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TECHNICAL AND ECONOMICAL ANALYSIS OF THE USE OF GLUED LAMINATED FROM COMBINATION OF APUS BAMBOO AND MERANTI WOOD AS AN ALTERNATIVE MATERIAL COMPONENT IN TIMBER SHIPBUILDING

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ABSTRACT

Development of glued laminated beam technology to become an alternative material of timber shipbuilding in shipping industry. In this study, laminated beam will be manufacture with combination of apus bamboo and meranti wood. The purpose of this research is to determine the value of tensile strength parallel to grin, compressive strength perpendicular to grin, influence of variation, strenght class of timber based on the regulation of BKI and the cost of manufacture with variations in the percentage of material (70% timber 30% bamboo, 60% timber 40% bamboo, 50% timber 50% bamboo, 40% timber 60% bamboo, 30% timber 70% bamboo). This study uses standard test methods SNI 03-3399-1994 for tensile test and SNI 03-3960-1995 for compression test. The results of the research laminated beam of timber and bamboo with MC 10 - 14% and dencity of 0.73 - 0,88 gr/cm3, has an average value of tensile strength of 92,43 - 127,43 MPa and average value of compressive strength of 41,64 – 41,99 MPa. Variations with material percentage greatly affect the value of tensile strength, but it's not on the compressive strength.. According to the timber ship regulation of BKI, glued laminated of apus bamboo and meranti wood can be categorized in Strength Class II and can be used as an alternative material of timber shipbuilding. Based on the analysis cost of manufacturing, the most optimal variation is K30B70, that increased 22,49% from the price of meranti wood and 34,93 % from the price of apus bamboo.

Key words: glued laminated beam, apus bamboo, meranti wood, tensile strength parallel to grin, compressive strength perpendicular to grin, strenght class of timber.

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1. INTRODUCTION

The available wood in the market is the result of a fast-growing tree with a small diameter because the cutting cycles are short, whereas a small-diametric wood is not yet as an efficient product in structural components or construction. The availability of small-diametric block is inversely proportional to the need for structural components of the blocks with large enough dimensions. It then requires a method that can meet those needs[1]. It also resulted in the manufacture of wooden ships in Indonesia because it is difficult to get the ship's main raw material, that is wood.

To meet the needs of the wood components in large quantities, it is then developed a form of structure consisting of a laminate made by gluing or so-called laminated beam or Glulam (Glued Laminated)[2]. The material to be used as a constituent of the laminated beam in this study are apus bamboo and meranti wood. In the manufacture of laminate beam with a combination of these two components, needs the proper type of adhesive that bamboo plants and glued-wood layers can be integrated optimally. This study was conducted to obtain data on the mechanical capabilities such as tensile and compressive strengths of laminated apus bamboo and meranti woods.

1.1. Research Problems

This study was taken the research problems are to determine whether the extent of laminated apus bamboo and meranti wood can withstand the tensile and compressive strengths, to find out the influence of variations in the percentage composition of the material to the value of tensile and compressive strengths, to identify any parts of the ship that can be laminated based on the regulations of BKI, as well as the cost analysis of laminated apus bamboo and meranti wood as wooden ship components.

1.2. Research Purposes

Based on the statement above, the intent and purpose of this research is to determine the strength of the laminated material from a combination of apus bamboo and meranti wood if it receives tensile and compressive loads to manufacture ship components based on the mechanical strength standard required or permitted by BKI (Biro Klasifikasi Indonesia), to determine the influence of variations in the composition of both materials toward the tensile and compressive strengths and to identify the price required for the application of laminated apus bamboo and meranti wood on timber ships.

2. LITERATURE REVIEW

2.1. Laminated Beam or Glulam (Glued Laminated)

Glulam (Glued Laminated) or laminated beams are wood products consist of small blocks which are laminated with an adhesive so as to obtain laminated beams that have a larger dimension[3]. The advantages of laminated beam are of its larger size, independent in architectural design, quality of the laminate, various cross-sectional area, efficient use, and environmentally friendly. The disadvantages are the higher production costs and the need for expertise in the manufacturing process[4].

2.2. Bambu Apus dan Kayu Meranti

Apus bamboo is known as awi rope or strap pring. Apus bamboo is included in the genus Gigantochloa who have dense clumps. Scientific name of rope bamboo is Gigantochloa lear.

Meranti wood or Shorea SP is a wood from the tropics island in Sumatra, Sulawesi, Borneo and Maluku which is including one of an industrial timber estates[5]. This wood including wood with strenght class II-IV and wood with durability class III-IV. Meranti wood is included in the category of lightweight hardwood that has a height of up to 60 m and a diameter of up to 175cm.

2.3. Perekat Epoxy (Melamine Formaldehyde)

Epoxy adhesive is a thermoset resin thas combination of these two component, there are resin and hardener as shown in fig1. Epoxy adhesive has special advantages among others those are, high adhesion, good cohesion, fully dense, low shrinkage, resistant to moisture and solvents, and easily modified. Epoxy also has disadvantages such as expensive, brittle adhesive lines, blunting the equipment and harden to clean the mixer equipment. Selection of Epoxy as adhesives due to mechanical and physical properties in accordance with the need for wooden ships adhesives[7].

Figure 1 *hardene*r and resin of *epoxy adhesive*

3. METODOLOGY

3.1. Standards Test Methods

- SNI 03-3399-1994 standard test method for tensile strength parallel to grin.
- SNI 03-3958-1995 standard test method for compressive strength perpendicular to grin.

3.2. Fixed Research Parameter

The machine to be used of tensile strength parallel to grin testing are Universal Testing Machine (UTM). Here are the details of the tensile strength paraller to grin testing standard to be performed:

- The number of specimens 3 specimens per variations.
- The loading speed // 20 Mpa/ min.
- The accuracy of cross-sectional size ± 0,25 mm.
- The accuracy of the length of the test specimen should not be more than 1 mm.
- The form of specimen as figure 2

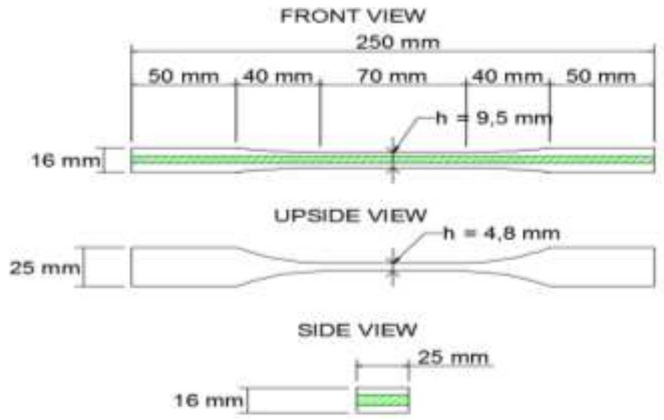

Figure 2 The form of tensile strength test specimen

The formula to be used as a calculation value of tensile strengt parallel to grin can be determined as follow [8]:

$$\sigma_{tr}\| = \frac{P}{b \times h} \quad (1)$$

Note: σ_{tr} // = tensile strength parallel to grin (MPa)

P = The maximum test load (N)

b = The width of the test area (mm)

h = The height of the test area (mm)

The machine to be used of compressive strength perpendicular to grin testing are Universal Testing Machine (UTM). Here are the details of the compressive strength perpendicular to grin testing standard to be performed:

- The number of specimens 3 specimens per variations.
- The accuracy of cross-sectional size ± 0,25 mm.
- The accuracy of the length of the test specimen should not be more than 1 mm.
- The form of specimen as figure 3

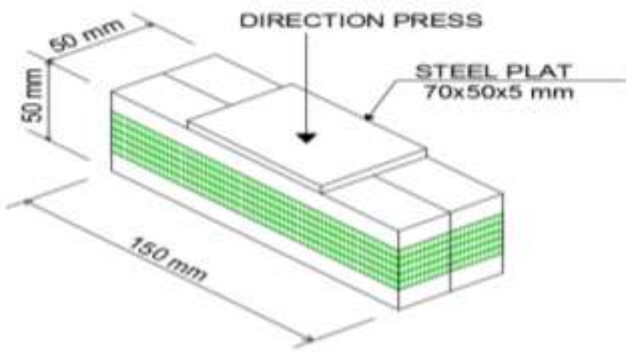

Figure 3 The form of compressive strength test specimen

The formula to be used as a calculation value of compressive strength perpendicular to grin can be determined as follow [8]:

$$\sigma_{tk} \perp = \frac{P}{b \times h} \quad (2)$$

Note: $\sigma_{tk} \perp$ = Compressive strength perpendicular to grin (MPa)

P = The maximum test load (N)

b = The width of the test area (mm)

h = The height of the test area (mm)

3.3. Variables Parameter

This study has 5 variation in the percentage composition of the materials, there are:

- 70% meranti wood and 30% apus bamboo with the test code K70B30.
- 60% meranti wood and 40% apus bamboo with the test code K60B40.
- 50% meranti wood and 50% apus bamboo with the test code K50B50.
- 40% meranti wood and 60% apus bamboo with the test code K40B60.
- 30% meranti wood and 70% apus bamboo with the test code K30B70.

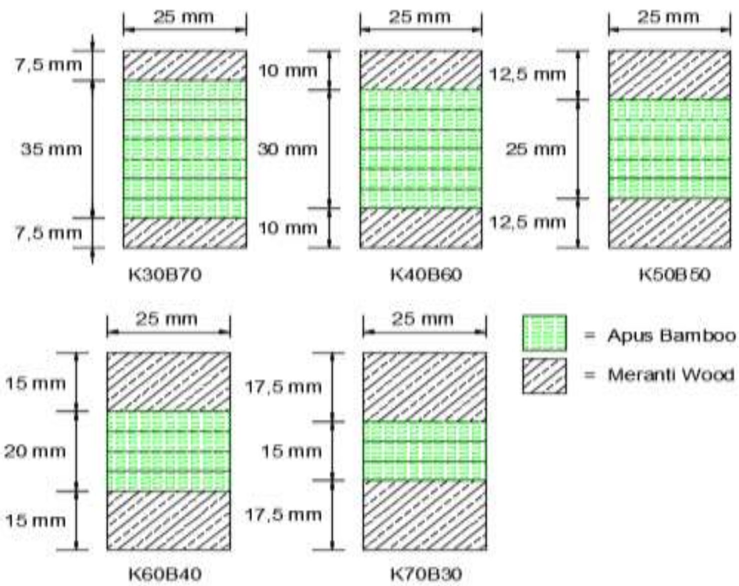

Figure 4 Laminates Composition

3.4. Laminated Beam Manufacturing Process

- Cutting bamboo
- Preservation bamboo
- Drying bamboo
- Splitting bamboo
- 4 side planning bamboo

- Making sapwood
- Sorting process
- Sandpaper process
- The process of measuring MC
- The process of gluing and pressing
- The drying process laminated beams
- The process of establishing the appropriate size specimen testing standards.

4. RESULTS AND DISSCUSION

4.1. Moisture Content (MC)

The moisture content is required to meet the testing standards contained in the SNI , where the standard moisture content of materials that can be used in the test should be < 20% [9][10]. In addition, the calculation of moisture content is used to qualify the material contained in the specifications of the adhesive used, that is <12%. In this study, the calculation of the value of moisture content of materials is done using the Moisture Meter. The results of the calculation of moisture content in apus bamboo and meranti woods are in the 10% - 12%. It shows that the materials of meranti wood and apus bamboo as laminate met the requirements of SNI testing standards and Epoxy adhesive specifications.

Figure 5 Calculation of MC using moisture meter

4.2. Density (ρ)

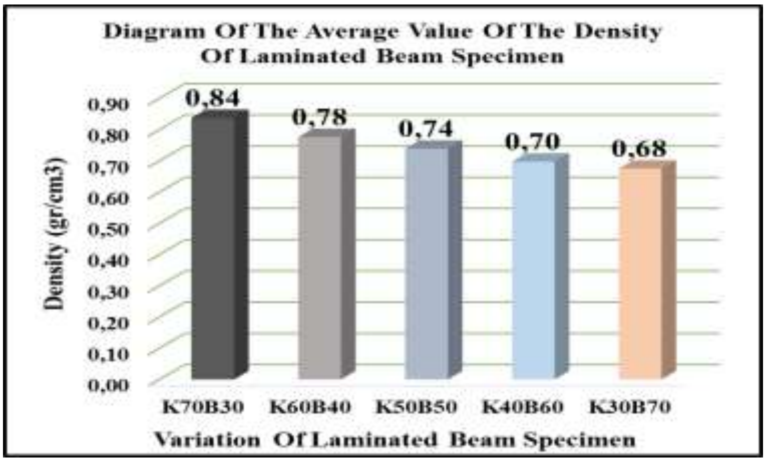

Figure 6 Average value of the density of Laminated beam specimen

Based on diagram of Figure 6 is obtained density values for the variation K30B70, K40B60, K50B50, K60B40 and K70B30 respectively is 0,68 gr/cm^3, 0,70 gr/cm^3, 0,74 gr/cm^3, 0,78 gr/cm^3 and 0,84 gr/cm^3. The largest density value contained in the variation of K70B30 and the smallest density value contained in the variation of K30B70. It shows that density value of laminated bamboo plants and meranti wood to variations in material composition tends to be greater if the percentage of meranti wood is larger than the percentage of bamboo plants.

4.3. Tensile Strength Parallel to Grin (σ_{tr} //)

The test is performed at the Laboratory of Materials Engineering Department of Mechanical Engineering, Vocational School of Gadjah Mada University. The size of the test object is made that is 250 mm long, 25 mm wide and 16 mm thick. The size of the test field is a length 70 mm, a width 4,8 mm and thick 9,5 mm.

Figure 7 Process of tensile testing and the specimen after the test

Table 1 Tensile strength test of laminated apus bamboo and meranti wood

Test code	σ_{tr} // (MPa)	Ɛ (%)	E (Mpa)
K30B70	127,43	27,50	463,46
K40B60	118,10	28,27	417,80
K50B50	106,88	26,67	400,78
K60B40	100,42	26,95	372,59
K70B30	92,431	28,93	319,46

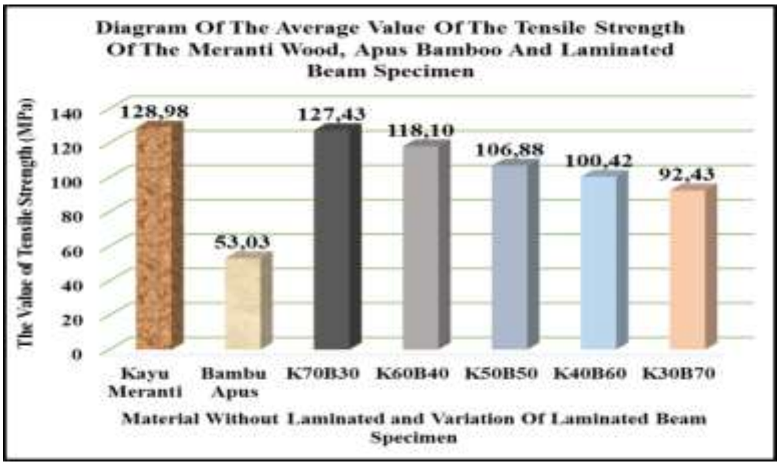

Figure 8 Average value of the tensile strength of the meranti wood, apus bamboo and laminated beam specimen

The smallest value of tensile strength parallel to grin contained in K30B70 variation with the value of 92,43 MPa and the largest tensile strength parallel to grin value contained in

K70B30 variation with the value of 127,43 Mpa as shown in table 1. This shows that the value of tensile strength parallel to grin of apus bamboo and meranti wood is due to variations in material composition, tend to be greater if the percentage of meranti wood is larger than compared to the percentage of apus bamboo material in laminated beam.

The value of the tensile strength parallel to grin of meranti wood without laminated based on the laboratory testing is 128,98 MPa, while the value of the tensile strength parallel to grin of apus bamboo based on previous research was 53,03 MPa[11]. It can be calculated the percentage of increasing and decreasing of the value of tensile strength parallel to grin of apus bamboo and meranti wood laminated toward the pure material or without lamination by figure 8. Where the value of the tensile strength parallel to grin on K30B70 variation decreased 28,34% from meranti wood, it increased 74,30% from bamboo plants. As for the largest value of tensile strength parallel to grin on K70B30 variation decreased 1,20% from meranti wood and increased 140,30% from apus bamboo. The decreasing of the value of tensile strength parallel to grin of the laminated apus bamboo and meranti wood due to a mix strength of meranti wood and apus bamboo during the process of manufacture of laminated blocks that make the value of tensile strength parallel to grin is between the amount of the value of tensile strength parallel to grin of pure apus bamboo and pure meranti wood.

4.4. Compressive Strength Perpendicular to Grin ($\sigma_{tk}^{\perp}$)

Compressive strength perpendicular to grin testing is the same as to the tensile test, which uses machine Universal Testing Machine (UTM) in the Laboratory of Materials Engineering Department of Mechanical Engineering,Vocational School of Gadjah Mada University. The size of the test specimen compressive strength perpendicular to grin is 150 x 50 x 50 mm. Imposition is done with the help of a steel plate has measurement of 70 x 50 x 5 mm.

Gambar 9 Press tested and specimen tested

Table 2 Compressive strength test of laminated apus bamboo and meranti wood

Test code	$\sigma_{tk}^{\perp}$ (MPa)
K30B70	41,64
K40B60	41,69
K50B50	41,69
K60B40	41,77
K70B30	41,99

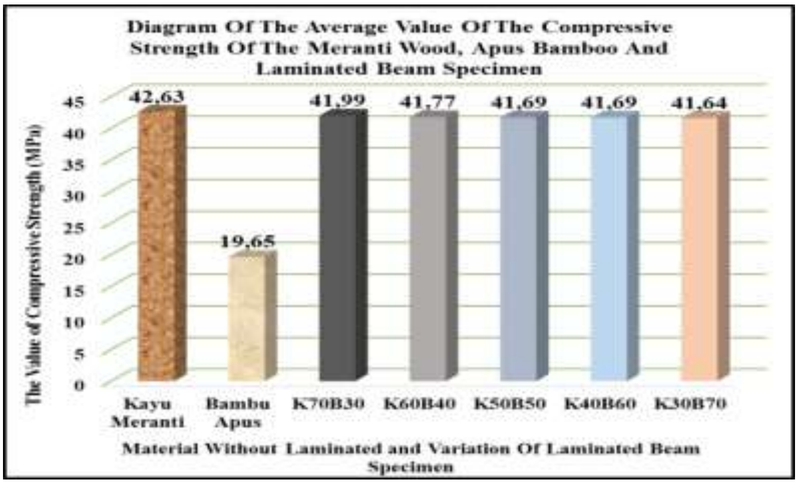

Figure 10 Average value of the compressive strength of the meranti wood, apus bamboo and laminated beam specimen

From Table 2, it is known that the average value of the compressive strength relative to each variation is between 41.64 MPa to 41.99 Mpa as shown in table 2. This shows that the laminated beam of apus bamboo and meranti wood with the additional composition variation of apus bamboo or meranti wood does not give a real change to the value of compressive strength perpendicular to grin.

The value of compressive strength of meranti wood based on laboratory testing is 42,63 MPa, while the value of compressive strength perpendicular to grin of apus bamboo based on previous research was 19,65 MPa[11]. According to figure 10, it can be calculated that the percentage of increasing and decreasing of the value of compressive strength perpendicular to grin of the apus bamboo and meranti wood laminated beam to the pure material or without lamination. Where the smallest value of compressive strength perpendicular to grin on K30B70 variation increased 2,33% from meranti wood and increased 111,90% from apus bamboo. Whereas for the largest value of compressive strength perpendicular to grin on variation K70B30 decreased 1,50% from meranti and increased 113,69% from apus bamboo.

4.5. Analysis and Comparison of Results of Laboratory Testing by Timber Ship Regulation of Biro Klasifikasi Indonesia (BKI) Volume VI, 1996

Based on timber ship regulation of Biro Klasifikasi Indonesia (BKI), it can be identified that the minimum requirements for the quality of the wood used in the important part of construction should be the minimum of strenght class III and durability class III. For plywood itself should use approvable adhesive, waterproof and has been tested and stamped by the BKI, or made according to recognized standards and must have tensile strength of minimum 430 kg/cm^2 in the longitudinal direction and 320 kg/cm^2 in the transversal direction. When used lighter wood than the minimum requirement set by the BKI, then the size of each construction should be enlarged (regarding the board thickness, the frame of deck contructions and the stiffener of bulkhead modulus cross section, the keel cross section) in proportion to the minimum density of wood according to the regulations of the real density of wood[12].

Table 3 Strenght class of timber[12]

Strength class	**Dry Density (gr/cm^3)**	**Bending Strength** (Kg/m^2)	**Compressive Strength**
I	≥0,90	≥1100	≥650
II	0,60-0,90	725-1100	425-650
III	0,40-0,60	500-725	300-425
IV	0,30-0,40	360-500	215-300
V	≤0,30	≤360	≤215

Based on test results conducted on the laminated apus bamboo and meranti wood with a percentage ratio values of material composition, obtained the value of air dry density ranging from 0,68 gr/cm^3 to 0,84 gr/cm^3. Laminated bamboo plants and meranti wood are categorized in the category of Strength Class II as shown in table 3.

The testing result for compressive strength test of laminated apus bamboo and meranti wood obtained the value of the average compressive strength of 41,64 MPa to 41,99 MPa or can be converted to 424,45 kg/cm^2 to 428,04 kg/cm^2. The strength class of timber, showing that the laminated apus bamboo and meranti wood are included in the Strength Class II.

The testing result for compressive strength test of laminated apus bamboo and meranti wood obtained the value of the average compressive strength of 92,43 MPa to 127,43 MPa or can be converted to 942,21 kg/cm^2 to 1298,98 kg/cm^2. It shows that the laminated of apus bamboo and meranti wood qualify the plywood requirement that can be used.

Based on comparison of result of laboratorium testing by timber ship regulation BKI Vol VI in 1996, laminated of apus bamboo and meranti wood can be recommanded on the ship as:

- stern
- stern block
- framing system
- keel plate
- floor
- Deck structure
- Deck plating
- Deck beam
- web frame
- Side Shell plating
- Bracket

4.6. Economic Analysis of Laminated Beam

Economic analysis is performed by calculating the price per m^3 is needed to make the timber ship components to each variation. Then the price is compared by the price of apus bamboo, meranti wood and some wood with Strenght class II.

Table 4 Price of each variation, meranti wood and some wood with Strenght Class II

Material	Cost (IDR per m^3)
Variant K30B70	6.999.584
VariantK40B60	7.079.485
Variant K50B50	7.159.386
Variant K60B40	7.348.645
Variant K70B30	7.537.904
Apus bamboo	5.187.706
Meranti wood	5.714.286
Sea Dammar wood	9.500.000
Merbau wood	13.500.000
Teak wood	14.500.000

Based on a price percentage ratio of the variation of meranti wood and bamboo plants, it is known that the K30B70 variation increased 22.49% of meranti wood price and 34.93% of apus bamboo price. Price of K40B60 variation increased 23,89% of meranti wood and 36.47% of apus bamboo. Price of K50B50 variation increased 25.29% of meranti wood and 38.01% of apus bamboo. Price of K60B40 variation increased 28,60% of meranti wood and 41.66% of apus bamboo. And the price for K70B30 variation increased 31.91% from meranti wood and 45.30% of apus bamboo. All variations of laminated apus bamboo and meranti wood have increased the price of meranti wood and apus bamboo material. The increase in prices occurred in laminated bamboo plants and meranti wood because of the additional raw materials such as adhesives and production costs increase in the production process during the manufacture of laminates.

It is known from table 4 that the price per m3 of laminated apus bamboo and meranti wood with the most economical price on K30B70 variation at Rp 6.999.584 per m^3. The K30B70 variation itself is a variation of the lowest mechanical value among other variations, but still classified in Strength Class II under timber ship Regulation of BKI Volume VI in 1996. This shows that the K30B70 laminate is the most optimal variation based on economic analysis and comparison with BKI Volume VI year 1996. Price of K30B70 variations is cheaper compared to some of the wood that includes other Strength Class II which commonly used on timber ship as sea dammar, merbau and teak wood. This becomes the advantage of laminated apus bamboo and meranti wood compared to the use of Strength Class II in timber ship manufacturing.

5. CONCLUSION AND SUGGESTION

5.1. Conclusion

Based on the calculation and analysis were conducted by the author of the research about laminating of apus bamboo and meranti wood as an alternative material components of timber ships, it can be deduced as follows:

- The avarage value of tensile strength parallel to grin is between 92,43 to 127,43 MPa, and The avarage value of compressive strength perpendicular to grin is between 41,64 to 41,99 MPa

- The influence of variations in the composition influences the value of tensile strength parallel to grin, but doesn't give significant effect on the value of compressive strength perpendicular to grin. Where the tensile strength values decreased from 1,20 to 28,34% of meranti woods and increased from 74,30 to 140,30% of apus bamboo, the value of compressive strength decreased from 1,50 to 1,33% of meranti woods and increased 111,90 to 113,69% of apus bamboo.
- Laminated of apus bamboo and meranti wood with all the variations in the composition can be categorized in Strength Class II under Timber Ship Regulation of BKI Volume VI in 1996, and can be recommended on the ship as stern block, frame, and others.
- The most optimal variation based on economic analysis and comparison with a strenght class table is a K30B70 variation Where the price of K30B70 variation increased 22,49% from meranti wood and 34,93% apus bamboo.

5.2. Suggestion

This study was made by author has many limitation and deficient. Therefore, as for some of the author's suggestion for the next research, there are:

- Existing the tensile and compressive strength using other variations such as variations in direction of the fibers, temperature variations and long felts, as well as variations in addition to the epoxy adhesive
- Extending the assessment and adding the test to comply with the eligibility rules need on timber ships BKI. For example, by adding some physical and other mechanical tests as well as analyzing the durability of laminate.

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