

## **Low-cost building material and building techniques for Ethiopia**

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**Abstract:-** *One of the core infrastructure elements in a smart city as per the Smart City Initiative is affordable housing, especially for the poor. Another key element is the sustainable environment. Attainment of these elements calls for low-cost solutions to building materials and building techniques. The former typically consists of locally sourced materials, while the latter requires prefabricated elements for construction; thus, ensuring lower environmental footprints coupled with low-cost, thus enabling housing for the poor. Unfortunately, the conventional construction techniques employ conventional materials and are neither environment, nor poor-friendly. The developing and underdeveloped countries typically tend to use the conventional building materials along with conventional construction techniques. This results in high cost of construction and low availability of affordable housing. This study investigates a number of building materials and construction technologies, with specific emphasis on Ethiopia- a developing African country with a large population and huge lack of affordable housing. The aim of the current work is to identify low-cost building materials and low-cost, mass-scale construction technologies for developing economies like Ethiopia, with broader applicability to African and Asian countries.*

**Keywords:** *Sustainability, low-cost, affordable housing, materials, construction techniques, smart city*

### **1. Introduction**

A house is the basic need for a human being and provides protection and security as identified by Maslow and Maslow in human being theories of needs [16]. 600 years ago, there was a building construction practice in the Mediterranean which consisted of unreinforced masonry construction method and materials where bricks were traditionally made up of fired clay [13]. In fact, bricks have been (and still are) the dominant construction material in much of the developing and under-developed world. The other building materials have undergone sea changes over few decades, with more emphasis on concrete (among others). However, the new construction materials, coupled with newer construction techniques, tend to make the housing relatively expensive, especially for many of the Asian and African countries.

Ethiopia has a high population growth rate like most developing countries. High population density and high population growth in Ethiopia have led to the families that require more area and desire for new buildings. These changes in the social need and status of a growing family that desire a new house may require repositioning (relocation) of people but people are unwilling to move out of the existing property due to the expenses associated with a new house, expense of material for relocation and many of them are familiar with the setting and are comfortable with the existing house and quality of life [18]. In addition, the short supply of affordable housing has become a major challenge for residents of Ethiopia. The overwhelmingly rising demand, particularly by low and middle-income groups, necessitates adequate alternative low-cost housing projects, techniques and materials.

Low-cost housing should be sustainable, have safe construction and (should ideally) use locally sourced building materials and involve households during design and construction (production) stage of the homes [17]. The use of locally available building materials for low-cost housing for developing countries not only ensures economics but sustainability as well. The applicability of locally available materials is determined by different local fortunes: availability of raw materials, the culture of making building materials, construction methods, the powers of individuals households and willingness of entrepreneurs to partake in housing construction. However, low-cost housing material is a key necessity to ensure low-cost housing and, also to improve and maintain sustainability in the construction sector. Apart from locally-sourced materials, the availability of local labour (including the prospective homeowners themselves) results in improved quality of the house and reduces the cost of construction. Entrepreneurs, small business, and households participating in house construction can significantly lower the building cost and transfer skill, knowledge, and technology to the community and also maintain sustainability [14].

Ethiopia is one of the least urbanized countries in Africa as well as in Sub-Saharan Africa. Center for Affordable Housing Finance in Africa (CAFH) states that construction cost is the largest component in the total cost of housing delivery across the sub-Saharan Africa region and ranges between 41% to 72% of total house cost. Construction cost

per square meter for some of the African countries are Ethiopia (\$ 730), South Africa (\$ 425), Nigeria (\$ 690), Ghana (\$ 627), Tanzania (\$ 460), and Kenya (\$ 569) [12]. Based on the CAFH data, the estimated construction cost in Ethiopia is higher than in other African countries. Therefore, the construction industry needs enhancement and development of the new technologies and innovations that reduce the cost of construction focusing on construction methods and alternative construction materials.

In Ethiopia, imported building materials such as cement, steel, and timber are commonly used in low-cost construction. The use of Scaffolding and formwork for concrete construction work causes expensive building, waste materials and put a strain upon the already scarce natural resource-trees. Currently, large construction companies who are heavily subsidized by the government build western concrete frame/slab construction and dominate the low-cost governed housing. Low-cost housing is expensive because of the imported construction materials [34].

The aim of the current work is to explore low-cost building materials and low-cost. Mass-scale construction technologies, esp. for Ethiopia, that will enable economical and sustainable housing for the masses. The paper presents the necessity of low-cost building materials and construction technologies, with the specific needs of Ethiopia and presents various options based on the available literature. Based on the available materials and technologies, the authors have attempted to provide the most optimal technology and materials for Ethiopia, to ensure affordable mass-scale housing.

## **2. House needs in Ethiopia**

Ethiopian population in 2008 was around 81 million but by 2025 the population of Ethiopia is likely to be more than 125 million. Therefore, locally available materials and construction capabilities need immediate enhancement and supported by technology and innovations for a sustainable way of housing development. Socio-economic condition of Ethiopia, nevertheless, is comparable to the rest of developing countries [13]. And hence it is expected that similar materials and construction technologies can be adopted by other developing countries as well.

In developing countries, quality and adequate structural safety are important for affordable housing. A novel technology, such as block fabrication (esp., terra block fabrication) ensures quality and structural safety. The fabricator has an advantage on productivity and creates high-quality blocks and uses locally available materials and manpower. Such appropriate technology may lead to sustainable economic growth and improvement of the living standard of low-income groups [35].

Many developing countries like, Ethiopia face challenges in low-cost housing due to a high rate of population growth which leads to rural-to-urban migration. The demand for housing increases and deforestation causes lack of timber for construction. Use of Adobe technology has many advantages. This technique is simple and uses locally available materials. Adobe technology involves houses built with sun-dried clay blocks. The attempt of Adobe technology in Ethiopia have not been effective due to factors like market impact, cultural factors and lack of appropriate training to users [34].

In developing countries, the provision of low-cost housing development has been stated in the policies of most of the countries, yet the governments have been unable to address the increasing house needs of the low-income groups. Policies directly providing housing within a short period of time are impossible due to less involvement of private sectors. The governments are unable to provide a suitable condition to encourage their participation. This may cause a serious shortage of housing in near future, esp. in developing or underdeveloped countries with high population growth rates and lower economic growth rates [9].

The Ethiopian government has been attempting to implement a condominium housing project for over a decade. However, there is an enormous gap between registered households for the program and the actual houses that have been built and transferred so far. Due to the huge gap between the built house and demand of the registered households, the government was forced to introduce alternative schemes. The 10/90, 20/80, and 40/60 housing programs are the option that have been introduced by the Ethiopian government.

## **3. Affordable housing**

Low-cost housing is known as the affordable house for low-income group and middle-income groups. Low-income households desire a house through renting while owning it needs 30% of the household's income [19]. In most developing countries such as Ethiopia, 20% of the population can have a normal house unit to rent and own. The low-income groups are, in general, difficult to get involved in the housing market in developing countries. Cost-effective housing deals with a concept of reduction of cost and budgeting through project management in an effective and efficient way, through proper planning, and reducing the cost of construction without compromising quality and life cycle of structures [15].

The development of housing needs the attention of the government and entire construction industries to achieve the social stability and welfare of societies. During the development of the housing project, two elements need to be considered, price and quality. However, reduction of cost is more essential to social housing projects rather than quality factors. But it is mandatory to set up an indicator to measure house quality. The quality management system needs to be updated and revised periodically (every 5 to 10 years) to integrate it with policy changes, new construction technologies and new design standards, etc. to measure housing quality [9].

A comprehensive analysis of cost-benefit of the panelized prefabrication and modular housing methods of construction showed that the latter is more cost-effective than construction methods of panelized prefabrication [8].

In Turkey, the most popular roof type built was reinforced concrete flat roof (RCFR) and freestanding wooden roof (FSWR). Cost estimation of these roof shown that reinforced concrete flat roof (RCR) with having similar insulation condition, middle-slope roof and hipped roof types found to be 34.5% cheaper in an initial investment cost and reinforced flat roof provides a cost-effective solution against weather effects. Therefore, architects and contractors should consider the better design of building and manage housing projects and low-cost roof types and materials, thereby decreasing their roof cost and ensuring that the customers can afford lower projects budgets [7]. Low-cost housing technology of roofing has saved 22.6% of the cost of roof construction including material cost and labour cost in comparison with traditional construction materials and method [3].

Providing adequate affordable housing is the major challenge of industrialized and unindustrialized countries. The conventional construction in dense urban centers, generally, puts pressure on cost and resource efficiency. Prefabrication can give great opportunities for economic and environmental sustainability [1].

#### **4. Low-cost building material for developing countries**

##### **4.1. Compressed Earth Block**

Compressed earth block can be defined as compressed soil or pressed earth block which is building material made up from damp soil compressed by themechanical press with high pressure to form block out of anappropriate mix of inorganic subsoil non-expansive clay. After applying pressure, compressed earth block gains compressive strength and can be used for three-floor construction but also has potentialto be used up to five-floor construction [24,32].

##### **4.2. Natural stone**

Stone in the past decades has been widely used as construction materials such as a dam, road construction, irrigation and building materials. Natural stone has been used in both loadbearing and non-loadbearing structure facing in the form of masonry. Nowadays natural stones are used as stone panels.Using natural stone for wall construction with natural lime mortar can reduce the cost of wall construction by 26-35% [21].

##### **4.3. Bamboo**

Bamboo has been used since ancient time as construction materials for bridges, frame structures and building construction. Recently, bamboo has been used in flooring, walling, paneling and as fiber materials. Bamboo has good compressive strength and tensile strength as compared to materials like,aluminium, plastics and steel and requires less energy for production [20].

##### **4.4. Terracotta hollow blocks**

Terracotta hollow blocks have been made by British engineers since 1825. These are made with clay and soil, have plasticity and recently an Indian tile company has modified them to smart brick or terracotta wall blocks. A block has a size of 750mm X 300mm X 200mm for external wall and based on the function and purpose, it is available in different sizes [22].

##### **4.5. Cement concrete hollow block**

Cement concrete hollow blocks aremade up of a mixture of aggregate, cement and water with a ratio of 1:7 cement to aggregate. To ensure desired quality, proper condition of mixing, placing and curing are mandatory for such blocks. Cement concrete hollow block is more than burnt clay brick and is enables easier and rapid construction. They are an effectivematerial dueresistance to fire, resistance to sound, thermal insulation and durability [20].

##### **4.6.Ferrocement**

Ferrocement is defined as a composite material and is made up ofcement mortar reinforced with one or multiple layers of small diameter steel bar/ wire mesh bound together to create stiff structure. It has a higher performance, lightness, strength and durability. It had been used for floor, wall and roof construction [20].

## 5. Mass housing technologies

### 5.1. precast concrete construction system

Precast concrete construction system uses a variety of precast elements such as column, slabs, walls, beams, staircase, landing, etc. The precast elements are produced using sand, aggregate, glass/steel fiber, water and admixture based on the purpose of element mix design. The structural elements are cast under controlled conditions in pre-cast factories/yards. Precast structures have high compressive and tensile strengths, durability, fire resistance and are economical. The advantage of using this precast technology are suitability for high rise construction, quality, rapid construction and avoidance of time delays [1, 2, 28, 33].

### 5.2. Modular construction technology

Modular construction technology is being used world widely and is found to be more applicable. The modular building construction has extensively been introduced for multi-story and high-rise buildings. The modular building method is energy-efficient, improves productivity, and has the potential to reduce construction project cost and time. Cost-Effective and efficient installation of modular building elements is the most optimal choice for mass-housing and can also be efficiently used for small-scale developments [2].

### 5.3. Expandable polystyrene panel system (EPS)

Expandable polystyrene panel is a factory-made system based on expanded polystyrene panel and reinforced with a double mesh of steel wire interconnected to each other. To form walls, the mesh is covered with a coat of shortcrete (1:4) applied under pressure using the pneumatic system. The wall supports are vertically connected to the frame structures. Such panels are cost-effective, lightweight construction materials with excellent insulation properties [25,33].

### 5.4. Glass Fiber Reinforced Gypsum

Glass fiber reinforced gypsum (GFRG) is an Australian technology and has been used since 1990, mainly for wall construction for buildings. However, in 2013, research conducted at IIT Chennai discovered that the technology can be used for other components such as columns, beams, slabs, walls, etc. as well. The panels can be manufactured with 124mm thickness, 12m length and 3m height and contains cavities which may be fully filled, partially filled or unfilled with reinforced concrete as per the project requirements. This technology can save 20-30% cost of construction and is suitable for mass housing [23,30,33]

## 6. Conclusion

Based on the literature review, the following conclusion can be made:

1. Prefabrication can give great opportunities for economic and environmental performance and renders easier and rapid construction.
2. Modular construction technology has a potential to improve productivity, save energy and reduce project cost and time.
3. Among the various low-cost construction materials presented in the paper, locally available materials will be the best suited.
4. Selection of appropriate building materials and construction technology is vital to ensure low-cost mass-scale housing. Architects and contractors need to select these at the earliest possible stage of project planning and execution.
5. Finally, selection of materials and technology can only succeed if appropriate policy and financial support is available from the government to the private sector and includes all the stakeholders in the process.

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