FRIM TIMBER TECHNOLOGY BULLETIN
NO. 107, 2021
ISSN: 139-258

MASS TIMBER BUILDING (MTB): A NEW GREEN REVOLUTIONISED BUILDING INDUSTRY

How SS

INTRODUCTION

Green buildings refer to building designs that emphasize on lowering the demand on environment in many facets. These include direct and indirect energy consumption, water usage, and carbon footprints (Srinivas, 2015). Malaysia is ranked as the 30th in the world that has the largest amount of carbon emission. According to the identified industrial sectors, the construction sector has accounted for 24% of the contribution of carbon dioxide (CO_2) emission (Kluffalah, 2014). Amongst the identified root causes to the contribution of carbon footprints is due to the lack of public awareness and knowledge on the benefits and importance of green buildings (or sustainable buildings).

The awareness on timber as an alternative building material, especially in multistories building projects, appears to be lacking. Furthermore, the acceptance on timber buildings by the general public and some stakeholders is low. A study initiated in Australia identified this as a psychological barrier due to lack of understanding in the building and construction process (Kremer & Symmons, 2016). As for Malaysia, many property buyers and some stakeholders are unaware about the presence of engineered timber products that can be incorporated partially or comprehensively in building designs. In addition, the general public has the misconception about timber (Symons, 2020) by equating the utilisation of timber as an absolute environmental unfriendliness. Unfortunately, many are not aware about the contribution of carbon footprints that are much higher from the conventional building materials. Many may have overlooked timber as a green material that is renewable and can be sustainably managed.

In this paper, the benefits of timber-based engineered materials for construction application are highlighted. Selected engineered timber products are introduced, followed by introduction to Mass Timber Buildings (MTB). Examples of global and local MTB projects are listed with the aim in promoting the potential of MTB to the readers. The objective of this paper is to bring greater awareness to the public on the importance and benefits of green buildings using timber-based engineered materials.

Benefits of Utilisation of Timber-based Engineered Materials in Construction

Sustainable material

Timber can be naturally harvested from trees. This is the only renewable mainstream construction material (Symons, 2020) that can be "regenerated" and recycled without the need of sophisticated technology. Unfortunatey, the utilisation of timber is often being misled as an act of “environmental thief”. Little do many realise that other natural elements, such as clay, lime, iron ore, chalk, bauxite, calcium…etc that are common in manufacturing of concrete and steel, are unreplenishable. On the contrary, timber is renewable and can be sustainably managed.

Recyclable

Timber is versatile even for its second life. In some countries, initiatives have been in placed in giving unwanted timber products a second life. Programme such as the Timber Stewardship implemented in Australia, is targetting on improving the recovery of post-consumer timber and timber products. Considering that timber is degradable in nature, the recycling process is simpler and faster. The material is lean; it is effectively zero to waste when comes to the end of its lifecycle because it can eventually be converted into compost for planting.

Green Material

Timber contributes to a smaller carbon footprint, and it emits less greenhouse gases than other materials. Common building materials such as concrete, metal and bricks, require greater amount of energy during production than timber. In regards to CO_2 emission, timber produces the lowest CO_2 emission per square meter: at an average of 48 kg of CO_2/m^2 in comparison to steel at 345 kg of CO_2/m^2, and concrete at 330 kg of CO_2/ m^2 (Buchanan & Levine, 1999). In terms of energy consumption for production, study showed that a ton of bricks requires 4 times more than timber, 5 times more for concrete, 24 times more for steel, and 126 times more for aluminium (Bracaglia, 2014).

In Malaysia, the energy consumption in the building sector using the Industralised Building System (IBS) has recorded that timber consumes only 1.5% of energy for the total building materials (Lim *et al.*, 2017). In terms of contribution of CO_2 emission in the manufacturing of construction materials, timber accounts for only 1.1% while the remaining are predominantly from cement, steel, and ceramic (Figure 1). A carbon footprint analysis carried out by Lim *et al.* (2017) had found that the manufacturing process of cement had accounted for the highest carbon footprint record due to its processing that requires heating up of elements to 1400 degree Celsius. Manufacturing of steel bars using the hot-rolled process had contributed to the second highest in CO_2 emission due to the high energy requirement in the process. Other significant CO_2 contributions include the extraction of diesel and manufacturing process of autoclaved aerated blocks.

Mass Timber Building (MTB)

The advancement in timber engineering has been on-going since early 1930s (Smith & Snow, 2008). The interest in fabricating tall timber structures using mass timber products picked up in the early 21st century, and has progressed more aggresively in recent decades when Cross Laminated Timber (CLT) was initiated by the green building movement (Anon., 2021). The emergence of engineered timber products - more popularly known as the mass timber (www.thinkwood.com), has enabled building multistories using engineered timber. This has created an uptrend on timber skyscrappers in conjunction with promoting green building projects at global scale.

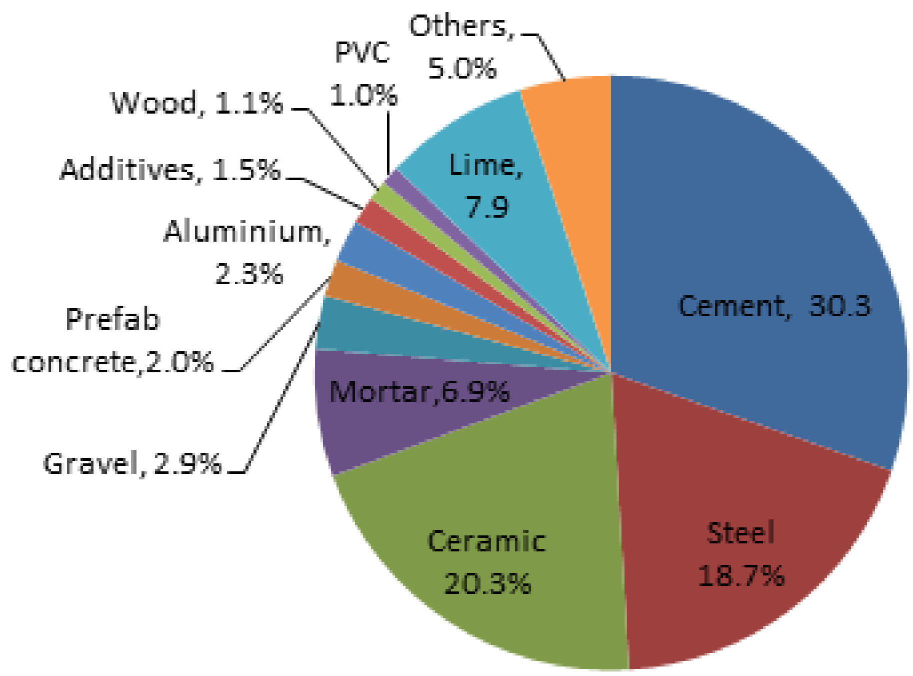

Figure 1 Contribution of CO_2 emissions for manufacturing of construction materials (Lim et al., 2017)

What is mass timber?

Mass timber has been classified as a new category of timber products that comprise of multiple solid timber panels glued or nailed together. It provides exceptional strength and stability. According to American Wood Council, mass timber is a category of framing style typically characterised by the use of large solid timber panels for wall, floor and roof construction (AWC, 2021).

There are several renowned mass timber products common in the marketplace. This includes glued-laminated (glulam) components, laminated veneer lumber (LVL), nail-laminated timber (NLT), dowel laminated timber (DLT) and cross laminated timber (CLT). The following are some brief introduction to the selected mass timber products:

a) *Glued-Laminated Timber (GLT or glulam)*

Glulam comprised of composition of solid timber laminates, oriented in the same direction along the length of the member, and laminated using adhesives. Glulam is renowned for its remarkable strength and stiffness. With these superior characteristics, glulam is often used for beams and columns. The main advantage of glulam over concrete beams and columns is its flexibility in manufacturing, which enables the possibility of fabricating into complex curvature or geometry in building designs. In addition, due to its high strength and stiffness performance allows design with wider column span in a building to be made. According to the International Building Codes (IBC), glulam is recognised under conformance with ANZI Products - Structural Glued-Laminated Timber (Anon.[2], 2021).

Figure 2 A section of glued-laminated (glulam) timber (Image by Fakrul Hisyam T.)

b) *Cross Laminated Timber (CLT)*
CLT consists of layers of solid timber (typically in odd number of layers) oriented and laminated at right angle (90°) to each other (Figure 3). It can be used in hybrid and composite applications with exceptional strength, dimensional stability, and rigidity. It shares much similarity to pre-cast concrete panel, and it is often used in replacing concrete slabs. Hence, CLT is well suited for box-framed structures such as floor, walls, and roof systems.

Figure 3 Cross laminated timber (CLT) - Image by Hamdan H

c) *Nailed Laminated Timber (NLT or Nail-lam)*
NLT refers to solid timbers being laid and fastened side-by-side using nails or screws to form a larger timber panel (Figure 4). This technology has been in placed for a century using handcraft method in joining the timber together. This lamination technique regained its popularity in recent years using machinery during nail-jointing. It is effective in adapting in shapes, thus it is popular in fitting timber members along the curved structures of roof and canopy.

Figure 4 Example of Nailed laminated timber (NLT) - www.thinkwood.com.

d) *Timber-concrete composite*

Timber-concrete composite flooring is a system that allows long-span flooring. The advantage of the product is that it satisfies the structural (increase load-bearing & rigidity), serviceability, acoustic (sound insulation), and fire requirements in high-rise buildings. In recent trend in mass timber systems, hybrid option appears to be more popular and as a faster solution in overcoming challenges in the timber building projects. Moisture resistance from weather and moisture proof from the underground are resolved using timber-concrete composite.

Figure 5a Timber-concrete composite of concrete and laminated timber (https://structurecraft.com/materials/mass-timber/timber-concrete-composite)

Figure 5b Timber-concrete composite with CLT (www.eurotec.team).

Advantages of MTB

MTB are often associated with green building projects. Nevertheless, the advantages of MTB can go beyond in providing as the carbon sink platform. There are many tangible and intangible benefits of using MTBs as follows:

1. *Cost-effective and On-site Building Friendly*

   Mass timber constructions can be well-managed with proper planning and careful design. It can be prefabricated in the manufacturing plant, and can be readily transported out for on-site assembly. The on-site building work is less labour intensive (75 percent lesser) and less reliant on heavy construction equipments. In general, the on-site building time is shorter. Study showed that a mass timber project is approximately 25 percent faster than that of the similar project using concrete (AWC, 2021). When all are taken into account, the project will effectively be more economically attractive to the construction stakeholders.

   Considering that the building assembly work in mass timber project is less intensive, the access to the project site is easier. An experienced engineering firm has claimed that the required construction traffic is at least 90 percent lesser than concrete and steel project (AWC, 2021). This effectively creates fewer disturbances to the neighbourhood during construction, having less on-site noise pollution, traffic congestion, and site waste (Kremer and Symmons, 2015).

2. *Flexibility in building designs*

   In general, mass timber products such as glulam are equivalent or stronger than solid timber (Suhaimi *et al.*, 2004) & (Komariah *et al.*, 2015). Such attribute has enabled MTB with wider span designs since it can easily be spanned to 30 meters or wider (APA, 2008). One recent example, the design of the Nanyang Technological University (NTU) Sports Hall in Singapore comprises of column-free arches spanning at 72 meter between the side supports (Alcer, 2018).

3. *Improved fire resistance performance*
   Timber is often associated for its combustible characteristics, while concrete and steel have given the false impression that they inherit better fire resistance performance. Unfortunately, such impression is misled and many may not be aware that concrete spalls at temperature higher than 100°C, steel buckles at 550°C and melts at 1300°C. This implies that concrete-steel building can easily collapse when the temperature rises up above the threshold values.

   As for timber members in large dimensions, charring on the surface of timber during burning will act as a natural fire insulator. The carbon content in the char limits the oxygen supply to the untouched timber and slows down the burning penetration. Larger timber member such as glulam is able to retain the building stability in a fire longer than other building materials. According to a study in 2015, timber below charred level will cool down and retains 85 to 90 percent of the structural integrity (Anon., 2015).

4. *Promote of Wellness to Occupants*
   Studies on the effect of occupants in timber buildings indicate that timber buildings and interiors have brought much benefit to the occupants. The benefits can be broadly grouped into a) healthier living, and b) improved overall well-being.

   The hygroscopicity nature of timber that absorbs moisture when the air is wet and release moisture when the air is dry under certain limit causes the humidity level of a room to be at an equilibrium state that is favourable for human comfort and health (Spiritos, 2021). Furthermore, timber used in structural and finished material improves the indoor air quality and sound insulation (ThinkWood, 2021).

   In addition, timber-based architectural and interior designs are well-known for bringing the "zen" ambience that portrays serenity and calm. Similar psychology studies has resulted the same research outcome that timber is beneficial to the emotional state of people: it reduces blood pressure and heart rate, it promotes calmness (Anon., 2014), and it reduces stress at large (Anon., 2017), (Augustin & Fell, 2015) & (Olt, 2021).

A Glimpse on Selected Local and Foreign MTB Projects

a) *Foreign Projects*

Figure 6 Mjøstårnet and surrounding in Norway (Photo from archdaily.com)

Building name	:	Mjøstårnet
Year	:	2019
Height	:	85.4 m
Location	:	Brumunddal
Country	:	Norway
Description	:	▪ Built with glulam columns, beam and diagonals for load bearings ▪ CLT is used for elevator shafts and balconies (https://www.moelven.com/mjostarnet/)
Application	:	Hotel

Figure 7 HoHoWien, Austria (Photo from SIGA.swiss)

Building name	:	HoHo Wien
Year	:	2019
Height	:	84 m
Location	:	Vienna
Country	:	Austria
Description	:	▪ Hybrid construction ▪ Prefabricated mass timber elements for ceiling panels, supports, joist and façade elements (https://www.e-architect.com/vienna/hoho-tower-in-vienna) (https://www.housingevolutions.eu/project/hoho-wien-the-worlds-tallest-wooden-high-rise/)
Application:	:	Multi-uses for office units, hotel, restaurants, retailers and apartments

Figure 8 Brook Commons, British Columbia (Photo by Archello.com)

Building name	:	Brook Commons Tall House
Year	:	2017
Height	:	53 m
Location	:	Vancouver
Description	:	▪ Prefabricated mass timber components ▪ Building was assembled in 70 days. ▪ Hybrid construction with floor construction from CLT panels and columns from glulam (https://www.thinkwood.com/projects/brock-commons-tallwood-house)
Application	:	UBC student residence

Figure 9 Treet, Norway (By Rune Abrahamsen)

Building name	:	Treet
Year	:	2015
Height	:	52.8 m
Location	:	Bergen
Country	:	Norway
Description	:	Load-bearing framework structure made of glulam beams, columns and diagonals were placed in every fourth level. The structure was later built with concrete slabs to weigh down the building from swaying in windy environment. (https://www.buildup.eu/en/practices/cases/treet-wooden-high-rise-building-excellent-energy-performance)
Application	:	Apartment

b) *Local Initiatives using Mass Timber Products in MTB Projects*

Figure 10 Glulam gallery located in Johor Bahru (MTIB)

Figure 11 Malaysian Pavillion at the Expo Milano 2015 (ConstructionAsia)

Figure 12 Curved glulam beams were used as the dome hovering design of the Crops for the Future Research Centre (CFFRC), University of Nottingham, Broga, Selangor, Malaysia

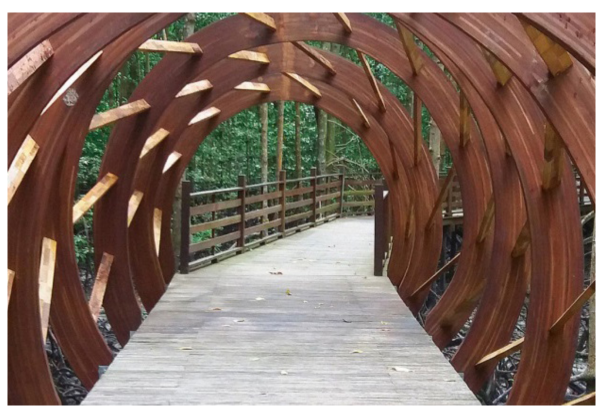

Figure 13 Lookout spot along the walkboard at Pulau Kukup National Park, Johor

CONCLUSION

Mass timbers are the future materials for green buildings. The awareness and knowledge about timber as green alternative material, especially for the building industry, are much needed. This paper introduces mass timber building and has tied in the information on the tangible and intangible benefits of timber skyscrapers. It is envisaged that by promoting awareness it would change the mindset of the property buyers and the building stakeholders. Lastly, it is hoped that through awareness and encouragement, this would bring forth mushrooming of many more mass timber projects in Malaysia.

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This paper intends to raise the awareness of mass timber products as alternative building materials for green construction projects. The benefits of timber-based engineered materials for construction applications and selected engineered timber products are highlighted herein. Mass Timber Building (MTB) is introduced, accompanied with examples of global and local MTB projects.

Series Editor : Mohamad Omar MK & Ong CB
Managing Editor : Vimala S
Typesetter : Rohayu Y

Set in Times New Roman 11

Printed by Publications Branch, Forest Research Institute Malaysia
52109 Kepong, Selangor