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The Impact of Population Growth on Construction Material Prices in Egypt Exploring Sandbags as a Viable Alternative

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ABSTRACT
This research paper focuses on addressing the challenges of inadequate urban housing and the high cost of traditional building materials in Egypt. As part of the study, a low-cost housing project utilizing sandbags as a construction material is presented as an applied example. The project aims to provide affordable housing solutions while minimizing construction expenses and maximizing the value of locally available resources.
The utilization of sandbags as a building material offers several advantages. It is a low-cost and readily available resource in Egypt, making it an ideal option for constructing affordable housing units. Additionally, sandbags demonstrate excellent thermal insulation properties, contributing to energy efficiency and reducing long-term maintenance costs. The project also explores the potential for incorporating sustainable design principles, such as rainwater harvesting and solar energy systems, to further enhance the efficiency and environmental performance of the houses. Despite the low initial costs associated with constructing sandbag houses, the research paper highlights the importance of considering long-term treatment costs. Adequate measures should be taken to protect the sandbag walls from moisture, pests, and erosion, ensuring the durability and longevity of the structures. Such treatments may include applying waterproof coatings, implementing proper drainage systems, and utilizing appropriate landscaping techniques. This applied example of a sandbag house serves as a demonstration of a practical and cost-effective solution to address the lack of adequate urban housing in Egypt. By utilizing locally available materials and incorporating sustainable design principles, the project aims to provide affordable and environmentally friendly housing options for low-income communities.

Keywords: *urban housing; traditional building; sustainable design.*

1. Introduction

The lack of adequate urban housing and the high cost of traditional building materials pose significant challenges in Egypt. This research proposal aims to address these issues by proposing a low-cost housing project that utilizes sandbags as a construction material. This applied example aims to provide affordable housing solutions while minimizing construction expenses and maximizing the value of locally available resources. The proposal also emphasizes the importance of considering long-term treatment costs to ensure the durability and longevity of the structures. the importance of addressing the challenges of inadequate urban housing and high material costs in Egypt. The presented low-cost housing project utilizing sandbags demonstrates a practical and sustainable solution for providing affordable housing options. By considering long-term treatment costs and implementing supportive policies, it is possible to overcome these challenges and improve the accessibility and affordability of urban housing in Egypt.

2. Research problem

Mitigating the Impact of Population Growth on Rising Construction Costs through the Application of Sandbags as an Affordable Building Material in Egypt. Egypt is experiencing rapid population growth, leading to a surge in demand for housing and infrastructure development. Consequently, the construction industry is facing significant challenges due to the escalating costs of traditional building materials, such as cement, steel, and bricks. This situation calls for innovative solutions to address the rising construction costs and ensure the availability of affordable housing options. One potential solution is the utilization of sandbags as a sustainable and cost-effective alternative building material. However,

further research is needed to investigate the feasibility and effectiveness of sandbags in mitigating the impact of population growth on rising construction costs in Egypt.

3. Objectives

1-To examine the factors contributing to the shortage of urban housing in Egypt and the inflation of traditional building material prices.
2-To explore the utilization of sandbags as a low-cost and sustainable alternative building material for affordable housing.
3-To assess the environmental and energy efficiency benefits of sandbag construction.
4-To identify the necessary treatment and maintenance measures to ensure the longevity of sandbag houses.
4-To propose policy recommendations to promote the adoption of low-cost housing projects utilizing alternative building materials.

3. Research methodology

The research methodology employed for this study involved a comprehensive review of existing literature, case studies, and expert interviews. The literature review covered relevant studies on sandbag construction, cost analysis, and housing challenges in Egypt. Case studies from other regions where sandbag construction has been successfully implemented were examined to extract valuable insights. Additionally, interviews were conducted with professionals experienced in sandbag construction and housing development in Egypt.

4. Population growth and its impact on housing in Egypt

Housing in Egypt is a complex and multifaceted issue, influenced by various factors such as population growth, urbanization, affordability, and government policies. The country faces challenges in providing adequate housing for its population, particularly in urban areas [1].

Figure 1- Random housing in Egypt, Reference: https:// https://orientxxi.info/dossiers-et-series/article5037

Population growth is a significant driver of the housing demand in Egypt. With a large and growing population, there is a constant need for new housing units to accommodate the increasing number of households. This demand is further amplified by rapid urbanization, as people migrate from rural areas to cities in search of better opportunities. Affordability is a critical concern for many Egyptians when it comes to housing. A significant portion of the population struggles to access decent and affordable housing options. High real estate prices, limited access to mortgage financing, and income disparities contribute to the affordability crisis. This issue is particularly acute for low-income households and informal settlements, where basic services and infrastructure may be lacking [2]. Informal settlements, commonly known as "ashwa'iyat" or "slums," are a prevalent feature of the Egyptian housing landscape. These settlements often lack proper infrastructure, sanitation facilities, and access to basic services. The government has initiated efforts to upgrade and regularize informal settlements, aiming to improve living conditions and provide legal tenure to residents.

Figure 2-Random housing in Egypt, Reference: https:// https://orientxxi.info/dossiers-et-series/article5037

The Egyptian government has implemented various policies and programs to address the housing challenges. These initiatives include the establishment of the Social Housing Fund, which aims to provide affordable housing units for low-income citizens. Additionally, there have been efforts to encourage public-private partnerships in the construction and development sectors to increase housing supply [3].

However, despite these efforts, there is still a significant gap between housing supply and demand in Egypt. The government continues to work on expanding affordable housing options, improving urban planning, and upgrading informal settlements. Additionally, there is a need for comprehensive policies that address issues of affordability, access to finance, and sustainable urban development

5. Graveyard Housing

Graveyard housing is considered an unusual phenomenon that has worsened due to the acute housing crisis in Egypt, where some cemetery enclosures have turned into places of shelter. Some low-income individuals have resorted to residing in graveyards due to the following reasons:

Demolition of old houses in popular neighborhoods to make way for residential buildings, leaving the occupants of these old houses unable to afford new apartments due to their high prices [4].

Figure 3-Housing cemeteries in Egypt, Reference: https://www.skynewsarabia.com/

Displaced individuals from rural areas seeking refuge in graveyards.

The population of Egypt (urban and rural) increases at a rate of approximately 1.25 million people annually, while the allowed population density according to the law is 150 people per acre.

The drawbacks of living in graveyards include:

Most individuals engaging in illegal activities use these areas to carry out crimes such as murder, drug trafficking, and theft of corpses, taking advantage of their distance from police centers and surveillance.

Lack of services in these areas, such as proper sanitation and water supply.

60% of children residing in these areas are completely deprived of education.

There are many types of substandard housing in Egypt due to citizens resorting to economic shelters as an escape from high housing prices (high prices of traditional building materials) in addition to the high cost of land for construction [5].

6. Housing of Huts

The emergence of a type of housing that cannot be called homes, as they are shelters that fail to achieve the basic principles of humanity. The residents of these huts represent a segment estimated at around 5% of the total urban population, and their number is increasing rather than decreasing. The average family size is large, ranging from 5 to 6 individuals.

Housing of huts consists of shacks made of wood, sheets, cardboard, broken bricks, or tree trunks. The majority of these huts consist of one bedroom, most of which lack bathrooms. The narrow corridors between the huts are filled with human waste and garbage

7. Developing low-income housing options to meet housing needs.

These housing types often consider the use of traditional building materials, which can be more affordable and readily available. Here are some types of low-income housing in Egypt, considering the increase in traditional building materials:

Informal Settlements: Informal settlements, also known as ashwa'iyat or slums, are a prevalent form of low-income housing in Egypt. These settlements often utilize traditional building materials such as mud bricks, local stones, and corrugated metal sheets. Due to their low cost and accessibility, these materials are commonly used by residents to construct their dwellings [6].

Self-Built Housing: Many low-income households in Egypt opt for self-built housing, where they construct their homes incrementally over time. Traditional building materials like mud bricks, adobe, and local stones are frequently used in this process. Self-built housing allows families to adapt their homes to their evolving needs and financial capabilities.

Figure 4- Housing of Huts- Reference: https://huts.com/

Cooperative Housing: Cooperative housing initiatives have been established to provide affordable housing options for low-income individuals and families. In some cases, these projects incorporate the use of traditional building materials to keep costs down. Cooperative members often contribute to the construction process, utilizing materials like mud bricks or other locally available resources.

Social Housing: The Egyptian government has implemented social housing programs to assist low-income citizens in accessing affordable housing. These programs often involve the use of cost-effective building materials, including traditional materials. For instance, mud bricks may be employed in the

construction of social housing units to reduce costs while ensuring durability [7].

Upgrading Informal Settlements: Efforts have been made to upgrade and improve the living conditions in informal settlements. Traditional building materials, such as mud bricks and local stones, might be utilized during these upgrading initiatives. The goal is to enhance the infrastructure, sanitation facilities, and overall quality of housing in these settlements.

Affordable Housing Projects: Various affordable housing projects have been initiated by the government and private sector entities to cater to low-income individuals and families. These projects might incorporate elements of traditional architecture and construction techniques, including the use of traditional building materials, to make housing more affordable and culturally appropriate

8. Urban problems resulting from informal settlements.

1-Overpopulation and Congestion: Informal settlements often lack proper planning and infrastructure, leading to overcrowding and congestion. The limited space and high population density can strain resources and services, such as water supply, sanitation, transportation, and healthcare.

2-Inadequate Infrastructure: Informal settlements are typically characterized by a lack of basic infrastructure, including roads, sewage systems, electricity, and waste management facilities. The absence of these essential services can pose health and safety risks to residents and contribute to environmental pollution.

3-Limited Access to Education and Healthcare: Informal settlements often face challenges in providing access to quality education and healthcare facilities. Schools and healthcare centers may be insufficient or absent, making it difficult for residents, especially children and vulnerable populations, to receive proper education and healthcare services.

4-Social and Economic Marginalization: Informal settlements are often associated with higher levels of poverty and social exclusion. Limited access to formal employment opportunities, inadequate social services, and marginalization from the formal urban fabric can perpetuate cycles of poverty and inequality.

5-Increased Crime Rates: Informal settlements can be vulnerable to higher crime rates due to limited law enforcement and surveillance. The lack of formal governance and the presence of socio-economic disparities can create an environment conducive to criminal activities.

6-Environmental Degradation: Informal settlements may disregard environmental regulations and lack proper waste management systems, leading to pollution and environmental degradation. Improper waste disposal, uncontrolled construction, and encroachment on natural areas can harm ecosystems and contribute to environmental hazards.

7-Lack of Resilience to Disasters: Informal settlements are often situated in hazardous areas, such as flood-prone zones or unstable terrains, increasing the vulnerability of residents to natural disasters. The lack of proper infrastructure and disaster preparedness measures can exacerbate the impact of disasters on these communities.

9. Study about the housing shortage and the high costs of traditional building materials in Egypt

The housing shortage and the high costs of traditional building materials in Egypt have become pressing challenges that impact the lives of thousands of individuals and families across the country. The scarcity of affordable housing options coupled with the rising prices of construction materials have created a complex crisis with wide-ranging social, economic, and environmental implications. Understanding the causes and consequences of this issue is crucial for developing effective strategies to address the housing shortage and mitigate the financial burden on potential homeowners and the construction industry [9].

The housing crisis in Egypt is characterized by a significant gap between the demand for housing and the available supply. Rapid population growth, urbanization, and rural-urban migration have contributed to an increasing need for housing, especially in urban areas. However, the construction industry has struggled to keep pace with this demand, resulting in a shortage of suitable and affordable housing units. One of the key factors exacerbating the housing shortage is the high costs of traditional building materials. The prices of cement, steel, bricks, and other essential construction materials have experienced substantial inflation, making them increasingly unaffordable for both individuals and developers. This has a cascading effect on the overall cost of housing, limiting access to homeownership and exacerbating the affordability crisis.

The reasons behind the escalating costs of building materials are multi-faceted. Factors such as limited competition among suppliers, fluctuations in global commodity prices, high import tariffs, and inefficiencies in the supply chain contribute to the inflated costs. Moreover, the dependence on traditional construction techniques and materials further exacerbates the issue, as they are often labor-intensive and require extensive resources, driving up production expenses.

The consequences of the housing shortage and high material costs are far-reaching. Low-income individuals and families face significant challenges in finding suitable and affordable housing options, often

resorting to informal or inadequate housing solutions. This leads to overcrowding, substandard living conditions, and the proliferation of informal settlements, which further strain urban infrastructure and services. Additionally, the construction industry is hindered by the financial burden of high material costs, hampering its ability to meet the housing demand and driving up property prices.

Clear visibility of the phenomenon of the lack of suitable urban housing and the increase in its value or monthly rent Table1 [10].

Table 1 illustrating the development of cement prices, iron prices, and wages twentieth century in Egypt. - Reference: author

Engineer's salary per month	The technician's wage per day	Iron in tons	Cement per ton	year
3000	700	3700	420	s2010
11000	2700	14600	5300	s2020

In the current era, the price of cement has reached 2100 Egyptian pounds per ton, while the price of iron ranges between 45000 and 47,000 pounds per ton. The daily wage for a worker has reached 600 Egyptian pounds.

The population of Egypt exceeded 92,000,000 in 2016. According to statistics, the population growth in Egypt from 1990 to 2008 reached 23.7 million (41%). In 2020, growth is expected to be 20%. [10].

The average development of construction prices in Cairo.

Table 2. Neural networks model for prediction of construction material prices in Egypt

Above average housing	Average housing	Economical housing	year
2500 - 500	600 - 200	220 - 180	2010
4500 - 2500	1900 - 600	100 - 220	2020

As for the price of land, it has now reached 200 thousand pounds in some locations.

The development of the cost of building per square meter for residential units in Cairo.

Table 3 Neural networks model for prediction of construction material prices in Egypt

Above average housing	Average housing	Economical housing	year
8000 - 4000	5000 - 1000	2000 - 900	2010
18000 - 6000	11000 - 6000	8000 - 5000	2020

The Proposed Solution: Low-Cost Housing:

(A house made of sandbags) Building with sand (which is a local and environmentally friendly material available in Egypt, as 75% of Egypt's land is within the desert region. Egypt also has an abundant workforce, but they require training to undertake this type of construction as it is considered modern).

10. The importance of using sandbags in creating low-cost housing

The use of sandbags in creating low-cost housing can offer several advantages and benefits. Here are some key reasons why sandbags are considered important in this context [11].

1-Affordability: Sandbags are inexpensive and readily available in many regions, making them a cost-effective building material for low-cost housing projects. Compared to traditional construction materials like bricks or concrete blocks, sandbags can significantly reduce construction costs, making housing more affordable for low-income individuals and communities.

2-Accessibility: Sandbags are relatively lightweight and easy to transport, making them accessible even in remote or hard-to-reach areas. This accessibility allows for the construction of low-cost housing in locations where the transportation of traditional construction materials may be challenging or costly.

3-Sustainability: Sandbags are an environmentally friendly building material. They are typically made from natural and biodegradable materials, such as jute or burlap sacks, which have a lower environmental impact compared to materials like concrete or steel. Sandbags can be reused or recycled after their lifespan, contributing to sustainable construction practices.

4-Flexibility and Adaptability: Sandbags offer flexibility in design and construction. They can be easily shaped and stacked to create various architectural forms and adapt to different building layouts. This flexibility allows for customization and adaptation to the specific needs and preferences of low-cost housing projects.

5-Thermal Insulation: Sandbags provide a certain level of thermal insulation when properly constructed. The natural materials used in sandbags can help regulate temperature and improve energy efficiency within the housing units. This can contribute to reducing energy consumption and enhancing the comfort of residents.

6-Disaster Resistance: Sandbags have proven to be effective in creating structures that are resistant to

natural disasters such as floods and earthquakes. When properly filled and stacked, sandbags can provide stability and act as a barrier against water or shifting ground. This resilience is especially valuable in areas prone to such hazards, offering a higher level of safety for low-cost housing residents.

7-When properly filled and stacked, sandbags can provide stability and act as a barrier against water or shifting ground. This resilience is especially valuable in areas prone to such hazards, offering a higher level of safety for low-cost housing residents. It is important to note that while sandbags offer advantages for low-cost housing, proper construction techniques and engineering considerations should be followed to ensure the structural integrity and durability of the buildings. Additionally, local building regulations and guidelines should be adhered to when using sandbags for construction purposes

Figure 5-Construction with sandbags,
Reference: Sandbag Shelters World Habitat

Figure 6-Construction with sandbags,
Reference: Sandbag Shelters World Habitat

11-Low-Cost Housing Project: The goal of the project is to provide affordable housing units to contribute to solving the housing problem in Egypt.

11-1Proposed Solution: (Case Study): (Using Sandbags as Building Material): The construction will be done using sandbags, which is a locally available and eco-friendly material in Egypt. Approximately 75% of Egypt's land is within the desert region, where sand is abundant. Egypt also has a plentiful workforce, although they may require training to carry out this type of construction since it is relatively new.

Project Studies:

Project Advantages:

1-Low Cost:

The walls made from sandbags are "earth-bagged" using cement mixed with certain additives to make them strong and adhere to the nylon bags. The cost of using sand in construction is half the cost of building with reinforced cement. The majority of the cost goes towards labor, as the workers put in significant effort to implement the idea. Labor costs more than the tools and building materials, which is one of the challenges faced by the project due to a shortage of labor. Building with sandbags can also be considered a form of overcoming the cement shortage during times of siege.

2-Quick Implementation:

The technique of building houses with sandbags is relatively new, with an application lifespan of no more than ten years. However, sandbags have been used in the past as structures to control river floods worldwide, as well as in the construction of trenches and military camps.

The advantages of building with sandbags include its cost-effectiveness. Sand is widely available in the deserts of Egypt, and its use does not require any prior treatment. It does not cost more than the value of the reinforced nylon bags. Building with sandbags is also environmentally friendly, providing thermal comfort for residents. The dwelling remains cool in summer and warm in winter due to the high thermal mass of the sand walls. Additionally, it is suitable for all region

12-The thermal mass of the sand walls plays a significant role in enhancing the thermal comfort of the residents in the following ways [12].

1-Temperature Regulation: Sand has a high thermal mass, meaning it can absorb and store a large amount of heat energy. During the day, when the external temperature is high, the sand walls absorb the heat from the surroundings. This process helps in preventing excessive heat gain inside the structure, keeping the interior cooler.

2-Heat Release: During the night or when the external temperature drops, the sand walls slowly release the stored heat back into the interior space. This gradual heat release helps in maintaining a relatively stable and comfortable temperature inside the building, preventing rapid temperature fluctuations.

3-Delayed Heat Transfer: The thermal mass of the sand walls also slows down the transfer of heat from outside to inside or vice versa. This delay in heat transfer helps in reducing the impact of external temperature fluctuations, allowing the interior to maintain a more consistent and comfortable temperature for a longer period.
4-Energy Efficiency: The thermal mass of the sand walls reduces the reliance on active heating or cooling systems. As the sand walls absorb, store, and release heat, they reduce the need for additional heating or cooling equipment. This aspect can contribute to energy savings and lower utility costs.
By utilizing the thermal mass properties of sand, the sandbag construction method can provide a more thermally stable and comfortable living environment for the residents, helping to mitigate temperature extremes and enhancing overall comfort levels.
Shortage of trained workforce (for this type of construction):
One of the challenges facing this project is the shortage of trained workforce. It requires a significant number of workers, and despite the availability of materials, we suffer from a lack of workers accustomed to brick and reinforced cement construction. This is due to the immense effort required for sandbag construction, which requires some training for workers to master this type of construction.

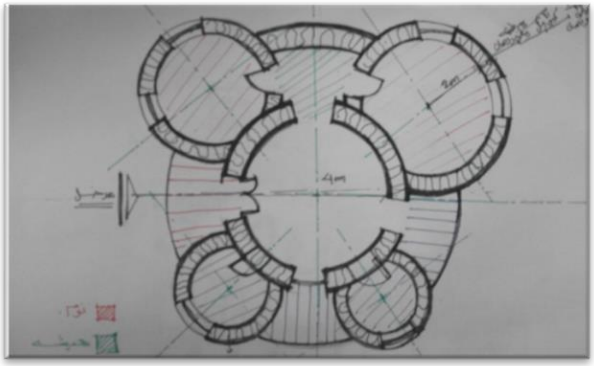

Figure 7-Plan - a building made of sandbags

Comparison between mud construction and sandbag construction: Mud construction requires higher costs and more advanced techniques, including selecting a specific type of clay. The available clay needs treatment for reuse and mixing with straw and cement. On the other hand, sandbag construction is easier and sand is abundantly available in Egypt. Additionally, sandbag construction is faster to complete. These buildings are environmentally friendly, and there is no fear of their stability as they can withstand up to 35 years without collapsing

13-The implementation method
It starts with sandbags and barbed wire, which are stacked row by row, with barbed wire placed between each row to connect the upper and lower layers. The wires play the role of "mortar" in traditional construction. The construction is completed with a dome or a basement, and the building can be diversified by adding one circular room to another and creating harmonious formations. This technique allows for a wide range of variations that can be implemented.

Figure 8-Construction stages using sandbags
Reference: Sandbag Shelters AKDN | targoncavilla.com

These chambers have demonstrated, through careful scientific evaluation, high thermal efficiency and high structural strength. The fundamental construction technique in this system involves filling sandbags with soil and stacking them in a circular horizontal course. The circular rows rise above each other to form a dome. Barbed wire is placed between the rows to prevent the sandbags from shifting and provide earthquake resistance [13].

The addition of barbed wire to compression structures generates earthquake resistance, the streamlined shape resists hurricanes, the use of sandbags helps resist floods, and the soil itself provides insulation and fire resistance. The system is particularly suitable for providing affordable housing because it allows for quick manual construction by the occupants themselves with minimal training.

Each shelter includes a main central space with attached spaces for cooking and sanitation services. The technique can also be used for both buildings and infrastructure such as roads, edges, retaining walls, and site coordination elements.
Since the construction uses local resources, such as the available soil on-site and human labor, it is fully sustainable. The materials used are soil or sand and plastic bags, with a preference for sand to withstand pressure and weight. It is also possible to use demolition debris (soft parts after being sprayed with water), transport and use iron rods from the debris by inserting them into the bags and connecting them together, as well as using debris from doors and windows in the supports.
The floor is properly leveled and compacted with fill material, and iron pipes are installed as the center of the circles. The room size varies between 3 to 4 meters in diameter, primarily depending on the stability and leveling of the initial rows and the proper weight and compaction of the bags. Clay can be used as a binding and welding material instead of cement [14].
The structure can be covered with clay both from the outside and inside, and lime and water can be used for painting.
The construction time for a building using this technique can vary depending on various factors such as the size and complexity of the structure, the availability of resources and labor, and the level of experience of the builders. However, generally speaking, this construction method is known for its relatively quick construction time compared to traditional building techniques.
With a skilled and experienced team, it is possible to construct a small to medium-sized building using this technique within a few weeks to a couple of months. The use of sandbags and barbed wire allows for rapid assembly and stacking, which can accelerate the construction process.
It's important to note that the construction time may also depend on other factors such as the preparation

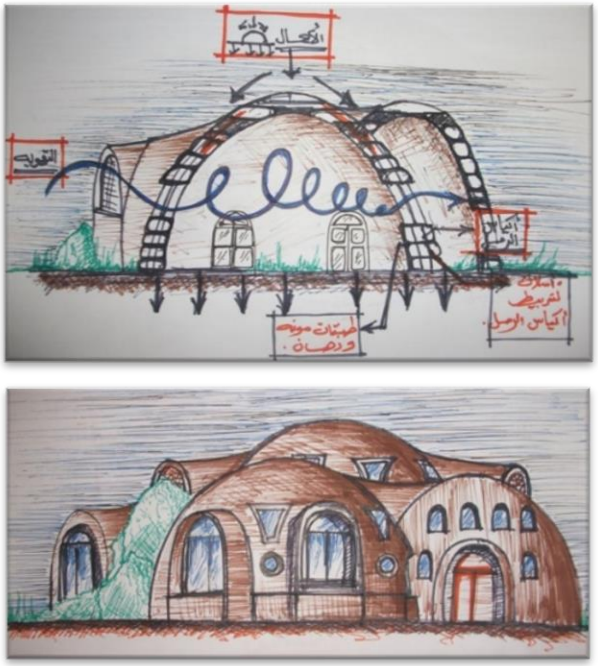

Figure 9-section-elev, Construction stages using sandbags Reference: author

of the site, sourcing and processing of the building materials, and any additional customization or finishing work required.
Overall, the construction time can vary, but this technique is generally considered to be faster compared to conventional construction method

14- Notable examples of buildings and projects around the world

1-Cal-Earth Institute, California, USA: The Cal-Earth Institute, founded by architect Nader Khalili, has pioneered the concept of "Super adobe" construction, which involves using sandbags filled with earth to create durable and environmentally friendly structures. The institute has constructed various buildings, including the Eco-Dome and the Vaulted House, to showcase the potential of this technique.
2-Gando Primary School, Burkina Faso: Designed by architect Diébédo Francis Kéré, the Gando Primary School in Burkina Faso was built using earthbag construction techniques. The school's walls were made with stacked sandbags filled with locally sourced earth, providing a cost-effective and sustainable solution for educational infrastructure in the region.
3-Earthbag Village, Nepal: After the devastating earthquake in Nepal in 2015, the concept of earthbag construction gained attention as a viable solution for post-disaster housing. Several organizations, including the Earthbag Building Association Nepal, implemented earthbag construction techniques to

rebuild communities and provide safe and affordable shelter.

4-Nka Foundation's Ghana Earthbag Project, Ghana: The Nka Foundation, in collaboration with the local community, built a series of earthbag structures in the Volta Region of Ghana. These structures, including a community center and a children's library, were constructed using sandbags filled with local soil, demonstrating the potential of earthbag construction in rural areas.

5-Sustainable Community Project, Thailand: In the village of Nong Bua Lamphu, Thailand, a sustainable community project called "Baan Dada" utilized earthbag construction techniques to build homes and community facilities. This project aimed to provide housing for orphans and underprivileged children using low-cost and locally available materials.

These are just a few examples of buildings and projects that have embraced sandbag construction techniques. Earthbag construction continues to be explored and implemented in various parts of the world as an alternative and sustainable building method.

15- Cal-Earth Makes Disaster-Resistant Super adobe Construction a Reality

15.1Envisioning a Building System for All

Architect and Cal-Earth founder, the late Nader Khalili, developed a form of earthbag architecture called Super adobe, inspired by traditional earth architecture in the deserts of his native Iran. Khalili drew on influences from years of meditation, as well as hands-on research and development, to adapt ancient tradition to modern applications. He conceptualized and developed a technology and system that was simple enough that anyone could build a sound adobe home.

Preserving and honoring their father's mission and goals, Nader Khalili's children continue to pursue Cal-Earth's architectural vision based on the natural elements of earth, water, air, and fire and their unity in service to humanity. The architect, author, humanitarian, teacher, and innovator's children continue his mission to provide shelter for the world's homeless and displaced, empower people to participate in the creation of their own homes and communities, and help preserve the planet that we all share.

Nader Khalili's vision is to empower individuals to be able to build a safe shelter for themselves that is in harmony with nature and has the ability to respond to natural disasters," says Dastan Khalili, President of the Cal-Earth Institute. In developing Cal-Earth, Nader focused on the idea of using the most abundant available material, which Dastan Khalili says, "is the earth below our feet.

Figure 10-Resistant Super adobe Reference Cal-Earth Makes Disaster-Resistant Super adobe Construction a Reality

16-Super adobe Built to Withstand Natural Disasters

Cal-Earth has eliminated the weaknesses of traditional adobe construction, resulting in products and building techniques that make adobe construction resilient. Dastan Khalili says that their Superadobe structures can withstand various weather and natural disasters, including earthquakes, wildfires, hurricanes and tornadoes "due to material usage, geometry, and physics."

"The key is not the usage of material so much, but the understanding of geometry and forces of physics," says Khalili. By using the arch or the dome and stabilizing the earth with 10% to 15% cement lime or other available stabilizing materials, one of their buildings can achieve its levels of resiliency and effectiveness.

Figure 11-Interior Design- Resistant Super adobe Reference: Cal-Earth Makes Disaster-Resistant Super adobe Construction a Reality

The arch dome, or vault, creates a monolithic structure that, with time, compresses and becomes even stronger due to gravity and the geometry of the circle. Examples of this can be seen in nature. Think of caves that are subjected to millions of tons of weight in

mountains or lava tubes that run underground—they are almost always in the shape of a vault or a dome.

Figure 12-layout- Resistant Super adobe Reference : Cal-Earth Makes Disaster-Resistant Super adobe Construction a Reality

How to Build Super adobe Homes

In developing Super adobe homes, builders use long or short sandbags filled with moistened earth arranged in layers or long coils. Strands of barbed wire are placed between each layer of sandbags to act as both mortar and reinforcement. Stabilizers such as cement, lime, or asphalt emulsion can be added. Builders then stack coils made up of earthbags to create a structure.

The Super adobe building system can be used for structural arches, domes and vaults, or conventional rectilinear shapes. Utilizing the same methods, developers can also build silos, landscaping elements, infrastructure like dams, cisterns, roads, and bridges, and structures that stabilize shorelines and watercourses.

Figure 13-Method of construction and making openings- Resistant Super adobe

Cal-Earth's building designs range from small, one-person emergency shelters that take one day to build, to temporary villages and larger homes that can include three bedrooms and a two-car garage. Importantly, regardless of their purpose or the land available, Super adobe homes are all built using the same proven principles [15].

The basic materials required to build Super adobe homes are few. They include synthetic, UV (ultraviolet) resistant degradable sandbags, four-point, two-strand, galvanized barbed wire, shovels, tampers, and soil and water.

Although the building process is intentionally simple, the structural integrity of Super adobe homes is the result of years of research. The structural design uses modern engineering concepts like base isolation (decoupling the ridged connection between structure and ground) and post-tensioning. The long coils of sandbags provide compression strength, vertically, while the barbed wire adds tensile strength, horizontally. The sandbags provide additional flood resistance and the earth that Super adobe homes are built on provides insulation and fire-proofing.

Founded with the principles of simplicity, accessibility, and inclusivity at its heart, Cal-Earth deemed that there should be no heavy lifting or backaches during construction, no expensive equipment to buy, and the building process be flexible and fast. Small containers like coffee cans or kitchen utensils are used to fill empty bags that are in place atop the highest layer of the home's rising walls.

Figure 14-elevation- Resistant Super adobe Reference Super Adobe Structures at Cal-Earth ideas earth bag homes, earth homes, earth ship

Addressing the Housing Needs of the Future

Cal-Earth understands that there are approximately twenty to forty million refugees and displaced persons today, and hundreds of millions more living in substandard or slum housing. When creating and following his architectural vision, Nader Khalili saw that the greatest rebuilding costs after global disasters go to infrastructure requirements and human shelter needs. In the coming decades, the organization anticipates that this housing shortage will only become more severe with compounding environmental challenges and the acceleration of natural and man-made disasters.

Figure 15-Interior Design- Resistant Super adobe
Reference :
Super Adobe Structures at Cal-Earth ideas | earth bag homes, earth homes, earthship

Figure 16-elevation- Resistant Super adobe
Reference: Super Adobe Structures at Cal-Earth ideas earth bag homes, earth homes, earth ship

comfortable, affordable, sustainable, and beautiful homes, Cal-Earth trains hundreds of people each year on environmentally sustainable building designs through on-site, international, and web-based educational programs on its California campus. Cal-Earth also organizes youth programs to foster respect for the environment and an awareness of sustainability practices.

In June 2021, after two years of research, testing, and fundraising, Cal-Earth was issued an ICC-ES number for Super adobe cement-stabilized earthbags. Calling it a "major accomplishment," Cal-Earth says that obtaining this number, along with an accompanying report and supplemental testing data, provides reassurance to building departments of Super adobe's compliance with the International Building Code [16].

17.Advantages of building with sandbags

1-Structural Limitations: Sandbag construction may have limitations in terms of structural strength and load-bearing capacity compared to traditional building materials like concrete and steel. Depending on the specific application and design, sandbag structures may not be suitable for large-scale or high-rise constructions.

2-Perceived Aesthetics: Sandbag construction may be perceived as less visually appealing or lacking the architectural aesthetics associated with conventional building materials. This could be a concern for projects where aesthetics are a priority or for areas with specific architectural guidelines or restrictions.

3-Longevity and Durability: While sandbags can be durable when properly protected from water damage and erosion, they may have a shorter lifespan compared to materials like concrete or bricks. The susceptibility to weathering, erosion, and degradation over time may require regular maintenance and repair.

4-Limited Availability and Sourcing: Availability and sourcing of quality sandbags can be a limitation, especially in regions where suitable sandbag materials are scarce or expensive to acquire. Ensuring a consistent supply of appropriate sandbags may be a challenge, particularly for large-scale construction projects.

5-Labor-Intensive Construction Process: Sandbag construction typically requires significant manual labor and skilled craftsmanship. The labor-intensive nature of the construction process may increase labor costs and construction timelines, which can be a potential limitation in terms of efficiency and productivity.

6-Regulatory Compliance and Perception: Building codes and regulations in some regions may not explicitly address or accommodate sandbag construction techniques. This could introduce challenges in obtaining necessary permits and approvals for sandbag structures. Additionally, there may be a perception among stakeholders, including investors, insurers, and potential buyers, regarding the acceptability and safety of sandbag construction.

7-Limited Research and Standardization: While sandbag construction has been used in various contexts, there may be a lack of comprehensive research, standardized guidelines, and building codes specific to sandbag construction techniques. This can affect the level of confidence and acceptance within the construction industry.

18. Results

Cost Efficiency

The use of sandbags in construction has proven to be a cost-effective alternative to traditional building materials. The low cost of sandbags, combined with the abundance of locally available soil, offers a sustainable and affordable solution for housing projects in Egypt.

Rapid Construction:

Sandbag construction techniques enable faster construction compared to conventional methods. The simplicity of the process allows for quick assembly and stacking, reducing construction time and labor requirements.

Adaptability and Versatility:

Sandbag construction techniques can be adapted to various architectural styles and building designs. The

method allows for flexibility in constructing different types of buildings, such as residential homes, community centers, and educational facilities.
Sustainability and Resource Efficiency: Construction with sandbags promotes sustainability by utilizing locally available resources and reducing the reliance on finite building materials. The use of soil-filled sandbags and barbed wire provides earthquake resistance, insulation, and fire resistance.

19. Recommendations:
Awareness and Training Programs:
To promote the adoption of sandbag construction techniques, it is recommended to conduct awareness campaigns and training programs targeting architects, engineers, and construction professionals. These programs should focus on the benefits, techniques, and best practices of sandbag construction.

Government Support and Policies:
The government should consider implementing supportive policies, such as providing incentives or subsidies, to encourage the use of sandbag construction for affordable housing projects. Collaboration with relevant stakeholders, including NGOs and research institutions, can facilitate the dissemination of knowledge and expertise in sandbag construction.

Research and Development:
Further research and development efforts should be undertaken to optimize sandbag construction techniques specifically for the Egyptian context. This includes exploring local soil characteristics, conducting structural analysis, and developing standardized guidelines for construction with sandbags.

Pilot Projects and Demonstrations:
Initiating pilot projects and demonstrations across different regions in Egypt can showcase the effectiveness and viability of sandbag construction. These projects can serve as models for future affordable housing initiatives and attract investment and public interest in this alternative construction method.

20. Conclusions:
Construction with sandbags presents a promising solution for Egypt's housing challenges in the face of population increase and escalating building material costs. The low cost, sustainability, and adaptability of sandbag construction make it a viable option to provide affordable housing while minimizing the financial burden on individuals and the government. Implementing the recommended measures can help unlock the potential of sandbag construction and pave the way for a more sustainable and affordable housing sector in Egypt.

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