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# AN OVERVIEW OF MANUFACTURING PROCESS OF GLUED-LAMINATED TIMBER

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Does glulam sound familiar to you? It is common in timber engineering but may be alien to the public with limited knowledge about building materials. So, what is glulam about and why has it gained such popularity in the building industry? Glulam, an abreviation of GLUed-LAMinated timber, is one of the engineered timber products that can be used as structural components. It is made of layers of laminations and these laminates can be made from full size timber without jointing, or jointed from short-length timber segments that are cleared of strength affecting defects and preferably with timber that has straight grain orientation. Most of the natural defects present in timber are deemed mechanically deteriorating. When these defects have been removed and the remaining timber reconstructed using adhesives, the mechanical performance of the laminated product is presumably performing at par to that of the full size member if not better. The glued-laminated beam can be used as a straight member, or as curved member as illustrated in Figure 1a and Figure 1b respectively.

Akin to glulam fabrication is the fabrication of wood veneers in the era of the ancient Egypt civilization (APA, 2015). Similar concept to fabrication of plywood was used and the technology had evolved to fabrication of glulam where constructions with glulam were found in Europe during World War I. The first patented glulam technology known as "Hetzer system" was widespreaded across the European regions (Chugg W.A, 1964). Nevertheless the application of glulam at that period was confined to in-door condition due to limited suitable adhesive. Glulams for exposed condition were started sometime later when synthetic resins became available. By then mushrooming of application of glulam as building materials can be witnessed across various constructions such as timber bridges, parabolic arches and other long span structures around the world.

Glulam has gained its reputation in the building industries for its versatility, high strength-to-weight ratio, superior fire performance and corrosion resistance. Due to its versatility, the material itself enables design of aesthetically pleasing structures without the need to be beautified by addition of cladding and thus saves site time and cost. It also allows design with large spans stretch as wide as over 50 meters span (GLTA, 2016). Amongst the recent glulam buildings showcasing the application of complex curved members using glulam can be seen as in Figure 2.

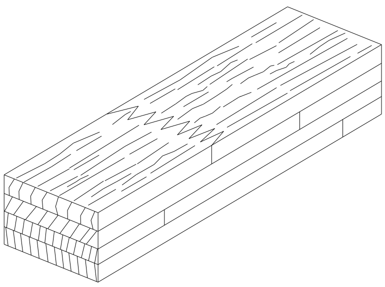


**Figure 1a** Straight glulam beam

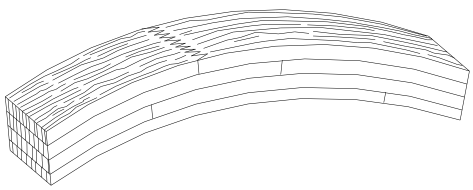


**Figure 1b** Curved glulam beam


**Figure 2** Acana glulam structure in Dominican Republic (photo exerpt from http://casadecampoliving.com)

The first glulam building project in Malaysia was the Masjid Jamek FRIM, Kepong constructed by FRIM in 1977. Glulam beams were used as the roof rafters (Figure 3 and Figure 4). This building is possibly the oldest existing glulam mosque in the world. In recent years, a glulam gallery was built in Johor Bahru in 2011 showcasing the potential of glulam made from local timber species as the future sustainable building material (Figure 5). Another example is the glulam domes designed for the Crops for the Future Research Centre (CFFRC) of the Nottingham University, branch in Malaysia (Figure 6a & b).


**Figure 3** Masjid Jamek FRIM

**Figure 4** The interior of Masjid Jamek FRIM - roof rafters made from Glulam beams

**Figure 5** Glulam gallery in Johor Bahru, Malaysia

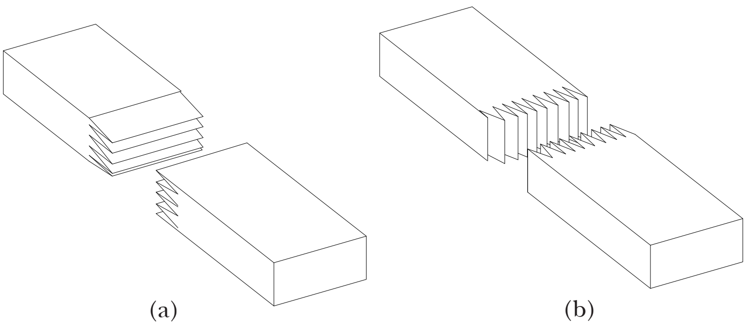
(a) (b)

**Figure 6** (a) The exterior of the dome building of the Crops for the Future Research Centre (CFRCC) Malaysia; (b) the interior of the CFRCC with closer lookup on glulam beams (Siti S. & Yeap Z.X., 2015)

## Orientation of finger-jointed timber for Glulam

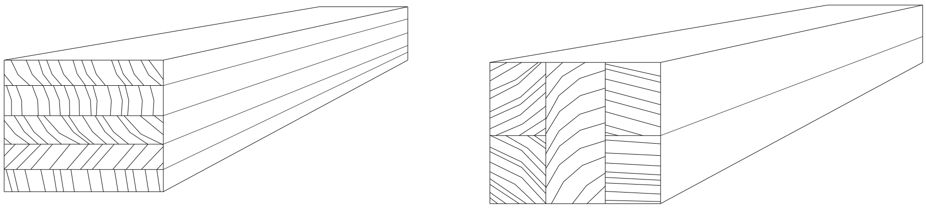
There are two types of finger-jointed lamination based on the arrangement of the finger profile, namely horizontal finger-joint (Figure 7a) and vertical finger-joint (Figure 7b). These finger-jointed timbers will be used as lamella or laminates in the lamination process based on end use application. Identification on the type of finger-joints is essential as this will determine the direction of the stresses to be distributed to the finger-joints during loading. Horizontal finger-joints are normally used for furniture, whereby the zig-zag finger profile is hidden to give homogenous surface. Vertical finger-joints are more stable and normally opted for glulam construction. Nevertheless, both horizontal and vertical finger-joints are widely being used for glulam.

In addition to the orientation of finger-joints, the orientation of the laminates would also depend on its end use. There are two types of laminated beams, namely horizontally laminated beam (Figure 8a) and vertically laminated beam (Figure 8b). Horizontally laminated glulams are the common configuration used in most construction. Vertically laminated glulams are meant for components that need to be curved when looking from plan view such as the timber rafters used in a round tent-like roof.



(a) (b)

**Figure 7** (a) Horizontal finger joint; (b) vertical finger joint



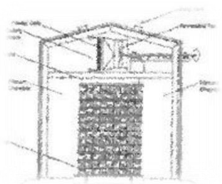
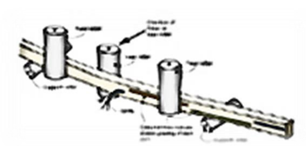
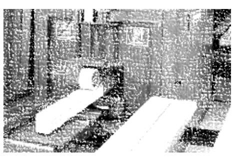
(a) (b)

**Figure 8** (a) Horizontally laminated beam; (b) Vertically laminated beam

## Type of Adhesives

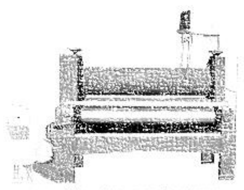
The most common synthetic adhesives in the glulam industry are phenol resorcinol formaldehyde (PRF), urea formaldehyde (UF), and polyurethane (PUR). As to-date, many of the structural glulam buildings are made using PRF. UF is considered for non-structural use due to its less weathering resistance nature, aesthetic and cost efficiency. In recent years, a new type of structural grade adhesive known as Polyurethane (PUR) is gaining popularity. It is a one-component adhesive that does not require any mixing of hardener or filler. The outcome from the adhesive bonding is durable and strong. However, it requires specific application method due to its fast curing characteristics. It is meant for glulam factories that are equipped with dedicated glue spreader and trained workers that enable working within short period of assembly time.

## Glulam Laminating Process

| Process | Descriptions |
|---|---|
| Preliminary grading | |
| Feedstocks are pre-select before drying (optional depending on production capacity and cost-benefit of the manufacturer) | |
| ***Preparation of Pre-gluing Feedstock:*** | |
| *Drying*  | Feedstocks are dried to within a range of moisture contents specified by adhesive suppliers. These can be air-dried or artificially dried to reduce the moisture content to between 8% and 14% as suggested by adhesive producer. |
| *Strength grading*  | Air-dried timbers are sent for strength grading. Only the structural grade timbers will be considered for fabrication of structural Glulam.<br><br>Grading can be done by means of non-destructive tools such as machine stress grader, natural frequency tools, or visual grading. |
| *Finger jointing*  | Undesirable defects are visually identified or by means of laser detector such as via using WoodEye ™ to determine the removable defects. Signals are sent to cross-cut the identified defects.<br><br>Later, these shorter length “defect-free” timbers known as shooks are conveyed to the finger profiling line for finger profiling followed by finger jointing (Figure 9 and Figure 10). |
| *Planing*  | Finger jointed timbers are sent for planing to improve surface smoothness and uniformity of dimension. This is to facilitate lamination and improve wood-adhesive bonding. It also helps to minimise raised grain, warping or cupping occurence |

**Lamination process:**

*Glue spreading*




Appropriate adhesive mixed are prepared and applied on the surface of the finger jointed timbers by either one or both of the following adhesive applicators:

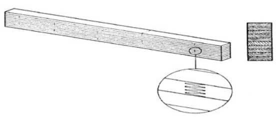
i) hand rollers (Figure 11)
ii) glue guns
iii) spray guns
iv) glue spreader (Figure 12)

Both sides of the lamella surface can be concurrently spreaded with adhesive using the glue spreader at a recommended spread ratio ($g/m^2$) by the adhesive manufacturer. However, the recommended spread ratio varies and should be customised based on the type of timber species handled in the lamination process. By rule of thumb, higher density timber requires lower spread ratio and vice-versa.

Freshly planed wood surface would make better and stronger glue joints and only minimum time should the timber be exposed between the planing, glue spreading and lamination process so as to minimise surface contamination, occurrence of raised grain, warping or cupping. It is best that gluing is done right after planing process. Thus, it is wise to ensure the glue spreader to be placed near to the planer to facilitate working both machines in tandem.

Assembly time is the duration for assembly of the glue surfaces together prior to application of pressure. Optimum handling time on the spreaded lamellae shall be taken into consideration to ensure the optimum assembly time as recommended by the adhesive supplier could be achieved.

*Layout of laminates*



End joints are the points of weakness. The use of greater number of end-joints in the laminates will introduce more point of weakness.

Approximately 15 percent of the thickness of the glulam beam on both sides of the outer zones is considered the critical zones where maximum compression and tension would occur under bending. Thus the laminations within these zones are considered the critical laminations. If mixed grades of laminates are used in the beam, these layers of laminates are required to be proof-tested (AS/NZS, 1998).

Another important criterion during layering of the laminates is that the end joints should not fall in line to the adjacents end joints to ensure uniform distribution of stresses is attained throughout the beam during loading.

*Cramping/Clamping*

After glue spreading, the glue spreaded laminations are transferred to the cramping or clamping station. Cramping or clamping is the process where the lamellae of the glulam member are clenched using clamping jigs, screws and bolts.

The type of cramping bed depends on whether the glulam member is curved or straight.

Assembly of a curved member involves transferring the glue spreaded laminations to the pre-determined cramping points on the cramping bed where the bending radii, thickness of laminations for bending and spacing of cramping blocks are to be erected on concrete floor or on a cramping bed. Careful consideration has to be made in providing allowance for "spring-back" at each curving point. This is particularly essential for members that require formation of a sharp curve. The brackets which form the shape of the section are bolted or screwed onto the floor using the vertical and horizontal cramps, slotted into the holes of the jigs and lock on the cramping bed on concrete floor. As opposed to curved member, cramping straight glulam member is much simpler and that only involves cramping on a cramping table. Once the bolts are tightened, pressure is applied on the edges of laminations. Tightening of the bolts can be done manually or automatically by means of pneumatic or hydraulic cramps. The pressure for PRF on local hardwood species is commonly range within 1000 - 1400 kPa (145 - 203 psi) depending on advice given adhesive producer.

Note that cramping process shall commence at the center and tightening up the cramps towards the ends so that it could release strain that were imposed upon the cramp when first applied and to ensure that the correct amount of pressure is maintained (Chugg, 1964). Uniform pressure throughout the cramping is essential. This can be checked using a torque wrench.

*Post curing*

This is also known as conditioning period. The bonded members are left for curing for several days depending on the requirement of the type of adhesive being used. In the case for PRF, it is common to leave the bonded member for 7 days or longer to allow full curing to take place.

*Finishing*

Trimming off the excessive adhesives and cut to required sizes.

**Figure 9** Finger profiler at Wood Lamination Laboratory, FRIM

**Figure 10** Finger jointer at Wood Lamination Laboratory, FRIM

**Figure 11** Hand roller for glue spreading

**Figure 12** Glue spreaders at Wood Lamination Laboratory, FRIM

## Conclusion

At present, Malaysian building industry is yet to fully explore the utilisation of glulam as a building material. The interest of uptakers in glulam manufacturing appears to be fairly mild and we can only find a handful of glulam manufacturers in the country. Nevertheless, we could easily equate the market demand of such product by looking at the present global trend in emphasizing the use of sustainable building materials and the needs of wood-based products in the building industries, particularly in seismic proned countries. Perhaps, it is high time for our local timber industries to be proactive and diversify by venturing into new technologies so they could meet the global demand.  It is hoped that this article would bring public awareness about glulam, most importantly to shed some lights to the timber industries and to stir interest in the potential uptakers.

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