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Shear bond characteristics of steel concrete composite deck slab

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Research Paper

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Shear bond characteristics of steel concrete composite deck slab

Steel-concrete composite slabs with cold-formed, profiled steel deck sheets are popularly used in steel-framed buildings. In these slabs, the deck platform acts as a working platform during construction and also as tensile reinforcement under in-service load conditions. The shear bond capacity of the composite slab is evaluated in this study for two different profile steel deck sheets. Specifically, their composite behaviour is investigated by casting and testing twelve full-scale composite deck slab specimens using the two-point loading system. In addition, based on the shear span length and profile height, the structural performance of the composite deck slab is analysed in terms of load-displacement response, shear bond capacity, ductility index, and load-slip behaviour. The results show that the most common failure of all tested specimens occurs due to the longitudinal shear failure between the concrete and profile deck sheets. As the longitudinal shear is a complex phenomenon, empirical approaches are used to evaluate the shear bond mechanism between the concrete and profile deck. The verification and comparison of experimental test results are performed with conventional and simplified m-k models based on the profile deck depth. The validated results reveal an acceptable level of reliability for prediction of each profile height based on the m and k interaction values.

Key words:

composite deck sheet, shear bond, m-k method, longitudinal shear, load-slip behaviour

Prethodno priopćenje

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Karakteristike posmične veze u spregnutoj ploči od čelika i betona

Spregnute ploče od čelika i betona s hladno oblikovanim profiliranim čeličnim limovima često se koriste u čeličnim okvirnim građevinama. U tim se pločama čelični lim koristi kao radna platforma u fazi izvođenja, dok u fazi uporabe djeluje kao vlačna armatura. Nosivost posmične veze spregnute ploče u ovom se radu ocjenjuje na dva različita profilirana čelična lima. Konkretno, izvedeno je dvanaest uzoraka spregnutih ploča te je ispitano njihovo ponašanje u stvarnoj veličini nanošenjem opterećenja u dvije točke. Osim toga, na temelju raspona sprezanja i visine profila, analizira se ponašanje konstrukcije spregnute ploče u pogledu odnosa između opterećenja i pomaka, otpornosti posmične veze, koeficijenta duktilnosti i odnosa između opterećenja i proklizavanja. Rezultati pokazuju da uzorci najčešće otkazuju zbog otkazivanja uzdužne posmične veze između betona i profiliranog lima. Kako je uzdužni posmik složena pojava, empirijski pristupi služe za ocjenjivanje mehanizma posmične veze između betona i profilirane ploče. Provjera i usporedba rezultata eksperimentalnog ispitivanja provedena je na konvencionalnim i pojednostavljenim m-k modelima na temelju dubine profilirane ploče. Validirani rezultati pokazali su prihvatljivu razinu pouzdanosti pri predviđanju visine svakog profila na temelju interakcijskih vrijednosti m i k.

Ključne riječi:

spregnute ploče, posmična veza, m-k metoda, uzdužni posmik, odnos između opterećenja i proklizavanja

1. Introduction

Composite slabs consisting of cold formed profile deck sheets are frequently used worldwide in steel-framed building construction. This type of floor slab system is cast with profile deck sheets, acting as permanent formwork during the casting of concrete, and is supported by steel beams. After the concrete hardens, the profile deck sheets can also serve as tensile reinforcement without removal of temporary forms at the site thus minimizing the erection time and improving concrete strength during service life. The interface behaviour between the profile deck and concrete in composite deck slabs is a very complex phenomenon. The primary action of composite deck slab is ensured by a reliable bonding mechanism in the interface layer. The composite action can be reproduced by mechanical interlock achieved by employing embossments and longitudinal stiffeners in profile deck, where the frictional interlocking can be achieved by virtue of re-entrant profile shape of deck, chemical bonding, and end anchorages. The end anchorages are adopted in practice as shear stud connectors welded to flanges of steel beams through the profile deck sheet. The use of welded shear stud connectors is encouraged primarily because they provide composite action through transmission of shear stress [1, 2]. The effect on profile shape enables better resistance to slip at the interface layer, while also improving resistance to vertical separation [3].

The ultimate strength at shear bond determines capacity of composite deck slabs. It is too difficult to predict theoretically the behaviour of shear bond; however, it relies on numerous parameters such as the end anchorage, profile geometry, length of shear span, thickness of deck sheet, slenderness of the slab, and position of embossments on the profile deck sheet [4]. Several researchers reported that the use of end anchorages increases the shear bond strength by 10–33 % on composite deck slabs, which is dependent of the span length and sheet profile thickness [1, 5, 6]. Numerous studies affirm that the load carrying capacity of composite deck slabs increases if stud connectors are used [5]. The strength, stiffness, and shear bond characteristics of composite slabs are determined by empirical methods such as the m-k method and the partial shear connection method as per EN1994-1-1:2012. In the m-k method, where 'm' refers to mechanical interlocking between steel deck and concrete and 'k' refers to friction between the two, 'm' and 'k' are two different parameters for evaluating shear bond characteristics of the composite deck slab [7]. The τ_u method has been proposed by many researchers as an alternative to the m-k method for determining ductility of composite deck slabs. To calculate the maximum shear stress τ_u, the shear span should be sufficient to ensure that the longitudinal shear failure would occur [8]. Later on, the simplified m-k curves have also been reviewed based on the experimental test results [9].

The predominant failure modes in composite deck slab are the flexure and shear at supports, while the interface layer, being the most susceptible to failure, failed during the testing due to shear bond. The brittle failure of slabs can be replaced by ductile failure by providing shear connectors and the ductile failure may exist if the failure load exceeds the load causing the first recorded end slip of more than 10 % [10]. The maximum ultimate load can be identified at the mid span deflection (Span / 50) unless prior failure occurs. The shear bond failure is often characterized by the diagonal tension crack formation at or near the load points in concrete area, continued by the lack of bond (delamination) between the deck sheet and concrete [6]. The end slip occurred obviously at later stages of loading with significant drop in the shear span region showing loss of composite action and horizontal slippage [7]. The strength and shear behaviour of composite deck slabs are analysed in this paper by evaluating m-k values and the simplified m-k by λ-q curves.

2. Materials and methods

2.1. Casting of composite deck slab

The experimental work is carried out for two sets of six full-scale composite deck slab specimens measuring 1000mm in length (L) and 650mm in width (b), designed as per specifications of EN1994-1-1:2012. The height of the profile deck sheet used in this study is D44 and D52 with the total slab height of 120mm (Figure 1.a and 1.b). The thickness of the profile deck sheet adopted throughout the study is 1mm, with the profile height of 44 mm and 5 2mm, respectively. The weight of D44 profile sheet was 10.2 kg/m^2 with the yield strength of 250 MPa, and the weight of D52 profile sheet was 10.02 kg/m^2 with yield the strength of 240 MPa for all specimens. Shear connectors - Ø16 mm half-threaded headed studs were fastened along the edges on corrugated steel deck sheets (Figure 1.c). The profile deck sheets were cleaned before concreting, after which the concrete was laid up to profile height. The reinforced bars of Ø8 mm in diameter with a spacing of 200 mm were used in both directions above the profile height with the proper cover of 20 mm. All composite deck slabs specimens were cast using the Ordinary Portland Cement (grade 43), M-sand, and 20 mm Coarse aggregate. The grade of concrete adopted for the study was M20 and the target compressive strength of concrete achieved is tabulated in Table 1.

Table 1. Test results of concrete properties

Specimen ID	**Compressive strength of M20 concrete** [MPa] **(after 28 days)**	**Average compressive strength** [MPa]
CS01	27.25	26.30
CS02	25.34	
CS03	26.31	

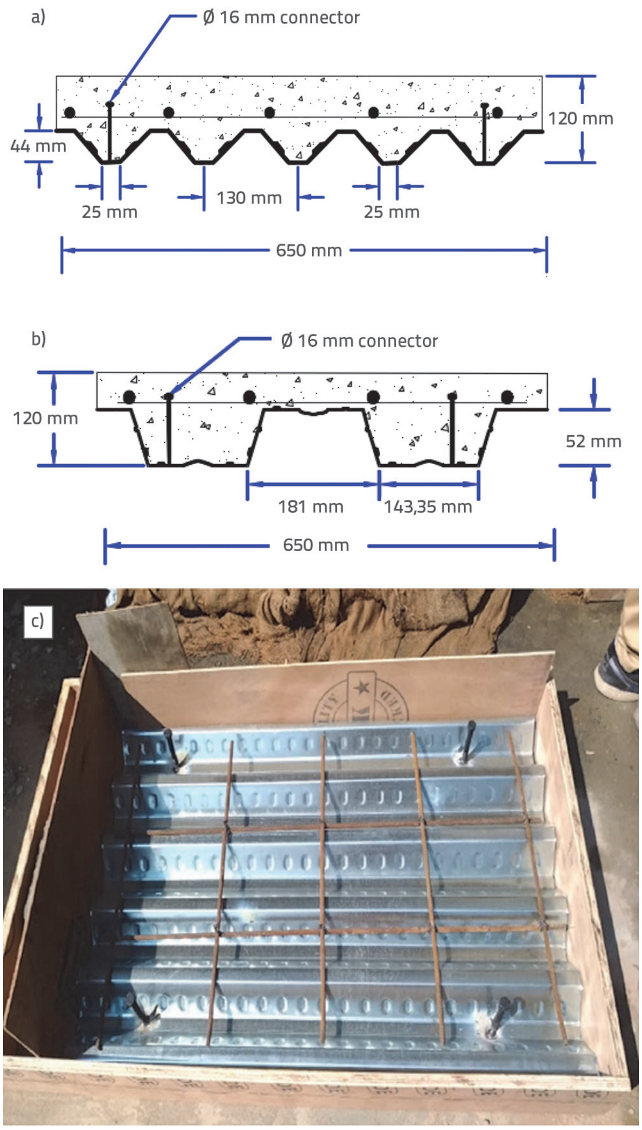

Figure 1. Sectional specifications of: a) D44 profiled deck sheet; b) D52 profiled deck sheet; c) showing the cast specimens

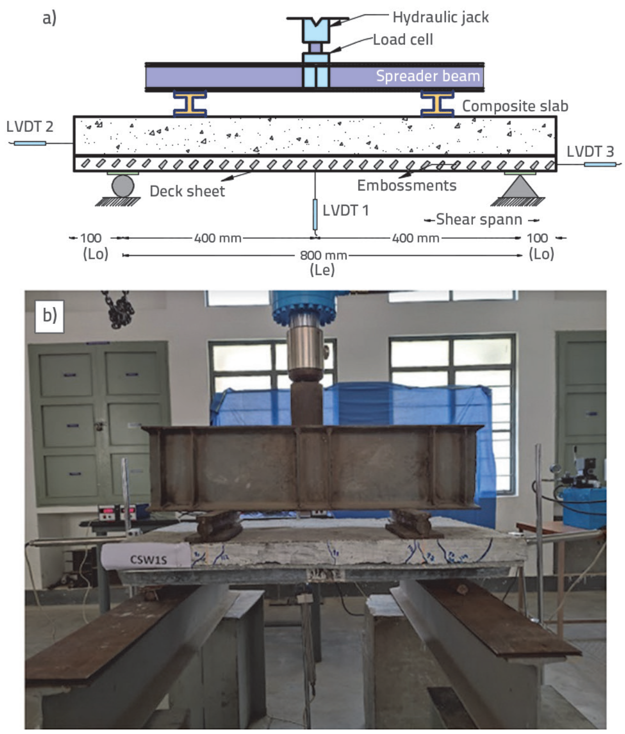

Figure 2. Experimental setup showing (a) schematic and (b) image of loading conditions

2.2. Testing of composite deck slab

The full-scale composite slab specimens were cast, lifted and symmetrically arranged for the loading setup under the 750kN capacity loading frame with the simply supported end conditions. A computerized data acquisition system was used, and the linear variable displacement transducers (LVDT) were placed at middle of the specimen and at the edges to measure vertical displacements and end slip. The schematic representation of the testing setup for the composite deck slab with simply supported end conditions subjected to

Table 2. Details of test specimens

Deck profile ID	Specimen ID	Length of shear span, Ls [mm]	Shear span ID	Shear connectors
D44	D44-CSW1S-SS1	125	SS1	Ø 16 mm headed stud connectors as end anchorages
D44	D44-CSW2S-SS2	150	SS2	
D44	D44-CSW3S-SS3	175	SS3	
D44	D44-CSW4S-LS1	225	LS1	
D44	D44-CSW5S-LS2	250	LS2	
D44	D44-CSW6S-LS3	300	LS3	
D52	D52-CSW1S-SS1	125	SS1	
D52	D52-CSW2S-SS2	150	SS2	
D52	D52-CSW3S-SS3	175	SS3	
D52	D52-CSW4S-LS1	225	LS1	
D52	D52-CSW5S-LS2	250	LS2	
D52	D52-CSW6S-LS3	300	LS3	

two symmetrically located loading points with uniformly distributed load is shown in Figure 2.a and 2.b.. The effective span of the composite deck slab specimen (Le) is 800mm, with an overhanging distance (Lo) of 100 mm on either side of the supports. Roller and hinged supports were simulated at the supports over the entire width of the specimen to obtain simply supported end conditions. Two line loads were created along the width of the specimen by placing a steel I–section with suitable shear span distances from the support. The spreader beam was placed above the two-line load points along the length of the slab wherein the load cell was positioned at the central position of the spreader beam to apply monotonic load. A preloading was initially applied to the composite deck slab specimens during each test to ensure good contact between the test specimen and the loading equipment. As the static loading gradually increased, the deflections of mid-span (at each load step) and end slips (on both supports) were recorded for two sets of six specimens for each profile deck. The variability in shear span was achieved in this case by varying the distance from the centre of one support to the nearest point of load application [11]. Based on specimen testing conditions, three sets of short shear spans (SS1, SS2 and SS3) were selected as 125 mm, 150 mm and 175 mm, while the corresponding long shear spans (LS1, LS2 and LS3) amounted to 225 mm, 250 mm and 300 mm, respectively.

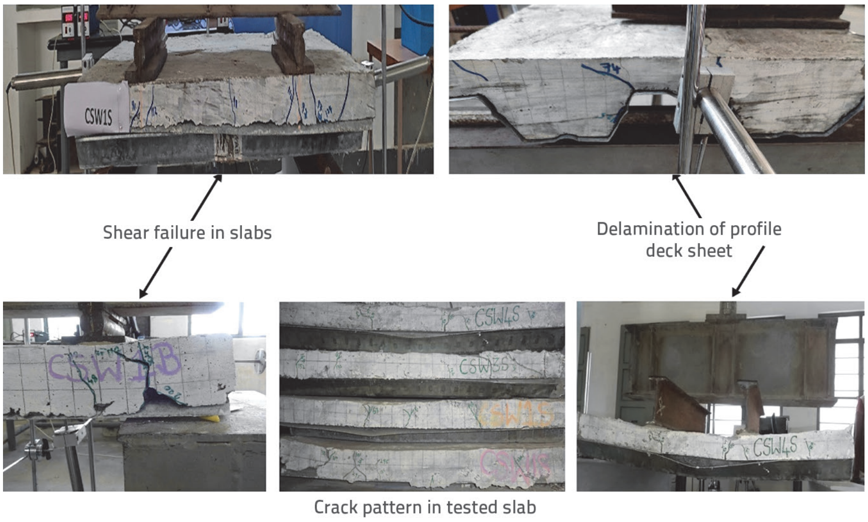

Figure 3. Crack patterns of composite deck slab

3. Results and discussion

3.1. Load-deflection behaviour of composite deck slabs

All specimens were subjected to the two-point load with variable shear span configuration to exhibit typical flexural and shear failure mechanism. The deflection at the mid-span as well as the horizontal end-slip near the shear span region between the interface layer of concrete and the deck sheet, were analysed in detail. It was observed that the tested specimens exhibit linear-elastic behaviour until initiation of the first slip. The crack patterns of all tested specimens were found to be mainly governed by the longitudinal shear, as

Table 3. Summary of loading results

Deck profile	Specimen ID	Shear span, Ls [mm]	Load at first crack, Py [kN]	Yield displacement [mm]	Failure load, Pu [kN]	Maximum deflection [mm]	End slip [mm]	Ductility index DI	Ratio Pu / Py
D44	D44-CSW1S-SS1	125	71	4.1	145.3	22.6	5.6	5.02	2.05
D44	D44-CSW2S-SS2	150	69	4.6	142.6	24.8	5.2	4.59	2.07
D44	D44-CSW3S-SS3	175	57	6.1	140.2	25.3	4.9	3.11	2.46
D44	D44-CSW4S-LS1	225	53	6.3	81.4	26.7	4.7	3.11	1.54
D44	D44-CSW5S-LS2	250	52	8.2	79.9	27.8	4.3	2.91	1.54
D44	D44-CSW6S-LS3	300	49	6.5	76.3	28.56	4.2	3.52	1.56
D52	D52-CSW1S-SS1	125	69	4.5	131.8	26.4	5.6	5.31	1.91
D52	D52-CSW2S-SS2	150	59	4.3	134.5	28.7	5.4	5.49	2.28
D52	D52-CSW3S-SS3	175	57	6.3	128.5	30.5	4.8	4.63	2.25
D52	D52-CSW4S-LS1	225	46	10.7	68.3	31.4	4.6	1.80	1.48
D52	D52-CSW5S-LS2	250	49	7.6	67.4	33.7	4.2	2.58	1.38
D52	D52-CSW6S-LS3	300	52	10	69.7	34.8	3.5	3.48	1.34

represented in the summary of experimental test results in Table 3 and Figure 3.

3.1.1. Load deflection behaviour

Static loading conditions were applied on composite slab specimens with two different configurations of profile deck sheets, i.e., D44 and D52, to determine the load deflection behaviour. Figure 4 depicts the behaviour of short and long shear span specimens of D44 profile, while Figure 5 depicts the load-deflection curve for short and long shear span specimens of D52 profile. For the shorter shear span (SS), shear cracks were found to originate from the support region to the loading point, followed by flexural cracks occurring near the bottom central span region. As the load increased further, a set of cracks appeared from the bottom of the slab and rapidly propagated towards the top of the concrete in line with the loading point. Further Increase in load led to the mid span deflection in slab that is not proportional [16]. The composite action between the profile deck sheet and the concrete portions broke down after reaching the ultimate load, indicating a partial delamination of sheet. The formation of shear cracks was observed to be near the loading points, with a gradual load drop towards initiation of end-slip. However, for the longer shear span (LS), the cracks were initiated at the bottom portion of the mid span region and gradually reached the loading point. After reaching the ultimate load, the delamination of sheet was initiated at the mid-span region, with gradual load reduction. Secondly, there was a slight load pick-up with subsequent flexural failure in the next stage with high rate of deflection. The average P_u/P_y ratios in the short and long shear span tests were found to be 2.19 & 1.54 and 2.14 &1.4 for D44 & D52, respectively, as shown in Table 3. The average values clearly indicate that short shear span test consumed a higher load carrying capacity. Furthermore, there was a significant increase in the load ratio (P_u/P_y) in short shear span to long shear span between D44 (42 %) and D52 profile slabs (52 %) respectively.

3.1.2. End slip behaviour of composite deck slabs

Little or no end-slip was observed during the initial stage of loading. After initiation of the first crack in all slab specimens, the end slip originated gradually with an increase in the rate of slip at shorter loading stages. This indicates that the interfacial bond between the profile sheet and the concrete slab is loosened, and it shows the variable amount of slip movement with independent action of profile deck sheet and concrete. The gradual de-bonding of slabs can be seen while nearing the ultimate load stage. To satisfy EN1994-1-1:2012 [9] requirements for ductile shear behaviour, the experimental ultimate load has to exceed the load at the end slip of 0.1 mm by not less than 10 %. The load slip behaviour is shown in figures 6 and 7 by comparing the vertical load vs. horizontal end slip for D44 and D52 specimens. The comparison of these figures shows that longer shear span has a smaller bond slip capacity than short shear span specimens. The average end slip for the long shear span specimens was 4.4 mm and 4.1 mm for D44 & D52 profile, respectively. The average end slip for short shear span specimens was 5.233 mm and 5.267 mm for D44 & D52 profile, respectively. The average end slip in the short shear span is 1.27 times of the slip in the long shear span.

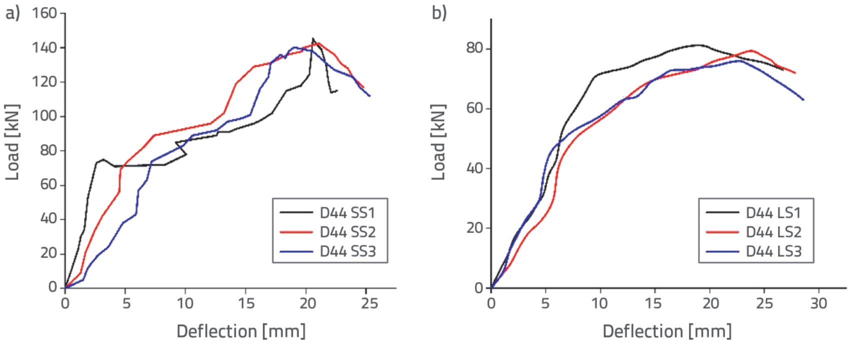

Figure 4. Load deflection behaviour for D44 specimen with: a) short span; b) long span

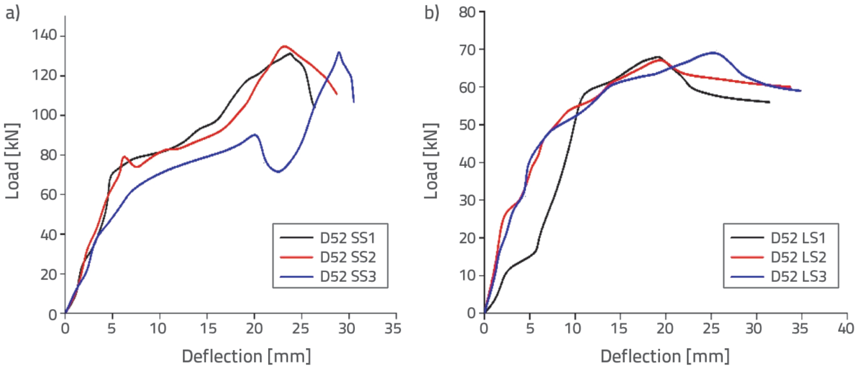

Figure 5. Load deflection behaviour for D52 specimen with: a) short span; b) long span

3.1.3. Ductility Index

The ratio of the mid-span displacement at ultimate maximum load to the elastic limit displacement is calculated as Ductility Index (DI) [9]. The average DI for the short and long shear span tests amounted to 4.24 & 3.18, 5.14 & 2.31

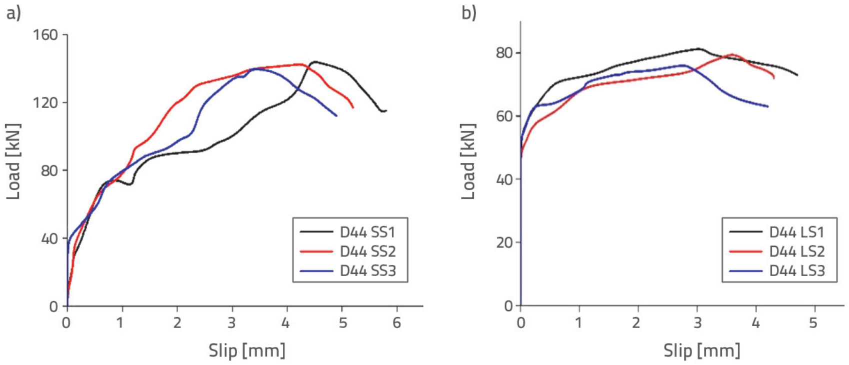

Figure 6. Load-slip behaviour for D44 specimen with: a) short span; b) long span

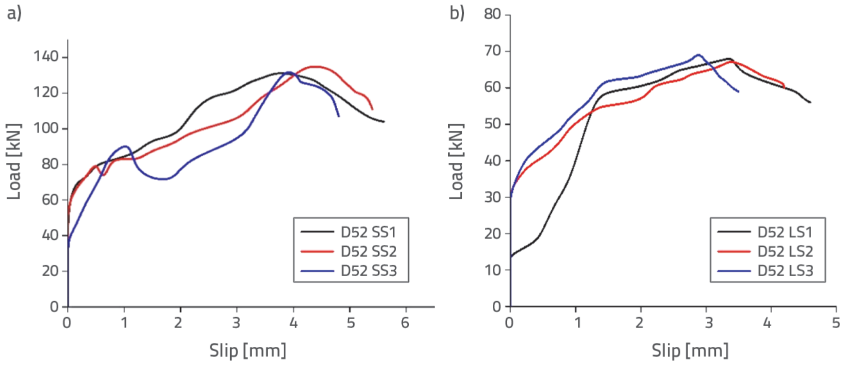

Figure 7. Load-slip behaviour for D52 specimen with: a) short span; b) long span

for D44 & D52, respectively. The enhancement of ductility was observed to be nearly 33 % higher for shorter shear spans for D44 specimens and 122 % higher for shorter shear span test, as shown in Table 4. The ratio of ultimate to the yield load carrying capacity was calculated for the short and long shear span as listed in Table 4. Based on the results, the D52 specimens exhibit better ductility index compared to D44 specimens.

3.2. Determination of shear capacity of composite slabs

3.2.1. Evaluation of m-k method

The shear bond capacity design and verification for composite deck slab was detailed as per EN1994-1-1:2012 to evaluate the strength parameters using 'm' and 'k' values [12,14,15,18]. The empirical value explains the shear transferring capacity of the profile deck sheet, wherein "m" signifies mechanical connection between concrete and profile deck sheet, and "k" signifies the friction between concrete and steel, as shown in Figure 8 for the short and long shear span test. The design equation (Eq.1) for the m-k method is shown below [6]:

$$\frac{V_u}{bd} = \tau_{u,Rd} = m\frac{A_p}{bL_s} + k\sqrt{f_c'} \qquad (1)$$

Table 4. Ductility index properties

Deck profile	Specimen ID	Shear span, Ls [mm]	Yield displacement, δ_y [mm]	Maximum deflection, δ_m [mm]	Ductility index, DI (δ_m / δ_y)	Average ductility, DI
D44	D44-CSW1S-SS1	125	4.1	22.6	5.02	4.24
D44	D44-CSW2S-SS2	150	4.6	24.8	4.59	
D44	D44-CSW3S-SS3	175	6.1	25.3	3.11	
D44	D44-CSW4S-LS1	225	6.3	26.7	3.11	3.18
D44	D44-CSW5S-LS2	250	8.2	27.8	2.91	
D44	D44-CSW6S-LS3	300	6.5	28.56	3.52	
D52	D52-CSW1S-SS1	125	4.5	26.4	5.31	5.14
D52	D52-CSW2S-SS2	150	4.3	28.7	5.49	
D52	D52-CSW3S-SS3	175	6.3	30.5	4.63	
D52	D52-CSW4S-LS1	225	10.7	31.4	1.80	2.62
D52	D52-CSW5S-LS2	250	7.6	33.7	2.58	
D52	D52-CSW6S-LS3	300	10	34.8	3.48	

Table 5. Test parameters related to m-k method

Specimen ID	Shear span, L_s [mm]	Failure load [kN]	$V_u = 0.8\ P_u/2$	$V_u/b{\cdot}d_p$ [N/mm^2]	$A_s/b{\cdot}L_s$
D44-CSW1S-SS1	125	145.3	58.12	0.912	0.0107
D44-CSW2S-SS2	150	142.6	57.04	0.895	0.0089
D44-CSW3S-SS3	175	140.2	56.08	0.880	0.0076
D44-CSW4S-LS1	225	81.4	32.56	0.511	0.0059
D44-CSW5S-LS2	250	79.9	31.96	0.502	0.0053
D44-CSW6S-LS3	300	76.3	30.52	0.479	0.0045
D52-CSW1S-SS1	125	131.8	52.72	0.862	0.0098
D52-CSW2S-SS2	150	134.5	53.8	0.880	0.0082
D52-CSW3S-SS3	175	128.5	51.4	0.841	0.0070
D52-CSW4S-LS1	225	68.3	27.32	0.447	0.0054
D52-CSW5S-LS2	250	67.4	26.96	0.441	0.0049
D52-CSW6S-LS3	300	69.7	27.88	0.456	0.0034

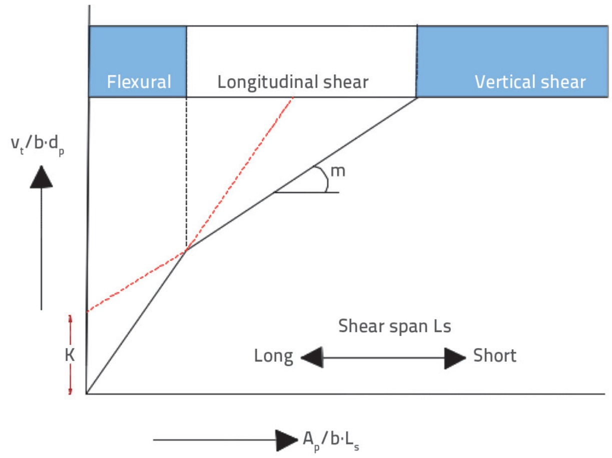

Figure 8. m-k method according to EN1994-1-1:2012

In Eq. (1) V_u is the ultimate shear capacity equal to a half of the total ultimate load (P_u) for the two-point loading system, wherein " b" is the width of the specimen, A_p is the area of cross-section of the profiled deck , and f'_c is the concrete cylinder strength. The Shear span length L_s; varies between 125 and 300 mm with six sets of specimens for testing m-k values according to BS5950: Part 4 [13,17] and ASCE 1992 Specification [12,19]. Eq. (1) can be rewritten as follows:

$$\frac{V_u}{bd\sqrt{f'_c}} = m\frac{A_p}{bL_s\sqrt{f'_c}} + k \qquad (2)$$

wherein the Eq. (2) shows the straight-line equation y = mx + c with basic empirical parameters for the plot of m-k curve represented in Table 3. The indication of 'm' and 'k' values for the composite deck slabs is shown in Figure 8. It can be noted from Figure 9.a and 9.b that m values of D52 slab are higher compared to D44 slab. The higher mechanical interlock is exhibited for D52 specimens at the interface zone with two sided embossments and horizontal stiffeners over the length of the profile. Shear bond capacities of the composite deck slab, as shown in Table 3, are calculated using Eq. (1).

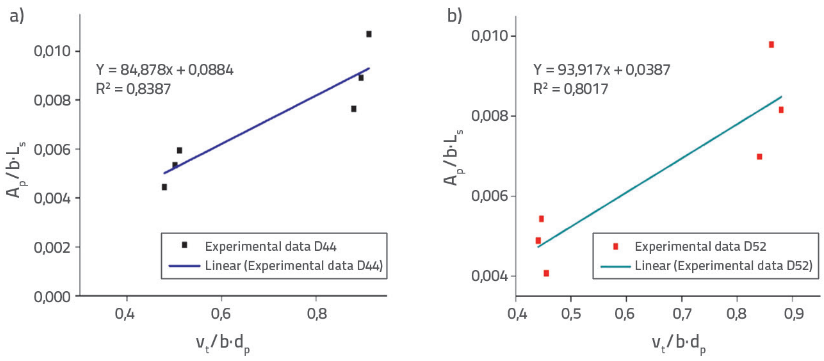

Figure 9. m-k curve for (a) D44 profile and (b) D52 profile

3.2.2. Effect of shear span on shear bond capacity

The design shear bond strength, $\tau_{U,Rd}$ is calculated as per Eq. (1) based on the area of the profile A_p and the shear span L_s. The effect of shear span on the shear bond capacity of a composite slab shows gradual decrease with an appropriate shear span length as shown in Figure 10. The shear bond capacity varies depending on the length of the slab, profile height, stiffeners on the profile sheet, and the pattern of embossments. The shear bond capacity of D44 specimen shows higher results with reduced width of the trough profile. In general, the use of shear connectors in combination with embossment on deck sheet shows better shear bond capacity for all composite deck slabs. However, D52 composite deck slabs also benefit more compared to D44 with the addition of shear studs, stiffeners and embossments that consequently develop higher shear bond resistance with limited variations.

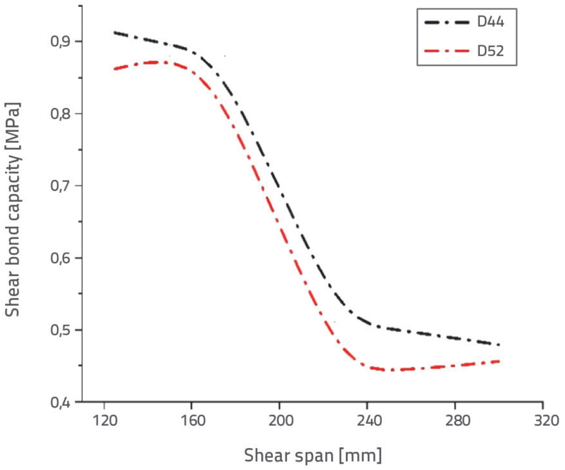

Figure 10. Shear bond capacity on shear span

3.2.3. Influence of 'dp/ls' ratio on shear bond capacity

The new simplified design equation λ -q derived from m-k equation is used to study the effectiveness of the longitudinal shear strength using the effective depth-shear span ratio ('dp/ls') [9]. The equation is expressed as follows:

$$\frac{Vt}{A_s}=\lambda\frac{d_p}{L_s} \tag{3}$$

Eq. (3) describes the longitudinal shear as a function of d_p/l_s ratio, where λ is the slope of the new empirical equation in form of y= λx + q. Figure 11 shows the evaluated longitudinal shear resistance capacity using the λ -q method. The empirical values are determined as 84.71 and 3.55 for both λ and q, respectively. A lower dp/l_s ratio (long shear span) results in lower longitudinal shear V_t, wherein higher d_p/l_s ratio (short shear span) leads to higher longitudinal shear resistance, as illustrated in Figure 11.a and 11.b.

4. Conclusions

An experimental investigation was conducted to study performance of composite slab specimens with stud connectors for various shear spans and profile heights of the slab. The following conclusions can be derived from the experimental studies.

- The strength of the tested composite slab specimens mainly depends on the shear span irrespective of the profile height of the deck sheet. Based on ultimate failure loads, the strength of shorter shear span specimens is higher than that of longer shear span specimens.
- The mode of failure of composite slab specimens showed a ductile failure at plastic stage phase. The ductility index shows 33 % higher ductility over shorter shear span than for longer shear span in D52 profile specimens.
- The average end slip in short shear span is 1.27 times of the slip in long shear span. The average slip efficiency decreased drastically for long shear span specimens. Higher slip is addressed in D44 specimens wherein the interaction is slightly lower without presence of stiffeners in deck sheet.
- Though the design shear bond resistance is higher for D44 specimens compared with shear span conditions, a closer width of trough profile may stumble upon control on resistance.
- Based on analysis of the m-k method, the shear bond values are higher for the D52 slab that generate better mechanical interlock in the interface layer compared to D44.
- Based on the modified m-k method, d_p / l_s ratio has and effect on longitudinal shear in which D52 specimens exhibits better performance compared to D44.

Further experimental and simulation studies can be developed to figure out the influence of stiffeners and embossments on particular profile deck sheets with variations in the overall depth of the slab.

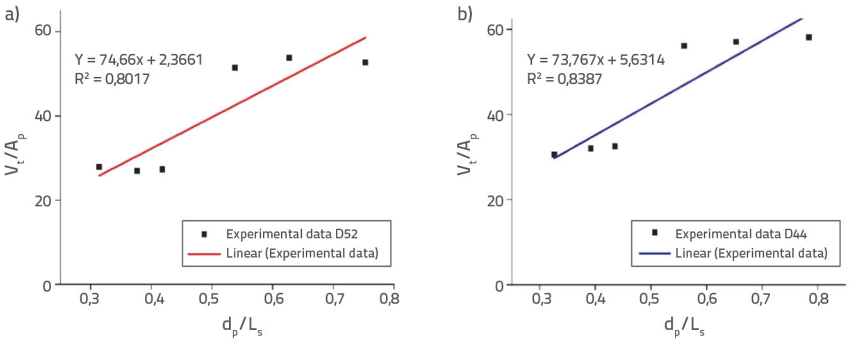

Figure 11. Modified m-k curve (λ-q) prepared for: a) D44; b) D52

REFERENCES

[1] Degtyarev, V.V.: Strength of composite slabs with end anchorages, Part I: Analytical model, J. Constr. Steel Res., 94 (2014), pp. 150–162, https://doi.org/10.1016/j.jcsr.2013.10.005.

[2] Molkens, T., Dobrić, J., Rossia, B.: Shear resistance of headed shear studs welded on welded plates in composite floors, Engineering Structures, 197 (2019), pp. 109412, https://doi.org/10.1016/j.engstruct.2019.109412.

[3] Hedaoo, N.A., Gupta, L.M., Ronghe, G.N.: Design of composite slabs with profiled steel decking: a comparison between experimental and analytical studies, Int. J. Adv. Struct. Eng., 4 (2012) 1, pp. 1, https://doi.org/10.1186/2008-6695-3-1.

[4] Cifuentes, H., Medina, F.: Experimental study on shear bond behaviour of composite slabs according to Eurocode 4, JCSR, 82 (2013) March, https://doi.org/10.1016/j.jcsr.2012.12.009.

[5] Rana, M.M., Uy, B., Mirza, O.: Experimental and numerical study of end anchorage in composite slabs, J. Constr. Steel Res., 115 (2015), pp. 372–386, https://doi.org/10.1016/j.jcsr.2015.08.039.

[6] Porter, M.L., Greimann, L.F.: Shear-bond Strength of Studded Steel Deck Slabs, International Specialty Conference on Cold-Formed Steel Structures, https://scholarsmine.mst.edu/isccss/7iccfss/7iccfss-session6/1 1984.

[7] Marimuthu, V., Seetharaman, S., Arul Jayachandran, S., Chellappan, A., Bandyopadhyay, T.K., Dutta, D.: Experimental studies on composite deck slabs to determine the shear-bond characteristic (m - k) values of the embossed profiled sheet, J. Constr. Steel Res., 63 (2007) 6, pp. 791–803, https://doi.org/10.1016/j.jcsr.2006.07.009.

[8] Chen, S., Shi, X., Qiu, Z.: Shear bond failure in composite slabs - a detailed experimental study, Steel Compos. Struct., 11 (2011) 3, pp. 233–250, https://doi.org/10.12989/scs.2011.11.3.233.

[9] Ahmed, S.M., Avudaiappan, S., Sheet, I.S., Saavedra Flores, E.I., Pina, J.C., Yanez, S.J., Guzmán, C.F.: Prediction of longitudinal shear resistance of steel-concrete composite slabs, Eng. Struct., 193 (2019) February, pp. 295–300, https://doi.org/10.1016/j.engstruct.2019.05.010.

[10] Lakshmikandhan, K.N., Sivakumar, P., Ravichandran, R., Jayachandran, S.A.: Investigations on Efficiently Interfaced Steel Concrete Composite Deck Slabs, J. Struct., (2013), pp. 1–10, https://doi.org/10.1155/2013/628759.

[11] Hicks, J.S., Smith, L.A.: City: Stud Shear Connectors in Composite Beams that Support Slabs with Profiled Steel Sheeting, Structural Engineering International 2/2014, https://doi.org/10.2749/101686614X13830790993122.

[12] EN 1994-1-1: Design of composite steel and concrete structures, Part 1-1: General rules and rules for buildings. CEN; 2004.

[13] Hedaoo, N., Raut, N., Gupta, L.: Composite concrete slabs with profiled steel decking: comparison between experimental and simulation study, American Journal of Civil Engineering, 3 (2015) 5, pp. 250-261.

[14] Ong, K.C.G., Mansurt, M.A.: Shear-bond capacity of composite slabs made with profiled sheeting, Int. J. Cem. Compos. Light. Concr., 8 (1986) 4, pp. 231–237, https://doi.org/10.1016/0262-5075(86)90050-3.

[15] Gholamhoseini, A., Gilbert, R.I., Bradford, M.A., Chang, Z.T.: Longitudinal shear stress and bond-slip relationships in composite concrete slabs, Eng. Struct., 69 (2014), pp. 37–48, https://doi.org/10.1016/j.engstruct.2014.03.008.

[16] Marčiukaitis, G., Jonaitis, B., Valivonis, J.: Analysis of deflections of composite slabs with profiled sheeting up to the ultimate moment, J. Constr. Steel Res., 62 (2006) 8, pp. 820–830, https://doi.org/10.1016/j.jcsr.2005.11.022.

[17] BS 5950, Part 4: Code of Practice for Design of Floors with Profiled Steel Sheeting, British Standards Institution, London, 1994.

[18] Chen, S.: Shear bond failure in composite slabs-A detailed experimental study, Steel Compos Struct, 11 (2011) 3, pp. 233–250.

[19] ASCE: Specification for the design and construction of composite slabs and commentary on specification for design and construction of composite slabs (ANSI/ASCE 2-84), New York, ASCE, 1985.