DOI: 10.23968/2500-0055-2023-8-1-44-50

USEFUL STRATEGIES FOR LOW-COST CONSTRUCTION

Omar Moustafa Alomari*[1], A M Faten Albtoush[2], Mohammad Al-Rawashdeh[1]

[1] Al-Balqa Applied University, Alsalt, Jordan

[2] Jadara University, Irbid, Jordan

*Corresponding author's e-mail: omar.alomari@bau.edu.jo

Abstract

Introduction: Everyone, regardless of culture, seeks a dwelling that provides comfort and safety at an affordable cost. Many countries worldwide have witnessed increased demand for residential buildings due to population growth. However, because of the economic conditions that most countries suffer from, the search for low-cost housing without compromising the quality of construction and materials has become extremely essential. Low-cost construction meets the demand for cost-effective design solutions without prejudice to quality. **Purpose of the study:** We aimed to determine the applicability of building materials and technologies used in low-cost construction. **Methods:** In the course of the study, we thoroughly reviewed literature sources addressing low-cost construction. **Results:** Based on the review, we determined six strategies of low-cost construction: effective planning, use of low-cost materials, use of environmentally-friendly materials, use of cost-efficient construction techniques, use of available alternative construction methods, and sustainable community through involvement and training. All over the world, knowledge exchange and technology development within local societies are considered techniques that reduce the cost of buildings at the expense of local manpower. We recommend governments to enhance the involvement of local resources by developing training programs in cooperation with local communities. Besides, governments should provide opportunities for the application of environmentally-friendly construction materials and encourage their use. This study will help researchers delve deeper into the issues and obstacles occurring in low-cost construction.

Keywords: low-cost construction, sustainability, environmentally-friendly materials.

Introduction

In all parts of the world, housing is not only a place of residence but also a place where one can live calmly, in prosperity and development. It is a place where people feel safe and enjoy privacy and sense of belonging. Besides, adequate housing allows people achieve their environmental, economic, and security needs. Therefore, everyone seeks a home that guarantees basic requirements for living a decent life. One of the most pressing challenges faced by developing countries is the provision of adequate shelter for all people (Tam, 2011). For these reasons, housing is one of the essential components of any country's national strategy. To stay healthy, people need a proper place to live for the rest of their lives, and that is home (Srivastava and Kumar, 2018).

According to Adeniyi et al. (2020), there is a major problem with providing adequate housing to the population globally. As the worldwide population increases, there is an increase in the demand for housing, leading to a massive demand for construction materials, such as cement, wood, steel, etc. This means that the consumption of natural resources to produce these materials increases as well. The continuous exploitation and depletion of natural resources damage the environment (Srivastava and Kumar, 2018). The production of construction materials from natural resources results in emissions of toxic gases harmful to the environment: nitrogen oxides, sulfur oxides, and carbon monoxide. These toxic substances contaminate soil, water, air, and aquatic life, affecting the human health and standards of living (Srivastava and Kumar, 2018). Besides, the process of producing construction materials from natural resources is costly. Thus, it is necessary to adopt cost-effective, advanced, and environmentally-friendly housing technologies enabling ordinary people to build houses at affordable cost (Tam, 2011). Many studies have addressed the possibility of using new technologies based on cost-effective materials in construction to design low-cost and efficient housing.

Low-cost architecture emerges as a response to the demand for economical construction solutions that still ensure good visual, hygrothermal, and acoustic performance (Oliveira et al., 2013). Cost-effective construction is a relative concept that has more to do with budgeting and seeks to reduce construction costs through better management and appropriate use of local materials, skills, and technology while maintaining performance and structure life (Tiwari et al., 1999). With the current economic crisis, this concept is becoming increasingly important in all areas and social strata (Oliveira et al., 2013). Low-cost housing is also a philosophy of cutting-edge budgeting ideas and

strategies that help to minimize construction costs by developing expertise and technology while utilizing locally accessible materials without compromising the structure's effectiveness, existence, or strength (Varun Raj et al., 2021). Accordingly, high-quality construction materials are long-lasting, have appealing features, and require only a little maintenance (Bredenoord, 2017). Cost reduction can be achieved through the effective use of locally available construction materials and techniques that are durable, economical, accepted by users, and do not require costly maintenance (Tam, 2011). The study conducted by Tam (2011) demonstrated that using low-cost housing technologies is a cost-effective construction approach for the industry. In the case studies for walling and roofing, it was found that by employing low-cost housing technologies, it is possible to reduce construction costs by about 26.11% and 22.68%, respectively, in comparison with traditional construction methods.

There is a huge misconception that low-cost housing can only be a result of substandard works when constructed from low-quality materials (Srivastava and Kumar, 2018). Thus, it is important first to understand the concept of low-cost construction to determine its benefits. That is why this study focuses on providing a clear concept of low-cost construction in addition to determining its importance and strategies required to construct affordable housing.

Literature review

Governments around the world, and particularly in developing countries, are concerned with the rising cost of construction (Danso, 2013). Most countries are aware of the importance of affordable housing, especially those with a huge population. For example, India is currently facing a housing shortage of approximately 17.6 million houses (Tam, 2011). For this reason, some studies focus on the adoption of low-cost construction in India. Osman et al. (2017) conducted a study in Malaysia and established that despite the affordable housing policy for the state of Johor, house prices are still quite high, making it difficult for most people to reach their goal of owning a home. This is evidenced by the fact that the housing affordability index for some areas was in the unaffordable category.

Low-cost construction technologies seek to reduce construction costs by replacing traditional methods and materials. Effective planning and project management, low-cost materials, cost-effective construction technologies, and the use of alternative available construction methods can help to provide low-cost housing. In this paper, we aim to present different strategies to achieve the goal of low-cost construction. It is about using local and indigenous building materials, local skills, energy-saving, and environmentally-friendly options (Tam, 2011). That is why in the next sections, we will focus on those strategies in more detail, in addition to presenting some practical ideas about low-cost construction at this stage of development.

Effective planning

There is a widespread misconception that low-cost housing involves only substandard work and uses cheap, low-quality building materials. But the fact is that it is implemented by appropriate planning and efficient management of resources. Effective planning of a low-cost building actually starts from site selection. The nature of soil at the construction site plays an important role in reducing the cost of construction. It is worth noting that the foundation takes approximately 11–16% of the total construction cost. Therefore, it is essential to choose such a construction site where it is not necessary to lay foundations at such a high cost. In case of soft soil, the goal of cost reduction may not be fully achieved or implemented properly. As known, this type of soil requires original designs and large volumes of reinforcement steel and concrete.

It is also important to select simple drawings, which do not demand additional materials. As for building materials, their selection and purchase require prior knowledge that allows a specialist to choose high-quality and, at the same time, low-cost materials. This can be achieved through effective planning at each stage of construction, which makes it possible to avoid numerous costly changes throughout the structure's life cycle.

Low-cost materials

Due to the economic factors that most countries suffer from, which have also clearly affected the construction industry, a serious search for ways to reduce the cost of construction has started. It should be noted that one of the important factors affecting the final cost of construction is the cost of building materials. It is actually the single most important factor in carrying out a project (Ugochukwu and Chioma, 2015). The cost of materials takes more than one-third of the overall cost of erecting a structure. Thus, the use of low-cost materials can be one the ways to obtain a low-cost building without compromising the desired quality. Based on the source of building materials, Srivastava and Kumar (2018) classified low-cost building materials into natural and man-made ones.

There are several options to obtain low-cost and effective materials: producing low-cost building materials by recycling construction waste, using local building materials, or using energy-efficient materials that consume less energy.

It is common for most countries, especially developing ones, to rely on importing construction materials from other countries. Such materials usually turn out to be quite expensive. Therefore, the use of locally available materials will help to

reduce construction costs since transportation takes approximately 30% of the total construction budget (Chowdhury and Roy, 2013). Furthermore, rather than importing from elsewhere, it is also possible to build a cooperative to supply alternative raw materials and thus save 20–30% of the costs (Srivastava and Kumar, 2018). Moreover, the introduction of technological improvements to local building materials can improve traditional construction techniques in local communities (Bredenoord, 2017). Ideally, low-cost housing should use locally available raw materials. It also would be preferable if those raw materials were abundantly available or renewable in nature (Danso, 2013).

Numerous researchers have investigated the use of natural fibers derived from various plants in building materials. When compared with concrete blocks, fiber cement composites show better properties. This is primarily due to the presence of fibers in them (Moslemi, 2008). Some of those properties include better workability, resistance to cracking, a lighter weight, high fracture toughness, and a greater degree of flexibility, which are quite important in the market. Thus, those materials can be used in low-cost construction. Table 1 shows the performance profiles of some important fibers produced in India, as compiled by Chowdhury and Roy (2013).

Use of environmentally-friendly materials

The majority of resources required to build houses are non-renewable. These issues highlight the necessity to reconsider the promotion of materials that result in lower construction costs and minimal environmental costs (Adegun and Adedeji, 2017). Green building materials are environmentally-friendly, which means that they are characterized by low environmental impact. Potential green building materials should be locally available and composed of renewable resources (Hebatalrahman and Mahmoud, 2016). In their work, Adeniyi et al. (2020) demonstrated that green materials are cost-effective, readily available, energy efficient, adaptable to the environment, eco-friendly, reduce construction costs and waste, improve the economy of the community, promote cultural heritage, enhance social well-being, and reduce carbon dioxide emissions. Moreover, the use of green materials cuts the costs of building a structure to a bare minimum, while also increasing cost-effectiveness and making houses affordable for more people (Ugochukwu and Chioma, 2015). Some researchers agree that the use of green materials provides a cost-effective solution when it comes to affordable housing (Adegun and Adedeji, 2017; Danso, 2013; Shen et al., 2019).

In various countries, such as Zimbabwe, Botswana, Mozambique, South Africa, Egypt, Tanzania, Kenya, and Nigeria, such environmentally-friendly building materials as earthen materials are used. Studies show that earthen materials are relatively clean to produce because the process involves little or no fossil fuel (Atolagbe and Fadamiro, 2005; Elkhalifa, 2011; Henry et al., 2014). In the production of 25 kg of ordinary Portland cement, approximately 2 kg of CO_2 are emitted (which is up to 900 kg per ton) (Browne, 2009). As a result, cement use reduction means lower carbon emissions and embodied energy in housing construction (Adegun & Adedeji, 2017).

Table 1. **Performance profiles of some important fibers produced in India**

Building materials	Properties				
	Structural	Thermal	Temperature and water resistance	Buildability	Cost (in Rs/ square meter)
Bamboo	Works better with moisture in shear forces; has a higher flexibility than steel and a lower Young's modulus.	Excellent	Moderate	Moderate	Depends on thickness
Concrete blocks	Strength may be added as needed; less mortar joint as the size grows, which increases stability	Excellent	Excellent	Excellent	31.25
Ferrocement and aerocon panels	Lightweight, does not require wet plastering (aerocon); high strength, low density, and high mortar crack resistance (ferrocement)	Excellent	Excellent	Excellent	Depends on thickness
Mud blocks (compressed)	Economic and energy efficient	Excellent	Excellent	Excellent	15.625
Straw bales (with bricks)	Stable, high load bearing power	Moderate	Also depends on brick composition as it is mixed with bricks and mud	Moderate	NA

Source: (Chowdhury & Roy, 2013).

According to Srivastava and Kumar (2018), the following environmentally-friendly building material technologies for low-cost housing can be adopted: paint for interior and exterior walls, wall plaster, cement-waste slag brick, lightweight concrete block, decorative concrete block, concrete paving block, lime- sand brick, and concrete hollow block.

Cost-effective construction technologies

To reach the goal of low-cost construction, in addition to the use of low-cost materials, new and advanced construction technologies must be followed without compromising the quality of materials and construction. It was found that cost-effective and alternative construction technologies, in addition to lowering construction costs by reducing the quantity of building materials though improved techniques, can play a significant role in providing better housing as well as protecting the environment. It is worth noting that cost-effective construction technologies do not compromise the security and safety of buildings and generally comply with the applicable building codes (Tam, 2011). Tam (2011) also found that the use of low-cost housing technologies instead of traditional construction methods for walling and roofing can save approximately 26.11% and 22.68% of the construction cost, respectively, including material and labor costs.

Precast concrete technology is an example of advanced construction technology. It is one of the technologies used in low-cost construction (Adabre et al., 2020). It is also one of the only to combine a whole range of benefits. Precast concrete technology is also a proven solution like rapid construction and mass production.

Although bricks remain the backbone of the building industry, the quantity of blocks that are broken into different sizes to fit into position at site is very large, which results in material waste. Increased wall block size will be more cost-effective due to faster construction and less mortar consumption, which can be achieved by producing low-density larger-size wall blocks from industrial wastes such as blast furnace slag and fly ash (Srivastava and Kumar, 2018).

To design buildings that meet the requirements of technical standards at the lowest possible cost, many researchers have sought to evaluate the application of construction technologies. In this section of the paper, we review a number of technologies currently applied, which make it possible to reduce the total cost of construction.

There are various construction techniques, which can be used for affordable housing (Kshirsagar et al., 2018), such as:

- On a terraced site, it is less expensive to build a house in the middle of the terrace.
- If a building is placed parallel to the contours rather than crossing them on a sloped site, less excavation and filling up will be required.

Among other techniques, the following, investigated by Manoj and Mohd (2016), can be mentioned:

- Rat-trap bond technology: This masonry technique uses bricks to create a cavity within the wall while maintaining the same wall thickness as for a conventional brick masonry wall. Because of the cavity formed in the wall, the main advantage of rat-trap bond is reduction in the number of bricks and mortar as compared to English/Flemish bond.
- Solid concrete and stone blocks: Walls can be built using modern methods that combine solid blocks with both lean concrete and stones.
- Filler slab technology: Part of concrete in a conventional reinforced cement concrete slab is replaced with a filler material, which can be waste material, to provide an economical advantage over an RCC slab.

It is worth mentioning through the proper management of resources, which contributes to reducing waste of various materials, it is possible to obtain a low-cost building. Besides, developing an effective plan to determine project's requirements corresponding to actual conditions makes it possible to avoid a lot of risks leading to continuous losses during building operation. For instance, it is suggested not to use wood for doors and windows. Instead, concrete or steel section frames shall be used to reduce costs by up to 30–40%. It is also suggested to use burnt bricks, which are immersed in water for 24 hours and then shall be used for the walls.

Use of alternative available construction methods

Low-cost housing can be implemented by the application of particular techniques and effective planning reducing the construction budget thanks to the use of locally available materials and economical construction technologies without compromising the structure's performance, strength, and service life. Profits from the use of such methods can decrease construction costs and make low-cost housing available to all (The Constructor, 2015).

3D printing is a computer-controlled manufacturing technique used to construct a product in layers from a CAD model or a digital 3D model (Varun Raj et al., 2021). By detecting and eliminating errors early in the design process, it is possible to reduce the costs associated with incorrect design (Varun Raj et al., 2021). Han et al. (2021) found that 3D printed concrete requires a larger amount of cement than cast-in-situ construction. However, they also concluded that 3D printed concrete is more cost-effective since it helps to reduce the cost of heavy formwork and labor (Han et al. 2021). Varun Raj et al. (2021) stated that such building components as windows, doors, etc. can be produced quickly and economically with technology in the future.

Haselau (2013) summarized five alternative construction methods, which can be used to erect low-cost buildings. They include: Moladi housing technology, speedwall building systems, hydraform interlocking bricks, modular and timber construction, and straw bale construction, as shown in Table 2.

Sustainable community through involvement and training

To provide low-cost housing, local communities can be engaged, educated, and trained since exchange of knowledge and technology plays an important role in the development of various economic sectors. Bredenoord (2017) proved that using local workforce and involving local residents in housing construction is beneficial for developing the communities. Local residents, craftspeople, and businesses can all be involved in procuring raw materials and their processing into ready-to-use building materials. This way, local residents can reduce their housing costs, which is the underlying goal of self-help housing and self-reliance (Bredenoord and van Lindert, 2014).

When local residents participate in housing construction as much as possible and gain knowledge and skills, we can talk about long-term socioeconomic development. There are, however, some excellent examples of corporate involvement in housing construction. For instance, a Mexican cement company developed a social aid program (Patrimonio Hoy) that provides self-builders with building materials and technical assistance as well as credit for home renovations (Bredenoord, 2017; CEMEX, 2023). Another example is a cement company in Malawi and other East African countries that provides durable soil and cement construction solutions for affordable housing, such as earth brick production, soil analysis and mix design training, and project technical assistance. The product is called Stabilized Compressed Earth Bricks (Bredenoord, 2017). The municipal training program 'Escuela Taller' in León, Nicaragua, among other things, provides young people with opportunities to learn basic carpentry, masonry, electricity, and welding. Practical training is provided in inner city renovation projects that restore traditional style housing.

Conclusions

Given the increasing population growth around the world, the future focus on providing low-cost buildings will be a challenge for most countries. Therefore, it is necessary to search for techniques, materials, methods and strategies that would provide buildings at a low cost. In this paper, we have presented the findings of previous studies addressing low-cost construction methods. The results show that it is possible to provide low-cost dwelling through the use of effective planning and project management, low-cost materials, cost-effective construction technologies, and the use of alternative available construction methods. Recent advancements gave a boost to many new materials and technologies, which can significantly reduce the cost of construction. It should be noted that it is not necessary to use low-cost materials and technologies to obtain low-cost buildings. The use

Table 2. **Summary of alternative construction methods**

Alternative construction method	Description	Construction cost reduction
Moladi housing technology	Moladi technology involves easy-to-use plastic panels joined to create plastic structures/forms of any length and height for various walls in a building.	It is 50% cheaper than ordinary brick wall methods.
Speedwall building systems	Speedwall construction technology uses a mobile panel manufacturing machine to manufacture the floor, wall, and roof panels on site.	Speedwall structures are characterized by high energy efficiency reducing energy costs, which is an advantage for low-cost homes.
Hydraform interlocking bricks	Hydraform blocks are used in strip footing foundations, eliminating the use of mortar in 70% of the building structure with no need for concrete or steel columns.	Hydraform machines are perfect for remote sites with high transportation, cement and sand costs since the dry-stacking technique ensures savings (by 30%) in time and construction costs.
Modular and timber construction	Timber homes were reintroduced as an alternative to traditional brick and mortar dwellings.	In comparison to bricks, blocks, and concrete, which have an embodied energy of 80%, and steel, which has an embodied energy of 95%, manufactured timber components have an embodied energy of 14%.
Straw bale construction	Straw bale structures represent a low-cost alternative for building highly insulating walls by constructing a frame (usually out of wood) and stacking straw bales as if they were cement bricks to create walls.	This technique can save up to 50% of the cost of traditional wall materials.

of sustainable materials, which consume less energy, significantly reduces the cost of buildings and their maintenance. Besides, the quality of construction is not compromised. We argue that it is important to use environmentally-friendly materials, which contribute to the sustainability of buildings and reduce energy consumption. In addition, governments should encourage the use of local materials and workforce to enable them to compete with imported materials. Governments can also develop training programs to prepare the local workforce and involve them in construction, which in the end will be less costly. The study will help other researchers investigate the obstacles that developing countries face when adopting low-cost construction technologies.

References

Adabre, M. A., Chan, A. P. C., Darko, A., Osei-Kyei, R., Abidoye, R., and Adjei-Kumi, T. (2020). Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective. *Journal of Cleaner Production*, Vol. 253, 119995. DOI: 10.1016/j.jclepro.2020.119995.

Adegun, O. B. and Adedeji, Y. M. D. (2017). Review of economic and environmental benefits of earthen materials for housing in Africa. *Frontiers of Architectural Research*, Vol. 6, Issue 4, pp. 519–528. DOI: 10.1016/j.foar.2017.08.003.

Adeniyi, S. M., Mohamed, S. F., and Rasak, K. O. (2020). Socio-economic benefits of using green materials for the construction of low-cost buildings in Nigeria. *American Academic Scientific Research Journal for Engineering, Technology, and Sciences*, Vol 67, No. 1, pp. 99–108.

Atolagbe, A. M. O. and Fadamiro, J. A. (2005). Energy policy for building materials technology: a global imperative for sustainable architecture. *Elektro Mesin Arsitektur Sipil (EMAS) Jurnal Sains Dan Teknologi*, Vol. 15, Issue 3, pp. 45–57.

Bredenoord, J. (2017). Sustainable building materials for low-cost housing and the challenges facing their technological developments: examples and lessons regarding bamboo, earth-block technologies, building blocks of recycled materials, and improved concrete panels. *Journal of Architectural Engineering Technology*, Vol. 6, Issue 1, 187. DOI: 10.4172/2168-9717.1000187.

Bredenoord, J. and van Lindert, P. (2014). Backing the self-builders: assisted self-help housing as a sustainable housing provision strategy. In: Bredenoord, J., van Lindert, P., and Smets, P. (eds.). *Affordable Housing in the Urban Global South*. London and New York: Routledge, pp. 81–98. DOI: 10.4324/9781315849539-16.

Browne, G. (2009). Stabilised interlocking rammed earth blocks: alternatives to cement stabilisation. In: *11th International Conference on Non-Conventional Materials and Technologies (NOCMAT, 2009)*, September 6–9, 2009, Bath University, pp. 25–26.

CEMEX (2023). *Patrimonio Hoy*. [online] Available at: https://www.cemexmexico.com/sostenibilidad/vivienda/patrimonio-hoy [12 December 2022].

Chowdhury S. and Roy S. (2013). Prospects of low cost housing in India. *Geomaterials*, Vol. 3, No. 2, 30868. DOI: 10.4236/gm.2013.32008.

Danso, H. (2013). Building houses with locally available materials in Ghana: benefits and problems. *International Journal of Science and Technology*, Vol. 2, No. 2, pp. 225–231.

Elkhalifa, A. A. (2011). *The construction and building materials industries for sustainable development in developing countries. Appropriate and innovative local building materials and technologies for housing in the Sudan*. DSc Thesis in Architecture and Design, 412 p.

Han, Y., Yang, Z., Ding, T., and Xiao, J. (2021). Environmental and economic assessment on 3D printed buildings with recycled concrete. *Journal of Cleaner Production*, Vol. 278, 123884. DOI: 10.1016/j.jclepro.2020.123884.

Haselau, J. (2013). *Alternative construction methods for low-cost housing in South Africa*. [online] Available at: https://icoste.org/wp-content/uploads/2012/09/ASAQS-Paper-1-Haselau.pdf [24 November 2022].

Hebatalrahman, A. and Mahmoud, M. (2016). Green building material requirements and selection (a case study on a HBRC building in Egypt). In: *6th International Engineering and Construction Conference (IECC'6)*, June 28–30, 2010, Cairo, Egypt, pp. 80–91.

Henry, A. F., Elambo, N. G., Tah, J. H. M., Fabrice, O. E. N., and Blanche, M. M. (2014). Embodied energy and CO2 analyses of mud-brick and cement-block houses. *AIMS Energy*, Vol. 2, Issue 1, pp. 18–40. DOI: 10.3934/energy.2014.1.18.

Kshirsagar, S., Patil, J., Chaudhari, S., and Kumbhar, S. (2018). Affordable housing materials and techniques. *International Journal of Scientific Research in Science, Engineering and Technology*, Vol. 4, Issue 1, pp. 999–1011.

Manoj, K. and Mohd, A. (2016). An overview: low cost house materials & techniques. RIET-*IJSET International Journal of Science Engineering and Technology*, Vol. 3, No. 2, 97. DOI: 10.5958/2395-3381.2016.00012.5.

Moslemi, A. (2008). Technology and market considerations for fiber cement composites. In: *11th International Inorganic-Bonded Fiber Composites Conference*, November 5–7, 2008, Madrid, Spain, pp. 113–129.

Oliveira, M., Couto, J. P., Mendonça, P., Branco, J., Silva, M., and Reis, A. P. (2013). Low cost construction: state of the art and prospects for using structure wood apartment buildings in Portugal. In: *Structures and Architecture: Concepts, Applications and Challenges*. London: Taylor & Francis Group, pp. 2168–2175.

Osman, M. M., Ramlee, M. A., Samsudin, N., Rabe, N. S., Abdullah, M. F., and Khalid, N. (2017). Housing affordability in the state of Johor. *Planning Malaysia*, Vol. 15, Issue 1, pp. 347–356. DOI: 10.21837/pm.v15i1.251.

Shen, L., Yang, J., Zhang, R., Shao, C., and Song, X. (2019). The benefits and barriers for promoting bamboo as a green building material in China—An integrative analysis. *Sustainability*, Vol. 11, Issue 9, 2493. DOI: 10.3390/su11092493.

Srivastava, M. and Kumar, V. (2018). The methods of using low cost housing techniques in India. *Journal of Building Engineering*, Vol. 15, pp. 102–108. DOI: 10.1016/j.jobe.2017.11.001.

Tam, V. W. Y. (2011). Cost effectiveness of using low cost housing technologies in construction. *Procedia Engineering*, Vol. 14, pp. 156–160. DOI: 10.1016/j.proeng.2011.07.018.

The Constructor (2015). *Building materials for low-cost housing construction*. [online] Available at: https://theconstructor.org/building/low-cost-building-materials/5352/#:~:text=Natural%20fiber%20materials%20are%20coming,are%20made%20from%20natural%20fibers [24 November 2022].

Tiwari, P., Parikh, K., and Parikh, J. (1999). Structural design considerations in house builders' model: optimization approach. *Journal of Infrastructure System*, Vol. 5, Issue 3, pp. 75–90. DOI: 10.1061/(ASCE)1076-0342(1999)5:3(102).

Ugochukwu, I. B. and Chioma, M. I. B. (2015). Local building materials: affordable strategy for housing the urban poor in Nigeria. *Procedia Engineering*, Vol. 118, pp. 42–49. DOI: 10.1016/j.proeng.2015.08.402.

Varun Raj, P., Surya Teja, P., Sai Siddhartha, K., Kalyana Rama, J. S. (2021). Housing with low-cost materials and techniques for a sustainable construction in India-A review. *Materials Today: Proceedings*, Vol. 43, Part 2, pp. 1850–1855. DOI: 10.1016/j.matpr.2020.10.816.