

The Assessment of Alternative Low-Cost Construction Materials and Techniques for Wall Structure: A review

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Abstract: This thesis reviews the different types of currently practiced low-cost alternative construction materials and techniques used for wall structure. In recent years, rising construction costs have become a major source of concern for the construction sector. Costs of materials and machinery are two elements that contribute to the raise of construction cost. Construction professionals have suggested that using alternate building materials and methods is one way to reduce construction costs. However, there is a lack of studies and application in the Malaysia regarding this topic. To address this need in Malaysia, this study is carried out to determine which alternatives will be suited to be implemented in Malaysia. The method to conduct this research is through case study based on past research by other researchers related to the topics of low-cost alternative building materials and techniques for wall structure. According to the findings of the case study, low-cost materials can be divided into two categories: natural materials and manmade materials. The materials and methods that are reviewed in this research are Rat Trap Bond, Cellular Lightweight Concrete Brick, Fly Ash Brick, Bamboo based walls and Rice straw and husk. These materials can be used as alternative materials to build walls and other building structure. The cost, properties, and advantages are studied and are analyzed in the end of this research. Through adopting cost-effective, innovative and environmentally friendly technology it will raise many advantages not only to the construction sector but also to the society.

Keywords: Low-cost, Alternative, Wall, Material, Technique.

1. Introduction

In line with the country's tremendous development, the construction industry is also swiftly booming. The demands for new buildings and infrastructures continue to be sought after and are not expected to stop anytime soon. As we know, there are many materials and techniques used in construction regardless of the infrastructure types either to build houses, buildings, highways, roads, bridges and more. However, in recent years the urgencies for low-cost alternative construction materials and techniques have been emerging. The reason is that construction costs are rising due to supply and demand. Due to the increasing numbers of new projects and demand, the supply of materials becomes scarce. Gladly, there are many options attainable and when are properly brought into service can save a significant amount of money resulting in lower construction costs.

The topic of alternative construction materials and techniques does not run far from the concept of sustainability. By using another material, it may save the dependencies towards natural materials that are gradually decreasing such as timber, brick, aggregate, sand and more. Most of the alternative materials and techniques that are currently present emphasize sustainability and green construction because that is what is in trend for the construction industry at the present time.

The aim of this research paper is to perform an assessment of alternative low-cost construction materials and techniques for wall structure. In order to achieve that, the following are the objectives of this research:

- i. To study different types of alternative low-cost construction materials and techniques.
- ii. To give recommendations for alternative low-cost materials and techniques for wall structure.

2. Literature review

2.1 Construction Cost

Construction cost is the total cost of the overall work involved with the development of a project. It includes the costs of materials, labor and overhead costs associated with the construction of the project. Among the factors that make construction expensive is the costs of materials and machinery [1]. To ensure that a construction project is executed within the estimated budget are to perform good strategies, careful cost planning and careful judgement [2]. Meanwhile, another method to cut down construction costs is to replace the current material with other materials that are cheaper but serve the same purpose or may have even better properties. Besides, by converting the traditional or conventional techniques into new techniques it may save the use of materials also may cut down the cost of a project.

2.1.1 Cost of Materials

The price of construction materials is continuing to rise. Building materials are the most vital key element in project development and hold a crucial role in the completion of construction projects [3]. The prices of materials were not only high but also unpredictable. Among the main reason that affected the cost to increase was the rising fuel prices [1]. Materials are often imported and requires to be transported to reach their destination, the large amount of fuel for those modes of transportation require more money. Other than that, most of the materials used are derived from oil such as pipes, plastics and more. Another reason for the rise of material prices is due to high demand. When demand for a product or service exceeds the supply, merchants will raise the price to ensure that it does not sell out quickly also giving them time to prepare the supply. The next reason is due to the scarcity of raw materials, the price of raw materials rises due to their limited availability.

2.2 Alternative Building Materials and Techniques

The definition of alternative building materials and techniques is another material or method in construction works that can be used to replace the conventional materials and methods. Recently, a lot of studies have been made regarding this topic. The implementation of new building materials would aid in reducing environmental damage [4]. Apart from curbing the issue of materials scarcity, the use of alternative building materials and techniques is also an effort to increase the opportunities for housing

for low-income families. Additionally, many regions of the world are experiencing materials scarcity thus affecting the economy and construction industry [5]. Many researchers are now looking for low-cost materials as a substitute or alternative for the current scenario. Numerous materials have been proven can be a suitable alternative for current construction technologies. It is important to consider the factor that may determine the prices of the materials such as type of materials, manufacturing process and source location.

The utilization of building materials for low-cost housing in developing countries focuses more on sustainable materials [6]. The materials used must have the characteristics of basic durability where the materials are low maintenance, have good features and are long-lasting. The materials used as well need to be eco-friendly where the utilization of the materials will not affect the environment and drain the worlds' resources. Next is social awareness regarding the usage of sustainable materials in construction, to boost the utilization of these methods more research need to be made. Also, all construction personnel should join forces to make this happen by getting involved with the process to acquire raw materials and the manufacturing process to turn it into ready-to-use materials.

2.3 Wall structure

Wall is a structural element that is built vertically. Walling material constitutes approximately 22% of construction. It can be classified into inner walls and outer walls. Inner wall divides space in a room, it is also called a partition wall. While outer wall provides safety and shelter to the residents and is called as exterior wall. There are many different types of walls according to its purpose. As an example, load-bearing wall, as the name suggests it is a wall that bears load transferred on it. This type of wall is usually built with strong materials such as brick. Another example is non load-bearing wall, it carries its own weight so materials such as glasses can be used to make them. There are many technologies invented to make walls and nowadays more low-cost alternatives are used in wall construction as wall consumes most part of the building, so it helps to reduce the cost of a building. The alternatives that are reviewed in this research are Rat Trap Bond, Cellular Lightweight Concrete Brick, Fly Ash Brick, Bamboo-based walls and Rice straw and husk.

2.3.1 Rat Trap Bond

Rat trap bond is a masonry technique of stacking bricks in a vertical position rather than the conventional method. This technique was introduced in Kerala during the 1970s by Architect Laurie Baker [7]. In the case of the Flemish bond and English bond, the bricks were stacked flat horizontally and closed together. While for rat trap bond, the bricks are laid on the edge where the shiner and rowlock are visible on the surface of masonry [8]. When arranging it this way, it will form a hollow space between the bricks thus forming an internal cavity within the wall. The presence of an internal cavity in the wall improves the thermal comfort inside the building [9].

Due to the arrangement of the bricks, it requires less brick than the conventional methods also less mortar is needed. This masonry technique can save construction cost as it requires approximately 20-35% less bricks and 30-50% less mortar compared to the conventional techniques, also it enhances the productivity of work [7]. However, there are certain drawbacks to this technique, it necessitates the need for a skilled person so that the mortar does not get wasted by dropping into the wall cavity when applying it. to produce the best rat-trap bond, good quality bricks with no half bricks or quarter bricks are needed so that they will not interfere with the stunning joints in the brickwork and affect the brickwork's reliability [8].

2.3.2 Cellular Lightweight Concrete Brick

Cellular Light weight concrete (CLC) or also known as Foam Concrete is a lightweight concrete that is produced by mixing cement, fly ash, sand and pre-formed foam [10]. The process of making CLC brick is almost similar to conventional brick, only that convention brick is made by hand while CLC brick is made in a mold. Next, the advantages of using CLC as a substitute for conventional bricks, first it saves transportation cost because the CLC brick were produced at the project site, next it saves raw material as it does not requires aggregates and uses low-cost materials, ease of handling because the size of CLC brick varies and can be handled manually in larger dimensions, also it is eco-friendly

as fly ash and other industrial waste materials were used in manufacturing and it does not release any harmful materials to ground or atmosphere, in addition, it provides good thermal insulation because of the air voids that present in the CLC brick, next is good fire protection with 100m thickness and the density of 1000 kg/m³ it offers 4 hours of fire rating [11].

Due to CLC brick low-density properties, it can be used for a variety of applications in construction and in various locations of the building. CLC brick can be used for acoustic construction, precast exterior walls, green construction, additional floors to existing structures, building materials for high-rise buildings, low-cost housing, subways and more [12]. Based on a previous experimental investigation of cost effectiveness of CLC in construction study, three types of bricks were studied and compared; clay bricks, fly ash brick and CLC brick. His findings concluded that using CLC brick it can cut down around up to 10% of construction cost compared with when using clay bricks. In addition, based on the comparison of the quantities of materials required for CLC brick versus clay bricks, it was discovered that the amount of cement and sand used for brickwork and plastering work can be decreased by roughly 50% [13].

2.3.3 Fly Ash Brick

Fly ash is the waste materials produced from the coal combustion used to generate electricity [14]. In Malaysia, there are a total of six coal-fired electric power stations. Our country produces a lot of fly ash every year. To dispose this requires a lot of energy, so to fix this fly ash is utilized in many parts of building development. Fly ash has good pozzolanic properties thus making it a good alternative to cement-based products. When mixed into concrete, it improves the strength and segregation of the concrete.

Fly ash is one of the big contributors to air and water pollution. It is disposed of either by being buried in the landfill returning it to strip mines. A proper management program has been planned to dispose of the waste. One of the plans is to utilize the fly ash into construction materials. Because of the properties of fly ash, it is competitive in comparison to the conventional method. The utilization of fly ash bricks results in the conservation of natural resources as well as the protection of the environment.

2.3.4 Bamboo-based walls

Bamboo has been long used as a building material in many types of construction, especially in rural areas for housing. Bamboo is a resource that is both renewable and durable. It is considered as world's fastest-growing woody plant as it grows three times quicker than other plant species [15]. Nevertheless, the implementation of these products is somewhat limited due to the factor that they degrade and disintegrate rapidly when exposed to the damp ground unless treated. Bamboo is commonly used for building walls and partitions. In spite of the popularity of using bamboo as building materials all over the world, Malaysia is exempted from that. Bamboo is not a major building material in Malaysia because there is limited knowledge on how to use and implement bamboo as a building material [16]. Bamboo has been traditionally utilized for building houses for low-income households. As a result, it has typically been used as a convenience material, with little consideration given to studying and improving the design and structural properties to maximize its potential.

Few types of bamboo-based walls panels used in various countries were listed; whole or halved bamboo culms, split or flattened bamboo, bajareque, quincha, woven bamboo and bamboo panels. These types are either done with tying the bamboo together and the cavity is filled with hardening materials such as cement or by weaving bamboo together and plastering the surface of the bamboo. Besides, bamboo is widely used as wall because of its higher tensile strength than steel and its low weight eases the transportation effort thus making the construction cost cheaper. It is high earthquake resistance and can withstand heat up to 4000C thus making it a high fire resistance material. Besides, bamboo does not need complicated tools or equipment as it is easy to be handled, cut, requires minimum repair, and maintenance. In addition, bamboo is greatly used in green construction given that it does not cause pollution because the unused parts can be used as fertilizer or processed as bamboo charcoal [17].

2.3.5 Rice straw and husk

Rice straw and rice husk are the main product of paddy residues. Rice straw is a product of agricultural waste and the leftover products when the rice is harvested. It is the outer protective layer of a paddy grain and makes up of 20-25% of its weight. Approximately 20% of the weight of rice is received as husk during milling. Meanwhile, rice husk is the generated product during the first stage of rice milling [18]. The rice by-products have been utilized as a construction material, fertilizer, insulation, and fuel. Malaysia produced more than 300 000 hectares of paddy production. Hence made it inexpensive and easy to procure in our country [19].

Due to the large number of paddy plantations in Malaysia, it produced a huge number of agricultural wastes. Rice husks are inedible, the usual method to dispose of them is through burning and baling, but some farmers may lack baling machines so burning remains the primary method of disposal as it is efficient and inexpensive [20]. Because of those actions, it will release toxic pollutants and significant amounts of greenhouses gas into the air and will contribute to other environmental problems. In an effort to reduce the number of these by-products disposal, a lot of construction materials start incorporating the uses of rice husk and rice straw as an alternative.

3. Methodology

3.1 Research Approach

The research approach is first to gather the data related to this research through case studies about the current construction materials and methods. It is important when searching for the data is to consider the cost of the materials. After that, it is also important to learn about the potential of these methods if they can be implemented in Malaysia. When making a selection without considering these factors, it will not achieve the objective of this research.

3.2 Research Design

The purpose of this study is to give suitable recommendations of low-cost alternatives for construction materials and techniques for the wall structure. The method used for this research is mixed method. The data findings are validated using both qualitative and quantitative data. By mixing these both methods, it will help to fully understand the contradictions between the quantitative result and qualitative findings. The case study was designed to focus on low-cost alternatives for building materials.

3.3 Research Methods

The method used in this research are through case study analysis. The purpose of case study in this research is to make enough collection and comparison of data that are related to this topic. One of the objectives of this research is to study different types of alternative low-cost construction materials and techniques, to achieve that information about existing low-cost materials was searched and studied thoroughly. Sources of data for this research is from secondary data, which mean data collected from source that has already been published in any form. Sources of secondary data used are from research articles by other researchers, internet articles, published censuses and other statistical data.

3.3.1 Procedure for case studies

The procedure for performing case studies in this research is through off-site data collection. Off-site data collection is conducted by studying through literature that is related to the topic of low-cost alternatives for construction material and techniques for the wall structure. The literature review mainly focuses on online resources such as journal articles, thesis papers, news and internet article that have relevant details related to this research. The main information that is focused on when reading through this literature review is type of material, construction techniques, cost minimization and benefits. The aim of conducting the case study will help to determine whether these recommendations can be carried out in Malaysia.

3.4 Method of Data Analysis

The method that are used to analyze the data is through comparison of data from case study. The actual price is not available for each of the materials recommended, so the cost is determined by comparing the quantitative data that were collected in any sources. Among the factors that is considered when making this analysis is the materials cost, transportation and importation of materials, labor cost, production cost and maintenance cost.

4. Findings and Discussion

4.1 Rat Trap Bond (RTB)

The application RTB saves about 25% of materials in making wall. It is 20-30% cheaper than the conventional English bond wall method. Raw materials such as cement, mortar and brick can be considerably saved by applying this method. 70% to 75% cement are saved when RTB are applied instead of the English bond wall. Also, it saves up to 18% of brick and up to 54% mortar usage. In addition, RTB's dead weight is lesser by 25% when compared to the English bond wall [21]. The results from a research of comparing the performance of RTB with conventional brick bond shows that the material cost can be reduced about 23% when using RTB. Because the rowlock bridges the internal cavity, the usage of brick and cement are reduced. Overall, RTB reduces materials usage by 25%. Besides that, RTB saves electricity consumption as it has a good insulation barrier [22].

Based on the research conducted by Joshi et al. [23], RTB can save approximately 20%-30% of bricks and 30%-50% usage of mortar. To build a one-meter cubic wall, conventional method requires 550 units of brick while for RTB it requires only 470 units of brick. Also, RTB saves cost for foundations as the wall has approximately 20% less dead weight than conventional methods. RTB reduces the labour cost as it is much simpler to construct with only eight courses are required for a 950 mm high wall compared to conventional English bond that requires eleven courses. Because of the smooth surface of the brick, it does not require plastering. Thus, this ease labour, saves time and plastering cost. When considering indoor thermal comfort, RTB is a good option for walling technique to choose as it provides good thermal reduction and saves electricity consumption up to 46%. Following is the monthly electricity cost of the conventional method and RTB.

Through the findings from the research done by Chaudhary [24], RTB saves the overall cost up to 26%. For one square meter wall, it requires approximately 80 bricks against 100 bricks used in conventional English bonds, which is 20% less. To summarize, RTB reduces the cost of materials as lesser brick, cement and mortar are required. Also, the labor cost is reduced because the method to construct RTB is much simpler compared to the conventional method. Other than that, RTB provides good thermal insulation which can reduce the cost of electricity as it requires less heating and cooling.

4.2 Cellular Lightweight Concrete Brick (CLC)

Application of CLC can reduce the usage of cement and sand up to 50% also it requires less 10% of the reinforcement bar. CLC reduces the usage of reinforcement steel up to 10% due to its lightweight properties. The use of CLC blocks can reduce the cost of labour by 54%. In addition, using CLC blocks ease the construction work as CLC block size can be made of any size according to requirements. Other than that, the cost of plastering work can be reduced up to 50% as the plastering works become easier because the surfaces are plane and neatly finished [25].

To summarize, the labour cost for CLC can be greatly reduced by using this method. This is because, due to the factors like size, shape, finishes and weight of the block, the work becomes simpler and shortens the construction time and plastering work. It cuts the material cost it does not require gravel which is an expensive material, also the volume of concrete can be increased at a low cost by adding air enclosed in foam bubbles. Other than that, CLC saves transportation costs as the blocks are manufactured on-site using standard concrete machinery and molds. CLC blocks can be used in the construction of both non-load bearing and load-bearing walls. It is very compatible to be used as a

partition wall in a multi-story building and for low rise, load-bearing construction. Besides being cost-effective, it has higher compressive strength compared to other bricks, also the brick life span is longer thus will make the maintenance cost lower.

4.3 Fly Ash Brick

The application of fly ash brick saves up to 30% of brick cost compared to conventional clay brick. It also reduces cement consumption by up to 50% as these brick does not require plastering on both sides. The bricks will readily be painted as it has a uniform shape and smooth finishes. Being lighter in weight as compared to conventional bricks, dead load on the structure is reduced and hence saving is the overall cost of construction

It is difficult to estimate the cost of producing fly ash bricks because it is dependent on the availability and cost of raw materials. However, aside from material and transportation costs, it is possible to produce the bricks using a much cheaper and simpler technique that can compete directly with conventional clay bricks.

4.4 Bamboo-based walls

The application of bamboo-based walls can reduce material costs up to 40% [26]. The material is easily accessible as Malaysia has a lot of bamboos and bamboo is a self-renewing and fast-growing crop which makes it a sustainable material. This cut the material cost as it is locally available and reduced the transportation cost as it does not require the importation of materials from outside the country. Bamboo-based wall has a life span of 30 to 40 years therefore this will save the maintenance cost.

Bamboo-based wall has a compressive strength 20% higher compared to wood. Due to its high tensile strength, bamboo-based wall requires less 35% of the reinforcement bar. When compared to hardwood, bamboo is much lighter in terms of weight. As a result, this will speed up the building process. Bamboo construction does not necessitate the use of complicated or heavy machinery, the process is simple and the usage of simple tool is adequate. Aside from being cost-effective, it also adds aesthetic value to a building. Most building concepts these days incorporate natural materials to give it a more pleasing and earthy look. To conclude, bamboo is very suitable for low-cost implementation in Malaysia based on the properties of materials and economic aspects.

4.4 Rice straw and husk

Rice straw and husk are the by product when harvesting rice. It has many alternatives uses as a wall structure to substitute wood products. Among the wall products that can be manufactured using these materials are particleboard, medium density fiberboard, strawboard, cement-bonded boards, gypsum board and lastly rice husk cement and concrete. These materials can mainly be used as a partition wall. Rice husk brick is 42.5% cheaper compared to a conventional brick.

Malaysia is a large paddy producer hence making it inexpensive and easy to procure in our country. This will greatly cut the transportation cost. These materials have high insulation properties therefore will reduce the amount of energy needed for heating and cooling thus indirectly will save cost. The development of wall materials using rice straw and husk is useful as an alternative to construction materials as it contributes to reducing the environmental impact caused by the waste products.

5. Conclusion

It has been discovered that many alternatives of building materials for wall structure have been studied and applied in the construction industry. Construction costs have been a significant topic in the industry. In order to keep the material resources sustainable, many new technologies or innovations have been pursued. The cost factor was especially important because the construction industry is a continuous activity. In this study, five low-cost wall structure alternatives were identified as suitable for adaptation in Malaysia: Rat Trap Bond, Cellular Lightweight Concrete Brick, Fly Ash Brick, Bamboo Based Wall, Rice Straw and Husk Based Wall. The Rat Trap bond only necessitates a change in brick arrangement, which can be implemented immediately in Malaysia. Cellular lightweight concrete brick is already used in several countries and has proven to save money while also providing additional benefits. Fly ash brick is recommended because Malaysia generates a lot of fly ash, and this is a good way to dispose of the waste while also helping to protect the environment. Then there's bamboo, of which Malaysia is a major producer. Finally, rice straw and husk are good alternatives to choose from because they are locally available as Malaysia produced more than 300,000 hectares of paddy production. Most of these materials are locally available thus saving a great number of transportation costs. All of these materials have been shown to be less expensive than the conventional method, and they also provide more benefits than the conventional method. However, in order for it to be used in Malaysia, construction personnel, entrepreneurs, and the industry itself must promote its use. These materials, if properly researched and developed, hold the key to addressing the current construction crisis.

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