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STEEL FIBRE REINFORCED FERROCEMENT SLABS UNDER UNIFORMLY DISTRIBUTED LOAD WITH TWO OPPOSITE EDGES FIXED

N.Venkata Ramana

Abstract

This article presents the behaviour of ferrocement slabs reinforced with low strength steel fibres. 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 fibres in the proportion of 0.75, 1.0 and 1.50% by volume of specimen. Total 16 slabs were cast and tested in the laboratory under uniformly distributed load with two opposite edges fixed and other two edges were simply supported. First crack and ultimate load capacity of the slabs were noticed for each slab. The results revealed that 1% of fibres volume is effective to take the more loads when compared to other dosages of fibres. The crack width was decreased for slabs wchich consists of steel fibres when compared with slabs without steel fibbers. The reserved factor (failure load/ cracking load) for the slabs varied form 1.6 to 2.6.

Keywords:
Ferrocementslabs;
Chicken mesh;
Low strength steel fibres Opposite;
edges fixed;
Reserved factor;
Uniformly distributed load.

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1. 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 fibres 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. Fibres, 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 behaviour of ferrocement slab panels reinforced with chicken mesh and discrete low strength steel fibres 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 [1] 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 cycle cost compared to conventional reinforced concrete. A.S.Alnuaimi et al,[2] 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,[3] 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., [4] 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.[5] 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.[6]) 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 has higher energy absorption and are effective in controlling the cracks.Hamid Eskandari, Amirhossein Madadi [7] 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 [8] 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 [9] 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,[10] 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,[11] 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,[12] 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 [13] 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 [14] 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 is increased. 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 are presented below.

2. Objectives

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

3. Experiemental Programme

Two categories of slabs were taken for the experimental study, first category of slabs were with single layer chicken mesh along with & without incorporation of fibres. Second categories of slabs are with double layer of chicken mesh along with and without steel fibres. In two categories of slabs, the dosage fibre was 0, 0.75,1 and 1.5% by volume of specimen. Total 16 slabs were cast with dimensions of 1.00x0.84x0.035m (8 slabs with single layer and other 8 slabs with double layer chicken mesh). All the slabs made with cement mortar 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 fixed on opposite edges & other two opposites are simply supported (Fig 1). The object of programme is to study the first crack, ultimate strengths, 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 programme shown in Table 1. In the nomentclature, FC indicates Fefforcemnt concrete slabs, FFC represents fibre reinforced ferrocement concrete slabs, the 1 and 2 numerical values idcicates the number of mesh layers and 0.75, 1.0&1.5 denotes the % of steel fibres present in the slabs.

Table 1: Test programme

<table>
<tr><td>Sl.No</td><td>Nomenclature</td><td colspan="2">No of layers and details of chicken mesh</td><td colspan="2">% steel fibre and details of fibres</td></tr>
<tr><td>1</td><td>FC-1-0</td><td>1</td><td rowspan="8">-Average diameter of chicken mesh wire 0.363mm
-Tensile strength of chicken mesh wire 960N/mm^2
-Area of wire 0.1035mm^2
-Number of wires in longer direction 92
-Total area provided in longer direction 92x0.1035=9.52mm^2
-Number of wires in shorter direction 148
-Total area provided in shorter direction 148x0.1035=15.3mm^2</td><td>0</td><td rowspan="8">-Aspect ratio 50
-Length of fibre 48mm
-Dia of fibre 0.96mm
-Ultimate tensile strength of fibre 360N/mm^2</td></tr>
<tr><td>2</td><td>FFC-1-0.75</td><td>1</td><td>0.75</td></tr>
<tr><td>3</td><td>FFC-1-1.00</td><td>1</td><td>1.00</td></tr>
<tr><td>4</td><td>FFC-1-1.50</td><td>1</td><td>1.50</td></tr>
<tr><td>5</td><td>FC-2-0</td><td>2</td><td>0</td></tr>
<tr><td>6</td><td>FFC-2-0.75</td><td>2</td><td>0.75</td></tr>
<tr><td>7</td><td>FFC-2-1.00</td><td>2</td><td>1.00</td></tr>
<tr><td>8</td><td>FFC-2-1.50</td><td>2</td><td>1.50</td></tr>
</table>

4. 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.

Fibres: 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 fibre used is 0.75, 1.00 and 1.50. The ultimate tensile strength of fibre 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

5. Test Specimens

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

6. Casting of Specimens

For casting the slabs the required number of meshes was 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 upto 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. Eight slabs were cast with single layer of chicken mesh reinforcement along with fibre dosage varying from 0.75 to 1.50%. Out of these eight slabs two slabs were prepared with no fibres. Similarly another set of eight slabs were cast with two layers of chicken mesh and which were 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.

7. 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. Adopting the whiffle tree arrangement or 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 of accuracy of 0.001 and positioned at the centre of the slab (bottom).

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.

Fig 1: Loading arrangement

8. Discussion of Test Results

The information about the behaviour of fibrous ferrocement slabs upto failure is presented in the following sections. During this investigation, it was found that with the addition of fibres (up to a limit) to ferrocement slabs, the first crack strength and ultimate strength increases. The behaviour of ferrocement slabs cast without fibres is compared with six slabs with different volume percentages of steel fibres (0.75, 1.00 and 1.50.). The comparison is done far the following two cases.

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

8.1 Effect of Steel Fibres on First Crfack Strength

The test results are presented in the Table 2, from this it is observed that, for single layer chicken mesh reinforced slab the Percentage increase in first crack strength due to addition of fibres is 78.57, 142.80 and 57.14 for the volume percentage of 0.75, 1.00 and 1.50 respectively over the slabs without fibres. Similarly in double layer chicken mesh ferrocement slabs the percentage increase in first crack strength due to addition of fibres is 64.7, 111.76 and 52.94 for volume percentage of fibre of 0.75, 1.00 and 12.50 respectively over the slabs without fibres. Hence it is seen that both for single layer chicken mesh reinforced ferrocement slabs as well as double layer chicken mesh reinforced ferrocement slabs the first crack strength increases with increase in percentage up to 1.00% volume of fibre and then decreases. Hence 1.00% volume percent of black steel fibres is the optimum for giving the maximum first crack strength in fibrous ferrocement slabs.

8.2 Effect of Steel Fibres on Ultimate Stregnth

The ultimate strength results are presented in Table 2 and from this it is noticed that, in single layer chicken mesh reinforced ferrocement slabs the increase in ultimate strength is 68.75, 90.63 and 81.25% for volume percentage of fibres of 0.75, 1.00 and 1.50 respectively over the slabs reinforced with single layer chicken mesh (with no fibres). For slabs reinforced with two layers of chicken mesh the increase in ultimate strength is 51.42, 74.29 and 65.7% respectively over the slabs with no fibres.Hence it can be seen that both for single layer chicken mesh reinforced slabs as well as double layer chicken mesh reinforced slabs, the ultimate strength increases with increase in percentage of volume of fibres up to 1.00% and then decreases. Therefore it can be concluded that one percent volume fibre is the optimum for giving maximum ultimate strength of fibrous ferrocement slabs. From the study of results presented in Table2, it is seen that the percentage increase in first crack strength as well as ultimate strength is more for the single layer chicken mesh reinforced slabs. Hence single layer chicken mesh reinforced fibrous ferrocement slabs are economical than double layer chicken mesh reinforced fibrous ferrocement slabs.

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	FC-1-0	1	0.00	11.69	26.72	2.286
2	FFC-1-0.75	1	0.75	20.87	45.09	2.160
3	FFC-1-1.00	1	1.00	28.39	50.92	1.790
4	FFC-1-1.50	1	1.50	18.37	48.43	2.640
5	FC-2-0	2	0.00	14.19	29.22	2.060
6	FFC-2-0.75	2	0.75	23.38	44.25	1.890
7	FFC-2-1.00	2	1.00	30.06	50.93	1.690
8	FFC-2-1.50	2	1.50	21.71	48.43	2.230

8.3 Effect of Steel Fibres on Deflections:

The deflection results are presented in Table 3, from this it is observed that, the central deflection at ultimate load of the ferrocement slabs decreased when fibres are added. The decreases in deflection are 18.33, 21.25 and 22.58% for the volume percentage of fibres 0.75, 1.00 and 1.50 respectively over the single layer slab (with no fibres). For the double layer slabs the percentage decrease in deflections are 27.33, 32.14 and 18.44 for the volume percentage of fibres 0.75, 1.00 and 1.50 respectively over the slabs without fibres.It is observed from Table 3, for ferrocement slabs with single and double layer of hexagonal chicken mesh, 1.00% volume of fibres is optimum for giving max percentage increase in first crack load, ultimate load and maximum percentage decrease in deflection. Again it is further observed that single layer chicken mesh slabs are far superior to double layer chicken mesh reinforced ferrocement slabs. The tested slabs can be viewed in fig 2.

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	FC-1-0	1	NIL	12.00	---
2	FFC-1-0.75	1	0.75	9.80	18.33
3	FFC-1-1.00	1	1.00	9.45	21.25
4	FFC-1-1.50	1	1.50	9.29	22.58
5	FC-2-0	2	NIL	12.04	----
6	FFC-2-0.75	2	0.75	8.75	27.33
7	FFC-2-1.00	2	1.00	8.17	32.14
8	FFC-2-1.50	2	1.50	9.82	18.44

Fig 2: Tested Slabs

8.4 Effect of Edge Conditions on the Behaviour of Fibrous Ferocement Slabs and Ferrocement Slabs

Both fibrous ferrocement slabs and ferocement slabs were tested with opposite long edges fixed with a view to study the effect of fixity of edge conditions on the behaviour of slabs. The arrangement for fixity of opposite slabs is shown in figure 1. However none of the slabs tested have developed cracks at the top along the fixed edges as is expected. This is attributed due to the fixity having not being developed either due to imperfections in the slab surfaces or due to insufficiency of the arrangement to develop fixity.

8.5 General Observations

From Table 2 and 3, it is observed that, for fibrous ferrocement slabs with single and double layer of hexagonal chicken mesh reinforcement with 1.00% volume of fibres is optimum for giving maximum increase in first crack and ultimate loads and also maximum percentage decrease in deflections. Again it is further observed that single layer chicken mesh slabs are far superior to double layer chicken mesh reinforced slabs. For single layer chicken mesh reinforced ferrocement slabs with 1.00% volume of fibres the percentage increase in first crack load is 142.8 while the percentage increase in the ultimate load for the same is 90.63. Hence fibrous ferrocement slabs with 1.00% volume of black steel wire fibres with aspect ratio 50 have better flexural performance compared to identical ferrocement slabs. From the modes of failure of slabs, it is observed that slabs with single layer of chicken mesh without fibres have a tendency to break or pieces by fracture of wire mesh, while identical slabs with fibres have not separated out indicating superior performance characteristics of fibres. Hence single layer chicken mesh reinforce slabs with 1.00% volume of fibres are superior to identical slabs without fibres.

9. Conclusions

The following conclusions are obtained from the experimental work.

1. Addition of fibres to ferrocement slabs, reinforced with chicken mesh increases their flexural strength and crack resistance.

2. The optimum volume of percentage fibre is 1% for single layer and double layer chicken mesh reinforced ferrocement slabs.
3. When fibres of optimum volume of percentage (1.00%) with an aspect ratio 50 are used in single layer in chicken mesh reinforced ferrocement slabs, the increase in first crack strength and ultimate strength are 142.8 and 90.63% respectively over the slabs without fibres. In double layer reinforced slabs the increase in first crack strength and ultimate strength are 111.76 and 74.29% respectively over the slabs without fibres.
4. The central deflection decreases by 21.25% in single layer chicken mesh reinforced slabs and 32.1 4% in double layer chicken mesh reinforce slab, when optimum volume percentage (ie.1.00%) of steel fibres are used.
5. Fibrous ferrocement differs from reinforced concrete 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 factors defined as the ratio of failure load to first cracking load is 1.79 for single layer chicken mesh reinforced fibrous ferocement slabs while the reserve factor is 1.69 for double layer chicken mesh reinforced fibrous ferrocement slabs at optimum percentage of steel fibres. Hence single layer fibrous ferrocement slabs are preferred when compared with double layer fibrous ferrocement slabs.

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