Effect Of Different Meshes On The Energy Absorption Of Ferrocement Panel

Darshan G. Gaidhankar, M. S. Kulkarni, Aman Jain

Abstract: Development of new construction materials, capable of absorbing more energy is the need of the society and this the area in which research needs. Because of the excellent behavior under flexural and impact strength, ferrocement is the widely used structural element under such circumstances. Also it has excellent mechanical properties. The thickness of ferrocement panel considered is 40 mm and 50 mm. As the thickness of the ferrocement panel is very less, M50 grade of mortar is used. The ferrocement panels are casted using galvanized welded square mesh and galvanized woven square mesh with 04, 05 and 06 mesh layers. For crack controlling, few ferrocement panels are casted using corrugated steel fibers and hooked steel Fibers in addition to the regular mesh (1% by weight of sample). The ferrocement specimens are tested under drop weight impact test. The drop weight impact test is done by dropping a weight of 3.5 Kg from a height of 0.5m and 0.75m. It is concluded that, the impact strength of the ferrocement panel reinforced with galvanized welded square mesh is excellent than the ferrocement panels reinforced with galvanized woven square mesh. When the steel fibers are added in the ferrocement panel, the energy absorption capacity of the ferrocement panel under impact loading is increased. The ductility index is found to be decreased with increase in the drop weight height.

Index Terms : Ferrocement, Mortar Grade, Mesh, Impact Strength, Corrugated steel fibres, Hooked steel fibres, Drop weight

1. INTRODUCTION

Ferro-cement has been described as densely reinforced mortar formed into a thin shell, which behaves as a composite material, whose properties depends on combination of steel and dense, high strength mortar. Generally the concrete structures are designed for static loads. But sometimes such structures may be subjected to dynamic loads arising from blasts, impulsive loads, impact by external projectiles, military or terrorist activities, and accidental explosions of various chemical compounds, machine vibrations and earthquake. During blast and fragment impacts from small charges, the structure will shake, vibrate, severe crushing of concrete occurs and crater forms in the front of the concrete and for large charge, large penetration will occur and will result in scabbing to the back side of the wall or perforation with risk of injury for people inside the structure. Ferro-cement panels can be found to be most useful under impact loading. In Reinforced Cement Concrete, the fundamental assumption in reinforced concrete design is that concrete is assumed to resist no part of flexural tensile force. In Ferro-cement specimens, one of the object of the mortar, reinforced randomly with fine wire is to improve the tensile strength compared to plain mortar. The tensile cracking stress increases proportionately with the amount of steel per unit volume of composite up to a practical limit imposed by maximum steel concentration for which mortar may be compacted. An increase of cracking stress of three to four times may be achieved at maximum steel density. Ferro-cement differs fundamentally from reinforced concrete is due to the use of meshes, the several layers of which enable the mortar to place without mould.

1.1 Objectives of the research work:

- Panel thickness effect on the energy absorption of the ferrocement panel.
- Type of mesh effect on the energy absorption of the ferrocement panel.
- Ductility index of the ferrocement panel by varying panel thickness and type of mesh.

1.2 Parameters of the study:

- Types of meshes used are, Galvanized welded square mesh and galvanized woven square mesh.
- Grade of mortar used is M50.
- Thickness of panels taken are 40mm and 50mm
- For low velocity impact loading a drop weight of 3.5 kg is used, the drop weight is dropped from a height of 0.5m and 0.75m.
- Two types of fibers are also used, corrugated steel fibers and hooked steel fibers.

2 LITERATURE REVIEW

Anitha M. et al carried out an experimental work to study the behavior of hybrid Ferro-cement slab subjected to impact. The square Ferro-cement panels of size 300 mm × 300 mm with thickness 25 mm and 35 mm were tested for impact by using drop impact test, by fixing all the sides of the panel. For the specimens 02 and 03 layered bundled wire mesh was used. Wire mesh used was of 1.2 mm diameter with grid size 20 mm × 20 mm. For testing the specimens a weight of 3.5 kg was dropped from the height of 1.185 m and 1.18 m. The authors concludes that, due to presence of number of bundled wire mesh in the path of impact, it required more number of blows to cause ultimate failure. Increase in number of layers of bundled wire mesh and thickness of hybrid Ferro-cement slabs increases the energy absorption and ductility index significantly. H. Sudarsana Rao et al carried out an experimental work on Slurry- Infiltrated Fibrous Concrete (SIFCON), Fibre-reinforced concrete (FRC), reinforced cement concrete (RCC), plain cement concrete (PCC) specimens for studying their response under impact. The square specimens 600 mm × 600 mm × 50 mm thick, with conventional reinforcement and without conventional reinforcement were cast and tested under impact with a steel ball drop weight. For the slabs with conventional reinforcement, 8 mm diameter High Yield Strength Deformed (HYSD) steel rods are used. For FRC slab panels, Black annealed steel wire of 1.0 mm

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diameter is used as fibre and percentage of fibres was 12 % which shows excellent results. The authors concludes that, the absorption of impact energy is more in SIFCON slab with conventional steel reinforcement when compared with the FRC, RCC and PCC slab panels. Essam Eltehawy carried out an experimental work on control panels and Ferro-cement panels to study enhancement of the mechanical properties of reinforced concrete slabs subjected to impact. The square specimens with thickness of 10 cm and 14 cm were tested under Impact test, Penetration test and fire test by dropping a weight of 335.5 kg and by means of gun shots. The author conclude that, the impact resistance and fire resistance of Ferro-cement panels has been improved with increase in number of mesh layers. The author suggested future research scope by using different types of meshes, using different thickness of Ferro-cement layer and comparing resistance of Ferro-cement to fire with different materials used in the field. Mamdouh E. Mohamed et al carried out an experimental work on square concrete panels of 200 mm thick to study penetration resistance. An experimental investigation was performed for seven specimens of reinforced concrete panels in which steel blunt-nose projectile with a diameter of 23 mm and a mass of 175 grams is fired with striking velocity about 970 m/s. The specimen incorporated different number of layers of wire mesh. Galvanized woven wire mesh of 2 mm diameter and 50 mm square opening was used to reinforce the concrete panels. For penetration test, the projectile used was of 23 mm diameter and 64 mm length and was fired from a distance of about 50 m. The specimens of size 550 mm × 550 mm × 200 mm was used for the experimental work. The authors conclude that, using Ferro-cement enhances the penetration resistance of concrete by reducing the penetration depth and reducing the front and rear face damage. Increasing number of layers of wire mesh in Ferro-cement panels has slight influence on the depth of penetration. G. Ramakrishna et al carried out an experimental work on square slab panels of size 300 mm × 300 mm × 20 mm for investigating their resistance to impact loading. The authors used four types of natural fibres like coir, sisal, jute and hibiscus cannebinus in their slab panels. The fibres used were from 0.5% to 2.5% by weight of cement. The impact load was applied by dropping a 0.475 kg metallic ball from a height of 200 mm. The authors concludes that, the impact resistance of the slab panels using natural fibres was about 3-18 times higher than that of plain cement mortar slabs. They also concludes that, coir fibre reinforced mortar slab specimens have absorbed the highest impact energy. P. S. Song et al had carried out an experimental work on high strength steel fiber-reinforced concrete (HSFRC) and high strength concrete (HSC) specimens for studying their impact resistance. The 3.5 mm long hooked-end steel fibres with aspect ratio 40 was used in the specimens. The compressive strength of the concrete mix was 66 MPa. The authors prepared cylinders of size 150 mm × 300 mm. Then these cylinders are cut using a diamond cutter into four 150 mm diameter by 64 mm thick discs. These discs are used for impact loading. The authors concludes that, the impact resistance of high strength steel fiber-reinforced concrete (HSFRC) was superior to that of high strength concrete (HSC). They also conclude that, the first crack strength of HSFRC was about 3.9 times that of HSC. Abdullah et al carried out an experimental work on square Ferro-cement panels with thickness 80 mm, 100 mm and 120 mm to study impact behavior. The panel size used during the experimental work was 750 mm × 750 mm. Galvanized welded wire mesh of 1.0 mm diameter and 10 mm square opening was used as reinforcement for Ferro-cement panel. The cement to sand ratio used was 1: 3.75 by weight. To improve workability, a superplastisizer was added at 0.05% by weight of cement. The water – cement ratio used was 0.67. The impact was given by a projectile of mass 0.5 kg and diameter of 45 mm, was ejected by air pressure at velocity of about 227 m/sec, which is sufficient to model collisions by an aircraft. The authors conclude that, after impact test, two modes of failure, perforation and scabbing, are observed. Increasing volume fraction of reinforcement does not improve impact resistance significantly, when Ferro-cement panel fail in perforation mode.

3 EXPERIMENTAL AND ANALYTICAL WORK :

The present research work deals with behaviour of thin composite elements (ferrocement) reinforced with galvanized welded square mesh and galvanized woven square mesh, with and without steel fibres subjected to under drop weight impact loading. The major parameters investigation are the effect of number of mesh layers, effect of panel thickness and effect of drop weight height on the impact strength of the ferrocement panels.

3.1 The properties of the materials used in the research work are as given below:

Cement used was ordinary Portland cement 43 grade, Fineness of cement = 3%, Standard consistency of cement = 28.75%. Initial setting time of cement = 47 minutes and final setting time of the cement = 432 minutes. The fineness modulus of the aggregate = 2.89% (Zone II). Silt content of the sand = 2.71%. Grade of the mortar = M50. The cement to sand ratio used was 1:1.75, water/cement ratio = 0.38, Admixture used – Perma Plast PS-34 for improving workability.

3.2 Properties of the mesh and fibres used for the research work :

a. Galvanized Welded Square Mesh -: The diameter of the mesh was 1.4mm and 15mm x 15mm opening. Modulus of Elasticity – 200 GPa (Longitudinal and Transverse direction), Yield strength (σ_{ry}) – 450 MPa.

b. Galvanized Woven Square Mesh -: The diameter of the mesh was 1.4mm and 15mm x 15mm opening. Modulus of Elasticity – 138 GPa (Longitudinal direction) and 165 GPa (Transverse direction), Yield strength (σ_{ry}) – 450 MPa.

C. Hooked and Corrugated Steel Fibres.

Table 1. Properties of Steel Fibres

Sr. No.	Properties	Hooked Steel Fibre	Corrugated Steel Fibre
1.	Fibre Length	50 mm	57 mm
2.	Equivalent Diameter	1.00 mm	1.00 mm
3.	Aspect Ratio	50	57
4.	Tensile Strength	1200 to 1300 MPa	700 to 900 MPa

3.3 Theory of Drop Weight Impact :

As we know that toughness of materials are determined by two methods, (i) by measuring deformation under impact load, (ii) by determining energy adsorption capacity of materials under impact load. Several methods were used to investigate to determining toughness of materials. In this research work, drop weight impact test were used. This test is also known as

"Repeated Impact Test". This test is very easy and simple to conduct so that, it is widely used in research work. Specially fabricated stand with drop weight mechanism was used to conduct this test. Impact specimen was placed on this stand under drop weight mechanism. Specimen was properly clamped all side with G-clamps. In this testing, numbers of blows were recorded for first crack and ultimate failure of specimen. A weight of 3.5 Kg made up of solid steel with tapered end was allowed to fall from height of 0.5m, and 0.75m through cylindrical pipe to avoid horizontal moment. This load was applied directly at the centre of specimen. For operation of drop weight mechanism, rope was attached to solid pipe and it pass through pulley for dropping it manually. This energy depends on the mass of the body (m) i.e. drop weight used for test, number of blows (N), the height from which the weight dropped (h) and the acceleration due to gravity is 9.81 m/s^2(g) for converting mass in KN. Ductility Index : Ductility ratio is the ratio of initial energy absorption to the final energy absorption of the ferrocement panel.
The impact energy (E_{imp}) is calculated by formula given below.

$$E_{imp} = E_p = N.\ mgh. \quad \text{(Joules)}$$

Where E_{imp}- Impact energy in joule
N - Number of blows required. h - height of drop weight (m)
m - mass of drop (kg) g - Acceleration due to gravity ($9.81 m/s^2$)

3.4 The maximum dynamic bending stress is given by,

$$\sigma_{max} = \frac{M_{max}\ (\frac{h}{2})}{I} \quad \text{in MPa.}$$

Where,
U = Experimental Strain Energy (J),
m = Modular Ratio, DI = Ductility Index,
H = Height of weight drop (m), L = Length = 1 (m)
E = Experimental Modulus of Elasticity (GPa),

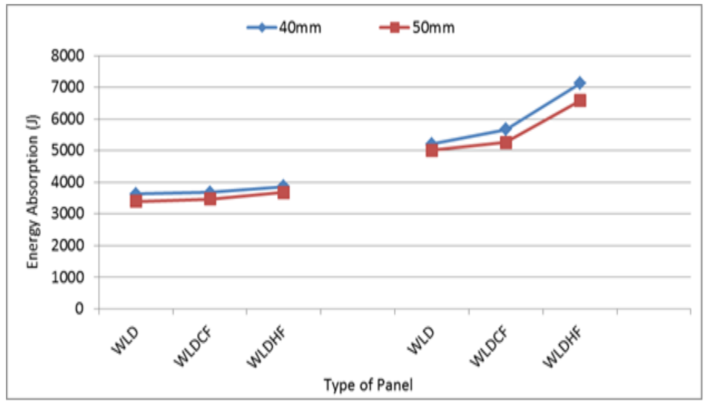
4 RESULTS

The results obtained from the experimental work under drop weight impact loading are as given below :

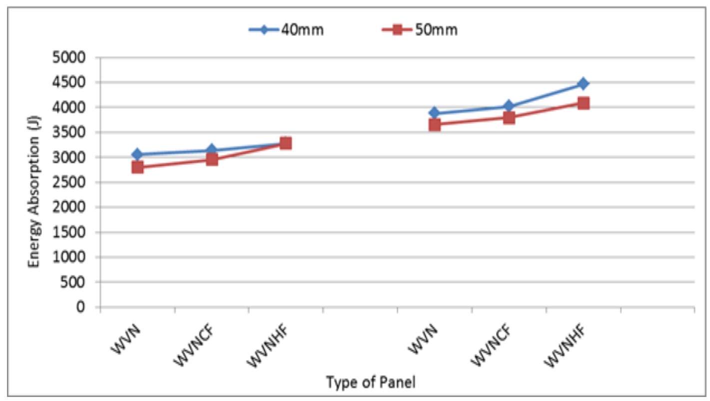
Table 2. Final Energy Absorption Capacity of Ferrocement Panels Ferrocement Panel Size : 250x250
(Drop weight height h = 0.5m)

Sr. No.	Description	Energy Absorption (J)		Energy Absorption (J)	
		40mm Thick Panel		50mm Thick Panel	
		04 Layers	06 Layers	04 Layers	06 Layers
1.	WLD	3622.23	5201.75	3399.06	5012.90
2.	WLDCF	3673.66	5665.27	3467.73	5253.25
3.	WLDHF	3862.57	7124.51	3673.73	6575.15
4.	WVN	3055.72	3879.85	2798.22	3656.67
5.	WVNCF	3141.56	4017.19	2952.72	3794.01
6.	WVNHF	3278.89	4463.55	3278.89	4085.86

Notations used for ferrocement specimens:
WLD- Welded square mesh, WLDCF- Welded mesh with corrugated fibres, WLDHF- Welded mesh with hooked fibers, WVN- Woven square mesh, WVNCF- Woven mesh with corrugated fibres, WVNHF- Woven mesh with hooked fibers.



Graph 1. *Energy Absorption Using 04 and 06 Layers of Welded Square Mesh (For h=0.5m)*

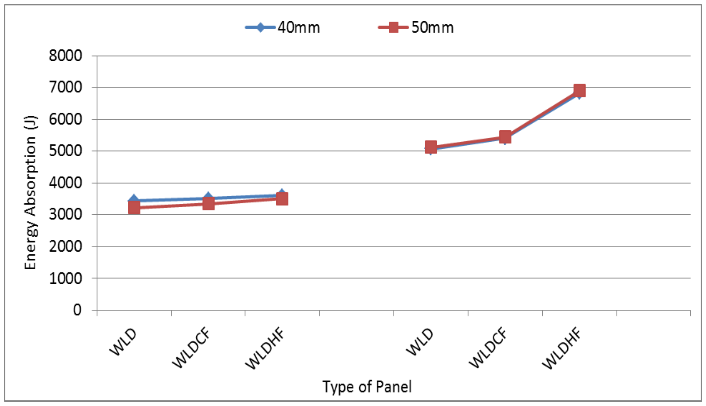


Graph 2. *Energy Absorption Using 04 and 06 Layers Woven Square Mesh (For h=0.5m)*

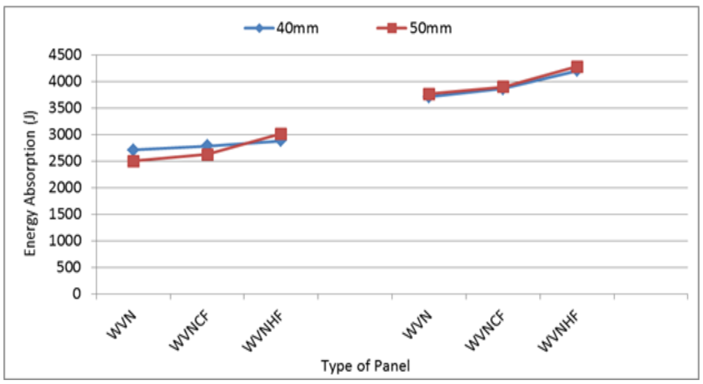
Table 3. Final Energy Absorption Capacity of Ferrocement Panels Ferrocement Panel Size : 250x250
(Drop weight height h = 0.75m)

Sr	Description	Energy Absorption (J)		Energy Absorption (J)	
		40mm Thick Panel		50mm Thick Panel	
		04 Layers	06 Layers	04 Layers	06 Layers
1.	WLD	3424.883	5072.990	3218.875	5115.901
2.	WLDCF	3502.136	5407.762	3347.630	5442.097
3.	WLDHF	3605.140	6824.081	3502.136	6901.335
4.	WVN	2703.855	3708.179	2497.847	3759.682
5.	WVNCF	2781.108	3862.686	2626.602	3897.022
6.	WVNHF	2884.112	4197.453	3012.867	4274.707

Notations used for ferrocement specimens:
WLD- Welded square mesh, WLDCF- Welded mesh with corrugated fibres, WLDHF- Welded mesh with hooked fibers, WVN- Woven square mesh, WVNCF- Woven mesh with corrugated fibres, WVNHF- Woven mesh with hooked fibers.



Graph 3. *Energy Absorption Using 04 and 06 Layers Welded Square Mesh (For h=0.75m)*



Graph 4. *Energy Absorption Using 04 and 06 Layers Woven Square Mesh (For h=0.5m)*

Table 4. Ductility Index of Ferrocement Panels Ferrocement Panel Size : 250x250 (Drop weight height h = 0.5m)

Sr	Description	Ductility Index 40mm Thick Panel		Ductility Index 50mm Thick Panel	
		04L	06L	04L	06L
1.	WLD	6.205	6.586	5.657	6.347
2.	WLDCF	6.294	6.875	5.771	6.652
3.	WLDHF	6.428	8.137	6.114	8.148
4.	WVN	5.934	6.647	5.258	6.085
5.	WVNCF	6.100	6.685	5.548	6.138
6.	WVNHF	6.366	7.222	6.161	6.432

Table 5. Ductility Index of Ferrocement Panels Ferrocement Panel Size : 250x250 (Drop weight height h = 0.75m)

Sr	Description	Ductility Index 40mm Thick Panel		Ductility Index 50mm Thick Panel	
		04L	06L	04L	06L
1.	WLD	6.045	6.566	5.434	6.418
2.	WLDCF	6.181	6.774	5.652	6.593
3.	WLDHF	6.363	8.030	5.913	7.882
4.	WVN	5.834	6.545	5.105	6.347
5.	WVNCF	6.000	6.521	5.368	6.291
6.	WVNHF	6.223	6.791	5.850	6.640

5. CONCLUSION

From the experimental work done using Galvanized welded square mesh and Galvanized woven square mesh, the following

Conclusions are drawn.

1. When the drop weight height is increased from 0.5m to 0.75m, the energy absorption capacity of the ferrocement panel reinforced with galvanized welded and woven square mesh is decreased.
2. When the drop weight height is increased from 0.5m to 0.75m, the ductility index of the ferrocement panel reinforced with galvanized welded and woven square mesh is decreased.
3. The increase in the mesh layers of 40 mm thick ferrocement panel reinforced with galvanized welded square mesh shows 43.606% increase in the energy absorption for 0.5m drop weight height and 48.121% increase in the energy absorption for 0.75m drop weight height.
4. The increase in the mesh layers of 50 mm thick ferrocement panel reinforced with galvanized welded square mesh shows 47.479% increase in the energy absorption for 0.5m drop weight height and 58.934% increase in the energy absorption for 0.75m drop weight height.
5. The increase in the mesh layers, 04 to 06, for 40 mm thick ferrocement panel reinforced with galvanized woven square mesh shows 26.969% increase in the energy absorption for 0.5m drop weight height, 37.144% increase in the energy absorption for 0.75m drop weight height.
6. The increase in the mesh layers, 04 to 06, for 50 mm thick ferrocement panel reinforced with galvanized woven square mesh shows 30.678% increase in the energy absorption for 0.5m drop weight height and 50.516% increase in the energy absorption for 0.75m drop weight height.
7. The ductility index of the ferrocement panel is found to be increased with the increase in the mesh layers, for both the types of meshes.

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