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Ferrocement Panels Under Flexure By Partial Replacement of Cement With Marble Powder.

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Abstract: Ferrocement is largely used material in today's modern structural engineering technology. In this case study the main aim is to study flexural behavior of ferrocement by replacing cement content by 5%. In this study, 40 cubes were tested to get desirable compression strength results and engineering properties input data. Various test specimens in the form of ferrocement plate of sizes (400x200x15) mm, (500x200x20) mm, (600x200x25) mm, (800x200x30) mm and tested analytically with three-point loading with linearly varying load. Equivalent stress and deflection are the main parameters of this study. From the results, it can be concluded that 5%replacement of marble powder and increasing number of layers has proven to be good at increasing strength and reducing deflections.

Keywords :Ferrocement, Square weld mesh, Marble powder, Flexure Strength, Compressive Strength.

I. INTRODUCTION

In India marble processing industry generates around 7 million tons of wastes mainly in the form of powder during sawing and polishing process. Generally, the marble wastes are being dumped in any nearby pit or vacant space near the marble processing industries, although notified areas have been marked for dumping the same. This leads to increased environmental risks as dust pollution spreads alongside for a large area. In the dry season, the dust dries up, floats in the air, flies and deposits on crops and vegetation. In addition, the deposition of such generated huge amount of fine wastes certainly creates necrotic ecological conditions for flora and fauna changing landscapes and habitats. The accumulated waste also contaminates the surface and underground water reserves. Ferrocement construction technique is believed to be one of the distinctive techniques of construction that now a days used in many countries.

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It is tightly spaced galvanized mesh layers in which the ferrocement is provided evenly throughout the thickness of slab. In last 20 years, there is large global developments in construction materials which could be effectively used in ferrocement so as to improve potential application of ferrocement such as additives, active or inactive micro filler, polymer, silica fume, fly ash, new development in meshes, fibers and micro-fibers geopolymers etc. the use of hybrid composites where mortar matrix is reinforced with mesh reinforcement improves certain characteristics.

II. LITERATURE REVIEW

Varma, Manish Hajare M BSAZ [1] carried out an experimental work on Flexural behavior of Ferro Cement panels with different types of Meshes. They studied the effect of different types of meshes as reinforcement in thin mortar specimen and selected the best suitable mesh for their work. The meshes they used were expanded metal mesh ,galvanized woven mesh and welded mesh having a diameter of 1.58 mm. The sizes of the openings were (20x35)mm, (10x10) mm and (15x15)mm. Panels reinforced were of size (560x150x35)mm. The panels were reinforced with three layers of wire mesh. They casted the panels with mortar having mixed proportion of 1:2 and having the water cement ratio 0.40. The test was conducted for four specimens under four-point loading system on universal testing machine after sanative period of around 7 days and a period of 28 days for 8 specimens .Thus the authors concluded that the flexural strength of the specimen with welded mesh exhibited greater flexural strength among the three meshes used.

Randhir J. Phalke [2]carried out an experimental work on the effect of using different no of wire mesh layers on the flexural strength of flat ferrocement panels and to compared the effect of varying the no of wire mesh layers and use of steel fibers on the ultimate strength and ductility of ferrocement slab panels. They used two, three and four layers of slab. Slab panels of size (550x200) mm with thickness 25 mm were reinforced with welded square mesh with varying no of layers of mesh. They casted the panels with mortar having a mix proportion (1:1.75). The water cement ratio was (0.38) along with-it super plasticizer (Perma PC-202) was used with dosage of 1% of total weight of cement. Also a few numbers of panels were casted composed of steel fibers (0.5%) of total volume of composite and bearing an aspect ratio (l/d) =57. A test was made on the panels under two-point loading system in UTM machine after period of 28 days. Thus, the authors concluded that panels with more no of layers exhibited greater flexural strength and less deflection as that compared with panels having less no of layers of mesh.

Rajendran, Mohana Soundarapandian, Nagan [3] carried out an experimental investigation on Geopolymer ferrocement panels under flexural loading. The flexural behavior of thin cement fewer composite panels reinforced with welded rectangular wire mesh and chicken mesh with varying number of mesh layers as well as varying concentration of alkaline solution was presented. A total of 30 panels was tested under flexural loading. The size of the panel used was 1000mm(length)×200mm (width)×25/35 mm (thickness). The parameters studied in the investigation included varying concentration of NaOH (8, 10, 12, 14 m) and thickness of composite panels. Cement was replaced by geopolymer mix to bind the ferrocement skeletal framework and its flexural behavior was studied. It was observed that the first crack and ultimate loads increased with the increase in the thickness of the element and the concentration of alkaline solution. The authors concluded that the load-carrying capacities, energy absorption, and deformation at ultimate load are high in the case of geopolymer ferrocement element. Further, they observed that there is reduction in crack width, and increase in number of cracks in the case of geopolymer ferrocement indicates delay in crack growth.

Damare, Prof Alok [4] carried out an experimental investigation based on Utilization of Marble power in cement mortar. It is observed that marble mining and production industry creates masses of solid waste and had no methodical processes for its disposal. Marble slurry is marble fines suspended in water generated during the processing of marble . It constitutes 10% of the total stone quarried and 5-7% compressive strength, abrasion resistance and water absorption in mortar specimen. The study by the authors focused on marble slurry as partial or complete replacement of aggregate in cement mortar**.** It elaborates on the tests conducted for compressive strength, abrasion resistance and water absorption in mortar specimen. The authors concluded that it is feasible to replace the sand by marble powder for improving the compressive strength (up to 20%), durability characteristics abrasion resistance value (up to 15%) and water absorption of the cement mortar. Thus, they used marble powder as an alternative for the production of mortar to minimize the cost of the construction and for the proper utilization of disposal of marble powder.

III. OBJECTIVES

- Effect of linearly varying gradual loads on deformation and flexural strength of ferrocement panels.
- Effect partial replacement of cement with marble powder on deformation and flexural strength of ferrocement panel.
- Effect of panel thickness on the deformation and flexural strength.
- Effect of number of welded steel wire mesh layers on the flexural strength of ferrocement panels.

IV. EXPERIMENTATION

a. Cement:

Ordinary Portland cement of grade 53 available in local market is used. The cement for all tests was from the same batch. Properties of cement were obtained from IS: 456-2000 and IS 12269: 2013. Initial setting time, final setting time, specific gravity and fineness were considered according to specifications given in code.

b. Fine aggregate:

Natural river sand passing through 2.36 mm sieve is used. Specific gravity and fineness modulus are according to IS 2386-1963.

Table 1: Properties of fine aggregate

Sr No.	Characteristics	category
1	Specific gravity	2.6
2	Fineness modulus	3.2
3	Grade zone	Zone 3
4	Water absorption	0.94%

c. Marble powder:

Marble powder was collected from the local market. The specific gravity is taken as 2.4.

d. Admixture :

Permaplast PS-34 is used to increase dispersing and deflocculating effect. This increases workability of the mortar.

e. Mix proportion:

Mix proportion is selected in such a way to get workable homogeneous mortar for casting of cubes. The proportion of cement : sand (1:1.5) is taken through experimentation trials having W/C ratio is 0.38.

f. Test specimen:

Total 40 cubes of size (70X70X70) mm were prepared, tested and studied to determine maximum compression strength. Test specimens are categorized in two categories,

1. Mortar
2. 5%MPRM (marble powder replaced cement mortar.)

g. Preparation of Test specimen:

Hand mixing is done to prepare fresh mortar. Cement, sand marble powder and admixture are placed and mixed thoroughly. The experimental work include preparing and testing of normal mortar and marble powder replaced mortar cube specimens. In trial mix we compared cement : sand ratio of 1:1.5, 1:1.75, 1:2 in which maximum compressive result was given by mixture 1:1.5. mixture 1:1.5 further studied for w/c ratio of 0.36, 0.38, 0.40 in which w/c 0.38 shown better workability as well as compressive strength of cube specimen.

After deciding ratio and water content we further added variation of marble powder with replacing some percentage of cement. The variation of marble powder considered are 5%, 10% and 15% taken from various research papers. In which we found that mixture with cement : sand ratio of 1:1.5, w/c 0.38, marble replacement of 5% cube specimen have shown good compressive results as compare to other. In above mixture 1% of PS-35 admixture is taken to achieve favorable workability.

Table 2: Effect of percentage of marble powder variation with admixture (28 days).

Sr no.	Category	W/C	Sizes of cubes(mm)	Load of failures(Kg)	Comp. strength (N/mm^2)	Avg. Comp. strength(N/mm^2)
1	Mortar	0.38	70x70x70	15800	36.43	
			70x70x70	16800	37.26	37.46

			70x70x70	17000	38.43	
2	5%MP RM	0.38	70x70x70	25000	51.02	
			70x70x70	22000	44.89	47.88
			70x70x70	23400	47.75	

V. ANALYTICAL WORK

An analytical model is prepared by using above results ANSYS 19.2 used for analytical study. A static analysis is used to determine the required data. For trial we have created model of (550x200x25)mm to mimic flexure test from experimental model of research paper and we succeeded to get approximate results of deflection of that specific model.

Modeling for flexure test:

a. Mortar and wire mesh:

In this ferrocement panels are modelled as per below table dimensions with varying number of layers of galvanized steel mesh. The diameter of steel mesh was taken as 1.2 mm. Poisons ratio of mortar is taken between 0.15 to 0.18. Modulus of elasticity of cubes were taken from 20000 GPa to 24000 GPa. Ultimate tensile strength is taken 3 to 5 MPa. All this data is collected during experimentation.

Table 3: Details of panels to be modeled

Panel sizes	Number of layers
400 X 200 X 15	2,3
500 X 200 X 20	2,3
600 X 200 X 25	3,4,5
800 X 200 X 30	3,4,5

b. Three-point loading:

For each panel sizes we have taken 50 mm overhang from edges and rollers are placed one third of remaining clear span. Upper roller has diameter of 15 mm and lower cylinder has diameter of 50 mm.

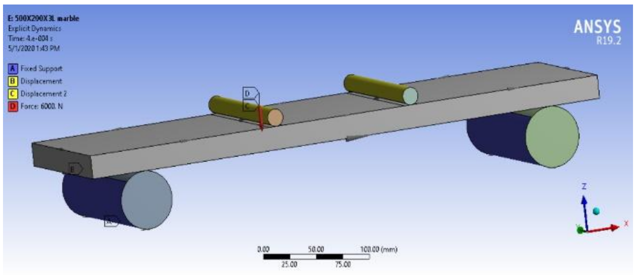

Figure 1: Typical geometry of three-point loading in ANSYS

c. Properties of mesh:

Youngs modulus of welded galvanized mesh is 250 GPa. Opening of welded mesh is (15x15)mm, having diameter of 1.2 mm.

d. Body to body contact:

Body to body contact is taken as friction less below contact surface. And body to body interaction of line body is taken reinforcement to make connection between mortar and mesh.

e. Fixed support:

Fixed support is assigned below surface of cylinder given in above figure.

f. Displacement:

Displacement is assigned below surface of plate and above smaller cylinder to allow displacement in z axis. Other axis are restrained for displacements.

g. Force:

Force is applied on surface of smaller cylinder.

The variation of forces are taken from 400 N to 8000 N.

VI. RESULT AND DISCUSSION

Table no 4, Table no 5, Table no 6 and Table no 7 show the variation of displacement of the plate (without 5% MPRM) with respect to loading for various number of steel mesh layers for samples of sizes (400x200x15)mm, (500x200x20)mm, (600x200x25)mm and (800x200x30)mm respectively. Deflection of (400x200) mm plate 0.28 mm for applied load of 400 N is found to be reduced to 0.24 mm for the plate containing 5% marble powder. Such similar variations due to replacement of 5% marble powder for the same samples as mentioned above are included in Table no 8, Table no 9, Table no 10 and Table no 11.

Strength improvement due to addition of each steel mesh layer for all plate samples, with and without 5% replacement by marble powder. Flexural Stress generated in (400x200x15)mm (2 Layers) plate, when applied with 400N load, is found to be 2.22 MPa. This stress is reduced to 2.05 MPa when a layer of steel mesh is added to the same plate. Similarly, for the samples with 5% MPRM, flexural stress generated for plate of (400x200x15)mm when applied with the load of 400 N is 2.298 MPa and is observed to be reduced to 2.15 MPa. This is how strength improvements are found to be more pronounced with 5% MPRM. Such similar variations of flexural stresses are shown in Graph 5, Graph 6 and Graph 7.

Moreover, displacement of plates is also found to be related to variation in number of steel mesh layers. For the plate of size (400x200x15)mm 2 Layers without 5% MPRM deflection for load of 400 N is reduced by 0.28 mm when a mesh layer is added to the same plate. This reduction is found to be 0.26 mm for same sample without 5%MPRM. This is how, the performance improvements are more desirable after replacement of 5% marble powder and addition of steel layers. Other such variations are shown in Graph 1, Graph 2, Graph 3 and Graph 4.

Table 4: (400X200X15)mm panel using mortar

Sr. no		2 layers		3 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.28	2.222	0.26	2.05
2	800	0.57	4.44	0.52	4.11
3	1200	0.85	6.66	0.78	6.16
4	1600	1.14	8.88	1.04	8.21
5	2000	1.42	11.11	1.31	10.26
6	2400	1.7	13.33	1.57	12.31
7	2800	1.99	15.55	1.83	14.36
8	3200	2.27	17.77	2.09	16.41
9	3600	2.55	20	2.35	18.46
10	4000	2.83	22.22	2.62	20.51
11	8000	5.67	44.44	5.24	41.03

Table 5: (500X200X20)mm panel using mortar

Sr. no		2 Layers		3 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.29	1.74	0.27	1.63
2	800	0.59	3.48	0.55	3.26
3	1200	0.88	5.22	0.83	4.89
4	1600	1.18	6.96	1.11	6.52
5	2000	1.481	8.71	1.38	8.16
6	2400	1.77	10.43	1.66	9.78
7	2800	2.07	12.17	1.94	11.42
8	3200	2.37	13.91	2.22	13.05
9	3600	2.66	15.65	2.5	14.681
10	4000	2.96	17.39	2.77	16.312
11	8000	5.92	34.78	5.55	31.626

Table 6: (600X200X25)mm panel using mortar

Sr. no		3 Layers		4 Layers		5 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.29	1.35	0.27	1.29	0.26	1.22
2	800	0.57	2.72	0.55	2.58	0.52	2.46
3	1200	0.86	4.21	0.82	3.87	0.78	3.69
4	1600	1.15	5.41	1.09	5.16	1.04	4.91
5	2000	1.44	6.77	1.37	6.45	1.3	6.15
6	2400	1.73	8.13	1.65	7.76	1.57	7.38
7	2800	2.01	9.48	1.92	9.02	1.83	8.61
8	3200	2.3	10.83	2.19	10.31	2.09	9.83
9	3600	2.59	12.19	2.47	11.6	2.35	11.06
10	4000	2.88	13.55	2.74	12.89	2.61	12.29
11	8000	5.77	27.09	5.49	25.78	5.23	24.59

Table 7: (800X200X30)mm panel using mortar

Sr no.		3 Layers		4 Layers		5 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	1.22	1.35	0.45	1.29	0.43	1.24
2	800	2.46	2.71	0.9	2.59	0.86	2.49
3	1200	3.69	4.05	1.35	3.89	1.29	3.73
4	1600	4.91	5.41	1.8	5.19	1.72	4.97
5	2000	6.15	6.76	2.25	6.48	2.16	6.216
6	2400	7.38	8.11	2.7	7.78	2.59	7.46
7	2800	8.61	9.47	3.15	9.07	3.02	8.7
8	3200	9.83	10.82	3.6	10.37	3.45	9.95
9	3600	11.06	12.17	4.05	11.67	3.89	11.19
10	4000	12.29	13.53	4.5	12.96	4.32	12.43
11	8000	24.59	27.06	9.01	25.93	8.64	24.86

Results with Marble powder:

Table 8: (400X200X15)mm panel using 5%MPRM

Sr no.		2 layers		3 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.24	2.298	0.22	2.15
2	800	0.489	4.597	0.45	4.3
3	1200	0.73	6.896	0.68	6.45
4	1600	0.979	9.195	0.91	8.6
5	2000	1.22	11.494	1.14	10.75
6	2400	1.47	13.799	1.37	12.9
7	2800	1.71	16.092	1.6	15.05
8	3200	1.95	18.391	1.83	17.2
9	3600	2.2	20.689	2.05	19.35
10	4000	2.44	22.988	2.28	21.5
11	8000	4.91	45.977	4.11	43.01

Table 9: (500X200X20)mm panel using 5%MPRM

Sr. no		2 Layers		3 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.25	1.79	0.24	1.69
2	800	0.5	3.57	0.48	3.39
3	1200	0.76	5.36	0.72	5.08
4	1600	1.01	7.14	0.96	6.775
5	2000	1.28	8.93	1.2	8.47
6	2400	1.52	10.72	1.44	10.16
7	2800	1.77	12.51	1.68	11.86
8	3200	2.02	14.29	1.92	13.55
9	3600	2.281	16.07	2.16	15.24
10	4000	2.54	17.86	2.4	16.93
11	8000	5.07	32.14	4.8	33.87

Table 10: (600X200X25)mm panel using 5%MPRM

Sr no		3 Layers		4 Layers		5 Layers	
	Load(N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.25	1.39	0.24	1.34	0.22	1.29
2	800	0.5	2.795	0.48	2.68	0.45	2.58
3	1200	0.74	4.19	0.71	4.02	0.68	3.87
3	1600	1	5.591	0.95	5.37	0.91	5.16
4	2000	1.24	6.99	1.19	6.71	1.14	6.44
5	2400	1.48	8.38	1.42	8.04	1.37	7.73
6	2800	1.73	9.78	1.67	9.39	1.6	9.02
7	3200	1.98	11.18	1.9	10.73	1.83	10.31
8	3600	2.23	12.57	2.14	12.07	2.05	11.6
9	4000	2.48	13.98	2.38	13.41	2.28	12.89
10	8000	4.96	27.95	4.76	26.83	4.11	25.78

Table 11: (800X200X30)mm panel using 5%MPRM

Sr. no		3 Layers		4 Layers		5 Layers	
	Load (N)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)	DEFLECTION (mm)	STRESS (MPa)
1	400	0.4	1.39	0.39	1.34	0.38	1.29
2	800	0.8	2.78	0.78	2.68	0.75	2.59
3	1200	1.2	4.16	1.17	4.02	1.12	3.89
4	1600	1.61	5.56	1.55	5.36	1.5	5.19
5	2000	2.01	6.95	1.94	6.7	1.87	6.48
6	2400	2.41	8.33	2.33	8.04	2.25	7.78
7	2800	2.81	9.72	2.72	9.39	2.62	9.07
8	3200	3.22	11.11	3.1	10.72	3	10.37
9	3600	3.62	12.51	3.49	12.06	3.38	11.67
10	4000	4.02	13.89	3.88	13.4	3.75	12.96
11	8000	8.05	27.78	7.77	26.81	7.5	25.93

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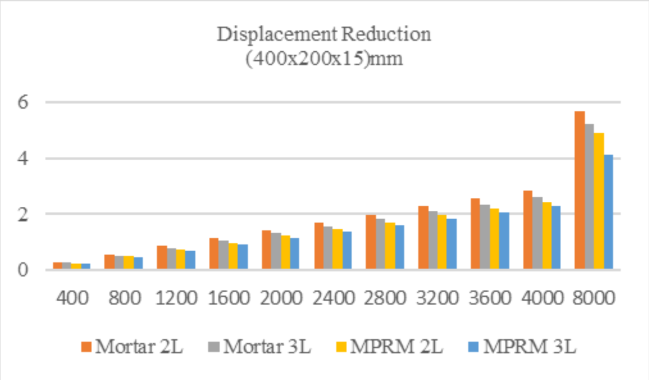
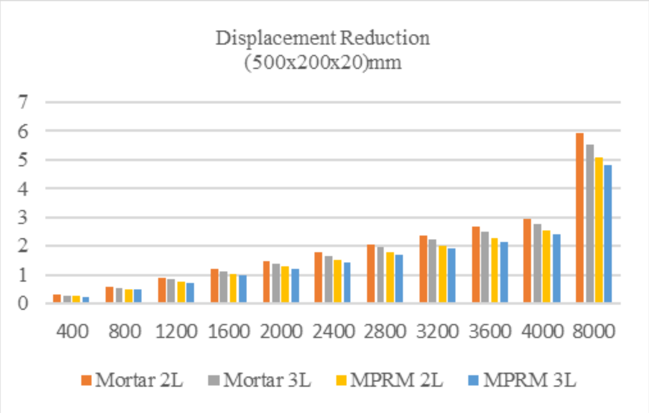
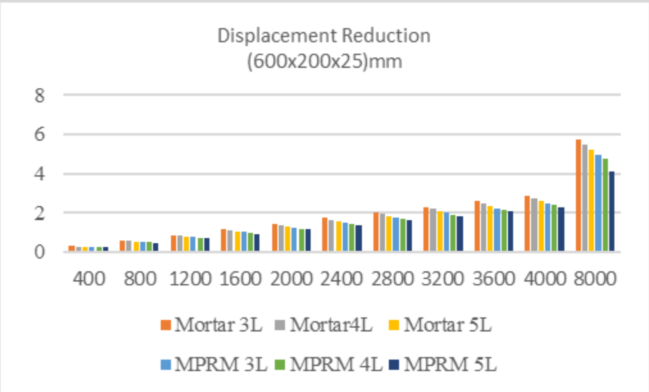
Graphs:



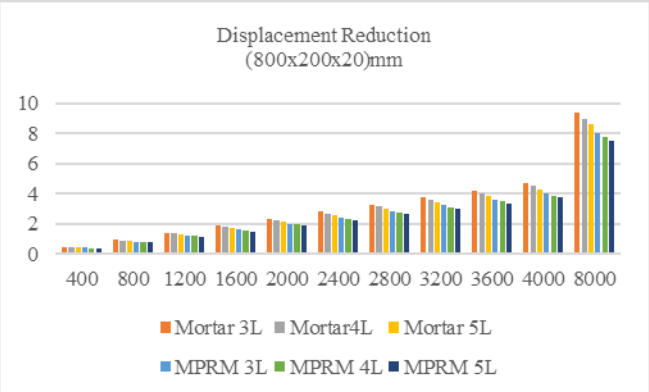
Graph 1: Load Vs Deflection for 2 and 3 layers (400X200X15)mm panel with and without 5% MPRM.



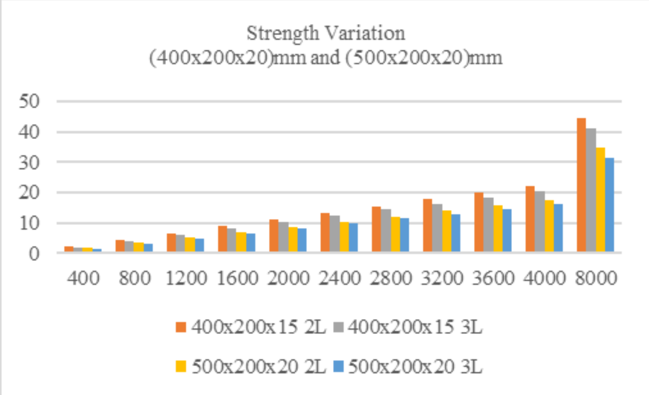
Graph 2: Load Vs Deflection for 2 and 3 layers (500X200X20)mm panel with and without 5% MPRM.



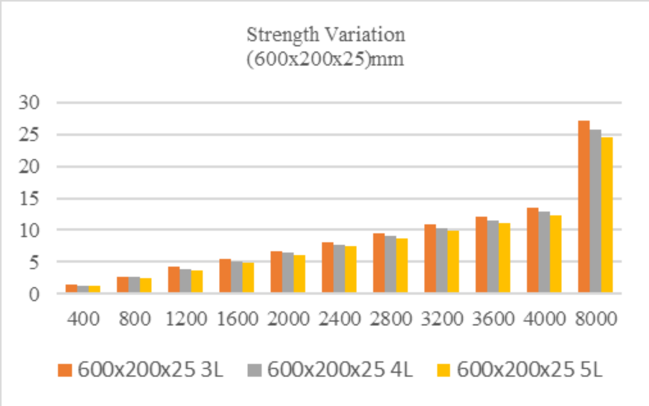
Graph 3: Load Vs Deflection for 3,4 and 5 layers (600X200X25)mm panel with and without 5% MPRM.



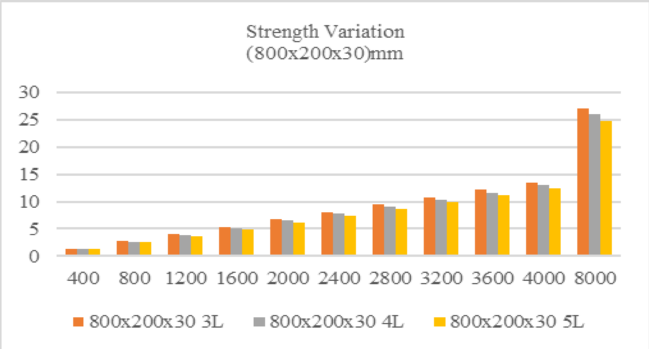
Graph 4: Load Vs Deflection for 3,4 and 5 layers (800X200X30)mm panel with and without 5% MPRM.



Graph 5: Load VS stresses for 2 and 3 layers (400X200X15)mm and (500X200X20)mm panel without MPRM



Graph 6: Load VS stresses for 3,4 and 5 layers (600X200X25)mm panel without 5% MPRM



Graph 7 : Load VS stresses for 3,4 and 5 layers (800X200X30)mm panel without 5% MPRM

VII. CONCLUSION

- When the thickness of ferrocement panel is increased from 15mm to 30mm the load carrying capacity of the ferrocement panel is increased gradually and the ferrocement flexural stress is decreased.
- The flexural stress of 15mm 5%MPRM ferrocement panel with 2 and 3 layers is found to be increased by 3 to 5% when compared with 15mm normal mortar panel. And same observation in increase of stress can be observed in all cases.
- The flexural strength in 25mm 5layers 5%MPRM panel increases by 10% as compare to 25mm 3layers 5%MPRM panel. Same observation is found in 30mm panel.

Average reduction in deflection of the plate found to be 6% with addition of each steel layer mesh of both with and without MPRM panels. Also, this observation is found to be same in all thickness of panels.

- The reduction in deflection of 15mm 5%MPRM ferrocement panels is found to be 4% when compared with 15 mm normal mortar panel.

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