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ANALYSIS OF FIBRE REINFORCED CEMENT MORTAR TILES AND DESIGN OF FIBRE REINFORCED CEMENT MORTAR PANEL FOR VARIOUS APPLICATIONS

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ABSTRACT

Cement concrete is weak in tension and to improve its tensile resistance different types of fibres can be used. Fibres may be continuous in the form of mesh or wire or may be discontinuous. Fibres may be steel fibres, synthetic made from plastic, polypropylene or natural fibres like coir, hairs, sisal etc. To understand the importance of fibres and to motivate students to undertake work on fibre reinforced cement mortar, a competition was organized in ”Conquest” event in national level program “Mindspark 2018” organized on 28-29 September 2018 at COEP. The paper presents details of competitions, experiences of participants and test results of cement mortar tiles of total 22 groups. The paper presents comparison of flexural strengths of tiles manufactured by students using short fibres of different types. From the success achieved in the program, it is decided to conduct research on large thin cement mortar panels using continuous fibres and randomly distributed fibres. The paper also presents possible applications of such panels with preliminary design of plain slab panel proposed for the roof of cost effective building system.

I. INTRODUCTION

MindSpark is annual national level technical festival of College of Engineering, Pune. This year we celebrated 12th edition of MindSpark on 28th, 29th and 30th of September, 2018. Theme of Mindspark this year was "Imbibing Technacy". Mindspark comprises of more than 55 events and more than 15 workshops. It is a platform for students with innovative ideas to present their talent. One of the event for civil engineering students was “ CONQUEST” Under this event up to 2012, theme was determination of average compressive strength of concrete cube of size 150 mm x 150 mm x 150mm. Then from year 2013, in order to give opportunity for students to know and work more on tensile resistance of concrete, the theme was determination of split tensile strength of concrete by testing of three concrete cylinders of diameter 150mm and height 300mm. Due these activities, many students from different Engineering colleges and polytechnics, started participating in Conquest every year and students learned and tested various factors affecting split tensile strength of concrete. They realized the importance and role of discontinuous fibres for the improvement of split tensile strength of concrete. Three concrete cubes and three cylinders were found heavy to carry for the students. To motivate students for the development of concrete products, this year it was decided to undertake competition on cement mortar tiles of size 300 mm x 300 mm x 25 mm under Conquest event. The ratio of average flexural strength of four such tiles to weight of tiles was the criteria for the winner in the competition. Some weightage was also given to architectural finish and efforts taken by students during manufacture of their tiles. Use of discontinuous fibres and admixtures was allowed. The diameter of fibres was restricted to 1mm for steel fibres and 5 mm for natural fibres and length of fibres was limited to 75mm. Continuous fibres or use of mesh was not allowed. Participants were instructed to prepare a brief report explaining proportion of materials, procedure, experience with photographs and results if any, signed by head of the institutions. COEP has received very good response for Conquest event in this year. Total 22 groups were participated from different colleges and polytechnics along with their tile samples. Here, we are taking opportunities to share our experiences as a participant and coordinator of the event in Conquest and this paper is based on the test results of tile samples of 22 groups participated in the event. The tiles are sub-grouped as per fibre types used and comparison is made within the subgroup. The discussion is made on the test results of sub groups and final conclusions are drawn based on the test results and various factors responsible for the variations of flexural strengths of tiles. This analysis has motivated us to undertake a research project on large cement mortar panels using suitable continuous fibres as well as discontinuous fibres. The possible applications of such panels are roof for small buildings, cycle stand, folded plates, small containers, water tanks, sheet piles, storage racks etc.

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II. LITERATURE REVIEW

Ferrocement is lightweight thin structural members prepared by using chicken mesh which is plastered by rich cement mortar. M.Amala, Dr.M.Neelamegam (1) have presented research work done on ferrocement slab made from 1 mm dia welded wire fabrics and cement mortar with different proportions from 1: 1, 1: 2, 1:3 The flexural properties of these Ferrocement slabs are evaluated and compared under four point static loading system using specific test setups and comparative study of the test results confirm that Ferrocement slabs made of copper slag are more effective in flexural strength and other mechanical properties. The article of P. Paramasivam(2) presents salient features of design, construction and performance of structural elements of ferrocement. The paper presents detailed case study of sunscreen, secondary slab panel, water tanks. Sonar I. P.(3) has presented applications of thin wire mesh reinforcements in innovative structural members like slabs, beams. There is scope for research on prototypes of such members. His another paper (4) states importance of natural fibres in composites and possible applications of natural fibre reinforced composites for eco-friendly products. These literatures have motivated us to undertake a research project on thin slab panel.

Details of fibre reinforced tiles

In the event, students from different engineering colleges and polytechnics participated with their four tiles. Based on the fibres used, tiles are grouped as per following criteria.

[1] Polypropylene fibre
[2] Steel fibre
[3] Steel and polypropylene fibre
[4] Steel and eco-friendly materials like sugarcane bagasse, bamboo fibres

Analysis of Polypropylene fibre reinforced tiles

Tiles of group A and group C consists of only polypropylene fibre as reinforcement. Tiles of group B consists of polypropylene of varying lengths which fit in the criterion. Group D came up with Polypropylene fibres as reinforcement and they replaced 25% of cement by micro silica.

Fig 1 Polypropylene fibre reinforced tiles

Table 1 Average flexural strength of Polypropylene fibre reinforced tiles

Group Name	Weight (Kg)	Flexural Strength (MPa)	Ratio (strength/weight)
Group A	5.669	5.618	0.990
Group B	6.577	4.818	0.732
Group C	5.719	5.125	0.896
Group D	6.536	6.799	1.040

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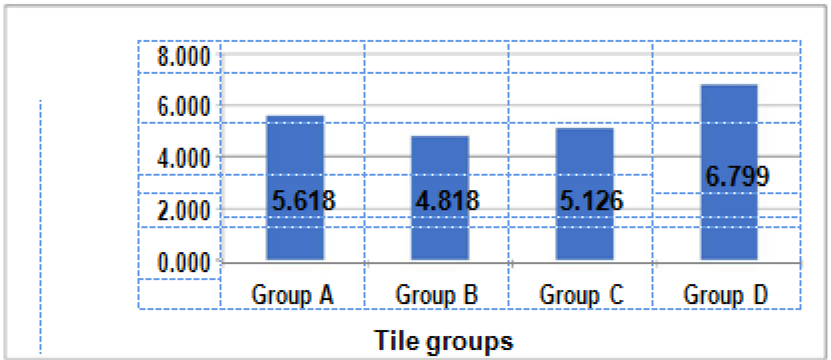

Fig 2 Flexural strength of polypropylene fibre reinforced tiles groups A,B,C,D

From the graph, it is observed that group D tiles have maximum flexural strength. The weight of these tiles is also comparatively higher than other group tiles. This is due to use of micro silica and micro silica makes concrete / mortar more dense, less voids and hence more strength due to better bonding with fibres.

Analysis of steel fibre reinforced tiles

In this group, type of fibre reinforcement is only steel material. Group E consists of hooked end steel fibres of length 50mm. Group F consist of steel fibre, Ground Granulated Blast Furnace Slag (GGBS) as substitute for aggregate and polycarboxylate as admixture. Group G used industrial steel fibres (manufacturer- Brekart fibres) and paste polyamine resin with polypropylene fibres at the bottom of tile for increasing the tensile strength of the tiles. The Group H came up with the hooked end as well as metallic open end steel fibres with conplast SP430-fosroc and brown liquid as admixture.

Fig.3 Steel fibre reinforced tiles

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Table 2 Average flexural strength of steel fibre reinforced tiles

Group Name	Weight (Kg)	Flexural Strength (MPa)	Ratio (strength/weight)
Group E	5.738	7.327	1.277
Group F	6.339	7.612	1.200
Group G	4.994	6.325	1.266
Group H	6.108	6.474	1.059

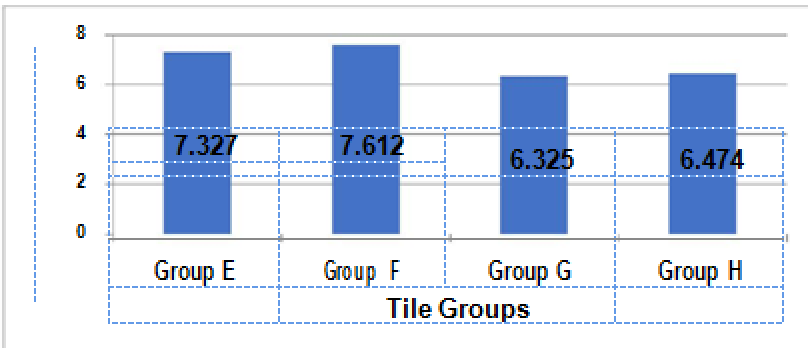

Fig 4 Flexural strength of steel fibre reinforced tiles groups E,F,G,H

From the above graph we can see that the flexural strength of group F tiles is maximum because tiles of group F are made up of Ground Granulated Blast Furnace Slag (GGBS) and weight of group F tile is more due to higher thickness. Flexural strength of group E is comparable with group E only because tiles of group E are made up of the steel fibres with hooked end. Tiles of group H has lower strength to weight ratio. The reason may be lower strength of mortar used and placing of fibres near neutral axis location. Group G shows lower strength and weight. However the flexural strength to weight ratio of group G is comparable since fibres are placed perpendicular to failure plane and aligned properly near tension face of tile.

Analysis of polypropylene plus steel fibres reinforced tiles

Tiles of group I consists of polypropylene fibres and steel fibres (Manufacturer- Stewols, Shaktiman) as a reinforcement and they replaced 20% of mass of cement by Fly ash, Group J, K, L also used the above fibres along with various kinds of admixtures.

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Fig.5 Polypropylene plus Steel fibre reinforced tiles

Table 3 Average flexural strength of Polypropylene plus steel fibre reinforced tiles

Group Name	Weight (Kg)	Flexural Strength (MPa)	Ratio (strength/weight)
Group I	6.417	6.298	0.981
Group J	5.841	3.917	0.670
Group K	6.907	7.485	1.083
Group L	5.928	3.308	0.558

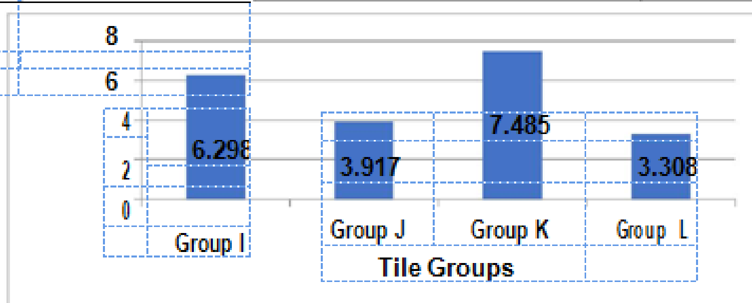

Fig. 6 Flexural strength of Polypropylene plus steel fibre reinforced tiles groups I,J,K,L

Strength of tiles of group K is more than other groups because they provided fibre reinforcement at the tension zone below neutral axis instead of providing them randomly. Group J and L show lower values of strength because fibres were placed near neutral axis and close to compression face and hence contribution of fibres were not observed. Use of higher percentage fly ash in Group I might be the reason of lowering of strength.

Analysis of steel plus ecofriendly fibre reinforced tiles

The following groups tried to implement some innovative ideas in the given endeavor, Group M used handmade steel hooked fibres (length 75 mm having diameter 0.9mm) prepared by cutting the galvanized iron wire in the ‘s’ shape. In addition bamboo fibres were used at neutral axis and lower level to reduce weight of tiles. The group N used polypropyne fibres with sugarcane bagasse. Group O used steel fibres with polypropylene mixed with steel and bagasse. Group P simply uses corrugated steel fibres.

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Fig.7 Steel plus eco-friendly fibre reinforced tiles

Table 4 Average flexural strength of Steel plus eco-friendly fibre reinforced tiles

Group Name	Weight (Kg)	Flexural Strength (MPa)	Ratio (strength/weight)
Group M	4.757	6.071	1.276
Group N	5.539	4.983	0.899
Group O	6.363	6.030	0.947
Group P	5.906	4.787	0.810

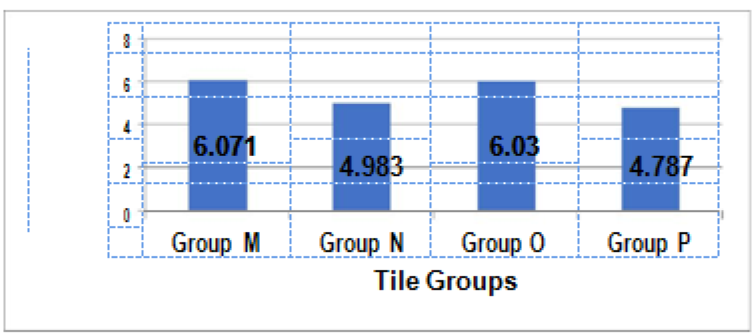

Fig. 8 Flexural strength of Steel plus eco-friendly fibre reinforced tiles groups M,N,O,P

Flexural strength of tiles of group M is maximum than any of the other group because steel fibres are turned into the shape of S so that they can have good grip with the cementing material. Reduction in weight of tiles of group M is due to use of bamboo fibres. Lower water cement ratio resulted in higher strength of mortar. Sugar cane bagasse fibres reduces weight but do not contribute much due to its lower tensile strength. Sugar content in bagasse affects setting of cement.

Our experience of making tiles

Fig 9

Fig 9 – Shows preparation of 'S' shaped steel fibres from steel binding wire by COEP group in laboratory. Nails are arranged sequentially and binding wire is tied around the nails so that wire can achieve 'S' shape.

Fig 10

Fig 10 - 'S' shaped steel fibre prepared in laboratory. This shape increases the bond stress of fibres in mortar/ concrete due to circular shaped ends. Fibres are cost effective.

Fig 11

Fig 11 Bamboo fibres of approximate size 2 mmx 0.5mm treated by oil paint and silica powder (rangoli) for increasing bond and durability. Bamboos are used as ecofriendly fibre in some of the tiles (COEP group) . Now a days there is need of ecofriendly fibres for the sake of life.

Fig 12

Fig. 12 Preparation of tile in a mould by placing mortar and fibres in three layers

Fig 13

Fig. 13 Test set up showing arrangement of three point loading assembly for testing of tile. Universal Testing Machine (UTM) used for taking the flexural strength of tile

Fig14

Fig. 14. Judges obse reports of tiles prep the participants

Fig 15 Participation of students in "Conquest" for testing of their tiles

Proposed research work : Design of Steel fibre reinforced thin panel for roof

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It is proposed to conduct research work on steel fibre reinforced thin cement concrete panel of size 1m x 3m. Thickness of panel considered as 60 mm, The panel is to be used as roof for room size having smaller dimension as 2.8 m. The concrete of Grade M35 and reinforcement will be in the form of welded mesh of steel wires of suitable diameter 3 to 4 mm and spacing as per design, is considered. Maximum size of coarse aggregate is 10 to 12 mm. These pre cast panels of size 3m x 1m can be used for as roof by bonding longer sides using epoxy and suitable method to prevent leakage. To improve stiffness of panel, longer edges can be stiffened by strip of suitable depth. The different profile of panel like sloping roof type or parabolic shape can be tried. The research in this area is needed. Here, the design of such panel by working stress method is presented. The slab panel is designed for the live load as 0.75 kN/m^2

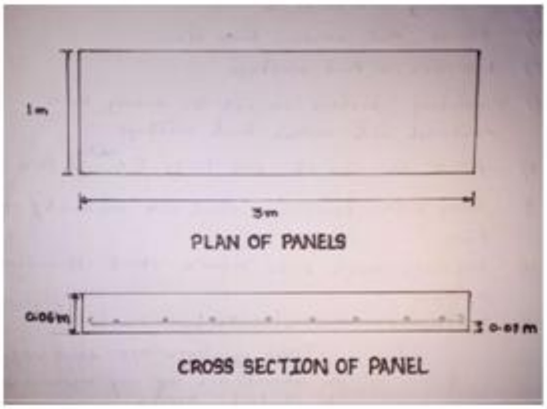

Fig 16 slab panel

Assume, 60 mm overall depth of slab,

Dead load = 0.06 x 25 =1.5 kN/m^2

Live load = 0.75 kN/m^2

Total load = 2.25 kN/m^2 say, 2.5 kN/m^2.

MOMENT AND SHEAR:-

Consider 1 m width of slab Therefore, Load = 2.5 kN/m. Maximum Moment = wL^2 /8 = 2.5 x 3^2/8 = 2.813 kN/m Maximum Shear = wL/2 = 2.5 x 3/2 = 3.75 kN Where, w = load per meter slab in kN/m

L= centre to centre distance between two supports

Effective Depth Required = $[M / Qb]^{1/2}$ = $[2.8125 \times 10^6/(1.305 \times 1000)]^{1/2}$ = 46.4mm Where, M = maximum moment = 2.8125 kNm

Q = moment of resistance factor for balanced rectangular structure, Q = 0.5 σ_{cbc} x k x j = 0.5x10x0.29x.9 = 1.305

j = lever arm constant, j= 1 - k/3 = 0.90

k = neutral axis constant, k = $1/(1+ \sigma_{st}/m\ \sigma_{cbc})$ = 1/(1+236/(9.33x10)) = 0.29 σ_{cbc} = permissible stress in concrete in bending compression

m = modular ratio, m = 280/3 σ_{cbc} = 280/(3x10) = 9.33 σ_{st} = permissible stress in steel in tension d = effective depth of beam or slab

Actual Depth = 60-10-2= 48mm

Ast. = BM / (σst x j d) = 2.8125 x 10^6/ (230 x 0.90 x 48) = 283.06 mm^2

Ast. Min. = 0.12 x b x D/ 100 = 0.12 x 1000 x 60/ 100 = 72 mm^2 Where,
Ast. = area of tension reinforcement

Spacing for 2 mm = (3.14 x 1000/ 283.06) = 11.09 mm say 11mm 3 mm = (7.06 x 1000/ 283.06) = 24.95 mm say 24 mm 4 mm = (12.56 x 1000/ 283.06) = 44.39 mm say 44 mm

To improve stiffness of Plain, sloping and curved panel the long edges (3.0 m) can be stiffened by plates of size 50 mm x suitable depth (say 150 mm) If such panels are attached each other total thickness of side plate will be 50 + 50 = 100 mm. These panels will rest on wall panels made from similar panels. Walls will be madefrom two plain panels with suitable spacer between them (150 mm) so that they both will be attached each other like sand witch panel. This will improve their stiffness, in plane strength and out of plane strength, and easy to accommodate doors and window frames. Panels will be connected with wall by nut bolts. Corners of walls can be braced (stiffened by triangular plates)

Advantages of such panels

1. Light in weight
2. Can be used in low cost house roofing, cycle stand roof, compound wall etc
3. Easy to transport
4. Less maintenance
5. Unskilled labours can also handle with little training
6. Scope for entrepreneurship

III. CONCLUSION

From the flexural strength test results of 20 tiles of size 300mmx 300 mmx 25mm, reinforced with different types of short discontinuous fibres it is concluded that tiles reinforced with hooked steel fibres have shown good performance. During test, it is also observed that fibres prevent sudden failure of tiles. Design of thin slab panel presented can be used as roof or compound wall. There is need to conduct research work on such panels using continuous and discontinuous fibres with or without edge stiffeners. Different profiles of such panels can also be tried for better performance.

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