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Experimental Investigation of Reinforced Ferrocement Concrete Plates under Impact Load

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ABSTRACT: This paper deals with the study of impact resistance and energy absorption properties of reinforced ferrocement plates under impact load. For this a series of five ferrocement plates with dimensions of 450×450×25mm were casted and tested. The impact loading was applied to the specimens by dropping a 3.5 kg steel ball from a height of 118 mm at the centre of plates. The plates were casted with reinforcing bars and different types of reinforcing meshes such as expanded mesh, rectangular welded mesh, welded mesh light and hexagonal mesh. Polypropylene fibre was used in the mix to produce fibrous concrete jacket to improve the concrete characteristics. The impact energy at initial cracking stage and at failure was determined for all the plates. The results indicated that higher energy absorption is achieved in expanded metal mesh light as they are effective in controlling the developed cracks.
Keywords: Impact load; Ferrocement; Concrete Plate; Reinforced Concrete.

INTRODUCTION

Ferrocement construction technique is a form of reinforced concrete which has several layers of mesh completely penetrated in to the mortar. Steel mesh is the most common type of reinforcement material used in this technique and other materials include selected organic, natural of synthetic fibres which may be combined with metallic mesh. Ferrocement have several advantages like, fabricated into any desired shape, low labour skill requirement, ease of construction, low weight and long lifetime, low construction material cost and better impact and earthquake resistance. The applications of ferrocement were floors and roofs, manhole covers, rehabilitation of structures, strengthening of RCC structures, soil stabilization and pre-cast ferrocement structures etc [1-3]. Although the concept of ferrocement is almost as old as reinforced concrete, the real development took place in recent years. The mechanical properties, and hence the technical information are now fairly well established [4- 6].

The investigation of ferrocement plates subjected to impact loads has received good attention among the researchers around the world as the understanding of the impact resistance of ferrocement slabs is very limited. The limitation is mainly due to the absence of standardized test technique for testing concrete under impact. Many researchers have used different impact machines, specimen configurations, geometry and instrumentations and have also adopted different analysis schemes. The impact load characteristics are different from that of static and seismic loads. Since the duration of loading is very short, the strain rate of material becomes significantly higher than that under static and seismic loading. Also structural deformation and failure modes will be different from those under static and seismic loading. Yousry et al. [7] studied the impact resistance of reinforced ferrocement concrete plates reinforced with various types of reinforcing materials. The experimental results emphasized that increasing the number of the steel mesh layers in the ferrocement composites increases energy at first cracking, energy at up to failure, and energy absorption properties. Sudarsana Rao et al. [8] investigated the behaviour of slurry-infiltrated fibrous concrete (SIFCON) slabs under impact loading and the test results revealed that SIFCON slabs with 12% fibre volume fraction exhibit excellent performance in strength and energy-absorption characteristics. Regression models have been developed to estimate the energy absorption for SIFCON slab specimens. Padmanaban et al. [9] worked on the impact characteristics of Indian fly ash mixes with locally available ingredients and the empirical relations were arrived between the impact strength and compressive strength. There is a good correlation between the experimental and predicted values. Deepa Shri et al. [10] proposed and developed new mathematical models by using a regression equation for the prediction of impact energy absorption of hybrid ferrocement slabs, which were made up of self compacting concrete and wrapped with Glass fibre Reinforced Polymer sheets (GFRP) (1 and 2 layers) along with a specified proportion (0 and 0.30%) of polypropylene fibres. the varying parameters such as number of layers of GFRP sheet, area of weld mesh and height of drop were used as variables in the prediction models and the models provided a good estimation of impact energy absorption and yielded good correlations with the data used in the study. Hago et al. [11] investigated the ultimate and service behaviour of ferrocement roof slab panels. The results indicated that the use of monolithic shallow edge ferrocement beams with the panels considerably improves the service and ultimate behaviour of the panels, irrespective of the number of steel layers used. The present investigation is principally aimed to study experimentally the behaviour of ferrocement concrete plates reinforced with different kinds of meshes under the impact load.

EXPERIMENTAL PROGRAM

In this study a series of five ferrocement plates were designed and casted with dimensions of 500 × 500 × 25mm. The ferrocement plates were reinforced with skeletal steel bars and metal meshes. The specimens were tested to study their behavior under impact resistance and the falling load was kept constant as 6.5 kg from a height of 118 mm.

A. The materials

The cement used was Ordinary Portland Cement. Its chemical and physical characteristics satisfied the Indian Standard Specification IS 1489:1991.

The fine aggregate used in the experimental program was river sand obtained from a local source, sand passing through IS sieve 4.75 mm. It was clean and nearly free from impurities with a specific gravity 2.6.

Polypropylene Fibres was used in concrete mixes to enhance the tensile strength of the matrix. The percentage of addition was chosen based on the recommendations of manufacture. The chemical and physical characteristics of Polypropylene Fibers are given in Table (1).

Table 1- Properties of Polypropylene fibre

Property	Specifications	Property	Specifications
Specific gravity	0.91	Tensile strength	0.67KN/Sq.mm
Alkali resistance	Excellent	Young's modulus	4.0KN/Sq.mm
Chemical resistance	Excellent	Melting point	>165 degree celsius
Acid & salt resistance	High	Ignition point	600 degree celsius

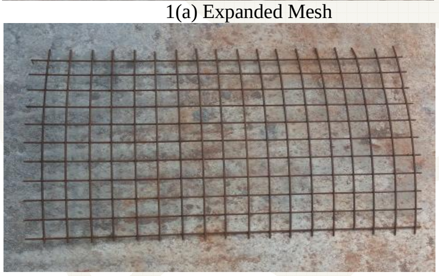
Water used was the clean drinking fresh water free from impurities for mixing and curing the plates.

Reinforcing Steel: Normal mild steel bars steel bars (nominal diameters 6 mm) were used as the reinforcing material in first series of ferrocement plates.

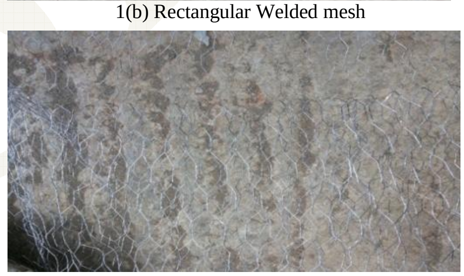
Reinforcing Meshes: The different types of reinforcing meshes used in this study are given in Table 2 and their geometry shown in Figure 1.

1(a) Expanded Mesh

1(b) Rectangular Welded mesh



1(c) Welded mesh light



1(d) Hexagonal mesh

Fig.1 Different type of reinforcing mesh

Table 2- Experimental program of all series

Plate ID	Type of reinforcement
PL1	Steel bars
PL2	Expanded metal mesh light
PL3	Rectangular welded mesh
PL4	Welded mesh light
PL5	Hexagonal mesh

B. Mortar Matrix: The mix properties for mortar matrix were chosen based on the (ACI committee 549 report: 2008). For all mixes, mechanical mixer in the laboratory with capacity of 0.05 m^3 was used, where the volume of the mixed materials was found to be within this range. The constituent materials were first dry mixed; the mix water was added and the whole batch was re-mixed again in the mixer. The mechanical compaction was applied for all specimens. The mix properties by weight for the series are given below in Table 3.

Table 3 Constituents of mortar used per m^3

Mix Design	Mix. Weight (kg/ m^3)
Cement	681.82
Sand	1363.64
Water	238.64
Polypropylene fibre	0.8%

C. Preparation and Casting of Test Specimens: Description of the ferrocement plates used for impact resistance and there reinforcement details of the ferrocement plates are shown Table 2. The wooden forms of plates were coated with thin oil before concrete mortar casting. The reinforcement was then placed in their right position in the forms. The concrete was then placed in the forms and compacted by using the vibrating table to ensure full compaction. After the moulds had been filled with concrete, the surface of concrete in moulds was levelled by using the trowel. Plates were lifted in the forms and covered with polythene sheets for 24 hours in laboratory conditions.

D. Impact Test Procedure

The test procedure adopted is as follows: A 3.5 kg steel ball was released from a height of 118 mm repeatedly, which would come in contact with the top surface of the centre of plates. The number of impact blows until the appearance of first visible crack was recorded. The loading was then continued and the number of blows until failure was recorded. The schematic diagram of impact test experimental setup is shown in Figure 2.

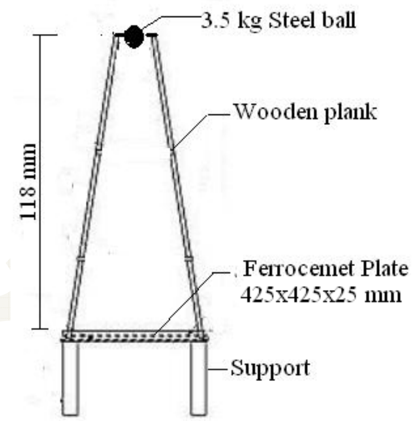


Fig. 2 Schematic diagram of experimental setup.

RESULTS AND DISCUSSIONS

The test results are presented in Table 3. The energy absorption value is obtained by:

E= N x (w x h) joules

Where, E is the energy in joules, w is weight in Newton, h is the drop height in meter and N is the blows in numbers.

Table 4. Average impact test results

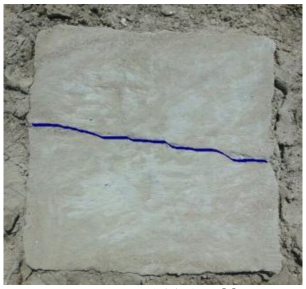
Plate id	Type	N_1	N_2	Impact Energy at First Crack (Kg mm)	Impact Energy at Failure (Kg mm)
PL1	Steel bars	10	18	4130	7434
PL2	Expanded metal mesh light	18	35	7434	14455
PL3	Rectangular welded mesh	16	28	6608	11564
PL4	Welded mesh light	18	31	7434	12803
PL5	Hexagonal mesh	15	25	6195	10325

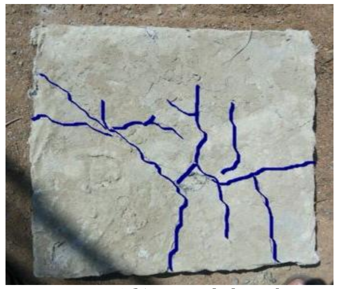
N_1- Number of blows at first crack; N_2- Number of blows at failure

Throughout the experiment the weight of the ball and height of fall is maintained as 3.5 Kg and 118mm respectively. Each value presented in the table is an average of three specimens is shown in Table 4. The first crack load is defined as the load which cause first crack of tested plates, and the ultimate load (Final load) is defined as the load which causes failure of the plates. The energy absorbed by the ferrocement slabs when impacted depends on the local energy absorbed both in contact zone and by the impactor. The impact energy at first crack is increased by 80% in PL2 when compared to PL1. Similarly the impact energy at first crack in case of PL3, PL4 and PL5 is increased by 60%, 80% and 50% respectively, when compared to PL1. The impact energy at failure is increased by 94%, 56%, 72% and 39% in case of PL2, PL3, PL4 and PL5 respectively when compared to PL1. Also it was found that the energy absorption capacity is maximum in PL2 and minimum in PL1.

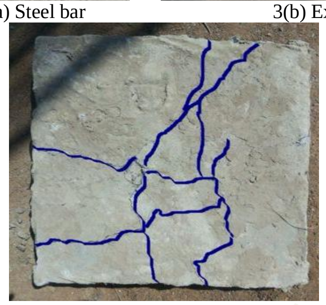
CRACK PATTERN

It can be seen from the Figure 3 that use of polypropylene fibre for ferrocement concrete slabs results in considerable reduction in the crack width and consequently increases the propagation of cracks. Also it is found that the specimen containing steel bar as reinforcing material fails under a single large crack whereas the specimens incorporating the meshes show better propagation of cracks. This shows the beneficial effect of mesh in the ferrocement composites.


3(a) Steel bar


3(b) Expanded Mesh


3(c) Rectangular Welded mesh


3(d) Welded mesh light

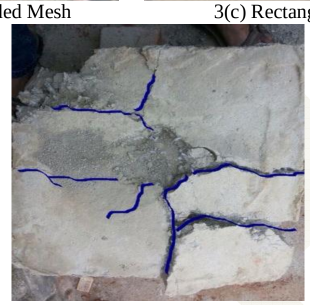

3(e) Hexagonal mesh

Fig. 3 Crack pattern of ferrocement plates with different mesh

CONCLUSIONS

Based on the results obtained from the experiment the following conclusions are drawn

- Higher energy absorption is achieved in the ferrocement plates using meshes than that of the plates using mild steel bars as the reinforcement material. This could be attributed to the effect of mesh in controlling the developed cracks.
- The presence of polypropylene fiber enhanced the first crack load, ultimate load and the impact energy absorption irrespective of the type of reinforcing meshes and steel bars in the ferrocement plates.
- The occurrence of first crack was delayed and better crack distribution is attained in the ferrocement composites due to the existence of fibers which led to the higher stiffness of the specimen.
- Ferrocement plates of least thickness with higher energy absorption, crack resistance and high strength, which are useful for dynamic applications with great economic and advantages were developed.

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