DOWEL-BEARING STRENGTH OF KEMPAS USING 'SPRING THEORY'

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ABSTRACT

Dowel-bearing strength of wood is one of the parameters that are needed to determine the load-carrying capacity of timber joint. However, none of the available standard consists of dowel bearing –strength of wood compressed with wood dowel. The existing standards are based on the dowel bearing-strength of wood based material compressed with steel dowel. The dowel bearing-strength of wood based material for this study was tested on the Kempas species compressed by 21 mm diameter dowel and was determined by using the 'Spring Theory'. The experimental work of the actual dowel-bearing strength of wood based material compressed with the steel dowel (WBCSD) and combined with the wood dowel that was compressed with steel block (WDCSB) were reported. It was found that the lowest 5% offset load was in the 'Spring Theory' (WBCSB + WDCSB) (*28.57 kN*) compared to the actual WBCSB *(36.35 kN*). These differences show that the actual WBCSD is 10% higher than the value of the 'Spring Theory'. Therefore the dowel-bearing strength of the based material of Kempas compressed with wood dowel is taken from the lowest bearing strength that is *33.19* Mpa resulted from the 'Spring theory'. It is therefore can be concluded that the 'Spring Theory' is also applicable to be used for the tropical timber species.

Keywords:
Load carrying capacity, Kempas, 5% offset stiffness

INTRODUCTION

In order to have a safe timber joint design, all parameters of interest that contributed to the load of carrying capacity of the joint design are considered as priority and contributed to a major factor in the design. One of the important parameters to design the load carrying capacity of a timber joint is the dowel bearing-strength of the wood based material. The existing information on the dowel bearing-strength of wood based material compressed using steel is available in the National Design Standard, (NDS, 2005) Eurocode 5 (EC 5, 2008). However, none of these standards has the dowel bearing-strength of wood based material compressed with wood dowel. This includes the Malaysian Standard 544 (MS 544, 2001). The only available method is proposed by Schmidt and Daniels (1999) and is named as 'Spring Theory'. This theory is applied in this study due to the possibility of its application to the tropical timber species since Schmidt and Daniels (1999) have reported a convincing result in their study using the softwood timber species.

The methods for designing joints of the dowel connector for steel are currently included in the National Design Specification for Wood Construction (NDS) (AFPA 2001) but not for the wood. The European Yield Model (EYM) failure modes are based on steel dowel connectors, instead of wooden dowels. Hence, designers of timber frames have little guidance when designing wood based joinery for load transfer purposes.

Currently there is no data available for dowel-bearing strength of wood based material compressed by wood (Schmidt and Daniels, 1999). This information is also not currently available in the existing design standard, including the NDS, 2005; EC 5, 2008 and MS 544, 2001. Therefore this study aims to evaluate the dowel-bearing strength of wood based compressed with wood dowel by using the 'Spring Theory' as proposed by Schmidt and Daniels (1999).

The main objective of this study is to determine the dowel-bearing strength of wood based material on Kempas compressed by wood dowel using the "Spring Theory'. Therefore, the specific objectives are to analyse the previous collected data of dowel-bearing of wood based material compressed with steel dowel (WBCSD) and to determine the dowel-bearing of wood dowel compressed with steel block (WDCSB). Finally the WBCSD and WDCSB data were compiled to determine the dowel-bearing strength of Kempas by using the 'Spring Theory'.

DOWEL-BEARING STRENGTH OF WOOD BASED MATERIAL

Dowel-bearing strength of wood based material is one of the important parameters need to be specified in order to design the load-carrying capacity of a timber joint. Many factors contributed especially from the wood members and the fasteners influence the dowel-bearing strength of the wood based materials. Among the factors are the influence of dowel diameter (McLain and Thangjitham, 1993), grain directions (Rammer, 1999), specific gravity (Wilkinson, 1991), moisture content (Rammer and Winistorfer, 2001 and Sauvat *et al.*, 2008, Rohana, 2011) and density (Jumaat *et al.*, 2006 and 2008 and Rohana, 2011).

However, all recorded data from the EC 5, 2008 are for the dowel-bearing strength of wood based material that was compressed by steel dowel. Only a few studies reported on the dowel-bearing strength of wood based materials compressed by wood dowel. These studies were reported by Church and Tew (1997), Sandberg et al. (2000), Schmidt and Mackay (1997), Schmidt and Daniels (1999), Miller (2004) and Miller (2010). Church and Tew (1997) determined that the dowel bearing strength had an additional experimental method to the ASTM-D5764 and the BS EN 383:2007. They have introduced a different method in determining the dowel bearing strength when compressed with wood dowel. Instead of pressing the steel dowel with the steel block, Church and Tew have compressed the wood dowel by using the wood block. Their work has been cited by Sandberg *et al.* (2000). However, Sandberg commented that Church and Tew's method was by limiting the deformation of both elements; the wood dowel and also the wood-based material (Sandberg *et al*, 2000). Since the results of Church and Tew's showed a significant reduction of 50% compared to the steel dowel value, Sandberg *et al.* has used different method in their study in order to separate the wood dowel and wood-based information.

DOWEL BEARING- STRENGTH USING "SPRING THEORY".

The study of Dowel bearing-strength by using the 'Spring Theory' was proposed by Schmidt and Daniels (1999). This theory of determining the dowel-bearing strength of wood compressed with wood dowel works by combining the load-deformation curves for the dowel-bearing strength of wood dowel and the dowel-bearing of based material. The load-deformation curves for the wood dowel is from the wood dowel compressed with the steel block (WDCSB) and for the wood based material is from the wood block compressed with the steel dowel (WBCSD). The illustration of this dowel-bearing spring theory is shown in Figure 1. The yield strength of the curves in combination is found by applying the 5% offset method to the combined load-deflection curve.

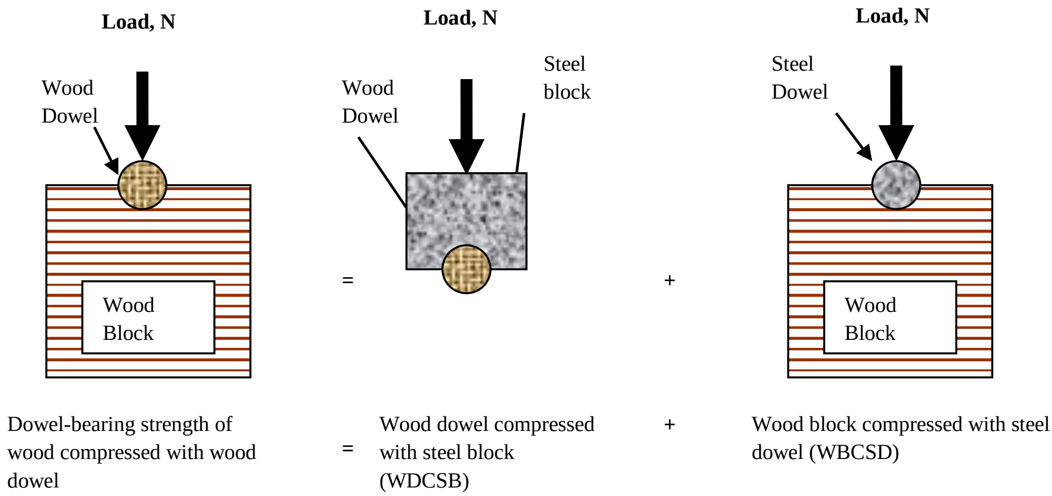

Figure 1: Method proposed by Schmidt and Daniels (1999)

METHODOLOGY

WOOD BLOCK COMPRESSED WITH STEEL DOWEL (WBCSD)

For sample preparations, all dowel-bearing strength specimens were prepared as shown in Figure 2. Ten (10) specimens were cut into half having the groove for the dowel parallel and another half (perpendicular) to the grain. The wooden block specimens were prepared in the sizes of 25 mm by 100 mm by 125 mm.

Figure 2: Bearing strength specimens ready for test

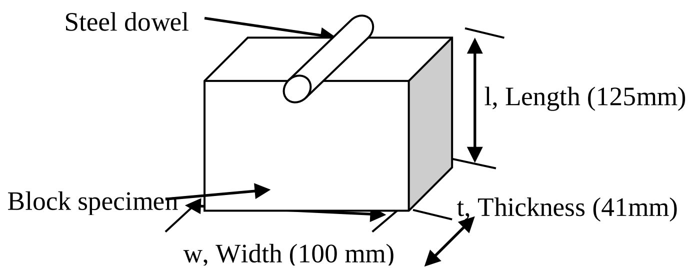

Figure 3: Shows the specimens configuration. These methods were applied to determine the WBCSD as shown in Figure 4.

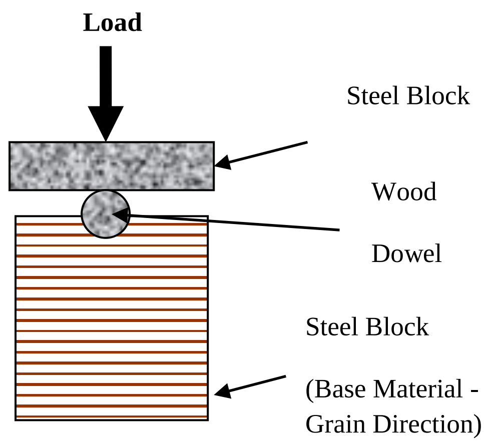

Figure 4: Methods approach to determine the dowel bearing strength

WOOD DOWEL COMPRESSED WITH STEEL BLOCK (WDCSB)

The tests conducted for this research were performed by using a 21 mm diameter and 323 mm length of wood dowel. The wood block and the dowels were both made of Kempas species. The moisture content and density of the specimens were also determined after the WDCSB test. The yield point was determined by 5% offset method per ASTM D5652 (ASTM, 1995a). The configuration of the WDCSB is as shown in Figure 5.

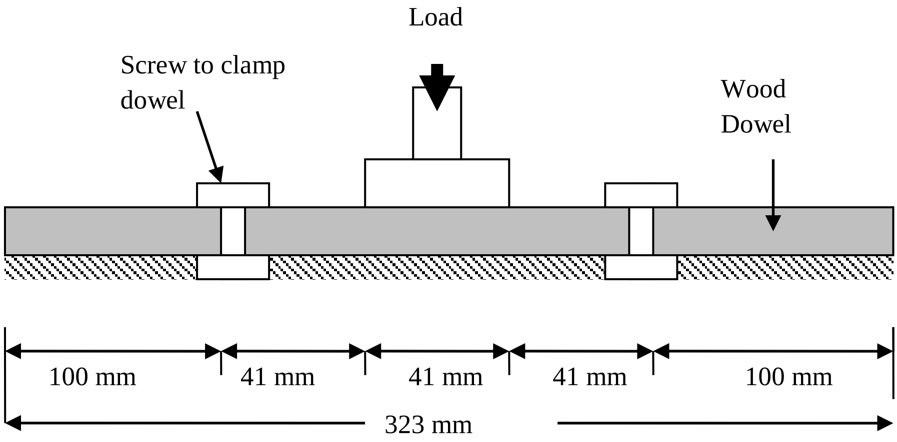

Figure 5: Configuration and the geometry of the wood dowel

The specimens were tested according to ASTM 1995a at a load rate of 0.024 in/min to reach failure in approximately four (4) to seven (7) minutes. The testing assembly consisted of a steel block with half-hole placed on the flat base on the Universal Testing Machine (UTM) and a load head made of steel plate that pressed the dowel into the specimen. A picture of the dowel bearing test setup is shown in Figure 6 and Figure 7.

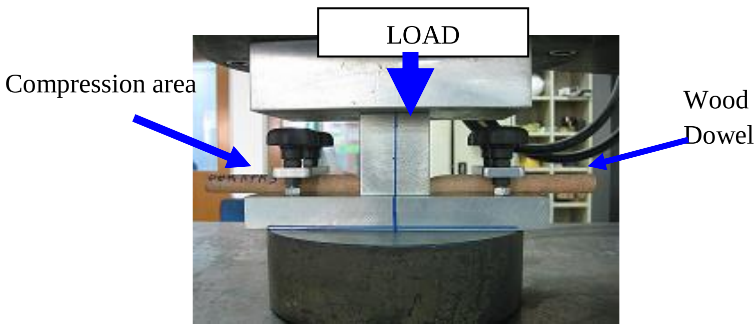

Figure 6: Test Set-up of WDCSB

Figure 7: WDCSB - After Test

RESULTS AND DISCUSSION

Detail discussion of the findings for this study is as shown in Table 1 and Figure 8 respectively. Table 1 shows the average result for ten (10) specimens. For the results of WBCSB, it was found that the 5% of the offset load, stiffness and bearing strength of Kempas was 36.35 kN, 9.76 kN/mm and 42.22 Mpa respectively.

Table 1: Compilation of WBCSD

Sample Code	Max.		Proportional value		5% Offset		Stiffness at 5% offset (kN/mm)	Bearing Strength (Mpa)
	Load (kN)	Displc (mm)	Load (kN)	Displc (mm)	Load (kN)	Displc (mm)		
KPS 1	55.18	19.47	31.74	2.01	38.09	3.41	11.17	44.24
KPS 2	57.14	10.07	23.93	2.01	31.74	3.72	8.53	36.86
KPS 3	55.18	8.85	28.81	2.19	42.00	4.15	10.12	48.78
KPS 4	48.35	6.77	38.09	2.80	42.97	4.21	10.21	49.91
KPS 5	39.07	8.18	22.95	1.95	31.25	3.60	8.68	36.30
KPS 6	50.79	8.73	26.86	1.70	36.33	3.23	11.25	42.20
KPS 7	49.81	11.23	27.83	2.31	37.11	3.96	9.37	43.10
KPS 8	50.79	8.18	31.25	2.31	40.53	4.15	9.77	47.07
KPS 9	49.81	14.28	18.55	1.40	25.88	2.93	8.83	30.06
KPS 10	49.32	8.36	26.37	2.25	37.60	3.90	9.64	43.67
AVERAGE	50.54	10.41	27.64	2.09	36.35	3.73	9.76	42.22

From Figure 8, it shows that the initial stiffness of the WBCSD curve is increasing until its load capacity reached about 34 kN load and about 4.2 mm displacement. Load is increasing until the maximum value is 39kN at displacment 8 mm. The fracture of the tests speciemens were recorded at 30 kN load with around 13 mm displacement. The fracture of the tests specimens were due to the splits or small cracks of the specimens.

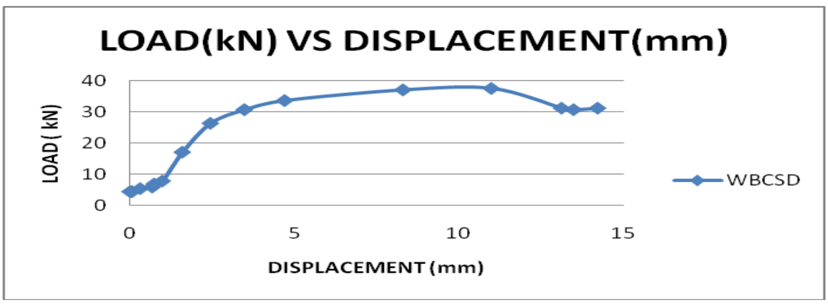

Figure 8 : Typical Plot for WBCSD

BEARING – STRENGTH OF WOOD DOWEL (WDCSB)

The yield point was determined by 5% offset method per ASTM D5652 (ASTM, 1995a). A plot is made of the load versus deflection for each test. (Figure 9) shows the typical Plot for WDCSB. The compilation results of the ten (10) samples are shown in Table 2.

Table 2: Compilation of WDCSB

Sample Code	Max.		Proportional value		5% Offset		Stiffness at 5%	Bearing Strength
	Load (kN)	Displc (mm)	Load (kN)	Displc (mm)	Load (kN)	Displc (mm)	(kN/mm)	(Mpa)
KPS 1	151.676	10.21	19.32	2.69	38.09	5.16	7.38	44.24
KPS 2	217.2	10.42	9.6	0.98	28.5	4.3	6.63	33.10
KPS 3	50.18	8.25	5.55	0.66	9.92	1.02	9.73	11.52
KPS 4	42.21	8.6	12.15	1.45	16.05	2.76	5.82	18.64
KPS 5	97.65	9.61	13.52	1.91	16.15	2.35	6.87	18.76
KPS 6	134.64	9.4	18.85	2.02	22.94	2.76	8.31	26.64
KPS 7	117.78	8.83	13.97	1.44	18.39	2.41	7.63	21.36
KPS 8	123.32	8.21	19.28	1.78	25.72	2.88	8.93	29.87
KPS 9	82.78	8.22	9.73	0.84	13.82	1.48	9.34	16.05
KPS 10	151.69	10.56	15.55	2.4	18.36	3.34	5.50	21.32
AVERAGE	116.91	9.23	13.75	1.62	20.79	2.85	7.61	24.15

Table 2 shows the average results for the ten (10) specimens. For the the results of WDCSB, it was found that the 5% of the offset load, stiffness and bearing strength of Kempas was *20.79 kN, 7.61 kN/mm* and *24.15 Mpa* respectively.

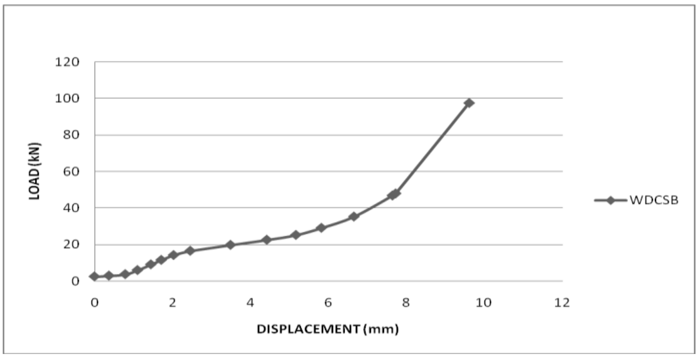

Figure 9 : Typical Plot for WDCSB

Figure 9 shows the initial stiffness of the WDCSB curve which is increasing smoothly until about 20 kN load and about 3.8 mm displacement. Load is increasing until the load head made of steel plate press the dowel to its maximum capacity. After it reaches the maximum capacity, the load keeps on increasing but with a smaller displacement. At this stage, it was seen that the wood dowel is no longer compressed.

DOWEL BEARING – STRENGTH OF WOOD BASED USING 'SPRING THEORY' (WBCSD + WDCSB)

In order to determine the dowel bearing-strength of the wood based material for Kempas using the 'Spring Theory', the WBCSD and WDCSB were combined and discussed. The results were then compared with the findings published by Schmidt and Daniels (1999). Figure 10 and Table 3 shows the results of the 'Spring Theory' by the combination of the WBCSD and WDCSB which were written as WBCSD + WDCSB in this study.

From Table 3, the average results for the ten (10) specimens could be seen. From the 'Spring Theory' (WDCSB+ WBCSD), it was found that the 5% of the offset load, stiffness and bearing strength of Kempas was 28.57 kN, 8.69 kN/mm and 33.19 Mpa respectively.

The comparison of the spring theory (WBCSD to the WDCSB) was shown that the 5% of the offset of WBCSD was 42.79 % higher than the results of WDCSD. However, the maximum capacity, stiffness and the bearing strength of the WBCSD were 131.31%, 28.16% and 74.81% which was lower than the results of WBCSD.

Table 3: Compilation of the Spring Theory (WBCSD + WDCSB)

Sample Code	Max.		Proportional value		5% Offset		Stiffness at 5% (kN/mm)	Bearing Strength (Mpa)
	Load (kN)	Displc (mm)	Load (kN)	Displc (mm)	Load (kN)	Displc (mm)		
KPS 1	103.43	14.84	25.53	2.35	38.09	4.29	9.28	44.24
KPS 2	137.17	10.25	16.77	1.50	30.12	4.01	7.58	34.98
KPS 3	52.68	8.55	17.18	1.43	25.96	2.59	9.92	30.15
KPS 4	45.28	7.69	25.12	2.13	29.51	3.49	8.01	34.28
KPS 5	68.36	8.90	18.24	1.93	23.70	2.98	7.78	27.53
KPS 6	92.72	9.07	22.86	1.86	29.64	3.00	9.78	34.42
KPS 7	83.80	10.03	20.90	1.88	27.75	3.19	8.50	32.23
KPS 8	87.06	8.20	25.27	2.05	33.13	3.52	9.35	38.47
KPS 9	66.30	11.25	14.14	1.12	19.85	2.21	9.08	23.06
KPS 10	100.51	9.46	20.96	2.33	27.98	3.62	7.57	32.50
AVERAGE	83.73	9.82	20.70	1.86	28.57	3.29	8.69	33.19

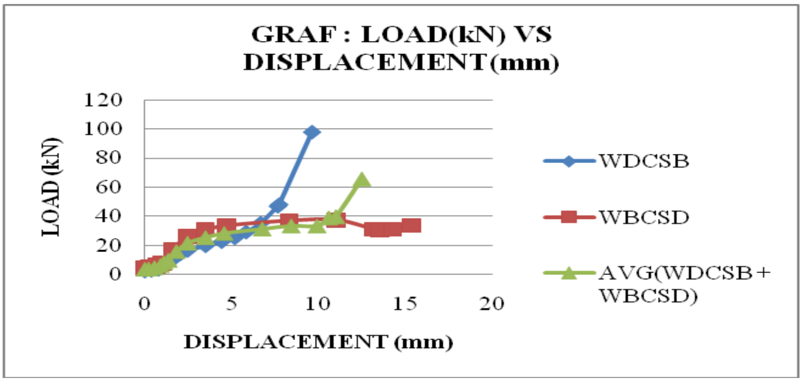

Figure 10 : Typical Plot for WBCSD + WDCSB

As illustrated in Figure 10 the initial stiffness of the WDCSB is relatively close to the WBCSD. This scenario was also typical for all of other comparisons. The difference in stiffness in average is *28.16%*. However, compared to Schmidt and Daniels (1999) this difference is higher than the Schmidt and Daniels(1999), since their finding shows the difference of the actual initial stiffness to the spring theory was 21.6%. This results show that Kempas species is stronger and stiffer than the oak species. It was also found that the weaker material was in the 'Spring Theory'(WBCSB + WDCSB) (*28.57 kN*) compared to the actual WBCSB *(36.35 kN*). This defferences show that the actual WBCSD is 10% higher than the value of the 'Spring Theory'. In comparison between the actual and the 'Spring Theory', the results of the 'Spring Theory' was the weakest. Therefore, the dowel-bearing strength of based material of Kempas compressed with wood dowel is taken as *33.19 Mpa*. Based on the results from this study, it is shown that the soft wood done by Schmidt and Daniels (1999) is less stiff than the results of the Kempas species.

CONCLUSION

It was found that the lowest 5% of the offset load was in the 'Spring Theory' (WBCSB + WDCSB) (*28.57kN*) compared to the actual WBCSB *(36.35 kN*). This defference shows that the actual WBCSD is 10% higher than the value of the 'Spring Theory'. Therefore the dowel-bearing strength of the based material of Kempas compressed with the wood dowel and is taken from the lowest bearing strength is *33.19* Mpa resulted from the 'Spring theory'. It is therefore can be concluded that the 'Spring Theory' is also applicable to be used for the tropical timber species.

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