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Experimental Investigation on Self-Compacted Hybrid fibres reinforced Ferrocement slabs Externally Strengthened by GFRP

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Abstract : *Self-Compacted Hybrid fibres reinforced Ferro cement slabs are tested for their flexural behaviour and have been strengthened externally by GFRP. Totally18 slabs were casted the size of the slab includes 650mm X 300mm X 60mm. The varying parameter in this study includes percentage of hybrid fibres, number of layers of welded PVC coated wire mesh and number of layers of strengthening with GFRP laminates. Testing of slabs were done under two point loading setup. Test results for various parameters of study such as percentage of hybrid fibres and number of wire mesh and number of GFRP layers have been briefly discussed.*

Keywords *- Self-compacting concrete, Hybrid fibres, Ferrocement slabs ,GFRP laminates, Flexural behaviour.*

I. Introduction

Self-compacting concrete (SCC) is an innovative concrete that does not requires vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same mechanical properties and durability as traditional vibrated concrete. Ferrocement construction technology is quite popular throughout the world. Ferrocement, a thin element, is used as a building construction as well as a repair material. This paper attempts to review the literature on ferrocement and bring out the salient features of construction, material properties and the special techniques of applying cement mortar on to the reinforcing mesh. The success of ferrocemment largely depends on its durability aspects and corrosion problems of thin reinforcing wire or welded mesh. As a laminated composite, ferrocement often suffers from spalling of matrix cover and delamination of extreme tensile layer. Combining the advantages of self-compacted concrete and ferrocement technique new hybridization in construction of RCC structures can be made. In order to overcome the above effects this project focuses on the various steps to be adopted in order to minimize the defects in ferrocement slabs.

Ferrocement concrete being a thin laminated composite matrix with wire mesh with small diameter of rods and cement sand matrix undergoes delamination at extreme tensile layer. Based on recommendations from past researches addition of discontinuous fibers increase tensile strength. Hybrid fibres include the combination of micro synthetic fibers with steel fibers or micro synthetic fibers with macro synthetic fibers. Hybrid fibre can be divided into following combination; the first type is based on the fiber constitutive response in which one of the fibers is stronger and stiffer and which provides stiffer and reasonable for first cracks strength and also ultimate strength. While the second type of fiber is relatively flexible and leads to improvement in toughness and strain capacity in the post cracking zone. The second type of combination is based on the combination of different aspect ratio. Short fiber bridges micro cracks, controls the growth of the cracks and also delays the coalescence in the fiber reinforced concrete. Long fibers prevent the propagation of macro cracks and then improve the fracture toughness of the composites. This work also aims at strengthening of slabs with GFRP both unidirectional and for bidirectional. GFRP is so chosen as is most resistant to acids and solvents and have fatigue resistance compared to aramid or carbon fibers polymers.

II. Significance of Research

A study on the behaviour of optimum dosage by volume of cement from 0% to 1% of Hybrid fibers (Steel and Poly ester) to get maximum strength for the M30 grade SCC concrete and to find out effect of variation in percentage of fibers on properties of concrete i.e Workability, Compressive strength, and split tensile strength. Test results showed that only on 0.75% of steel fibers with 0.25% of polyester fiber passed the test results as recommended by EFNARC guidelines of SCC. This work focuses on strengthening of self-compacted ferrocement slabs incorporated with hybrid fibers by GFRP(E type glass fibres) laminates and its increased flexural behavior and compared with unstrengthened slabs.

III. Experimental Investigation

3.1 MIX PROPORTION OF SCC

Ordinary Portland Cement 53 grade has been used in this study as per EFNARC guidelines. Class F fly ash has been used for the study as it has good cementious properties. Super plasticizer used under study is MASTER GELINUM SKY 8650 which is a polycarboxylic ether. Fine aggregate most of which passes through a 4.75 mm IS sieve and contains not more than 5 per cent coarser material of specific gravity 2.6 and Coarse aggregate of standard IS sieve in which 10mm passing and 12.5mm retaining of specific gravity 2.85. Table 1 indicates the properties of fibers used.

TABLE 1 PROPERTY OF FIBRES

Description	Steel	Polyester
Type	Crimped	Triangulated
Length	12.5mm	6mm
Diameter	0.45mm	0.30mm
Aspect ratio	33	30

Various trail mixes have been done as per EFNARC guidelines which are listed below

TABLE 2 TRAIL MIX PROPRTION FOR SCC USING FLYASH

SL. NO.	**Mix**	**Cement Kg/m^3**	**Flyash Kg/m^3**	**F.A Kg/m^3**	**C.A Kg/m^3**	**Water Kg/m^3**	**SP Kg/m^3**	**W/P Ratio**
1.	T1	375	175	785	735	214.5	3.85	0.39
2.	T2	375	175	785	735	214.5	4.4	0.39
3.	T3	375	175	785	735	214.5	4.95	0.39
4.	SCC1	315	175	785	735	214.5	5.5	0.39
5.	SCC2	375	175	785	735	214.5	6.05	0.39
6.	SCC3	375	175	785	735	214.5	6.6	0.39

For all trial mix proportions of SCC water cement ratio 0.4 is adopted, 30% of fly ash is replaced with cement is kept costant. Glenium percentage is varied from 0.7% to 1.2%.From various trial mix for SCC the trial mix with 1.1% Glenium satisfied the basic test results of SCC.

TABLE 2.2 FINAL MIX PROPORTIONS FOR M30 GRADE

CEMENT (kg/m^3)	FLY ASH (kg/m^3)	FINE AGG. (kg/m^3)	COARSE AGG. (kg/m^3)	WATER (LITERS)	SP (%)	W/P Ratio (%)
375	175	785	735	214.4	1.1	0.39

The following tests has to be conducted as per EFNARC guidelines

3.2 TESTS CONDUCTED FOR SCC

Various test methods for workability properties of SCC are listed in table No.3.1

TABLE 3 TESTS FOR WORKABILITY PROPERTIES OF SCC

SL.NO	**METHODS**	**PROPERTY**
1	Slump flows by Abrams cone	Filling ability
2	T50cm slump flow	Filling ability
3	J-ring	Passing ability
4	V-funnel	Filling ability
5	V-Funnel at T 5minutes	Segregation resistance
6	L-box	Passing ability

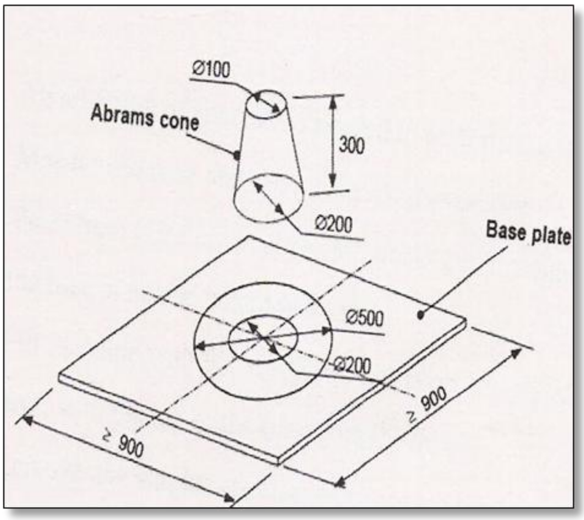

Fig 3.1 Slump Flow Test Apparatus

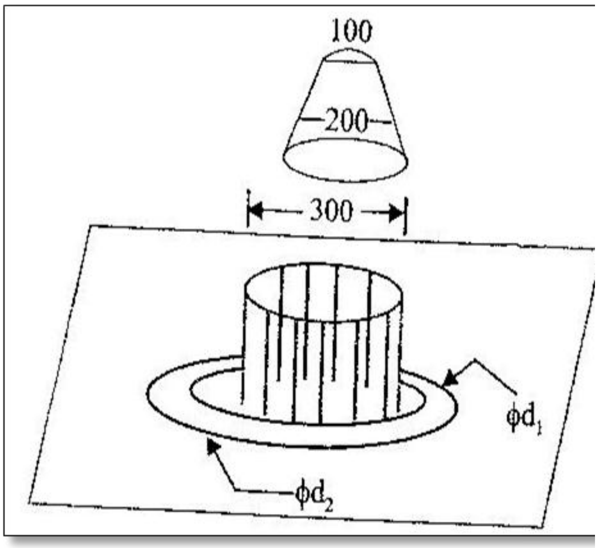

Fig 3.2 J-ring test apparatus

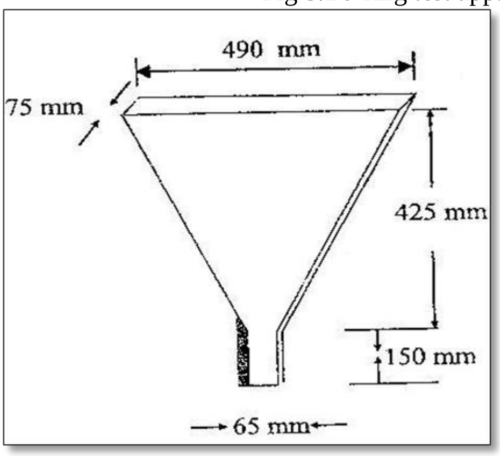

Fig 3.3 V-Funnel Test Apparatus

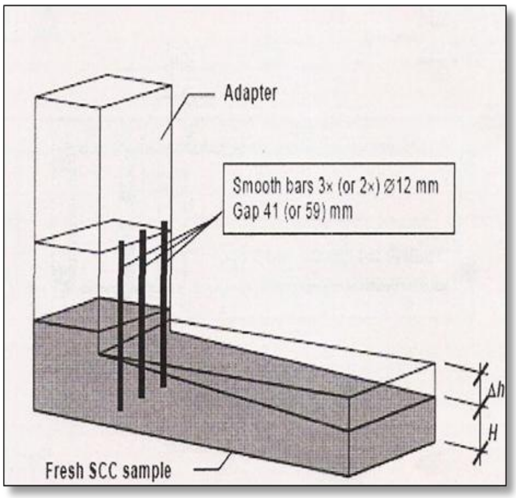

Fig 3.4 L Box Test Apparatus

TABLE 3.1 ACCEPTANCE CRITERIA FOR SCC

S.No	Methods	Unit	Typical range of value	
			Minimum	**Maximum**
1	Slump flows by Abrams cone	mm	650	800
2	T50cm slump flow	S	2	5
3	J-ring	mm	0	10
4	V-Funnel	S	6	12
5	V-funnel at T 5minutes	S	0	+3
6	L-box	(h_2/h_1)	0.8	1.0

TABLE 3.2 TEST RESULTS OF SCC WORKABILITY PROPERTIES

Trail mix	Slump flow (mm)	T50 (s)	V-funnel (s)	V-funnel @ T5min	L-box	J-ring (mm)
T1	540	8	25	80sec	0.4	18
T2	560	6	20	60sec	0.5	15
T3	585	7	18	50sec	0.5	12.5
SCC-1	650	4	10	12sec	0.7	9
SCC2	680	2	8	10sec	0.9	8
SCC-3	685	3	10	10sec	0.85	8

Based on various trail proportions of varying the fibre fraction out of which 0.75% of steel and 0.25% of polyester fibre proportion alone satisfied the SCC criteria and hence it has been chosen as optimum dosage.

3.3 CASTING OF SPECIMENS

Total of 18 self-compacted ferrocement slabs reinforced with hybrid fibres were casted of size 650mm X 300mm X 60mm which comprises of PVC coated welded wire mesh in order to overcome corrosion. The structural steel used is of 6mm diameter with spacing of 100mm c/c . The numbers of mesh layers are varied in order to study the flexural load carrying capacity of slabs. Strengthening of slabs were done with GFRP laminates made of E type of glass fibres. Slabs were strengthened in unidirectional i.e. fibre orientation of GFRP were done along the longer span of the span as it improves flexural load carrying capacity with single and double layer of GFRP. Strengthening with GFRP were done carefully such that the surface was kept clean from dirt and then coated with polyester premixed with accelerator cobalt nitrate and catalyst peroxide and then GFRP laminated have been placed above and rolled in order to remove air bubbles. After strengthening with GFRP slabs were dried for 7 days and then tested in loading frame of two point load setup. The compressive strength, splitting tensile strength of cubes and cylinder respectively and flexural strength of slab are listed below.

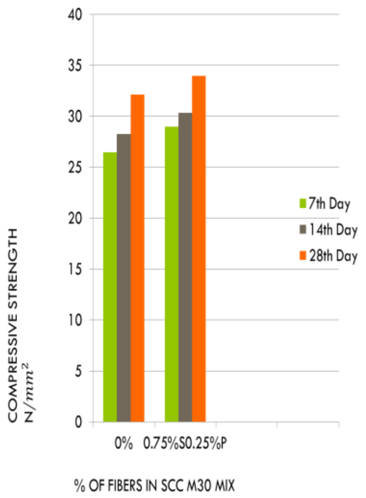

FIG.3.5COMPRESSIVE STRENGTH TEST RESULTS

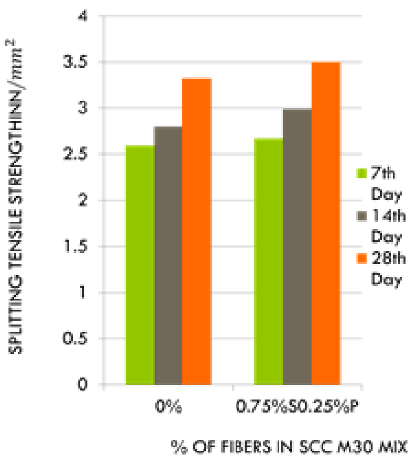

FIG.3.6: SPLITTING TENSILE STRENGTH RESULTS

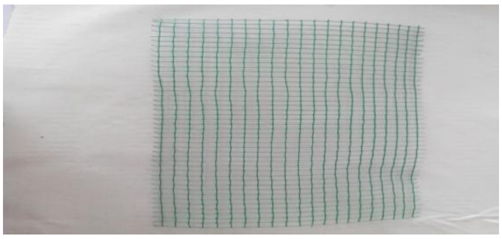

FIG.3.7: PVC COATED MESH

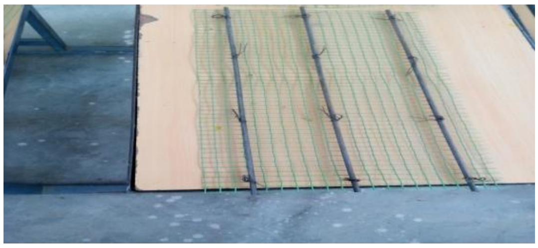

FIG.3.8: MESH WITH SKELETAL STEEL

FIG.3.9.SCC MIX WITH HYBRID FIBERS

FIG.3.10: LAYING OF MESH WITH SKELETAL STEEL

FIG.3.11: LAYING OF SCC LAYER BY LAYER

FIG.3.12: FINISHED SLAB

FIG.3.13 STRENGTHENED SLAB WITH GFRP

3.4 TEST SETUP

3.5 TEST RESULTS

For self-compacted hybrid fibers reinforced ferrocement slabs were tested in loading frame of 50 Tonne capacity. Ferrocement slabs were tested under two point loading with load cell of 250kN dial gauges of 0.01mm accuracy where placed at mid span and at l/3 distance of slab. Deflection for corresponding load were noted and plotted in the form of graph.

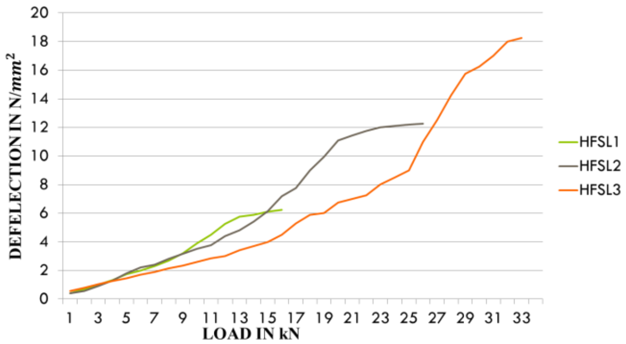

FIG.3.14 LOAD vs MIDSPAN DEFLECTION FOR SELF-COMPACTED FERROCEMENT SLABS WITH FIBRES

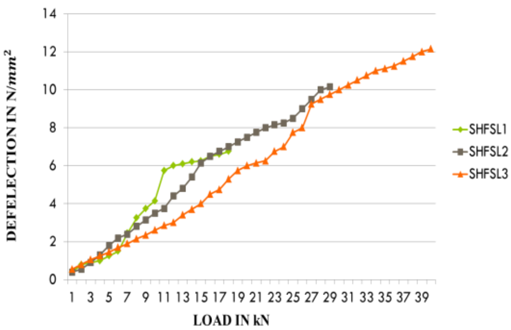

FIG.3.15 LOAD vs MIDSPAN DEFLECTION FOR STRENGTHENED SELF-COMPACTED FERROCEMENT SLABS WITH FIBERS

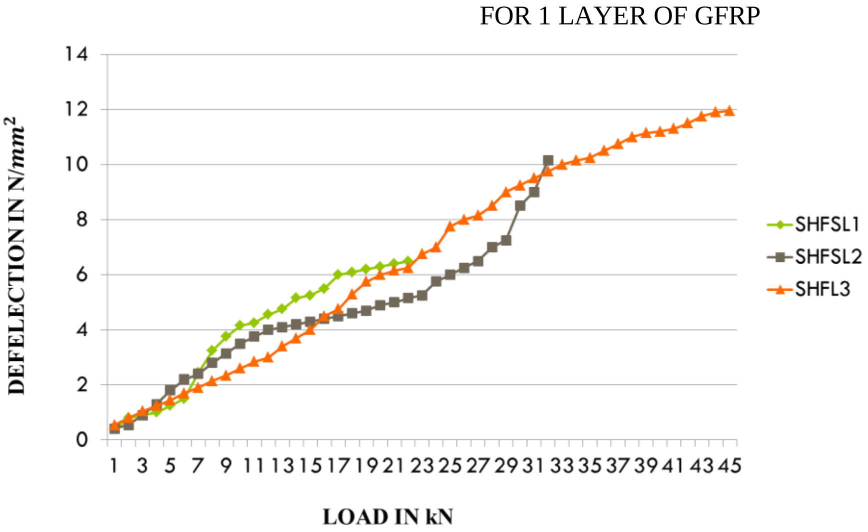

FIG.3.16 LOAD VS MIDSPAN DEFELECTION FOR STRENGTHENED SELF-COMPACTED FERROCEMENT SLABS WITH FIBERS FOR 2 LAYER OF GFRP

IV. CONCLUSION

From the present study following conclusions are made:

1. Mix proportion for SCC of grade M30 has been found out from various trial mixes.
2. Volume fraction of hybrid fibers for M30 SCC using steel and triangulated polyester has been found to be 0.75% and 0.25% respectively for 1% of total volume fraction.
3. Increasing the number of wire mesh in ferrocement self-compacted concrete slabs showed increase in flexural strength of slabs.
4. Hybrid fiber reinforced self-compacted ferrocement slabs showed delayed initial cracks at which intial cracks propagated at application of load at 5 kN for 1 layer and at 12kN for 2 layered mesh and 19 kN for 3 layered mesh with that of without fibre the cracks propagated at 4 kN for 1 layered , 10kN for layer 2 and 14 kN for layer 3 of wire mesh in slabs.
5. GFRP Strengthened with 1 layer slabs showed better flexural behavior than the slabs without strengthening. The defelection were also much reduced compared to the control specimen. The load carrying capacity of 1 layer of GFRP strengthened slab was 1.2 % increased compared to control specimen.
6. For 2 layers of GFRP strengthened slab showed increased flexural behavior than control specimen and the load carrying capacity increased to 1.36%.

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