# Sustainable Usage of Earthen Materials as a Shelter for Homeless People in Palestine


Ayşe Pekrioglu Balkis [1]
**Aya Ahmad[2]**
Department of Civil Engineering,
Cyprus International University,
99258 Lefkoşa, via Mersin 10, Turkey,
North Cyprus
apekrioglu@ciu.edu.tr

## ABSTRACT

Sustainable development is development that meets today's demands without compromising the ability of future generations to fulfill their own needs. Nowadays, the building industry accounts for 23-40% of global greenhouse gas emissions, which has a negative impact on the environment. The average carbon footprint is estimated to be four tons. Modern construction materials with high energy costs and $CO_2$ emissions should be gradually replaced with widely available and environmentally friendly materials. Alker is a gypsum-stabilized earthen material composed of 6–10% clay, 2% lime, 10% gypsum, and 20–25% water by dry unit weight of soil. Alker Technology was developed at Istanbul Technical University to improve the properties of earthen buildings. Alker is a sustainable building material because of the availability of materials, ease of construction, energy efficiency, earthquake resistance, good thermal properties, and low cost. For these reasons, Alker can serve as a shelter for many people, particularly those who have been rendered homeless as a result of the war, and its applicability should not be underestimated. Earthen materials were the most cost-effective option in both urban and rural areas of Palestine's lowlands, and adobe buildings dominated the construction industry until the mid-twentieth century. Throughout Palestine's history, stone and earth have been used as the primary building materials. Palestine is known for its use of adobe masonry. Despite the fact that adobe masonry is more eco-friendly than other building methods, its use is declining in Palestine. A cost comparison of Alker and Reinforced concrete structures was performed, and it was found that Alker buildings are 13% less expensive than conventional construction materials. Alker materials were determined to be significantly more cost-effective than conventional building materials like steel, brick, and concrete. Earthen housing is a long-term, cost-effective, and environmentally friendly means of relocating forcefully displaced communities and disaster-affected places.

**KEY WORDS :**

Sustainable Development, Alker, Shelter, Eco-friendly, Cost effective

# 1 INTRODUCTION

Earth construction is becoming increasingly popular in today's environment as a means of generating and utilizing more environmentally friendly resources. Adobe is one of the oldest known building materials, and it is widely available everywhere at a low cost. They are not only simple and inexpensive, but they are also fireproof, durable, non-toxic, have a low degree of sound transmission between walls, and supply adequate heat to structures. The heat and moisture storage capacity of the earthen walls balances the relative humidity inside the building and so increases indoor comfort.
Low-income people's access to cheap housing is tied to building materials and technologies [1]. Because of the minimal manufacture, recycling, and reuse, earthen houses are environmentally sustainable [2]. Earthen houses are regarded as beneficial to one's health. The health benefits were unknown, but most people attributed them to a pleasant indoor climate and the soil's ability to absorb poisons. There are a lot of parasites that can be dangerous to humans when wet feet come into the house during the rainy season.

For the world's homeless and poor populations, there is an urgent need to identify low-income housing solutions that are both affordable and sustainable. Traditional building materials such as concrete, ceramics, steel, and bricks have also become more expensive as a result of rising energy costs, resource scarcity, and transportation costs. Various dangerous compounds, such as high quantities of carbon monoxide, sulfur oxides, nitrogen oxides, and suspended particulate matter, are always released into the environment throughout the manufacturing process of those construction materials. Harmful substance emissions pollute the air, water, soil, vegetation, and aquatic life, harming human health and living situations. Earth saves energy making it an environmentally beneficial material [3].
Earthen walls have been shown in tests to absorb high-frequency electromagnetic radiation (radio, radar). They are non-toxic and have the ability to passively manage indoor temperature and humidity, which is very useful in hot areas. In addition they can absorb both interior temperatures and relative humidity due to their enormous heat and moisture mass [4]. Earthen materials are simple to use, fire resistant, and soundproof [5,6]. Clay has a high thermal mass but a low thermal conductivity [7-9]. Clay's water absorption capacity and hydrophilic nature aid to keep internal humidity levels acceptable. Earth is viewed as an appealing material capable of contributing to bioclimatic design in order to create optimal interior conditions, hygiene, health, and comfort [10].

In contrast, earthen materials exhibit poor mechanical properties, shrinkage, and low water resistance [11]. Water movement (capillary action, rain, floods, and so on) causes clay particle swelling and shrinkage, which eventually leads to fissures and material loss [9]. This technique is more effective on montmorillonite clay [12,13]. Although earth is one of the most commonly used building materials, it is also one of the most moisture-sensitive [14]. Water exposure lowers adobe's strength, erosion resistance, dimensional stability, and durability. It was discovered in 1978 by Istanbul Technical University, which has been researching earthen construction materials since then, that stabilizing earth with gypsum and lime increases its durability, as well as its physical and mechanical properties. Adobe stabilized with gypsum is known as "Alker," a Turkish abbreviation of the words "alçı" (for gypsum) and "kerpic" (for adobe) [15].

## 2 Alker Technology

The earth used in Alker technology is significantly more readily available than the earth required for traditional earthen construction due to its lower clay content. Alker is a common term for a stabilized earth-based building material produced by adding gypsum, lime, and water to the earth. It consists of 10% gypsum, 2% lime, and 20–22% water, based on the dry weight of the soil [16]. The use of lime and gypsum in mixes minimizes the time required for mixing, molding, compacting, and turning out of molds [17]. Gypsum helps reduce the shrinkage of the building material, while Alker provides the durability required for load-bearing wall construction. Additionally, Alker is permeable and lighter than unstabilized earthen materials due to the fact that the gypsum hardens before the clay dries [18]. Heat resistance and durability are particularly high in gypsum-stabilized earthy materials, especially in

wet conditions. The manufacturing process is simple, and the energy usage in buildings constructed with this material is negligible. Buildings that are healthy also generate a healthy environment for people.

The binding property of the earth can be achieved with a clay content of about 30–50%. The addition of gypsum assists in this binding, and the earth's clay content of between 8% and 10% is sufficient for the production of Alker. Işık et al.[18] discovered that a high clay content enhances shrinkage, whereas a low clay content reduces binding. Although the earth's clay mineralogy has not been defined, a sufficient amount of clay is required in order to create a suitable bond [19]. The use of Alker, a low-energy building material, helps achieve long-term sustainability in both indoor and outdoor construction [16].

## 3 Alker as a Shelter for Homeless People: A Case Study from Palestine

Earth architecture is a viable option in many countries, including Palestine, where importing building materials is difficult due to the high cost and environmental impact of other commonly used materials (natural stone, for example). This choice is bolstered by the difficulty of importing building materials. In Palestine, earth architecture is an option. More than half of the world's population still resides in earthen constructions, which have been a common building material for thousands of years. There have recently been a number of initiatives in Palestine to develop a low-cost and low-effect alternative to natural stone because of the high cost and negative environmental impact of stone mining.
A conventional house is more vulnerable to the effects of severe external air temperatures than an earth-sheltered structure. Earth-sheltered dwellings also require less outside care, and the earth that surrounds them acts as soundproofing. Earth-sheltered homes may be less expensive to insure since they provide more protection against high winds, hailstorms, and natural disasters like tornadoes and hurricanes.

Forced migration is the world's most serious developmental and humanitarian issue, impacting mostly poor nations. All sectors must work together to support millions of displaced people and victims of disasters. So, the most basic necessity for a displaced population is shelter. To improve living conditions and achieve the global sustainability goal, sustainable housing must be provided. Sustainability meets several financial and environmental criteria. Earth as a building material is environmentally friendly, natural, and adaptable. Using earthen housing also meets the three pillars of sustainability: economic, environmental, and social. Gaza's early recovery and reconstruction plan predicts that more than 10,000 homes were completely destroyed, over 10,000 had severe damage, and almost 40,000 had minor damage, according to the Palestinian national authority. Contrasting these numbers with the total number of families living there (220,000), which means around 60,000 families were homeless [20]. Residents are unable to repair entire communities, which remain in ruins. At the same time, Palestinians are not allowed to import building supplies from outside Gaza.

Despite this, there are a few examples of individual attempts to innovate. As a result of the pressing need for shelter, some organizations donated containers for homeless families to stay in, but they weren't enough for their daily needs and were simply a short-term solution. Resurrecting earth as a building material and building houses out of wood are two more noteworthy undertakings. Coinciding with the paucity of construction materials, an extra 71,000 housing units are needed for Gazans in 2020 (UN, 2012) to satisfy the population growth, which worsens the difficulty of providing people with acceptable residences and gives rise to the need for rethinking sustainable alternatives [20]. Because the prohibition encompasses steel and cement, among other critical resources, the siege of Gaza has rendered construction and reconstruction activity difficult. The siege has prompted some Gazans to build new earthen houses to protect themselves from the weather, utilizing compressed earthen bricks made from dirt excavations. The material used in Palestine's return to earthen architecture is the most widely available and cheapest priced on the planet.

Gaza's housing shortage is a major problem. The Mediterranean Sea's proximity to the Gaza Strip makes it a key strategic location for Palestine. There were numerous attacks on Gaza by the Israeli

occupying troops. These hits resulted in the destruction of a large number of buildings. The Palestinian early recovery and reconstruction plans for Gaza estimate that about 10,000 homes were completely destroyed, another 10,000 were seriously damaged, and another 40,000 homes were slightly damaged. Even though there are only roughly 220,000 people in the area, these numbers indicate that 60,000 families have become homeless as a result of the recent storms [20].
Communities have been destroyed, and residents have been unable to rebuild their houses. The importation of building materials (such as steel, cement, and so on) from outside Gaza is also prohibited. Some groups provided homeless families with a kind of container to live in, but it was simply a short-term solution; it wasn't suitable for their core needs of living; it was only a temporary solution.

Individual efforts to build using wood and other low-cost materials are aimed at reintroducing earth as a building material. The population of Gaza was predicted to increase by 71,000 in 2020, making it more challenging to provide appropriate housing for the growing population [21]. Because traditional building materials are becoming scarcer, it is more important than ever to look for environmentally friendly alternatives.

In comparison to other countries, Palestine is currently experiencing political and economic setbacks as a result of the occupation, in which Palestinians are unable to control their natural resources or make use of urban expansion regions for future development. In the same manner as elsewhere in the world, the building sector needs to be rethought in order to save money and restore social and cultural ties in the community. To do this, viable and low-cost supplies for construction materials such as earth, as well as employ active solutions in architectural design to save money while restoring social and cultural bonds in the community must be identifed. A typical earth-sheltered house is illustrated in Figure 1.

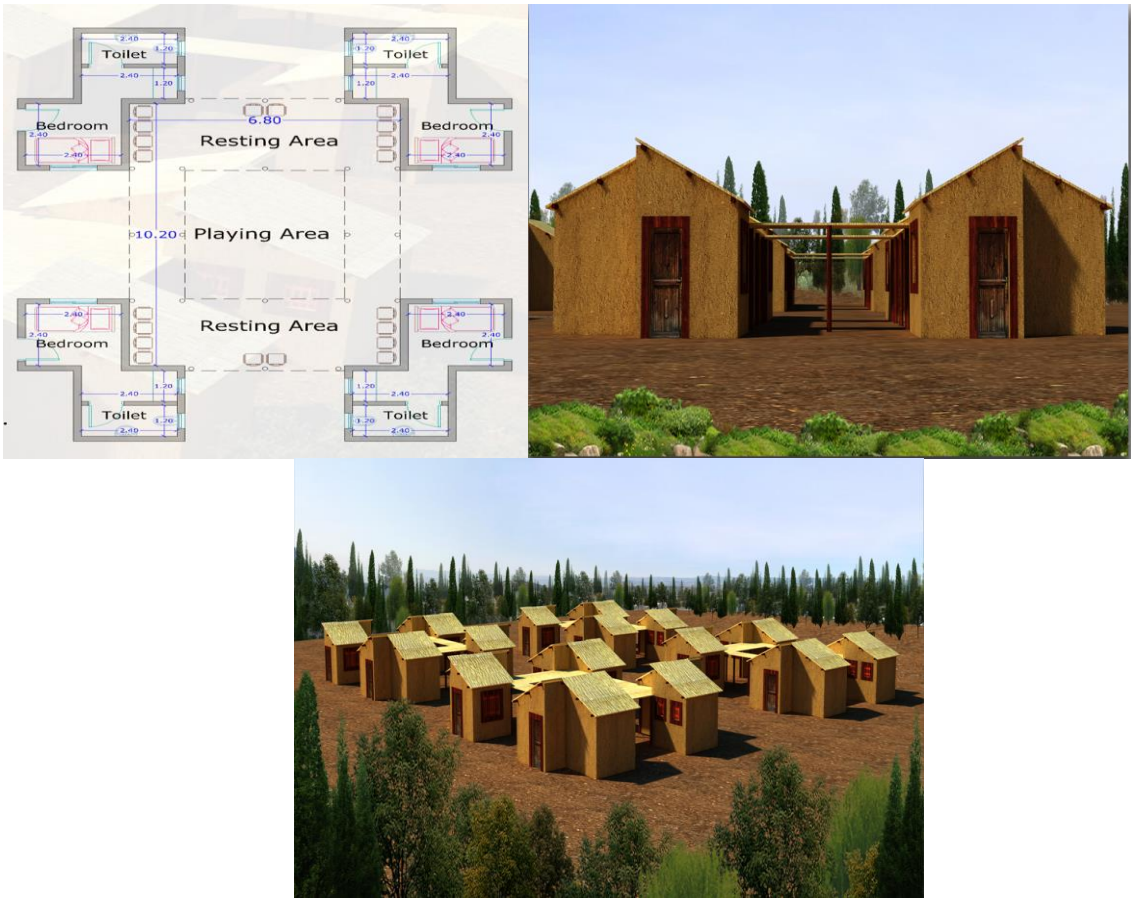


**Figure 1 :** Design of Earth-Sheltered House

## 4 Crack Propagation of Reinforced Alker

Ahmad et al. [23] investigated the image processing conducted on the Alker samples to examine the crack propagation (Figure 2). Figure 3 shows the Peak Signal to Noise Ratio (PSNR) results for 1, 7, 14, and 28-day images of control and modified Alker samples comprising 0.5, 1.0, and 1.5%.

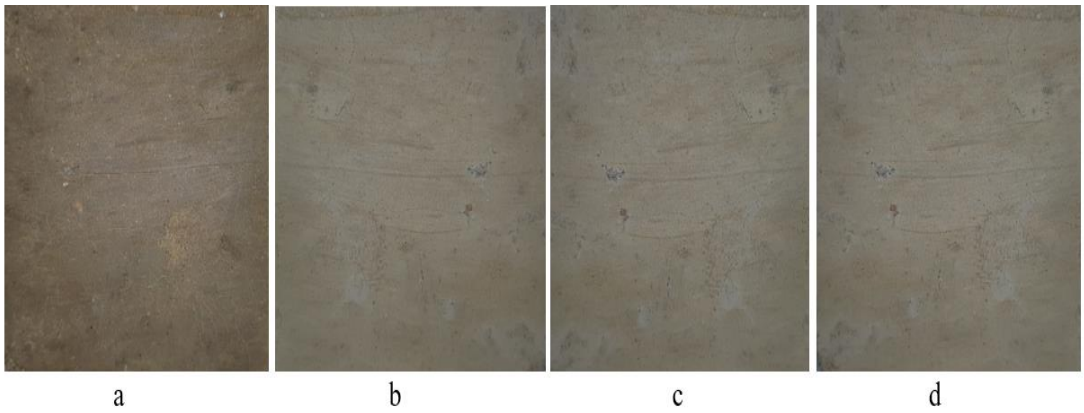


**Figure 2:** Images of Alker with 1% SPW on days (a) 1 (b) 7 (c) 14 and (d) 28

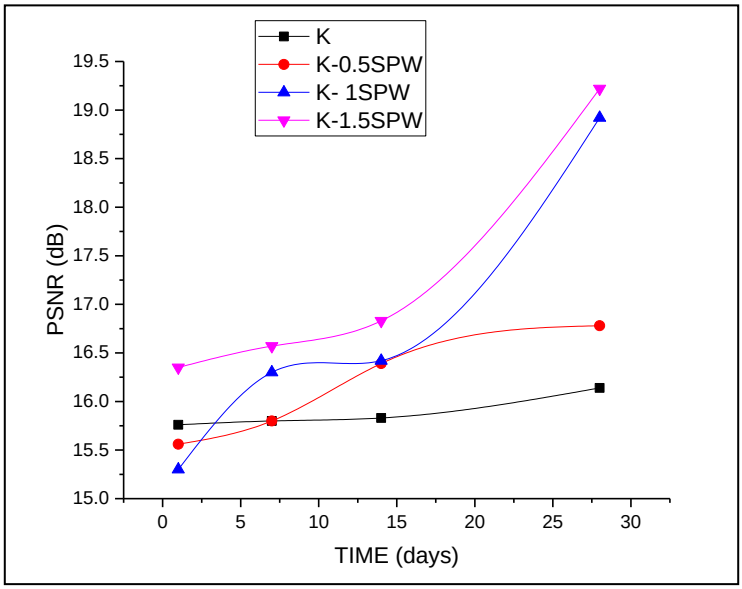


**Figure 3:** Propagation of cracks in Alker

The PSNR of the control samples rose by 0.25 and 0.44 % after 7 and 14 days, respectively. The gain was 2.35 % after 28 days. The PSNR values of the modified samples with 0.5 % SPW improved by 1.52 and 5.06 % after 7 and 14 days, respectively. Furthermore, after 28 days, the PSNR increased by 7.27 %. The crack behavior was much improved over the control sample. PSNR values increased 6.14 % and 6.82 % in 7 and 14 days for modified samples with 1.0% SPW. The 28-day PSNR rose 19.13 %. The adjusted sample with 1.5% shredded plastic waste recorded 1.33, 6.12, and 14.93%.

The Alker sample having 1.0% shredded plastic wastes content demonstrated better results compared to other samples. The PSNR value increase after 28-day reveals that there was a close bonding of the internal structure of the sample when the air drying happened, consequently permitting restricted shrinking, which reduced the spread of the cracks. This also explains the limited linear shrinkage findings observed in the sample modified with 1.0% compared to the control and other modified

samples. Images of crack behavior in Alker samples were previously analyzed using image processing, and our finding is in line with Onochie and Balkis [19].

## 5 Conclusion

Earth as a building material is a prehistoric and popular building technique employed by populations in poor countries. Earth has changed over time and space to meet a wide range of social and cultural needs. This has led to a rich cultural heritage that can be found all over the world. Adobe construction is currently playing a significant role in Palestine due to its availability and low cost in contrast to other construction materials. Experimental houses were developed in order to assess the cost analysis of the materials used in construction. Alker buildings are 13% less expensive than conventional construction materials, according to cost estimates [23]. To sum up, earthen housing is a sustainable, cost-effective, and environmentally beneficial method of resettling forcibly displaced communities and disaster-affected areas.
A green and sustainable environment with minimal lifecycle impact is achieved by using eco-friendly materials and metrologies. Around the world, earth is the most common building material. To improve the lateral load carrying capacity of the building and to minimize cracking due to drying, reinforcing should be added to important areas. A stabilizer is also added to earthen structural members to boost load-carrying capacity and material strength. Resettling forcibly displaced communities and places damaged by disasters with earthen houses is both economical and environmentally friendly.

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