SHEAR BEHAVIOUR OF COMPOSITE SLAB REINFORCED WITH STEEL FIBRE CONCRETE TOPPING

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ABSTRACT

The objective of this paper is to presents experimental results on the composite slab reinforced with steel fibre compared to prefabricated welded wire mesh in concrete topping; subjected to applied shear load. In order to achieve the objective, 24 composite slabs reinforced with different types and amounts of steel fibres were prepared. At the same time, three composite slabs reinforced with prefabricated welded wire mesh were also prepared as comparison. The type of steel fibres was hooked-end deformed with different dimension, which are; length of 50 mm with diameter of 0.75 mm and length of 33 mm with diameter of 0.55 mm. Both types of steel fibres were cast as concrete topping with amounts of 0.25, 0.50, 0.75 and 1.00 percents volume fraction to that of concrete volume. The result shows that by substituting prefabricated welded wire mesh with steel fibres improves the shear behaviour of the composite slab.

Keywords: Composite slab, concrete topping, steel fibre, volume fraction, aspect ratio.

1. INTRODUCTION

Composite slab consists of two different element connected together to achieve composite action in a structural system. In normal precast construction practices, precast slab may be used with or without in-situ concrete topping. The practice depends on the structural design and performance. However, construction with in-situ concrete topping is widely chosen by construction practitioners. Composite action is a compulsory behaviour for existing slab with their in-situ concrete topping in order to give the maximum diaphragm action throughout the floor in one structural system. Many researches have been conducted regarding shear behaviour of structural elements reinforced with steel fibres. However, there are still restrictions to the research focus on composite slab element. Most of the existing researches concentrated on the structural elements of beams, columns, foundations, corbels and other popular types of elements. As only a few researchers reported on the application of steel fibres in a slab element, thus, reference on the current work is mostly referred to steel fibre application on beam element.

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S.F. Junior et al. (1997) investigated the effects of steel and polypropylene fibres in a reinforced concrete beams. Results showed that higher aspect ratio of both type of fibres reduced the workability of the fresh concrete compared to lower aspect ratio. In terms of the hardened state of concrete strength, an addition of the fibres especially steel fibres do contributed to a small increment to the compressive and splitting tensile strength of the concrete. In the case of the beam element, beams with steel fibres showed an increase for their shear strength, with the failure mechanism changed from shear to flexure failure. J.S. Cho et al. (2009) studied on the shear resistance of prestressed concrete beams when reinforced with steel fibres. The aim of their research focused on assisting the ACI Building Code provisions in using minimum amount of steel fibres in prestressed concrete beams after considering the prestressing force effect in the beam element. Results from the works revealed that the first cracking load of beam with steel fibres was delayed to higher load compared with the ones without steel fibres. The failure shear cracking angle for both with and without steel fibres were almost the same, however, there is a difference in terms of the cracking pattern when approaching the extreme fibre of the beam. The deviation for beam with steel fibres was early compared to beam without steel fibres.

In general, the action of steel fibres subjected to shear load in an element can be seen from two phenomenons. Firstly, fibres action against inclined shear cracks propagation and secondly, improved shear capacity due to the fibres ability to control cracking and helps concrete surrounding to effectively transferring the transverse forces [S.F. Junior et al., 1997]. This current work aim to discover the shear behavior of composite slab reinforced with steel fibre concrete topping. This work is different when compared with other available literatures. The contribution of the steel fibres revealed in this current work either does or does not contribute to the performance of composite slab under shear load.

2. EXPERIMENTAL PROGRAM

2.1. Specimen Preparation

Two types of steel fibres were used in this experimental work. The types of steel fibres were; length of 50 mm with diameter of 0.75 mm and length of 33 mm with diameter of 0.55 mm. Both types were high strength hooked-end deformed steel fibres with density of 7850 kg/m^3. In this paper and as a simplification, both fibres were abbreviated as SF50 and SF33; based on their respective length. The aspect ratio of a steel fibre is the value of fibre length divided by its diameter (L/D). As the steel fibres contribution strongly depended on the added amount of fibres in a concrete volume, thus, fibre volume fraction is introduced in this experimental work. The volume fraction, V_f chosen in this work were 0.25%, 0.50%, 0.75% and 1.00%. Each amount of volume fraction was added in a concrete volume for each type of SF50 and SF33.

The composite slab consists of bottom slab with in-situ concrete topping. The configuration of the bottom slab is 500 mm long, 350 mm wide and 100 mm thick. While, the configuration for the in-situ concrete topping is 500 mm long, 350 mm wide and 75 mm thick. The bottom slab is reinforced by three numbers of high strength steel reinforcement with diameter of 10 mm. At the same time, nine cube moulds (150 mm x 150 mm x 150 mm) were prepared for each concrete batch to determine the concrete compressive strength. The design concrete strength for the bottom slab was 60 N/mm^2, while, 40 N/mm^2 for the in-situ concrete topping. Table 1 summarised the specimen parameters, with their respective abbreviation.

Table 1: Summary of in-situ concrete topping

Type of reinforcement in concrete topping	*Volume fraction of steel fibre, V_f*	*Steel fibre aspect ratio, $V_f L/D$*	*Group Type*	*Abbreviation*
Prefabricated welded wire mesh	0.00	0.00	C	C
SF50	0.25	16.75	SF	SF50-1
	0.50	33.50		SF50-2
	0.75	50.25		SF50-3
	1.00	67.00		SF50-4
SF33	0.25	15.00	SF	SF33-1
	0.50	30.00		SF33-2
	0.75	45.00		SF33-3
	1.00	60.00		SF33-4

2.2. Testing Procedure

The composite slab was tested under shear load subjected to a two point loading as shown in Figure 1. The two point loading was located 100 mm between each other and 175 mm from their nearer support with selected ratio for shear span to effective depth of a/d = 1.25. This ratio was chosen to ensure that the composite slab fails in shear

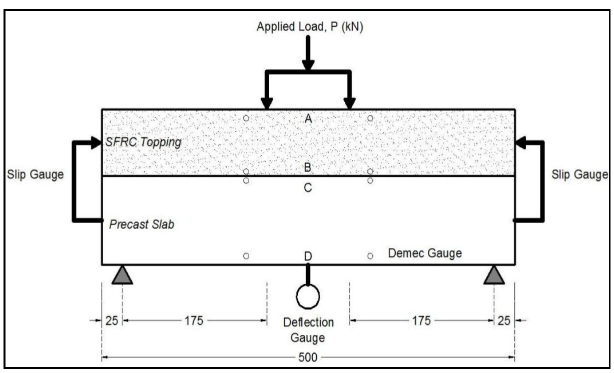

Figure 1: Shear test set-up.

3. RESULTS AND DISCUSSION

3.1. Cube Compressive Strength, f_{cu}

Figure 2 shows the relationship between the relative performance and volume fraction for all specimens. The relative performance is calculated based on the effectiveness of cube compressive strength for specimens with fibre to that of the control specimen. The relationship shows that concrete with SF33 has little improvement towards the compressive strength. Unlike concrete with SF50, it produces higher performance when compared with the control specimen. This shows that higher aspect ratio of steel fibres contributed to the improvement of the cube compressive concrete strength.

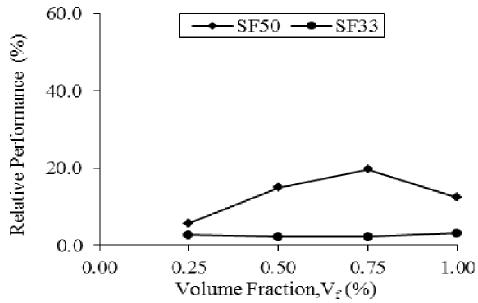

Figure 2: Relative performance versus volume fraction.

3.2. Cracking Pattern of Composite Slabs with SF50 and SF33 Concrete Topping

Figure 3(a) shows the cracking pattern of the control specimen at failure. The slab failed abruptly with diagonal cracking about 45° from the horizontal plane. The diagonal crack initially started from the support and propagates diagonally to reach the top extreme fibre of the concrete topping. The failure is sudden and assisted by a loud sound upon failure. Figures 3(b) ï 3(e) show the cracking pattern of the composite slabs for type SF50, while Figure 3(f) ï 3(i) for type SF33 at failure for V_f = 0.25%, V_f = 0.50%, V_f = 0.75% and V_f = 1.00%, respectively. When comparing the behaviour of the composite slabs at failure between type SFs and C, type SFs does not produce a loud sound at failure. Even though the diagonal failure was sudden (same as with the control), however, the rhythm of collapsed were predictable and less dangerous. This specially occurred at a higher volume fraction of V_f = 0.75% and V_f = 1.00%. While, less volume fraction of V_f = 0.25% and V_f = 0.50%, the amount of steel fibres were small to improve the sudden failure of plain concrete into a predictable failure.

On the other hand, comparing composite slabs with SF50 and SF33 concrete topping gives different perspectives. The study found that the effect of steel fibre lengths affected the behaviour of shear failure for composite slabs. This introduced aspect ratio parameter was considered when discussing about steel fibre reinforced concrete. Like in a steel fibre volume fraction, the higher aspect ratio increased the shear performance of a steel fibre reinforced concrete. Concrete topping with SF50 is better in terms of arresting cracking propagation to reduce the loud sound and sudden failure, as compared with SF33. This associated SF50 configuration is longer and thicker diameters as compared with SF33. Thus, higher volume fraction that is assisted by longer and thicker diameters can helps to improve the shear behaviour of composite slab reinforced with steel fibre concrete topping.

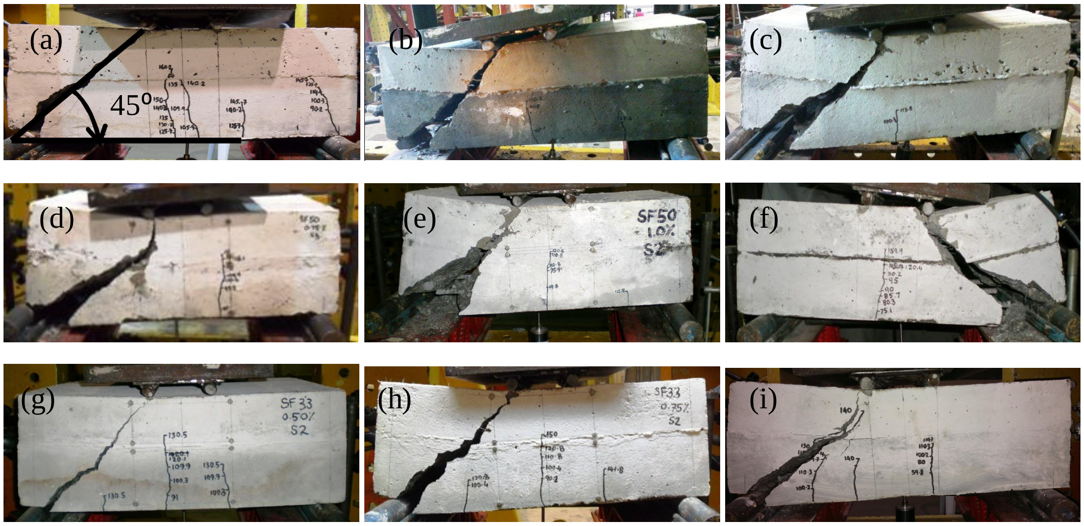

Figure 3: Cracking pattern of type C and SFs composite slab specimen at failure.

3.3. Shear Behavior of Composite Slabs with SF50 and SF33 Concrete Topping

The behaviour of type C and SFs composite slabs in the form of shear force versus mid-span deflection are shown in the following Figure 4. Basically, shear force capacity for all SFs composite slabs were close to that of the value obtained for type C. This may be due to the addition of steel fibres in the concrete topping, at which it was subjected to the compression stress during the applied load. In the other words, total shear capacity of a composite slabs either reinforced by steel fibres or prefabricated welded wire mesh were contributed by the capacity from the bottom slab and not from the concrete topping, resulted to a nearly close shear capacity for all specimens.

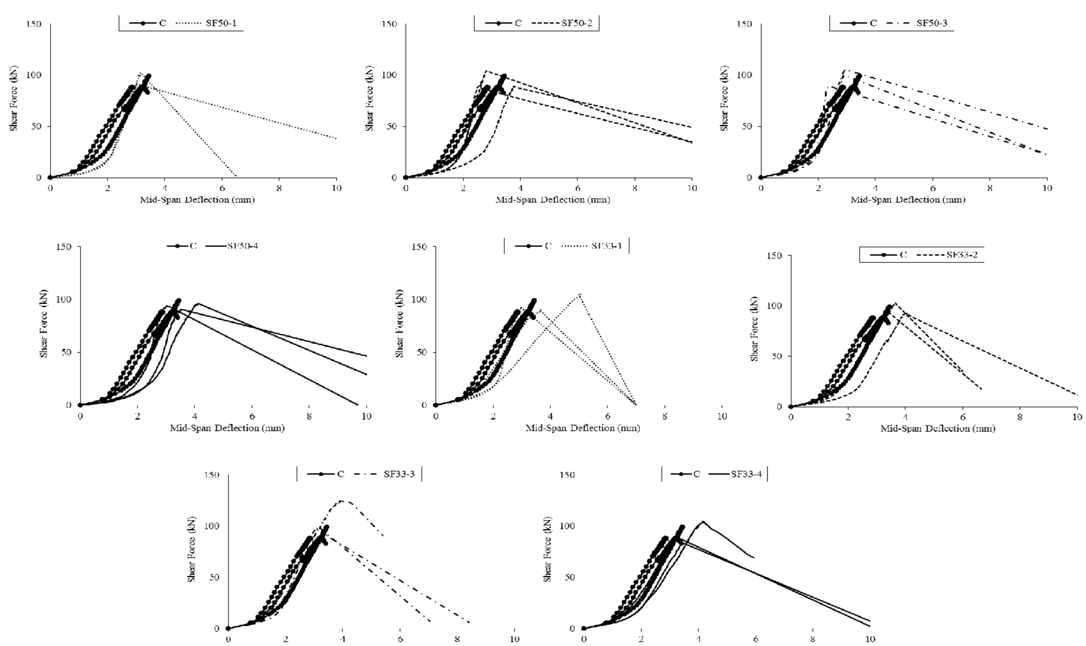

Figure 4: Shear load versus mid-span deflection for SFs.

However, close observation in Figure 4 found that the gradient of the graph before the ultimate shear load was higher for type C composite slabs compared to that of the SFs. The smaller gradient for type SFs composite slabs shows the effectiveness of steel fibres to arrest the propagation of cracking occurred in the concrete topping. The effectiveness of steel fibres to arrest the cracking caused the composite slabs to buckle or deflect at higher value compared to type C slabs. However, the value of type SFs composite slab deflection are not critical and perhaps this is one of the behaviour of steel fibres to make sure the composite slabs failed in a less sounds and determinate failure.

4. CONCLUSIONS

Research conducted from current work revealed that the shear behavior of composite slab reinforced with prefabricated welded wire mesh in a concrete topping, as a conventional construction technique can be improved when substituted the mesh into steel fibres. The shear improvement can be seen in terms of the cracking pattern at failure in all slabs. Even though, the shear capacity is not improved due to the addition of steel fibres in a compression zone, however, it changed the sudden collapsed of a conventional type into more silence and determinate failure.

5. ACKNOWLEDGMENTS

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