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EXPERIMENTAL TESTS OF NAIL AND SCREW CONNECTORS FOR TIMBER CONCRETE COMPOSITE DECK

Jalal mushina
Shatra municipality, Thi-qar municipality, Shatra Iraq

Wissam Mushina
Shatra Technical Institute, Southern Technical University, Shatra Iraq

Dr. NorHayati Abd Ghafar
Department of civil engineering, UTHM University, Parit Raja Malaysia

Dr. David Yeoh
Department of civil engineering, UTHM University, Parit Raja Malaysia

Koh Heng Boon
Department of civil engineering, UTHM University, Parit Raja Malaysia

ABSTRACT

This paper reports the experimental results of symmetrical push-out tests performed on nails and screws connectors for natural laminated timber (Kempas timber) concrete composite floor systems. The characteristic shear strength and slip modules were evaluated for two types of connectors: Type (A) Nail connector with 73.37 mm length x 4.35 mm diameter; Type (B) Screw connector with 68.7 mm length x 5.47 mm diameter. The shear force, relative slip and slip modulus results were analyzed and design of TCC deck connectors were performed using the Gamma Method. The failure mechanisms of these two connectors type are discussed. Analytical design formulas for shear-strength evaluation of (nail and screw) connections derived in accordance Eurocodes are proposed based on four possible failure mechanisms. Good approximation was found if a slight modification of the Eurocodes formulas is introduced.

Keyword: timber, nail connector, screw connector, TCC deck

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1. INTRODUCTION

Timber–concrete composite structures TCC primarily consist of a concrete member attached to a timber member through the use of connectors. The use of TCCSs is a relatively young technology. The technology has become more acceptable with more successful applications since the 1980's [1].

Timber–concrete composite systems are a well-known solution for the rehabilitation and strengthening of old timber structures as well as for the laying of new floors. This composite system combines a relatively high compression strength and stiffness of concrete with a relatively high tension strength of timber. The system relies on a connection system that transfers the stresses between the two materials leading to an effective composite behavior [2], [3].

The mechanical behavior of the connections has a direct influence on the most important mechanical properties of the composite system, namely load-carrying capacity, stiffness and ultimate deformation capacity. Among the properties of the connection, the ones with the greatest influence on the mechanical behavior of the composite system are the load-carrying capacity, stiffness and ductility [4],[5],[6]. In most cases, the calculation method used in the analysis and design of this type of composite structure is the one indicated in annex B of EC5 [7].

Due to the mechanical properties of the two materials, such composite systems usually show a low deformation capacity, always strongly dependent on the deformation capacity of the connections. Moreover, in most cases, the greatest deformations will take place in the fasteners next to the beam ends. Consequently, the failure of the first connector will result in an additional load in the remaining fasteners that might lead to a more brittle failure of the whole composite system.

The risk of this can be significantly reduced by using ductile connections, namely connections with an ultimate deformation capacity higher than the maximum slip demand between timber and concrete in the composite system, allowing load redistribution among the connections. In practice, however, this might be difficult to calculate and achieve with certainty, mainly due to the material non-linear behaviour of the connections. Moreover, different connection systems show rather different mechanical properties.

This factor becomes clear when looking at the experimental load–slip curves of the connection system. Load–slip diagrams have to be obtained from empirical evaluation through shear test experiments in accordance with EN26891 [8], and results can also be obtained from already published sources [9], [10], [11].

Despite this, it is often the case that stiffer connections show lower ultimate deformation capacities and more flexible connections show higher ultimate deformation capacities [12].

In Europe, floors are the primary application for TCCSs. The motivation to use TCCSs for floors is to meet standards of serviceability related to acceptable vibration and small deflections, and to improve the load carrying resistance. Renovating historical timber floors to TCCSs has become the most important market for this technology in Europe. The solution is an economical and ecological alternative to removing the old floor and replacing it with a reinforced concrete slab [13].

The most commonly used techniques of joining concrete to timber can be grouped as follows: (a) punctual connection devices such as nails, screws, studs and similar; (b) small metallic plates or nets located at constant spacing; (c) saw-tooth shaping of the beam and screws located at each indentation; (d) metallic trellis or mesh that realize a continuous connection device. All these systems are generally applied to new composite floor constructions [14].

The role of shear connectors is transmitting the shear force and reduces the relative movement (slip) between the two parts of the (TCC). The efficiency of the connection depends on the degree of shear force transmitted and connector capacity. The upper part of TCC (concrete flange), mainly undertake the compression force, due to the high compression strength and stiffness of concrete. The lower part of TCC (timber lamination) mainly undertakes the bending and tension forces, using the advantage of the high tensile strength of timber, especially in the case of laminated kempas timber. In Europe many types of shear connectors have been developed.

And each of these connectors varies in its rigidity and strength. Presented a large number of fasteners that can be used to connect the concrete slab to the timber and sorted them in different categories in relation to their degree of rigidity. The shear strength and stiffness or "slip modulus" of the shear connectors at serviceability and ultimate limit state ULS are important parameters required for the design of a TCC floor.

The paper report the laminated timber concrete composite connectors behavior for two types nail and screw connectors using push out test according to EuroCode5. The behavior of connectors is exhibited through connector stiffness, the failure mode and strength capacity.

2. EXPERIMENTAL PROGRAM

2.1. Test Specimens

Shear test was performed on two types of connection to determine their strength characteristics and slip modules. These types are: nail and screw. First is Nail connector, referred to as Type (A), with 73.37 mm length and 4.35 mm diameter installed at the center of specimen. The specimen geometry is 200 length, 90 width and 40 mm thickness of pieces as shown in Table 1 and Figure 1.

The second is screw connector, referred to as Type (B), with 68.7 mm length and 5.47 mm diameter installed at the center of specimen as shown in Table 1 and Figure 1. The type of timber used for this paper is natural Kempas timber (Scientific name Koompassia malaccensis).

Table 1: Details of nail and screw connectors

No	**Type of connector**	**Length (mm)**	**Diameter (mm)**
1	Nail (A)	73.37	4.35
2	Screw(B)	68.70	5.47

The timber lamination for this paper is mean many timber beams connected together to make a deck such as, first group (G1)are double timbers and triple timbers, second group (G2) are five timbers and ten timber as shown in Table 2.

For each connection type, twelve specimens were used. The specimens detail is shown in Table 2, Figure 2,3 and 4.

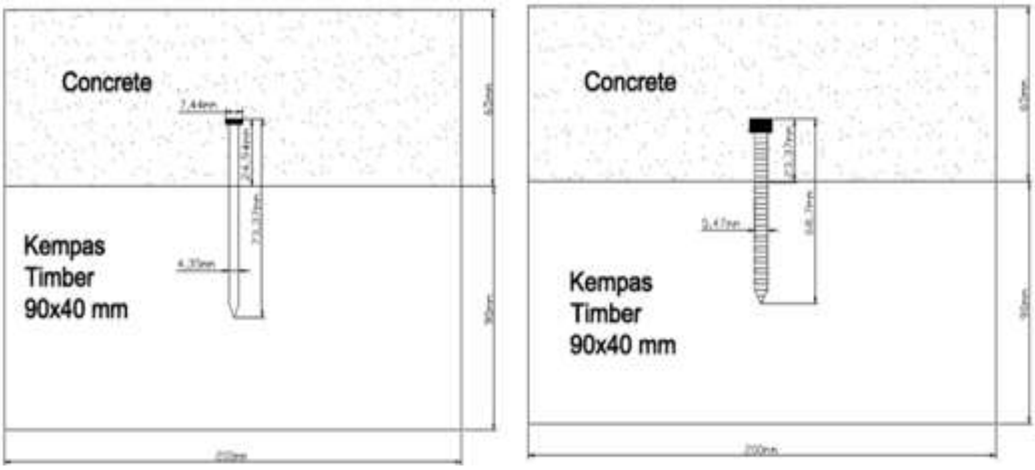

Figure 1: Details of nail and screw connectors

Table 2: Details of timber specimens detail

Group	Specimen	Type shear connector	Specimen label	Number of sample per Specimen
First group of Specimen (G1)	Single timber	Nail Screw	PN-1 PS-1	4 4
	Double timbers	Nail Screw	PN-2 PS-2	4 4
	Triple timbers	Nail Screw	PN-3 PS-3	4 4
Second group of Specimen (G2)	Five timbers	Screw	PS-5	2
	Ten timbers	Screw	PS-10	2

Note: - The specimen label for push out test are recognized by the first two alphabets and the number right after the alphabet as shown in Table 2. The first alphabet tells the type of testing, the second alphabet indicate the type of shear connectors (N represent the nails while S represent the screws) and the number represent the sequence. For instance PS3 indicates push out test of specimen connected by using screw for the triple sample.

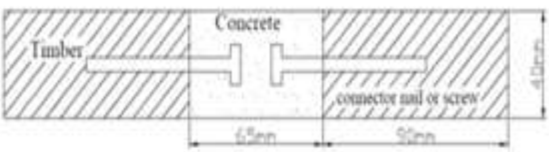

Figure 2 Push out test specimen plan view for single timber (T1)

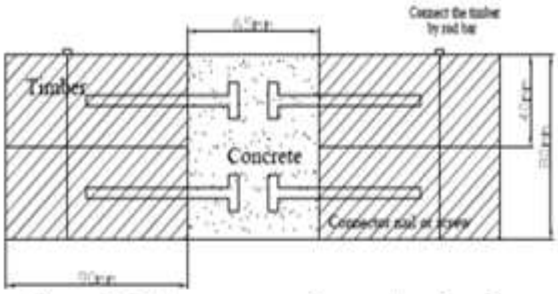

Figure 3 Push out test specimen plan view for double timber (T2)

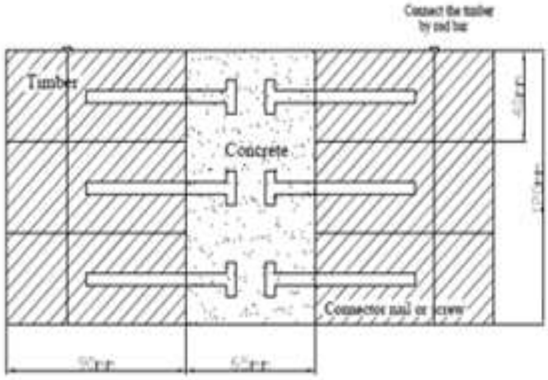

Figure 4 Push out test specimen plan view for Triple timbers (T3)

2.2. Material Properties

The materials used are natural kempas timber and concrete. The concrete mix was designed for target characteristic strength of 35MPa based on DOE method (British Standard).This mix design used for push out tests specimens, a total of 6 concrete cubes were made and 3 tested at age 7 day and the others at age 28 days respectively.

The concrete had gain average compressive strength up to 36.6 Mps on 7th days after casting and 44.9 Mps after 28th days, also the slump test was up 90 mm.

These results verify the target strength Grade 35MPa and the suitable workability of fresh concrete mix (80- 120 mm) slump test. The elastic modulus for concrete was 32.53GPa. This was estimate theoretical based on Eurocode using the experimental fcm.

For kempas timber the density, bending strength and elastic modulus was 850 kg/m3, 88.9 MPa and 12.5 GPa, respectively.

2.3. TEST PROCEDURE

The test setup of the symmetrical push-out test carried out in compliance with EN 26891 [15] under a 500-kN Avery make universal testing machine. It is worth to mention the specimen's type (A and B) used only a Kampas timber, see Figure 5.

The connections were loaded in shear and the load-slip relationship recorded using a LVDT was placed at the side of specimen to measure the displacement of specimen when subjected to load. The loading procedure is carried out in compliance to the European Standard [15] as shown in Figure 6 and it adopted for the next tests. In short, the basic loading procedure is as follows:-

1. Initially, specimen is loaded gradually to 0.4 F within timeframe of 120 seconds.
2. At the moment the load approached 0.4 F, the load was held for 30 seconds.
3. After 30 seconds, the load released gradually to 0.1 Fest within timeframe of 90 seconds.
4. After reaching the load of 0.1 F, the load was held again at the same level for 30 seconds.
5. Finally, the specimen was loaded at a constant rate to failure.

After that, the loads were increased gradually to the ultimate rate of load, (Fmax.). A LVDT was placed at one or two on each side of the specimen to measure the specimen displacement when it is loaded. The essence of the initial loading and unloading phase was to eliminate any internal friction in the connections and to ensure that any initial slip or slack presents in the connection does not effect on the results. The slip measurements were recorded for each specimen test specimen using LVDT. The slip at maximum load (F_{max},) defined as the shear strength ,was also logged.

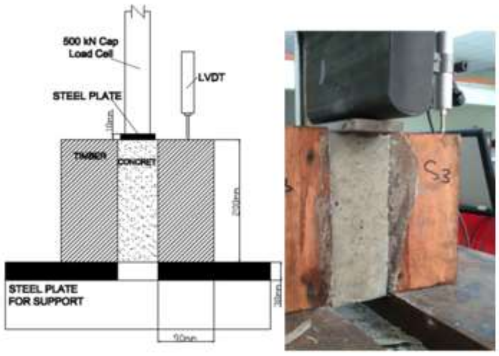

Figure 5 : Experiment set-up for push out test

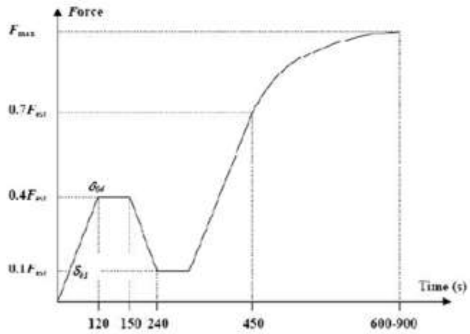

Figure 6 Loading regime as per [15]

2.4. Push-out Test Criteria

The assessment of the behaviour and effectiveness of the tested shear connectors were based on their strength (maximum load or failure load), stiffness and failure mode. The definition of the strength of the connectors is the maximum load that can be applied in the

Push out tests before its failure. The connection slip modulus (stiffness), which means the resistance to the relative displacement between the timber joist and the concrete slab, the stiffness reflects the efficiency of a shear connection. The calculations of the stiffness are essential to characterize a shear connection for the serviceability limit state (SLS) and ultimate limit state (ULS). The stiffness for SLS (Ks) was calculated based on equation 1. The stiffness for ULS (Ku) is calculated from equation 2 BS [15].

$$K_s = \frac{\mathbf{0.4Fm}}{\mathbf{v0.4,mod}} \tag{1}$$

$$K_u = \frac{\mathbf{0.6Fm}}{\mathbf{v0.6,mod}} \tag{2}$$

where Fm is the estimated peak load and v0.4mod and v0.6 mod are slip corresponding to 40% and 60% Fm.

3. EXPERIMENTAL RESULTS

The results of push out test included two groups. The first group present (single, double and trouble timber specimens) for nail and screw connectors, this group investigate the proper type that can be used for next group (second group) five and ten timber specimens.

3.1 Failure Mode

In the screw connection of push-out test, there are commonly two typical modes of failures.

First was shear deformation (screw bent) and second was shear failure (screw broken), compare to nail connector as shown Figure 7 and 8 respectively. It can also be noticed, that there is no pull out to the screw connectors because the thread of the screw locks into wood fiber. This makes screws more difficult to remove, as they need to be spun out of the wood. The nails after push out test show the pulled out nails, no deformation in any form due to the nails smooth shank tare not providing enough grip to hold the external load as shown in Figure 9.

Figure 7: Type (B) Screw specimen after testing (shear deformation)

Figure 8: Type (B) Screw specimen after testing (screw broken)

Figure 9: Condition of nail after concrete removed

3.2. Load Slip Behavior

Load-slip results for push out tests (single, double and triple timber specimens) with two connectors type nail (A) and screw (B) are shown in Figure 10. The load-slip behaviour of (B) series connectors were more consistent when compared to the (A) series. This mean that load-slip relationship for series (B) is linear in most part of the curves and the strength loss is consequences in short drops. Unlike the (A) series connectors, the load-slip curves were generally linear and the strength loss is consequences in long drops in compared. The both types could sustain further load.

The other factor affecting is the number of timber specimens. For nails specimen the increase in the timber number the peak value increased while the slip value decreased. For screws specimens the increase in the timber number the peak value increased while the slip value was nearly the same as shown in Figure 10.

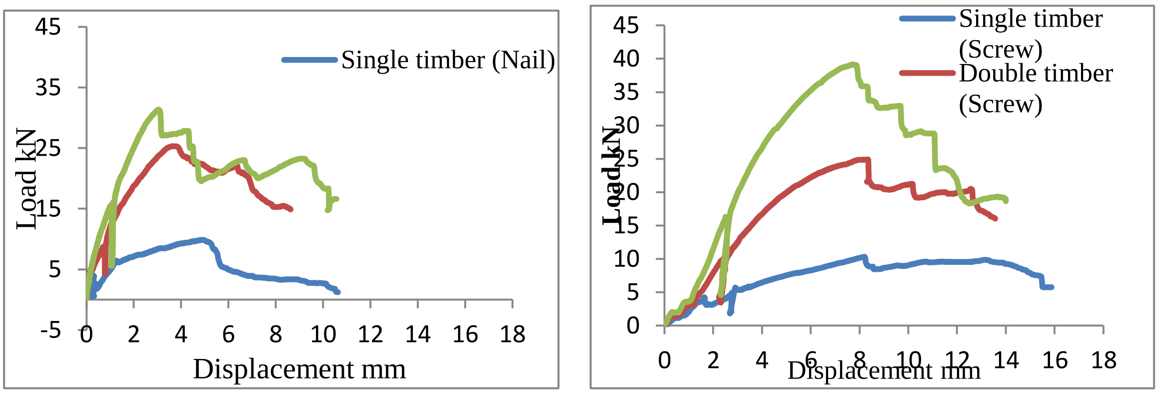

Figure 10: Test result of Type A nails (Left) and Type B screws (Right) connectors

3.3. Strength and Stiffness Results

Strength and stiffness results for the two connectors are summarized in Table 3. The mean shear strength (one side of connector or the max force of specimen/2) for type (A) 5.845, 12.2, 15.545 kN single, double and triple timber specimens, respectively. The mean strength for type (B) 6.71, 12.645, 19.86kN single, double and triple timber specimens, respectively. The mean stiffness for serviceability and ultimate limit state calculations (Ks and Ku) for the (A) series connectors were 2.948, 2.651kN/mm single timber, 3.733, 3.059 kN/mm double timber and 5.519, 5.458 kN/mm triple timber respectively. While the same for the B Series connectors were 3.11, 2.737kN/mm single timber, 4.39, 3.769kN/mm double timber and 6.223, 5.6kN/mm triple timber respectively. The nail shear strength (the max force per one nail) range is between 5.18 to 6.1 kN. It increased the value of slip modules (K) with number timber lamination as shown in Table 3. After the push-out test, observation found that the pulled out nails showed no deformation in any form due to the nails smooth shank tare not providing enough grip to hold the external load as indicated in Figure 9. Table 3 shows the screw shear strength (the max force per one screw) is in the range of 6.32 to 6.71 kN. It is remarkably clear that the screw has higher shear strength than nail.

Table 3: Mean values for F_{max}, slip modules of service limit state (K_s) and slip modules of ultimate limit state (K_u) for Type (A) Nail and Type (B) Screw

Specimen	**Fmax (kN) one side of connector**		**Fmax per one connector(kN)**		**Ks(kN/mm)**		**Ku(kN/mm)**	
	Nail (A)	Screw(B)	Nail (A)	Screw(B)	Nail (A)	Screw(B)	Nail (A)	Screw(B)
Single Timber Factor	5.845 [1]	6.71 [1]	5.85	6.71	2.948 [1]	3.11 [1]	2.651 [1]	2.737 [1]
Double Timber Factor	12.2 [2.08]	12.645 [1.88]	6.1	6.32	3.733 [1.26]	4.39 [1.4]	3.059 [1.15]	3.769 [1.37]
Triple Timber Factor	15.545 [2.66]	19.86 [2.95]	5.18	6.62	5.519 [1.87]	6.223 [2]	5.458 [2.05]	5.6 [2.04]

Note:- Fmax (kN) is mean one side of connector (the shear force of specimen/2) as shown in Figure 11, Factor is Load Factor per single timber beam

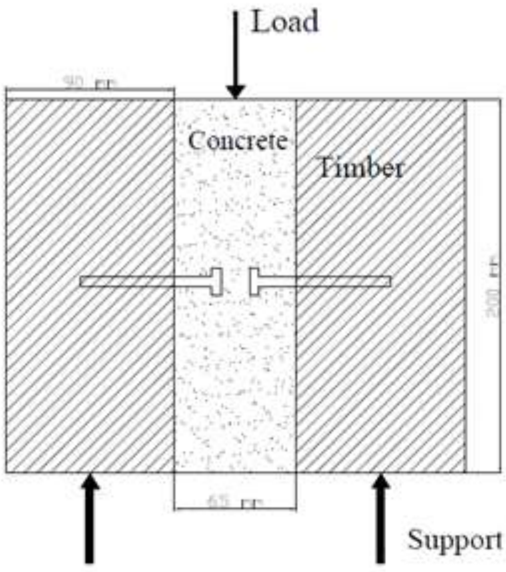

Figure 11 Push out test specimen typical side elevation for single timber (T1)

4. THE CHOSEN TYPE OF CONNECTOR

Both type (A) nail and type (B) screw are mechanical connectors but each has different strength and stiffness. These properties are essential for the design Process of bend strength of the timber concrete composite beam. The comparisons between both shear connectors are presented in Table 4.

The performed test showed the shear strength of single screw was higher than single nail, it was 1.14 times of nail strength in SLS and ULS respectively. Furthermore, the slip module (K) of screw was greater than the one of nail. Therefore, the screw was chosen to be used as shear connector in timber concrete composite beam and K_u =2.73 kN/mm to be used to design the spacing of the single Kampas timber with 1200 mm length.

To design TCC floor deck with 20 timber specimens, extra screw push out tests were performed. These tests are 5 and 10 timber specimen's push out test as the second group (G2) of test. The five and ten Kampas timber of Type (B) showed in Table 5, Figure 12 and 13, the max load for five timber (F_{max}) 53.48 kN and slip modules of ultimate limit state (K_u) 15.8 kN/mm, for ten timber (F_{max}) 109.77 kN and slip modules of ultimate limit state (K_u) 41.21 kN/mm respectively.

Note: The Values of F_{max} and K are taken average for all cases shear connector.

Table4 : Mean values of Comparison between nail and screw in shear strength and slip modules

Type	**F_{max} on single Nail**	**K_u for Nail**	**F_{max} on single Screw**	**K_u for Screw**
F_{max} (kN)	5.71	2.65	6.55	2.73

Table5: Mean values for Fmax, slip modules of service limit state (Ks) and slip modules of ultimate limit state (Ku) for 5 and 10 timber of type (B) screw

Group	**Specimen**	**F_{max} (kN)**	**value of K_s(kN/mm)**	**value K_u(kN/mm)**
Second group(G2)	Five Timber	53.581	18	15.8
	Ten Timber	109.77	43.187	41.21

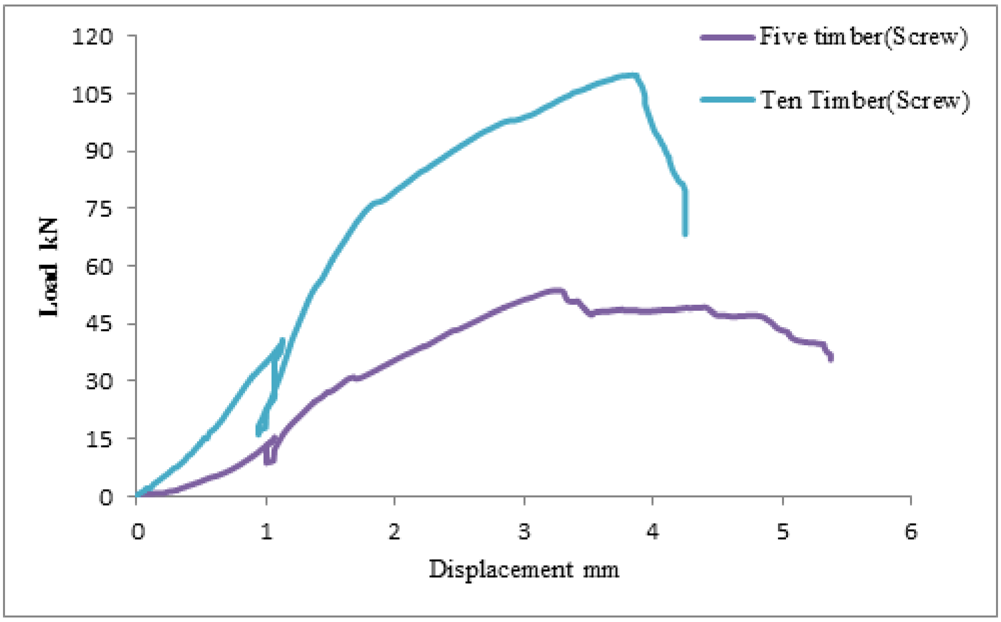

Figure 12: Test result of type (B) screw connectors for 5 and 10 timber

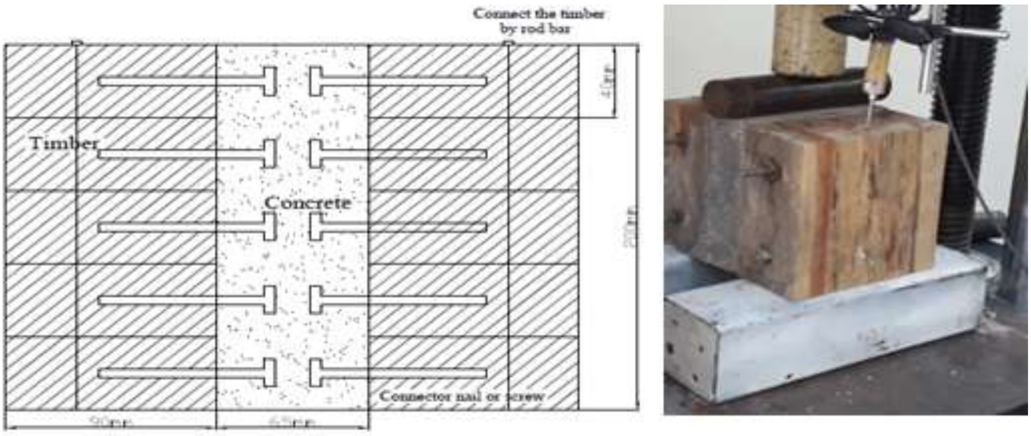

Figure 13 Push out test specimen plane view for 5 timbers (T5

5. DESIGN EXAMPLE OF TIMBER CONCRETE COMPOSITE FLOOR DECK

According to previous results it need to predict the results of Ku and Ks for 20 laminated timber deck. This will be done depending on the tests data available for screw connectors (1,2,3,5 and 10 timber specimens). Figure 14, It made line equation depended on shear strength for single , double , triple, Five and ten Kampas timber of type (B) screw.

To calculation the value of slip modules of ultimate limit state (K_u) and service limit state (Ks) for 20 timber using Eq.(3), Eq.(4) and Eq.(5), Eq.(6) respectively, the value of spacing(S) from Euro cod Design as shown in Table 6.

The experimental shear force versus relative slip curves of each connection type tested were fitted with an average analytical curve comprising of a prepeak and a postpeak behavior Figure 14 and 15 respectively. The prepeak behavior fitted with the least-squares method is based on the nonlinear analytical model proposed by [16] and described by Eq. 3, 4, 5 and 6.

To calculation the value of slip modules of ultimate limit state (K_u) for 20 timber use:

$$K_u=K_{u\,max}\,(1-e^{\beta})^{\alpha} \quad 3$$

$$\alpha= 6.01 \ , \beta= 0.37 \quad 4$$

K_u = 46.7867 for 20 timbers (PS20) from graph

To calculation the value of slip modules of service limit state (Ks) for 20 timber use:

$$K_s=K_{s\,max}\,(1-e^{\beta})^{\alpha} \quad 5$$

$$\alpha= 8 \ , \beta= 0.44 \quad 6$$

K_s = 46.90 for 20 timbers (PS20) from graph

K_{max}=maximum slip reached by the approximating curve; and α, β =constants. It is important to remember that the toothed metal plate connection

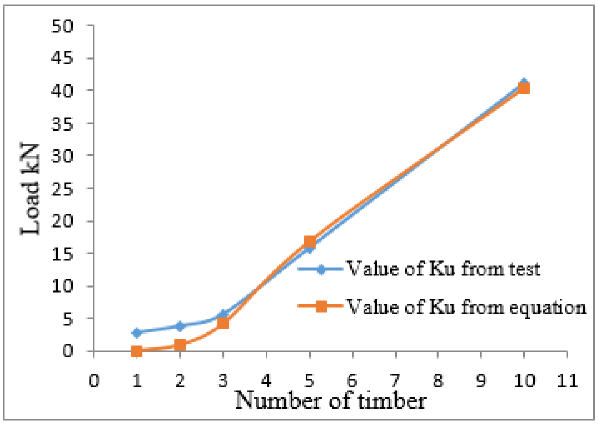

Figure 14 Slip modules of (Ku) versus number of screw connector.

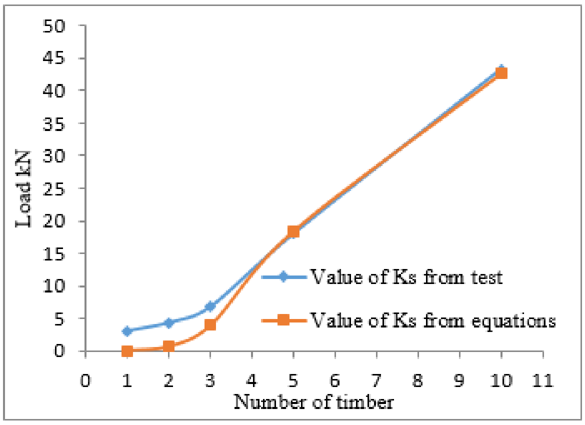

Figure 15: Slip modules (Ks) versus number of screw connector.

6. DESIGN OF SPACING BETWEEN THE SCREWS FOR TCC FROM EUROCODE 5

A- Calculation the spacing design for single Kampas timber with length 3.6 m

The span length used is 3.6 m, the concrete width is 0.12 m , 0.04 is the timber width and 0.09 m is depth of timber and 0.065 m is depth of concrete as shown cross section from it in Figure 16.

E_1 = 32.562 GPa ,E_2 = 12.5 GPa

E_1= Young's modulus of Elasticity of the concrete

E_2= Young's modulus of Elasticity of the timber

Ku =2.737 kN/mm, fetched from Type (B) push out test result

The push out test result of the specimens of the nails and screws of all the cases, it found the screw is better than nail in term of loading as the screws can bear up to (6.552KN) whilst the nail can bear up to (5.709 KN). Therefore, screw is selected to be used for TCC and (6.556 KN) is been used for design and connection slip modulus Ku= 2.737 KN/mm (for single kampas timber case)

The shear strength in screws= 6.556 KN

The step of design for spacing from code

W = 1.35 G+ 1.5 Q

G= Characteristic permanent (dead load) = 0.912 kN/m

Q= Variable action (Live load)= 0.36 kN/m

W= 1.7712 kN/m

M= W*L^2 /8 = 2.87 kN.m

Vd = WL/2 = 3.19 kN

A_1= area of concrete = 65* 120= 7800 mm^2 , A_2= area of timber = 3600 mm^2

Assume the spacing S=100 mm

$\gamma 1 = \frac{1}{1+\pi^2 E_1 A_1 sef/Kl^2}$ = 1.24 and γ2 =1

from code

$a_1 = \frac{\gamma 2 E_2 A_2 H}{\gamma 1 E_1 A_1 + \gamma 2 E_2 A_2} = 9.68$

$a_2 = \frac{\gamma 1 E_1 A_1 H}{\gamma 1 E_1 A_1 + \gamma 2 E_2 A_2} = 67.8$

$EI_{ef} = E_1 I_1 + E_2 I_2 + \gamma_1 E_1 A_1 a_1^2 + \gamma_2 E_2 A_2 a_2^2 = 3.563 \times 10^{11}$

Fn = 2.73 kN less than shear strength of screw = 6.556 KN, it is OK

Fn= Shear strength from equation of design cod

The spacing S = 100 which was assumed it OK

However, took this value S=100 for TCC with 1200mm length

B-Calculation the spacing design for TCC Deck timbers (20 Kampas timber with 3.6 m length and 0.8 width

The length of span is 3.6 m, 0.8 m width of concrete, 0.04 width of pieces of timber, 0.8 the total width of timbers(20 pieces of Kampas timber), 0.09 m depth of timber and 0.065 m depth of concrete as shown cross section from it in Figure 16

E_1 = 32.562 GPa , E_2 = 12.5 GPa

E_1= Young's modulus of Elasticity of the concrete

E_2= Young's modulus of Elasticity of the timber

Ku = 46.7867 kN/mm, get it from push out test(Type (B) Screw)

The shear strength in screws=109.77/2 = 54.885 kN

W = 1.35 G+ 1.5 Q

G= Characteristic permanent (dead load) = 6.08 kN/m

Q= Variable action (Live load)= 2.4 kN/m

W= 11.808 kN/m

M= W*L^2 /8 = 19.13 kN.m

Vd = WL/2 = 21.25kN

A_1= area of concrete = 65* 800= 52000 mm^2 , A_2= area of timber = 72000 mm^2

Assume the spacing S=250 mm

$\gamma 1 = \frac{1}{1+\pi^2 E_1 A_1 sef/Kl^2} = 1.27$ and $\gamma 2 = 1$ from code

$a_1 = \frac{\gamma 2 E_2 A_2 H}{\gamma 1 E_1 A_1 + \gamma 2 E_2 A_2} = 22.88$

$a_2 = \frac{\gamma 1 E_1 A_1 H}{\gamma 1 E_1 A_1 + \gamma 2 E_2 A_2} = 54.61$

$EI_{ef} = E_1 I_1 + E_2 I_2 + \gamma_1 E_1 A_1 a_1^2 + \gamma_2 E_2 A_2 a_2^2 = 5.01 \times 10^{12}$

Fn = 52.1 kN less than shear strength of screw = 54.885 kN it is OK

Fn= Shear strength from equation of design cod

The spacing S = 250 which was assumed it OK However, took this value S=250 for TCC deck with 3600mm length and 800 width

C-Calculation the spacing design for TCC Deck timbers (20 Kampas timber with 2.4 m length and 0.8 width

The length of span is 2.4 m, 0.8 m width of concrete, 0.04 width of pieces of timber, 0.8 the total width of timbers(20 pieces of Kampas timber), 0.09 m depth of timber and 0.065 m depth of concrete as shown cross section from it in Figure 16.

E_1 = 32.562 GPa ,E_2 = 12.5 GPa

E_1= Young's modulus of Elasticity of the concrete

E_2= Young's modulus of Elasticity of the timber

Ku = 46.7867 kN/mm, get it from push out test(Type (B) Screw)

The shear strength in screws=109.77/2 = 54.885 kN

W = 1.35 G+ 1.5 Q

G= Characteristic permanent (dead load) = 6.08 kN/m

Q= Variable action (Live load)= 2.4 kN/m

W= 11.808 kN/m

M= W*L^2 /8 = 8.5 kN.m

Vd = WL/2 = 14.17 kN

A_1= area of concrete = 65* 800= 52000 mm^2 , A_2= area of timber = 72000 mm^2

Assume the spacing S=400 mm

$\gamma 1 = \frac{1}{1+\pi^2 E_1 A_1 sef/Kl^2}$ = 0.39 and γ2 =1 from code

$a_1 = \frac{\gamma 2 E_2 A_2 H}{\gamma 1 E_1 A_1 + \gamma 2 E_2 A_2}$ = 44.8

$a_2 = \frac{\gamma 1 E_1 A_1 H}{\gamma 1 E_1 A_1 + \gamma 2 E_2 A_2}$ = 32.69

$EI_{ef} = E_1 I_1 + E_2 I_2 + \gamma_1 E_1 A_1 a_1^2 + \gamma_2 E_2 A_2 a_2^2 = 3.48 \times 10^{12}$

Fn = 47.869kN less than shear strength of screw = 54.885kN it is OK

Fn= Shear strength from equation of design cod

The spacing S = 400 which was assumed it OK

However, took this value S=400 for TCC deck with 2400mm length and 800 width.

Table 6: Value of Spacing(S) from Euro cod Design

Specimen of TCC	Length mm	Width of concrete (mm)	Width for Timber (mm)	S mm
Single (TCC1)	3600	120	40	100
TCC Deck	3600	800	800	250
TCC Deck	2.400	800	800	400

Note: the thickness of Timber 90 mm and concrete 65mm.

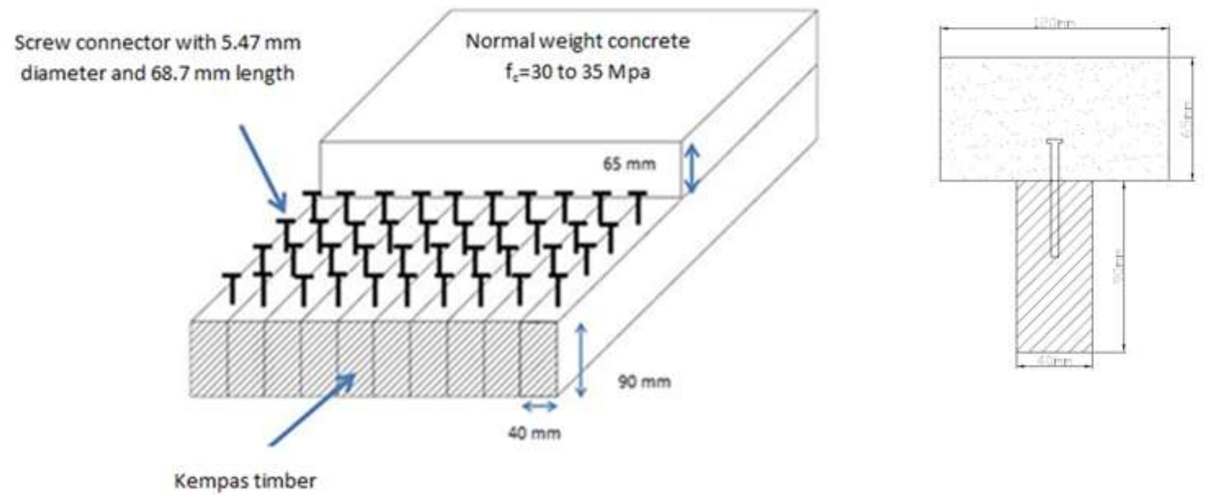

Figure 16 Cross section for Timber concrete composite (TCC) deck(Left) and Single TCC1(T section) Right.

7. CONCLUSIONS

The paper reports the outcome of experimental push-out tests implemented on two connector types of Kampas timber concrete composite beams. The first connector type, referred to as Type (A) is nail connector, the second type, referred to as Type (B) is screw connector. It observed that the Type (B) connecters were significantly enhanced the strength performance of the connection and improved the slip modulus at ULS compared to Type (A).

The average shear strength of nail and screw are 5.71 and 6.5kN respectively, this mean the strength of Type (B) screw is (6.552KN) and Type (A) is (5.709 KN) and hence, the shear strength of screw is greater than nail by 1.14 time because of the friction surface of screw.

The screw connector exhibits better properties than the nail connector does. Therefore, it is quite reassuring to be adopted as shear connector in the production of TCC specimen. The failure in the connections is primarily due to concrete shearing in the shear plane.

Post push-out test, type (A) showed no deformation in any form due to the nail's contact area is not providing enough a friction to resist the external load while type (B) indicated two types of damage, one was shear deformation (screw bent) and the other was shear failure (screw broken). It also can be noticed, that there is no pull out failure to the screw connector because of the screws threaded parts created enough friction to the surrounded area.

According the design of spacing between the connector for TCC from Eurocod 5.The spacing value (S) = 100 mm between screws for TCC with 1200mm length, 400 mm for TCC with 2400mm length and 250 mm for TCC with 3600mm length.

REFERENCES

[1] Natterer, J., Hamm, J., and Favre, P. 1996. ''Composite wood–concrete floors for multistory buildings.'' Proc., Int. Wood Engineering Conf., Omnipress, Madison, Wis., Vol. 3, 3431–3435.

[2] Ceccotti A. Timber–concrete composite structures. In: Blass H, editor. Timber engineering step 2. The Netherlands: Centrum Hout; 1995.

[3] Fragiacomo M, Amadio C, Macorini L. Short- and long-term performance of the ''Tecnaria'' stud connector for timber–concrete composite beams. Mater Struct 2007;40(10):1013–26.

[4] Dias AMPG, Lopes SMR, Van de Kuilen JWG, Cruz HMP. Load-carrying capacity of timber–concrete joints with Dowel-type fasteners. J Struct Eng 2007; 133(5):720–7.

[5] Dias AMPG, Cruz HMP, Lopes SMR, van de Kuilen JW. Stiffness of dowel-type fasteners in timber–concrete joints. Proc Inst Civ Eng Struct Build 2010;163(4):257–66.

[6] Sebastian W. Ductility requirements in connections of composite flexural structures. Int J Mech Sci 2003;45(2):235–51.

[7] CEN. Eurocode 5 design of timber structures part 1–1: general common rules and rules for buildings. Brussels: CEN; 2003.

[8] CEN. ISO EN 26891 Timber structures joints made with mechanical fasteners general principles for the determination of strength and deformation characteristics. In: ISO (Ed.), ISO EN 26891. Brussels: CEN; 1991.

[9] Lukaszewska E, Fragiacomo M, Johnsson H. Laboratory tests and numerical analyses of prefabricated timber–concrete composite floors. J Struct Eng 2010; 136(1):46–55.

[10] Steinberg E, Selle R, Faust T. Connectors for timber-lightweight concrete composite structures. J Struct Eng 2003;129(11):1538–45.

[11] Jorge LFC, Lopes SMR, Cruz HMP. Interlayer influence on timber–LWAC composite structures with screw connections. J Struct Eng 2011;137:618.

[12] Dias AMPG. Mechanical behaviour of timber–concrete joints. Ph.D. thesis. Delft University of Technology. 2005.

[13] Kreuzinger, H. 1999. ‘‘Holz-beton-verbundbauweise timber–concrete composite structures.’’ Informationsdienst Holz. Fachverlag Holz., Du¨sseldorf, Germany.

[14] Ceccotti, A. 2002. Composite concrete-timber structures, Pro2g7re5s.s in Structural Engineering and Materials 4(3): 264–275.

[15] BSI 1991, Timber Structures, Joints made with mechanical fasteners, General principles for the determination of strength and deformation characteristics, BS EN 6891:1991, BSI British Standards, London, UK.

[16] Ollgard, G., Slutter, G., and Fischer, W.“Shear strength of stud connectors in lightweight and normal weight concrete.” AISC Eng J, 1971, pp.8, 55–64.