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Impact Behavior of Ferrocement Slabs with High Strength Mortar

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Abstract

Developing countries have an increasing the building construction using various alternate materials due to materials constraint. Building construction in developing countries are undertaken as a combination of alternative materials and reducing the structure sizes to economize costs. In this regards, the investigation of ferrocement slabs subjected to impact test. A total of 4 slabs were casted and tested, the size of these slabs are of 300m x 300mm x 25mm. These slabs were cast by varying the number and size of reinforcing mesh layers. Cement mortar matrix mix for ferrocement slabs was finalized by developing 5 mixes of high strength mortar. A mix of ratio 1:1 mortar with 90% cement, 10% silica fume and M-sand gives the compressive strength of 80-90MPa, therefore it is adopted as a best mix for ferrocement slab. Further welded mesh of 2 and 4 layers of 60mm and 30mm openings were used as reinforcement for these slabs. The results concluded that impact strength and energy were increases with increased in mesh layers and mesh size.

Index Terms; *Ferrocement slabs, Welded and wire mesh, High strength mortar, Impact energy..*

I. INTRODUCTION

In India, Developing Countries are needed more infrastructures for various purpose like residential, educational, commercial, industrials and IT sectors. In this connection, to develop above mentioned all the sectors need the buildings. Developing countries are an increasing the building construction using various alternate materials due to materials constraint [1]. Building construction in Developing countries is undertaken as a combination of alternative materials and reducing the structure sizes to economize costs. Alternative construction materials were using to develop the Civil Engineering structures. In most of the countries "The ferrocement slab is directly helping to low income group peoples for constructing their house". The Ferrocement technique and application invented and patented by Joseph-Louis, in the year 1852, in France. The patent called "Ferro - cement", which translates into, "iron-cement". Most common material is ferrocement. This ferrocement is

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combination of cement, sand, water and reinforced with layer of thin wire mesh. In the year 1887, Mr. Boon, fabricated a small craft of ferrocement, the seagull and barges of mesh mortar to carry ashes and retain the water on river/canals.

Pier Luigi Nervi (1940) had studied and revived that original concept of "Ferrocement". Study concluded that Ferrocement be utilized to fabricate to fishing boats. Ferrocement finally achieved wide acceptance for boat fabrication in the United Kingdom (UK), New Zealand, Canada and Australia [2]. The ferrerocement Slabs have enough compressive strength, tensile, hardness, durability and lightweight compare than other building materials [3–6]. American Concrete Institute (ACI) Committee, recommended that Ferrocement for the thin wall reinforced concrete for construction [7]. Pama et.al (1978) conducted a study, With such mechanical properties of the ferrocement, study found that the various applications like residential, small houses, water shed, toilets, aquaculture, agriculture, water resources, temporary buildings [8].

The ferrocement slab is mainly uses to rural peoples for constructing their small house and toilets". Ferrocement Slab has more toughness, ductility, durability, strength and also cracking resistance. Alnuaimi et al (2009) conducted a study, prepared nine roof panels of Ferrocement the specimens are, two kinds of channel sections and one kind of box section[9]. A. A. Skudra & A. M. Skudra Experimental investigation and concluded that regular type of reinforcement utilize for ferrocement is Woven Wire Grids (WWG). The benefits of such reinforcement include its moderately economical and effortlessness of use. The size of the openings in the hexagonal weave grids were range from 10mm to 25 mm [10].

Letitia (2013) Demonstrated the study that durability of ferrocement slab can be improved with the help of appropriate surface coating & surface coating will present the most excellent preserve for the mortar and the mesh [11]. S. R. Suryawanshi & Ashish Dahatre , Studied the ferrocement is consist of cement and reinforcement contain several layers of mesh. Ferrocement techniques are mostly used these days in most of the developing countries. This technique is directly linked with mechanical properties of strength, benefits, improvements, excellent design parameters, research and development, application, low cost [12].

The generally the load vs deflection response of ferrocement slab in bending can be acknowledged in Figure.1.

Totally five stage, each stage and its behavior are presented are below.

First stage, there is no development of structural cracking.

Second stage is multiple cracks were developed due to increasing loads.

Third stage is an area where gradual yielding of the steel reinforcement occurs.

Fourth stage is the strain-hardening section during which the maximum load is reached

Fifth stage is peak portion is failure occurs due to mortar failure in compression or due to failure of the extreme layer of mesh. [13 - 15].

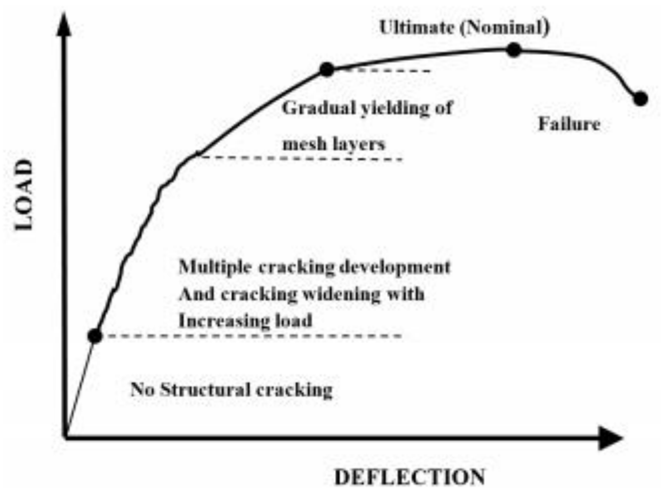

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Fig.1. Typical load and deflection of Ferrocement slab

The ferrocement material has different features compare than Reinforced Cement Concrete (R.C.C). The important features are presented in below table 1.1

Table 1: Comparison of ferrerocement & (R.C.C)

Property	R.C.C	Ferrerocement
Strength	Weak in tension	**High tensile strength**
Tensile strength	4-6 kg/cm^2	**80- 90 kg/cm^2**
Strength to Weight Ratio	15 to 50	**45 to 90**
Matrix material	Cement concrete	**Rich cement mortar**
Thickness	Mini. 75mm	**Thin walled, 25 to 50 mm**

Observations were made from the literatures.

a. Based on observation, ferrocement is old technique but it is fastest mode of technique to build the any shape of building.
b. Ferrocement materials were easily available material in overall world.
c. Ferrocement consisting of wire meshes and cement mortar.
d. Ferrocement is light weight materials and minimum of material cost.
e. Excellent resistance against fire, earthquake and natural distresses.

Moreover, due to material constraint, speed of construction, architectural and aesthetic look more need the ferrocement slab for building construction. Therefore, an attempt has been made in this paper to study the impact behavior of ferrocement slabs.

II. OBJECTIVES OF THE STUDY

- To develop a high strength mortar matrix mix ferrocement slabs.
- To find the mechanical properties of developed mortar mixes.
- To find the impact behaviour of Ferrocement Slab by varying the reinforcing mesh layers.

III. METHODOLOGY OF THE STUDY

The present experimental study is Impact Behavior of Ferrocement Slabs with High Strength Mortar. The study consists of three stages are as follows:

First stage:

Selection of ferrocement material such as cement, fine aggregate, M-Sand, silica fume, Reinforcing welded and wire mesh, Super plasticizer and water. Those materials conducted tests.

Second stage:

The preparation ferrocement slab using high strength mortar, Reinforcing welded and wire mesh.

Third stage

Conduct the experimental test and drawn conclusion and recommendation.

IV. IV. MATERIALS

A. Cement

Cement is a binding material; Ordinary Portland Cement (OPC) of 53 Grades was used in this present work. Cement properties are as follows in Table no.2

Table 2. Properties of Cement

S.No.	Properties	Value
1	Specific gravity	3.13
2	Normal Consistency	32%
3	Initial setting time	35 minutes

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4	Final setting time	350 minutes
5	Fineness	6%

B. Fine aggregates

Manufactured sand was used as a fine aggregate in this study. M-sand is produced from hard granite stone by crushing. M –Sand obtained from Chennai and superior quality of granite stone were used in the mortar mixes. M-Sand properties are as follows in Table no .3

Table 3 properties of M-Sand

S.No.	Properties	Value
1	Specific gravity	2.9
2	Fineness modulus	3.07
3	M-Sand size less than	4.75

C. Silica fume

It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles. Silica fume properties are as follows in Table no . 4

Table 4 properties of Silica flume

S.No.	Properties	Value
1	Specific gravity	2.63
2	Dossage	7-10%
3	Particle diameter	150 nm

D. Reinforcing welded and wire mesh (RWWM)

Weld mesh is used as reinforcement for ferrocement elements. Mesh a small diameter steel rod which is welded together at a specific interval in both directions. Weld mesh of 2.45mm diameter with 60mm opening and 3mm diameter with 30mm is used in this work. Then wire mesh of 1mm diameter with 10mm spacing is used for even distribution of mortar.

E. Super plasticizer (SP)

In this study used in Polycarbolica super plasticizer. SP, is high range water reducers, are chemical admixtures used. SP properties are as follows in Table no . 5

Table 5 properties of super plastizer

S.No.	Properties	Value
1	pH	6.0
2	Specific gravity	1.10

F. Water

Water is an important constituent material in construction. It should be potable and free from impurities. pH of the water should be within the limit (6-7). These characteristics should be applicable to both mixing and curing water.

V. EXPERIMENTAL PROGRAMME

A. Development of High Strength Mortar

Mortar is an essential and important material for ferrocement. Usually, mortar is a mix which consists of cement, fine aggregate and water. But here, a high strength mortar is developed. Totally 5 mixes were developed for high strength mortar. These mixes were prepared by adding admixtures like silica fume and super plasticizer. By varying the percentage of silica fume and cement content, these mortar mixes are developed. Table 6 shows the different mixes of mortar.

Table 6 – Mix Proportions of mortar

S.No.	Mix ratio	Cement content	Silica fume content	M -sand	w/c ratio	Super plastizer content
1	Mix1 - 1:1.1	85%	15%	100%	0.275	1%

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2	Mix2 - 1:1.5	85%	15%	100%	0.3	1%
3	Mix3 - 1:2	90%	10%	100%	0.3	1.2%
4	Mix4 - 1:1	90%	10%	100%	0.3	1%
5	Mix5 - 1:1.5	90%	10%	100%	0.3	1.2%

B. Mechanical properties of high strength mortar

Further, mechanical properties of mortar mixes were found by casting and testing the different specimens like cubes, beams and cylinder. The below table no. 7 shows the mechanical properties of developed mortar:-

Table 7- Mechanical properties of High strength Mortar

Mix No	Compressive Strength (MPa)			Flexural Strength (MPa)	Split tensile Strength (MPa) 3rd day
	3rd day	7th day	28th day		
Mix – 1	37.43	53.35	69.56	6.34	2.99
Mix – 2	34.65	44.66	58.46	6.55	3.16
Mix – 3	42.43	48.75	60.67	6.68	4.18
Mix – 4	54.56	70.33	85.13	6.75	4.45
Mix – 5	48.46	60.78	72.65	6.28	4.36

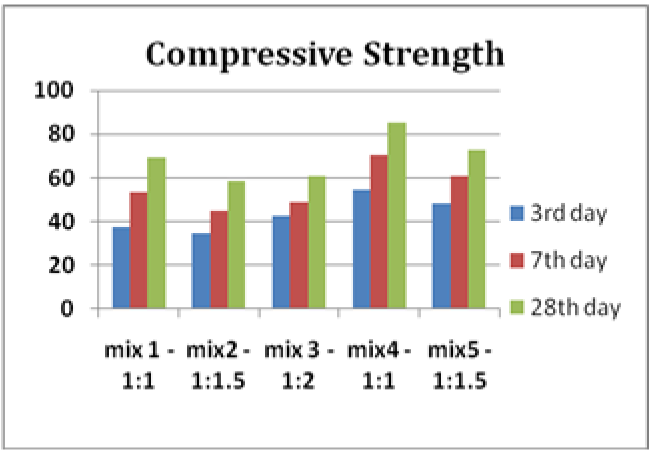

Figure 2- Comparison of Compressive strength for developed mortar mixes

The figure 2 shows the result of Comparison of Compressive strength for developed mortar mixes. The maximum compressive strength obtained 85.13 MPa. The minimum compressive strength value obtained 58.46 MPa for mix no.2 with mix ratio 1:1.5.

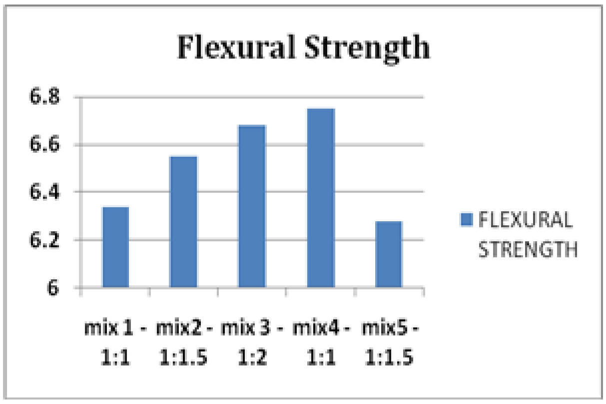

Figure 3: Comparison of Flexural Strength for developed mortar mixes

The figure 3 shows the result of Comparison of Flexural Strength for developed mortar mixes. The maximum flexural strength obtained 6.75 MPa. The minimum flexural strength value obtained 6.28 MPa for mix no.5 with mix ratio 1:1.5.

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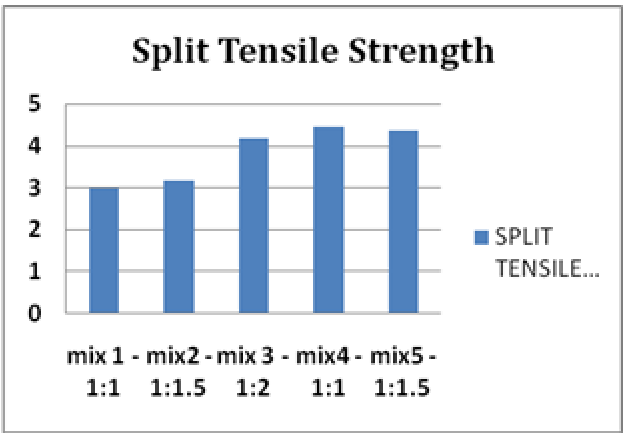

Figure 4 – Comparison of Split tensile strength for developed mortar mixes

Figure 4 shows the test results were indicated the highest split tensile strength values of 4.45 Mpa was obtained for mix no. 4 with ratio 1: 1. From the table 7 test results were indicated that compressive strength, flexural strength and split tensile strength the maximum values obtained for mix no.4 with ratio 1:1.

C. Casting of ferrocement slabs

A weld meshes of size 2.45mm diameter with 60mm opening and 3mm diameter with 30mm opening was cut for 290mm x 290mm, as reinforcement for slabs. These meshes were arranged as 2 and 4 layers for showing variation in reinforcement. Wire meshes are also tied together with the weld mesh for the purpose of even distribution of mortar. Each reinforcing meshes were straightened and all layers are tied together with the help of binding wire. Then wooden moulds were prepared for a size of 600mm x 300mm x 25mm. Mortar mix for these slabs is adopted from the above mixes which are of high strength. Mix 4 of ratio 1:1 is chosen as an optimized mix and slabs were cast for this mix. Mortar was prepared by calculating the exact amount of cement, m- sand, super plasticizer and water by considering the appropriate mix design and water-cement ratio. At first the cement and m-sand were mixed dry. Water is gradually added to the dry mix and is mixed by using mixer machine and shovel.

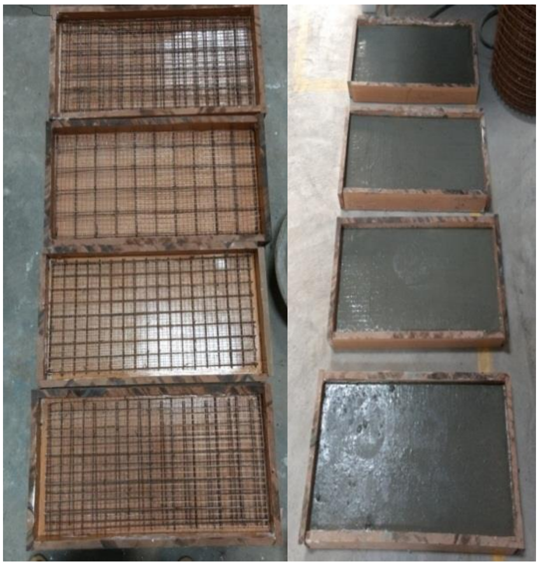

Figure 5- Mould with reinforcement and finished ferrocement slab

After the preparation of mould, mortar is filled for certain thickness and reinforcing mesh was placed over it and again mortar is filled over the mesh upto the required thickness. Then, after 24 hours slabs are removed from the mould and it is placed in the curing tank for 28 days. The details of the slab are given below,

1) 4LB – 4 layers mesh of 2.45mm diameter and 60mm opening

2) 2LB – 2 layers mesh of 2.45mm diameter and 60mm opening

3) 2LS – 2 layers mesh of 3mm diameter and 30mm opening

4) 4L2S2B – 4 layers, 2 layers of 2.45 diameter and 60mm opening at outer side and 2 layers of 3mm diameter and 30 mm opening at inner side.

D. Testing of ferrocement slabs the following steps are as follows.

Step (i): Curing process completed, the ferrocement slabs were withdrawn from the curing tank/curing process and applied washes to the slabs in order to get indication of cracks on repetitive drops.

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Step (ii): Impact test was conducted on the square slabs after 28 days of curing by using a drop weight and the test setup is shown in Figure 6.

Step (iii): It consisted of a rigid welded steel frame square in plan and supported by short columns. The specimen was laid flat resting on four 75 mm diameter bars to provide line support along the four edges.

Step (iv): The test setup consists of a cylindrical ball of 60mm diameter, 150mm height (the plunger) with hemispherical blunt tip to a height of 50mm. The height of the drop was kept as 250mm.

Step (v): the plunger which loads the panel has a spherical tip enabling a point contact to be made. A rope and pulley arrangement with a pipe guide, which enables a central impact in the vertical direction, was used to manually raise the hammer to the required height for repeatedly dropping it on the specimen surface.

Step (vi): Grease was applied on the rollers to reduce friction and to ensure a smooth fall. The weight of the ball is 3.22kg and it is dropped from a height of 670mm.

Step (vii): The mass was then dropped repeatedly and the number of blows required to cause first crack was recorded. Then the number of blows required for the failure is also recorded. Then the process was continued further, till the crack propagated further and appeared at the sides of the specimen.

Step (viii): The number of blows required to cause the crack width of 2mm were also noted down.

Step (ix): The total energy absorbed by the ferrocement slabs when struck by a hard impactor depends on the local energy absorbed both in contact zone and by the impact.

Step (x): The energy absorption can be obtained by using the following formula as given below.

E= N x (w x h),------------------------------(1)

Where,

E= Energy In Joules ,

N= Blows in Numbers,

w= Weight in Newton,

h= Drop Height in Meter,

Figure 6 – Test setup for slab and failure of slab

VI. TEST RESULTS AND DISCUSSION

Table 3 – Test results of slab

Slab Id (% rein)	No. of drops for 1St crack	No. of drops for failure	Impact Energy for 1st crack (N-m)	Impact Energy at failure (N-m)
2LB (0.63)	2	16	42.3	338.6
4LB (1.25)	4	42	84.6	888.8
2LS (1.69)	3	20	63.5	423
4L2S2B (2.32)	8	45	169.3	952.3

From the results of impact test on slabs, it was observed that

All the slabs fail by developing a through hole at the centre.

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Initially, first crack was developed at initial impact drops and then further cracks are increased and propagated to a length of 50-60mm.
Then on further impact loadings, cracks propagate and reached the boundaries of the slab.
Spalling occurs at the edges of the slab, then cover mortar and mesh wire becomes visible on consecutive impact loads.
The slab 4L2S2B has the highest impact energy and hence it shows that, by increasing the layers of mesh impact strength increases.
The slab 2LB has the lowest impact strength and it is due to less layers of mesh and more spacing between the mesh rods.

VII. CONCLUSION

Based on the results concluded that number of mesh layers and spacing between the mesh rods influences the impact behaviour of slab. Closely spaced mesh rods and more number of mesh layers gives good impact behaviour. Mortar strength also influences the impact behaviour and hence usage of high strength mortar in ferrocement slab will give good behaviour.
Further, these ferrocement panels with high strength mortar can be recommended for strengthening of structural elements.

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