Flexural Behaviour of SCC Ferrocement Slabs Incorporating Steel Fibers

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Abstract

This paper presents the details of behavior of self-compacting concrete (SCC) ferrocement slab panels incorporating shaktiman steel fibers under flexure. A total of 18 slab panels have been tested under flexural loading. The size of the slab is 700 mm (length) x 300 mm (width) x 40 mm (thickness). The parameters studied in this investigation includes the number of weld mesh layers and the percentage of shaktiman steel fibers i.e (0.25% and 0.5%) . Test procedures for self compacting (SCC) have been explained in brief and all the tests have been performed as per EFNARC. From the studies, it is observed that the load carrying capacities, deformation at ultimate load are high in the case of SCC ferrocement shaktiman steel fibers. The stiffness of the specimens with 1-layer bundled weld mesh is lower than that of the specimens with 2 layers bundled.. further, there is reduction in number of cracks with increase in fiber content.

Key words: *Self compacting concrete, ferrocement slab,shaktiman steel fibers, fly ash, deflection,crack pattern.*

1. Introduction

The development of new technology in the material science is progressing rapidly. In recent two or three decades, a lot of research was carried out throughout globe for how to improve the performance of concrete in terms of strength and durability qualities. Consequently concrete has no longer remained a construction material consisting of cement, aggregate, and water only, but it has become an engineered custom tailored material with several new constituents to meet the specific need of construction industry. The growing use of concrete in special architectural configurations and closely spaced reinforcing bars have made it very important to produce concrete that ensure proper filling ability, good structural performance, and adequate durability. In recent years a lot of research was carried out throughout the world for how to improve the performance of concrete in terms of its most important properties that is strength and durability. Concrete technology has under gone from macro to micro level study in the enhancement in strength and durability properties from 1980's onwards. However till 1980's the research study related to flow ability of concrete to strength and durability did not draw lot of attention of the concrete technologists. This type of study has resulted in the development of Self Compacting Concrete (SCC), a much-needed revolution in concrete industry. Self-Compacting concrete is highly engineered concrete with much higher fluidity without segregation and is capable of filling every corner of formwork under its self-weight only. This SCC eliminates the need of vibration either external or internal for the compaction of concrete without compromising its engineering properties

Nowadays it is well known that the benefits of adding fibers to concrete, mainly the improvements in the residual load-bearing capacity, are influenced by the type, content and orientation of the fibers. Fibers are added not to improve the tensile strength itself, but mainly to control the cracking, prevent coalescence of cracks, and to change the behavior of the material by bridging of fibers across the cracks. The use of fibers may extend the possible fields of application of self compacting concrete (SCC). A high content of fibers is difficult to distribute uniformly; a good distribution, however is required to achieve optimum benefits of the fibers. When high volume fiber fractions are needed SCC mixing techniques may result a more workable concrete Ferrocement is one of the construction materials which may be able to fill the need for building light structures. Ferrocement composite consist of cement-sand mortar and single or multi-layers of steel wire mesh to produce elements of small thickness having high durability, resilience and when properly shaped it has high strength and rigidity. These thin elements can be shaped to produce structural members such as folded plates, flanged beams, wall pane,. etc for use in the construction of cheap structures.

From the above discussion, it can be noted that, research work out on the integral behaviour SCC ferrocement slab with fibers is limited. The present investigation is aimed at to investigate the flexural behaviour of SCC ferrocement slabs with and without considering the effect of fibers.

2. Experimental investigation

The experimental investigation consists of testing of eighteen SCC ferrocement slabs. The variables considered in the study (i) number of layers of weld mesh and (ii) addition of fibers i.e (0.25% and 0.5%). The details of experimental studies including characterization are presented below.

2.1. Materials used

Ordinary Portland Cement (OPC) was used for all the test specimens conforming to the requirements of IS 1489: 1991.Fly ash is added to reduce the dosage of chemical admixtures needed to get required slump. 10 mm nominal maximum aggregate is used as coarse aggregate and fine aggregate is the natural sand free from impurities.

In the present study, cement content is used with and without shaktiman steel fibers. To make the mix more workable, chemical admixture Conplast SP-430 and viscosity modifying agent Gleniumstream 2 were added as 1.20% and 0.15% of weight of cementitious material respectively to mix 1 mix 2 and mix 3. For the case of mix 2, 0.25% by weight of cementitious material is added as shaktiman steel fibers and for case of mix 3, 0.5% by weight of cementitious material is added as shaktiman steel fibers The quantities of materials are presented in Table 2.

Table 1: Properties of Steel Fibres

Type	Crimped round
Length	30mm
Diameter	0.55mm
Aspect ratio	54

Table 2: Mix Proportions

	MIX 1 Content kg/m^3	MIX 2 Content kg/m^3	MIX 3 Content kg/m^3
Cement	409.09	409.09	409.09
Water	225	225	225
Coarse aggregate	766	766	766
Fine aggregate	833.37	833.37	833.37
W/C ratio	0.55	0.55	0.55
Fly ash	114.9	114.9	114.9
Shaktiman steel fibers	--	1.3	2.61

Weld mesh is arranged in different layers in ferrocement slab instead of reinforcement. Weld mesh of size 590 mm X 290 mm with grid size 15 mm X 15 mm and 1.2 mm dia. skeleton reinforcement is used for casting of ferrocement slabs. Weld mesh layers (1 and 2) are tied with binding wire and no spacing is provided between them keeping a clear cover of 6mm from bottom of the slab. Fig. 1 shows the weld mesh adopted in the present study.

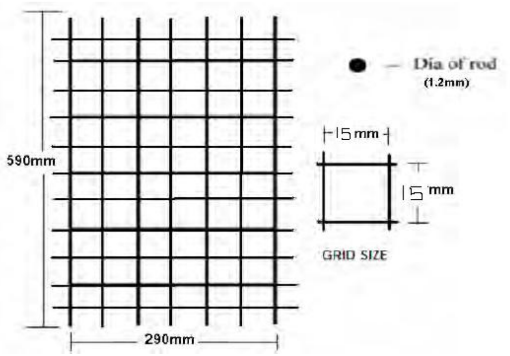

Fig.1 Mesh reinforcement

3. Test procedures for SCC

A Concrete can be classified as self-compacting concrete only when the requirements such as filling ability, passing ability and segregation resistance are fulfilled.

Filling ability (excellent deformability) Passing ability (ability to pass reinforcement without blocking) and High resistance to segregation.

Table 3: Acceptance Criteria for SCC

Property	Test Methods
Filling Ability	Slump flow
	T $_{50cm}$ slump flow
	V funnel
Passing Ability	L-Box
	U-Box
	Fill-Box
Segregation resistance	GTM screen stability test
	V Funnel at 5 minutes

3.1 Slump Flow Test

The slump flow is used to assess the horizontal free flow of SCC in the absence of obstruction. The slump cone, filled with concrete is lifted off and concrete is allowed to flow and the diameter of slump flow is measured. The average of the diameter of the circle is a measure of filling ability of concrete. T_{50} is the time required in seconds for concrete to cover 50cm diameter spread from the time of lifting of the slump once. The T_{50} time is a secondary indication of flow. It may give some indication of resistance to segregation. Lower time indicates greater flow ability. According to Nagataki and Fujiwara, a slump flow ranging from 500 -700 mm is considered as necessary for a concrete to be self compacted.

3.2 V Funnel Test:

The test was developed in Japan and used by Ozawa etal. The equipment consists of a V shaped funnel. The test determines the filling ability of the concrete with a maximum aggregate size of 20 mm. The funnel is filled with 12 liters of concrete and the time taken for into flow through the apparatus is measured. After this, the funnel is refilled with

concrete and left for 5 minutes to settle. If the concrete shows segregation then the flow time ($T_{5\ min}$) will increase significantly compared to the first measurement.
According to Khayat and Mani, a funnel test flow time < 6s is recommended for a concrete qualify as SCC. The inverted cone shape restricts flow and prolonged flow time may give some indication of the segregation and blocking.

3.3 L- Box Test:

The passing ability is determined using the L-box Test . The vertical and horizontal sections are separated by a movable gate, in front of which vertical reinforcement bars are fitted. The vertical section is filled with concrete. The movable gate is lifted to let the concrete flow into the horizontal section. When the flow has stopped, the height to the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (H2/H1 in the diagram). This is an indication of the passing ability. The horizontal section of the box can be marked at 200 mm and 400 mm from the gate. T20 and T40 are the time taken to reach these points. These are the indications of ease of flow of the concrete.

Table 4: Suggested Value of acceptance for different test methods of SCC

Sl. No.	Methods	Unit	Typical range of Values	
			Min.	Max.
01	Slump flow by Abrams cone	Mm	600	800
02	T_{50}cm slump flow	Sec	2	8
03	V-funnel	Sec	6	12
04	L-Box	(h_2/h_1)	0.8	1.0

Table 5: Test results on Fresh concrete

Sl. No.	Methods	Unit	Values
1	Slump flow by Abrams cone	Mm	755
2	T_{50cm} slump flow	Sec	4
3	V-Funnel	Sec	8
4	L-box	h_2/h_1	0.9

4. Casting and testing of specimens

Total 18 slabs (6 series – 3 in each series), each of size 700mm (length) x 300mm (width) x 40mm (thickness) were casted. The weld mesh layers were bundled with binding wire and placed in the mould keeping a minimum cover of 6mm. All these specimens were cured for 28 days. Concrete cubes were also made while casting of slabs. The primary variables considered are (i) number of layers of weld mesh and (iii) percentage of Shaktiman steel fibers i.e(0.25% and 0.5%). The details of the specimens are presented in Table 5.

Table 6: specimen details

Specimen ID	Layers of weld mesh (bundled)	Shaktiman steel fibers (%)
A1	1	0
A2	1	0.25
A3	1	0.5
B1	2	0
B2	2	0.25
B3	2	0.5

All the 18 slab specimen were tested under the loading frame and the load is applied by means of a proving ring of capacity 25T. The dial gauge of 0.01mm least count and 25mm range were fixed under the loading point to measure the deflection The load was applied as two symmetrically arranged concentrated loads. The deflections were measured for each interval of load increment .Various loads such as crack initiation and ultimate loads and corresponding deflections were also recorded .The crack patterns of the specimens are also observed.

Fig 2: Test setup of specimens under flexural loading

5. Crack patterns

The following figure 3 and figure 4 shows some of the crack pattern of specimens.

Fig 3:Crack pattern on the surface

Fig 4: Crack pattern on the edge

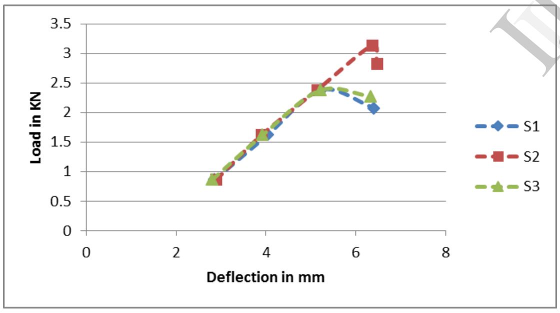

Fig 5: Load Vs Deflection for slabs of series A1

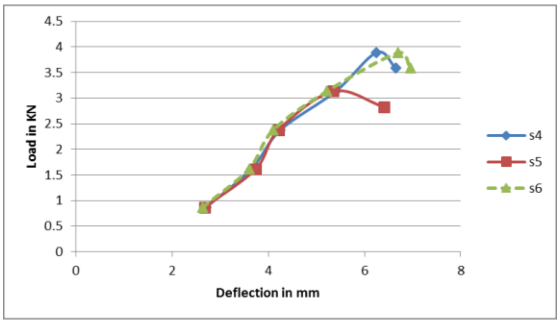

Fig 6: Load Vs Deflection for slabs of series A2

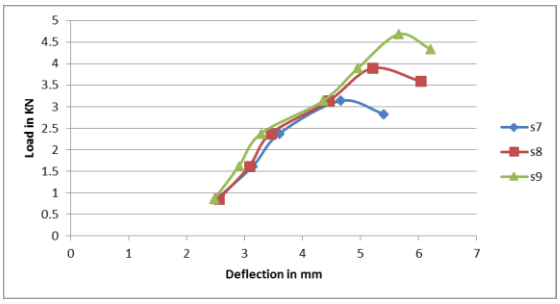

Fig 7: Load Vs Deflection for slabs of series A3

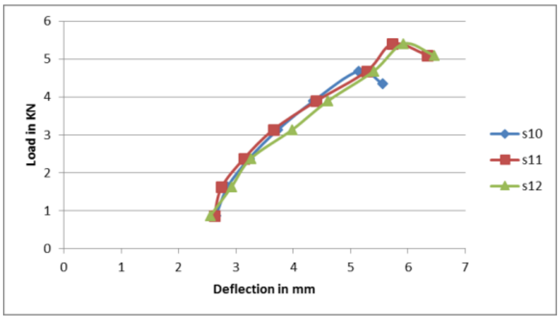

Fig 8: Load Vs Deflection for slabs of series A4

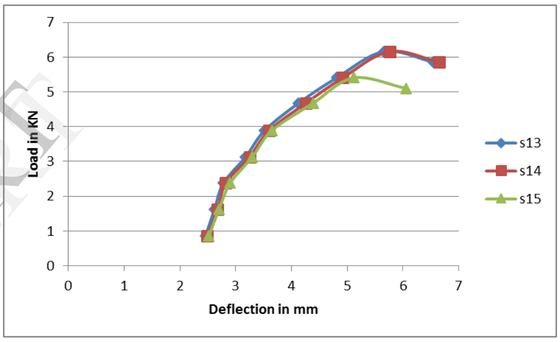

Fig 9: Load Vs Deflection for slabs of series A5

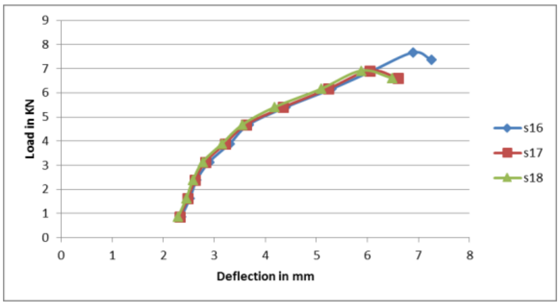

Fig 10: Load Vs Deflection for slabs of series A6

Table 7: Experimental Results

Specimen ID	Ultimate	
	Load Pu (KN)	Deflection Δu (mm)
A1	3.134	6.36
A2	3.891	6.7
A3	4.68	5.65
B1	5.405	5.92
B2	6.162	5.76
B3	7.676	6.9

6. Conclusion

1. From the study, it was observed that the load carrying capacity and deformation at ultimate load are high in case of SCC ferrocement shaktiman steel fibers.
2. The stiffness of the specimens with 1-layer bundled weld mesh is lower than that of the specimens with 2 layers bundled.
3. The study shows that the fibrous self compacted concrete at 0.5% fibers content exhibits better performance in flexure in comparison with non fibrous and 0.25% fibers content.
4. These tests will be useful for damage tolerant design of SCC ferrocement structural components subjected to variety of loadings.
5. Further, it is observed that there is reduction in the number of formation of cracks in case of SCC ferrocement slab with high percentage of shaktiman steel fibers i.e 0.5%.

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