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CROSS-LAMINATED TIMBER: PRODUCTION OF PANEL USING SESENDUK TIMBER SPECIES

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Introduction

Engineered wood is an alternative material for the construction industry to overcome the dwindling supply of solid timber. The history of engineered timber dated back few decades ago whereby small pieces of timber were glued together with the available adhesive technology at that time to produce large piece of timber to sustain the load when used as an element in buildings. Over the years, technologies were developed based on numerous research to improve the structural integrity of the product. But the concept is still the same, that is to produce large timber product from small timber element. It has been recognised as a sustainable way to use timber for building construction. In addition to that, it provides the architects and engineers unlimited possibilities of designing building with exceptional design and at the same time retain the beauty of timber.

In Malaysia reinforced concrete and clay or sand brick are the main materials for building construction, but without an alternative material to complement the resources, the industry will have to face a shortcoming in the supply of material in the future. The solution is to use more engineered timber products that will definitely have more environmental benefits and economical advantages.

Normally engineered wood is always associated with glued-laminated timber. In fact, there are also other products such as Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), I-joist etc. and the newly industrialised product, Cross-laminated Timber (CLT) that have been developed over the years.

What is CLT?

CLT is a panel product that is manufactured by laminating pieces of timber boards in perpendicular orientation to form the layers of the panel. The layers for the panel are usually in odd number that ranges from 3 to 7 layers. Nine layer panel is feasible but it would be impractical and uneconomical due to more layers and adhesive being used. The usual width is up to 3 m and length can be up to 18 m. Each individual lumber thickness can be in the range of 12 mm to 45 mm and width in between 60 mm to 240 mm. Even though the width and length of the panel is limitless, the manufacturing facilities and transportation of the panel to construction site have also to be considered. Since CLT was pioneered and developed in temperate climate countries, the main species used for production consist of softwood that were cultivated from plantation such as spruce, fir and pine. Hardwood species have also been utilised in some CLT building projects that include birch, ash or poplar. The important criteria of selecting species for CLT is that the resources must be adequate, has the economic value as well as meeting the minimum requirement in terms of the mechanical properties.

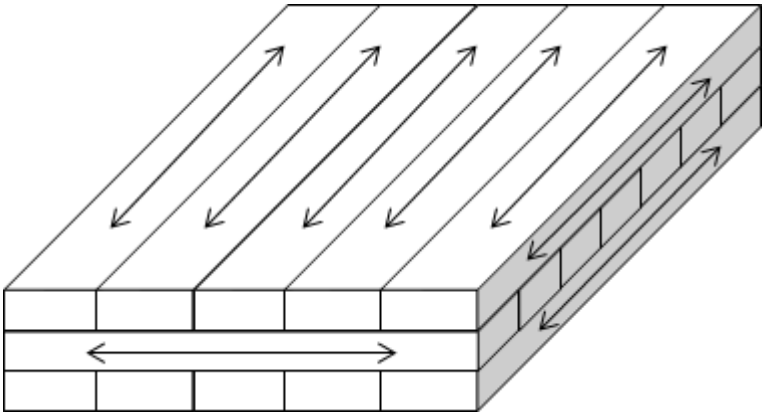

Figure 1 Direction of grain for each layer of Cross-laminated Timber

Advantages of CLT

Benefit to the construction industry	1. Short construction time and minimized labour usage as the panel is prefabricated 2. Less waste as panels are manufactured to specific end-use 3. Cost effectiveness as compared to concrete, masonry and steel building
Benefit of the material	1. Flexibility in design for longer spans by increasing thickness 2. The cross structure of components guarantees integral stability 3. Fire resistance is better due to thicker timber member 4. Acoustic performance improves due to the mass of the wall 5. Environmentally sustainable material that has lighter carbon footprint
Material properties and performance	1. Relatively high in-plane and out-of-plane strength and stiffness properties 2. High axial load capacity for walls 3. High stiffness/strength-to-mass ratio 4. High shear strength to resist horizontal loads

Application of CLT

CLT can be practically used in the following parts of a building:

1. Load bearing wall
2. Roof
3. Floor

CLT project at FRIM

FRIM through the project "Development of Cross-laminated Timber (CLT) Using Pioneer Species Timber into Structural Panel for IBS Application" funded by Ministry of Science and Technology (MOSTI) embarked on development of CLT in Malaysia. Being the first known CLT project being developed locally, it receives cooperation from the industry.

Process flow of Cross-laminated Timber

(1) BASE MATERIAL (Kiln dried)
- Moisture content of 12%±3%
- Board thickness 38 mm and width 115 mm
  Boards length; parallel 3048 mm,
  perpendicular (core) 1219 mm

(2) PROCESSING
- Strength (stiffiness) grading
- Trimming
- Finger jointing

(3) LAMELLAS
- Thickness after sizing is 30
  mm, width 100 mm
- Adhesive application to
  edges for single layer gluing

- (four-side) planing
- Edge-gluing

(4) SINGLE LAYER PANELS
- Edge-gluing; number of
  lamellas; parallel layer 13 pieces,
  perpendicular layer 31 pieces
- Resurface to 25 mm thickness
- Adhesive application to panel
  surface for face gluing

- Resurface
- Face-gluing

(5) CROSS LAMINATED TIMBER
- 3 layer panel; 75 mm
  thickness; outer layer parallel
  to the length of panel

- (four-side) planing
- Face-gluing

Production process

The production of CLT follows the scheme as follows:

1. Selection of timber
2. Preparation of timber
3. Gluing processes
4. Trimming and edging of finished panel

Timber boards received in bulks from mill usually contain certain percentage of under graded timber and have to be sorted out. The moisture content of the timber received needs to be ensured approximately 12%±3%. High moisture content will cause high dimensional movement of the timber thus recondition or drying of the timber is compulsory. Timber is selected based on the degree of deformation be it warping, cupping, twisting etc. Extensive deformation may result in loss of timber size when processing. Any sign of deterioration of the timber is strictly prohibited. Preservative treated timber is preferred somehow untreated timber is acceptable provided that timber has the durability. Timber preparation starts with sizing of the timber boards for edge gluing process to the size of 30 mm thickness and 100 mm width. Consideration on the thickness has to be taken into account as further surfacing after gluing is needed. Adhesive application is controlled by the adhesive spread rate, open assembly time, close assembly time, pressing pressure and pressing time. These are the important factors that will affect the bonding performance of the glued area. Phenol-resorcinol formaldehyde which is known for its structural capabilities in bonding are used in the gluing process. In addition to that, the phenolic resin has the ability to be used for outdoor application. The gluing process starts from edge-gluing to resurfacing to face-gluing. The panel is assembled in a way that the layer is perpendicular to the next layer's grain direction. Final sizing are done accordingly after the adhesive has fully cured. Size and cutting for window and door fixing depends on the specification as stated by the builders.

Use of sesenduk for CLT

Sustainable resources from lesser known pioneer species are applicable to the production of CLT. For example, sesenduk (*Endospermum malaccense*) is a pioneer species that is fast growing with wood density that ranges from 305 to 655 kg m^{-3}. The medium to large trees that is capable of reaching 40 m tall and 3 m in girth is commonly found in lowland to lower mountain forest of peninsular Malaysia. It is classified as light hardwood timber with strength grouping of SG7 as in MS544:2001. The timber is non-durable but very easy to be treated with preservative. The timber properties is considered applicable to be used in construction of building through lamination. There is an initiative for plantation using sesenduk species to complement the supply of the timber in the future. On recent study, the properties of the species from plantation is comparable to the species derived from forest.

Properties of sesenduk CLT panel

Strength of an engineered timber product such as CLT is important as these material will be impose to load in its structural application. Engineers and designer of buildings made using CLT panel would need such information to prevent mishap once the building is erected. Testing of the panel is done in the laboratory based on the method specified in *British Standard EN 408:2003 Timber structures- Structural timber and glued laminated timber.Determination of some physical and mechanical properties.* Sesenduk CLT panel with thickness of 75 mm were cut to strips with width 300 mm and length correspond to 18 times the thickness of the strips. The strength of the CLT panel from sesenduk were as Table 1.

Table 1 Mean ultimate and basic stress properties of 3 layer 75 mm CLT panel made from sesenduk timber based on BS EN 408:2003

Panel	Maximum Load, kN	Modulus of Rupture, N/mm²		Modulus of Elasticity, N/mm²	Compressive Stress N/mm²	
		ultimate stress	basic stress		ultimate stress	basic stress
75 mm	56.96	47.14	14.37	13069	28.10	9.61

Figure 2 a) bending test of CLT strips; b) rolling shear failure; c) Glueline failure of CLT strips after tested

Bonding properties

Table 2 show the results for total and minimum delamination in percentage of samples tested. The properties of the adhesive used in producing CLT panel have to be good enough to withstand the climatic condition during its service period. To determine this, an accelerated aging test were done to observe the delamination of the bondline when exposed to extreme condition. The method used was according to *prEN16351 Annex c : Delamination test of glue lines between layers,* where a gradient of moisture content were introduced that will build up internal stress to the panel. The movement of wood between layer would cause delamination to occur if bonding were insufficient. As sesenduk timber has moderate shrinkage in tangential and radial direction, and the adhesive is phenol-resorcinol formaldehyde, the bonding properties are fairly well.

Table 2 Total and maximum delamination percentage of 3 layer 75 mm CLT panel from sesenduk

Panel	Total Delamination, %	Maximum Delamination, %
75 mm	3.24	6.06

Test satisfied if Delamtot ≤10% and Delammax ≤40% for all samples

Construction of structural building

Construction of CLT building from sesenduk has to take into consideration the durability of the panel for long term use as the timber is susceptible to biodegradable agent. Proper consideration on protecting the wood from these agent has to be taken care of in the designing of the building. Preservative, coating and sheathing are essential for the CLT building to prolong its serviceability. Other consideration would be on the fire protection of the timber. As timber tends to ignite easily, a proper protection of the timber is needed to prevent the ignition process of fire from breaking in a CLT building. This can be carried out either during the process of panel making by introducing fire retardants or when the building has been constructed by applying repellents in the finishing.

Normally, construction of building in modern and traditional building method use the concept of post and beam system. Static loads from the roof or upper floor are distributed to the post that support it. The advantage of using CLT is that the loading area is much bigger as the whole wall system is a load bearing system. This makes the system more stable and does not need the support of post to maintain load. Also the design of the building can be different from the current building design as no post and beam is used. CLT incorporates and relies on the integrity of the connection system used. Few connection systems have been recognised to connect CLT floor and wall panels.



(source: http://www.wbpionline.com/uploads/images/files/feb_mar_2012/cross_laminated_7.jpg)
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(source: http://www.woodsolutions.com.au/dotAsset/3b972752-ec7b-4c0f-a182-00473b09e336.jpg)

Conclusion

Engineered wood product such as Cross-laminated Timber is the preferred building material among timber builders for the advantages that the panel has such as utilization of small dimension timber as structural components. Issues of excessive forest logging and environmental impact results in depreciating supply of local timber resources in Malaysia thus price are increased. These factors does affect builders' decision in using timber in their construction projects. Many are substituting timber component such as roof truss with aluminium or steel component. Research done on CLT panel enable builders to utilize non-structural grade timber and lesser known species into structural component. This also reduced the dependency on high-grade commercial timbers that are decreasing in numbers. Furthermore, the advancement of CLT building system provides a new method for builders to design and build their structure as well as the advantages of reduced construction time and labour cost. CLT building may include other engineered wood product component such as glulam, LVL, I-joist etc. and can also be hybrid building of concrete and CLT. The possibility of using the panel is limitless as it is the future direction of timber utilization in building construction. There are already medium-rise building made out of CLT and many residentials and municipal buildings are built using CLT in Europe and other developed countries. In Malaysia, CLT is still at introductory stages where few studies are done at Forest Research Institute Malaysia (FRIM). There is huge potential for CLT to be implemented in Malaysia and the construction industries have the opportunity to use timber as their building materials.

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