

## **Examination of Earthen Building Material of Modern Architectural Examples**



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### **ABSTRACT**

Earthen materials have been used as a building material for a shelter since the existence of human beings. It is still used as the main building material in many geographies. Soil is an economical and nature-friendly material that can be easily processed. On the other hand, the act of building includes many parameters such as construction techniques, materials, and design. Today, because of increasing energy demands and deterioration of the natural balance, the concept of sustainable building has gained importance for the act of building with these techniques and materials.

Today, we are faced with many environmental problems such as the rapid depletion of natural resources, environmental pollution, increased energy consumption, and increased carbon dioxide emissions. The construction industry, which has a large share of this consumption and damage, has started to turn to sustainable construction techniques and materials. Changing living conditions bring along new construction techniques and materials. Earth, which is one of the traditional and sustainable building materials, is still a preferred building material among contemporary architectural examples.

In this context, the study's main purpose is to reveal the importance of natural building materials within the scope of sustainability. Within the scope of the study, the relationship between adobe obtained from the earth, which is the oldest known building material, with sustainability, and examples made up to date in this context, and with the development of technology today, it is to examine the techniques used to construct adobe in modern buildings.

In today's world, with the development of technology, it has been evaluated on the examples of buildings selected in different geographies, that were built using different construction techniques. The examined building samples were compared with the tables and suggestions were made to encourage the use of earth building materials for sustainable construction.

**Keywords:** Earth based material, Sustainable materials, sustainability, Modern architecture

### **1 INTRODUCTION**

The act includes many parameters such as construction techniques, materials, and design. Changing living conditions bring along new construction techniques and materials. Today, the deterioration of the natural balance because of increasing energy demands has highlighted the concept of sustainable building. The danger of depletion of reserves because of rapid urbanization, increase in industrialization, and uncontrolled use of natural resources has brought the concept of sustainability to the fore in the construction sector, as in every other field, and studies in this field have increased [1].

Building materials are one of the important foundation stones for sustainable architecture. It is observed that the materials used in the construction of structures compatible with nature are mostly already available in that region and the construction process is based on local construction techniques. As a result, it is possible to see many positive aspects of the built structures within the scope of sustainability.

Today, the rates of greenhouse gases and carbon dioxide emissions are increasing with increasing energy demands. This situation also harms the ecological balance. The energy demand met by non-renewable sources tends to renewable sources as the reserves of these sources are limited and they harm the ecological environment. In this context, structures with low energy consumption gained importance. For these reasons, high-performance buildings that meet their energy needs from renewable resources are encouraged in the construction sector [2].

In this context, it stands out with the advantages of sustainable architecture. The concept of 'sustainability' is a multidisciplinary perspective that aims to meet the needs of today by taking into account the needs of future generations, leaving them a more livable world, and using resources sensitively without harming the environment. Making the concept visible in terms of architecture for a sustainable society; The concept of 'place' has a great meaning in the context of the continuity of culture and identity issues, as well as the continuity of local resources [1].

Sustainable architecture is an ideology that is dependent on climatic conditions and has goals at every stage from the project stage to post-construction using ground data. The first step in this regard was taken in 1987 with the Brundtland Report, 'Our Common Future', and the concept of sustainability was redefined architecturally. This report (United Nations World Commission on Environment and Development, 1991) was developed as a joint integration of the development ideology of the 1960s with the environmentalist ideology of the 1970s [3]. Especially after the industrial revolution, many policies, laws, and scenarios have been developed to minimize energy consumption and reduce losses against the increasing energy demands. Changes in this process; Increasing materials and manufacturing techniques necessitated using fossil energy sources more frequently. This has accelerated studies and research on natural environmental protection and sustainability.

Within the scope of the study, the oldest known building material, adobe obtained from earth, and examples of earthen based buildings related to sustainability and the techniques used in modern buildings with the development of technology today are examined. In addition to this, examples of the use of sustainable traditional adobe from the world and our country, in general, are given. In the study, first of all, the relevant literature was examined and the construction material in question was evaluated by considering its usage areas and today's production methods. It is aimed that the findings obtained as a result of the study and the suggestions developed will contribute to the widespread use of earthen-based materials in the context of sustainable architecture. Soil construction methods have features that can be used not only in rural areas but also with modern materials and systems.

## **2 EARTH AND ADOBE AS SUSTAINABLE BUILDING MATERIAL**

Today, the ecological balance, which is deteriorating with increasing energy demands, has enabled individuals to turn to more sustainable ones in terms of material selection and construction techniques in building production. The use of soil or mud, which is a sustainable building material, is as old as human history itself. Mankind has benefited from the soil as a building material since ancient times. Soil is a material that is used in every geography, climate-specific, easily accessible and its usage techniques can be applied by everyone. With these features, soil-based materials are considered sustainable, environmentally friendly, and ecological building materials, with their features such as being completely recyclable and not creating waste. The reasons for this are listed below;

- Using local possibilities and very simple construction techniques, being easy to manufacture and not requiring any facility and/or qualified personnel,
- Ease in supply and manufacture, easy to process, and economical in terms of cost,
- Does not harm human health in the production of space, does not leave waste to the environment in the building-life cycle,
- Providing thermal comfort, having high thermal insulation,
- Being recyclable, not polluting the atmosphere with harmful gas emissions such as CO<sub>2</sub>, not threatening nature and the environment [4]

It has been used for thousands of years in the construction of elements such as walls, roofs, floors, etc.,

together with soil, mortar, and plaster as a building component. The adobe structures constitute the largest share of the traditional earthen structures. Today, much international scientific research; The construction process of adobe emphasizes its advantages in terms of ease of use, longevity, environmentalism, and sustainability. It is seen that the use of oil-based materials with new techniques and systems has become widespread [5]. Used as a local material in the past, adobe is a contemporary building material that can also be preferred for urban areas today. Earthen based materials and adobe are drawing attention once again with their capacity to be an important solution to today's social, economic, and environmental problems [6].

As a local material, adobe is used extensively in rural areas due to its rapid construction methods, being easily applicable and accessible by everyone, and today it continues to be used in modern buildings with new techniques. Adobe structures are seen in almost every continent in the world (Figure 1-3) [7]. Being an earthen based material increases its applicability in every continent. The places where adobe structures are used extensively are; It can be said as the lands of Africa, Central Asia, Central and South America, and Anatolia. Apart from these, examples of adobe structures are also encountered in different countries and regions. One of the cities that stand out in terms of the density of adobe building applications in the world is the state of Santa Fe in the USA (Figure 1). The adobe building architecture in Santa Fe, which developed under the influence of many different cultures; has been brought to the present day because of the works carried out by a group of artists and intellectuals at the beginning of the twentieth century, both with a sense of protecting traditional values and to protect local architecture from the negative effects of rapid construction. Bam Castle (Arg-ı Bem), located in the city of Bam in Iran, is referred to as the largest mudbrick structure in the world (Figure 2). Although most of the castle was destroyed after the 2003 Bam earthquake, it was later restored and entered the UNESCO World Heritage list in 2004 [8]. In our country, it is possible to see examples of adobe structures in every region. Anatolia has had many different examples of residential architecture since the early ages. The buildings in Çatalhöyük are planned as rectangular mud-brick houses adjacent to each other (Figure 3). There are no doors in the houses and they can be entered from the roofs. These houses meet the need for shelter [9].



**Figure 1** Santa Fe [10]



**Figure 2** Bam Castle [11]



**Figure 3** Çatalhöyük [12]

## **2.1 Earthen Based Construction Material Production Methods**

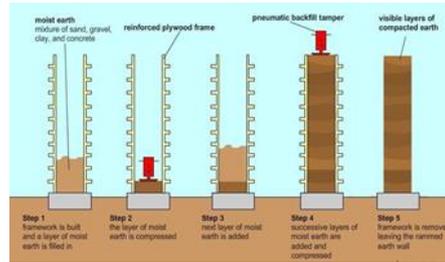
Earth material stands out compared to other building materials with its availability in every geography and easy construction techniques. There are many different techniques in the use of soil as a building material. In today's modern buildings, mostly mold block brick technique, compressed soil technique, and earthen-based wall construction with prefabricated panels are encountered. In the traditional mold block masonry technique, the soil is mixed with water and additives. The muddy mortar is poured into the block molds and kept until it dries (Figure 4).

In the earth wall construction technique, also known as "rammed earth", the compressed earth forging technique, firstly, the inner and outer walls are covered with molds. Later, the prepared soil mortar is filled into the molds from the top. It is then compressed with a tool (Figure 5). This process continues until the wall is built. If the clay ratio of the mortar mixture is high, this ratio can be reduced with stones, sand, branch pieces, or plants. After pouring 10-12 cm mortar and beating, it can go down to 7-8 cm. After the mud is poured on all walls at the same level, first the edges and then the middle parts are pounded and compacted [13].

Today, another production method of earth construction material is the use of ready-made prefabricated products. This method, which is used to minimize the construction and drying time of the soil mix, is more common in Europe (Figure 6).



**Figure 4** Mold block brick technique [14]



**Figure 5** Rammed earth [15]



**Figure 6** Prefabricated wall [16]

### 3 EARTHEN BASED BUILDING EXAMPLES

Within the limitations of the study, the compressed soil construction technique used in today's modern buildings and earthen based wall construction examples in different scales and different geographies were examined. Below are examples of buildings produced after 2000 using the mold block brick and rammed earth technique. In this context, the architectural and construction features of the Gando School, Bayalpata Hospital, New Delhi Boutique Hotel, and Anatolian Angel Women's Training and Production Center buildings were examined. The energy-efficient, thermal comfort, low carbon emission, and sustainable features of the selected samples are at the forefront.

#### 3.1 Gando School

Gando primary school was built in 2001 in Burkina Faso, Africa, by Francis Kere Architecture, using a combination of traditional and modern construction techniques (Figure 7). Francis Kere, who put forward a pioneering architectural style, made his first architectural project in his hometown. It aims to meet the needs by combining traditional construction techniques with contemporary engineering methods. The determining factors in the design of the school were cost, climate, resource accessibility, and construction feasibility. Clay, which is the most accessible material in the region, was chosen. To maximize results with few resources at hand, Kéré has tested a clay/mud hybrid structure that can withstand high temperatures and semi-arid climates. Traditional clay building techniques have been modified and modernized to create a more structurally sound structure [17]. The blocks were strengthened with cement placed in the clay. The structure consists of traditional load-bearing walls made of stabilized and compacted earth blocks.



**Figure 7** Gando primary school view, construction phase and floor plan [18]

The architect of the project, Francis Kere, completed the building with the participation of the local people throughout the construction process. In this process, Kere also benefited from the knowledge of the local people and combined this knowledge with modern techniques. Gaps were left between the ceiling and the metal roof, and the heated air was expelled from these gaps by opening holes in the ceiling. Thus, a passive ventilation system was implemented (Figure 8). By separating this metal roof cover from the ceiling, besides providing passive ventilation, a shaded area was created inside the space

and protected from rain [19]. Gando Primary School received the Aga Khan Architecture Award in 2004. After the school received the award, it encouraged efforts to build sustainable buildings in local areas with local materials.



**Figure 8** Gando primary school roof view [19]

### 3.2 Bayalpata Hospital

Construction was started by Sharon Davis Design in 2014. The design team placed the structures around two courtyards (Figure 9). These courtyards serve as the core where medical programs take place. The courtyards also buffer between more public programs towards the south entrance, such as outpatient care and pharmacy, and more specialized programs to the north, such as the surgery and maternity ward. The buildings are built as single and double stories and use sunlight as passive ventilation. Except for the laboratories and the operating part in the complex, all units are passively heated and cooled [20]. The 4,200-square-metre facility gets its energy, thanks to a 100-kilowatt array of solar panels integrated into the roofs of the buildings.



**Figure 9** Bayalpata Hospital appearance and site plan, construction phase [21]

Rammed earth was chosen in terms of thermal mass to support the passive design and to take advantage of local data. Thus, heat gain is maintained in winter, and it stays cool in summer. The soil is stabilized for more durable seismic resistance. For this purpose, the local soil was mixed with a cement content of 6%. Each of the five medical buildings uses a composite structure of cement and steel-reinforced rammed earth that supports lateral loads and integrated concrete columns. It not only provides containment but also acts structurally within the entire system. Energy use is reduced in low-rise buildings. Thanks to the low-rise buildings, there is no need for electrical elevators. Employees and their families live here, as commuting would be impractical for those working here [20]

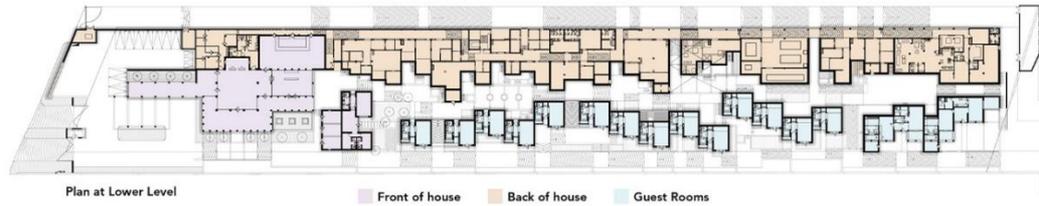


**Figure 10** Bayalpata Hospital courtyard and other units [21]

### 3.3 New Delhi Boutique Hotel

It was built in India in 2019 by architects Ashwin Alva and Lalit Mangar. The soil itself was used as the

primary building material for the rammed earth load-bearing walls, resting on a random rubble pedestal made of brown quartzite. The Northern Blocks are located at the same elevation. The load-bearing compacted earth walls of the guest rooms above are carried by the rubble walls on the ground floor (Figure 11). In the South Block, single-story guest rooms built on the ground are planned in parallel.



**Figure 11** New Delhi Boutique hotel floor plans [22]

The area is 15.300 m<sup>2</sup> in size, 275 m in length, 10 m downslope, and descends into a valley 30 m lower. It is aimed to increase the thermal performance by leaving insulated spaces on the walls of 17 cm obtained from compacted soil. The continuous insulation blanket with minimum thermal bridges extends over 220 m of the property. It wraps over both vertical and horizontal faces, forming the world's largest insulated compacted earth structure. The design is arranged around a series of courtyards typical of the organic growth of Indian villages, with stepped sites connected in and around clusters of rooms. All rooms face south, which provides better flexibility in thermal control and increases winter sun exposure [23].



**Figure 12** New Delhi Boutique Hotel Accommodations [22]

### **3.4 Anatolian Angel Women's Training and Production Center**

It was built by Architect Özgül Öztürk in 2019 in the Keban district of Elazığ. The structure was formed by rammed earth in these molds using steel molds. Thus, smooth surfaces were obtained on the walls. Wall thicknesses consist of 45-50 cm. It expands inward at the window openings and lets the light in. Architect Özgül Öztürk defined this building as a sustainable architecture, produced with local and natural materials, consuming less energy, and economically maintained. In terms of its architectural features, the building provides energy from the sun. Its roof was arranged as a green roof, and it collected rainwater and used it in hydrophores and reservoirs (Figure 13). As in Anatolia, wet volumes were resolved outside the building. It also meets its electricity needs with solar energy. Architect Öztürk defined this building, which he built as an example of ecological architecture, as a structure that is produced with local and natural materials, requires less energy, is healthy, economical, and can be easily maintained [24].



**Figure13** Anatolian Angel Women's Training and Production Center [25]

## **4 EVALUATION**

Earth, one of the main building materials from past to present, has been used in many buildings with different functions. As a building material, earth can adapt to different construction techniques. While earth bricks were used as bricks in the Gando primary school library, rammed earth walls were built in the Bayalpata hospital, reinforced with steel in molds. When we evaluate it as an area, it is seen that it is used in different building functions, from small residential buildings to large-scale cultural, library, and hospital centers. Earth material can be used in construction with many different techniques. The use of soil as a building material in all examined samples was obtained from the soil and stone quarries in their regions. Earth material has always taken its place in the design process with both architectural design and context. When we look at the contemporary structures built, the soil can quickly adapt to today's technologies and contribute to the design. One of the important parameters in the selection of building materials and techniques in all examined examples in economics. Locally made materials were used in all examples. Earth material has been successful in its use with many construction techniques and materials. In all examples, local and contemporary construction techniques were used by blending them. In addition, it is seen that the people of the region are involved in the construction process of these buildings. To minimize the disadvantages of the earth material, additions were made to the construction techniques (material, additives, etc.). Some features of the buildings examined within the scope of the study are shown in Table 1.

**Tablo 1** Evaluation of Earth Based buildings

	<b>Build Name Designer</b>	<b>Date/ Place</b>	<b>Structure</b>	<b>Evaluation</b>
	<b>Gando School</b> / Francis Kere	2001 Africa- Burkina Faso	clay brick, earth and steel roof	During the construction, local materials and techniques of the region were used. Clay bricks made of soil were dried in molds and used. Passive ventilation is provided by leaving a gap between the ceiling and the steel roof.
	<b>Bayalpata Hospital</b> / Sharon Davis Design	2015- 2019 Nepal- Achham	4.200m2 Steel- reinforced rammed earth	Due to the social situation brought by the geography where the complex is located, the building was built with the capacity to serve everyone and with sustainable building materials and methods. It is designed not only as a hospital, but also with the principles of social, economic and environmental sustainability.
	<b>New Delhi Boutique Hotel</b> / Ashwin Alva &Lalit Mangar	2019	15.300 m2 rammed earth	Considering the hot semi-arid climatic conditions, the design approach was based on the principle of being ecological. It improved thermal performance by developing an insulated space between 175 mm of compacted soil. An on-site laboratory was established to make soil measurements.
	<b>Anatolian Angel Women's Training and Production Center</b> / Özgül Öztürk	2019/ Elâzığ- Keban	rammed earth	Gray water is used in the building and the building is heated passively by solar energy. As the building is in Anatolia, the wet volumes were solved outside the building. It also meets its electricity needs with solar energy.

## 5 CONCLUSION

Earth, which has been used for shelter throughout history, has been applied in almost every region. It is among the preferred natural materials due to its easy workmanship, economy, and high thermal performance. Although it lost its importance with the realization of important advances in technology with industrialization, it has gained importance again intending to reduce energy consumption, where

natural resources are being consumed rapidly today. According to the understanding of sustainable architecture, building materials that do not harm the natural environment, consume the least energy throughout their life cycle, and do not produce harmful emissions during the process from the production to the use and destruction of building materials are given priority. In addition to being economical, the soil material successfully adapts to the construction techniques that have emerged with today's technological developments. With the use of traditional techniques and contemporary techniques together, the usage area of earth material has increased.

When we look at the examples of different scales and functions examined within the scope of the study, it is seen that soil material is used in almost every country. Contemporary practices have further expanded the use of earth material. The earth material, which can meet the thermal comfort requirement in places with its structural features, is easy to use because it is suitable for both on-site and precast production. In our country, especially in rural areas, the use of adobe is very common in housing. It is possible to see examples of it in many regions, thanks to the fact that the soil is easily accessible and easily cultivated. In addition, it is possible to see individual examples as contemporary building stock. Considering the increasing energy demands in the building sector, the transition to more sustainable materials has increased the interest in the soil in our country. Although it has rich potential as soil, we can say that the existing building examples are few compared to the examples abroad. In this direction, awareness-raising announcements can be made to architects and society in general, such as encouraging the use of earthen building materials and organizing competitions for architecture students.

Within the scope of the study, it is thought that the value of earth material will increase gradually and gain importance in the construction sector as a result of the examination made of contemporary architectural applications built using soil construction materials in different geographies. Today, local material is applied in different ways by combining traditional construction techniques with current technology. It is ensured that the local materials and techniques continue to be included in the designs and that the architectural knowledge is not lost and kept alive.

## 5 REFERENCES

- [1] Arslan, Z.D. '*Bilinen ve Sürdürülebilir, Ekoyapı*', Ekolojik Yapı ve Yerleşimler Dergisi, 2010.
- [2] Yüksek İ., Esin T., *Yenilenebilir Enerji Kaynaklarının Yapılarda Kullanım Olanakları*, 5. Uluslararası İleri Teknolojiler Sempozyumu (IATS'09), 13-15 Mayıs 2009, Karabük, Türkiye
- [3] Tekeli, İ., '*Habitat II Konferansı Yazıları*', T.C. Toplu Konut İdaresi Başkanlığı, Ankara,1996.
- [4] Esin T., Yüksek İ. (2008). " A Study on Ecological Properties of Building Materials Used in Traditional Buildings (in Turkey)", Emerald Insight journal Vol. 26 Iss 5/6 pp. 229 - 241.
- [5] Olgun T., Akyıldız N., Gülten A., Ekici B., Ulaş M., *Doğal Yapı Malzemelerinin Sürdürülebilirlik Bağlamında Değerlendirilmesi: Kerpiç Malzeme Örneği*, Ubak Uluslararası Bilimler Akademisi, 2019,
- [6] Değirmenci, N. '*Endüstriyel Atıkların Kerpiç Stabilizasyonunda Kullanılması*', Gazi Üniversitesi Fen Bilimleri Dergisi, Ankara, 2005, 18 (3): syf:505-515.
- [7] Özgünler, M., *Kırsal Sürdürülebilirlik Bağlamında Geleneksel Köy Evlerinde Kullanılan Toprak Esaslı Yapı Malzemelerinin İncelenmesi*, Süleyman Demirel Üniversitesi Mimarlık Bilimleri ve Uygulamaları Dergisi 2017, 2(2):33-41.
- [8] <https://www.topragizbiz.com/konular/bem-kalesi-arg-i-bem-iran.12993/> E.T: 03.04.22
- [9] Uysal,Ö.N., "*Geleneksel Türk Evi İç Mekan Kurgusunun İncelenmesi ve Süleymaniye Bölgesi Örneklerinin Analizi*", Y.Lis.Tezi, M.S. Güzel Sanatlar Ü., Fen Bil. Ens., İstanbul, 2007,syf:56
- [10]<https://www.bloomberg.com/news/articles/2018-09-30/new-mexico-top-performing-state-economy-since-trump-took-office> E.T: 25.03.22
- [11] <https://www.topragizbiz.com/konular/bem-kalesi-arg-i-bem-iran.12993/> E.T: 26.03.22
- [12] <https://arkeofili.com/sehir-hayatinin-ilk-adimlari-catalhoyuk/> E.T: 26.03.22
- [13] Acun, S., Gürdal, E, *Yenilenebilir Bir Malzeme Kerpiç ve Alçı Kerpiç*, TMH-Türkiye Mühendislik Haberleri. 2003. 427.syf:7177.
- [14] <http://www.hayoungroup.com/product/mud-brick/> E.T: 25.03.22
- [15] <https://akalab.gr/project/bioclimate-school-crete/> E.T: 25.03.22
- [16] <https://www.lehmtonerde.at/en/projects/project.php?PID=87> E.T: 25.03.22
- [17] <https://xxi.com.tr/i/el-emegi-okul> E.T.25.03.2022 E.T: 25.03.22
- [18] <https://www.archdaily.com/785955/primary-school-in-gando-kere-architecture>
- [19] <https://www.arkitektuel.com/gando-ilkokulu/> E.T.25.03.2022
- [20] <http://mimdap.org/2020/04/pazarlik-edilemeyen-sey-saglik-yapisinda-surdurulebilirlik/> E.T.03.04.2022
- [21] <https://www.theplan.it/eng/award-2020-health/bayalpata-hospital-a-model-of-sustainable-rural-health-sharon-davis-design> E.T.03.04.2022
- [22] <https://www.stirworld.com/inspire-visits-an-ode-to-the-lost-architecture-of-rammed-earth-ndash-lalit-mangar-hotel> E.T.03.04.2022
- [23] <https://sirewall.com/portfolio/new-delhi-boutique-hotel/>
- [24] Yardımlı, S., *Çevreci Yaklaşımlarda Malzeme ve Yapım Tekniği: Çağdaş Kerpiç Yapılar*, Kent Akademisi, Volume, 14, Issue 2, 389-413,2021
- [25] [https://twitter.com/seda\\_ozen/status/1223166171345752065](https://twitter.com/seda_ozen/status/1223166171345752065) E.T: 28.03.22