COMPARING THE COMPRESSIVE STRENGTH PROPERTIES OF STRUCTURAL SIZE AND SMALL CLEAR SPECIMENS FOR MALAYSIAN TROPICAL TIMBER

Muhammad Bazli Faliq Mohd Puaad [1,*], Zakiah Ahmad [2,]
[1] Universiti Teknologi Mara (UITM), 40450 Shah Alam, Selangor, Malaysia
[2] Institute of Infrastructure Engineering and Sustainable Management, Universiti Teknologi Mara (UITM), 40450 Shah Alam, Selangor, Malaysia
[*]For correspondence; Tel. + (60) 0126452598, E-mail: bfaliq86@gmail.com
[*]For correspondence; Tel. + (60) 0192151781, E-mail: zakiahah@hotmail.com

ABSTRACT: *The mechanical properties presented in the code of practice MS544: PART 2: 2001 such as tension, compression, and bending stresses, given in Table 1 and 2 of the code were obtained from tests of small pieces of wood as known as clear specimen. Other international codes, the strength data are developed based on structural size specimens. Therefore the aim of this study was to evaluate the timber compressive strength properties for eight selected Malaysian timber of different strength grouping; Resak (SG4), Kapur (SG4), Merpauh (SG4), Bintangor (SG5), White Meranti (SG5) Jelutong (SG6), Sesendok (SG7) and Kelampayan (SG7). Two different types of specimens were prepared; small clear specimens and structural size specimens according to ASTM D-143 and ASTM D-198 respectively. The results of small clear specimens were statistically correlated with the results from the structural size specimens. The application of structural size specimen data can be used to predict the much higher quality and the strength of timber to be used in construction field and it also can be at published in the Malaysian code of practice.*

Keywords: Compressive strength, Structural size, Malaysian tropical timber

1. INTRODUCTION

Timber is grown naturally, thus it is a difficult material to characterize and partly accounts for the wide variation in the strength of timber, not only between different species but also between timber of the same species and even from the same log [1].

At present, Malaysian standard established the strength properties of structural timber into grades or classification on the basis of appearance only (visual grading rule). The grade stresses in [2] such as tension, compression and bending stresses were obtained as a factor of small clear timber stresses. Clear wood refers to clears and defect-free small size wood, usually used in laboratory investigations for standard tests.

The presence of defects in timber makes it more brittle than clear wood and timber mechanical characteristics are affected by defect considerably, especially the brittle fracture properties of timber, tension strength [3]. Because the size, location and distribution of the defects in timber elements are hard to investigate, their effects on timber properties are difficult to predict. Therefore, strength properties obtained from testing on clear wood cannot be taken as timber strength properties. The current approach to deal with the difference is to assume the section area occupied by defects totally functionless conservatively. [4] stated that modification factors are introduced to adjust strength properties of clear wood.

According to [5] stated compressive strength is one of the strength properties that are considered important in timber design. [6-9] stated that compression parallel to the grain strength is of particular importance values in the design of post and columns. Columns are vertical load-bearing elements that are normally loaded in compression. Axially loaded wood columns may fail either by crushing or buckling. A short column fails when its compressive strength parallel to the grain is exceeded. When timber is loaded in axial compression parallel to the grain, it exhibits linear stress-strain behaviour up the yield stress that approximate half of the rupture modulus. Then the timber column drops until ductile crushing at ultimate load. While the ultimate load is reached, wood cell themselves fold into S shapes forming characteristic compression wrinkles due to local buckling of wood fibers become visible [5].

Compression test normally required clear, straight-grained material from small specimens. However, compression tests in structural size did received attention. [7,10-12]provided more in depth analysis of the compression parallel to the grain of wood. [11] compared the performance of the structural timber in compression parallel and small clear specimens where he states that the compression strength of the structural specimen value has a good agreement between the compression strength provided in the DNA-ECS (Portuguese Nationally Determined Parameters of Eurocode 5) based on the small clear specimen.

As Malaysian Tropical Timbers may have different properties compared to timbers from other countries, therefore there is a need to evaluate the difference between the strength of small clear specimens and large size specimens. This study investigates the compressive strength properties of selected Malaysian tropical timber based on structural size specimens and compared the results with the data from small clear specimens.

2. EXPERIMENTAL DETAILS

All timber materials used in this project were selected on one occasion in order to obtain a test material without too high a variation in strength which could be arisen from different growth condition. The timbers used for this study were sourced from reserved forest in UiTM Jengka. Based on MS544 Part 2, these species are in the different strength group. The total number of specimens in structural size was 160 (20 sample for each species) and the total number of specimens for small clear was 240 (30 sample for each species). Table 1 shows the timber species used in this study.

Table 1: Timber Species

Species	Family	Strength Grouping (SG)
Kapur	Dipterocarpaceae	SG 4
Merpauh	Anacardiaceae	SG 4
Resak	Dipterocarpaceae	SG 4
Bintangor	Guthiferea	SG 5
White Meranti	Dipterocarpaceae	SG 5
Jelutong	Apocynaceae	SG 6
Kelempayan	Rubiaceae	SG 7
Sesensdok	Euphorbiaceae	SG 7

The specimens were planned on four sides to the size of 50 mm x 50 mm x 1500 mm (structural size) and 50 mm x 50 mm x 200 mm (small clear specimen) which were prepared according to [13,14-15]. Then the specimens were visually stress graded for standard and better grade in accordance with [16].

A special compression jig has been fabricated in accordance to the method in [13]. During compression test for structural timber, column either crushes (a strength failure or it buckles a stability failure). The lateral supports are provided at regular spaced intervals to ensure that the specimen will fail in crushing instead of buckling. The idea of using the lateral support for the stability control also being applied by [10,12,17]. A solid metal is used to make a roller and act as a lateral restrained. Each roller were placed at the C-channel with spacing between them is 240mm. The roller will allow the longitudinal movement of specimen freely, to prevent any shear force acting on the surface of the specimen (Figure 1).

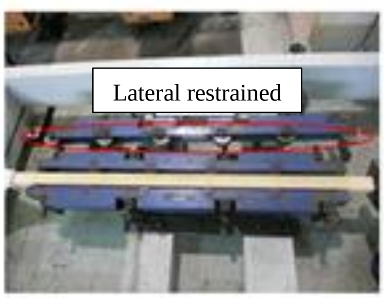

Fig (1) Showing the roller as lateral restrained

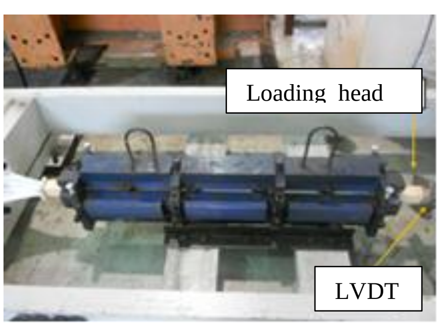

Fig (2) Fully Assembled Compression Jig

The compression tests in structural size were carried out in accordance with [13,14] were use to carries out the test for small clear specimens. After physical measurements had been taken and recorded, the structural specimen was placed in the jig and screwed to tight up the upper C-channel (Figure 2). One linear variable differential transducer (LVDT) was attached in horizontal positioned to the loading head to monitor the deformation occur and connected to the data logger to received and recorded the reading during testing. The testing were done using 200kN spherical bearing block loading head.

As for small clear specimens, the compression load was applied using the 200 kN Universal Test with loading rate of 0.01 mm/s (0.025 in/min). Figure 3 shows the test set-up for a compression parallel to the grain for small clear specimen.

Fig (3) Compression Test Set-up for Small Clear Specimen

3. RESULTS AND DISCUSSION

Compression Failure Characteristics for Small Clear Specimens:

For each specimen, load and displacement were recorded continuously throughout the test. Failure pattern were recorded for each specimen as well. Table 2 shows the summary of failure characteristics after subjected to compression parallel to the longitudinal axis. It can be seen that there are six different types of failure modes and these modes are shown in Figure 4.

[5] mentioned that, if the objective of testing is to characterize defect-free timber only then data from specimen with crushing, shearing and wedge splitting modes of failure should be included in final result due to that they are free from the internal defect. Therefore compressive strength properties values should only compiled based on the timber failed in three modes of failure only. Other result should be rejected. The splitting, crushing and splitting and brooming failure modes indicate that the timber still possesses internal defects.

Table 2: Summary Failure Characteristic for Compression Parallel to the Grain for small clear specimens

Species	Percentage of Failure Modes (%)					
	Crushing	Shearing	Wedge Splitting	Splitting	Crushing & Splitting	Brooming
Kapur	70	27	-	-	-	3
Merpauh	77	-	13	10	-	-
Resak	30	30	20	20	-	-
Bintangor	47	33		3		17
White Meranti	63	-	17	3	-	17
Jelutong	80	3	3	-	-	14
Kelempayan	60	13		-	4	23
Sesendok	40	3	3	14	10	30

Fig(4) Characteristic of Compression Failure:
(a) crushing (b) shearing
(c) crushing and splitting (d) wedge splitting
(e) splitting (f) brooming

Although the timbers used in this study has been graded as clear specimen (standard and better) there is 37% allowance for defects for the calculations of the grade [1]. When the percentage of failure in splitting, crushing and splitting and broomming is higher than 37 %, then the result should be omitted in the calculation of compressive strength. In this case only Sesendok has 54% failure in splitting, crushing and splitting and brooming.

Compression Failure Characteristics for Structural Size Specimens:

Failure patterns were recorded for each specimens and Figure 6 shows the different modes of failure found after the compression test and the percentage of failure modes are summarized in Table 3. It can be seen that Kapur, Merpauh, Resak, Bintangor, White Meranti, Jelutong and Sesendok have more than 50% crushing failure rather than shearing failure and there was none for buckling. In this study, the specimen generally failed in crushing (Figure 5a) and shear (Figure 5b).

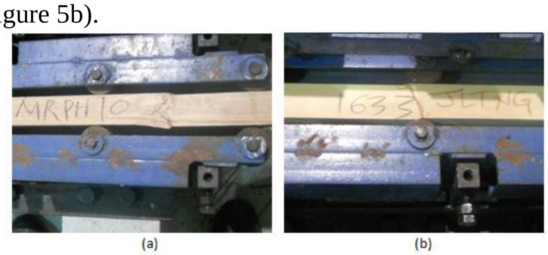

Fig 5: Compression Failure:
(a) Crushing failure (b) Shear failure

Table 3: Summary Failure Characteristic for Compression Parallel to the Grain for large size specimens

Species	Percentage of Failure Modes (%)		
	Crushing	Shearing	Buckling
Kapur	55	45	-
Merpauh	75	25	-
Resak	60	40	-
Bintangor	60	40	-
White Meranti	65	35	-
Jelutong	80	20	-
Kelempayan	64	35	-
Sesendok	95	5	-

A combination of three factors, homogeneity of material, straightness of column and the even distribution of load govern the compression strength parallel to the grain. The homogeneity of material is believed to be responsible for the effect of timber species on the compressive strength parallel to the longitudinal axis. [5] noted that there are generally two types of specimens loading, axial and eccentric. Axially loaded specimens failed in crushing gave the higher compressive strength. As for eccentrically loaded specimen usually fail in shearing and buckling. As the lateral restrained was provided in this study, there is no failure caused by buckling occurred.

In this case the combination of crushing and shearing failure for specimen used in the same species may be affected by the influence of defects which may still exist inside the specimen which cannot be seen from outside as the timbers as these timbers were only visually graded which based on surface appearance.

Compressive Strength Properties:

Table 4 and 5 show the compressive strength properties of small clear specimens and large size specimens. In general, as the density increases the compressive strength also increases and this finding is supported by [6]. As these timbers have moisture content below 19% which considered dry, the effect of moisture will not be significant.

For small clear specimens, the ANOVA analysis revealed that there was significant difference in ultimate compressive strength (UCS) values for all species between the different species (p-value < 0.05). From Table 4, it can be seen that there is no significant different in the UCS values for Merpauh, Kapur and Bintangor and also there is no significant different in the mean value for Kelempayan, Sesendok and Jelutong. Table 4 also shows that the UCS in the order of Resak > Merpauh, Kapur and Bintangor > White Meranti > Jelutong, Kelempayan and Sesendok. These results suggested that Merpauh and Kapur should be in same strength grouping. Jelutong, Kelempayan and Sesendok also should be in the same strength grouping. As for Bintangor, it tends to shift to Kapur and Merpauh. The compressive strength of Resak is the highest and Kelempayan is the lowest.

As for large size specimens, there are also significant differences in the MOR and MOE values. The ANOVA analysis revealed that there were significant difference in UCS values for all species (p-value < 0.05). From Table 5, it can be seen that there is no significant different in the UCS values for Merpauh, Kapur and Bintangor However there is significant different in UCS for Kelempayan and Jelutong which is different from the finding from Table 4. The UCS values are in the order of Resak > (Merpauh, Kapur and Bintangor) > White Meranti > Sesendok > Kelempayan > Jelutong. Bintangor tends to shift to the grouping of Kapur and Merpauh. These results give an indication that Merpauh, Kapur and Bintangor can be group together. So this is important information regarding large size specimens which may be useful information for the development of timber strength class or grouping based on large size specimen for MS 544 Part 3.

In terms of compression strength values, for structural size specimens, Resak gives the highest value of compressive strength, 57.6 MPa. Meanwhile, Kelempayan has the lowest values of compressive strength, which is 20.2 MPa. It can be seen that Sesendok which is in lower strength grouping (SG7) has compressive strength (31 MPa) which is higher than Jelutong which is in strength group 6.Table 6 shows the comparison of compression strength parallel to the grain between structural size and small clear specimens. It can be seen, that the UCS values of structural size are much lower than small clear specimen except for Sesendok. This finding contradicts the result provided by [11] where stated that the compression strength of the structural specimen value has the good agreement between the compression strength provided in the DNA-ECS (Portuguese Nationally Determined Parameters of Eurocode 5) based on the small clear specimen.

Table 4: Duncan Multiple Comparison for Compressive Properties among Timber Species in Small Clear Speciemen

Adhesive	Subset for alpha = 0.05			
	1	2	3	4
Resak	64.67[a]			
Merpauh		55.22[b]		
Kapur		54.30[b]		
Bintangor		52.37[b]		
White Meranti			44.87[c]	
Sesendok				26.86[d]
Jelutong				26.10[d]
Kelempayan				23.68[d]

Table 5: Duncan Multiple Comparison for Compressive Strength Among Timber Species in Structural Size Specimen

Adhesive	Subset for alpha = 0.05					
	1	2	3	4	5	6
Kapur	57.60[a]					
Merpauh		51.94[b]				
Resak		51.02[b]				
Bintangor		49.53[b]				
White Meranti			38.19[c]			
Sesendok				31.03[d]		
Kelempayan					24.60[e]	
Jelutong						20.20[f]

Table 6: Summary Statistics for Compressive Strength

					Small Clear Specimen			Large Size Specimen		
Species	Strength Group	No. of samples	Moisture Content (%)	Density (kg/m)	Compressive strength			Compressive strength		
					Mean (MPa)	SD	COV (%)	Mean (MPa)	S.D	COV (%)
Kapur	SG 4	30	12.12	795	54.3	7.02	12.92	51.0	5.596	10.96
Merpauh	SG 4	30	8.99	747	55.2	4.93	8.92	51.9	5.067	9.74
Resak	SG 4	30	10.86	974	64.6	7.04	10.89	57.6	7.802	13.54
Bintangor	SG 5	30	13.14	701	52.3	8.43	16.10	49.5	6.670	13.46
White Meranti	SG 5	30	11.17	645	44.8	4.46	9.95	38.2	8.069	21.12
Jelutong	SG 6	30	10.58	421	26.1	4.60	17.62	24.6	4.115	16.72
Kelempayan	SG 7	30	9.74	425	23.6	4.65	19.64	20.2	5.763	28.52
Sesendok	SG 7	30	10.18	457	26.8	5.15	19.18	31.0	3.815	12.29

Even though Sesendok is in SG 7 but the compression strength of small clear specimen and higher than SG 6 for large size specimen. One possible explanation for this behaviour is the mode failure produced by Sesendok itself. In Table 2, shows that 90% of failure mode of Sesendok is crushing while other is shearing. As stated by [5], specimens fail in crushing gave the higher compressive strength. So, it shows that the good quality timber in large size may lead to the higher compression strength than the small clear specimen.

4. CONCLUSIONS

The outcomes shown that structural size specimen have lower compressive strength comparing with compressive strength small clear specimen. These results are maybe due to the fact that these types of timbers in the structural size have the high possibility containing internal growth defects as it increased in size in the form of knots, zones with compression wood, and whole lot more. In short, the compression parallel in to the grain in structural size produces lower compressive strength than the small clear specimen. It is very crucial and vital in terms of safety because it could lead to the miscalculation of timber in structural design using timber as a material if only depending to the data produced by the small clear specimen. Other than that, the compression jig needs the further modification in order to improve the accuracy in the measurement. The jig also needs modification to take up different sizes of the specimen tested.

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*For correspondence; Tel. + (60) 0126452598, E-mail:bfaliq86@gmail.com