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Eric Strauss *Editor*

# Proceedings of the 8th International Conference on Civil Engineering

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# Proceedings of the 8th International Conference on Civil Engineering

ICOCE 2024, 22–24 March, Singapore

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Michigan State University  
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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

<b>Engineering Vibration and Mechanical Properties of Building Structures</b>	
<b>Research on Seismic Performance of Existing Skew Bridges Considering Performance Degradation of Laminated Bearings</b> .....	3
Gang Wu, Yiqin Wang, Youquan Zou, Bitao Wu, Xuzheng Liu, and Liang Ren	
<b>Numerical Study of Cold-Formed Steel Built-Up Compression Members for Long-Span Structures</b> .....	19
Johnny Setiawan, Ridho Bayuaji, and M. Arif Rohman	
<b>Inspection, Appraisal, and Rehabilitation Plan for the Main Shaft Tower at a Gold Mine</b> .....	33
Sen Li	
<b>Evaluation Equations of Global Stability for Single-Layer Cylindrical Grid Shells Based on Parametric Analysis and Regression Analysis</b> .....	49
Baoxin Liu, Pei-Shan Chen, Yaozhi Luo, Hui-Bin Ge, and Yanbin Shen	
<b>Flexural Behavior of Indonesian Berua Timber: Experimental Test and Numerical Analysis</b> .....	61
Yosafat Aji Pranata, Anang Kristianto, and Novi	
<b>Mechanical Properties of Concrete Structures</b>	
<b>Experimental and Numerical Study of Full-Size Reinforced Geopolymer Concrete Beams</b> .....	75
Borui Wu and Yao Yao	

<b>Structural Behavior of Reinforced Concrete Spliced Beams Subjected to Repeated Loads: An Experimental Study</b> .....	87
Alaa Hassoon, Haider M. Al-Jelawy, Alaa Jaleel Naji, and Dheyaa A. N. Alobaidi	
<b>Theoretical Study on the Influence of Plate Position Parameters on the Compressive Bearing Capacity of Concrete Expanded Plate Double Pile</b> .....	101
Hanyuan Chang, Yongmei Qian, Lian Zhai, and Ji Yuan Zhang	
<b>Detecting Debonding in FRP Retrofitted Concrete Beams Using Nonlinear Ultrasonic Waves</b> .....	113
Reza Soleimanpour, Mohammad Hany Yassin, Naser Khaled Mohammad, Mohammad Khaleel Bo Arki, and Miryan Nabil Sweid	
<b>CFRP Strengthening of Corroded Short Thin-Walled Steel Tubular Columns Filled with Concrete Under Direct Loading</b> .....	127
Ali Hameed Aziz and Zainab Faiq Yawer	
<b>Hydraulic Engineering and Flood Control</b>	
<b>Selection of Highway Underpass Accessibility Solution for Flooded Area Using Analytical Hierarchy Process Method</b> .....	143
Danang Atmodjo, Slamet Imam Wahyudi, Henny Pratiwi Adi, and Rahmatia Sarah Wahyudi	
<b>Local Scour Studies on Spur Dyke with Grouped Piles</b> .....	153
Arun Goel and Neeraj Pandey	
<b>Analysis of Karst Water System and Upper Reservoir Leakage of the Pumped-Storage Power Station in Jiangyou, China</b> .....	167
Chunwen Chen, Xingcan Wei, Sijia Li, and Nengfeng Wang	
<b>Indicators to Check Global Optimality of Design Solution of Looped Water Distribution Networks</b> .....	181
Rajesh Gupta, Laxmi Gangwani, and Shilpa Dongre	
<b>Urban Flood Resilience: A Comparative Exploration of Rain Garden Infiltration with Diverse Vegetation</b> .....	191
Krishna Kumar Singh and Sandeep Kumar	
<b>Urban Planning and Infrastructure Engineering</b>	
<b>Generative Urban Design Methods Based on Interactive Web Application</b> .....	209
Gang Liu, Xinchun Jiang, Meng Yang, Siyu Chen, and Yi Liu	

**Research on the Availability of Outdoor Space Under the Background of Aging** ..... 221  
 Shouli Yi, Di Hu, Guo Chen, Yuanbo Tuo, and Suping Gao

**Mitigation Measures to Protect the Quality of Life in an Expansion of Thailand’s Mega Port** ..... 231  
 Cherdvong Saengsupavanich, Lanlila Chitsom, Sarinya Sanitwong-Na-Ayutthaya, Phansak Iamraksa, Salisa Wangtong, Worawut Poma, Naruphun Chotechuang, and Nuttikan Saejew

**Preparation of Porous Concrete Suitable for Vegetation Growth: An Approach Toward Green Infrastructure** ..... 245  
 John Bosco Niyomukiza, Amin Eisazadeh, and Somnuk Tangtermsirikul

**An Integrated Design Method for Public Buildings with Digital Technology Collaboration: Taking Three Practical Projects as Examples** ..... 255  
 Di Ai and Xin Ge

**Infrastructure and Sustainable Development Goals: Unveiling Latent Factors in Bangkok** ..... 271  
 Ketsutee Ngamgwong and Piyanut Wethyavivorn

**Properties of Building Materials and Structures**

**Influence of Nanoceramic Waste Powder on the Properties of Interlocking Bricks** ..... 285  
 Niragi Dave, Nancy Chavda, and Dorji

**Self-compacting Geopolymer Concrete: A Critical Review** ..... 295  
 Huma Afrin, Alfia Bano, and S. V. Deo

**Optimizing Soil Strength Through Rice Husk Ash Incorporation: A Sustainable Geotechnical Solution** ..... 307  
 Abdelmageed Atef and Zakaria Hossain

**Shear Strength of Red Meranti (*Shorea Spp.*) Timber at an Angle to the Grain** ..... 315  
 Yosafat Aji Pranata, Novi, Deni Setiawan, Vivi Arisandhy, Hendry Wong, and Sofhie Angela Hagiyanto

**Building Environment and Environmental Impact Assessment of Buildings**

**Summer Microclimate of Urban Built Environment Research** ..... 327  
 Shouli Yi, Di Hu, Yuanbo Tuo, Suping Gao, and Guo Chen

**Assessment of Life Cycle Energy and Green House Gas of a Two-Storied Residential Building in Central India Using Open Source Data** ..... 337  
A. D. Prasad, Ajay Vikram Ahirwar, and Padma Ganasala

**Impact of Building Plan Shape on Natural Ventilation Efficiency for Thermal Comfort in Educational Facilities: A Post-occupancy Evaluation** ..... 355  
Emeka J. Mba, Francis O. Okeke, Peter I. Oforji, Ikechukwu W. Ozigbo, Ezema C. Emmanuel, and Chinelo A. Ozigbo

**Noise Monitoring During Ganesh Chaturthi, Dussehra, and Diwali Festival for Raipur City, India** ..... 371  
A. D. Prasad, Ajay Vikram Ahirwar, Vishal Kumar, and Sahil Ali

**Engineering Project Management and Optimization**

**A Hybrid Genetic Algorithm—Artificial Neural Network Model for Cost Estimation and Corruption Detection of Public Road Rehabilitation Projects in Quezon City** ..... 385  
Christopher Jose C. Carlos and Angelo Benjamin D. Dizon

**Influence of Factors Affecting the Delay in Bridge Construction Using Neural Network-Based Sensitivity Index Method** ..... 401  
Karlo Allen R. Piedad, Dante L. Silva, Russell L. Diona, and Kevin Lawrence M. de Jesus

**Explore Owner Organizational Capability in Thai Construction Industry** ..... 413  
Panorm Chanderm and Piyanut Wethyavivorn

**Identification of Green Construction Indicators and Project Performance in Green Construction Based Project Management Using the Delphi Method** ..... 429  
I. G. A. Istri Mas Pertiwi, Yulvi Zaika, Kartika Puspa Negara, Solimun, and M. Agung Wibowo

**Artificial Neural Network Prediction of Total Construction Cost Using Building Elements for Low- to Mid-Rise Buildings** ..... 441  
Abo Yasser L. Manalindo, Dante L. Silva, Russell L. Diona, and Kevin Lawrence M. de Jesus

**Comparative Analysis of the Features of Major Green Building Rating Tools (GBRTs): A Systematic Review** ..... 453  
Francis O. Okeke, Emmanuel C. Ezema, Eziyi O. Ibem, Chinwe Sam-amobi, and Abdullahi Ahmed

**Building in Uncertain Time: Investigating New Normal Construction Risks Arising from the Military Coup** ..... 471  
Zin Bo Aung, Wasaporn Techapeeraparnich, Nathee Athigakunagorn, and Charinee Limsawasd

# 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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Y. A. Pranata (✉) · Novi · D. Setiawan · V. Arisandhy · H. Wong · S. A. Hagiyanto  
Faculty of Engineering, Universitas Kristen Maranatha, Bandung, West Java 40164, Indonesia  
e-mail: [yosafat.ap@gmail.com](mailto:yosafat.ap@gmail.com)

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315

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 ( $0^\circ$  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  $0^\circ$ . 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  $30^\circ$  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  $0^\circ$  to  $10^\circ$ . 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  $0^\circ$  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  $0^\circ$  to  $10^\circ$ .



## 2 Basic Theory

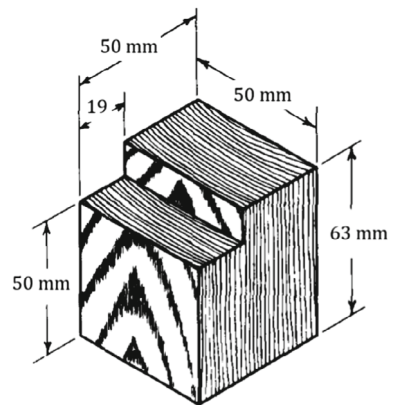
### 2.1 Shear Strength Mechanical Properties

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 are 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  $\theta$  from grain angle,  $Q$  is strength perpendicular to the grain,  $P$  is strength parallel to the grain, and  $n$  is a constant [9].

### 2.4 Polynomial Regression Method

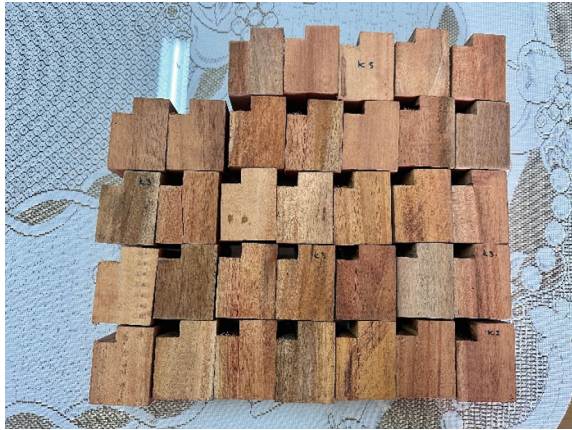
Polynomial regression is a regression model that is formed by adding up the influence of each independent variable raised to increasing powers up to the  $n - 1$  order. The highest power of the independent variable determines the shape of the response curve. The polynomial model can be used to find 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  $0^\circ$  to  $10^\circ$ . 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

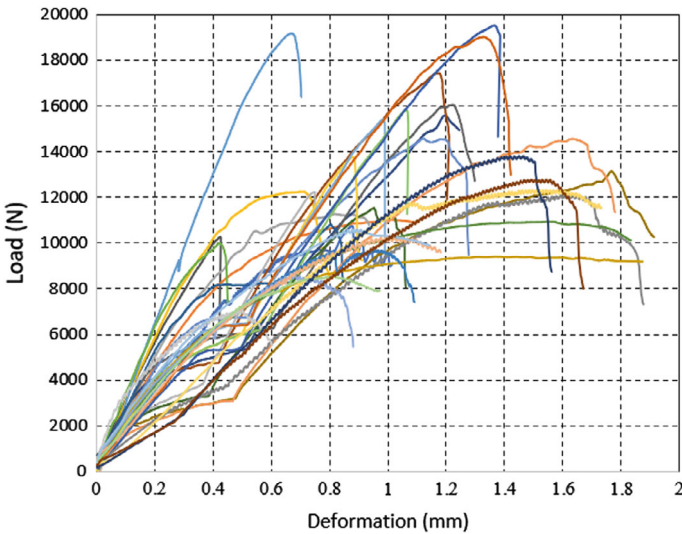


### 3.2 Results

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°).

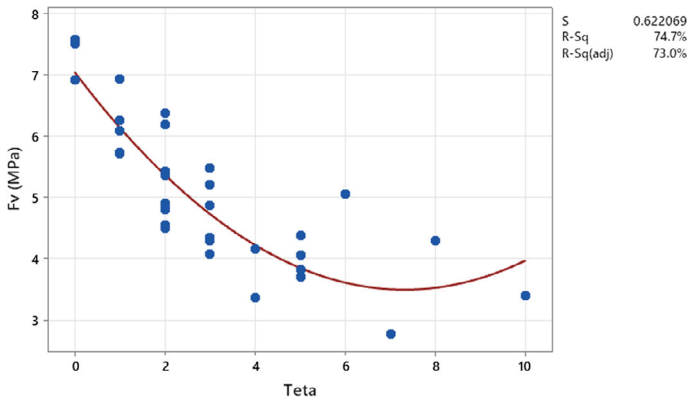
Results obtained from study which is equation to predict the shear strength at an angle to the grain shown in Eq. 2.

$$F_v = 7.03 - 0.97\theta + 0.066\theta^2 \tag{2}$$

$$R-Sq = 74.7\% \tag{3}$$

**Table 1** Shear load (peak) obtained from experimental tests

Specimen	Specimen	Area (mm <sup>2</sup> )	$P_U$ (N)	$F_v$ (MPa)	$D_{max}$ (mm)	$\theta$
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  $0^\circ$  to  $10^\circ$  in a range from 2.77 MPa ( $10^\circ$  grain angle) to 7.57 MPa ( $0^\circ$  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  $R\text{-Sq} = 74.7\%$ . 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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