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Eric Strauss *Editor*

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ICOCE 2024, 22–24 March, Singapore

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Preface

The 2024 8th International Conference on Civil Engineering (ICOCE 2024) was successfully and physically held in Singapore during March 22–24, 2024. This event has provided a unique opportunity for international scholars, researchers and practitioners working in a wide variety of scientific areas with a common interest in civil engineering to interact and share knowledge.

This year, there were more than 40 participants in total. They were from China, Singapore, USA, Philippines, India, Thailand, Kuwait, UK, Japan, Korea, Indonesia, etc. The conference has included discussions on topics such as wastewater treatment and water quality analysis, renewable energy and electric motor technology, infrastructure engineering and hydraulic engineering, properties of building materials and structures, environmental pollution control and resource management, seismic response of engineering structures and construction management, building materials, building environment, and construction management, engineering vibration and mechanical properties of building structures. In addition, two excellent keynote speeches were delivered by Prof. Joseph Kim from California State University Long Beach, USA, and Assoc. Prof. Ong Ghim Ping Raymond from the National University of Singapore, Singapore. After that, Assoc. Prof. Kwun Nam Hui from University of Macau, China, Assoc. Prof. Chian Siau Chen, Darren from the National University of Singapore, Singapore, and Dr. Kim Yongmin from the University of Glasgow, Singapore, gave outstanding invited speeches. All the speeches and presentations focused on the latest information and most innovative developments in their respective expertise areas of civil engineering.

ICOCE 2024 has received more than 70 papers. Thirty-six papers were accepted for publication in the Conference Proceedings. All the submissions were peer reviewed by Conference Committees. The papers selected depended on their originality, language, quality, and their relevancy to the conference. The proceeding is divided into six chapters, including engineering vibration and mechanical properties of building structures, mechanical properties of concrete structures, hydraulic engineering and flood control, urban planning and infrastructure engineering, properties of building materials and structures, building environment and environmental impact assessment of buildings, engineering project management and optimization. We are sure that the proceedings will serve as an important research tool to become a source of references and knowledge, which will lead to not only scientific and engineering findings but also to new products and technologies.

Finally, we would like to deeply express our heartfelt appreciation to all our delegates, keynote speakers, invited speakers, session chairs, and international reviewers as well as all the committee members involved in the technical evaluation of conference papers and in the conference organization for your enthusiasm, effort, and great contributions. Apart from that, we would like to extend our thanks to all the authors and external reviewers for your willingness to make the conference a worthwhile experience. It is your recognized competence, enthusiasm, valuable time, and expertise that have enabled us to prepare and hold the conference and make it a great success.

Dimondale, USA Prof. Eric Strauss

Contents

Shear Strength of Red Meranti (*Shorea Spp.*) Timber at an Angle to the Grain

Yosafat Aji Pranata, Novi, Deni Setiawan, Vivi Arisandhy, Hendry Wong, and Sofhie Angela Hagiyanto

Abstract The shear strength is one of the parameters that is used for the design of beam members in wood buildings. Shear strength is also used as a parameter for bridge girder design. Red meranti (*Shorea spp.*) is a species that is easily found in Indonesia and is commonly used as a construction material for buildings, docks, or bridges. The objective of this study is to obtain an empirical equation for the shear strength with different grain angles from 0° to 10°. The research of the influence of the grain angle must be carried out under real conditions, since the direction of the wood grain is not perfectly 0° and the inclination of the grain can influence the shear strength of the wood. The method of making the specimens and the experimental methods refer to ASTM D143-22, and the total number of test specimens was 33 specimens. The tests were performed using a universal testing machine, with the test speed (crosshead) 0.6 mm/minute. The test results show that the shear strength of wood with a directional fiber angle ranging from 0° to 10° in a range from 2.77 MPa (10° grain angle) to 7.57 MPa (0° grain angle). The results of the analysis by the polynomial regression method give an empirical equation, namely $F_v = 7.03 - 0.97\theta + 0.066\theta^2$ with R-Sq = 74.7%. Fiber angle has an effect on shear strength. Empirical equations offer advantages to building designers in calculating the design capacity of wood beams, especially due to shear forces.

Keywords Shear strength · Red Meranti (*shorea spp.*) · Timber · Angle

1 Introduction

The shear strength is a fundamental mechanical property of timber and is used in general timber structural design such as beam of column members. The shear strength can be determined by clear specimen testing as recommended by testing standards such as ASTM D143-22 [1]. This paper has presented the outline results of a series of shear tests to determine the shear strength of Red Meranti (*Shorea spp.*) timber at

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an angle to the grain. The shear test procedure has been to produce shear strengths based on ASTM D143-22 [1]. It was noticed that the cracks were commonly initiated within clear timber and caused shear failure. As the grain angle increasing from zero to certain value, the mechanical properties will be decreased. The greatest influence of grain deviation angle on mechanical properties was recorded for ultimate load values.

Several previous researches of wood shear testing to obtain mechanical properties of shear strength, among others, were carried out by He et al. [2] which is studying shear testing of spruce and Douglas-fir woods to obtain shear strength parameters and their influence on the main axis of the wood, namely in the tangential–longitudinal plane and in the radial–longitudinal plane directions, and the shape of the test object and the test method refers to the ASTM D143, with the aim of obtaining shear strength parameters and failure modes. Other research has also been done by Teixeira et al. [3], namely studying the shear strength of Angelim-pedra wood with an orientation parallel to the grain, and then, another research with the Red Meranti wood type was carried out by Rizki [4], namely studying the shear strength parallel to the grain (0° grain angle). In 2011, the author himself [5] also carried out experimental research to obtain shear strength parameters parallel to the grain of Red Meranti wood with a grain angle of 0°. The grain angle is a deviation of fibers from a line parallel to an edge of sawn wood [6]. Variability in timber mechanical properties can be mainly attributed to the grain angle, beside the wood density, of course. Grain deviation from the directions of the forces causes a decrease in mechanical properties of timber [7–9]. A strength reduction due to the increase in the grain deviation angle was also observed in the shear strength property, and the grain deviation angle from 0 to 30° causes a decrease in shear strength by about 30 to 45% [10, 11] and reaching even about 70% [12].

The objective of this study is to obtain an empirical equation for the shear strength with different grain angles from 0° to 10°. The research of the influence of the grain angle must be carried out under real conditions, since the direction of the wood grain is not perfectly 0° and the inclination of the grain can influence the shear strength of the wood. The method of making the test specimens and the test methods refer to ASTM D143-22 [1], and the total number of test specimens was 33 specimens. The tests were performed using a universal testing machine, with the test speed or crosshead is 0.6 mm/minute. The significance of the research works is to obtain the empirical values of the shear strength at an angle to the grain ranged from 0° to 10°.

2 Basic Theory

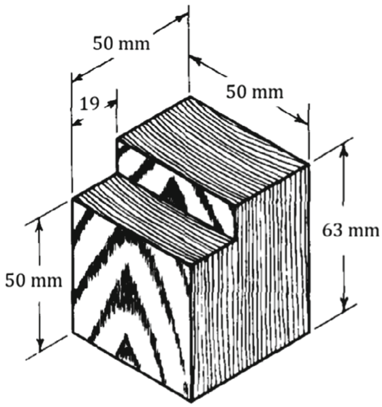
2.1 Shear Strength Mechanical Properties

The shear strength is an important parameter for the design of beam members in wood buildings. Shear strength is also used as a parameter for bridge girder design. Red meranti (*Shorea spp.*) is a species that is easily found in Indonesia and is commonly used as a construction material for buildings, docks, or bridges. The objective of this study is to obtain an empirical equation for the shear strength with different grain angles from 0° to 10°. The research of the influence of the grain angle must be carried out under real conditions, since the direction of the wood grain is not perfectly 0° and the inclination of the grain can influence the shear strength of the wood.

2.2 Clear Specimen Tests

The shear specimen test shall be made on a 50 mm by 50 mm by 63 mm specimens notched in accordance with Fig. 1 to produce failure on a 50 mm by 50 mm surface. The load applied to and support the specimen on end-grain surfaces. The shear tool shall include an adjustable crossbar to align the specimen and support the back surface at the base plate [1]. The shear load for calculation of the shear strength is the maximum or ultimate load that causes the failure of specimen in term of shear plane 50 mm by 50 mm. The tests were performed using a universal testing machine, with the test speed (crosshead) 0.6 mm/minute.

Fig. 1 Specimen for shear tests [1]



2.3 Hankinson's Formula

Elastic theory can be used to obtain the mechanical properties in directions other than along the parallel and perpendicular grain angle. Mechanical properties of wood which area elastic modulus, tensile strength, compression strength, and many more in directions ranging from parallel to perpendicular to the grain can be calculated using a Hankinson formula [9].

$$N = \frac{P \cdot Q}{P \cdot \sin^{n} \theta + Q \cdot \cos^{n} \theta} \quad (1)$$

where N is strength at angle θ from grain angle, Q is strength perpendicular to the grain, P is strength parallel to the grain, and n is an constant [9].

2.4 Polynomial Regression Method

Polynomial regression is a regression model that is formed by adding up the influence of each independent variable raised to increasing powers up to the $n - 1$ order. The highest power of the independent variable determines the shape of the response curve. The polynomial model can be used to find out that there is a linear curve influence on the response, and its shape resembles a curve. The polynomial model is also useful as an approximation function for very complex models and nonlinear relationships [13].

3 Experimental Test and Results

3.1 Experimental Test

Shear test specimens were made from raw timber logs, which have been visually sorted to obtain defect-free parts. The number of test objects in this study was 33 test objects with grain angle variations ranging from 0° to 10°. The method of making the test specimens and the test methods refer to ASTM D143-22 [1]. Figure 2 shows some of the test object that has been made. Figure 3 shows the wood shear testing process.

Fig. 2 Specimen for shear tests

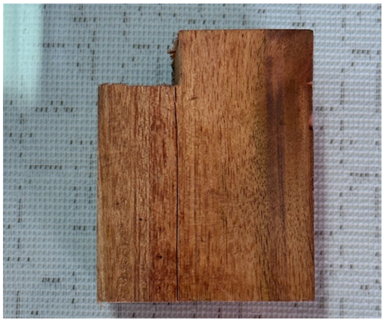
Fig. 3 Shear tests

3.2 Results

Figure 4 shows several examples of test results, namely the failure modes of the specimens after destructive testing to obtain the ultimate load which resulted in failure in the shear plane. Figure 5 shows the test results, namely the load versus deformation relationship curve for each test object with a grain angle direction of 0° to 10°. Table 1 and Fig. 6 show the results of calculating the shear strength of wood at various angles of the grain angle. To calculate the shear strength, parameter of cross-section of shear area (Fig. 1) is calculated using real shear area of each specimen.

The test results in Table 1, namely the parameters of the shear strength of wood and the direction of the grain angle, are then processed further using quadratic-type polynomial regression analysis to obtain predictions of the empirical equation for the shear strength of wood. The analysis is carried out using Minitab software [14]. The

Fig. 4 Shear test result specimen with grain angle 0°



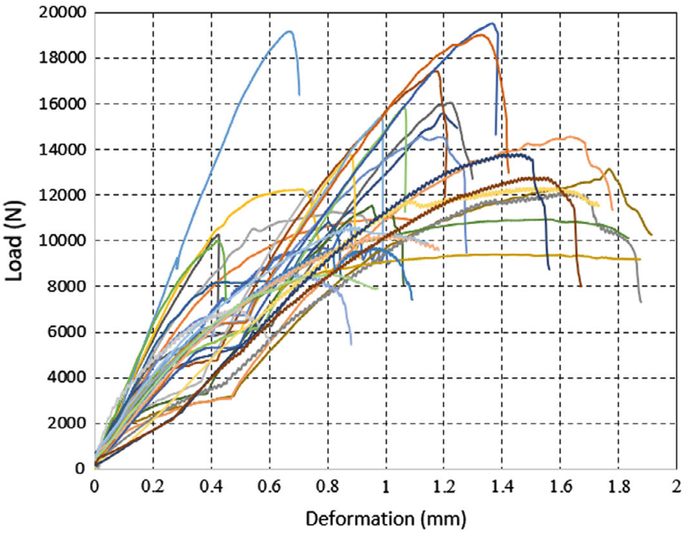


Fig. 5 Load versus deformation results obtained from experimental tests

analysis results (Fig. 6) show that the experimental test results, namely the ultimate load versus deformation curve, have a tendency for the ultimate load to decrease as the direction of the wood grain angle increases. This indicates that the shear strength of wood has the highest value at the grain angle parallel to the direction of the wood grain (grain angle 0°).

Results obtained from study which is equation to predict the shear strength at an angle to the grain shown in Eq. 2.

$$F_v = 7.03 - 0.97\theta + 0.066\theta^2 \quad (2)$$

$$\text{R-Sq} = 74.7\% \quad (3)$$

Table 1 Shear load (peak) obtained from experimental tests

Specimen	Specimen	Area (mm^2)	P_U (N)	F_v (MPa)	D_{max} (mm)	θ
K3.20	K.1	2525.55	17,431.86	6.90	1.18	0
K3.50	K.2	2533.78	19,018.69	7.51	1.33	0
K3.1	K.3	2531.77	19,172.62	7.57	0.67	0
K3.37	K.4	2539.30	14,563.99	5.74	1.13	1
K3.38	K.5	2549.24	14,559.46	5.71	1.63	1
K3.45	K.6	2533.27	15,401.46	6.08	0.98	1
K3.47	K.7	2526.74	15,813.41	6.26	1.06	1
K3.49	K.8	2530.23	17,521.24	6.92	1.37	1
K2.32	K.9	2499.49	11,261.84	4.51	0.82	2
K2.34	K.10	2492.99	12,239.55	4.91	0.71	2
K3.6	K.11	2521.18	13,491.15	5.35	0.43	2
K3.17	K.12	2517.53	15,578.01	6.19	1.20	2
K3.25	K.13	2517.02	16,044.29	6.37	1.22	2
K3.34	K.14	2534.78	11,515.32	4.54	0.95	2
K3.40	K.15	2534.12	12,225.97	4.82	0.75	2
K3.44	K.16	2536.80	13,758.22	5.42	0.88	2
K4.7	K.17	2523.70	12,133.17	4.81	1.62	2
K3.32	K.18	2526.74	13,135.80	5.20	1.77	3
K3.33	K.19	2520.20	10,813.73	4.29	0.81	3
K4.33	K.20	2516.51	10,929.15	4.34	1.57	3
K5.4	K.21	2517.20	10,245.69	4.07	0.98	3
K5.13	K.22	2533.75	12,327.81	4.87	1.52	3
K5.44	K.23	2520.20	13,796.70	5.47	1.42	3
K5.32	K.24	2543.69	10,585.16	4.16	0.89	4
K5.38	K.25	2533.72	8536.98	3.37	0.81	4
K1.32	K.26	2522.21	10,261.53	4.07	0.43	5
K2.28	K.27	2515.18	11,021.94	4.38	1.01	5
K4.22	K.28	2536.80	9400.73	3.71	1.38	5
K4.27	K.29	2528.58	9690.99	3.83	0.95	5
K5.45	K.30	2528.24	12,769.15	5.05	1.54	6
K5.12	K.31	2531.42	7018.90	2.77	0.50	7
K2.2	K.32	2503.94	10,748.10	4.29	0.88	8
K5.1	K.33	2538.13	8623.11	3.40	0.67	10

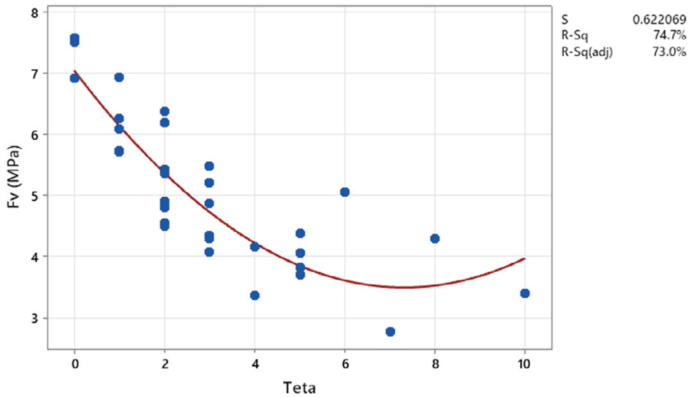


Fig. 6 Results obtained from study: equation to predict the shear strength at an angle to the grain

4 Conclusion

The test results show the shear strength of wood with a directional fiber angle ranging from 0° to 10° in a range from 2.77 MPa (10° grain angle) to 7.57 MPa (0° grain angle). The results of the analysis by the polynomial regression method give an empirical equation, namely $F_v = 7.03 - 0.97\theta + 0.066\theta^2$ with R-Sq = 74.7%. Fiber angle has an effect on shear strength. Empirical equations offer advantages to building designers in calculating the design capacity of wood beams, especially due to shear forces.

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