IMPROVEMENT ON STRENGTH PROPERTIES OF MAHANG WOOD

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2017

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DECLARATION

I hereby declare that work embodied in this report is the result of the original research and has not been submitted for a higher degree to any universities or institutions.

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Date :

I certify that the report of this final year project entitiled " Improvement of Strength Properties of Mahang Wood" by Khazanah Binti Mohd Wi, matric number E13A079 has been examined and all the correction recommended by examiners have been done the degree of Bachelor of Applied Science (Natural Resources Science) with Honours from Faculty of Earth Science, University Malaysia Kelantan in year 2017.

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ACKNOWLEDGMENTS

"In the name of ALLAH SWT, The Most Gracious and The Most Merciful"

Upon completing this final year project, I wish to express my most gratitudes to my supervisor, Dr. Sitti Fatimah Binti Mhd. Ramlee, Prof. Madya Dr. Razak Bin Wahab (ex supervisor), Prof. Madya Dr. Hashim Bin Md Nor, Encik Ahmad Auzan Bin Azhar and Encik Mohammad Firdaus Bin Mohd Ridzuan (lab assistants) and Mohammad Saiful Bin Sulaiman (Master student) for their valuable time, guidance and full encouragement throughout the course of this final year project report.

I wish to extend my gratitude and thanks to my final year project partner, Siti Nuralia Basirah Binti Azmi and my colleagues, Siti Natrah Binti Saufi, Nur Nabihah Binti Md. Nawi and Wan Nur Fathiah Binti Wan Mazlan for full supporting me along doing this project. Not forget, I wish to thank my parents, Mohd Wi Bin Salleh and Siti Rahmah Binti Ismail, for supporting the budget for this project.

ABSTRACT

This research emphasized the Improvement on Strength Properties of Mahang wood. Currently, the demand on the alternative wood has increased. Mahang wood is a light hard wood and it is a fast growing plant. The objectives of this research were to study the strength properties of Mahang wood and to study the improvement on the strength properties of Mahang wood through lamination process. The strength properties studied were regarding the different ages of wood, young at four years old and atured at eight years old. The samples were air dried for thirty days. The moisture content od samples was standardized at twelve percent. The samples were ran under Universal Testing Machine (UTM) for bending and compression test. The result showed that matured Mahang wood was stronger than young wood. It also showed that laminated form of Mahang wood was stronger than natural form. The result was analysed using S Plus Program for Analysis of Variance (ANOVA) and Correlation Analysis. In a conclusion, the objectives of this research was successfully met and Mahang wood could be recommended as an alternative in wood industry.

ABSTRAK

Kajian ini menekankan mengenai Panambahbaikan Ciri-ciri Kekuatan Kayu Mahang. Masakini, permintaan terhadap kayu alternatif telah meningkat. Kayu Mahang adalah sejenis kayu keras dan ia merupakan tumbuhan yang cepat membesar. Objektif kajian ini adalah untuk mengkaji ciri-ciri kekuatan kayu Mahang dan penambahbaikan ciri-ciri kekuatan kayu Mahang melalui proses laminasi. Ciri-ciri kekuatan kayu Mahang dikaji berdasarkan umur muda, empat tahun, dan matang, lapan tahun. Sampel kayu dibiarkan kering selama 30 hari. Sampel kayu diuji dengan menggunakan Mesin Uji Universal, (Universal Testing Machine, UTM) untk ujian lenturan dan mampatan. Keputusan menunjukkan bahawa kayu Mahang matang lebih kuat berbanding kayu muda. Ia juga menunjukkan bahawa kayu yang dilaminasi adalah lebih kuat berbanding kayu semulajadi. Keputusan telah dianalisi menggunakan Program S Plus untuk Analisa Varian (ANOVA) dan Analisa Hubungkait. Kesimpulannya, objekif kajian ini telah tercapai dengan jayanya dan kayu Mahang boleh disarankan sebagai alternatif dalam industri perkayuan.

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CHAPTER 1

INTRODUCTION

1.1 Research background

Currently, the wood supply from Peninsula Malaysia is decreasing (H'ng, 2010). Plus, reduction in plantation areas in Peninsula Malaysia also occurs in about 25.5%, similarly to 313,680 hectares from year 1998 to 2007 (Anonymous, 2008). The world has been seriously damaged by the deforestation due to increasing demand for secondary sectors of wood industry. So the industry needs alternative method to face the increasing demand. And, apparently, people are tend to move to another way of using wood-based product by utilizing *Acacia mangium*, sesenduk, and rubber wood, *Hevea brasiliensis* to reduce the deforestation issue and create wood based products from their utilization. The decline in the raw material sources of rubber wood for particle board and incline of market price of rubber wood has totally led manufacturers to find the alternatives to resolve this issue (Loh, 2010).

Traditionally, rubber wood is used as basic raw material in another alternative in wood industry which is regarding particleboard production due to its medium density hardwood favoured and natural light colour (Dinwoodie, 1981). The increasing population and well developed wood processing industries are the primary forces lead to the continuously growth of the wood products. In a recent study, it is stated that the declining supplies of forest resources in Malaysia has become worst after 1995 which causes scarcity of quality logs of wooden products (Lim, 2004). Manufacturers are tend to know less about the special features and properties of another species of alternative wood that can be further used in manufacturing industries such as *Macaranga* spp.

Mahang wood is a pioneer tree species and light density hard wood which emerge in sizeable quantity in logged over forest in Southeast Asia (Loh, 2010). It is a fast growing plant (Lee, 2010). Thus, it can be harvested at the early ages rather than other plants. Nearly similar to Mahang wood that can be harvested at the age of four years old with diameter of stem reaching 50cm, at DBH or diameter at breast height, *Acacia mangium* can be harvested for their wood at the age of six years old with the diameter of 45cm at stem (Krisnawati *et al*., 2010) and rubberwood is at the age five to ten years old respectively.

Mahang wood is having few lacks in the means of its strength properties, but the lacks can be improved and overcome through the strength property tests implementation throughout this research. Thus this lesser known wood species which can be found in large quantity in secondary forests can hence be used as potential alternative of raw materials if the weaknesses can be reduced. The benefits that can be obtained from Mahang wood will be helpful in fulfilling future demand of raw sources of wood. Mahang wood has a possibility to be commercialized furthermore as a source of timber for manufacturing products (Lum, 2010).

Based on the physical characteristics of Mahang, this tree can be easily found in the stem diameters of 45cm for young tree and and 95cm for matured trees. These are based on the stem diameter measurement of the samples that was found in Agropark of UMK.

Mahang tree can be found grows up to 15m tall with spreading crown especially the matured ones. The bole can be found in brown distinctly lenticellated. The underside parts of the leaves and the shoots are finely velvety. The leaves are also found in tri-lobed; shallowly tri-lobed. The leaves are glaucous beneath and deeply peltate. The tree has solid twig and it does not house ants. Basically, stipules can be found in light green colour, hairly, huge, erect and also papery.

Therefore, the main objectives of this study were to study the strength properties of Mahang wood and study the improvement of its strength properties through lamination process.

1.2 Problem statement

Currently, the use of rubber trees in furniture industries has helped much in the growth of the Malaysian economy. But the source of their raw materials declines throughout time. Mahang wood is a good alternative to overcome this issue. Mahang wood comes with various colours and it is a light hard wood plant. By implementing the lamination process on the wood; by cross matrix and/or parallel lamination methods, the strength of this light hard wood can be increased due to the potential of Mahang wood to further used in furniture industry and overcome the lack of rubber tree sources.

1.3 Hypothesis

H_0: There is no significant difference between age and form of Mahang wood with its strength properties.

H_1: There is significant difference between age and form of Mahang wood with its strength properties.

1.4 Significance of study

This study of strength properties of Mahang was done on the purpose of studying the improvement on that strength properties through lamination process. The finding of the study is to know the strength properties based on different ages and forms of Mahang wood samples.

1.5 Objectives

I. To study the strength properties of Mahang wood.

II. To study the improvement on the strength properties of Mahang wood through lamination process.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Characteristics of *Macaranga* spp.

Mahang wood is a fast growing tree (Lee, 2010). At the age of three to four years it can achieve a diameter of about 40cm to 50cm bigger than common diameter of a rubber tree which is also at the same age. According to the Standard Malaysian Name and ASEAN Standard Name, Mahang wood is known as *Macaranga* spp. (Euphorbiaceae). Sarawakians call it in vernacular names, as benuah, Sabahans call it as sedaman, linkabong, marakubong and merkabong, while in Peninsula Malaysia it is known as kubin, mesepat and mahang (Menon *et al*., 1986).

Mahang tree (*Macaranga* spp.) can be found in lowland forest of Malaysia where many species of tall trees including Mahang wood can be found. This Mahang wood is classified as soft to moderately hard and light to moderately heavy, and in Malaysia it is catagorized under Light Hardwood (Bolza, 1982). Mahang wood can be found in several major species including *M. winkleri*, *M. lowii*, *M. hosei*, *M. gigantean*, *M. hypoleuca* and *M. pruinosa* (Menon *et al*., 1986). The laminated design of Mahang wood can be used in furniture industry in Malaysia, like other recent success of using *Acacia mangium* and rubberwood products in the same industry (Krisnawati *et al*., 2010). But apparently, rubberwood can only be obtained in the smaller sizes compared to other wood species from the forest. The decrease in the wood volume is hence influence the decline of furniture industry.

The market of rubberwood industry has declined due to its lack value in economy due to the need for the preservative treatment. Japan has been a regular country which tends to import rubberwood based-products from Malaysia due to the attractive light colors of the wood (Hong, 1996). In previous years, rubberwood has become as the raw material used in panel industry in Malaysia (Hong, 1996). Rubberwood has also becoming as the only sawmills processed in Malaysia in 1990's (Killmann, 1992).But the decline in the rubberwood supply and plantation in Peninsula Malaysia has led us to take a better alternative like consuming Mahang wood for the same purpose like rubberwood have in recent (Hong, 1996). Mahang wood is a wood that has a moderately fine and even texture, and the grain is straight and shallowly interlocked.

Throughout this research, the bending test that had been ran was study based on the Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) results. Both the MOE and MOR result were observed based on ages (matured and young), forms (natural and laminated), portions (bottom, middle and top) and positions (heartwood and sapwood) of Mahang wood. Heartwood is known as a dead biomass of non-respiring structure and it functions to maintain the structure of the wood (Schulze *et.al*, 2005). Heartwood is inner wood that involved most of a stem's cross section (Snyder, 2007). In contrast, sap wood is known as the living and the outermost portion of the woody stems or branches (Snyder, 2007). The difference between heartwood and sapwood can be determined by lighter colour that heartwood has than that of sapwood (Smith, 2013). But there can be misleading in wood colours since not all heart wood is found in dark and not all dark-coloured wood is found as heart wood. In fact, the relative amounts of heartwood and sapwood in stems can be different among individuals, species and growing conditions of the tree (Snyder, 2007).

Majority of woods including Mahang start with sapwood and sapwood can be found as the position forming just below the bark, and is known as the cambium as a thin layer of living cell. Cambiums or vascular cambiums are the cells arranged in regular rows and also columns (Koning *et. al*, 1994). Woody plants like Mahang needs cambium to produce additional secondary xylem and phloem that further contributing to the production of huge diameter of wood trunks. These layers will make all the woods that are used in manufacturing, and building home and furniture. Thickness of sapwood increases throughout good years and decreasing throughout bad years. Sapwood contains many physiologically active and living cells. Sapwood can be the position where dissolves mineral and water to be transported among roots, crown of tree and lesser extents where the energy for reserves are stored (Snyder, 2007). But the increase of age of the trees leads the increase in the diameter leads changing in things. The entire cross section of the trunk need no longer to conducting sap. Plus, the young trees or young parts of older trees require the increase of the structural supports which will causes significant changes in the wood itself (Snyder, 2007). These young trees or young parts older trees are dominated by sapwood (Snyder, 2007). The requirement of structural supports at those young trees and young parts of older trees causes the cells nearest the trunk centre die but they will remain mostly intact. Throughout times, the older sapwood will then become heartwood by which they are changed and accommodated shifting in their function. As they being the residues of once-living cells in the wood and the chemicals from elsewhere in the tree accumulated in heartwood, the cells ended their function in transporting store energy reserved or water (Snyder, 2007).

2.2 Importance of *Macaranga* spp.

As an added value of Mahang wood, the wood is reported to be easy to work for machinery (Panshin, 1970). Mahang wood is also suitable to be used in furniture industry for making plywood, cement-bonded board, pulp and paper, match boxes, and particleboard. Specifically the purpose of this research is to produce (improved strength of laminated furniture and flooring). The laminated design of Mahang wood can be used in making wooden shoes in Philippine. This shows that the demand of wooden wood products in the world has increased drastically. In Malaysia, the demand for particleboard which is made based on laminated wood is high. For sure it can be can suggested that the making of more laminated product like flooring and furniture to be done in order to fulfil the demand in our country since the strength property tests of bending and compression in this study will show the related result for both types of products.

2.3 Improvement of Strength Properties of *Macaranga* spp.

The lamination process which that has been implemented on Mahang wood was a good technique in improving its strength properties. The lamination process was done by making two layers of wood to wood by applying white glue to stick both layers. The strength properties of Mahang wood can be determined by applying compression and bending tests after lamination process is implemented on it. The strength properties of Mahang wood and the improvement on its strength properties by implementing the lamination process (Razak, 2005). Strength property is the property of wood that measure its ability to resist any forces applied onto it which might change its shape and size. The resistance of wood on the forces is based on manner of application (Lee, 2010).

In this research, the Mahang logs in the wood workshop were air dried and were standardized at twelve percent moisture content before undergone the lamination process, compression and bending tests a month later. This methodology was applied to let the logs dry in an optimum condition that will promise of undisrupted results in further process and tests. I sprayed every end of the logs with painting spray before leaving them to air-dry to prevent the absorption of water from the air. The air dry process of the Mahang logs was due to hygroscopicity characteristic of the wood. Due to this property, the wood was always containing moisture. Such moisture content was the vital need to be reduced in optimum condition for this research. Air dry process was important to ensure that the Mahang logs were dried without cracking and defects.

The lamination process that has been implemented in this research was due to the effort of reducing waste when the use of the glued small dimensions of Mahang wood was applied. Due to the relative thinness of the individual planks of Mahang wood, the gluing process through the lamination process will be easier (Razak, 2005). The removal of knots can be done as well accordingly. After lamination process, both the compression and bending tests were done by using Universal Testing Machine (UTM). UTM is a machine that can test metals and other materials like wood planks under tension, shear loads, bending and compression.

CHAPTER 3

MATERIAL AND METHODOLOGY

In this research, there were few basic materials that have been prepared in order to accomplish the best significant result through the methodologies that were followed. The procedures for this study followed ASTM D143 with modification for cutting process and ASTM D1037 through bending and compression tests under Universal Testing Machine.

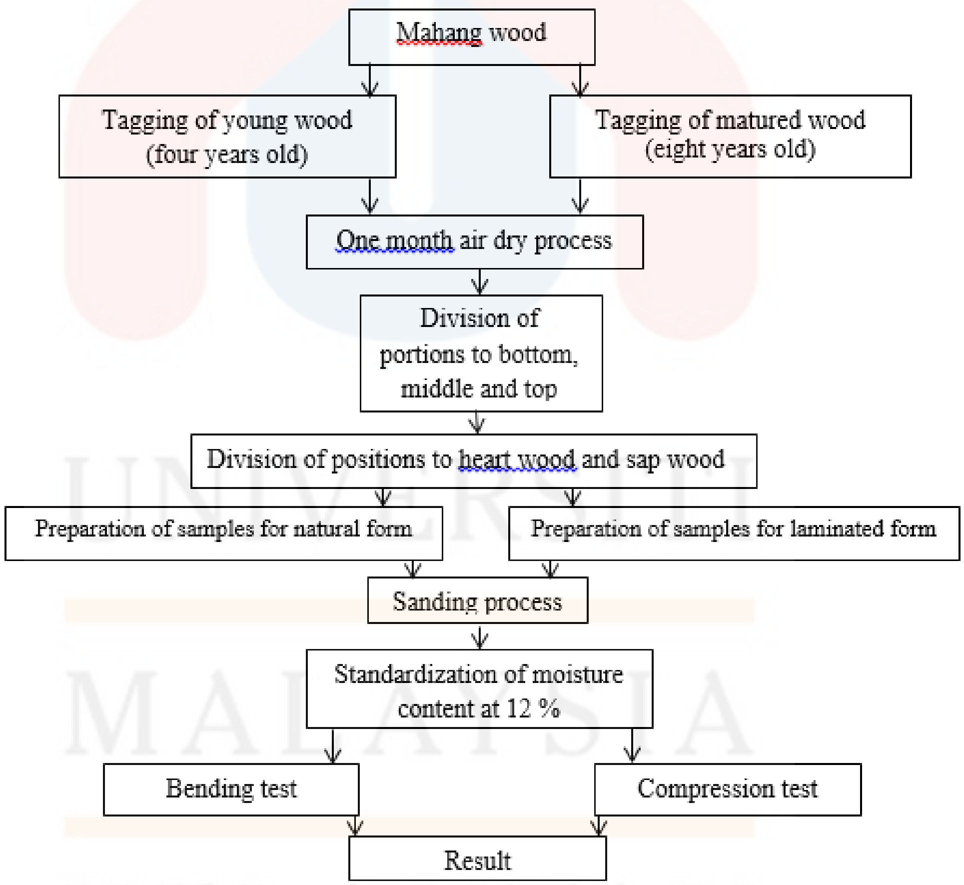

Figure 3.0: Research flow chart

3.1 Materials

The materials and apparatus prepared for this research were the samples of Mahang wood with two different range of years (year four (4) and eight (8), white glue (polyvinyl acetate (PVA)), a measuring tape, painting spray, sanding machine and Universal Testing Machine (UTM) for the compression and bending tests, condition chamber, chain and table saws.

In accordance to the materials that has been used in the research, I have found the trustable and enough source of information and knowledge about Mahang wood in the term of its background characteristics, habitats where it can be found, growth rate and strength properties of Mahang wood.

3.2 Methodology

3.2.1 Sample selection characteristics

The samples were tagged according to the years that can be determined based on their trunk's diameter. The measurement of diameter taken was applying the diameter of breast height of the trunk or DBH. A measuring tape was used to measure the trunk's diameter at a 30cm height to further divide the portions of bottom, middle and top of Mahang wood. The selected samples were a four-year-old (young) and eight-year-old (matured) tree. Portions of top (20%), middle (30%), and bottom (50%) of both young and matured samples were determined for both ages of wood. The total length of all portions selected for matured Mahang wood selected was seven metres meanwhile the young wood portions was five metres.

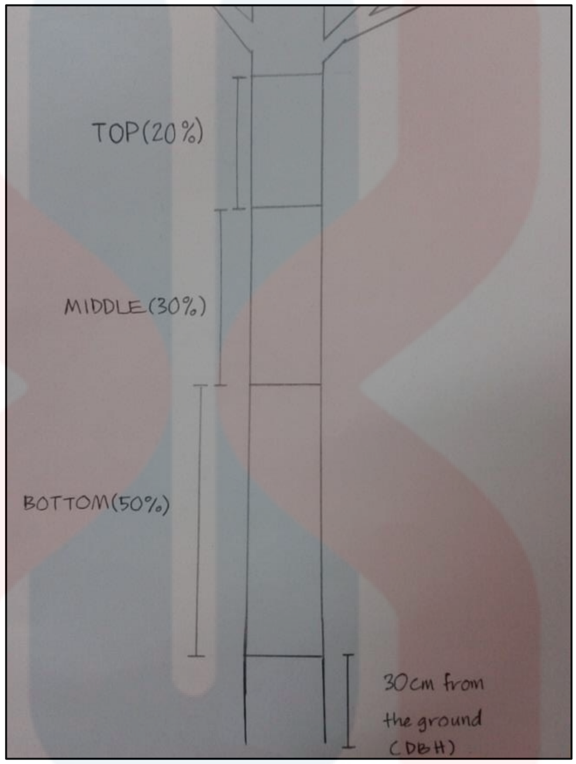

Figure 3.1: Determination of portions of samples

3.2.2 Tagging of sample

Tagging of samples was done according to the two different range of years of *Macaranga spp.* (young at four years old and matured at eight years old). This process was continued by cutting down the tagged trees into logs. The logs were cut down into three portions that were tagged earlier, which were bottom, middle and top. The tagging of bottom portion was made by measuring 30cm height from the ground. At that 30cm breast height, bottom, middle and top portions were then tagged and cut. This process was allocated with precautionary steps in order to avoid the danger and risks that might occur during the running of the process.

3.2.3 Air dry process of samples

Next, the samples were kept for one month balanced air dryness in the wood workshop of UMK Jeli Campus. The samples were sprayed at every edge of the portion before they were kept safely and away from direct exposure to sunlight and rainfall. The samples were avoided from direct touching with the floor to ensure that there were no nutrient loss to occur and affect the wood structure and the result.

3.2.4 Cutting of samples

Each position of bottom, middle and top portions of samples were cut down into half using a chain saw (for young age samples) and table saw (for matured samples). Both samples with different range of years had undergone the same procedures of portion cutting. The cutting of Mahang samples were done to divide the positions of heart wood and sap wood. Then the samples were further cut into planks with a length of 32cm for both young and matured wood. The planks were hence formed by cutting the samples using table saw. The planks were prepared to undergo lamination process (laminated form) and few samples were left for natural form. ASTM D143 standard with modification through bending test was followed with cutting measurement of 32cm length, 2cm width and 2 cm height (natural form), 32cm length x 2cm width x 1cm height (laminated form). Cutting process of samples that ran the bending test followed ASTM D143 standard with modification, in which here means throughout this research, I applied the same measurement of 32cm length x 2cm width x 2cm height to complete the lamination process through bending test. The only modification was about the lamination of two wood to wood layers rather than normal layering of three and above of wood with ASTM D143 standard without modification. The cutting process of samples that ran the compression followed ASTM D1037 standard. ASTM D1037 standard was different to ASTM D143 standard with modification in this research was regarding the measurement of cuttings. ASTM D1037 standard through compression test was followed with cutting measurement of 4cm length x 2cm width x 2cm height (natural form) and 4cm length x 2cm width x 1cm height laminated form) (refer Fig. 3.2 and Fig. 3.3).

3.2.5 Sanding process

This process was done onto samples to ease the gluing process and compression test that were ran onto Mahang wood. Sanding process was important to make the compression test ran smoothly and obtain accurate result. As a normal procedure for running compression test, the samples that were implemented by sanding process throughout this research were easier to stand vertically under UTM due to smooth flattened surfaces.

3.2.6 Standardization of twelve percent moisture content

The standardization of moisture content at twelve percents of Mahang wood was done by transferring the wood samples to Kepong FRIM where the samples were placed in the condition chamber for two weeks. The condition chamber was set at 65 percents relative humidity and 25 degree Celcius to obtain the final moisture content of 12 percents.

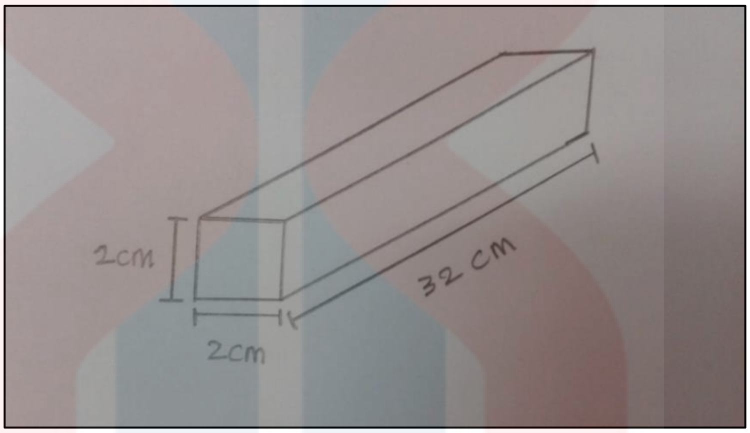

Figure 3.2 : Measurement of samples of natural form through bending test

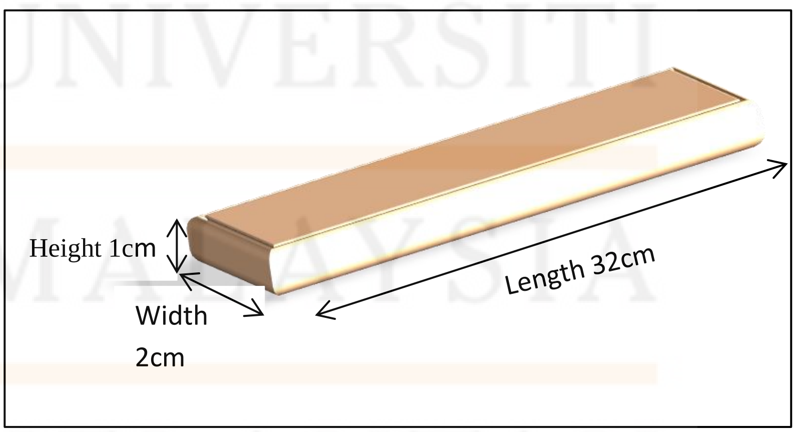

Figure 3.3: Measurement of samples of laminated form through bending test

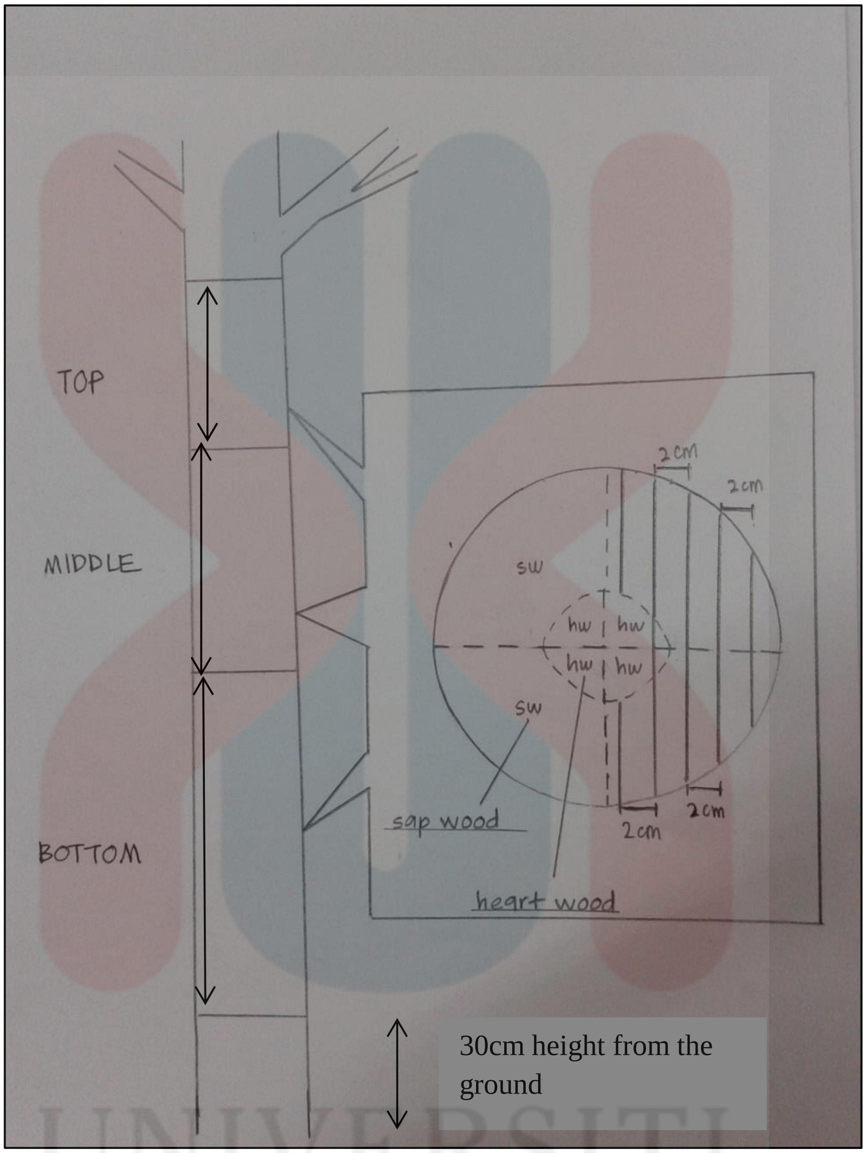

Figure 3.4: Cutting measurement of Mahang wood portions

Figure 3.5: Chain saw used to cut young samples of *Macaranga* spp.

Figure 3.6: Cutting process of the matured sample into half

Figure 3.7: Cutting of samples into half for both different years

Figure 3.8: Cutting of the young samples by using table saw

Figure 3.9: Labelling of samples according to different portion and position

Figure 3.10: Cutting of the samples into planks using table saw

3.2.7 Lamination process

After one month air dried, the samples had undergone lamination process. Lamination process is a process that making layers of the wood samples in order to measure and improve the strength properties of the wood. Basically, this process is familiar in the making of plywood industry. A two-layer of wood to wood lamination was applied in this research. Each lamination involved a 1cm + 1cm layers forming a 2cm height for each planks of matured and young, and natural and laminated forms to be ran through bending and lamination tests. Throughout this research, the lamination process was done onto samples prepared to undergo compression and bending tests. Both tests used Universal Testing Machine or UTM at the wood workshop. The standard used for lamination process through bending test was ASTM D143 with modification. The modification was referred to the application on number of layering of wood to wood lamination. The white glue was used to complete the lamination process. White glue or polyvinyl acetate (PVA) was the best chosen glue for the lamination process of *Macaranga sp.* in this research compared to urea formaldehyde, phenol formaldehyde and phenol resorcinol formaldehyde. This was because white glue was non-toxic, inexpensive and performed stronger bonds according to the cellulose polymers. The white glue turned to colourless after applied onto the samples so it did not affect the surface structure of the samples and the result. The samples that ran the compression test were also following ASTM D143 standard with modification, only the cutting measurement was different from bending test, which followed ASTM D1037 standard.

3.2.8 Strength property tests

The test of compressing the samples was done by using the UTM on the purpose of determining how strong the four-year-old-sample compared to the eight-year-old one, in the means of the measurement of strength properties before and after lamination process that being implemented on the samples. Basically, two types of lamination processes could be done in two different methods which are parallel lamination and cross matrix lamination. Running the cross matrix lamination tends to give higher strength result to the Mahang wood than that with parallel lamination. But both lamination methods can improve the strength properties of this Mahang wood. For this research context, parallel lamination was applied. The replication of each position of bottom, middle and top were three per one tree so there were 18 replications of samples we required for both two ranges of years of the trees. In total, we required 18 replications for the natural form of samples and another 18 samples for the laminated form.

After that, the strength property of the samples was examined through the bending test. Bending test is a vital process to be done because the strength of different range of years of the samples can be differentiated according to the flexibility characteristic of Mahang wood. This bending test was done by using the UTM. Basically bending test is done for testing the strength property of the wood used in making the bench for example, which can resist forces applied onto it. The bending of the wood identifies how strong the wood can support people sitting on the bench. For this research, I applied the bending test in order to study the bending property that Mahang wood had. Modulus of Rupture (MOR) and (Modulus of Elasticity) MOE of Mahang wood were being the bending strength properties that were measured throughout this research.

MOR can be defined as the measurement of force that is needed by a substance before rupture. This can be applied to measure the overall strength a wood has, unlike MOE that measures a wood's deflection not the wood's ultimate strength. Here it can be said that, some wood species have the tendency to bow, but they are not easily to break. It is expressed by eighteen times the load needs to break a bar of an inch square and it is supported at two points in one foot measurement and the substance is placed and loaded in the middle of the two points supporting it under UTM. MOE can be defined as the ratio of stress that is applied onto a substance to the strain within the elasticity limitation. In this research, MOE was referred to the value of elasticity, before and after the wood broke when running bending test under UTM.

Compression test is the basic strength property test in the flooring industry. Both compression and bending processes were important methodologies to be followed for making good inference of the strength properties of Mahang wood that can be improved and enhanced since this wood is actually having less comparable strength properties from other strong hard wood for example Teak wood that do not require alternative ways to enhance their strength like Mahang wood did. In this research, Young's Modulus was referred as the value of compression strength of Mahang wood. Young's Modulus is a numerical constant that was named by Thomas Young, an English physician who described about the properties of elasticity a solid performed, when it undergone compression in one direction (Anonymous, 2006).

3.2.9 Statistical analysis

The statistical analysis applied in this research was S Plus Program for ANOVA (Analysis of Variance) and Correlation Analysis.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Bending test of natural form of Mahang wood

Based on the findings, the result of the research done can be referred to Table 4.1 for further discussion on the result obtained for bending test.

Table 4.1: Bending test of natural form of Mahang wood

Portion of wood	Position of wood	Matured natural		Young natural	
		MOR	MOE	MOR	MOE
Bottom	Heartwood	43.9673	3881.71	26.991	3327.9627
	Sapwood	37.7967	3268.202	26.9977	3006.21
Middle	Heartwood	40.847	3463.598	26.145	2816.7413
	Sapwood	34.9857	3224.116	27.3173	2772.8923
Top	Heartwood	44.4203	4173.811	29.321	3569.2487
	Sapwood	40.656	4233.495	27.6203	3089.093

Table 4.1 shows the MOE and MOR result for the mean value of three replications at each position of heartwood and sapwood. Based on Table 4.1, it shows that Mahang wood performed Modulus of Elasticity (MOE) higher than Modulus of Rupture (MOR) of both matured and young ages of natural form. Observing through the MOE result of matured and young ages of natural form of Mahang wood, it can be determined that top portion performed the highest MOE than that of bottom and middle portions. As shown in Table 4.1, the highest MOE of matured age of natural form of Mahang wood was at top

portion and sapwood (4233.495 N/mm²) and for young age of Mahang wood was also at top portion but at heartwood (3569.2487 N/mm²). It was clear that positions of wood, neither heartwood nor sapwood did not influencing on the increase of that MOE of matured and young ages of natural form of Mahang wood. This can be due to; in any young trees and young parts of any older trees, the stems of all the woods are built of sapwood (Snyder, 2007). But the heartwood in these young trees or young parts of older trees is less.

The main function of heartwood is to support the tree. When the heartwood did not covering those young trees or young parts of older trees, the wood had less support thus the wood could perform more bending ability. But, MOE for matured age of Mahang wood shows higher result than that of young age of Mahang wood with the same form of natural wood. Based on the MOR result, matured age of Mahang wood of natural form shows higher MOR than that of young wood. MOR is the measurement of force that is needed by a substance before rupture. This shows that matured age of natural form of Mahang wood was having higher tendency to break or rupture when was stressed with forces on the wood than that of young age of natural form.

4.2 Bending test of laminated form of Mahang wood

Table 4.2: Bending test of laminated form of Mahang wood

Portion of bending	Position	Matured laminated		Young laminated	
		MOR	MOE	MOR	MOE
Bottom	Heartwood	315.9715	52153.026	144.69	15166.1383
	Sapwood	220.8327	18830.8183	159.233	15624.047
Middle	Heartwood	228.0777	17160.5797	74.7427	8426.048
	Sapwood	238.4203	20304.9337	91.1403	13460.8446
Top	Heartwood	227.0803	21273.377	156.1703	11494.758
	Sapwood	195.064	16901.186	134.2253	10235.9245

Table 4.2 shows the MOE and MOR result for the mean value of three replications at each position of heartwood and sapwood. Table 4.2 shows that for laminated form of matured and young Mahang wood, the MOE results were higher at bottom portion which was at heartwood (52153.026 N/mm²) than that of other portions. This shows that the highest MOE for matured Mahang wood was at heartwood position but the highest MOE results young wood was at sapwood. The position of wood neither heartwood nor sapwood did not totally effecting on the increase on the MOE results for matured and laminated form of Mahang wood. MOR results also shows the same trend for matured and young ages of wood, by which the highest MOR shown was at bottom portion of Mahang wood. But MOR results which was higher at bottom portion of laminated form of matured Mahang wood was at heartwood position than that at bottom portion of young wood which was at sapwood position. Again, this shows that position of wood did not totally effecting on the increase of MOR results for laminated form of matured and young Mahang wood. But, the portion where the MOE and MOR was the highest from the overall results through bending test for the laminated form of Mahang wood was only at the bottom portion. Bottom portion of

matured Mahang wood is built of less sapwood than that of young part of the matured wood, this was referring to its top portion as for a comparison to bottom portion. Sapwood is functioning in increasing the structural support that will causes significant changes in the wood (Snyder, 2007). Since bottom portion of matured had less sapwood than top portion of Mahang wood, this shows that bottom portion did not requiring the main function of sapwood to be in the wood structure of that bottom portion.

This can further explaining that the bottom portions of matured and also young laminated Mahang wood were having stronger mechanical strengths than that of other portions of the wood. Furthermore, bottom portion of Mahang wood did not has the same efficiency of biological reaction like photosynthesis reaction because the portion did not comprises of green leaves to fully functioning in trapping sunlight for that photosynthesis. Photosynthesis needs chlorophyll pigments, usually can be found in green leaves and stems to run the photosynthesis. Basically, the crown part of a tree is the only part that comprises of most leaves and branches and crown is located at top portion or upper part of the tree. This shows that upper part of Mahang tree needed higher structural support by its sapwood that comprises most at that upper part at top portion than that of bottom part. Plus, bottom portion of Mahang wood had developed more as heartwood over time (Snyder, 2007). Heartwood comprises more in the wood especially at bottom portion of matured and young Mahang wood. Mahang tree needed more in heartwood to support the tree from the bottom portion other than root of tree. Bottom portion of matured laminated Mahang wood was not easy to rupture or break and had higher elasticity than that of other portions. Meanwhile, bottom portion of young laminated Mahang wood was also not easy to rupture or break and had higher elasticity than that of other portions. But, matured laminated Mahang wood performed higher MOE and MOR than that of young laminated Mahang wood. Lamination of wood to wood layering in this research was a good technique in order to improve the mechanical strength of Mahang wood even more.

4.3 Compression test of natural vs laminated form of Mahang wood

Based on the findings, the result of the research done can be referred to Figure 4.1 for further discussion on the result obtained for compression test.

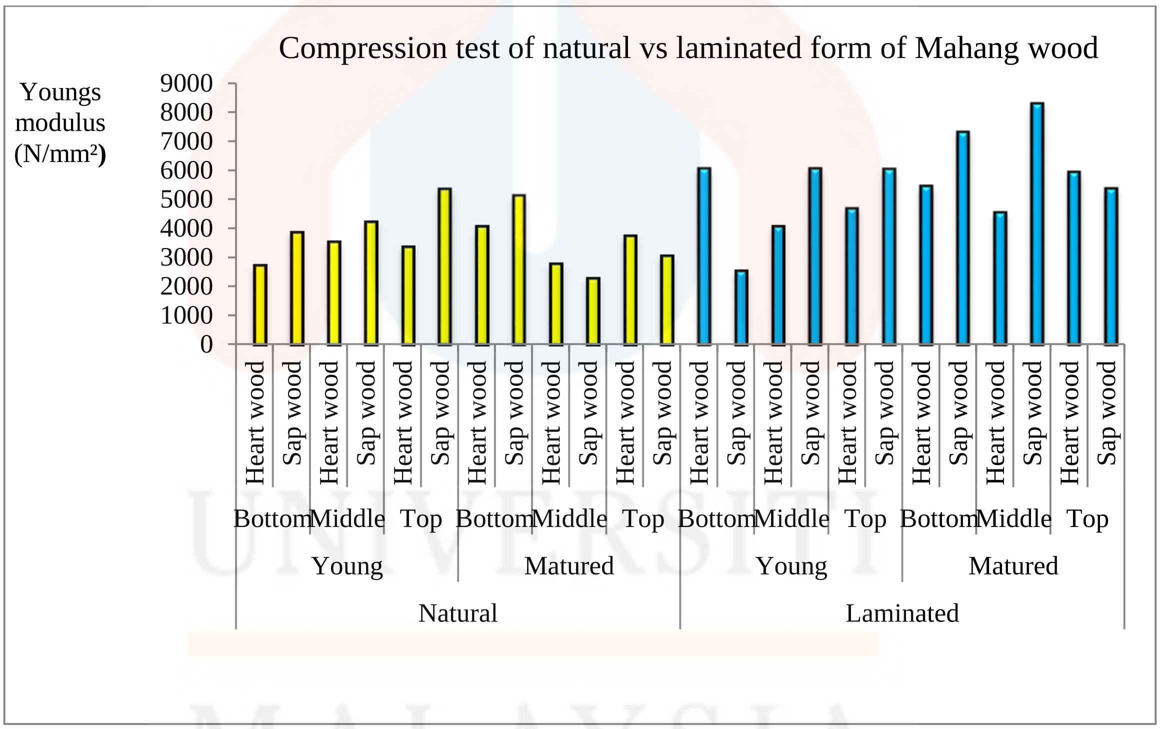

Figure 4.1: Compression test of natural form of Mahang wood

Figure 4.1 shows about the compression test and its result of laminated of matured and young Mahang wood, which each position of heartwood and sapwood at each portions were based on the mean of three replications of samples. Figure 4.1 shows that laminated form of Mahang wood performed the higher compression ability or Young's modulus when it was loaded with loads compressed in one direction under UTM during compression test, than that of natural form of Mahang wood. Based on natural form of Mahang wood, the highest Young's modulus was at top portion and at sapwood of young age of wood (5338.393 N/mm²).

Based on laminated form of Mahang wood, the highest Young's modulus was at middle portion and at sapwood of matured age of wood (8283.643 N/mm²). Top portion of natural form of young Mahang wood had more sapwood comprised in the wood (Snyder, 2007). This helped to improve the compression ability of it when was loaded with loads since the sapwood since the sapwood can increase the structural support for the tree from within the top portion. Based on laminated form of Mahang wood, the highest Young's modulus was at middle portion of matured wood, at sapwood (8283.643 N/mm²). This shows that lamination process that had been implemented by making two layers of wood of matured wood at sapwood position was good to improve the compression ability of the wood when loaded with loads onto it. So, this means that laminated form of matured Mahang wood can be used in flooring purposes and is more preferable for flooring than that of natural form of Mahang wood.

4.4 Analysis of Variance (ANOVA)

Based on the findings, the result of the research done can be referred to Table 4.3, Table 4.4 and Table 4.5 for further discussion on the analysis of variance (ANOVA) result obtained for bending and compression tests.

Table 4.3: Analysis of variance of modulus of elasticity (MOE) through bending test

	Df	Sum of Sq	Mean Sq	F Value	Pr (F)
Age	1	24083853	24083853	1.38230	0.2542325
Portion	2	8337416	8337416	0.47853	0.42974566
Position	1	16470279	16470279	0.94532	0.3431306
Form	1	686592793	686592793	39.40718	0.0000050
Residual	19	331037705	17423037		

Based on Table 4.3, form of wood had significance at 99% based on the Pr (F) values.

Table 4.4: Analysis of variance of modulus of rupture (MOR) through bending test

	Df	Sum of Sq	Mean Sq	F Value	Pr (F)
Age	1	19983.0	19983.0	12.36171	0.0023103
Portion	2	1868.9	1868.9	1.15611	0.2957380
Position	1	1868.9	1868.9	0.79059	0.3850409
Form	1	124355.9	124355.9	76.92803	0.0000000
Residual	19	30713.9	1616.5		

Based on Table 4.4, age and form of wood had significance at 99% based on the Pr (F) values.

Table 4.5: Analysis of variance through compression test

	Df	Sum of Sq	Mean Sq	F Value	Pr (F)
Age	1	9207454	9207454	19.9596	0.00003119977
Position	1	55565738	55565738	120.4537	0.00000000000
Portion	2	23259747	23259747	50.4218	0.00000000100
Form	1	115449293	115449293	250.2674	0.00000000000
Residuals	68	30307349	461304		

Table 4.5 shows that age, wood, portion and form of wood had significance at 99% based on the Pr (F) values.

4.5 Correlation Analysis

The result regarding correlation analysis between tests can refer Table 4.6.

Table 4.6: Correlation analysis between tests

Test	Bending	Compression
Bending	$1.00e^{+}000$	$8.15e^{-}001$
Compression		$1.00e^{+}000$

Based on correlation result between tests, it can be stated that between bending and compression, there was no correlation. This was based on correlation value of $8.15e^{-}001$ that exceeded the probability value (probability equal to 1.0).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Conclusively, Mahang wood has a potential to be further recommended as raw material in wood industry for our country and the world universally. Mahang wood can fulfil the increasing demands of the raw materials as a source in manufacturing and wood industry. Through bending test of Mahang wood, it can be suggested that the top portion of young wood and matured wood in natural from and moreover in laminated form. So, Mahang wood can be used in furniture industries like making of chairs and coffee tables. Through compression test, it can be suggested that matured Mahang wood can be used in flooring, plus when lamination of wood to wood layers were made. Its strength properties were successfully studied and the result shows that its strength properties can be further improved by applying lamination process. For young Mahang wood, the strength properties of bending was higher at bottom portion of sample than that of top portion because the bottom portion had higher density and had developed as wood (had developed more as heartwood) better than that of top portion (mostly developed more as sapwood). But, the laminated form of young Mahang wood performed higher strength properties than that of natural form. So the use of laminated form of young Mahang wood is more suitable for raw source in wood industry. Nevertheless, matured Mahang wood with laminated form performed higher strength properties than that of natural form of wood sample and also than that of laminated form of young wood. Hence the most usable and suitable wood age for wood industry was matured, plus with lamination process undergone. Age and form of wood did have the influence in choosing Mahang wood as alternative raw materials in wood industry with improved wood strength properties.

Along doing this research, I have taken three recommendations into my consideration to be emphasized, in order to improve the success of further studies regarding this research. The first recommendation is, the authority of University Malaysia Kelantan, Jeli Campus, needs to provide more ample facilities especially conditioned chamber to ease the standardization of moisture content (MC) of samples. Thus, the students who run the similar study do not have to go far to Forest Research Institute Malaysia, FRIM, for instance, only to do that purpose on the wood samples they use. The space for placing and keeping the samples for air dryness also need to be prepared to avoid damage like cracking of wood when left for thirty days in the wood lab.

Secondly, the staffs who are in charge in handling the machines and other wood lab tools need to be prepared with best skills and knowledge along assisting the students to run the research. This will also important to aid the students in safety awareness while accomplishing the study. Nice skilled and professional staffs are also needed to handle Universal Testing Machine for running bending and compression test without mistakes or errors.

Lastly, due to lack contact or connection between University Malaysia Kelantan with the industries outside, especially, wood industry, UMK needs to have good collaboration with the industries. This is vital to support the final year student in obtaining enough information about the research samples.

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APPENDICES

Appendix 1: Matured *Macaranga* spp. selection at Agropark UMK Jeli

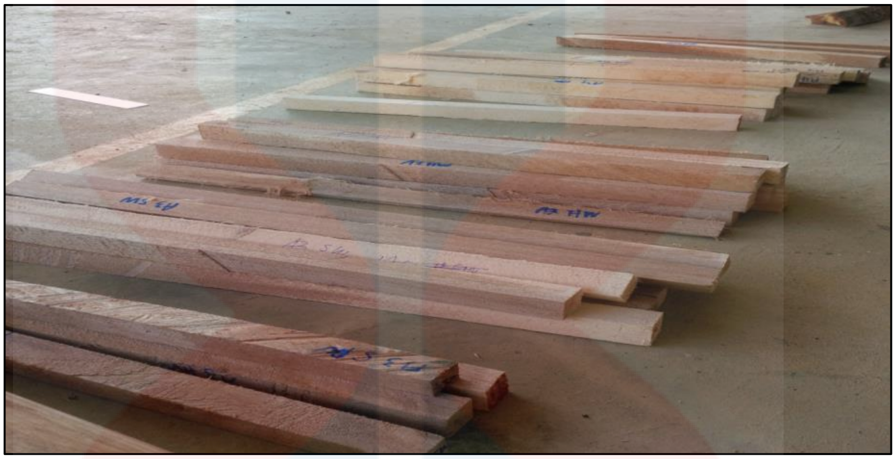
Appendix 2: Young *Macaranga* spp. selected at Agropark UMK Jeli

Appendix 3: Leaf structure of *Macaranga* spp.

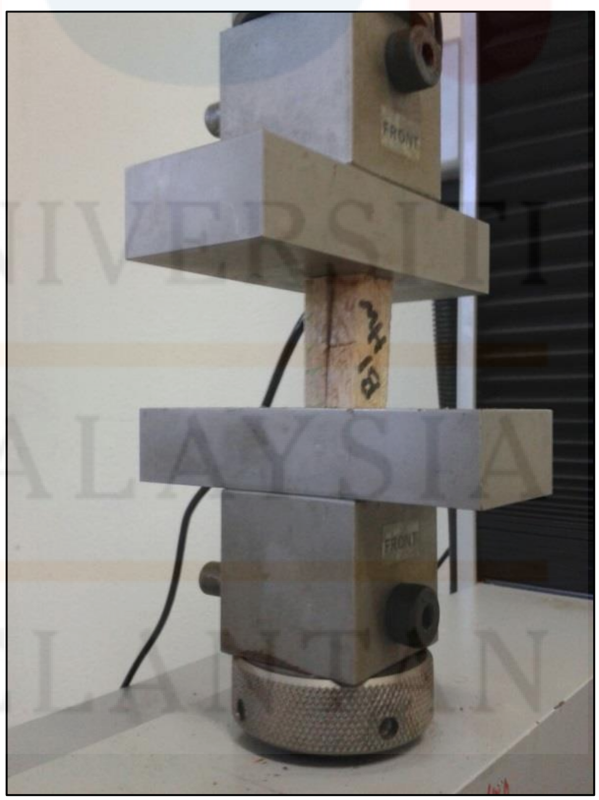
Appendix 4: Tagging of matured *Macaranga* spp.

Appendix 5: Preparation of samples for natural and laminated form

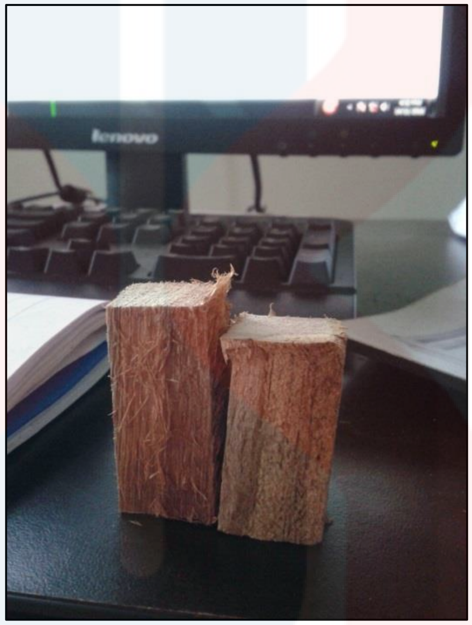
Appendix 6: The collection of planks arranged according to different portions



Appendix 7: Compression test ran onto 4cm x 2cm x 1cm laminated form sample



Appendix 8: Natural form 4cm x 2cm x 2cm compression sample before and after being compressed by UTM

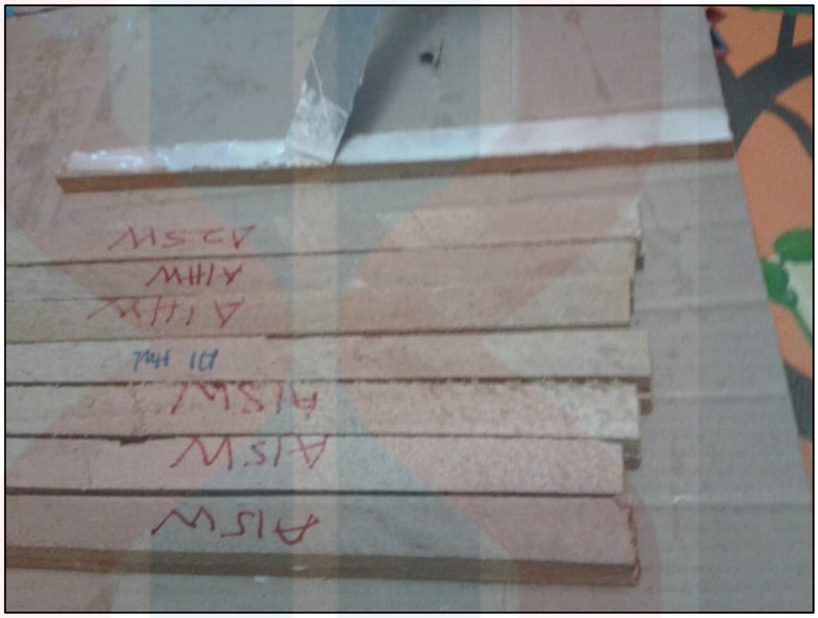


Appendix 9: Labelling (coding) samples for compression test

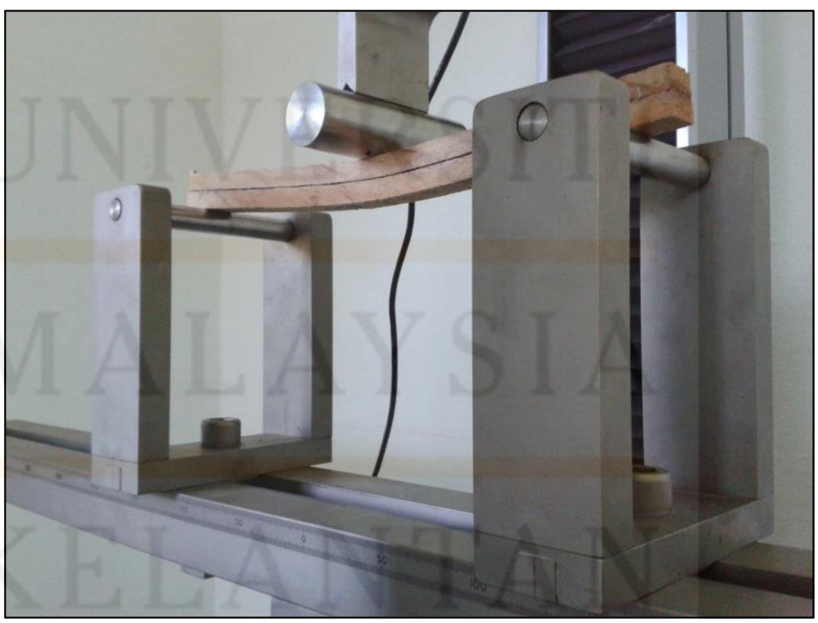
Appendix 10: Sanding of samples before running samples under UTM

Appendix 11: Lamination of samples for compression test

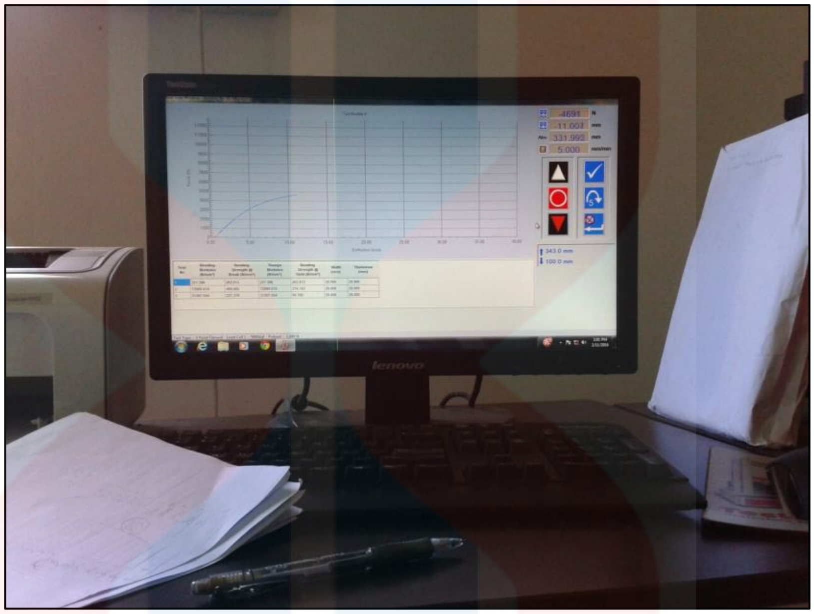
Appendix 12: Gluing process of sample using white glue



Appendix 13: Bending test using UTM of laminated form of wood



Appendix 14: Running of strength properties test of bending and compression using UTM



Appendix 15: UTM result for bending test for young natural form

UNIVERSITI MALAYSIA KELANTAN KAMPUS JELI
BENDING TEST REPORT

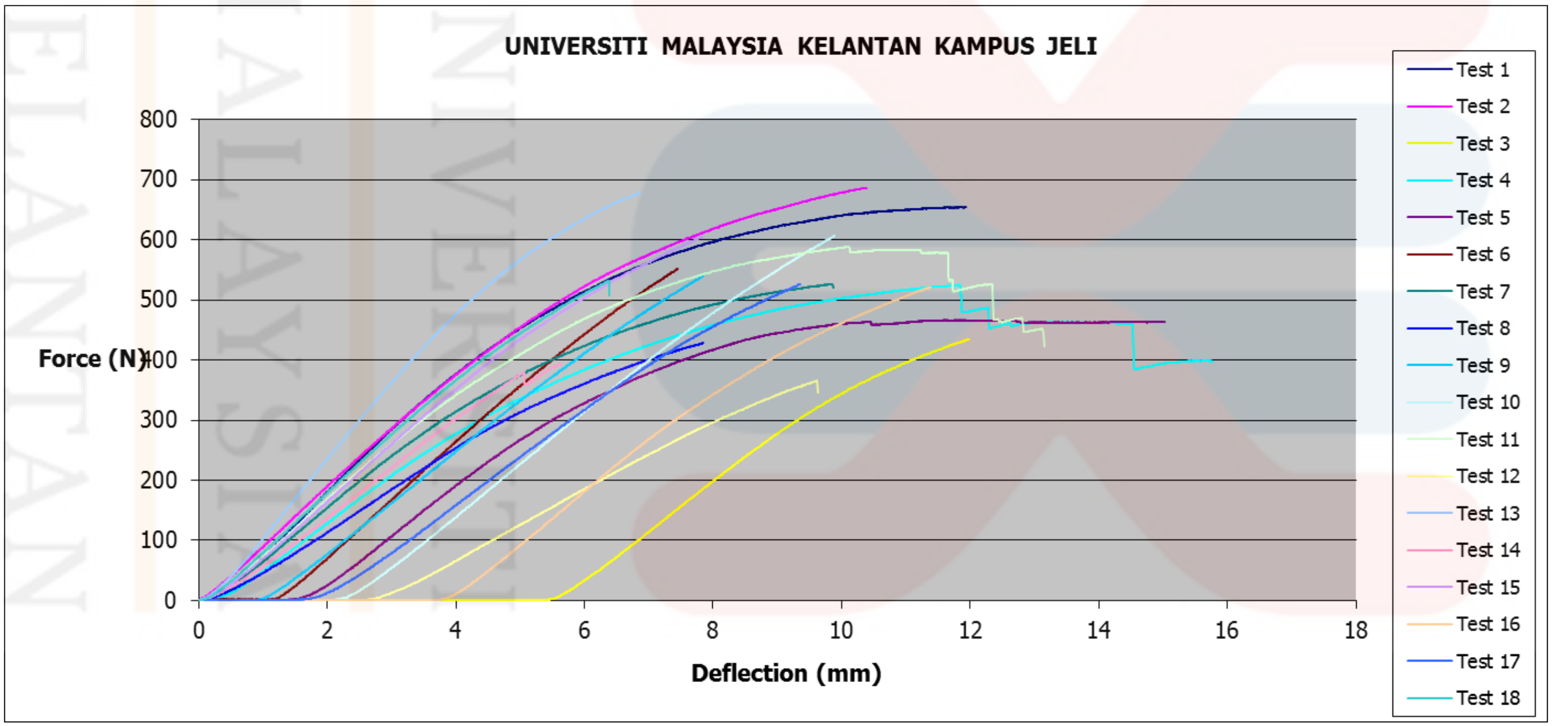
Sample Name : nature mahang young
Material : wood
Lab No :

Test Name : Bending for ASTM D1037
Test Type : 3 Point Flexural
Test Date : 11/10/2016 11:06:52 AM
Test Speed : 10.000 mm/min
Preload : 1.000 N
Width : 20.000 mm
Thickness : 20.000 mm
Span : 280.000 mm

Comments :

MOE

Test No	Width (mm)	Thickness (mm)	Bending Strength @ Peak (N/mm²)	Def. @ Break (mm)	MOR (N/mm²)	Youngs Modulus (N/mm²)	Maximum Compressive Force (N)
1	20.000	20.000	34.351	11.931	34.351	3699.548	654.300
2	20.000	20.000	36.031	10.381	36.031	3384.964	686.300
3	20.000	20.000	22.827	11.978	22.827	2899.376	434.800
4	20.000	20.000	27.563	15.757	27.563	2762.219	525.000
5	20.000	20.000	24.497	15.019	24.497	2913.706	466.600
6	20.000	20.000	28.933	7.448	28.933	3342.705	551.100
7	20.000	20.000	27.631	9.871	27.631	3078.590	526.300
8	20.000	20.000	22.475	7.841	22.475	2429.141	428.100
9	20.000	20.000	28.329	7.842	28.329	2942.493	539.600
10	20.000	20.000	31.841	9.895	31.841	3013.237	606.500
11	20.000	20.000	30.901	13.148	30.901	3262.329	588.600
12	20.000	20.000	19.210	9.630	19.210	2043.111	365.900
13	20.000	20.000	35.600	6.869	35.600	4560.744	678.100
14	20.000	20.000	20.638	5.635	20.638	2868.550	393.100
15	20.000	20.000	31.726	7.825	31.726	3278.452	604.300
16	20.000	20.000	27.353	11.378	27.353	3091.622	521.000
17	20.000	20.000	27.604	9.364	27.604	2757.213	525.800
18	20.000	20.000	27.904	6.386	27.904	3418.444	531.500
Min	20.000	20.000	19.210	5.635	19.210	2043.111	365.900
Mean	20.000	20.000	28.078	9.900	28.078	3097.025	534.828
Max	20.000	20.000	36.031	15.757	36.031	4560.744	686.300
S.D.			4.866	2.878	4.866	528.752	92.677
C. of V.			17.328	29.069	17.328	17.073	17.328
L.C.L.	20.000	20.000	25.659	8.469	25.659	2834.084	488.741
U.C.L.	20.000	20.000	30.498	11.331	30.498	3359.965	580.915



Appendix 16: UTM result for bending test for young natural form

Appendix 17: UTM result of bending test for matured natural form

UNIVERSITI MALAYSIA KELANTAN KAMPUS JELI
BENDING TEST REPORT

Sample Name : nature mahang mature
Material :
Lab No :

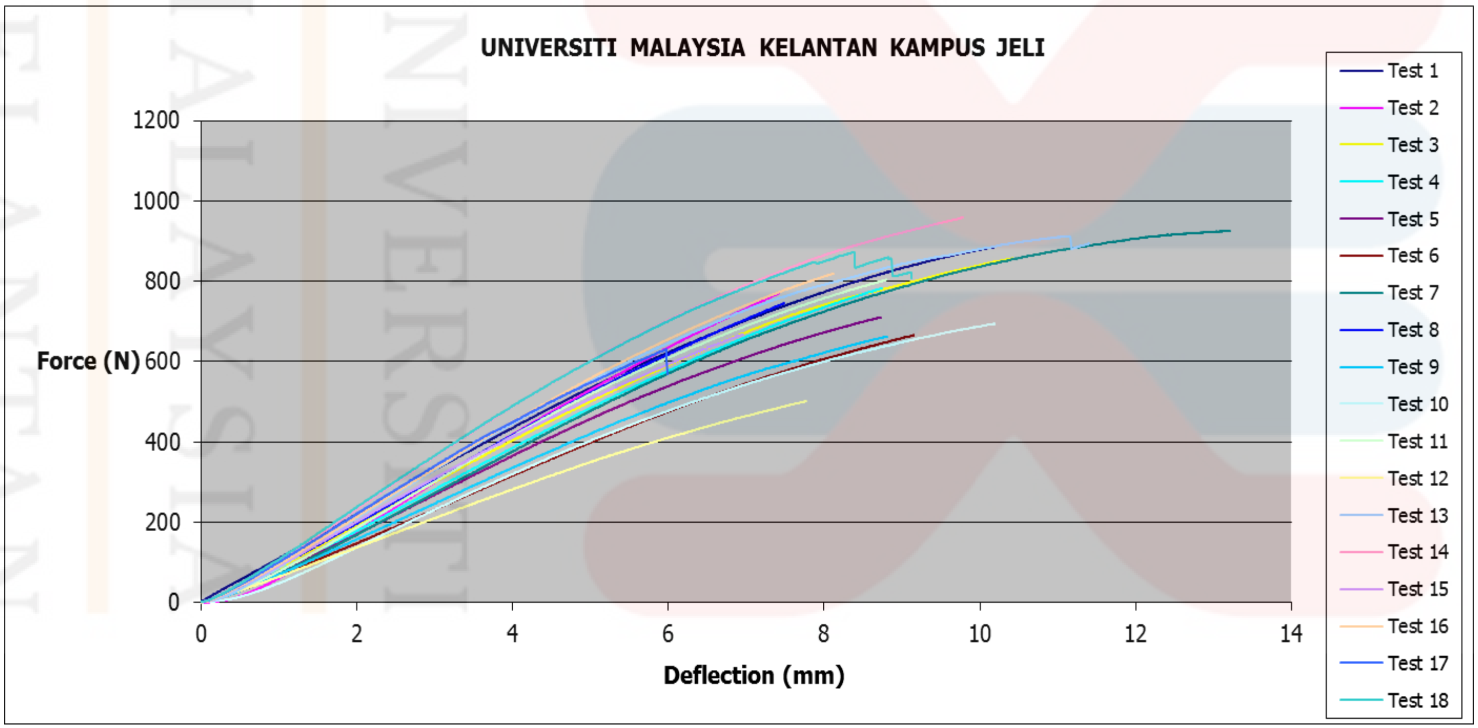
Test Name : Bending for ASTM D1037
Test Type : 3 Point Flexural
Test Date : 10/10/2016 5:14:13 PM
Test Speed : 10.000 mm/min
Preload : 1.000 N
Width : 20.000 mm
Thickness : 20.000 mm
Span : 280.000 mm

MOE

Comments :

Test No	Width (mm)	Thickness (mm)	Bending Strength @ Peak (N/mm²)	Def. @ Break (mm)	MOR (N/mm²)	Youngs Modulus (N/mm²)	Maximum Compressive Force (N)
1	20.000	20.000	46.473	10.190	46.473	3798.963	885.200
2	20.000	20.000	40.436	7.424	40.436	4180.437	770.200
3	20.000	20.000	44.993	10.420	44.993	3665.730	857.000
4	20.000	20.000	41.134	8.748	41.134	3554.869	783.500
5	20.000	20.000	37.296	8.730	37.296	3360.832	710.400
6	20.000	20.000	34.960	9.151	34.960	2888.904	665.900
7	20.000	20.000	48.631	13.211	48.631	3549.786	926.300
8	20.000	20.000	39.144	7.490	39.144	3778.817	745.600
9	20.000	20.000	34.766	8.807	34.766	3062.191	662.200
10	20.000	20.000	36.435	10.190	36.435	3226.749	694.000
11	20.000	20.000	42.199	8.795	42.199	3944.073	803.800
12	20.000	20.000	26.323	7.774	26.323	2501.527	501.400
13	20.000	20.000	47.885	11.402	47.885	4163.328	912.100
14	20.000	20.000	50.295	9.779	50.295	4550.749	958.000
15	20.000	20.000	35.081	6.969	35.081	3807.356	668.200
16	20.000	20.000	43.034	8.130	43.034	4104.738	819.700
17	20.000	20.000	33.086	5.993	33.086	4131.996	630.200
18	20.000	20.000	45.848	9.121	45.848	4463.751	873.300
Min	20.000	20.000	26.323	5.993	26.323	2501.527	501.400
Mean	20.000	20.000	40.445	9.018	40.445	3707.489	770.389
Max	20.000	20.000	50.295	13.211	50.295	4550.749	958.000
S.D.			6.363	1.705	6.363	546.321	121.196
C. of V.			15.732	18.904	15.732	14.736	15.732
L.C.L.	20.000	20.000	37.281	8.170	37.281	3435.812	710.120
U.C.L.	20.000	20.000	43.610	9.866	43.610	3979.165	830.658

Test No	Strain @ Break	Stress @ 0.000



Appendix 18: UTM result for matured natural form

Appendix 19 : UTM result of compression test for matured laminated

UNIVERSITI MALAYSIA KELANTAN KAMPUS JELI
COMPRESSION TEST REPORT SEH LAB 1

Sample Name : LAMIN MAHANG
Material : WOOD
Lab No : 1

Test Name : Compression test d1037
Test Type : Compression
Test Date : 15/11/2016 9:57:48 AM
Test Speed : 5.000 mm/min
Preload : 5000.000 N
Width : 20.000 mm
Breadth : 20.000 mm
Sample Height : 40.000 mm

Comments :

Test No	Width (mm)	Breadth (mm)	Force @ Peak (N)	Def. @ Break (mm)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Youngs Modulus (N/mm²)
1	20.000	20.000	50010.000	0.648	18.315	125.025	9502.572
2	20.000	20.000	50398.000	1.236	17.018	125.995	4867.249
3	20.000	20.000	50441.000	0.917	18.683	126.103	7570.340
4	20.000	20.000	50413.000	0.811	13.558	126.033	6483.614
5	20.000	20.000	50287.000	1.227	15.453	125.718	4551.044
6	20.000	20.000	50426.000	1.108	18.450	126.065	5276.281
7	20.000	20.000	50381.000	1.022	15.528	125.953	5216.877
8	20.000	20.000	50356.000	0.728	17.088	125.890	8756.408
9	20.000	20.000	50237.000	0.459	14.175	125.593	10877.644
10	20.000	20.000	50427.000	2.138	23.903	126.068	3625.792
11	20.000	20.000	50450.000	1.621	23.073	126.125	5667.798
12	20.000	20.000	50477.000	3.515	28.433	126.193	4305.564
13	20.000	20.000	50489.000	0.892	20.065	126.223	6910.929
14	20.000	20.000	50397.000	3.663	26.973	125.993	4498.560
15	20.000	20.000	50359.000	1.827	28.835	125.898	4663.940
16	20.000	20.000	50331.000	0.793	16.173	125.828	5612.703
17	20.000	20.000	50430.000	1.120	14.845	126.075	5590.086
18	20.000	20.000	50368.000	0.840	15.458	125.920	6561.431
19	20.000	20.000	50430.000	1.784	15.663	126.075	2445.085
20	20.000	20.000	50476.000	1.659	13.770	126.190	1956.158
21	20.000	20.000	50413.000	1.633	15.605	126.033	3158.260
22	20.000	20.000	50477.000	0.982	13.605	126.193	7174.436
23	20.000	20.000	50497.000	1.437	14.045	126.243	4263.053
24	20.000	20.000	50350.000	1.166	20.023	125.875	6696.112
25	20.000	20.000	50411.000	1.218	13.585	126.028	3040.961
26	20.000	20.000	50480.000	0.853	16.683	126.200	8599.174
27	20.000	20.000	50414.000	1.559	16.690	126.035	6523.963
28	20.000	20.000	50481.000	1.362	17.018	126.203	5428.309
29	20.000	20.000	50433.000	1.452	14.943	126.083	2070.609
30	20.000	20.000	50469.000	1.129	13.175	126.173	4704.486
31	20.000	20.000	50478.000	0.922	15.883	126.195	5355.155
32	20.000	20.000	50482.000	1.154	15.095	126.205	3422.309
33	20.000	20.000	50387.000	-2.445	0.143	125.968	9284.594
34	20.000	20.000	50384.000	0.867	14.433	125.960	4397.768
35	20.000	20.000	50251.000	1.495	16.478	125.628	5591.495
36	20.000	20.000	50410.000	1.868	13.805	126.025	4052.365
Min	20.000	20.000	50010.000	-2.445	0.143	125.025	1956.158
Mean	20.000	20.000	50400.000	1.241	16.852	126.000	5519.531
Max	20.000	20.000	50497.000	3.663	28.835	126.243	10877.644
S.D.			92.746	0.922	5.021	0.232	2112.824
C. of V.			0.184	74.336	29.798	0.184	38.279
L.C.L.	20.000	20.000	50368.619	0.928	15.153	125.922	4804.657
U.C.L.	20.000	20.000	50431.381	1.553	18.551	126.078	6234.405

Test No Strain @ Peak

Appendix 20: UTM result of compression of young and matured natural form

UNIVERSITI MALAYSIA KELANTAN KAMPUS JELI
COMPRESSION TEST REPORT SEH LAB 1

Sample Name : NATURAL MAHANG
Material : WOOD
Lab No : 1

Test Name : Compression test d1037
Test Type : Compression
Test Date : 14/11/2016 4:14:02 PM
Test Speed : 5.000 mm/min
Preload : 5000.000 N
Width : 20.000 mm
Breadth : 20.000 mm
Sample Height : 40.000 mm

Comments :

Test No	Width (mm)	Breadth (mm)	Force @ Peak (N)	Def. @ Break (mm)	Stress @ Break (N/mm²)	Stress @ Peak (N/mm²)	Youngs Modulus (N/mm²)
1	20.000	20.000	50421.000	1.255	22.895	126.053	5191.094
2	20.000	20.000	50467.000	1.420	23.520	126.168	4923.962
3	20.000	20.000	50447.000	1.058	20.973	126.118	5222.276
4	20.000	20.000	49293.000	1.236	123.233	123.233	2275.335
5	20.000	20.000	50276.000	1.865	31.835	125.690	5001.325
6	20.000	20.000	50342.000	2.114	29.558	125.855	4894.390
7	20.000	20.000	50401.000	1.621	15.898	126.003	1963.999
8	20.000	20.000	50398.000	1.375	14.215	125.995	3144.730
9	20.000	20.000	50475.000	2.420	16.448	126.188	1698.798
10	20.000	20.000	50413.000	1.944	16.038	126.033	2571.805
11	20.000	20.000	50467.000	1.545	15.840	126.168	3162.003
12	20.000	20.000	50495.000	1.407	14.988	126.238	2575.037
13	20.000	20.000	50276.000	1.670	16.115	125.690	2148.699
14	20.000	20.000	50254.000	1.158	16.273	125.635	3476.431
15	20.000	20.000	50413.000	1.541	20.455	126.033	3518.762
16	20.000	20.000	50450.000	1.278	18.060	126.125	2890.074
17	20.000	20.000	50386.000	1.787	23.278	125.965	3216.215
18	20.000	20.000	50446.000	1.261	16.693	126.115	5122.665
19	20.000	20.000	50470.000	1.535	16.853	126.175	2827.293
20	20.000	20.000	50390.000	0.934	14.863	125.975	4170.453
21	20.000	20.000	50359.000	1.207	19.008	125.898	4590.366
22	20.000	20.000	50484.000	1.841	13.948	126.210	2182.801
23	20.000	20.000	50474.000	1.177	13.535	126.185	2401.555
24	20.000	20.000	50495.000	0.978	15.045	126.238	3566.972
25	20.000	20.000	50410.000	0.737	13.593	126.025	5350.808
26	20.000	20.000	50458.000	0.889	13.010	126.145	3749.451
27	20.000	20.000	50413.000	1.138	13.600	126.033	3575.322
28	20.000	20.000	50426.000	1.474	12.828	126.065	2993.501
29	20.000	20.000	50464.000	1.331	13.600	126.160	3147.114
30	20.000	20.000	50464.000	1.203	13.280	126.160	4432.755
31	20.000	20.000	50316.000	0.923	16.685	125.790	4820.997
32	20.000	20.000	50390.000	1.349	22.258	125.975	5463.195
33	20.000	20.000	50198.000	0.725	13.628	125.495	5730.987
34	20.000	20.000	50365.000	1.185	18.158	125.913	3628.506
35	20.000	20.000	50426.000	2.060	12.743	126.065	3025.862
36	20.000	20.000	50435.000	1.511	13.910	126.088	3430.491
Min	20.000	20.000	49293.000	0.725	12.743	123.233	1698.798
Mean	20.000	20.000	50376.583	1.393	20.190	125.941	3669.056
Max	20.000	20.000	50495.000	2.420	123.233	126.238	5730.987
S.D.			198.883	0.390	18.239	0.497	1141.437
C. of V.			0.395	27.998	90.335	0.395	31.110
L.C.L.	20.000	20.000	50309.291	1.261	14.019	125.773	3282.851
U.C.L.	20.000	20.000	50443.875	1.525	26.361	126.110	4055.262

Test No	Strain @ Peak (%)

Appendix 21: UTM result of compression of young and matured natural form