Experimental Test Of Indonesian Wood Joint Lateral Resistance With Bolt As Fasteners Versus Yield Limit Equations Of SNI 7973-2013

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Abstract— The use of bolt fasteners as a connecting device has been used for a long time. Calculation of lateral resistance capacity used in Indonesia that is SNI 7973-2013 method is adopt American standard that is NDS 2012. Due to climate and weather difference since its growth, humidity factor and openness to sunshine and rain hence the nature of wood in Indonesia is different from wood in America. This study aims to examine the accuracy of the equation of lateral resistance capacity in the standard for timber in Indonesia.The results show that the comparison between the experimental results and the result of calculation by the method of SNI 7973-2013 is 92.7%, means that the method of SNI 7973-2013 is suited to the fastened joints of bolts for Indonesian wood. Keywords— bolt fasteners, Indonesian wood, SNI 7973-2013, NDS 2012

1. Introduction

The use of bolts as a connecting device has been widely used and can be applied in wooden constructions can accept large loads (Breyer et al., 2007). In 1932, Trayer undertook a study of the fastened steel dowel joints, which many researchers considered it was the first joint research. The study was the calculation of wooden lateral connection resistance with empirical approach, ie through a series of tests, then made the graph as a calculation guide. The calculation of lateral connection resistance with the yield limit mode was first introduced by Johansen (1949) based on the dowel bending yield strength of a single bolt and the dowel bearing strength of the wood. This yield mode then adopted by American Standard that is Design Specification for Wood Construction (NDS) and Indonesian Standard (SNI 7973-2013) as a guide to calculate the strength of the wood connection. Due to climate and weather difference, since its growth, humidity factor and openness to sunshine and rain hence the nature of wood in Indonesia is different from wood in America. This study aims to examine the accuracy of the equation of lateral resistance capacity in the standard for timber in Indonesia

2. Literature Review

NDS-2015 and SNI 7973-2013 are adoption with modifications from the National Design Specification for Wood Construction, 2012 Edition (NDS-2012) states, a yield mode in single shear and double shear connections with bolt connectors , can be described as in Figure 1, namely:

a. Yield mode I : Wood connection crushed on the side wood or middle wood if the stiffness of the bolt is larger than the wood. Yield mode lm, is happened if the midddle timber is destroyed, while the yield mode Is is happened if the side timber is destroyed.
b. Yield mode II: Wood connection crushed due to pivoting / turning rigid bolts to the sliding plane.
c. Yield mode III: Bolt melt against bending with a single plastic joint per shear plane and with wood crushing. Yield mode IIIm is happened if crushed happened in the middle wood and plastic joints of bolts on side wood, while the yield mode IIIs is happened if crushed happened in the side wood and plastic joints of bolts on middle wood.
d. Yield mode IV: Bolt melt against bending with two points of plastic joint per sliding plane and with wood destruction.

In a double shear connection (Figure 1b) the yield mode II and IIIm does not occur. The yield limit equation can be seen in Table 1.

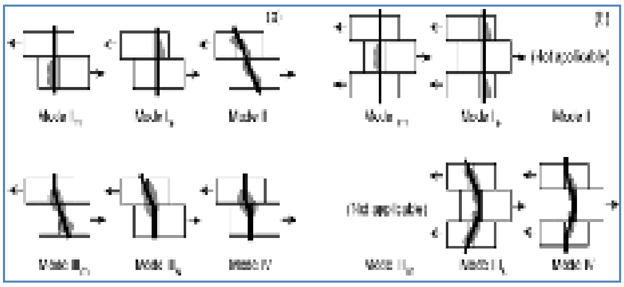


Figure 1. Yield mode of SNI7973-2013, on wood connections with bolt fastener

Table 1. Yield Limit Equations (NDS 2015 and SNI7973-2013)

Yield Mode	Single Shear		Double Shear	
I_m	$Z = \frac{D \ell_m F_{em}}{R_d}$	(12.3-1)	$Z = \frac{D \ell_m F_{em}}{R_d}$	(12.3-7)
I_s	$Z = \frac{D \ell_s F_{es}}{R_d}$	(12.3-2)	$Z = \frac{2 D \ell_s F_{es}}{R_d}$	(12.3-8)
II	$Z = \frac{k_1 D \ell_s F_{es}}{R_d}$	(12.3-3)		
III_m	$Z = \frac{k_2 D \ell_m F_{em}}{(1+2R_e) R_d}$	(12.3-4)		
III_s	$Z = \frac{k_3 D \ell_s F_{em}}{(2+R_e) R_d}$	(12.3-5)	$Z = \frac{2 k_3 D \ell_s F_{em}}{(2+R_e) R_d}$	(12.3-9)
IV	$Z = \frac{D^2}{R_d}\sqrt{\frac{2 F_{em} F_{yb}}{3(1+R_e)}}$	(12.3-6)	$Z = \frac{2 D^2}{R_d}\sqrt{\frac{2 F_{em} F_{yb}}{3(1+R_e)}}$	(12.3-10)

Notes:

$k_1 = \frac{\sqrt{R_e + 2R_e^2(1+R_t+R_t^2) + R_t^2 R_e^3} - R_e(1+R_t)}{(1+R_e)}$

$k_2 = -1 + \sqrt{2(1+R_e) + \frac{2F_{yb}(1+2R_e)D^2}{3F_{em}\ell_m^2}}$

$k_3 = -1 + \sqrt{\frac{2(1+R_e)}{R_e} + \frac{2F_{yb}(2+R_e)D^2}{3F_{em}\ell_s^2}}$

D = diameter, in. (see 12.3.7)
F_{yb} = dowel bending yield strength, psi
R_d = reduction term (see Table 12.3.1B)
R_e = F_{em}/F_{es}
R_t = ℓ_m/ℓ_s
ℓ_m = main member dowel bearing length, in.
ℓ_s = side member dowel bearing length, in.
F_{em} = main member dowel bearing strength, psi (see Table 12.3.3)
F_{es} = side member dowel bearing strength, psi (see Table 12.3.3)

3. Method

To find out the accuracy of the yield limit equations of SNI 7973-2013 on the symmetric double shear connections using bolt type fastener, a comparison of experimental results with the calculation using the yield limit equation as shown in Table 1 was performed. According to the equation, lateral connection resistance is a function of the dowel bending yield strength of a single bolt, the dowel bearing strength of the wood and the wood thickness. The experimental test method uses the standard as in Table 2. Determination of the proportional load, the yield load and ultimit load are calculated according to ASTM D -5652 as shown in Figure 2. The yield load is determined by the 5% offset method.The wood used in this experiment is Bayur , middle wood cross section was 58 mm x 20 mm, while side wood cross-section were 29 x 20 mm. The bolt diameter was 10 mm.

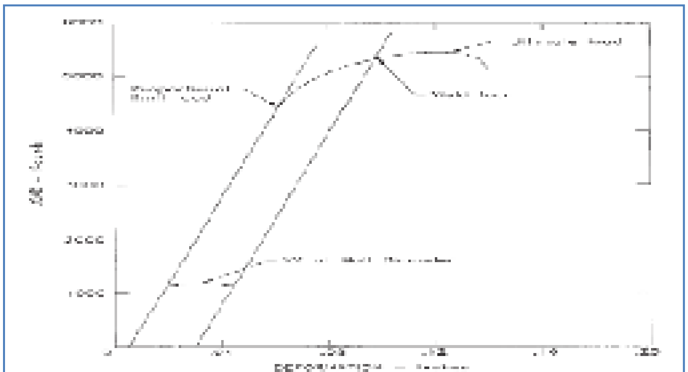


FIG. 4 Definition of Loads to Be Obtained from the Load-Deformation Curve

Figure 2. Definition of loads obtained from the load-deformation curve (ASTM D 5262-95)

Table 2. Testing Standards

No	Mechanical test	Standard
1	Dowel bearing yield strength	ASTM D 5764-97a
2	Dowel bending yield strength	ASTM F 1575-03
3	Symmetric double shear connections strength	ASTM D 5652-95

4. Result And Discussion

4.1 Dowel Bearing Strength

Dowel bearing yield strength was conducted for eighteen samples. Photo test and samples can be seen in Figure 3. In general failure wood occurs. Wood is cracked or compacted by pressure from bolts. See Figure. 3c. The load versus deformation graph are initially elastic (linear graph) then becomes plastic (curved convex graph). The test is stopped when the appliance presses touch the wood sample. It is marked by a turning point on the graph line. After reaching the turning point, the graph line will suddenly rise upward, as the pressure on the tool presses the wood sample, while the bolt becomes flat with the top half of the sample hole. This kind of failure occurs when the wood at the base of the bolt solidifies. Another failure is wooden cracking. The relation between the load and deformation can be seen in Figure 4. The dowel bearing stress strength is taken from the average of three samples. Its strength ranges from 30 N / mm2 to 38 N / mm2. See Table 3.

(a) (b) (c)

Figure 3. (a, b) Dowel bearing strength test photo, (c) Samples

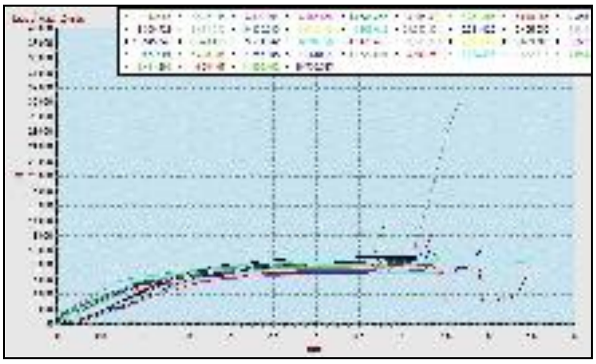


Figure 4. The relationship between the load and the deformation of dowel bearing strength test

Table 3. Test results of dowel bearing strength

Sample	$P_{bearing}$ 5% off	Sample width (t)	Bolt Dia. (d)	F_{eb} (P/t)	F_{eb} average
	(N)	(mm)	(mm)	(N/mm2)	(N/mm2)
TUBT 1a	7500	20	10	37.50	
TUBT 1b	7550	20	10	37.75	

TUBT 1c	7800	20	10	39.00	38.08

Table 4. Test results of dowel bearing strength (cont)

Sample	$P_{bearing\ 5\%\ off}$	Sample width (t)	Bolt Dia. (d)	F_{eb} (P/t)	F_{eb} average
	(N)	(mm)	(mm)	(N/mm2)	(N/mm2)
TUBT 2a	5600	20	10	28.00	
TUBT 2b	6125	20	10	30.63	
TUBT 2c	6250	20	10	31.25	29.96
TUBT 3a	6600	20	10	33.00	
TUBT 3b	6600	20	10	33.00	
TUBT 3c	6900	20	10	34.50	33.50
TUBT 4a	7000	20	10	35.00	
TUBT 4b	7125	20	10	35.63	
TUBT 4c	7150	20	10	35.75	35.46
TUBT 5a	7200	20	10	36.00	
TUBT 5b	7250	20	10	36.25	
TUBT 5c	7500	20	10	37.50	36.58
TUBT 6a	6250	20	10	31.25	
TUBT 6b	6500	20	10	32.50	
TUBT 6c	6550	20	10	32.75	32.17

4.2 Dowel Bending Strength

Dowel bending strength was conducted for six samples. The test photos and samples condition after tested can be seen in Figure 5. The samples curved after the bottom of the bolts is melted. The samples failure were bending failure. The relation between load and deformation in the bending test can be seen in Figure. 6. The dowel bending strength equation (F_{yb}) by NDS 2005 (AFPA 2005) is as follows$F_{yb} = 0.5(F_y + F_u)$. The magnitude of the bending stress ranges from 49 N / mm 2 to 100 N / mm2. See Table 4.

Figure 5. (a) Dowel bending strength test photo (b) samples condition after tested

Figure 6. The relationship between the load and the deformation of dowel bending strength test. (measured in the middle of the bolt span)

Table 5. Test results of dowel bending strength

Sample	Bolt dia.	Fyb	Fu	Fyb = 0.5(Fy +Fu)
	(mm)	(N/mm^2)	(N/mm^2)	(N/mm^2)
LTBT 1	10	427.64	1219.37	823.51
LTBT 2	10	534.55	652.15	593.35
LTBT 3	10	473.45	1018.69	746.07
LTBT 4	10	427.64	1114.91	771.27
LTBT 5	10	488.73	1109.41	799.07
LTBT 6	10	389.45	1067.56	728.51
	Average	478.55	963.40	746.65

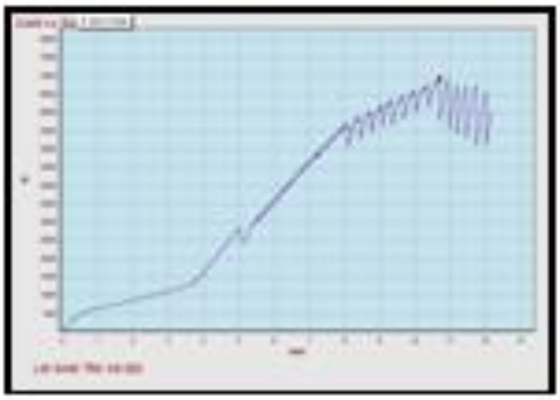
4.3 Symmetric Double Shear Connection Tensile Test

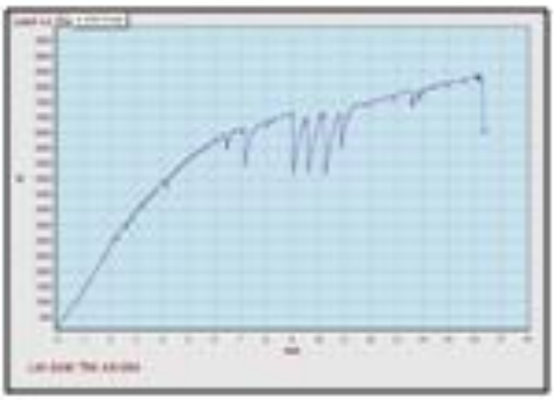
(a)

(b)

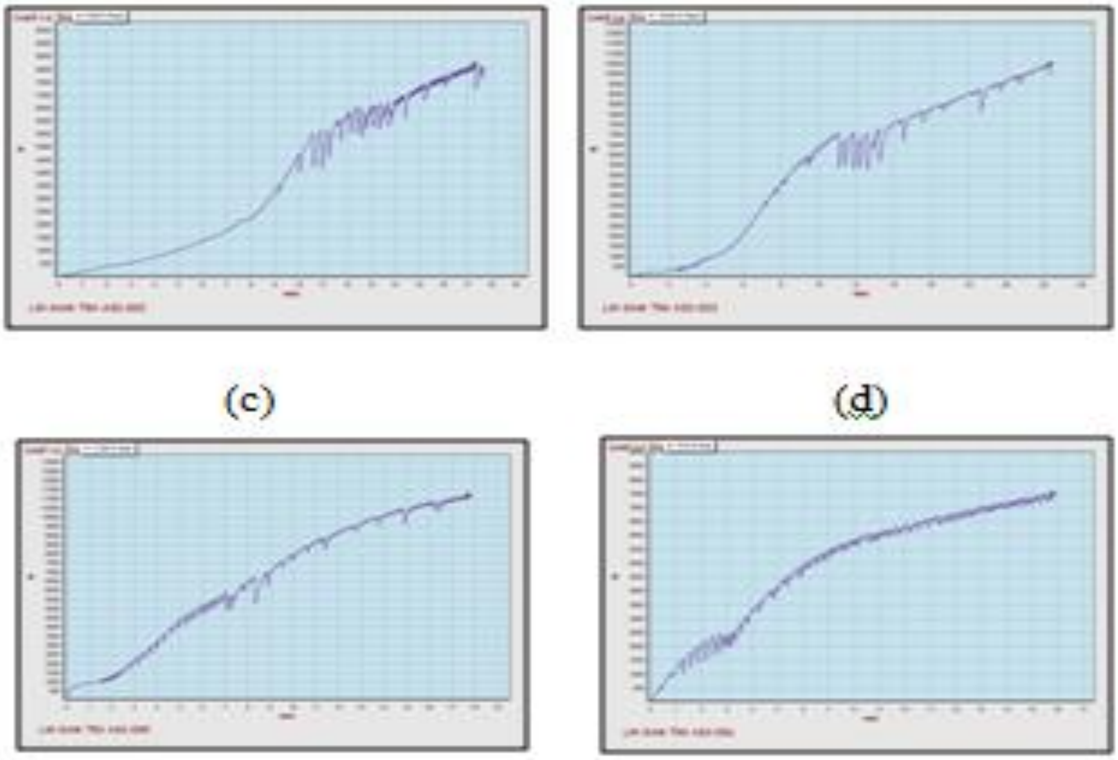
Figure 7. (a) Symmetric double shear connection tensile test photo (b) The bolt after the connection tensile test takes place of the IIIs yield mode.

Symmetric double shear connection tensile test was conducted for six samples. Photo test and samples after testing can be seen in Figure 7. Samples failure due to bending failure. There was one bending on the middle wood. The relation between the load and the deformation on the tensile traction test can be seen in Figure 8. The magnitude of the lateral connection resistance is between 5200 N to 6200 N. See Table 5. If the lateral resistance of this connection is calculated by the yield limit equation of SNI 7973-2013, then the result is 5200 N to 6200 N.The lateral resistance of the connection is calculated by SNI 92.7 % lateral resistance of the experimental results.





(a) (b)



(c) (d)

(e) (f)

Figure 8. The relation between the load and the deformation on the tensile traction test using bolt fastener (a) SBT 1 (b) SBT 2 (c) SBT 3 (d) SBT 4 (e) SBT 5 (f) SBT 6

Table 5. Comparation of experiment and calculated by equation of SNI 7973-2013 of lateral connection resistance

Sample	Experiment		SNI 7973-2013		
	P	Yield	P	%	Yield
SBT 1	6200	V	6190.5	99.85	IIIs
SBT 2	5200	V	4174.7	80.28	IIIs
SBT 3	6000	V	5193.6	86.56	IIIs
SBT 4	6000	V	5585.4	93.09	IIIs
SBT 5	6000	V	5860.7	97.68	IIIs
SBT 6	5000	V	4931.3	98.62	IIIs
Average	5783		5322.68	92.68	

5. Conclusion
Yield limit equations in SNI 7973-2013 can be used for calculating the strength of the connection with the steel dowel fasteners (bolt), although the resulting yield modes are different

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