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A Case Study on an Engineered Timber Building in Johor Bahru

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Abstract: Engineered timbers are nowadays widely used as construction materials and might be a kind of high demand materials in common construction of buildings of structures in the future generation. Owing to difficulties to fit most of the complex structural designs, engineered timber has been introduced to progressively solve problem as such. This research was conducted to investigate the material quantity of an engineered timber building in Malaysia. This study focused on the comparison of material quantity used for the similar building in both engineered timber and steel design. Comparison of material quantity was determined in this study by analysis of result of a specified engineered timber building with other conventional buildings using steel. This study revealed that engineered timber building had an overall lighter mass as compared to steel designed building. Engineered timber building was comparatively higher volume in material quantity as compared to steel design of the similar building, but the overall mass of steel building was larger than in engineered timber building. This showed that engineered timber building was comparatively a better choice as it was not only lighter than steel building, but also proffered forth more advantages to environment. In fact, the engineered timber has gained popularity to our community as the pros outweighs the cons such as lightweight and this revealed that engineered timber was growing more popular and was widely used in Malaysia.

Keywords: Engineered Timber, Material Quantity, Comparison

1. Introduction

In this era of globalization and modernization, the use of engineered wood products in construction industry has grown rapidly. The popularity of engineered wood products continues to increase due to some important factors such as sustainability, aesthetics and speed of construction. Although timber has been proven to have those basic principles which is suitable to be used as construction materials, to some extent, it is considered to be too difficult and complex to apply for more rigorous structural

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designs. With development and evolution of time and experience, introduction of "engineered timber" has progressively overcome this problem [1].

Engineered timber like structural timber which includes strong solid timber, Glued-Laminated Lumber (Glulam) and Laminated Veneer Lumber (LVL) has gained popularity both in term of usage and application as well as in research area. Large trusses and glulam beam and arches industry have also gradually improved to cope with the wide range of applications of engineered multi-storey projects. Glulam is an engineered stress-graded product, which is made by gluing lumber together for 50mm or thinner pieces. The final product can be made into a form of straight beam or a complex and curved structural member. For LVL, it is a structural lumber product designed to compete especially with large size of sawn timber which is primarily to be used as beams, headers, rafters in construction and flanges for wood I-joints. LVL consists of thin wood veneer sheets which is bonded adhesive and the orientation direction is parallel to the long direction [2].

Advantages of engineered timber building are environmental-friendly, sustainable and lightweight. Prefabricated modular construction systems of low-carbon with the use of prefabricated engineered solid wood panel construction systems such as principles of design for disassembly and load-bearing cross-laminated wood panels will provide golden opportunities for reducing Greenhouse gas (GHG) emissions and avoiding waste which is essential to maintain and preserve a sustainable environment [3]. In the effort to protect our environment, some industries have successfully adopted new technologies by recycling the wood from demolished buildings for use in new ones and it will biodegrade rapidly becoming natural soil when it is eventually discarded. It is our only green building material which is renewable, one that will be available to us as long as our forests are being well maintained with an eye to everlasting for wood production [4]. In addition, prefabricated modular construction systems of low-carbon with the use of prefabricated engineered solid wood panel construction systems such as principles of design for disassembly and load-bearing cross-laminated wood panels will provide golden opportunities for reducing GHG emissions and avoiding waste which is essential to maintain and preserve a sustainable environment [5]. There is also another comparative research analyzed emissions of GHG in timber replacement buildings which gives results indicating that a net carbon dioxide emissions reduction can be achieved in buildings with the use of timber as construction materials [6]. The weight of wood constitutes only 20 percent of the concrete weight for the same structural volume and capacity. Due to this lightweight, there is 80% of weight reduction as compared to concrete. Hence, this is reason of promoting the use of wood instead of other heavier material like concrete [7]. Compared to a concrete framework, this reduction reflects approximately a 30 percent saving on construction time [8]. There are some research projects have evaluated the safety of CLT high-rise buildings in several areas regarding the functional and safety requirements such as fire safety [9], sound insulation, thermal performance and durability[10].

The study was aimed to investigate the comparison of material quantity for both engineered timber and steel design building. Comparison of materials for both glulam timber and steel in floor, beams, columns as well as purlins of frames with respect of quantity in volume and mass was determined. This comparison contributes significantly in encouraging the application of engineered timber in Malaysia by replacing other conventional building materials like steel and concrete.

2. Materials and Methods

2.1 Materials

In the study, the similar case study building was selected with two different building materials such as engineered timber glulam as well as steel and concrete. Timber Concrete Composite (TCC) flooring was used in this engineered timebr building which is the combination of engineered timber and concrete in timber design whereas full concrete flooring was used in steel concrete design. For beams, columns and purlins of frames, the materials used were glulam and steel.The data for engineered timber building was obtained from the WOODSFIELD company whereas the data of steel design was obtained from the manual calculation of the similar building.

2.2 Methods

In the study, quantity of materials of a building can be measured using method of takeoff quantity. Long wall and short wall method also known as general method, separate method, individual wall method or out-to-out and in-to-in method was used to measure the length and width of floor as well.

Since the comparison of material quantity is in term of floor, beams, columns and purlins of frames, therefore, for the calculation of floor, beams, columns and frames in both timber and steel design can be obtained by using Microsoft Excel to generate the result.

Whereas for material quantity of an engineered timber building and in steel design building, the quantity can also be measured by using service unit method. For the building in both timber and steel design, the service unit will be number of glulam columns, glulam beams, glulam portal frames as well as steel columns, steel beam and steel monopitch frame.

2.3 Equations

Material quantity in volume can be determined as shown in the Eq.(1) whereas mass of materials used can be determined as shown in the Eq.(2):

$$V = l\ x\ b\ x\ h \quad Eq.1$$

where V is volume, l is length, b is width and h is height.

$$\rho = \frac{\mathrm{m}}{\mathrm{v}} \qquad Eq.2$$

where ρ is density, m is mass and v is volume.

3. Result and Discussion

3.1 Comparison for quantity of TCC flooring and full concrete flooring

By referring to Figure 1 and Table 1, the quantity of material for both TCC flooring and full concrete flooring can be determined. There is a total of six parts which are Part A, Part B, Part C, Part D, Part E and Part F.

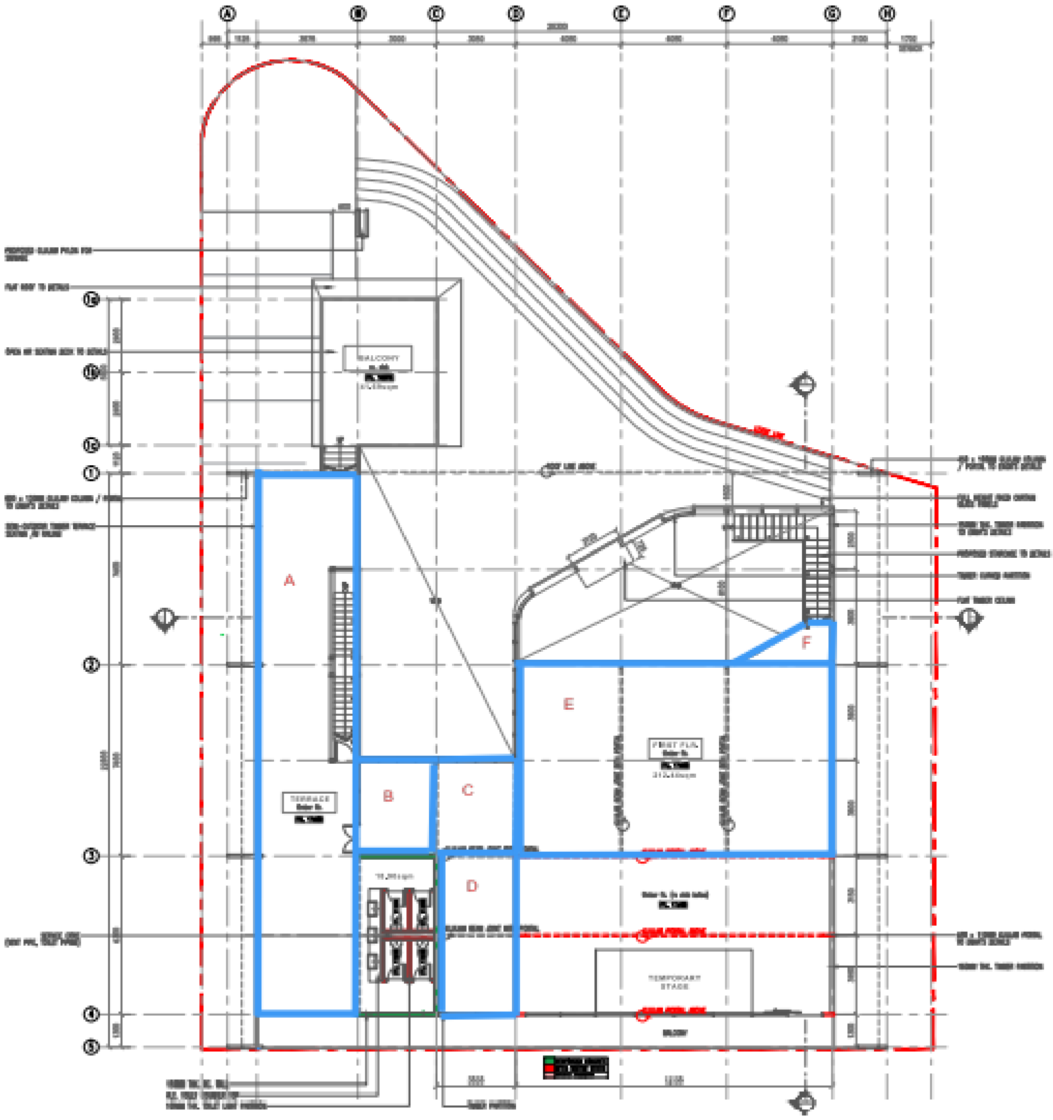

Figure 1: Six parts labelled from Part A to Part F

Table 1: Timber Concrete Composite (TCC) flooring quantity

Description	Slab thickness, d (mm)	Concrete weight (kN/m^3)	Volume (m^3)	Weight (kN)
TCC flooring	60	25	13.31	332.85
Full concrete flooring	125	25	27.74	693.48

Table 1 shows material quantity and weight required for TCC flooring and full concrete. Assumption of slab thickness was made and for TCC flooring, the slab thickness, d = 60 mm whereas for full concrete flooring, the slab thickness, d = 125 mm. In the real case of engineered timber building located in Masai, Johor, the total volume of material quantity of the building with TCC flooring is 13.31 m^3 whereas for the full concrete flooring, the total volume of material quantity required is 27.74 m^3. Assumption of concrete weight with 25 kN/m^3 was made and the weight of the building with two different types of flooring can be calculated. The entire weight of the TCC flooring is 332.85 kN whereas for the full concrete flooring, the weight is 693.48 kN. Therefore, it can be clearly seen that the weight of TCC is about halved lighter than the weight of building flooring using full concrete.

3.2 Comparison for quantity of glulam beams and steel beams

Table 2 shows the volume and mass required for glulam beams and steel beams. By referring to Appendix A, the overall volume of glulam beams denoted as "B" and "J" is 20.76 m^3. Based on the glulam density of 900kg/m^3, the overall mass of glulam beams required for the entire building is 18688.23 kg. Based on steel design in Appendix B, the volume and mass of steel beams required was also calculated as shown in Table 2 which are total in volume of 2.60 m^3 and total mass of 19989.10 kg. Even there is a big difference of small beams connecting between glulam main beam, the overall mass of steel beams is still larger than in glulam beams. Therefore, it can be clearly seen that the same building in timber will generally have smaller entire building mass than in steel building.

Table 2: Volume and mass required for glulam beams and steel beams

Description	Density (kg/m^3)	Volume (m^3)	Mass (kg)
Glulam beams	900	20.76	18688.23
Steel beams	7700	2.60	19989.10

3.3 Comparison for quantity of glulam columns and steel columns

Table 3 shows the volume and mass required for glulam columns and steel columns. Based on steel columns design in Appendix C , the number of steel columns required is 31 whereas for glulam columns based on Appendix A, the number of glulam columns required for the entire case study building is 25. Table 3 shows the material quantity in volume required for glulam columns is 7.93 m^3 whereas the volume required for steel columns is 1.19 m^3. The total mass of glulam columns required for the entire building is 7140.78 kg whereas for columns in steel design, the mass is 9197.26 kg. From the result, it shows that the total mass of steel columns required is larger than in glulam columns.

Table 3: Volume and mass required for glulam columns and steel columns

Description	Density (kg/m^3)	Volume (m^3)	Mass (kg)
Glulam columns	900	7.93	7140.78
Steel columns	7700	1.19	9197.26

3.3 Comparison for quantity of glulam portal frames and steel monopitch frames

In timber design, the quantity of glulam portal frames is 4 which is similar as the number of steel monopitch frames in steel design. Table 4 shows the purlins volume and mass required for glulam portal frames and steel monopitch frames. For purlins which connecting the frames in glulam portal frames, there is a volume of 15.31 m^3 whereas for purlins in steel monopitch frames, there is a volume of 0.06 m^3. The mass for the glulam portal frame is 13780.80 kg whereas the mass for the steel monopitch frame is 479.45 kg. The mass for purlins in steel monopitch frames is smaller than glulam portal frame and this may be due to smaller size of purlins and shorter length designed in steel solution.

Table 4: Purlins volume and mass required for glulam portal frames and steel monopitch frames

Description	Length (m)	Density (kg/m^3)	Volume (m^3)	Mass (kg)
Purlins of glulam portal frame	24	900	15.31	13780.80
Purlins of steel monopitch frames	21.324	7700	0.06	479.45

4. Conclusion

Instead of choosing conventional building materials to construct a building, engineered timber can also be a good choice to be used for construction or building materials. From the comparison of both timber and steel design of similar case study building, the main advantage of engineered timber building is lightweight. This shows that the overall lightweight for a building using engineered timber as materials can provide a similar performance to the serviceability features comparing to those conventional building using steel and concrete as materials.

To summarize, use of engineered timber as building materials improved the overall lighter weight of the similar building. Hence, the use of engineered timber as building materials is encouraged as this will help to save cost in foundation design as compared to heavyweight construction load like steel and concrete of the similar building. This is especially true if the reduction in loads allow use of a shallow raft foundation rather than deep piles that might otherwise be required. Due to its lightweight, this is especially encouraged to be used in highly seismic sites. The use of engineered timber as materials will surely proffer forth advantages such as save cost, sustainable and environmental-friendly.

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