International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Study on Flexural properties of folded plates covered with GGBS replaced ferrocement concrete

S.Sameer[1], P. Dhanabal[2], P. Narendra Reddy[3] and P. Hema Kumar[4]

Assistant Professor, Department of Civil Engineering, Annamacharya Institute of Technology and science, Tirupati, Andhra Pradesh, India[1,2,3,4]

A B S T R A C T

The purpose of this study is to evaluate suitability and flexural behavior of ferro-cement in folded plates. Ferro cement is one of the building materials that is emerging as a replacement for the traditional RCC in many respects. Ferro cement is the future of the low cost houses and precast houses. Folded plates are the economical and asthetic solution for longer span roofs. This project incorporates the benefits of both Ferro cement and folded plates. In ferrocement , cement is partially replaced with GGBS. The trough style Ferro cement folded plates of size 0.6 m x 1.80 m x 0.15 m are cast in consideration of various journals & RCC folded plates when fixing dimensions. properties of the materials used for casting are tested and the compressive strength of the mortar used is tested, the test is performed at 1:2 cement: sand ratio and 0.35 water cement ratio. The specimen is cast with a 2 mm opening stainless steel mesh and 2 layers are laid on the front and back sides of 6mm dia 150m of spaced skeleton steel. Cast specimens are tested for 28 days in loading frame strength and the results are compared with analytical analysis The use of ANSYS for load vs deflection and the suitability of the application of ferro-cement in folded plates are studies. The test results show good results, finally with low expenditure and low self-weight Ferro cement structures being a good alternative to RCC.

Keywords: Ferro-cement, Flexural behaviour, folded plates, ANSYS, suitability of ferro-cement in folded plates, skeleton steel.

1. Introduction

1.1 Ferrocement

The term "Ferro cement" has been used by extension to other composite materials, including those containing no cement or ferroceous content (R. Mohana et al., 2021) : (Ren Xin and Pengfei Ma. 2021): (Abeer M. Erfan et al., 2021) : (Fatimah H. Naser et al., 2020) : (T. Chaitanya Srikrishna and T.D. Gunneswara Rao, 2020) : (Hosein Naderpour et al., 2020). Ferrocement is a system of reinforced mortar or plaster spread over a metal mesh sheet, woven with extended metal or metal fibers and tightly spaced thin steel rods such as rebar, metal widely used iron or other form of steel (M.S. Deepak et al., 2020) : (I.A. Sharaky et al., 2020) : (Ubaid Ahmad Mughal et al., 2019) : (Ru Mu, Peng Xing et al., 2019) . Ductility was found to be strongly influenced by the form of mesh reinforcement (Ibrahim G. Shaaban et al., 2018). Many ferrocement beams displayed higher loads of serviceability compared to control specimens (Dimas Smith et al., 2021) : (Majid Jafar Sada et al., 2021) : (Wenhu Zhao et al., 2021). However, specimens reinforced with expanded metal mesh often reached their serviceability loads prior to the initiation of the first crack, while other specimens reinforced with welded wire mesh formed the first crack before reaching their serviceability load (Juby Mariam Boban et al., 2021) : (Muazzam Ghous Sohail et al., 2021) : (M. Amala, Lenin Dhal et al., 2021) : (Ibrahim G. Shaaban et al., 2018). The ultimate load is roughly twice that of the first crack load. The contribution of the bamboo strips to the mortar and wire mesh of the theoretical final load capacity of the slab is approximately three times higher corresponding to the experimental final load capacity (Oscar Javier Sandoval et al., 2021) : (Sarga S et al., 2021) : (Linda Giresini et al., 2021) : (S. Jeeva Chithambaram

* *Corresponding author.*. P. Dhanabal
E-mail address: dhanabalgce@gmail.com

and Sanjay Kumar, 2017). Replacement of concrete with new advanced eco- friendly materials and wastes also help to decrease the demand and scarcity of existing materials (P. Dhanabal et al., 2021).

Folded Plates

Folded plate roofs are composed of a series of rectangular reinforced concrete slabs (whose length is more than three times its width) placed inclined to one another and joined monolithically, one after the other, along their longitudinal edges. The unit as a whole is supported rigidly at its ends, by transverse diaphragms, as in the case of cylindrical shells. These structures are also called prismatic structures or hipped plates. These can be made into various shapes (Quan Shi et al., 2017) : (Yuguo Sun et al., 2017) : (S. Sadamoto et al., 2017) : (Julien Gamerro et al., 2017). Since the structure is proposed to be folded using a pre-cut board, the dimensions of the square dome are reduced(Zhejian Li et al., 2018). The geometric constraints of the folded plates, such as the conditions at the end and the intermediate supports, are modelled by very rigid springs (R.J. Jiang, F.T.K et al., 2011). The major objective of this study is to achieve high strength mortar also bending response above folded plate with covered with ferrocement under UDL. Compare experimental results between ANSYS Analysis at the end.

2. Material and Properties

Cement

Cement used for this study was having specific gravity 3.15. It confirms to IS: 12269(2013). Properties of cement given in Table 1.

S.No	Property	Test Result
1	Normal consistency	33%
2	Initial and Final setting time	55 min & 295 min
3	Specific Gravity	3.17
4	Soundness (Le-Chatlier Exp)	1.00 mm

Table 1: Properties of Cement

Ground Granulated Blast furnace Slag (GGBS)

GGBS with Specific gravity 1.24 used for this work .

Steel

Steel is an alloy of iron and carbon containing less than 2 per cent of carbon and 1 per cent of manganese and minimal quantities of silicon, phosphorus, Sulphur and oxygen. Square mesh used for study given in Figure 1. Steel is the most important engineering and building commodity in the world. It is used in every part of our lives; in vehicles and building goods, in refrigerators and washing machines, in cargo ships and in surgical scalpels.

Ultimate hexagonal mesh strength= 270 N/mm2.

Yield strength of 6mm MS bar, FI= 250 N/mm2.

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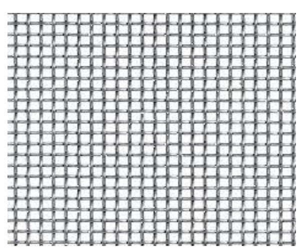

Figure 1: Square mesh

2.4 Sand

Sand with specific gravity sand was 2.62. It confirms to IS 2386 (1963). Properties of fine aggregate given in Table 2.

S.No	Property	Test result
1	Specific Gravity	2.60
2	Bulk density	1750
3	Fineness Modulus	2.77

Table 2: Properties of Fine Aggregate.

2.5 Water

Ordinary water with pH 7.40 was used for this study.

3. Numerical Analysis

Numerical analysis very important to compare results with experimental study results. In this work we analysis the folded plates with ferrocement model using Ansys Software. The numerical results (Maximum deformation and Ultimate load) compared with Experimental tested results.

3.1 Element types

The types of elements for this used for study model are given in Table 3.

Cement mortar	Solid 65
Steel reinforcement	Beam 188
Mesh	Shell 181

Table 3: Types of elements in ANSYS

4. Hardened Properties

4.1 Compressive Strength of Mortar

The average strength of three cubes was taken as the compressive strength of the Mortar casted ratio. The specimens used for this purpose are (70.6x 70.6x 70.6) mm mortar cubes. Compressive strength results are given in Table 4. Mortar cubes with 10 % replacement of GGBS has given high compressive strengths compared to others.so that we have adopted 10% GGBS as cement replacement in our experimental work.

S.No	GGBS replacement	Compressive strength (MPa)
1	10 %	61
2	20 %	55
3	30%	57

Table 4: 28 day's compressive strength of mortar cubes

4.2 Casting & Testing Of Ferro Cement Folded Plate Specimens

Two specimens are tested with dimensions of 0.6m x 1.82m x 0.15 m with thicknesses of 25mm and 6mm mild steel rods as a skeleton reinforcement with a spacing of 150mm c/c (as shown in figure) with a stainless steel mesh with a spacing of 2mm are placed on both sides of the skeleton reinforcement with a cover of 9mm. Specimen reinforcement in folded plate used for work shown in figure 5.

4.3 Manufacturing of Test Models

The mortar was placed in the frame within a few minutes of the time of the final mixing and the manual compaction was used to compact the concrete in the frame. During the casting of the specimen, the mortar with trough force should be applied for proper compaction of the material since the chicken mesh is placed. The surface was eventually finished using steel troughs. After 24 hours of the mortar, the specimen is demolished.

The specimen was shielded to avoid the evaporation of water by the use of gunny bags after the destruction of the formwork. The specimens were healed by ambient healing prior to the date of research by gunny bags. The specimens were painted with white lime water solution so that cracks were clearly observed during the test. The positions of the deflection gauge on the bottom of the specimens were labeled. Casting of specimen covered with GGBS replaced ferrocement shown in figure 6.

4.4 Experimental Setup

4.4.1 Loading Systems

Application of uniformly distributed load: Uniformly distributed load is applied to specimens on a ridge plate by means of a 100-ton jack manual. The load was assessed by a test ring with a capacity of 10 tonnes. A cylindrical steel plate of 8 cm diameter was used to transmit the load from the jack to the specimen

4.4.2 Setup Test Models for Testing

The test model was shifted to its place on the loading frame using an electrical crane with a capacity of 100 tonnes. The specimens rest on the top of the test frame for simply assisted edge condition. Placing of folded plate in loading frame given in figure 7. Ferrocement folded plate during testing shown in figure 8.

4.4.3 Test results

Zero reading of the dial gauges, a test ring was registered. The load has been noted down. The load was then progressively added to the manual jack and the load readings were taken from the test ring. After each loading, the deflection readings were registered. The process was continued until the cracks became evident and the load at which the cracks began was noted. More loading was then applied until the crack propagation was complete. This stage was followed by excessive deflections, as clearly indicated by the continuous rotation of the dial gauges, and the failure load was registered. Load and Deflection results of specimen 1 and 2 are given in Table 5 and Table 6.

S.No	LOAD 'kN'	Deflection 'mm'	Remarks
1	0	0	-
2	1.33	2.8	-
3	2.66	4.95	-
4	4	5.64	-
5	5.33	9.08	-
6	6.66	9.73	First crack load
7	8	11.72	-
8	9.33	13.2	-
9	10.66	15.8	-

Table 5 load deflection behavior for specimen 1

S.No	Load kN	Deflection 'mm'	Remarks
1	0	0	-
2	1.33	1.22	-
3	2.66	2.03	-
4	4	4.03	-

5	5.33	4.18	-
6	6.66	5.00	-
7	8	6.08	First crack
8	9.33	6.67	-
9	10.66	7.32	-
10	12	9.05	-
11	13.33	-	-
12	14.66	-	-
13	16	-	Ultimate load

Table 6: load deflection behavior for specimen 2

5. Discussion of results

5.5.1 Observation of Crack Development

The Experimental Crack Pattern of The folded plate shown in Fig., For Simply Supported. Generally for RCC trough type folded plate crack is observed in transverse section at tension zone which is on bottom side of the plate since moment carrying capacity is week in longitudinal direction rather than transverse section.

5.5.2 Load deflection behavior

Ferro cement trough type folded plate crack is, initially started at bottom in transverse section similar to the RCC folded plate but after that it is observed that is also get cracked in longitudinal section with increased deflection when compared to the RCC since Ferro cement is flexible member.

5.5.3 Comparison of first crack load and ultimate load

For the tested 2 specimens the first crack load is observed at 8 kN & 6.6 kN /m respectively and the ultimate load is observed at 16 kN & 14.4 kN respectively.

5.5.4. Comparison of Experimental and Analysis Results:

Comparison result of Folded ferrocement plates performance in Numerical and Experimental Investigation given in Table 7.

S. No	ANSYS	Experimental
ultimate load	23 KN/m	16 KN/m
max deformation	15 mm	9.05mm (8.0 KN/m)

Table-7: Results drawn from ANSYS

6. Conclusion

The below conclusion we arrived at the end of this work

- Ferro cement systems are high ductile structure failure of the members only by cracking not by sudden failure, even at higher loads.
- Use of Ferro cement in folded plates due to good results as folded plates are effective for a longer period of time. Ferro cement has rendered the components smaller for carrying the load because Ferro cement elements are high on stress as reinforcement is spread.
- For the tested 2 specimens the average first crack load is observed at 8 kN/m and the ultimate load is 16 kN /m respectively. The analytical values are nearer to the experimental values
- Ultimate load is 25% higher than the first crack load in experimental observation.
- The cracks observed in the folded plate of ferrocement begin at the tension zone.

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