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Study on Flexural Behaviour of Hybrid Ferrocement Slabs

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Abstract:
Inmultistorey building structures the slab and floor units account for something like 50 to 60% of the material requirements. The thickness of the slabs is selected so that deflections and cracks will not be a problem. However, for very heavily loaded slabs, such as slabs supporting large-span lengths and slabs of the garage, it is unavoidable that the self weight of the slabs will be increased because the thickness of those slabs must be increased. Slabs are the most widely used structural elements of modern structural complex. The cast in – situ reinforced concrete roof floor slab is the simplest form of slab construction, but it is rather wasteful in materials particularly cement. Substantial savings can be effected by modifying the composition of the slab so that its weight is reduced without imparing its strength or behaviour. For that we go for ferrocement slabs. 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. In order to overcome the above effects this study focuses on the various steps to be adopted in order to minimize the defects in ferrocementslabs. This paper presents the details of self compacting concrete (SCC) ferrocement slab panels incorporating micro steel fibers and polyester fibers (RECORN 3 S) under flexure. A total of 18 slab panels have been casted. The size of the slab is 650mm (length) x 300 mm (width) x 60 mm (thickness). The parameters studied in this investigation includes the number of weld mesh layers and the percentage of steel fibers and polyester fibers i.e (0.75% and 0.25%). Test procedures for self compacting (SCC) have been explained in brief. Aim of the study is that observation of the load carrying capacities, deformation at ultimate load.

Keywords: *Self compacting concrete, ferrocement slab, hybrid fibers (steel fibers and polyester), pvc coated mesh, deflection, crack*

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 the 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 undergone 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 lots of attention of the concrete technologists. This type of study has resulted in the development of Self Compacting Concrete (SCC), a much-needed revolution 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 selfweight 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 consists 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 works 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.

1.1. Litreature Review

P.B. Sakthivel & A. Jagannathan investigated flexural load behavior on PVC coated and GI coated welded wire mesh made of ferrocement slabs with varying layers from 1 to 3 and thickness of slab accordingly with number of meshes. The dimension of the specimen was 700×200×15mm and s/c ratio was 1:2.For slabs using PVC meshes, the ultimate loads were found to increase by about 24.68% (i.e., from 0.474 kN to 0.591 kN) when the mesh layers were increased from 1 to 2, and found higher by 36.38% (i.e., from 0.591 kN to 0.806 kN) when 2 layer mesh is increased to 3 layers. Increasing the number of weld mesh layers in slabs with GI meshes from 1 to 2 causes to increase the ultimate load by about 33.26% (i.e., from 0.484 kN to 0.645 kN) and for 2 to 3 layers, the load has increased by 41.70%k (i.e., from 0.645 kN to 0.914 kN). This implies that PVC-coated steel weld mesh is as effective as GI coated weld mesh for use as reinforcement in ferrocement slabs. The author recommends, optimum number of mesh layers for 15 mm thick ferrocement slabs is 3 layers, this study suggests that in order to increase the flexural load capacity and ductility, as well as decrease the crack-width of ferrocement slabs, discontinuous fibers may be used as additional reinforcement.

Randhir J. Phalke & Darshan G. Gaidhankar investigated the effect of using different no of wire mesh layers on the flexural strength of flat ferrocement panels and to compare the effect of varying the number of wire mesh layers and use of steel fibers on the ultimate strength and ductility of ferrocement slab panels. The no of layers used are two, three and four.Slab panels of size 550×200×25 mm are reinforced with welded square mesh with varying no of layers of mesh. Panels were casted with mortar of mix proportion (1:1.75) and water cement ratio (0.38) including super plasticizer (Perma PC-202) with dosage of 1% of total weight of cement. Some panels were casted with steel fibers of 0.5% of total volume of composite and aspect ratio as 57. Totally 18 specimens were cast. Incorporation of steel fibers along with an increment in number of layers leads to 58% increase in load carrying capacity and 33% decrease in deflection.

Raj kishorsah, M. Pradeep kumar studied the general behaviour of Fiber Reinforced Ferrocement composite & the studies carried out by various investigators on ductility, Stiffness, degradation, Ultimate load carrying capacity and Energy absorption were determined. Two slab panels of size 3000 mm in length and 140 mm in depth with the breadth of 770 mm in the bottom and 690 mm in the top were cast. The specimens were placed on the Self Straining load frame. The load applied to the slab was cyclic loading with an increment of 5kN. The top and bottom strains of the Fiber Reinforced Ferro cement Hollow Slab are measured by means of curvature meter. Moment, curvature, relative and cumulative ductility factor, stiffness degradation, relative and cumulative energy absorption capacity for ferrocement slab without and with recorn fibers are 24.7 to 28 kNm , 2.58×10^{-2} mm^{-1} to 2.857×10^{-2} mm^{-1} , 6.712 to 7.371, 19.98 to 22.416 , 196.37 to 347 kN,2.1 kNm^2 to 2.67 kNm^2, 420.319 kN to 519.58 kN respectively. The Energy absorption for the fiber reinforced ferrocement hollow slab is 1.24 times greater than that of the ferrocement hollow slab without fiber.

1.2. Research Gap

Fibrous ferrocement is a new area of research and not many studies are available [7], [9] and hence an emphasis is needed on testing of FRF composites for impact and toughness [7]. Naaman (2000) [20]; ACI 549 [21] and Sakthivel and Jagannathan (2011) [22] have also recommended that new and innovative non-corrosive reinforcing materials may be employed in ferrocement composites and energy absorption capacity analysed under impact loads. Accordingly, Sakthivel and Jagannathan (2012 b) [23] have introduced a new non-corrosive mesh material in ferrocement, namely the PVC-coated steel weld mesh ('P' mesh) and conducted studies on flexural strength, and Sakthivel and Jagannathan (2012 c, d) [24], [25] on impact strength, and found that 'P' mesh is compatible with ferrocement. Subsequently, Sakthivel et al. (2012 a) [26] have experimented on cementitious matrix reinforced with discontinuous Stainless Steel (SS) fibers, and found out that there is an increase not only in its engineering properties such as compressive, split-tensile and mortar flexural strength but also in the energy absorption level of cementitious slabs when the percentage of SS fibers is increased from 0.5% to 2.5%. Further, Sakthivel et al. (2012 b) [27] researched upon the influence of SS fibers (0.5-2.5%) on ferrocement slab elements reinforced with several layers of 'P' mesh, and the results show that there has been an increase in the energy absorption of FRF slabs.

2. Experimental Investigation

The experimental investigation consists of casting of of eighteen SCC ferrocement slabs. The variables considered in the study (i) number of layers of weld mesh and (ii) addition of fibers(1% of volume fraction of steel fibres and triangulated polyester fibres). Various trial mix proportions were done to satisfy SCC acceptance with choosen hybrid fibers steel i.e. fibres and triangulated polyester fibres , out of which best satisfied proportion has been choosen for ferrocement slabs.

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. 10-12 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 steel fibers. To make the mix more workable, chemical admixture MASTER GELINUM SKY 8650 is used. Trail mixes where prepared mix 1 mix 2 and mix 3. For the case of mix 3 0.75% by weight of cementitious material is added as steel fibers and 0.25% polyester fibers by weight of cementitious material is added. The quantities of materials are presented in Table 2.

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

Table 1: Properties of Fibers Used

Materials	**Trail Mix 1 Kg/m^3**	**Trail Mix 2 Kg/m^3**	**Trail Mix 3 Kg/m^3**
Cement	375	375	375
Water	214.5	214.5	214.5
Fly ash	175	175	175
Fine aggregate	785	785	785
Coarse aggregate	735	735	735
S.P.	5.5	6.05	6.6
Steel fibers	-	-	15.525
Polyester fibers	-	-	5.175

Table 2: Mix Proportion

Weld mesh is arranged in different layers in ferrocement slab instead of reinforcement. Weld mesh of size 620 mm X 270 mm with grid size 12.5 mm X 12.5 mm and 6 mm dia. Skeleton reinforcement is used at 100 mm c/c for the casting of ferrocement slabs. Weld mesh layers (1,2and 3) are tied with binding wire keeping a clear cover of 12mm from the bottom of the slab Fig. 1 shows the weld mesh adopted in the present study.

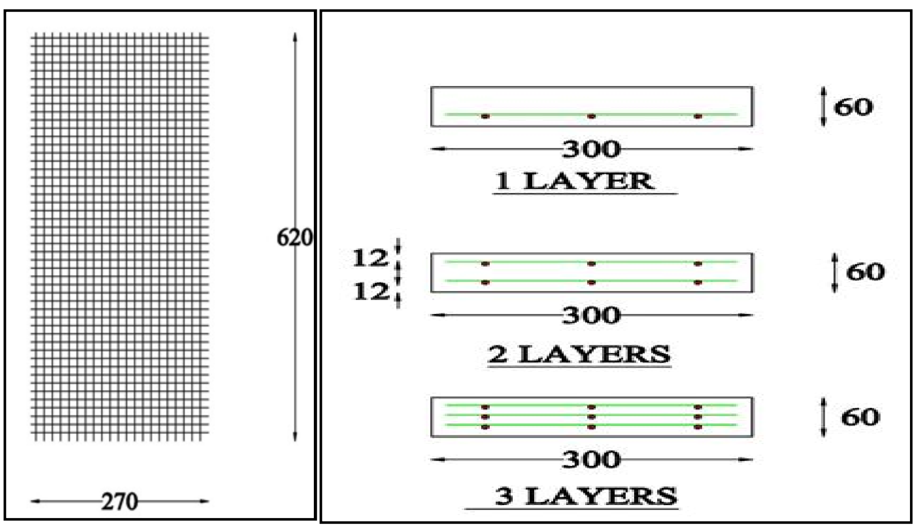

Figure 1: Mesh Reinforcement and Details of Specimen

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.

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. T50 is the time required in seconds for concrete to cover 50cm diameter spread from the time of lifting of the slump once. The T50 time is a secondary indication of flow. It may give some indication of resistance to segregation. Lower time indicates a 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.

Figure 2: Slump Cone Test

3.2. V Funnel Test

The test was developed in Japan and used by Ozawa et al. 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 (T5 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.

Figure 3: V Funnel Test

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 stops, the height to the concrete at the end of the horizontal section is expressed as a proportion of that remaining in the vertical section (h_2/h_1 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.

Figure 4: L Box Test

3.4. J-Ring Test

J-ring test denotes the passing ability of the concrete. The equipment consists of rectangular section of 30 mm x 25 mm open steel ring drilled vertically with holes to accept threaded sections of reinforcing bars 10 mm diameter 100 mm in length. The bars and sections can be placed at different distance apart to simulate the congestion of reinforcement at the site. Generally, these sections are placed 3 x maximum size of aggregate. The diameter of the ring formed by vertical sections is 300mm and height 100 mm.

Figure 5: J Ring Test

METHODS	UNITS	TYPICAL RANGE OF VALUE	
		MINI.	MAX.
Slump flows by Abrams cone	mm	650	800
T50cm slump flow	Sec	2	5
J-ring	mm	0	10
V-Funnel	Sec	6	12
V-funnel at T 5minutes	Sec	0	+3
L-box	(h_2/h_1)	0.8	1.0

Table 3: Suggested Value Acceptance as SCC

Trail mix	Slump flow (mm)	T50 (sec)	V-funnel (sec)	V-funnel @ T5min	L-box	J-ring (mm)
1	645	4	9	13sec	0.7	9
2	685	3	6	11sec	0.9	8
3	695	2	10	10sec	0.8	7

Table 4: Test Results for SCC without Fibers

Trail mix	Slump Flow (mm)	T50(sec)	V-funnel (sec)	V-funnel @ T5min	L-box	J-ring (mm)
1	675	2	10	12sec	0.7	7
2	680	3	11	13sec	0.8	8
3	690	4	12	14sec	0.85	9

Table 5: Test Results for SCC with Fibers

4. Casting and Testing of Specimens

Total 18 slabs (6 series – 3 in each series), each of size 650mm (length) x 300mm (width) x 60mm (thickness) were casted. The weld mesh layers were bundled with binding wire and placed in the mould keeping a minimum cover of 12mm. All these specimens are 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 steel fibers and polyester fibers i.e. (0.75% and 0.25%). Test results for compressive strength and splitting tensile strength are presented in the figure below.

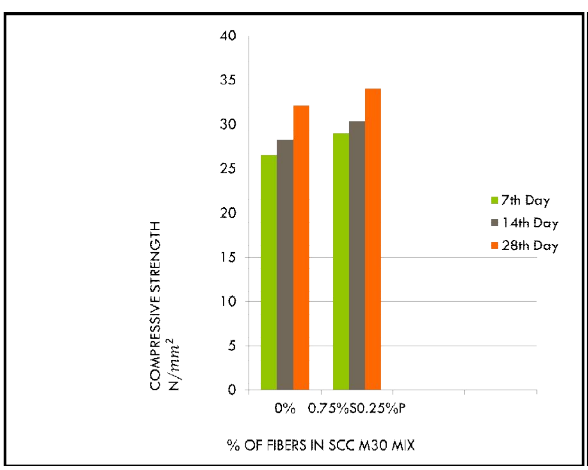

Figure 6: Compressive Strength Test Results

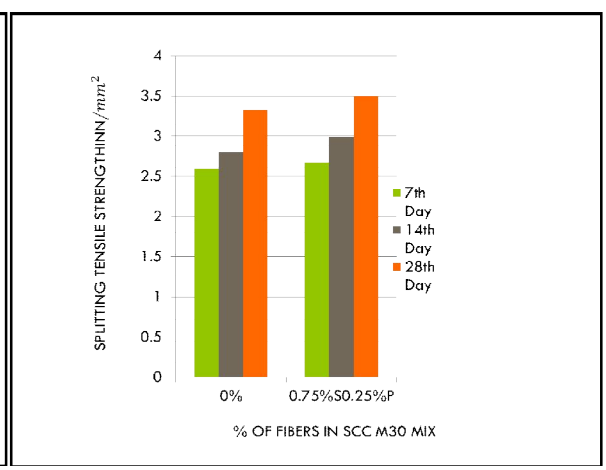

Figure 7: Splitting Tensile Strength Results

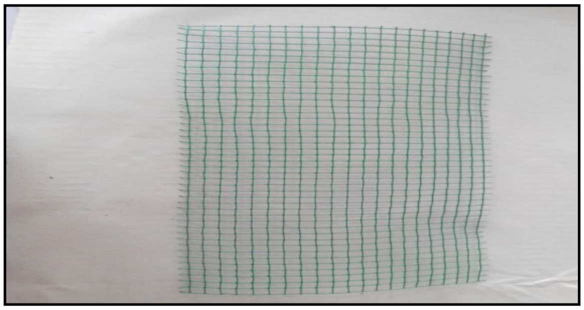
Figure 8: PVC Coated Mesh

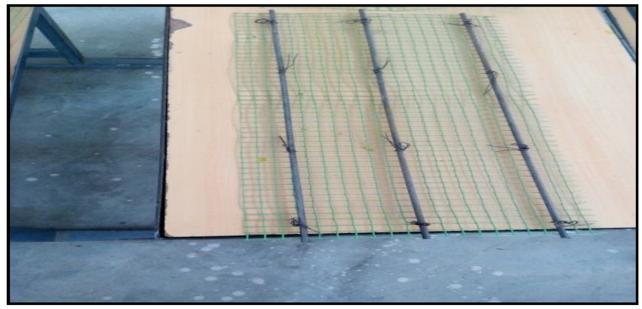
Figure 9: Mesh with Skeletal Steel


Figure 10: Laying of Mesh with Skeletal Steel

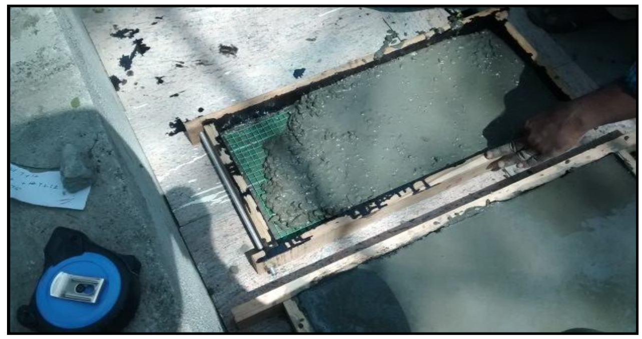
Figure 11: Laying of SCC Layer by Layer


Figure 12: Finished Slab

4.1. Testing of Specimens

Ferrocement slabs were tested in a 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 were placed at mid span and at l/3 distance of slab. The load setup as indicated below.

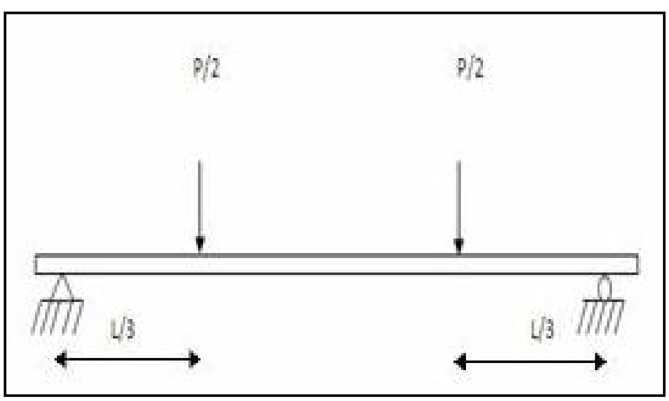

Figure 13: Load Setup

Figure 14: Testing of Ferrocement Slabs

4.2. Test Results

The test results for ferrocement slabs with and without hybrid ferrocement slabs are represented in graph below.

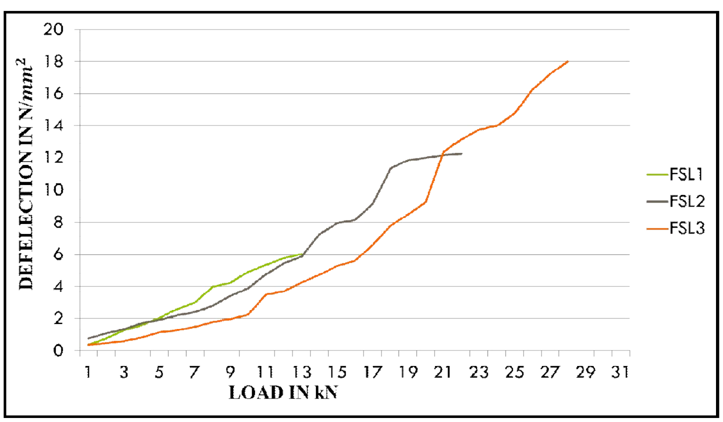

Figure 15: Load Vs Midspan Deflection for Self-Compacted Ferrocement Slabs Without Fibre

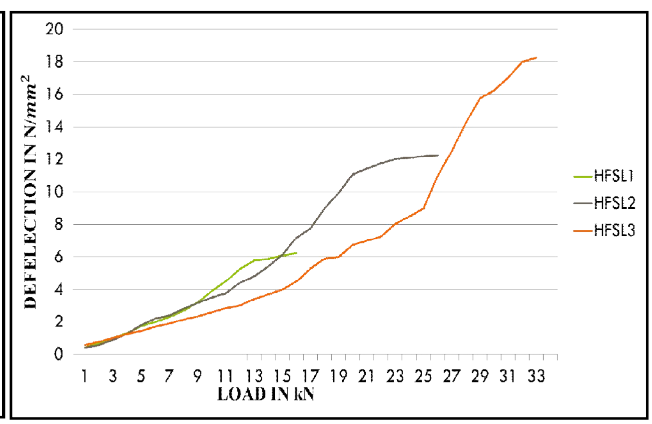

Figure 16: Load Vs Midspan Deflection for Self-Compacted Ferrocement Slabs with Hybrid Fibres

5. 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 the total volume fraction.
3. Increasing the number of wire mesh in ferrocement self-compacted concrete slabs showed an increase in flexural strength of slabs.
4. Self-compacted one-way ferrocement slabs for chosen span, under two point loading with 3 layers of wire mesh has the showed high load carrying capacity to withstand load upto 28 kN.
5. Hybrid fiber reinforced self-compacted ferrocement slabs showed delayed initial cracks at which initial 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.
6. Hybrid fiber reinforced self-compacted one-way ferrocement slabs with 3 layered mesh has highest flexural strength of 117.85% with that of self-compacted one-way ferrocement slabs without fibers.

6. References

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