Derivation of Mechanical Properties of Rubberwood Laminated Veneer Lumber

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Abstract

This experimental project is an investigation of the mechanical properties of Rubberwood (*hevea brasiliensis*) Laminated Veneer Lumber (LVL). LVL is a product recently developed to substitute solid wood in an engineered form. Three common mechanical properties have been studied, i.e. static bending, compression parallel to grain and tension parallel to grain. The test method was based on ASTM (D-198). For each test specimens, basic stress, maximum load, maximum displacement and failure mode were observed. Experimented results show that basic compression stress value is 35.00 N/mm² for rubberwood LVL and 29.91 N/mm² for solid rubberwood. For basic tension stress, rubberwood LVL and solid rubberwood achieved 29.59 N/mm² and 59.61 N/mm². While in three point bending test, basic bending stress for rubberwood LVL is 53.18 N/mm² and 44.62 N/mm² for solid rubberwood. From the results, it is found that rubberwood LVL is stronger than solid rubberwood in compression parallel to grain and bending properties but it is weak in tension parallel to grain condition. The information gained in this research hopefully can make contribution in determining the suitability of rubberwood LVL in structural propose and development of rubberwood LVL product especially in Malaysia.

Keywords: Laminated veneer lumber (LVL), rubberwood (*hevea brasiliensis*), mechanical properties.

Introduction

Laminated veneer lumber (LVL) is an engineered wood product created by layering dried and graded wood veneer with waterproof adhesive into blocks of material known as billets. Cured in a heated press, LVL is typically available in various thicknesses and widths and is easily worked in the field using conventional construction tools. LVL is also known as structural composite lumber (SCL). It was first produced in the early 1970s and since then has been commercially available in the United State. It has been used structurally for several years in the Northern America and in many European countries [1]. Uses of laminated veneer lumber include beams, joists, headers and scaffold planking. One of the main ideas of LVL is to disperse or remove strength-reducing characteristics. LVL is an engineered, highly predictable and uniform lumber product.

Solid wood is widely used in construction as engineered product such as in the manufacture of trusses. However there are natural defects in the solid timber, which will influence the quality of lumber. Hence, good timbers with minimum defect are needed for construction purpose to attain safe and economical sections. Statistics show that from 1992 to year 2000, there has been a drop of 64% in log production and an average of 100% price increment in hardwood logs [2]. The demand for timber keeps on increasing due to increasing demand from construction and furniture industry. Malaysia has to import timber from other country to fulfill the log or timber shortages. In view of this, it is timely to look into converting plantation timber species such as rubberwood from non-structural status to structural status by engineering them into laminated veneer lumber as an alternative.

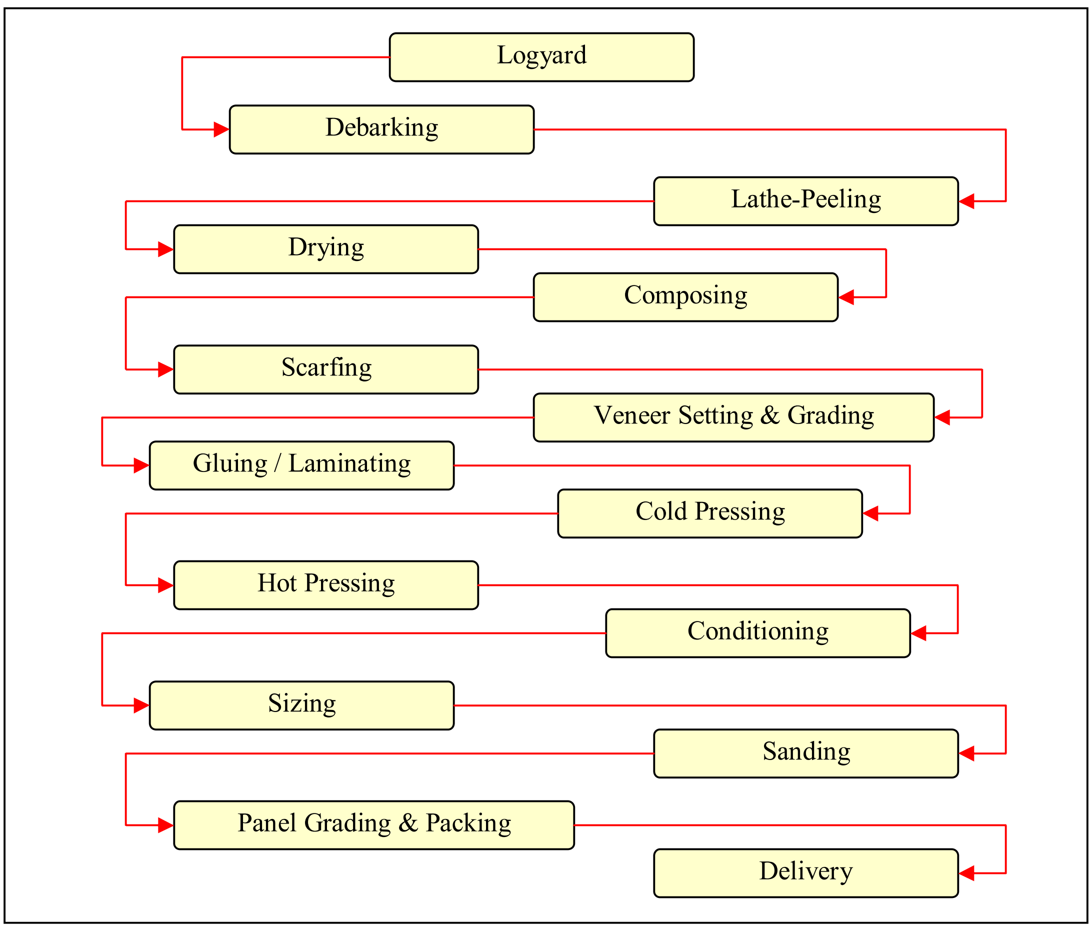
The objectives of this study are:

(i) to study the processes involved in making structural laminated veneer lumber;
(ii) to experiment the mechanical properties based on the strength of rubberwood as an engineered product;
(iii) to examine the suitability of rubberwood laminated veneer lumber (LVL) as a structural element; and
(iv) to identify the advantages and disadvantages of rubberwood laminated veneer lumber (LVL).

Experimental Methodology

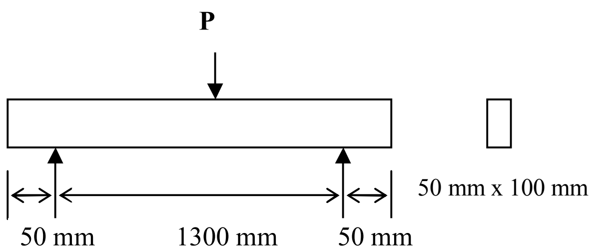
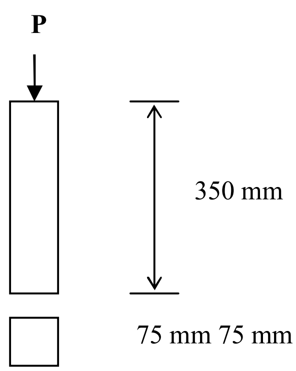
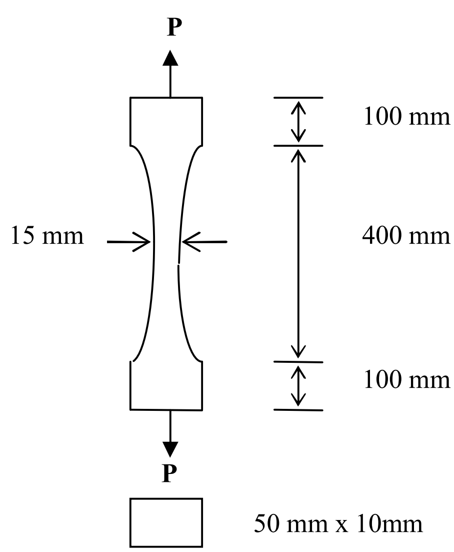
The rubberwood LVL are manufactured in a factory environment for structural purposes. The manufacturing process is provided in Figure 1. The veneers are laid with grain parallel to the length of the section having core veneer thickness of 2.6 mm and, face and back veneer 2.0 mm thick. The adhesive applied is WBP type phenol resorcinol formaldehyde. Pre-pressing or cold press is required followed by hot press under temperature range from about 120° to 230°C and specific pressure of 7 to 8 kg/cm^2.

Figure 1: Manufacturing process of LVL



The rubberwood LVL is prepared for three different tests to determine three selections of mechanical properties; compression parallel to the grain test, tension parallel to the grain test and bending test. For compression parallel to the grain test, the specimens of rubberwood LVL are 75 mm x 75 mm in cross section and 350 mm in length. Size of specimens of rubberwood LVL in tension parallel to the grain test are 50 mm x 10 mm in cross section, 600 mm in length and 15 mm x 10 mm in neck. Bending test used 50 mm x 100 mm in cross section and 1400 mm in length for every specimen of rubberwood LVL. For comparison purpose, solid rubberwood specimens having the same size as rubberwood LVL in three different tests are used in this study. The dimension of wood in bending, compression and tension test are given in Table 1. The specimens are surfaced on all sides and both ends squared smoothly and evenly. This determination of strength and the related properties of wood specimens by testing the structural sizes of the specimens are all conducted based on ASTM D198 - American Society for Testing and Materials - Standard Methods of Static Tests of Timbers in Structural Sizes [3].

Table 1: Test type arrangement schedule

Test Type	**Dimension**	**No. of Specimen**	
		LVL	**Solid**
Three point static bending		25	25
Compression parallel to grain		30	30
Tension parallel to grain		30	30

Result and Discussion

From the compression, tension and bending tests, load-displacement graphs were established for every sample. The ultimate load that failed the sample and the relationship between increment of load and the deformation can be obtained from the graph. The summary for the test results is given in Table 2.

Table 2: Summary of test result in compression, tension and bending

Type of Test	**Type of Sample**	**Average Max. Load (kN)**	**Average Stress (N/mm²)**	**Basic Stress (N/mm²)**	**CV (%)**	**Average MC (%)**	**Average SG**
Compression	LVL	199.42	35.45	35.00	3.32	11.5	0.70
	Solid	180.05	32.05	29.91	17.57	16.1	0.59
Tension	LVL	5.08	33.87	29.59	33.28	10.6	0.67
	Solid	10.36	69.05	59.61	35.99	13.5	0.63
Bending	LVL	14.24	55.53	53.18	10.02	11.3	0.68
	Solid	12.33	48.10	44.62	17.20	16.3	0.57

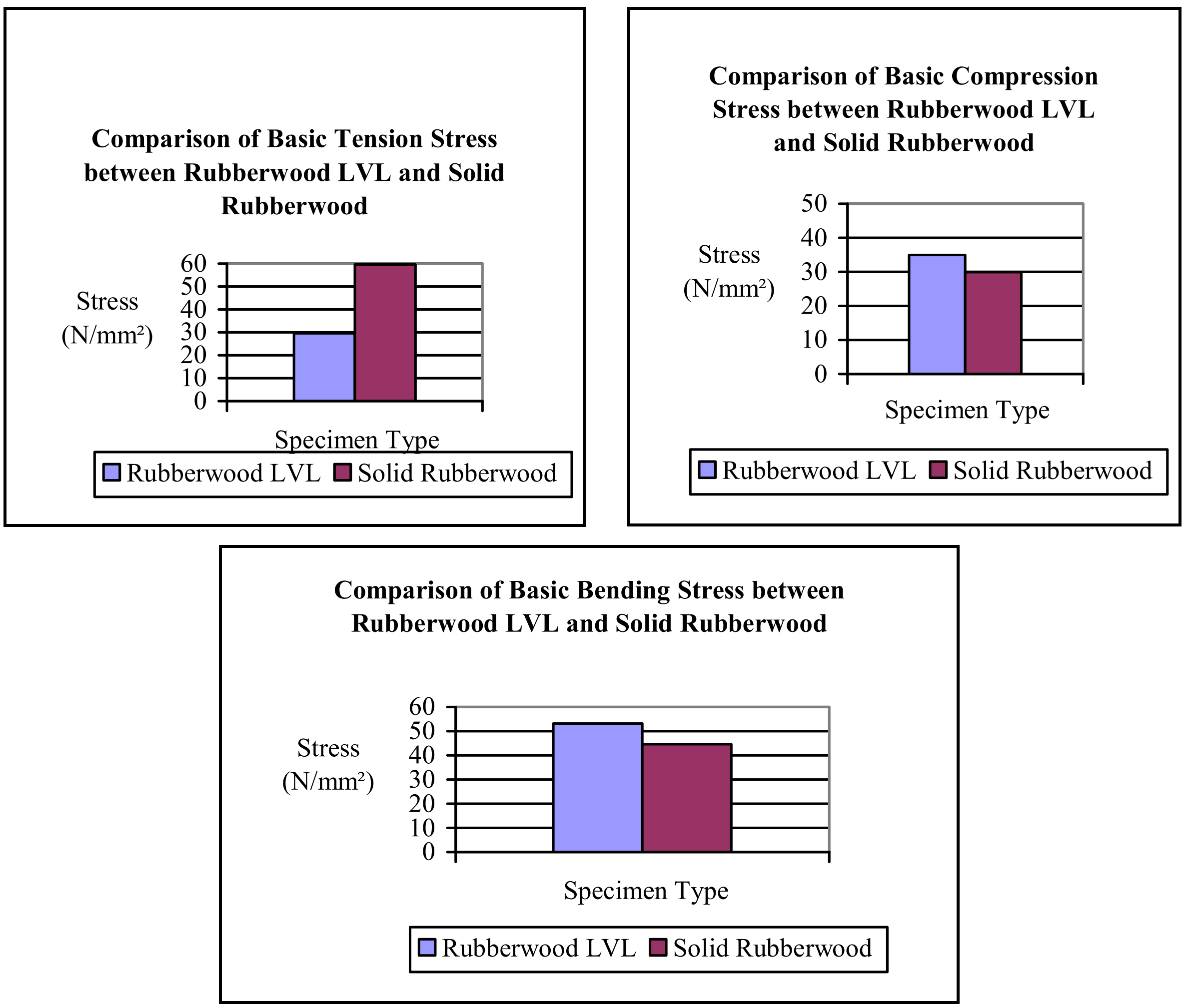
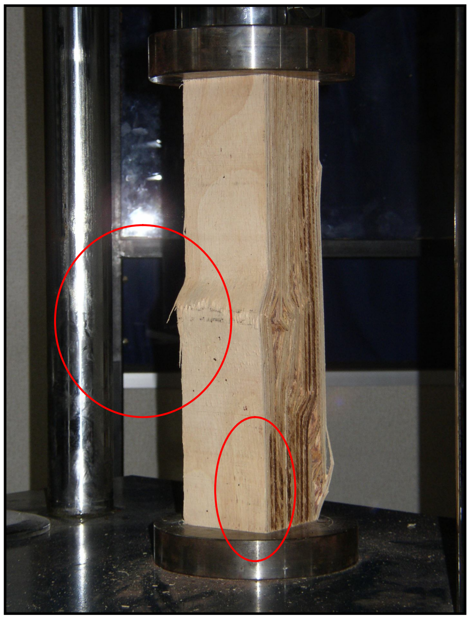


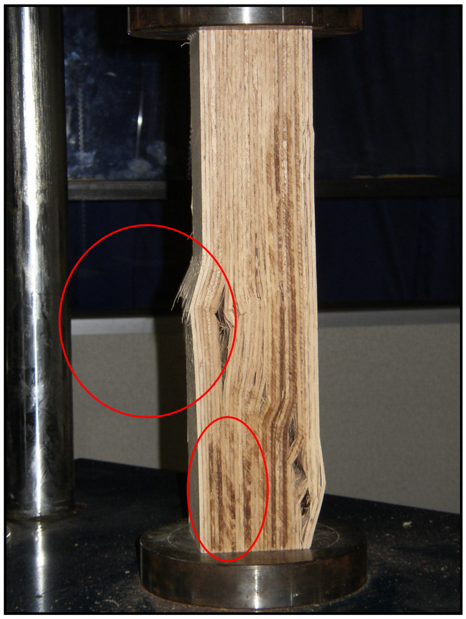
Figure 2: Comparison of stresses between LVL and Solid rubberwood

It is found that comparison of the basic stress between rubberwood LVL and solid rubberwood shows that the basic compression stress of rubberwood LVL (35.00 N/mm²) is 14.5% higher than solid rubberwood (29.91 N/mm²). This gives the conclusion that rubberwood LVL is stronger than solid rubberwood in compression parallel to grain condition. Such increment is also observed in the bending stress where rubberwood LVL (53.18 N/mm²) is 16.15% higher than solid rubberwood (44.62 N/mm²). However, on the contrary, the tensile stress of LVL (29.59 N/mm²) is significantly weaker than the solid section (59.61 N/mm²) by 101.5%. This experiment shows that LVL is weak in tension while stronger in both compression and bending properties (see Figure 2).

The calculated modulus of elasticity (MOE) for rubberwood LVL is 6620.29 N/mm² and solid rubberwood 5464.13 N/mm² higher by 21.2%. The failure modes of each test properties are observed and recorded. Special attention is given to LVL test in order to study the characteristic leading to failure. Four types of failure in compression parallel to grain were encountered in this study, i.e. crushing, wedge split, shearing, and compression and shearing parallel to the grain. From the observation, shearing is the highest failure that occurred in both solid rubberwood and rubberwood LVL test specimens. For rubberwood LVL specimens, most of the splits occurred between the veneer layers nearer to the faces (see Figure 3). It is found that almost half of the solid rubberwood and rubberwood LVL or 56.7% of solid rubberwood specimen and 50.0% of rubberwood LVL specimen failed in the shear condition under tensile parallel to grain (see Figure 4). With regards to bending test, inspection showed that all the specimens including solid rubberwood and rubberwood LVL had splintering tension failure according to the view of tension surface. 80% of both rubberwood specimens i.e. solid and LVL failed as cross grain tension and remaining 20% specimen failed in simple tension failure.



(a) Front view

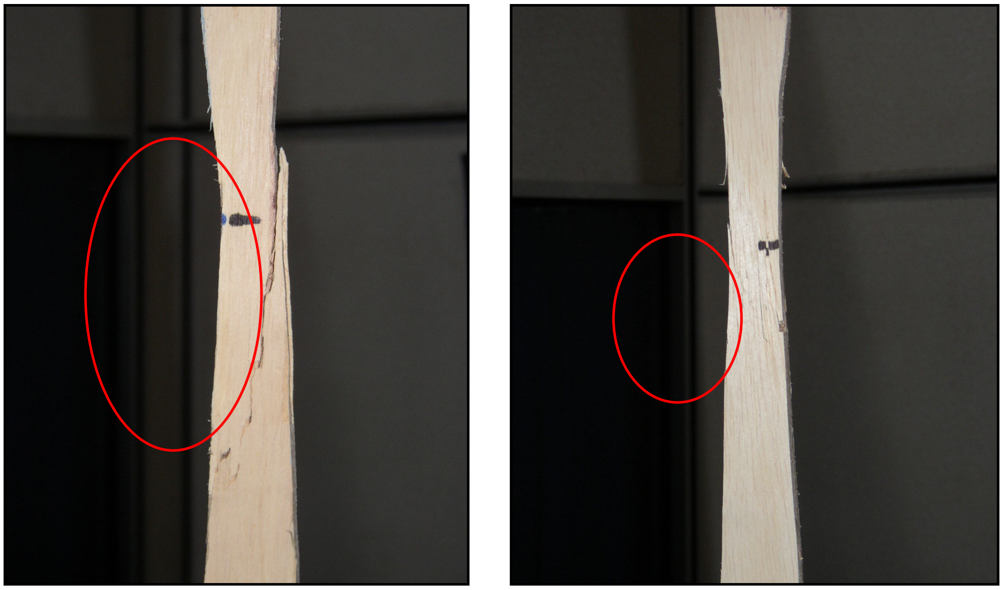


(b) Side view

Figure 3 : Failure found in compression test for rubberwood LVL

There are several factors which influence the performance of rubberwood. These include glue bonding, moisture content and defects. During the production of rubberwood LVL, the process of gluing veneers into a panel or billet is a critical procedure. If the gluing process is not done properly, it will cause splitting between layers easily. When tests are conducted, especially in compression parallel to grain test, it is found that veneers splitting occurred in almost every rubberwood LVL specimen. In this case, it will affect the performance of rubberwood and reduce its strength properties.

Moisture content is also an important factor affecting the strength properties of rubberwood LVL. In general, the mechanical properties of timber increase with decreasing moisture content. Therefore the same things will also happen to the LVL. The strength of rubberwood LVL will increase with decreasing moisture content.



(a) Shear (b) Splintering tension

Figure 4: Failure found in tensile test rubberwood LVL

Rubberwood LVL has the same problem as solid rubberwood, namely, defects. In the manufacturing process of LVL, veneers which have the defects problem are put as a core (inside) layers. Although the defects will disperse uniformly in LVL, affect it may cause a small impact to the strength properties of LVL.

Conclusion

The mechanical properties based on the strength i.e. bending, compression and tension of rubberwood LVL are studied and the comparison between solid and LVL shows that LVL product is much stronger than the solid product. As summarized in Table 3, the basic stresses of compression, tension and bending are 35.00 N/mm², 29.59 N/mm² and 53.18 N/mm² for rubberwood LVL and 29.91 N/mm², 59.61 N/mm² and 44.62 N/mm² for solid rubberwood.

Table 3 : Basic stress for compression, tension and bending test

Basic Stress (N/mm²)	**Compression Parallel to Grain**	**Tension Parallel to Grain**	**Three Point Bending**
Rubberwood LVL	35.00	29.59	53.18
Solid Rubberwood	29.91	59.61	44.62

Final result shows that rubberwood in LVL product gives a higher basic stress with the exception of tension parallel to grain, in compression parallel to grain and three point bending properties. For that reason, it is concluded that rubberwood LVL has a potential to be used as structural element.

Limited research has been done to determine the performance of LVL as engineered product. Several recommendations can be outlined for further technical and commercial studies on LVL using plantation spesies. These include, among others:

(i) further study of the mechanical properties such as tension perpendicular to grain, compression perpendicular to grain, impact bending, toughness, etc. using rubberwood LVL.

(ii) similar testing conducted with different timber especially from plantation timber species.

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