Recent Trends in Civil Engineering and Built Environment Vol. 5 No. 1 (2024) 104-117

RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Experimental Study on Flexural Properties of Self-Compacting Concrete Composite Slab with Profiled Steel Deck and the Presence of Reinforcement Bar

Nur Khalisah Khairudin[1], **Wan Inn Goh**[1]*

[1]Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Senior Lecturer, Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia

DOI: https://doi.org/10.30880/rtcebe.2024.05.01.011
Received 6 January 2022; Accepted 1 January 2024; Available online 30 June 2024

Abstract: This paper focus on experimental study on flexural properties of self-compacting concrete composite slab with profiled steel deck and the presence of reinforcement bar. The slab samples were designed and tested under 4-point load test. The workability of Green Self-Compacting Concrete (GSCC) under filling ability and passing ability have been determined. In addition, performance of GSCC composite slabs with the presence of longitudinal reinforcement bar based on ultimate load, load-deflection response, strain development in concrete and steel and failure modes was studied in this research. Next, the longitudinal shear bond behaviour and GSCC composite slab strength with the presence of longitudinal reinforcement bar was experimentally investigated. The 4-point load test results of the composites slabs shows that GSCC composite slab with reinforcement bar was higher in ultimate load by 4.65%. In addition, the mid-span deflection can be reduced by 30.27% with inserting additional reinforcement bar into the composite slab. In the other hand, reinforcement bar added to the composite slab show higher load capacity as well as significant ductility compared to composite slab without reinforcement bar.
Keywords: Composite Slab, Self-Compacting Concrete, Reinforcement Bar

1. Introduction

Over time, a composite slab (CS) with profiled steel decking has shown to be one of the faster, simpler, lighter, and cost-effective building methods. Because of its numerous benefits over other kinds of floor systems, the system is widely used in the building sector. Since the previous decade, the building industry has been seeking for ways to improve upon traditional methods in order to meet today's difficulties, and composite slab building is among the potential possibilities. Usually, profiled steel decking that widely being used in composite slab construction was embossed on the top flange and bottom flange. The steel decking serves as the formwork during the casting process and became the tensile reinforcement when the

Corresponding author: wigoh@uthm.edu.my

concrete gain strength after its hardened. In order to reduce cracks due to shrinkage and temperature, the nominal mesh reinforcement can be added into the composite slab design. Recently, additional reinforcement bar in composite slab is being studied in order to increase the ultimate load of the composite slab.

Composite deck slab with profiled steel sheet has shown to be an efficient and cost-effective structural building technology. Because of its numerous benefits over other types of floor systems, the system is widely used in the building sector [1]. It is often made of thin-walled, profiled steel deck that serves as a permanent formwork for in situ construction. Furthermore, the steel sheet can withstand tensile forces in the same way that longitudinal steel bars can [2].

To accommodate for shrinkage and temperature, nominal mesh reinforcing bars are necessary [3]. Other parameters influencing the strength and performance of the composite slab include profile geometry, steel decking thickness, concrete types/compressive strength, span, embossments/shear connectors, and the steel-concrete interface shear bond controlling the composite action [4]. If the composite slab is made of low-quality materials, it will be a low-quality slab that is not tough, durable, or meets the criteria provided. As a result, before they can be utilized for construction, all materials need be evaluated to confirm that they fulfil the predetermined standards.

2. Composite Slab with Profiled Steel Deck and Reinforcement Bar

Frictional interlock (profiled decking design), mechanical interlock (embossments on the sheet), and end anchorage interlock can all be used to create shear action between the sheet and the concrete (studs on the profiled decking). The steel deck geometry and its related mechanical shear transfer have the greatest impact on the steel deck load bearing capability.

In the early days of steel deck development, one of the earliest attempts to provide mechanical shear transfer was done by welding steel reinforcing bars to steel roof cover panels. Subsequent options for providing steel deck to concrete slab interlock included more complicated geometries with indentations and corrugations on the steel deck web and flanges. The trapezoidal steel deck was preferred by North American nations. The heights of these steel decks range from 38 to 90 mm, with thicknesses ranging from 0.76 to 1.5 mm. Based on these facts, it is not difficult to assume that the steel deck geometry is closely connected to its mechanical shear transfer capability, by the steel deck web corrugations. The primary goal of this geometrical detail is to improve the concrete-to-steel deck interlock resistance at the bottom deck corrugations due to the related concrete three-dimensional state of stress in this area.

In the design manual for composite slabs (1995), a method for allowing for the additional resistance to longitudinal shear provided by reinforcing bars parallel to the troughs of the sheeting was proposed for composite slabs with trapezoidal profiled sheeting. However, Johnson and Shepherd (2013) advised against using this approach blindly for reinforcement sections more than one 16-mm bar per trough, profiles considerably different from the trapezoidal sheeting employed here (60 mm deep, including a top rib), or very thin slabs [5].

According to Grossi et al. (2020), the addition of longitudinal reinforcement, may increase the load capacity and ductility of the longitudinal shear [6]. The plastic bending capacity of the composite section may be used more effectively by adding longitudinal reinforcement bar because it will improve the function of the steel decking in the composite slab. In the same study shows that additional reinforcement bars of 4.71cm^2 section area are showing better deflection resistivity compare to 1.87cm^2 section area of the reinforcement bar. In addition, the end slip of the composite slab without additional bars are higher than the composite slab with addition bars.

3. Materials and Methods

3.1 Material properties of GSCC

As for this study, material used for the green self-compacting concrete (GSCC) are Ordinary Portland Cement. sand, coarse aggregate, water, superplasticizer (SP) and additional material used includes Palm Oil Fuel Ash (POFA) and Eggshell Powder (ESP). POFA and ESP are used as the partial cement replacement for the concrete mix. The GSCC mix composition is as suggested in EFNARC while for the POFA and ESP that utilized in this study was 5% POFA and 2.5% ESP from cement content as suggested in previous study [7]. The size of aggregate, sand, POFA and sand are as in Table 1.

Table 1: Materials and its corresponding size

Material	Size
Course Aggregate	≤ 20 mm
Sand	≤ 4.75 mm
POFA	≤ 300 µm
ESP	≤ 75 µm

3.2 Material properties of GSCC composite slab

Trapezoidal profiled steel deck are the mostly used due to their capacity to span larger distances and to economize steel and concrete than re-entrant profiles, however, their ductility is lower in terms of longitudinal shear strength. Comflor60 with trapezoidal profiles was utilized in this study. For this research, the reinforcement bar with 8 mm in size was used as the longitudinal reinforcement in the composite slab and act as the manipulative variable for the study. Mesh reinforcement is a prefabricated grid consisting of a set of parallel longitudinal and cross wires with precise spacing that may be used as an alternative to the conventional steel rebar. In comparison to traditional reinforcement, steel wire mesh reinforced concrete found in self-compacting concrete allows for a wide range of structural geometries with "programmable" performance, and its mechanical and physical qualities may be modified by modifying the steel grade and volume percentage.

Table 2: Details and dimension of the composite slab

		Sample	
Component		**CSRB**	**CS**
Length, L (mm)		1800	1800
Width, w (mm)		600	600
Thickness, t (mm)		150	150
Steel deck		ComFlor60	ComFlor60
Mesh reainforcement	Opening (mm)	50 x 50	50 x 50
	Bar size (mm)	3	3
Reinforcement bar	Length (mm)	1800	NA
	Bar size (mm)	8	NA

3.3 Methods

3.3.1 GSCC Mixing Procedure

The mixing technique for this study follows the standard procedure for the GSCC, and all methods were carried out manually, as in EFNARC [8]. Weighted OPC and sand are combined in a concrete mixer until the dry mix was consistently blended. To allow for any losses that may occur during mixing and testing, the volume of concrete was raised by 10%. Water then be weighted and added to the dry mix until the wet mix is uniformly blended.

The cement, POFA, ESP and sand were mixed together in a free fall mixer to begin the concrete mixing process. Following 30 seconds of dry mixing, 1/2 of the superplasticizer and water were added and combined for 90 seconds. The water, superplasticizer, and coarse aggregate then were added, and the mixture were mixed for another 150 seconds.

After mixing, the concrete was tested for workability using the slump flow test and J-ring test. More of superplasticizer were added if the slump flow is too low and was mixed for one more minute. The procedure for incorporating the superplasticizer into the mixer were determined by trial and error.

3.3.2 Fresh State Property Tests for GSCC Mixture

Filling Ability (Slump Flow and T_{500} test)

The method for conducting a slump flow test 60 for GSCC is similar to that for conventional concrete. The variation is that instead of measuring vertical height, horizontal spreads are used to determine slump flow. The T_{500} test is a secondary indicator of GSCC flow, where T_{500} is the time between the moments of the diameter cone removed from the base plate and the time when the concrete spread reaches a diameter of 500 mm. The slump flow test procedure is based on BS EN 12350-8:2017 [9]. A base plate, stiff material such as steel was clearly marked with circles, a stopwatch, a ruler, a bucket to fill with concrete, and a moist sponge to moisten the inside surface of the cone and the surface of the base plate were used for this test. The slump-flow SF is given by adding d1 and d2 and divide by two, stated to the closest 10 mm, and is given by Eq. 1.

$$SF = \frac{d_1 + d_2}{2} \quad \text{Eq. 1}$$

Where;

SF slump-flow (mm)

d1 largest diameter of flow spread (mm)

d2 flow spread at 90° to d1 (mm)

Passing ability (J-Ring test)

The J-ring test is designed to imitate flow through reinforcements in an unconfined space. The test was carried out in accordance with the standards given in BS EN 12350-12:2010 [9]. This research will employ a Class PJ2 small gap spacing J-ring test with 16 bars. Using Equation 2, the results of the passing ability J-ring test should be less than 10 mm.

$$PJ = \frac{\Delta h_{x1} + \Delta h_{x2} + \Delta h_{y1} + \Delta h_{y2}}{4} - \Delta h_o \quad \text{Eq. 2}$$

Where;

PJ passing ability, measured by the blocking step (mm)

Δh measurement heights (mm)

3.3.3 Fabrication and casting of GSCC composite slab

For the purpose of this study, the formworks were constructed early in the process of composite slab fabrication because it became the mould for the composite slab in contrast to fabricating composite slab in construction. The formworks were provided with 1800 mm in length, 600 mm in breadth, and 150 mm in height. Bridges and connectors were also provided to the formwork to ensure the formwork do not deform during concrete pouring process.

The steel deck was assembled together with the formwork during construction as the base of the formwork. The next process is to ensure the 30 mm lean concrete is attached to the longitudinal reinforcement bar before placing them in the through. The purpose of attaching lean concrete to the bars is to avoid displacements of the bars during pouring the concrete and to ensure the distance of the longitudinal reinforcement bar are exact.

The mesh reinforcement was placed after placing the longitudinal reinforcement bar in the through. The wire mesh was positioned 30mm from top surface of the composite slab. After that, the self-compacting concrete can be poured into the formwork after passing all the fresh state property tests for GSCC. After 28-days of curing, the formwork was dissembled and the composite slab is ready to be tested. Figure 1 shows the set-up of the composite slab in the formwork.

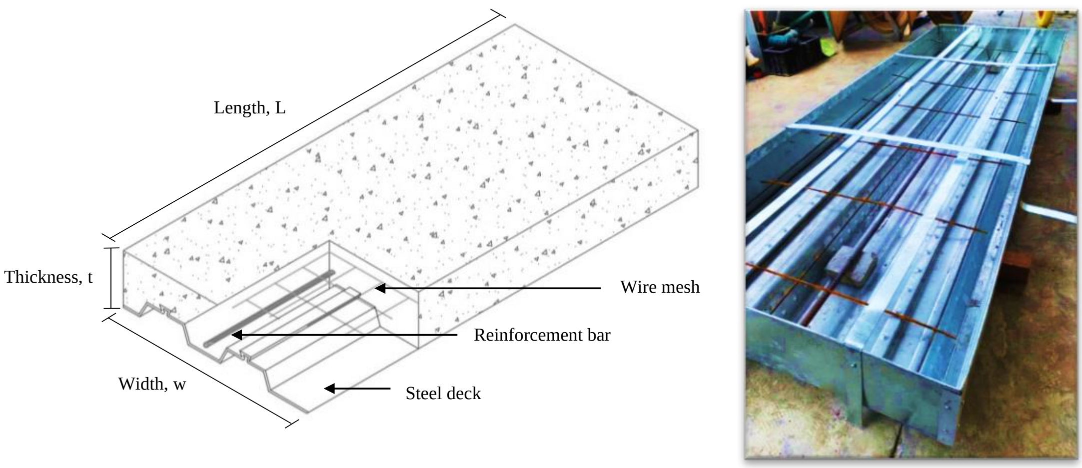


Figure 1: The set-up of longitudinal reinforcement bar and wire mesh

3.3.4 Experimental program for GSCC composite slab under 4-point load test

All the samples were tested after 28 days curing process. Figure 2 shows the schematic diagram of composite slab under 4-point load test that had been set up in the laboratory. A hydraulic jack applied load via transverse and longitudinal spreader beams. The effective span length of composite slab specimens is 1600 mm.

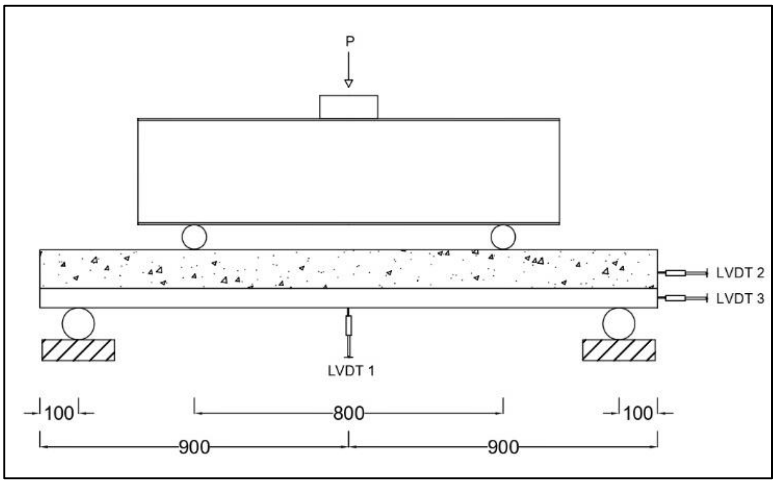


Figure 2: Composite slab laboratory set-up

Figure 3: LVDT 2 and LVDT 3 set-up

By referring to Figure 2, two transducers were connected to the short span of the composite slab to measure the end slippage of the concrete and the steel deck. They were denoted by the symbols LVDT 2 and LVDT 3. The extender as in Figure 3 was used to connect the steel deck and the transducer because the steel deck was too thin for the transducer to get the data. While one transducer named LVDT 1, was used to measure mid-span deflection. It was positioned in the central trough of the profile decking in the center of the span.

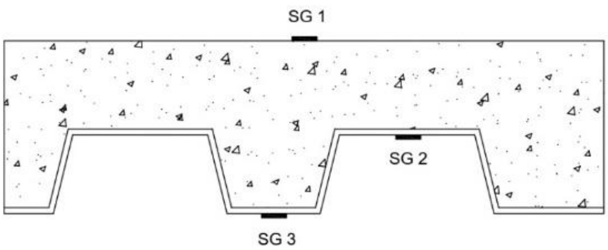


Figure 4: Schematic diagram of train gauge position

Figure 4 shows three strain gauges were placed in each composite slab to measure strain. One strain gauge was located on the top surface of the concrete (SG1), the second one was on the upper flange of the steel sheeting (SG2) and the last one was on the bottom flange of the steel decking (SG3).

4. Results and Discussion

4.1 Fresh State Property Tests for GSCC Mixture

4.1.1 Filling Ability (Slump Flow and T_{500} test)

The slump flow test is used to assess the horizontal free flow of GSCC in the absence of obstructions, and it indicates the filling ability of concrete. Table 3 shows the variation of workability of GSCC of different mixture. It should be noted here that the workability of GSCC is represented by slump-flow measurements. A control sample without POFA and ESP was used to make a comparison with the GSCC containing 5% POFA and 2.5% ESP for both specimen composite slab with reinforcement bar (CSRB) and composite slab without reinforcement bar (CS). Figure 5 shows the workability of GSCC with different mixture for different specimen. Overall, the addition of POFA and ESP resulted in the reduction of slump-flow diameter due to the high specific surface area and porous structure of POFA and ESP which led to increased demand of water, hence, needing a higher dosage of superplasticizer. The highest workability is given by controlled GSCC which is 690 mm, whereas the lowest value is 655 mm that is given by mixture for specimen CSRB. Although the quantity used for both mixture (CSRB and CS) is the same, the slump flow result quite different. This might be due to the moisture content of fine aggregate and course aggregate. However, all the outcomes of slump flow satisfied the EFNARC 2005 specifications.

Table 3: Result of filling ability using slump flow and t500 test

	Slump Flow Test			
	Diameter of Spread (mm)			**Time of Spread to t_{500}**
	d1	**d2**	**d_{avg} 550mm ≥ SF ≤ 850mm**	**Time (s)**
Control	700	680	690	3.0
CSRB	655	650	655	4.0
CS	657	655	656	4.1

d1 is the largest diameter of flow spread (mm)
d2 is the flow spread at 90° to d1 (mm)
Slump Flow, SF = (d1+ d2)/2

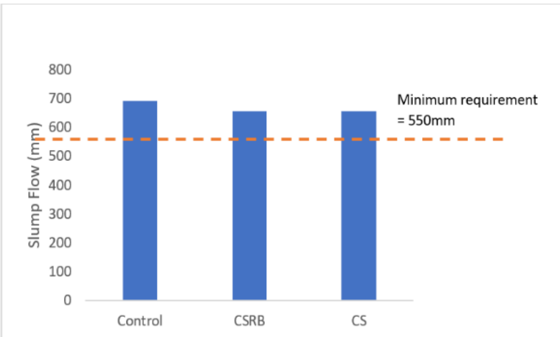


Figure 5: Slump flow of the GSCC

4.1.2 Passing Ability

The J-ring test is used to determine the passing ability of GSCC. Passing ability refers to the ability of GSCC to pass, under its own weight without vibration, to flow into and completely fill the spaces within an intricate framework, containing obstacles such as reinforcement bars and small openings. The difference in average height (h_{avg}) and the middle height (h_0) must be less than 10 mm. If it is more than 10 mm, the GSCC will fail in passing ability (EFNARC 2005). If the difference between h_{avg} and h_0 is less than 10 mm, the passing ability will be high. Table 4.2 shows the result of passing ability by using J-ring test while from Figure 4.2, the results shows that all the specimen were below the maximum difference in average height (h_{avg}) and the middle height (h_0) which means all the mixture for the specimens fulfilled the requirement.

Table 4: Result of passing ability using J-ring test.

Specimen	J-ring Flow						
	Height of Spread (mm)						Passing Ability
	h_{x1}	h_{x2}	h_{y1}	h_{y2}	h_{avg}	h_0	$h_{avg} - h_0 \leq 10$mm
Control	119	118	118	120	118.8	111	7.75
CSRB	120	120	120	120	120.0	115	5.00
CS	120	118	120	120	119.5	115	4.50

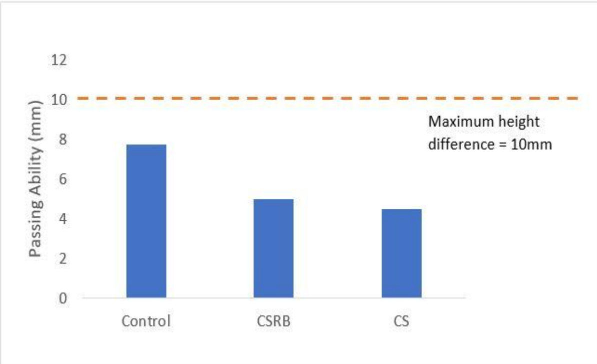


Figure 6: Passing ability of the GSCC

From Table 4 it can be seen that mixture for specimen CSRB and CS with 5% POFA and 2.5 % ESP have lower difference in heights between middle and the average heights outside the J-ring compared to control. Both materials of POFA and ESP might have porous structure of surface area that led to absorb more water absorption thereby retaining the height of concrete (Kamaruddin, 2011). However, by referring to Figure 6 all the mixture for the composite slabs fulfilled the J-ring flow requirement which not more than 10mm difference in in heights between middle and the average heights outside the J-ring.

4.1.3 4-Point Load Test Result

4.1.4 General Observation

The bending failure for composite slab with both mesh reinforcement and reinforcement bar which is specimen CSRB was observed. At the beginning of the loading, the load-deflection response of specimen CSRB was typically linear, but when the ultimate load reached roughly 47-56%, fine crack was noticed. Additional fractures formed at the loading point and the maximum moment region of the specimens as the load increased. In addition, vertical separation on steel-GSCC interface observed at the short span of the slab. The small end slippage of the slab specimens was observed when the load applied about 55-58% of the ultimate load. The end slippage was quite notable when the ultimate load was achieved, measuring roughly 4.5 mm. The load was gradually increased, and the deflection was constantly increased until the specimen failed and the test was terminated.

The load-deflection response of specimen CS was generally linear at the initiation stage of the loading, with the first fine cracks for this specimen were observed near the loading line when the load reached around 69-78% of the ultimate followed by the development of subsequent cracks at the maximum moment region observed. For specimens with mesh reinforcement but without reinforcement bar which is specimen CS, shear failure was observed. End slippages began to form when the load reached 92–94% of the ultimate load. With the increasing of load, the cracks at the loading point and the pure bending segment of the specimens increasing. However, unlike CSRB specimen, CS specimen does not show obvious steel-GSCC interface separation. Furthermore, Figures 7 and Figure 8 provide an illustration on the cracks pattern and region between the CSRB and the CS respectively.

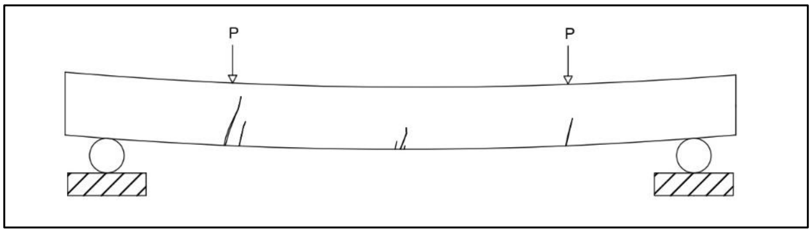


Figure 7: Crack pattern on CSRB

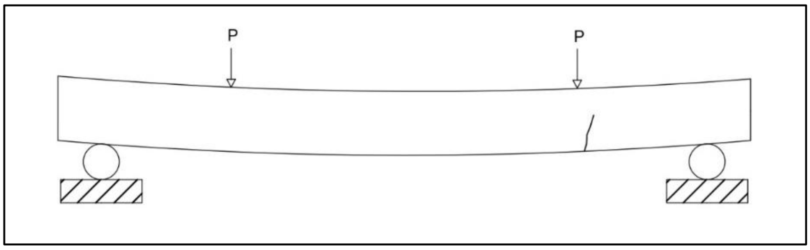


Figure 8: Crack pattern on CS

For the specimen CSRB’s loading area a few of cracks appeared. The crack opening width was varying with the maximum crack width was 4 mm at the ultimate load. For the specimen CS, main crack appears near the loading point with smaller crack opening width compared to specimen CSRB with the maximum crack opening width of 1.5 mm. In addition, less cracks were observed in specimen CS than specimen CSRB. Plus, the crack width observed in CSRB are longer compared to CS specimen. Furthermore, from the observation more flexural cracks were appeared in CSRB specimen than in CS specimen. This flexural crack was predicted because CSRB received higher applied load compared to CS. The cracks pattern and cracks region can be referred in Table 5.

Table 5: Cracks pattern types based on specimen

Slab	Crack Type	Region	Possible reason
CSRB	Flexure Cracks	Maximum moment region	Flexural capacity of the slab is inadequate
		Below the applied load line	It is loaded more than defined loads
CS	Flexure Cracks	Below the applied load line	It is loaded more than defined loads

4.1.5 Load-deflection Relationship

The applied load versus deflection shows sudden drop in load explains the decrease in stiffness of the composite slab. This event occurred because the shear stress at the interface between steel decking and concrete encouraged by the early adhesion. The load applied (P) versus mid-span deflection (δ) graph are shown in Figure 9. As illustrated in Figure 2, LVDT 1 was utilised to measure the deflection of the slabs, and the LVDT data records were used as the deflection in Figure 9

Table 6: Summary of the test result

Sample Name	P ultimate (kN)	δ max (mm)	End Slip (mm)	Max. crack opening (mm)	Difference in P ultimate compared to control sample (%)
Control	102	23.63	5.00	6.50	-
CSRB	106	17.08	6.00	4.00	+ 4.65
CS	36	2.36	2.50	1.50	- 64.50

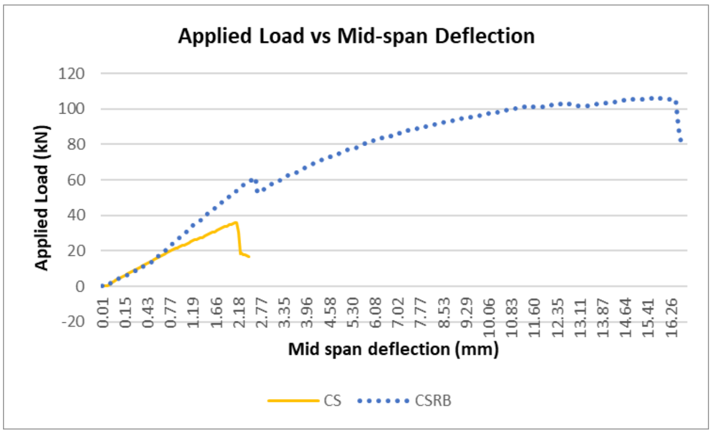
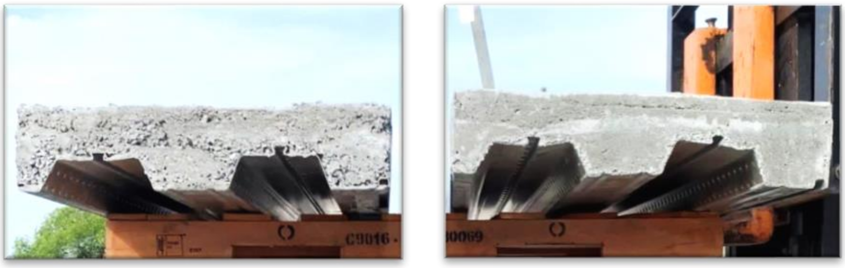


Figure 9: Applied Load versus Deflection of CSRB and CS

In Figure 9, along the loading history of the slab, two distinct behaviours connected to the steel decking-concrete slab strength may be observed. Both concrete and steel deck were in full interaction at the start of loading and showed a linear relationship of showed in load-deflection curve, however this became non-linear as the load decreased due to concrete cracking. The shear stress at steel-concrete interface surpassed the shear strength. This was due to the initial adhesion that illustrated as dramatic drop in the load-deflection graph in Figure 9 as resulting in stiffness loss.

There are different patterns showed in the graph after the sudden drop of load. Specimen CSRB graph showed load increasing gradually until reach the ultimate load while specimen CS graph showed load decreasing linearly after the sudden drop. These phenomenon shows that specimen CS was failed just after the sudden drop of load. This circumstance might happen because of the specimen CS was in the imperfect slab conditions.

However, during post-peak stage the CSRB specimen showed drastic drop while the CS specimen showed gradually decrease pattern. The load-deflection curves in the CS specimen graph displayed great ductility with smooth decreasing phases following the ultimate load. It can be observed in Figure 10 (a) and (b) that there are honeycombs that can be found at the CSRB specimen surfaces compared to CS specimen the honeycombs are hardly to be seen. This might explain the brittle shear failure of the concrete in CSRB specimen.



(a) (b)

Figure 10: Surface of the composite slab with honeycomb; (a) CSRB, (b) CS

4.1.6 End Slippage

As shown in Figure 2, two LVDTs were used to measure the end slippage at the GSCC and the steel decking of the tested slabs, which is LVDT 2 and LVDT 3 for GSCC and steel decking respectively. Figures 11 and Figure 12 illustrate the Applied Load (P) versus End Slippage (S) graph of the specimens.

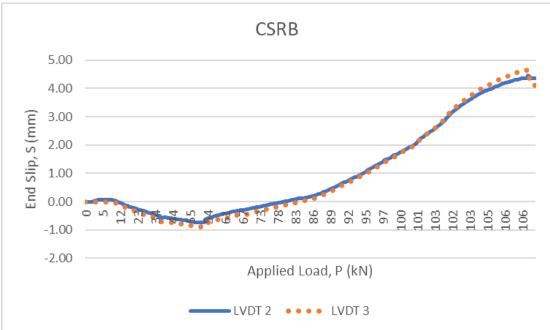


Figure 11: End slippage in CSRB

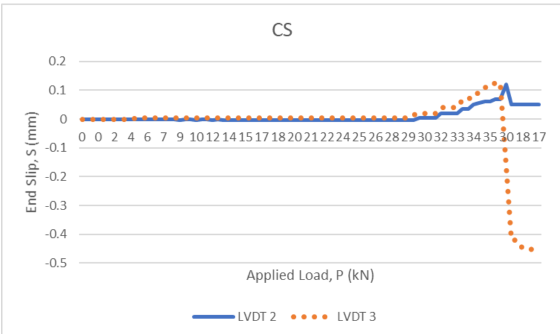


Figure 12: End slippage in CS

Slippage did not occur during the early stages of loading, as seen in both graphs. However, it can be seen that both graph present different manners in applied load versus end slip curve. As for CSRB specimen, the graph shows decreasing curve before started to increase after the first crack can be observed. From Figure 11, there are only slightly different can be seen between end slippage on GSCC and the steel decking. This express that the shear strength of GSCC surface and steel decking is quite high.

While specimen CS, end slippage behaviour can be seen by referring to Figure 12, both GSCC and steel deck show gradually increasing linear to the load increment. However, during the ultimate load applied, the difference between the two curves is quite large before the CS specimen failed. For this case, one of the reasons that can be explained is because the slab is originally twisted along the long span before the testing conducted. In addition, LVDT 3 results shows that steep decreasing line after the slab was failed at around 36kN in contrast to LVDT 2 which recording the slippage on the GSCC that also illustrate decreasing line but less steep compared to slippage on steel deck. On the other hand, slippage on both GSCC and steel deck on CS specimen remain the same after the failure based on the horizontal straight line after the sudden drop showed in Figure 12.

To conclude, CS specimen showed smaller slippage compare to CSRB during ultimate loading. However, slippage started to form when the load around 30-34kN on both specimens. This shows that, additional longitudinal reinforcement bar has not affected the end slippage of the composite slabs.

4.1.7 Strain Development

The strain development of the specimens was measured using Strain Gauges (SG) during the testing. There are three strain gauges used in this experiment placed at the centre of the slab and the positions are as illustrated on Figure 4. The load (P) versus strain (με) curves of the CSRB and CS specimen are shown in Figure 13 and Figure 14.

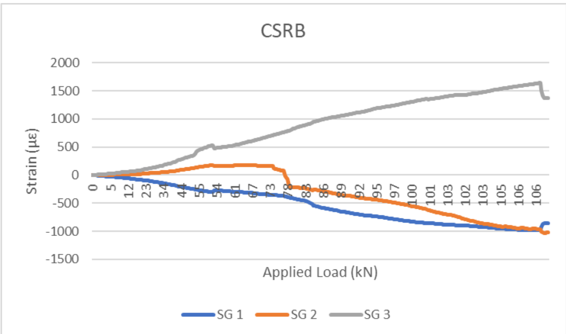


Figure 13: Strain curve in concrete slab CSRB and steel decking

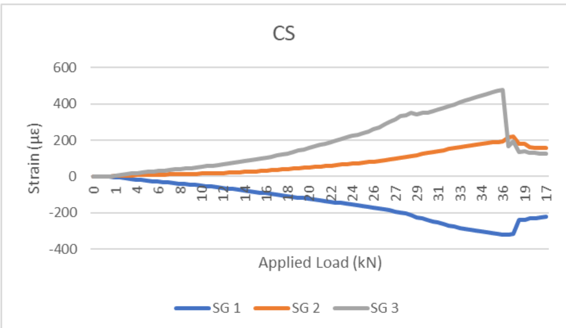


Figure 14: Strain curve in concrete slab CS and steel decking

The strain of the steel decking's upper flanges in specimens CSRB changed from tension to compression before the ultimate load was reached, as shown in Figures 13, indicating that the neutral axis moved into the steel sheeting and part of the steel participated in resisting compression. In the other hand, upper flange of steel decking in specimen CS shows increasing curve until ultimate load was reached. It appears that the strain of upper flange of steel decking specimen CS was in tension from the beginning the load was applied until the slab failed. This situation might occur because the twisted condition of slab tries to restraighten.

From Figure 13 and Figure 14, it can be observed that both load versus strain curve of GSCC are increasing linearly before reaching ultimate load. However, the strain of bottom flange of the steel decking in both specimens are in tension while the upper flange of the steel decking was more to compression. In the other hand, CS specimen curve are smoother than specimen GSCC and this might due to honeycombs that presence in GSCC specimen.

5. Conclusion

From the experimental study, the objectives of fresh properties were successfully achieved. There are two governing factors for the workability of GSCC. These factors are the filling ability and passing ability. All the mixture for the composite slab specimens were fulfil the EFNARC 2005 requirements.

In accordance to the outcomes, it can be concluded that the GSCC composite slab with ComFlor60 and reinforcement bar, the ultimate load is higher compare to the one without reinforcement bar. By comparing the result with control specimen, ultimate load of CSRB was 4.65% more than control while CS was less 64.50% from the control specimen. However, the ultimate strength of CS is not suitable to be compared with control specimen since the slab failed due to improper condition.

The composite slab with reinforcement bar load-deflection results was 47.66% less from the control sample while composite slab without reinforcement bar 92.77% less. Although the difference in mid-span deflection of CS and control was high, the result is not accurate due to the condition of the CS specimen. The stress-strain development in concrete and steel can be determined with the experiment. It is proved that concrete undergoes compression while steel deck undergoes tension during the load applied. In conclusion, the presence of reinforcement bar in composite slab can increased the ultimate load and reduce crack before fail

Composite slabs with reinforcement bars often have higher load capacity and ductility than comparable specimens without reinforcement bars. The addition of reinforcement bar might improve in longitudinal shear ductility of the composite slab. The transition from full to partial connection encourage in the reduction of stiffness loss. However, in this study, the longitudinal shear bond was not able to compare between composite slab with reinforcement bar and without since the CS specimen failed due imperfect condition. In the other hand, the strength of the composite slab with additional reinforcement bar was increased by 4.65% from control specimen. By employing reinforcement bar, it improved the deformability of a composite slab without compromising its strength.

Acknowledgement

The authors would also like to thank the Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] de Andrade, S. A., Vellasco, P. C. D. S., da Silva, J. G. S., & Takey, T. H. (2004). Standardized composite slab systems for building constructions. *Journal of Constructional Steel Research*, *60*(3-5), 493-524.

[2] Evans, H. R., & Wright, H. D. (1988). *Steel–concrete composite flooring deck structures* (pp. 21-52). Elsevier, London.

[3] Chen, S. (2003). Load carrying capacity of composite slabs with various end constraints. *Journal of Constructional Steel Research*, *59*(3), 385-403.

[4] Gholamhoseini, A., Gilbert, R. I., Bradford, M. A., & Chang, Z. T. (2014). Longitudinal shear stress and bond–slip relationships in composite concrete slabs. *Engineering structures*, *69*, 37-48.

[5] Johnson, R. P., & Shepherd, A. J. (2013). Resistance to longitudinal shear of composite slabs with longitudinal reinforcement. *Journal of Constructional Steel Research*, *82*, 190-194.

[6] Grossi, L. G., Santos, C. F., & Malite, M. (2020). Longitudinal shear strength prediction for steel-concrete composite slabs with additional reinforcement bars. *Journal of Constructional Steel Research*, *166*, 105908. https://doi.org/10.1016/j.jcsr.2019.105908

[7] Kamaruddin, S., Goh, W. I., Mohamad, N., & Jhatial, A. A. (2021). Development of Self-compacting Concrete Incorporating Palm Oil Fuel Ash and Eggshell Powder as Partial Cement Replacement. In *Proceedings of the Sustainable Concrete Materials and Structures in Construction 2020* (pp. 1-12). Springer, Singapore.

[8] EFNARC. (2005). The European Guidelines for Self-Compacting Concrete. The European Guidelines for Self-Compacting Concrete, (May), 63. Retrieved from http://www.efnarc.org/pdf/SCCGuidelinesMay2005.pdf

[9] British Standards Institution, BS5950. Structural use of steelwork in buildings. Part 1: code of practice for design in simply and continuous construction: hot rolled sections. 1985, London