Structural behaviour of PSCC slab panel under four-point bending test

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Abstract. Precast Self-Compacting Concrete (PSCC) is one of many types of approach in Industrialised Building System (IBS) that were used to speed up construction to meet consumer’s demand. The usage of Self-Compacting Concrete (SCC) will profit in many ways such as faster construction, reduction in manpower, easier placing, uniform and complete consolidation, better surface finishes, improved durability, increased strength, and safer working environment. The addition coir fibre in PSCC can improve the tensile strength and flexural strength in the concrete mixture by combining the two elements of SCC and CF in PSCC slab panel, the desired structural behaviour can be achieved. The four-point bending test was conducted on the all 4 type of PSCC slab panel that is solid control, solid CF, hollow control, and hollow CF. The solid PSCC-CF slab panel has the best structural performance compared to the other 3 other PSCC slab panel. The crack and ultimate load of the solid PSCC-CF slab panel recorded are 24.5 kN and 35 kN respectively compared to the reading collected from the other 3 slab panels. The crack propagation on the solid PSCC-CF slab panel also less propagated due to the addiction of CF that build concrete bridges. The load-deflection profile of solid PSCC-CF slab panel also shown the best result compared to the other slab panel. The load-strain profile recorded also shown the highest values of 105 micro strain on top and 53.14 micro strain on side of solid PSCC-CF slab panel.

1. Introduction

Conventional building construction that has been practiced in this country does not seem to be able to fulfil the high demand of affordable housing. As such, innovative construction system such as IBS need to be adopted to move away from this traditional construction technique in order to meet the demand. Precast Self-Compacting Concrete, PSCC, will be studied in this project due to its several advantages especially speed of construction. Its high workability and strength are highly desired for structure element. Self-compacting concrete, SCC, is a non-segregated concrete free of air and spaces which flows constantly. Advantages of SCC include faster construction, reduction in manpower, easier placing, uniform and complete consolidation, better surface finishes, improved durability, increased strength, and safer working environment [1].

Meanwhile, agricultural waste is a by-product from the agricultural industry that could pollute the environment if not properly managed. The high demand of coconut causes massive waste product of coir fibre left abandoned in the open field. This coir fibre has high ductility that can improve the tensile and flexural strength concrete mixture [2].
Precast self-compacting concrete panel, PSCC, with added coir fiber will be investigated extensively subjected to flexure load. SCC could be designed to have a strength which is at par or higher than conventional concrete. As such, PSCC, combined with coir fiber as a filler in the SCC mixture, could perform structurally with enough strength to sustain the applied load and better crack propagation control.

2. Methodology
The four-point bending load test then were conducted on both solid and hollow PACP to determine structural behavior such as ultimate load, crack pattern, load-deflection profiles, and strain distribution. These panels will be tested under four-point bending load at the Structural and Material Laboratory, UTHM.

There will be four (4) PSCC panel that will be fabricated that are solid PSCC panel without coir, solid PSCC panel with coir, hollow PSCC panel without coir and hollow PSCC panel with coir. Table 1 shows the detail of each PSCC panel that will be casted while Figure 1 shows the schematic drawing of PSCC panel.

| Specimen  | H x W x t                | Panel Type | Fiber |
|-----------|--------------------------|------------|-------|
| PSCC-1    | 1400 mm x 500 mm x 150 mm| Solid      | -     |
| PSCC-2    | 1400 mm x 500 mm x 150 mm| Hollow     | -     |
| PSCC-3    | 1400 mm x 500 mm x 150 mm| Solid      | Coir  |
| PSCC-4    | 1400 mm x 500 mm x 150 mm| Hollow     | Coir  |

Figure 1. Schematic drawing of (a) solid PSCC slab panel, and (b) hollow PSCC slab panel.
Precast self-compacting concrete slab incorporating with POFA and CF (PSCC-POFA-CF), reinforced with BRC steel (6 mm x 6 mm). The BRC was cut at 1340 mm length and 440 mm width that fulfill the requirement of 30 mm concrete cover, according to BS EN 1992-1-1 [3]. The 0.2% CF mixture was chosen as the variable to be compared to control SCC-POFA mixture because its compressive strength is the highest which was 28.5 MPa, which was obtained from the test cube and achieved highest ultimate load when the prisms were tested under flexural load. The finished product of precast self-compacting concrete slab was shown in Figure 2.

Figure 2. Precast self-compacting concrete panel.

PSCC-POFA-CF slab was tested under four-point bending load test to determine its flexural behaviour, which include its ultimate load, load-deflection profile, crack pattern, and strain distribution. Total number of four (4) slabs were tested; namely, PSCC-Control slab without POFA and CF, and PSCC-POFA-CF with added POFA and CF. The dimensions of the slab and reinforcement diameter and orientation were similar for both slabs.

3. Results and discussion
The results from the experiment were analysed in the context of the slap panel’s ultimate load, crack pattern, load-deflection profile, and strain distribution.

3.1. Ultimate load
Table 2 presents the results of crack and ultimate load obtained by the PSCC slabs. From the table, it can be seen that the highest ultimate load was recorded by Solid PSCC-0.2% CF slab, with ultimate load value of 11% higher compared to Solid PSCC Control slab panel. Meanwhile, the Hollow PSCC-Control slab panel show the lowest ultimate load compared to the other three slab panel tested. The addition of CF in concrete mixture increased the ultimate load of slab panel that cause by the enhancement in the internal bonding which was responsible to improve the flexural capacity and ductility. CF as filler was obviously responsible to improve the strength of slab.

| Specimen               | Crack Load (kN) | Ultimate Load (kN) |
|------------------------|-----------------|--------------------|
| Solid PS CC-Control    | 22.5            | 31.5               |
| Solid PSCC-0.2%CF      | 24.5            | 35                 |
| Hollow PS CC-Control   | 19.5            | 28.5               |
| Hollow PSCC-0.2%CF     | 22              | 32.5               |

These CF filler function as bridges in the SCC concrete mixture; thus, control the crack propagation. These findings are in good agreement with findings from previous research [4-5]. Adhavanathan et al. [4] examined the mechanical characteristics of concrete when CF was utilized in SCC. The results showed that the incorporation of 0.5% CF in the SCC resulted with the flexural capacity of SCC increased more than 50%. Another study by Li et al. [5] showed that when three
layers coir mesh matting as reinforcement in slab tested under four-point bending load, it resulted in 40% enhancement of flexural stress and about 20% higher in flexural ductility.

Beside the increase of ultimate load, the addition of CF also effects the first crack load of the slab panel. The slab with addition of CF shows higher crack load due to the concrete bridge that occurs in the bonding of concrete in slab panel. It is found that ultimate and crack load are highest in PSCC-0.2% CF solid, and lowest in Hollow PSCC-Control slab. This is as expected because hollow sections in the slab reduced the total weight of the slab significantly; thus, reduce the ultimate load and crack load.

3.2. Crack pattern

Figures 3 and 4 show the crack pattern on the front surfaces of Solid PSCC-Control slab and Hollow PSCC-Control slab, respectively. Solid PSCC-Control slab experienced both shear and flexural crack at both its front and rear surface. The cracks were scattered at its middle, left and right zones on the front surface. On the other hand, on its rear surface, crack was noticed only at its left zone.

The PSCC slab panel were tested under four-point bending test under simply supported manners. The slab was loaded equally in two point on the slab surfaced from start to end, when the slab panel failed. Control PSCC slab panel showed that the crack initiated from the mid-span zone of the panel. The crack started when the load applied on the slab panel is 22.5 kN and achieved ultimate load at 31.5 kN. The crack continued until the slab panel totally failed at 2.5 mm deflection. The crack length recorded were varied from 20 mm to 185 mm.

![Figure 3. Crack pattern on the front surface of PSCC-Control slab.](image)

![Figure 4. Crack pattern on the front surface of Hollow PSCC-Control slab.](image)

From Figure 4, it is noticed that the hollow PSCC-Control slab experience much less cracks compared to the Solid PSCC-Control slab. Flexural cracks were detected from the bottom part of its right zone. The crack’s width and length recorded in hollow PSCC-Control slab were smaller
compared to the width and length recorded in solid PSCC-Control slab. The flexural crack started when the load applied on the slab panel is 19.5 kN and achieved ultimate load of 28.5 kN.

Figures 5 and 6 show the crack pattern of front surfaces of Solid PSCC-CF slab and Hollow PSCC-CF slab. The cracks in Solid PSCC-CF slab initiated from bottom part of both left and right zone of slab. The right zone of the slab recorded totally flexural crack while the left zone recorded flexural and shear crack. The first crack load was recorded at 24.5 kN and the ultimate load is 35 kN.

The flexural crack in hollow PSCC-CF slab was initiated from the bottom part near its left zone. Small cracks were also noticed at the bottom left and right zones of the slab. The first crack load occurred at 22 kN and it achieve ultimate load of 32.5 kN. The cracks’ width and length recorded in hollow PSCC-CF slab were also smaller compared to the width and length of solid PSCC-CF slab. In general, it can be seen that hollow PSCC-Control and hollow PSCC-CF slabs recorded less cracks compared to the solid PSCC-Control and solid PSCC-CF slab.

3.3. Load-deflection profile
Figure 7 shows the load-deflection profiles for all four slab specimens tested under four-point bending load test. Three LVDT were placed at the mid span of slab to obtain its deflection.

From Figure 7, it is clearly seen that CF does have a significant effect on the ultimate flexure load achieved in each slab. Solid PSCC-CF achieved 11% higher in ultimate load compared to Solid PSCC-Control. The existence of 0.2%CF was most significance in Hollow PSCC panels, with the increased of Pu about 14% compared to Pu in Hollow-PSCC-control.

From the load-deflection profile in the figure, it is also seen that presence of fiber in PSCC slab increased the ductility of the slab. The deflection of PSCC-CF slabs recorded higher values compared
to PSCC without CF, each at 3.4 mm and 2.7 mm for solid PSCC-CF and hollow PSCC-CF, respectively. The lowest deflection was recorded by hollow PSCC-Control slab. The ductile behavior noticed in all slabs agree with the results obtained from previous work by Li et al. [5] which found that added CF mesh in a slab improved its ductility, even though the orientation of CF utilized in Li et al. [5] is different with the authors’ work. Li et al. [5] utilized a three layers non-woven CF mesh matting which were inserted along the edge’s span of the slab, whereas the CF added in this experiment was mixed in SCC mixture during its mixing process. It is interesting to know that even though both CF fillers and CF mesh functioned differently in the concrete mixture, with the former as filler and the latter as reinforcement, both managed to behave in a ductile manner.

Figure 7. Load deflection curve of all specimens.

3.4. Load-strain profile
The load-strain relationship on the PSCC-CF slab surface are discussed in this section. Figure 8 shows the load-strain curves on the top and bottom surface of the self-compacting concrete surface for solid PSCC-0.2% slab and solid PSCC-Control slab. The overall trend of the strain curves showed that all PSCC beams were under tension until it reached the ultimate load. This is as expected because the weakest zone is laid in the bottom part of beam which is under tension.

3.4.1. Top and bottom surface
For solid PSCC-Control slab, the top surface experience compression strain while the bottom part experience tensile strain. It is as expected because under flexure load, the slab experienced bending. The maximum strain recorded was 105 micro strain at top and 98 micro strain at the bottom. Meanwhile, for PSCC-CF slab, the strain recorded was 116 micro strain at the top surface and 115 micro strain at the bottom surface. The differences in strain recorded for top surfaces of these two slabs is 10.5%, while for the bottom surfaces, the difference is 17.3%.

3.4.2. Side surface
The strain of side surface was recorded as shown in Figure 9. The compressive zone and tensile zone show different value of maximum strain. The tensile zone of solid PSCC control shows higher maximum strain value of 46 µε compared to compressive zone with the value of 44.44 µε. While on the solid PSCC 0.2%CF, the compressive zone shows higher maximum strain value of 82.13 µε compared to tensile zone value of 51.5 µε. The highest maximum load of maximum strain recorded for both solid PSCC control and solid PSCC 0.2%CF is 46 kN and 53.14 kN respectively.
4. Conclusion
As the conclusion, the solid PSCC-CF slab panel has the best structural performance compared to the other 3 other PSCC slab panel. The crack and ultimate load of the solid PSCC-CF slab panel recorded are 24.5 kN and 35 kN respectively compared to the reading collected from the other 3 slab panels. The crack propagation on the solid PSCC-CF slab panel also less propagated due to the addiction of CF that build concrete bridges. The load-deflection profile of solid PSCC-CF slab panel also shown the best result compared to the other slab panel. The load-strain profile recorded also shown the highest values of 105 micro strain on top and 53.14 micro strain on side of solid PSCC-CF slab panel.

5. References
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