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The Compressive Strength of Light Weight Steel and Timber Composite

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Abstract

Timber is a building material that is easy to obtain and has a more affordable price than concrete. Therefore, timber composited with light weight steel is expected to be an alternative for a truss roof in simple buildings. This research aims to determine the compressive strength of light weight steel and timber composite and determine whether timber and light weight steel composite materials can be used for the construction of truss roof. This experimental research was carried out by compression tests on timber composited with light weight steel. To determine the compressive strength value three different test objects were used. The materials used are Palapi Wood and Light Weight Steel. The Composite Compressive Strength test results for samples 1 and 2 were 3.81 MPa, and 4.57 MPa for sample 3. From the test results, the compressive strength values for the Timber and Light Weight Steel Composites were not much different from the initial test. Timber material composited with Light Weight Steel can be used in simple truss roof structures.

Keywords: *Palapi Wood, Light Weight Steel, Composite, Compressive Strength*

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I. INTRODUCTION

Steel material are increasingly used due to the rising need for steel materials that are lighter, economically, strong, durable and easy to use [1, 2, 3]. Light weight steel is one of steel type in the form of thin plates which are affected by local buckling in the web and flange cross section could be more significant than ordinary steel [2, 3, 4].

On the other hand, timber is a material that is easy to obtain and has a more affordable price [5, 6]. In structural construction, timber was met the requirements for rigidity and strength to carry the load design, timber also have stiffness and structural stability [6, 7, 8]. Therefore, it is necessary to optimization the timber structural design by composited with light weight steel. From each of the properties of these materials, when composited, it is necessary to combined of these two properties materials to obtained a better beneficence than a single material. To achieve a composite action, the combination of the two types of cross-sections must be equipped with a connector, thus that the two cross-sections can work together to carry the load [7, 8, 9].

Based on this background, an experimental research was carried out regarding how to combine these two types of materials to form a single structural element and determine the compressive strength value of timber composite with light weight steel as a construction material for simple truss roof structure.

Timber has relatively high tensile and compressive strength and low weight, can be easily worked, relatively cheap, can be easily replaced and can be obtained in a relatively short time. Timber also has weaknesses as follows; a. timber is easily attacked by termites or other insects; b. easy to contains water that has a big effect on the shape of the timber and easily becomes soft and rots if soaked in water for a long time; c. timber elements are not 100% usable; d. has a limited diameter so it is difficult to get wider dimensions; and e. timber is very flammable, especially when dry [2, 4, 5, 9, 10, 11].

In SNI 03-3527-1994, chapter (4) Classification of timber building is divided into 3 (three) groups [12], as follows:

1. Timber structural building is used for structural elements of buildings and its use requires load designs.
2. Timber non-structural building is used in building elements, the use of which does not require load designs.

3. Timber building for other purposes is timber building that is not included in the two categories of 1 and 2 above, but can be used as auxiliary building materials or temporary buildings.

II. MATERIALS AND RESEARCH METHOD

All of the experimental research carried out at Faculty of Engineering Laboratory, University of Tadulako. Light Weight Steel Tension Strength Specimens were test at Mechanical Engineering Laboratory. On the other hand, the Timber Compressive Strength Specimens and Light Weight Steel and Timber Composite Compressive Strength Specimens were test at the Structural and Materials Laboratory.

2.1.1. Light Weight Steel Tension Strength Specimens

The material that will be used in this research is Light Weight Steel Channel type. The tensile test is carried out to determine the stress and strain diagram, thus that the elastic modulus value can be obtained based on Equation 1 and 2. The tensile test was carried out according to ASTM E8/E8M-13 standard (Standard Test Methods for Tension Testing of Metallic Materials) and can be seen on Figure 1.

$$\sigma = \frac{P}{A} \quad (1)$$

$$E = \frac{\sigma}{\varepsilon} \quad (2)$$

Where : $\sigma =$ Stress (MPa)
P = Load (N)
A = Cross Section Area (mm2)
E = Modulus of Elasticity (MPa)
$\varepsilon =$ Strain (mm/mm)

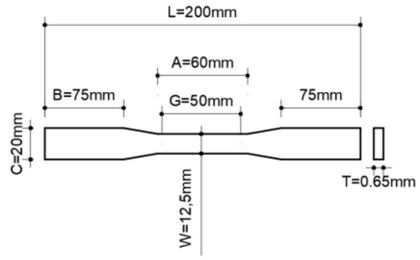

Figure 1: Light Weight Steel Tension Specimen

2.1.2. Timber Compressive Strength Specimen

The steps used for running flow sheet simulation in Aspen HYSYS were as follows: The timber material was used in this research is Palapi wood. The timber material is first air-dried for ± 3 months until its moisture content of 10-12% is reached. Timber that has reached equilibrium moisture content is then shaped according to the standards for each type of test as presented in Table 1.

Table 1: Types and variations of wood properties testing standards

No	Test Type	Test Method	Test results
1	Water Content	SNI ISO 3130:2011	Equilibrium Water Content
2	Density	SNI ISO 3130:2011	ρ
3	Modulus of Elasticity	SNI ISO 16978:2010	E
4	Compression Strength //	SNI 03-3958-1995	Fc //

2.1.3. Light Weight Steel and Timber Composite Compressive Strength Specimens

In this research, the specimen used were timber composited with light weight steel in 3 types and the composite connected by screw bolt can be seen in Figure 2 through 4.

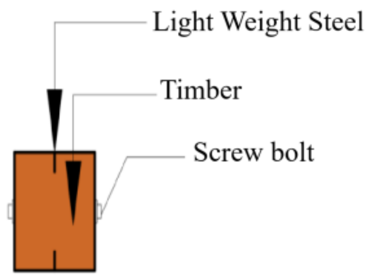

Figure 2: Specimen Type 1

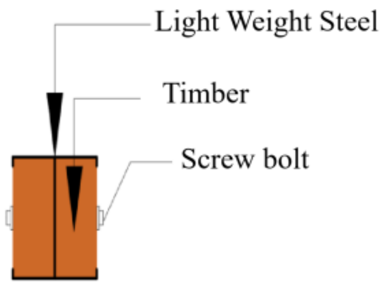

Figure 3: Specimen Type 2

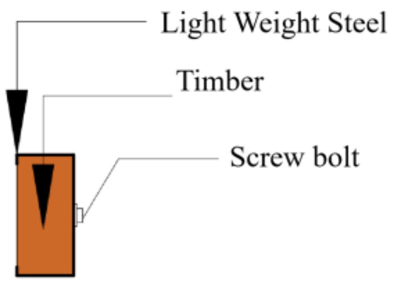

Figure 4: Specimen Type 3

The Timber dimension was 7.5 x 3.5 x 21.0 cm. Contrary, the light weight steel size was 75.65 x 21.0 cm and was made from Channel profile. Specimen type 1 consists of 2 channel profiles and 2 timbers were composited by screw bolt with face to face lip of channel profiles, the second type consists of 2 channel profiles and 2 timbers were composited by screw bolt with back to back web of channel profiles and the last type consists of 1 channel profile and 1 timber were composited by screw bolt. All specimens were made in Structural and Materials Laboratory, Faculty of Engineering, University of Tadulako, Palu, Central Sulawesi.

III. RESULT AND DISCUSSION

3.1.1. Light Weight Steel Tension Strength

Three specimens of Light Weight Steel were test to find out their tension strength using UTM (Universal Testing Machine) refer to Figure 1 and can be seen in Figure 5 and 6.

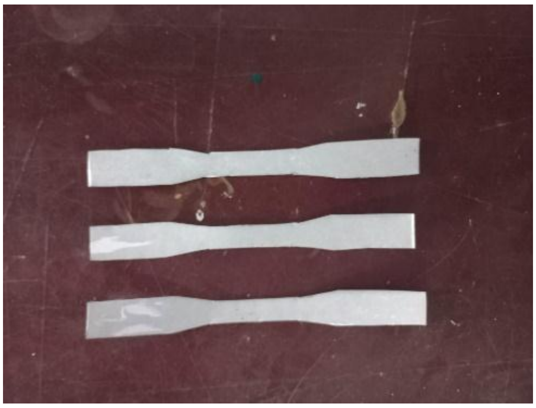

Figure 5: Three specimens of Light Weight Steel

Figure 6: Light Weight Steel Specimen Tension Strength Testing

The stress-strain relationship of the typical light weight steel specimen are shown in Figure 7 and Table 2.

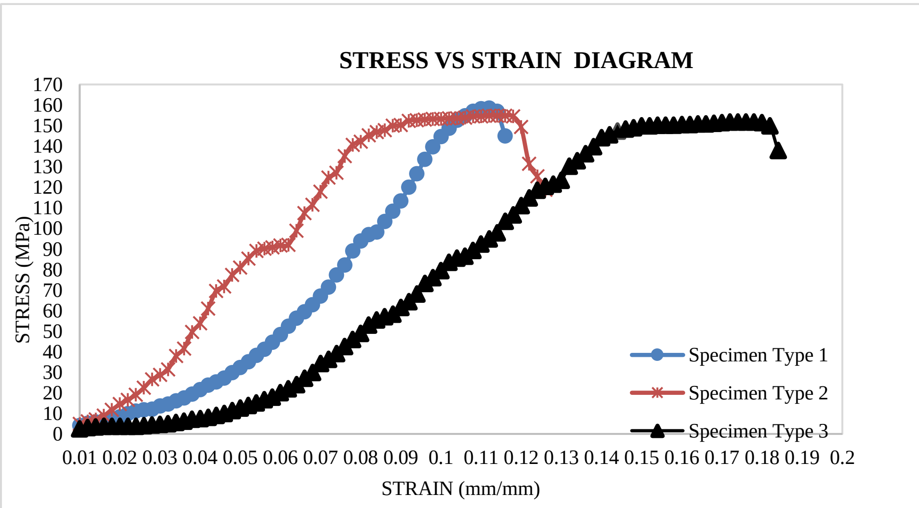

Figure 7: The Stress-Strain Relationship of Light Weight Steel Specimen

According to Figure 7 and Table 2, the strain of specimen type 3 has greater strain than other specimen types was approximately 0.116 mm/mm. All specimens has relatively the same stresses higher than 150 N/mm2. The Modulus of Elasticity average value was 136.01 N/mm2. The failure mode shown in Figure 8, all specimen types has the same kind of fracture, close to the edge of specimen slope and sideways failure.

Table 2: The Light Weight Steel Specimen Tension Strength Result

No.	Area (mm²)	Tension Force (N)	Stress (N/mm²)	Strain (mm/mm)	Modulus of Elasticity (E, N/mm2)
1	325	51500	158.46	0,112	141.48
2	325	50300	154.77	0,114	135.76
3	325	49300	151.69	0,116	130.77
Average					136.01

Figure 8: Failure Mode of Specimens

3.1.2. Timber Compressive Strength

The Timber dimension was 7.5 x 3.5 x 21.0 cm, and refer to the results of the compressive strength test parallel to the grain (fc //) shown in Figure 9, Table 3 for single timber and Table 4 for double timber, obtained an average parallel compressive strength value for timber respectively were of 3.9 MPa and 5.0 MPa. The results of this test also prove that the density of the wood has an effect on the compressive strength of the wood. The timber compressive strength experimental protocol can be seen in Figure 10.

Table 3: The Single Timber Compressive Strength Parallel to The Grain Result

Code Number	Wood Type	Weight (gr)	Dimension		Compression Force (kN)	Compressive Strength (MPa)
			b (mm)	h (mm)		
1	Palapi	222.60	35	75	12.50	4.76
2	Palapi	228.90	35	75	13.50	5.14
3	Palapi	225.50	35	75	13.00	4.95
Average						5.00

Table 4: The Double Timber Compressive Strength Parallel to The Grain Result

Code Number	Wood Type	Weight (gr)	Dimension		Compression Force (kN)	Compressive Strength (MPa)
			b (mm)	h (mm)		
1	Palapi	333.90	70	75	21.00	4.00
2	Palapi	412.00	70	75	20.50	3.90
3	Palapi	383.35	70	75	20.00	3.81
Average						3.90

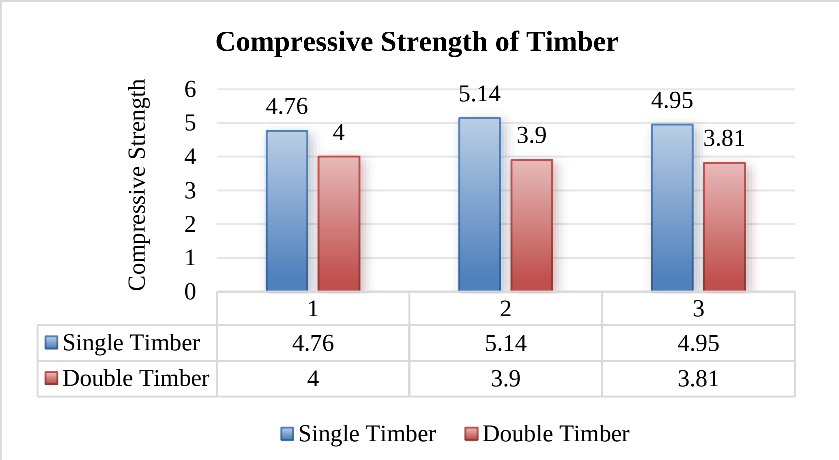

Figure 9: The Timber Compressive Strength Parallel to The Grain Result

Figure 10: The Timber Compressive Strength Experimental Protocol

3.1.3. Light Weight Steel and Timber Composite Compressive Strength

The compressive strength of Light Weight Steel and Timber Composite shown in Figure 11, Table 5 for specimen type 1, Table 6 for specimen type 2 and Table 7 for specimen type 3. As we can seen in those table and figure, the single specimen has greater compressive strength than double specimen of 4.57 MPa. The double specimen for all type has the same compressive strength of 3.81 MPa. obtained an average parallel compressive strength value for timber respectively were of 3.9 MPa and 5.0 MPa. The results of this test also prove that the density of the wood has an effect on the compressive strength of the wood.

Table 5: The Compressive Strength of Specimen Type 1

Code Number	Wood Type	Weight (gr)	Dimension		Compression Force (kN)	Compressive Strength (MPa)
			b (mm)	h (mm)		
1	Palapi	333.90	70	75	20.00	3.81
2	Palapi	412.00	70	75	20.00	3.81
3	Palapi	383.35	70	75	20.00	3.81
Average						3.81

Table 6: The Compressive Strength of Specimen Type 2

Code Number	Wood Type	Weight (gr)	Dimension		Compression Force (kN)	Compressive Strength (MPa)
			b (mm)	h (mm)		
1	Palapi	333.90	70	75	20.00	3.81
2	Palapi	412.00	70	75	20.00	3.81
3	Palapi	383.35	70	75	20.00	3.81
Average						3.81

Tabel 5: The Compressive Strength of Specimen Type 3

Code Number	Wood Type	Weight (gr)	Dimension		Compression Force (kN)	Compressive Strength (MPa)
			b (mm)	h (mm)		
1	Palapi	222.60	35	75	12.00	4.57
2	Palapi	228.90	35	75	12.00	4.57
3	Palapi	225.50	35	75	12.00	4.57
Average						4.57

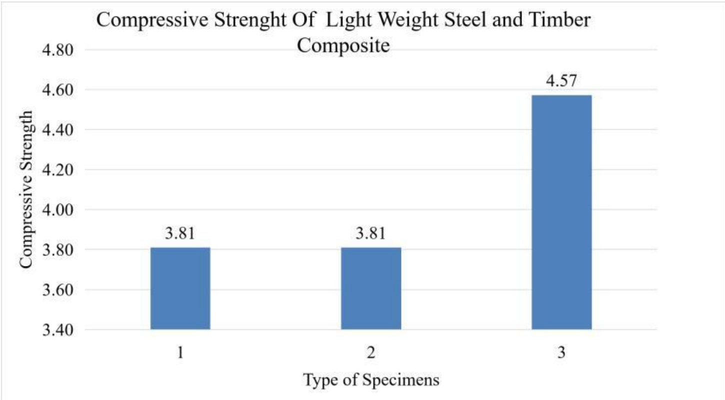

Figure 11: Light Weight Steel and Timber Composite Specimens Compressive Strength

Figure 12 through 14 respectively represent the failure mode of specimen type 1, 2 and 3. All specimens have buckling failure mode in their light weight steel, particularly in the end edge web of Channel profile and slip between the timber and steel.

Figure 12: Failure Mode Specimen Type 1

Figure 13: Failure Mode Specimen Type 2

Figure 14: Failure Mode Specimen Type 3

IV. CONCLUSION

The experimental study results of The Composite Compressive Strength for specimens 1 and 2 were 3,81 MPa, and 4,57 MPa for specimen 3. From the test results, the compressive strength values for the Timber and Light Weight Steel Composites were not much different from the initial test. Timber material composited with Light Weight Steel can be used in simple truss roof structures. Specimen type 3 was most affordable for simple truss of roof structures.

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