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The application of green building concept through fabrication modular construction system in special house construction

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Abstract. The cost of housing construction tends to continue to increase and various efforts have been made to reduce the cost of building special houses. One of the technologies chosen in the construction of special houses with a fast process is to use a fabricated modular construction system. The purpose of this research is to produce a technical design for the Special House as a reference in the optimal and efficient physical construction of the Special House. Research and development research methods by way of assessing and testing a product. Product assessment and testing were carried out on 11 manufacturers who fit the criteria and have produced prefabricated / precast houses. After the implementation of primary data collection, it was concluded that there were 8 Manufacturing Modular Construction systems that were likely to be optimally applied to special home products. The conclusion of the research is based on an assessment matrix from the aspects of the work system, time to work, the number of workers, financial, social and cultural as well as zoning, which get the highest score, namely Steel as the main structure. Steel has been tested for its structural strength and can produce quite a number of building material components.

1. Introduction

Green buildings or environmentally friendly buildings have a contribution to reduce the rate of global warming. Green Building is a form of concern for environmental sustainability in the construction sector. Green Building is not only related to energy saving management and waste management but also how to ensure that the building materials do not endanger the environment, both in the short and long term. The use of materials in a building plays an important role in relation to energy saving and environmentally friendly goals. Selection of the right building material for green building is Green Material, which is an environmentally friendly material. The use of Green Materials can produce quality buildings as well as environmentally friendly, especially the users of ecological materials.

The green building aspect of selecting materials is considered as a result of the increased use of some of these materials threatened with exhaustion [1]. Therefore, this aspect is especially with regard to the reuse, reduction and recycling of waste. Maximizing the use of recycled, reusable, renewable, bio-based materials that are managed in a sustainable manner. Identified ways to use high recycled material content that ranges from mixed concrete using fly ash, slag, recycled concrete aggregate or other mixtures for structural steel, ceiling and floor tiles, rugs, carpet cushions etc. Bio and based materials finishing such as various types of agriboard made from agricultural waste and byproducts include straw, wheat, barley, soybeans, sunflower skin, peanuts shells etc [2]. Reuse of household waste in the bio gas form is also a feature of this aspect. Household separation waste followed.



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One of the applications of the green building concept in house construction is the fabricated modular construction approach. Construction consisting of large-scale modulated components of a pre-fabricated building at an off-site manufacturing facility for rapid assembly on-site is increasingly gaining attention in the building industry. Modular construction involves the production of construction components (e.g., structures, materials, various types of equipment) built off-site, and modules assembled with minimal on-site effort [3,4]. In modular construction, a type of industrial construction, factory production is very important, because it is closely related to the duration, quality and project sustainability. The advantages of modular construction are shortened construction period, superior quality, transportation and reuse of materials, and reduced construction costs [5]. As such, modular construction is becoming increasingly popular worldwide, providing a solution to a shortage of skilled labor, increased labor costs, decreased productivity and sustainable construction [6,7].

Previous studies that analyzed the modular system with an assessment of the important characteristics of a successful modular project were also identified in this research. The characteristics are categorized into three areas: (1) project management, (2) design and engineering, and (3) fabrication. Meanwhile, this research is to provide a solution to the speed of providing housing which is still a major problem in the housing sector. Likewise, the quality of the material and the results of the work produced still do not meet the requirements of a livable house, constrained by various factors related to natural factors and weather. There are several obstacles in the construction of a special house in a conventional way, including a long and time-consuming construction process that is constrained by weather factors, quite a number of construction errors due to the lack of coordination of several types of work, the large amount of concrete formwork waste and the remaining pieces of unused material, inaccurate calculation of material requirements, material quality below feasibility standards, poor construction quality and even many non-technical matters. Therefore, it requires a faster construction system with good quality by reducing modifications in the field, natural factors and non-technical matters, especially for the provision of special houses.

2. Theoretical framework

2.1. Special house

Based on data from the Ministry of PUPR, the housing backlog reached 7.64 million units as of early 2020, consisting of 6.53 million housing units for low-income people (MBR) non-fixed income, 1.1 million housing units for fixed income MBR and 0, 56 million housing units for non-MBR [8]. To fulfill the housing backlog, the Government through the Ministry of PUPR provides a special housing program. Special Houses are houses that are organized to meet special needs, among others, for community houses in the border area of the country, people affected by government development programs, people who live on the outer islands, in remote areas, people who are victims of disasters, prone to social risks, cultural heritage areas, transmigrants, the elderly, poor, orphaned, and / or neglected children, communities in natural resource processing areas [9].

There are several obstacles in the construction of a special house in the conventional way, including a long and time-consuming construction process that is constrained by weather factors, quite a number of construction errors due to lack of coordination of several types of work, the large amount of concrete formwork waste and unused material pieces. used, the calculation of material requirements is not accurate, the quality of the material is below the standard of feasibility, the quality of the construction is not good and even many non-technical matters. Therefore, a faster construction system with good quality is needed by reducing the modification in the field, natural factors and non-technical matters, especially for the provision of special houses.

2.2. Green building concepts

The Green Building concept emphasizes increasing the efficient use of water, energy and building materials, which can reduce the impact of new buildings on the environment and human health [10]. The building materials chosen must also be of high quality and environmentally friendly. Several

manufacturers have made products that are able to minimize the impact of damage to the environment and at the same time save energy. Various circles agree that the concept of Green Building is a concept of the future, where all will go there in line with the increasing human awareness of environmental sustainability and energy scarcity.

In the green building concept, which always applies the principle of preserving the environment in planning and constructing buildings, in terms of materials in the green building concept, materials are renewable (renewable material). However, it does not mean that the entire material used "must" be renewable. The use of reinforced concrete and steel can still be allowed, but it must be planned as efficiently as possible to reduce the amount of material used or use an optimum material use plan (economical and strong). This is because steel is included in the Green material criteria which has advantages, among others; strong, anti-rust, easy to install and lightweight, and recyclable waste steel can be reshaped as needed [11].

2.3. Modular fabrication construction systems

The modular system is a method of implementing construction by utilizing fabricated materials or components that are made outside the project site or inside the project site, the installation of which needs to be assembled first between the components (erection) where they should be / the position of these components [12]. In a modular system, there are three levels of construction methods, namely [13]:

- Prefabrication is a manufacturing process that is carried out using special tools in which various types of materials are put together to form part of a building.
- Preassembly is the process of assembling pre-fabricated components in places that are not where these components are located
- Modules are the result of the assembling process of pre-fabricated components, usually requiring a large enough mode of transportation to move them to their proper positions.

The implementation of a construction project that applies a modular system will follow the sequence of activities as follows: (1) planning; (2) design and engineering; (3) procurement; (4) fabrication; (5) transportation, handling and erection [14]. Of the five activities planning is a process that deserves attention, this is because the aspects to be considered are more numerous and more complex when compared to conventional methods. Compared to conventional methods, the application of a modular system requires the interaction of various activities. The modular system will change the relationship between activities that were previously independent from each other (conventional methods) to become interdependent. As in the implementation of building structural elements, which are usually carried out sequentially, it is very possible to be carried out in parallel (fabrication, on-site implementation). Plans for some activities can be implemented in advance, for example: arranging permits for transportation, handling, erection.

3. Research methodology

Using the Research and Development System / Research and Development. Is a method for developing and testing a product [15]. The idea of a modular system has been around for a long time and requires deeper study and thought so that it can be maximally applied in planning the construction of a special house. Data collection can be divided into 2 types, namely data collection at the location of the planning sample and data collection by surveying the manufacturers of houses. Collecting data in the planning sample locations to find out problems related to special houses, the existing conditions of the location, a description of the acceptance and understanding of the local community on the application of the modular system for special house buildings. Meanwhile, the survey of manufactured house manufacturers aims to obtain the most effective and efficient system to be applied to special house buildings using a modular system. Determination of samples of prefabricated houses using the Solvin formula.

Based on the results of the calculation of determining the sample using the Solvin formula above, the producers who will be used as data collection materials are obtained by 50 producers. Data collection from 50 producers was further classified into primary data sources and secondary data. Primary data is obtained by conducting a direct survey to the factory to determine the production procedure in the factory to the direct installation technique of the fabrication house, while secondary data is obtained by using a material catalog from each manufacturer. The determination of primary and secondary data is done by first classifying the material produced from each producer.

After obtaining the system to be studied then determining the producer as the sample to obtain primary data. Sampling to obtain primary data is to use a purposive sampling system. Where according to Sugiyono, stated that purposive sampling is a technique of determining the sample with certain consideration [16]. Based on the criteria of producers who have produced prefab houses, 11 producers will be obtained as primary data sources. After determining the 11 producers then preparing a survey implementation document as a condition for conducting a visit in the form of a structured interview instrument and documentation during the survey in the factory.

4. Results and discussion

After the implementation of primary data collection, information was obtained that if there are several modular products produced by one manufacturer, there is only one system that is prioritized for making prefab / precast housing products. Although it does not rule out other systems to be developed. So it can be concluded that there are 8 systems that are likely to be optimally applied to special home products. Manufacturing Modular Construction Systems, is the answer to the construction problems mentioned above. Where the understanding of the Manufacturing Modular Construction System is:

- Modular Construction System, which is a combination of certain elements with the same or different scales that can be arranged into one complete unit by using the unification system.
- Fabrication method is a construction method in which mass-produced components are assembled in a building with the help of other lifting and handling equipment.
- So that the Manufacturing Modular Construction System is a building construction system whose components are mass produced by a manufacturer, which is a combination of elements arranged into one unified whole.

4.1. Types of fabricated modular systems

There are many manufacturing modular construction system technologies that are developing in Indonesia. Of the 50 manufacturers studied, 11 of them were visited their production sites and 39 others were studied through secondary data, it can be concluded that there are 8 Manufacturing Modular Construction systems, namely: 1) Light steel systems, 2) RISHA systems, 3) Steel systems as the main construction, 4) Precast concrete system as the main construction, 5) Expanded Poly Sterene (EPS) walls, 6) Concrete Mix walls (a mixture of cement and styrofoam), 7) Poly Urethane (PU) walls, and 8) Styrofoam walls and plastered wire mesh.

The main advantages of mild steel structures are the light weight of the material and the mild steel system is well known to the public. Galvalume material quality both in terms of thickness, protective layer and tensile strength of the material [17]. But the assembly system requires a high level of accuracy and requires a very careful initial planning because it consists of many lightweight steel frame components. Must have a mature Standard Operating Procedure (SOP) and clear component connection pictures. The packing system per part must be correct so that at the time of assembly there are no difficulties. Requires a highly skilled workforce.

The RISHA system is a construction system developed by Puslitbangkim of the Ministry of Public Works, Bandung. It consists of the main structural components (sloof, column and beam) made of high quality concrete [18]. Concrete material is the most common material known by the public. But in terms of weight, concrete material has a high weight. So that usually the printing of RISHA material is carried out in a small workshop that is made as close as possible to the location of the construction of a special house. So that it is still unable to produce almost all building elements, it is still limited to producing

building structural components. Materials such as walls, frames, doors, windows, ceilings, electrical, plumbing and sanitary are supplied from outside. Coordination of work is rather difficult, so there may be delays in construction schedules or construction errors.

The precast concrete system as the main structure has a large weight because the forming material consists of several components (concrete iron, cement, concrete sand and split stone) [19]. In terms of shipping costs, using this material will experience price swelling in terms of distribution / delivery of goods. Apart from this, it is a solid concrete material, which produces a high self-weight, so the connection system must be very good between one structural component to another. EPS (Expanded Poly Sterene) and PU (Poly Urethane) wall systems are modern building material innovations consisting of structural components and infill walls of the same material [20]. The connection system is very easy and has been formed in the factory that produced it. The assembly process is relatively easy because it is a wall panel that is designed to be easy to connect. The similarity of the material forming the structure and the infill walls, make the house building look compact and homogeneous. The building material is very light so it can produce cost efficiency in terms of shipping goods. In addition, this EPS wall material has a disadvantage if there will be changes in the plumbing and electrical installations on the walls in the future. Because the outer layer of the wall component is made of metal. Metal materials will be difficult to repair completely compared to coating materials made of kalsi board or GRC.

Styrofoam and cement wall systems or known as concrete mix panel walls have a large weight even though they are still under the weight of precast concrete [21]. The high weight of the material results in large shipping costs. Some of the forming materials are still imported so that some materials are dependent on fluctuations in the dollar exchange rate. Like the EPS walls above, in material storage, before being installed, it also needs special treatment, such as not touching the ground directly. It is feared that there will be a decrease in quality, especially in terms of structural strength.

The Styrofoam system with wire mesh still requires a lot of time-consuming work in the field. For example, aci plaster work is still needed in the field, which is a work item that takes up a lot of time in the construction process. Likewise, in the wall material there is wire mesh as a structural component whose connection must be done by binding one part to another one by one. Requires slightly more manpower to assemble this system material compared to other modular materials.

4.2. Determination of the appropriate manufacturing modular system

To determine the modular system that will be applied to the construction of this particular house based on the following assessments: 1) Indicators of the success and accuracy of technology in the construction system, analysis of technology or the appropriate construction system, in this case, is based on indicators; Availability of materials, production capability, quality of production, ease of construction systems, ease of distribution of materials. 2) Indicators of the success and accuracy of technology based on construction workers based on an assessment of the number of workers. 3) Indicators of Success and Accuracy of Technology Based on Socio-Cultural Aspects regarding the level of public understanding of the modular system, conformity to community culture and the level of public sense of security towards this system. 4) Indicators of the success and accuracy of technology based on financial aspects in terms of price, shipping costs, field implementation and building quality. 5) Indicators of the success and accuracy of technology based on zoning aspects in terms of the process of transporting materials, materials around the location, wall materials can use materials from the local area, and the ability to withstand the strength of an earthquake 7 on the Richter scale. The results of the indicator assessment are used to analyze the selection of a fabricated Modular construction system that will be applied to a special house construction project. The following are the eight (8) assessment matrices of fabricated modular construction systems that will be applied to a special house building project as follows:

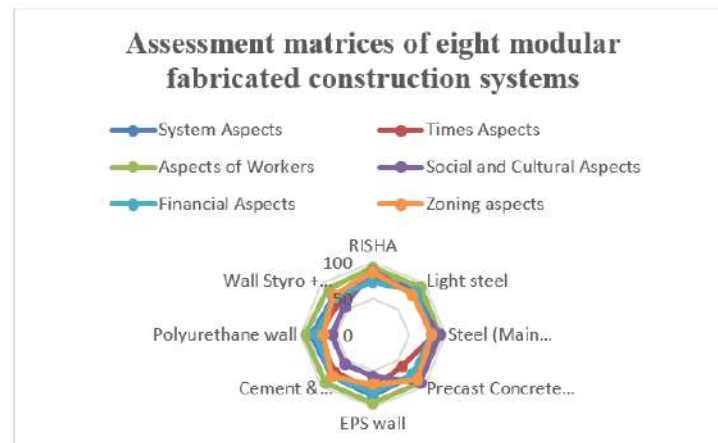


Figure 1. The results of the analysis of the fabrication modular system selection. Source: researcher analysis 2020.

Based on the assessment matrix in figure 1, the one that gets the highest score, namely steel as the main structure is chosen as the main structure, is considered the most optimal fabrication material to be applied in the construction of a special house. From 5 samples of the planning area, the analysis results show that in 4 locations the steel system as the main structure is superior in various aspects. In addition to steel having been tested for structural strength, steel producing companies are generally large-scale companies with high production capacities, can produce quite a number of building material components such as the main superstructure (columns and beams), roof truss and coverings, window door frames. as well as the ceiling frame. This manufacturer also has many possibilities to be able to produce other supporting material products such as wall panel products, Engineering Doors, and can supply materials that form components of ceiling coverings, floor coverings, plumbing and electrical (because it has sufficient land to store goods supplied from outside). Work coordination can be better maintained because it is in a production environment.

5. Conclusion

Based on the assessment and product testing carried out on 11 manufacturers who match the criteria and have produced prefabricated / precast houses, it is concluded that there are 8 Fabricated Modular Construction systems that are likely to be optimally applied to special housing products. Based on the assessment matrix from the aspects of the working system, processing time, number of workers, financial, social and cultural as well as zoning, the highest score was Steel as the main structure. Steel is chosen as the main structure is considered as the most optimal fabrication material to be applied in the construction of special houses. The concept of an environmentally friendly building or green building concept takes into account the planning, implementation and use of construction products that are environmentally friendly, efficient in energy and resource use, and low cost, and pay attention to the health and comfort of the occupants, all of whom adhere to sustainable principles. The Green Building concept pays attention to the level of operation to building maintenance. Benefits of Green Building Development include environmental benefits, economic benefits, social benefits. The environmental benefits of steel materials include environmentally friendly materials, economic benefits in terms of cost efficiency, saving time and labor, and social benefits, especially steel materials are easily obtained in all corners of Indonesia. With advantages from various aspects, the steel system is the main structure. combined with fabricated wall materials, EPS is the most optimal system applied in a special house with a modular system.

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