who.int/data/#highlights>
- Yalçın, Ç., Kavut, İ. E., & Bingöl, K. (2022). Kerpiç malzemenin Anadolu'da geleneksel yapılarda kullanımı. *8gen-ART*, 2(1), 82-96.
- Yezioro, A. (2009). A knowledge based CAAD system for passive solar architecture. *Renewable Energy*, 34(3), 769-779. <https://doi.org/10.1016/j.renene.2008.04.008>
- Yıldız, F., & Çobancaoğlu, T. (2019). Bursa-Keles ilçesi Gelemiş kırsal yerleşmesi geleneksel mimari dokusunun incelenmesi ve koruma amaçlı değerlendirilmesi. *TÜBA-KED Türkiye Bilimler Akademisi Kültür Envanteri Dergisi*, 20, 143-174. <https://doi.org/10.22520/tubaked.2019.20.009>
- Yue, J., Zhang, Y., Li, P., Zhang, J., Huang, X., Yue, Y., & Han, Z. (2022). Experimental study on the mix ratio of restored heritage building adobe. *Materials*, 15(11), 4034. <https://doi.org/10.3390/ma15114034>
- Yüceer, S. Y. (2011). Mimari tasarımlarında iklim çözümlenme: İstanbul üzerine bir deneme. *Mimarlık Dergisi*.
- Ziegler, S., Leshchinsky, D., Ling, H. L., & Perry, E. B. (1998). Effect of short polymeric fibres on crack development in clays. *Soil and Foundation*, 38(1), 247-253.

## Resume

*Figen Altiner is a landscape architect and Assistant Professor at the Faculty of Architecture, Balıkesir University. She completed her PhD in Landscape Planning at Çanakkale Onsekiz Mart University in 2022. Her academic and professional work centers on sustainable landscape planning, ecological planning, and the modeling of future land-use patterns and spatial change processes. Her research aims to support the sustainable management of natural and cultural landscapes by integrating ecological principles into planning and decision-making processes. She has produced numerous scientific publications in national and international journals, contributing to the development of sustainable landscape planning approaches in both urban and rural contexts. Through her interdisciplinary research, she seeks to enhance landscape resilience, environmental quality, and long-term sustainability.*

*Ayşegül Ağan is an Assistant Professor at the Faculty of Architecture, Balıkesir University. She received her Bachelor's and Master's degrees in Architecture and completed her PhD in Architecture–Restoration at Istanbul Technical University in 2024. Her academic and professional work focuses on cultural heritage, architectural conservation, and traditional–historic building materials. She has conducted research on architectural heritage, defensive structures, and industrial heritage, and her recent studies concentrate on rural settlements and local building materials.*