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Research Article

SIMPLY SUPPORTED STEEL FIBER REINFORCED FERROCEMENT SLABS

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ABSTRACT

This article presents the behavior of ferrocement slabs reinforced with low strength steel fibers. The ferrocement slab were fabricated with dimensions of 1.0x0.84x0.035m and provided chicken mesh in one and two layers along with the discrete fibers in the proportion of 0, 0.5, 0.75, 1.0 and 1.50% by volume of specimen. Total 20 slabs were cast and tested in the laboratory under uniformly distributed load with all edges simply supported. First crack and ultimate load capacity of the slabs were noticed for each slab. The results revealed that 1% of fibers volume is effective to take the more loads when compared to other dosages of fibers. The crack width was decreased for slabs which consist of steel fibers when compared with slabs without steel fibbers. The reserved factor (failure load/ cracking load) for the slabs varied from 1.75 to 2.64.

INTRODUCTION

Ferrocement is a form of reinforced concrete that differs from conventional reinforced or pre stressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. Raw materials for ferrocement construction in developing countries are easily available, and it could be constructed in any complicated shape, whereas it needs low level of skill which is required. This kind of material has superior strength properties as compared to conventional reinforced concrete.

Normal unreinforced concrete is brittle with a low tensile strength and strain capacity. Ordinary concrete includes numerous micro cracks which are rapidly increased under the applied stresses. These cracks are responsible of the low tensile, flexural strength, and impact resistance of concrete. The fibrous reinforced concrete is a composite materials essentially consisting of concrete reinforced by random placement of short discontinuous, and discrete fine fibers of specific geometry. It is now well established that the addition of short, discontinuous fibers plays an important role in the improvement of the mechanical properties of concrete. It increases elastic modulus, decreases brittleness; controls crack initiation, and its subsequent growth and propagation. Deboning and pull out of the fibers require more energy absorption, resulting in a substantial increase in the toughness and fracture resistance of the material to cyclic and dynamic loads. Concrete, the dominant construction material in our time, suffers from a major shortcoming; it cracks and fails in a brittle manner under tensile stresses caused by external loading or restrained shrinkage movements. Concrete failure initiates with the formation of micro cracks which eventually grow and coalesce together to form macro cracks. The macro cracks propagate till they reach an unstable condition and finally result in fracture. Thus, it is clear that cracks initiate at a micro level and lead to fracture through macro cracking. Fibers, used as reinforcement, can be effective in arresting cracks at both micro cracks and macro cracks from forming and propagating. In this view the present experimental work has been planned to study the behavior of ferrocement slab panels reinforced with chicken mesh and discrete low strength steel fibers with aspect ratio of 5. In this view recent past works has been placing here in to know the status of work progressed in this area.

P.Paramasivam (2001) presented the applications of ferrocement and some case studies based on research work carried out in national university of Singapore. Ferrocement can provide good crack control, better durability and long life

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cycle cost compared to conventional reinforced concrete. A.S.Alnuaimi *et al*, (2006) conducted experimental study on nine roof panels made of ferrocement. Results showed that two types of section showed closer failure loads and deflection. All panels showed acceptable cracking and failure load for roofing systems. Boshra Aboul-Anen *et al*,(2009) studied the composite action of ferrocement slabs and steel sheeting. Experimental models of ferrocement slabs with and without steel sheeting and their numerical models using Finite element method were developed. The behavior of slab through non linear response and up to failure was simulated using ANSYS package. The comparison between the theoretical and experimental models was presented. Y.B.I. Shaheen *et al*, (2013) conducted experimental investigation on possibility of using ferrocement concrete in water supply pipe. Finite element models were developed and comparisons between theoretical and models were reported. Ezzat.H.Fahmy *et al*, (2014) conducted an experimental program and a theoretical model was adopted to develop reinforced concrete beams consisting of precast permanent U-shaped reinforced mortar forms filled with different types of core materials to be used as a viable alternative to the conventional reinforced concrete beam. The experimental results showed that better crack resistance, high serviceability. Good energy absorption could be achieved by using proposed beams. The results compared well with the experimental values. G. Murali *et al*,(2014) conducted an experimental investigation to study properties(impact resistance and energy absorption) of reinforced ferrocement plates under impact load. The results showed expanded metal mesh light has higher energy absorption and are effective in controlling the cracks. Hamid Eskandari and Amirhossein Madadi (2015) stududied and provided an experimental sample to assess deflection in a standard ferrocement channel. The Abaqus Unified finite element analysis (FEA) has been also used to model the ferrocement channel by various system supports and beam spans. The obtained results indicated the acceptable accuracy of FE simulations in the estimation of experimental values. Such models can thus be used as quick, simple, and inexpensive methods to calculate the optimal deflection of ferrocement channels for various spans and sizes of tensile reinforcement. Rahul Reddy and vaijanath Halhalli (2015) studied the ductile characteristics of hybrid ferrocement slab incorporating poly propylene fibers and GFRP sheet. The GFRP wrapped ferrocement slabs showed high ductility than that of conventional ferrocement slabs and presence of fibers reduce the cracks. Er.A.Murali Dharan and Er.P.Ragunathapandian (2016) studied the flexural failure of flanged beam under various ranges (60% to 70%) of loading for ultimate strength of control beam. Results showed hat in rehabilitation of reinforced structures ferrocement is a feasible alternative materials. S.Priya vadana *et al*,(2016) took up to study the design and analysis of building using Staad and construction of ferrocement store room and also concluded that flexural behavior of ferrocement slab is higher. Shubham R.Dakhane *et al*, (2016) presented a review work on ferrocement and its properties and also focused on structural behavior of ferrocement and concluded that it can be a viable material in upcoming years. Amol Dilip thorat *et al*, (2017) took up to study the effect of using 2 layers of chicken wire mesh on flexural strength of flat ferrocement slab panels. Results showed that panels with more number of layers exhibits greater flexural strength and less deflection as that compared with panels having less number of layers of mesh. K.Vetri adithya and Dr P.chandrasekaran (2017) carried out review on journals which have considered Ferrocement as the high performance face sheets encasing aerated concrete as lightweight infill material. The ferrocement panels which are known for their high bending capacity are suggested to replace the conventional rebar mat in the tension face of the slab and also used as encasements on both the sides of the slabs. M.Amala and Dr.M.Neelamegan (2017) conducted study on structural behavior of ferrocement slabs and its mechanical properties. Slabs made of copper are more effective in flexure and other mechanical properties. It is also found that a copper sag content is increased kinetic energy. From the recent past literature it is observed that no work has been taken up with low strength of steel fibres in the ferrocement slabs. In this view the experimental work has planned to study the effect of low stregh fibres in the ferrocement slabs. The detailed experimental work presented in the following sections and the specific objectives presented below.

Objectives

1. To study the behavior of ferrocement slabs reinforced with one and two layers of chicken mesh reinforcement.
2. To study the contribution of fibers towards influencing the strength of the ferrocement slabs.
3. To study and compare the deflection characteristics of fibrocement slabs with and without the addition fibers.
4. To arrive the optimum content of steel fibers for a particular aspect ratio to give maximum flexural strength.

Experiemental Programme

Two categories of slabs were taken for the experimental study, first category of slabs were with single layer of chicken mesh along with & without incorporation of fibers. Second categories of slabs are with double layer of chicken mesh along with and without steel fibers. In two categories of slabs the dosage fiber was 0, 0.5, 0.75, 1.00 and 1.5% by volume of specimen. Total 20 slabs were cast with dimensions of 1.00x0.84x0.035m (10 slabs with single layer and other 10 slabs with double layer chicken mesh). All the slabs made with cement mortal proportion of 1:2 (cement: sand) and the water cement ratio was adopted as 0.5. They are tested by applying gradually increasing uniformly distributed load to the slab using the 'Wiffle Tree' arrangement and the each slab was simply supported on all four edges (Fig 1). The object of program is to study the first crack and ultimate strengths of the slabs, crack pattern of the slabs and the deflections as the load increases gradually. One day before testing, the slabs were properly white washed to obtain clear picture of the cracks under different stages of loading. The detailed test program was shown in Table 1. In the table FC1 indicates as ferrocement slab with 1 layer of chicken mesh, FFC11 indicates, fiber reinforced ferrocement slab, the first numerical value represents volume of fibers [1 is for 0.5%, 2 is for 0.75%, 3 is for 1.0% and 4 is for 1.5% fibers] and second numerical value represent number of mesh layers used in the slab.

Table 1 Test program

Sl.No	Nomenclature	No of layers and details of chicken mesh		% steel fiber and details of fibers	
1	FC1	1	Average diameter of chicken mesh wire	NIL	
2	FFC11	1	0.363mm	0.50	
3	FFC 21	1	-Tensile strength of chicken mesh wire	0.75	
4	FFC31	1	960N/mm^2	1.00	
5	FFC41	1	-Area of wire 0.1035mm^2	1.50	Aspect ratio 50 -Length of fiber 48mm -Dia of fiber 0.96mm -Ultimate tensile strength of fiber 360N/mm^2
6	FC2	2	-Number of wires in longer direction 92	NIL	
7	FFC12	2	-Total area provided in longer direction	0.50	
8	FFC22	2	92x0.1035=9.52mm^2 -Number of wires in shorter direction 148	0.75	
9	FFC32	2	-Total area provided in shorter direction 148x0.1035=15.3mm^2	1.00	
10	FFC42	2		1.50	

MATERIALS

Cement: Ordinary Portland cement of grade 43 was used and the cement properties were conformed to IS code provisions.

Sand: Locally available river sand passing through 2.36mm sieve is used.

Fibers: Black steel wire of 0.96mm diameter is used by cutting the rolls to the required length of 4.8 cm to give an aspect ratio of 50.The volume percentage of fiber used is 0.75, 1.00 and 1.50. The ultimate tensile strength of fiber is 360N/mm^2

Reinforcement: Hexagonal chicken mesh of 0.363mm diameter is used. The area of reinforcement provided in shorter direction is 15.3mm^2 and in longer direction 9.52mm^2. Ultimate strength of wire is 960 N / mm^2

Test Specimens

All the slabs were cast with size of 1.0 m x 0.84 m x 0.035m and a clear cover of 6mm. The mortar mix adopted is 1:2 by weight and a water cement ratio of 0.5 is used for better workability. Hexagonal chicken mesh of 0.363 mm diameter is used as reinforcement. Steel fibers of 0.96mm diameter and 48mm long (i.e., with aspect ratio of 50) are used.

Casting of Specimens

For casting the slabs the required number of meshes were kept ready. Spacer bars of 6mm diameter at 200 mm length were placed beneath the mesh to maintain uniform clear cover of 6mm. Cement mortar of 1:2 was placed in the mould up to a depth of 6mm approximately which was the required cover for reinforcement. The first layer of reinforcing mesh was then placed over the compacted mortar. The mould was then filled with mortar to a depth of 35mm. Ten slabs were cast with single layer of chicken mesh reinforcement along with fiber dosage varying from 0.5 to 1.50%. Out of these ten slabs two slabs were made only with chicken mesh (no fibers). Similarly another set of ten slabs were cast with two layers of chicken mesh and these two layers are separated by 6 mm apart. All the slab were kept for curing for 28 days, later they were taken out and white washed before going to test.

Load Arrangement and Test Procedure

Experimental set up for loading on the slab consists of R.S. joists of 125mm x 75mm at 119 N/m run suitably arranged. By adopting the whiffle tree arrangement by using R.S Joists, the load is applied from the top at the centre point of the top R.S.joist using an hydraulic jack of capacity 25 tones and proving ring of capacity 10 tones (Fig 1). The deflections were measured using dial gauges (with accuracy of 0.001) positioned at the bottom (centre) of the slab. The load on the slab is applied in the increments of 835N corresponds to five units on dial gauge of proving ring (i.e, 5 x 167 = 835 N). Cracks propagated were observed regularly till the collapse of slab. The load at the first crack and the corresponding deflection at the bottom centre of the slab were recorded.

Figure 1 Loading arrangement

DISCUSSION OF TEST RESULTS

The information about the behavior of fibrous ferrocement slabs up to failure is presented in the following sections. During this investigation, it was found that with the addition of fibers (up to a limit) to ferrocement slabs, the first crack strength and ultimate strength increases. The behavior of ferrocement slabs cast without fibers and are compared with slabs provided with different volume percentages of steel fibers (0, 0.5, 0.75, 1.00 and 1.50 %.). The comparison is done for the following two cases.

1. Slabs with single layer chicken mesh reinforcement
2. Slabs with double layer chicken mesh reinforcement.

Effect of Steel Fibers on First Crack Strength

The first crack strength results are presented in Table 2, form this it is observed that, in single layer chicken mesh ferrocement slabs the % increase in first crack strength due to the addition of fibers is 36.40% 72.70%, 136.40% and 55% for the volume percentage of 0.5, 0.75, 1.0 and 1.5 respectively over the slab with no fibers. Similarly in double layer chicken mesh ferrocement slabs the % increase in the first crack strength due to the addition of fiber are 23.10%, 61.50%, 115.40% and 53% for the volume percentages of fibers of 0.5, 0.75, 1.0 and 1.5 respectively over the slab with no fibers.

Effect of Steel Fibers on Ultimate Strength

The ultimate strength results are also presented in Table 2, from this it is noticed that, in single layer chicken mesh ferrocement slabs, the % increase in ultimate strength are 45.80%, 75%, 95.80% and 80.50% for the volume percentages of fibers 0.5%, 0.75%, 1.0% and 1.5% respectively over the slabs reinforced with single layer chicken mesh with no fibers. For the slabs reinforced with two layer chicken mesh the % increase in ultimate strength are 40.70%, 63%, 81.50% and 70.40% for the volume percentage fibers 0.5%, 0.75%, 1.0% and 1.5% respectively over the slabs with no fibers. The variation of reserved factored is about 1.75 to 2.64.

From the load deflection curves it is observed that, the stiffness is increasing for the slabs as the fiber dosage increases. From the Table it is noticed that, the central deflection at ultimate load of the ferrocement slabs decreases when fibers are added. The decreases in deflections are 5.10%, 8.60%11.90% and 15.20% for the volume percentages of fibres 0.5%, 0.75% 1.0% and 1.5% respectively over the single layer slab with no fibres. For the double layer slabs the % decreases in deflections are 3.20%, 7.20%10.70% and 13.0% for the volume percentages of fibers 0.5%, 0.75%, 1.0% and 1.5% respectively over the slabs with no fibers.

Table 2 First Crack and Ultimate Strengths

S No.	Specimen Designation	No. of Layers	Vol. % Fibre	Load at first Crack(kN)	Ultimate Load (kN)	Reserved factor = failure load / cracking load
1	FC1	1	NIL	9.18	20.04	2.18
2	FFC11	1	0.50	12.52	29.22	2.33
3	FFC 21	1	0.75	15.86	35.07	2.21
4	FFC31	1	1.00	21.71	39.24	1.81
5	FFC41	1	1.50	14.19	37.57	2.64
6	FC2	2	NIL	10.85	22.54	2.07
7	FFC12	2	0.50	13.36	31.73	2.37
8	FFC22	2	0.75	17.53	36.74	2.09
9	FFC32	2	1.00	23.38	40.91	1.75
10	FFC42	2	1.50	16.70	38.41	2.30

Effect of Steel Fibers on Deflections

The load vs deflection curves are presented in figure 2 and 3. The central deflections for the slabs presented in Table 3. The values presented in table 3 are obtained from load deflection curves.

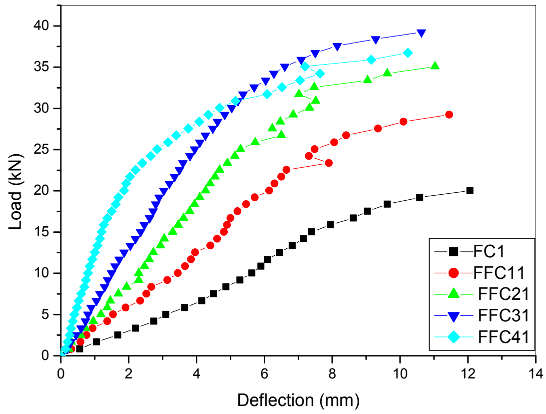

Figure 2 Load vs Deflection for single layer chicken mesh reinforcement

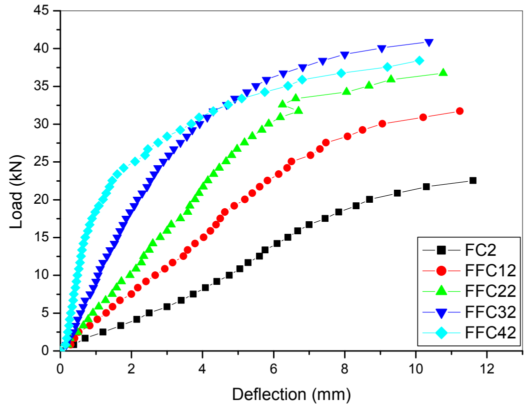

Figure 3 Load vs Deflection for double layer chicken mesh reinforcement

For ferrocement slab with single and double layer of hexagonal chicken mesh reinforcement, the 1% volume of fibers is optimum for giving maximum % increase in first crack load, ultimate load and maximum % decrease in deflection. Again it is further observed that single layer chicken mesh slabs are far superior to double layer chicken mesh reinforcement. For single layer chicken mesh reinforced ferrocement slabs with 1% volume of fiber the percentage increase in the first crack load is 136.4 while the percentage increase in ultimate load for the same is 11.9%. Hence fibrous ferrocement slabs with 1% volume of black steel wire fibers with aspect ratio of 50 have better flexural performance compared to identical ferrocement slabs. From the mode of failure of slabs it was observed the slabs with single layer of chicken mesh reinforcement without fibers, have a tendency to break to pieces by fracture of wire mesh while identical slabs with fibers have not separated out indicating superior performance characteristics of fibers. In case of double layer chicken mesh reinforced slabs without fibers and with fibers have identical failure without separation of the failed components of the slab. The tesed slabs can be view in figure 4.

Table 3 Central Deflections at Ultimate Load

S No.	Specimen Designation	No. of Layers	Vol. % of Fibre	Central deflection at Ultimate load in mm	Decrease over the deflection without fibre
1	FC1	1	NIL	12.07	---
2	FFC11	1	0.50	11.45	5.10%
3	FFC 21	1	0.75	11.13	8.60%
4	FFC31	1	1.00	10.63	11.90
5	FFC41	1	1.50	10.23	15.20%
6	FC2	2	NIL	11.61	---
7	FFC12	2	0.50	11.24	3.20%
8	FFC22	2	0.75	10.77	7.30%
9	FFC32	2	1.00	10.365	10.70%
10	FFC42	2	1.50	10.10	13.0%

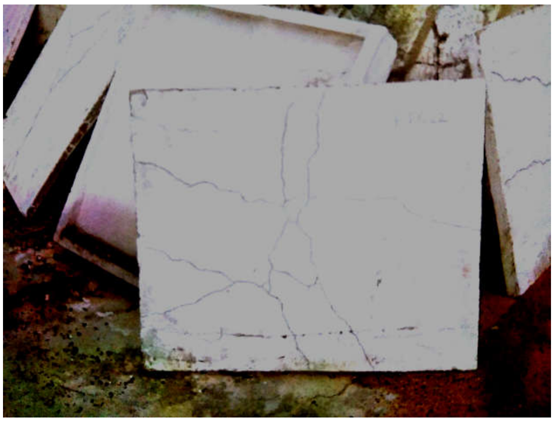

Figure 4 Tested Slabs

CONCLUSIONS

The following conclusions are obtained from the experimental work.

1. Addition of steel fibre to ferrocement slabs, reinforced with chicken mesh, increases their flexural strength and crack resistance.
2. The optimum volume of percentage is 1.0% both for single layer and double layer chicken mesh reinforced ferrocement slabs.
3. When fibres of optimum volume of percentage (i.e.1%) with an aspect ratio of 50 are used in single layer chicken mesh ferrocement reinforced slabs the increase in first crack strength and ultimate strength are 136.40% and 95.80% respectively over the slabs cast without fibres. In two layers reinforcement slabs the increase in first crack strength and ultimate strength are 115.40% and 81% respectively over the slabs cast without fibres.
4. The central deflection is decreased by 11.90% in single layer chicken mesh reinforced slab, and 120.70% in two layer chicken mesh reinforced slab when optimum volume percentage (i.e. 1.0%) of steel fibres are used.
5. Fibrous ferrocement differs from reinforced concrete in the matter of formation growth and propagation of cracks. It has higher strength and greater extensibility than reinforced concrete and the fine and narrowly spaced cracks show the tendency to close when loads are withdrawn even at the threshold of collapse.
6. The values of reserve strength factor defined as the ratio of failure load to first cracking load is 1.81 for single layer chicken mesh reinforced fibre ferrocement slabs while the reserve factor is 1.75 for double layer chicken mesh reinforced fibrous ferrocement slabs at optimum percentage (1%) of steel fibres.

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