Review On Flexural Behavior Of Ferrocement Panels

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Abstract— *Construction trade is developing quickly all over the world. Concrete and steel are the basic construction materials which are being used with different concepts for construction such as Reinforced concrete, Prestressed and Ferrocement. Ferrocement is an innovative technology and it is composed of mortar and galvanized steel wire mesh. This paper is aimed to present the research made continuously to improve the ferrocement properties and performance and its uses in the different application and to encourage practical application of ferrocement especially in developing countries. This paper covers the theoretical and experimental studies conducted by several researchers to investigate the mechanical and structural properties of ferrocement. The aim of this paper is to summarize presented literature on the use of ferrocement and to talk about new application of ferrocement.*

Keywords— ***Ferrocement, Galvanized steel and wire mesh.***

I. Introduction

I. Ferrocement

Ferrocement is a highly flexible form of reinforced concrete ended up of wire mesh, sand, water, and cement, which possesses distinctive behavior of strength and serviceability. It can be constructed with a smallest amount of skilled labor and utilizes readily available materials. There are a number of applications of Ferro cement which consist of building industry, irrigation sector, and water supply and sanitation areas. Studies point out that it appear to be an excellent compound in the case of seismic resistant structures.

Ferrocement is a building substance composed of a relatively skeletal layer of concrete, casing such reinforcing material as steel wire mesh. Since the building techniques are simple sufficient to be done by unskilled labor, ferrocement is an good-looking construction method in areas where labor costs are low. There is no necessitate for the difficult formwork of reinforced cement concrete (RCC) construction, or for the welding needed for steel construction, all can be completed by hand, and no expensive machinery is required.

The main differentiation between ferrocement and reinforced concrete is ferrocement is a thin composite made with cement matrix reinforced with directly spaced little diameter wire meshes instead of larger diameter rods and large size aggregates. The thickness of ferrocement normally ranges from 25 - 50 mm. The latest ACI Code encourages the use of non - metallic strengthening and fibers.

Ferrocement is an environment friendly resonance technology and possesses admirable exclusive property such as good tensile strength, improved toughness, water tightness, lightness, fire resistance, resistance to cracking and cost, time and material successful construction technology. The following explanation was adopt by the ACI Committee: “Ferrocement is a type of thin wall reinforced concrete usually constructed of hydraulic cement mortar reinforced by closely spaced layers of unbroken and fairly small size wire mesh. The mesh may be made of metallic or other proper material”.

B. Durabillity Of Ferrocement

According to the ACI Committee, 'durability' is define as capability to oppose Weathering act, chemical attack, abrasion, or any other progression of deterioration', that is, durable concrete will preserve its original form, worth and serviceability, when showing to its environment. The various measures necessary ensuring 'durability' in predictable reinforced concrete is also relevant to ferrocement, since, ferrocement has almost the same type of ingredient/constituent, apart from, coarse aggregates and the use of lesser fine aggregates, than conventional concrete and a thin cross sector. However, other unique factor, which influences durability, particularly, the susceptibility to corrosion of ferrocementare:

- The cover to the mesh reinforcement is very little
- The cross sectional region of the mesh reinforcement wires is very little
- The plane area of the reinforcement is high because of minute wires being used
- Mesh reinforcement are galvanized to avoid corrosion, but the zinc coating can reason and produce hydrogen gas bubbles for the duration of hydration.

C. History Of Ferrocement

Joseph Louis Lambot a horticulturist research with plant pots, seats and tubs through of meshes and plastered with sand and cement mortar replaced his rotting rowing boat. There was very little appliance of true ferrocement construction between 1888 &1942 when Pier Luigi Nervi began a series of experiment on ferrocement. He experimental that reinforcing concrete with layers of wire mesh produced a material possessing the mechanical individuality of an approximately homogeneous material capable of resisting high impact. In 1945 Nervi built the 165 ton Motor Yatch "Prune" on a supporting frame of 6.35mm diameter rods spaced 106 mm apart with four layers of wire mesh on each side of rods with total thickness of 35mm. It weighed five percentages less than a comparable wooden hull & cost forty percentage less at that time. In 1948 Nervi used ferrocement in first public structure the Tutrin Exhibition building, the central hall of the building which spans 91.4m was built of prefabricated elements linked by reinforced concrete arches at the top &bottom of the undulations. In1974 the American Concrete Institute formed committee 549 on ferrocement.ACI Committee 549 first codified the description of ferrocement in 1980 which was subsequently revised in 1988,1993 and 1997(AE Naaman2000).

D. Property Of Ferrocement Composites

- ✓ Wire diameter 0.5 to 1.5 millimeters
- ✓ Size of mesh gap 6 to 35 millimeters
- ✓ Maximum use of 12 layers of mesh per inch of thickness
- ✓ Maximum 8% volume fraction in both directions
- ✓ Maximum ten square inches per cubic inch in both directions.
- ✓ Thickness six to fifty millimeters
- ✓ Steel cover 1.5 to 5 millimeters
- ✓ Ultimate tensile strength up to 34 MPa
- ✓ Allowable tensile stress up to 10 MPa
- ✓ Modulus of rupture upto 55MPa
- ✓ Compressive strength up to 28 to 69Mpa

E. Constituent Materials For Ferrocement:

1) Cement:

The cement should be clean of homogeneous consistency and free of lumps and foreign matter and of the type or grade depending on the application.

2) Fine Aggregates:

Normal weight fine aggregate clean, hard, and strong free of organic impurity and deleterious substance and relatively liberated of silt and clay.

3) Water:

Potable water was use in the experimental effort for both mixing and curing.

4) Wire Mesh:

The different types of wire meshes such as square woven or square welded mesh and chicken wire mesh of hexagonal shape and extended metal mesh. Some mesh filaments are galvanized iron. Properties of the resulting ferrocement invention can be predictable to be affected by mesh size, ductility, fabricate and treatment.

F. Advantages Of Ferrocement:

- ✓ Basic raw materials readily exist in most countries.
- ✓ Made-up into any desired outline.
- ✓ Low labour skill necessary.
- ✓ No difficulty of construction, low mass and extended lifetime.
- ✓ Low construction material cost.
- ✓ improved resistance against earthquake.

G. Disadvantages Of Ferrocement:

- ✓ Structures made of it can be puncture by collision with pointed substance.
- ✓ Corrosion of the reinforcing materials due to the unfinished coverage of metal by mortar.
- ✓ It is complicated to tie up to ferrocement with bolts, screws, welding and nail etc.
- ✓ Large no of labors necessary.
- ✓ Cost of semi-skilled and unskilled labors is high.
- ✓ Tie rods and mesh together is especially monotonous and time uncontrollable.

H. Objective

To study the flexural behavior of ferrocement panels with different wire mesh layers.

II. LITERATURE SURVEY

Manojkumar reddy *et.al*, for this study, specimens of size 250mm× 250mm × 25mm were casted with different Combination of meshes such as 4 layers of chicken mesh, 6 layers of chicken mesh, 2 layers of welded mesh, combination of 4 layers of chicken mesh plus 1 layer of welded mesh and 6 layers of chicken mesh plus 1 layer of welded mesh. Geo-polymer mortar was prepared by using fly ash to sand ratio is 1:1, sodium hydroxide to sodium silicate ratio is 1:2 and molarity of NaOH is 10m. Geo-polymer mortar and cement mortar cubes of size 70.5mm × 70.5mm × 70.5mm and cylinders of size 100mm diameter and 200mm height were casted to test the compressive and split tensile strength of both geopolymer mortar and cement mortar. This paper deals with the study of impact resistance capacity of ferrocement and geo-polymer ferrocement slabs subjected to impact loading by drop weight test method. Combination of 6 layers of chicken mesh plus 1 layer of welded mesh of geo-polymer ferrocement specimen showed higher impact energy absorption capacity as compared to other mesh combinations.The volume fraction of mesh reinforcement was higher, the impact resistance was also higher.

G.Murali *et.al,* Study has been done on the impact resistance and energy absorption properties of reinforced ferrocement plates under impact load. For this study, five ferrocement plates with dimensions of 450×450×25mm were casted and tested. The plates were casted with reinforcing bars and different types of reinforcing meshes such as expanded mesh, rectangular welded mesh, and welded mesh light and hexagonal mesh. The dimensions of mortar cube is 5cm x 5cmx 5cm and cement to sand ratio is 1:2.Polypropylene fibre (0.8%) was used in the mix to produce fibrous concrete to improve the concrete characteristics.The impact energy at initial cracking stage and failure stage was determined by drop weight (3.5 kg). Higher energy absorption is achieved in the ferrocement plates using meshes than that of the plates using mild steel bars as the reinforcement material. The presence of polypropylene fiber enhanced the first crack load, ultimate load and the impact energy absorption.

Mohamad N. Mahmood *et.al,* the present paper describes the result of testing folded and flat ferrocement panels reinforced with different number of wire mesh layers. Seven ferrocement elements were constructed and tested each having (600x380mm) 20mm thick, consisting of four flat panels and three folded panels.The used number of wire mesh layers is one, two and three layers. The grid size of wire mesh is 12.5x12.5 mm, and diameter of wire is 0.65mm.The flexural strength of the folded panel increased by 37 and 90 percent for panels having 2 and 3 wire mesh layers compared with that of single layer. The flexural strength of the flat panel increased by 65 and 68 percent for panels having 2 and 3 wire mesh layers compared with that of plain mortar panel. Finally increasing the number of wire mesh layers from 1 to 3 layers significantly increases the ductility and capability to absorb energy of both types of the panel.

Vincent Prabakar Rajaiah *et.al,* this paper describes flexural behavior of folded ferrocement panels reinforced with skeletal steel and galvanized iron wire mesh with varying number of wire mesh layers. The geometry of the panel is 1000 mm x 400 mm x 30 mm. Super plasticizer-Conplast SP430 was added to improve the workability of fresh mortar. The mild steel having diameter of 6 mm@100mm diameter c/c in the transverse and longitudinal direction was used. Galvanized chicken mesh with a hexagonal opening of size 12mm and wire thickness of 1.29mm is used. The load deflection curves for the panels that increasing the number of wire mesh layers from 1 and 2 layers that increase the ultimate load from 20KN to 27.5KN. The percentage increases in the load capacity of panel double layer with respect to single layer is in order of 38% respectively.

R.Padmavathy *et.al,* Studied the effect of flexural behavior of flat ferrocement panels reinforced with skeletal steel and galvanized iron wire mesh with varying number of wire mesh layers is presented. The slabs are tested under flexural loading by applying line loads at $1/3^{rd}$ points.The dimensions of flat ferrocement panels are 1000 mm x 350 mm x 30mm. Super plasticizer-Conplast SP430 was added to improve the workability of fresh mortar. The failure load increased from 1.9KN for single layer (FP-FT01) to 2.8KN for double layer (FP-FT02). Finally increasing the number of wire mesh layers from single and double layers increases the ductility in both types of the panel.The cracking load was not significantly affected by the number of the wire mesh layer particularly for the Flat panel.

Darshan. G. Gaidhankar *et.al,* studied the results of testing theflat ferrocement panels reinforced with different number of wire mesh layer and variation in panel thickness. Forty eight Ferro-cement elements were constructed and tested. The number of wire mesh layers varying from one, two, three, four and also thicknesses of panels are 20mm, 30mm, 40mm. The Panels were casted with mortar of mix proportion 1:1.75 and water cement ratio is 0.38 including super plasticizer (Perma PC-202) with dosage of 1% of total weight of cement.Panels were tested under two point loading system in UTM machine after curing period of 28 days.The flexural loads at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement panel. Increasing the number of wire mesh layers from 2 to 4 layers significantly increases the ductility and capability to absorb energy of the panels.

Randhir J *et.al,* to study the effect of using different number of wire mesh layers on the flexural strength of flat ferrocement panels. To compare the effect of varying the number of wire mesh layers (1,2,3 layers) and use of steel fibers on the ultimate strength and ductility of ferrocement slab panels. Slab panels of size (550*200) with thickness 25 mm are reinforced with welded square mesh with varying number of layers of mesh. Panels were casted with mortar of mix proportion (1:1.75) and water cement ratio (0.38) including super plasticizer (Perma PC-202) with dosage of 1% of total weight of cement.Panels were tested under two point loading system in UTM machine after curing period of 28 days.The flexural loads at first crack and ultimate loads depend on number of reinforcing mesh layers used in ferrocement panel. Increasing the number of layers of wire mesh from 2 to 4 layers significantly increases the ductility and capability to absorb energy of the panels. Presence of steel fibers also increases the flexural strength of panels as compared to those without fibers. A steel fiber also increases the ductility of panels and decreases the central deflection tendency as compared to without steel fibers. Result shows that incorporation of steel fibers with increase in number of layers leads to 58% increase in load carrying capacity and 33% decrease in deflection.

S.Nagan *et.al,* this paper deals the experimental investigations of the resistance of geopolymer mortar slabs to impact loading. For this project, the specimen of size is 230mmx230mmx25mm and varying mesh combination such as 4 layers of chicken mesh, 2 layers of rectangular weld mesh and combination of single layer of weld mesh and four layers of chicken mesh were cast and applying impact loading by drop weight test. For each specimen type, three mortar cubes of sizes 70.7x70.7x70.7 mm, 3 mortar cylinder specimens of size 75 mm diameter and 150 mm height, and 3 mortar beam of standard size 100x100x500 mm long are cast to test the characteristics strength, split tensile strength and flexural strength of geopolymer mortar. All these geopolymer mortar and geopolymer ferrocement specimens were heat cured for 48 hours at 75˚c in heat curing chamber, ferrocement specimens were cured at under water for 28 days. The percentage increase in compressive strength, flexural strength, split tensile compared to control cement mortar specimen for 10M geopolymer mortars are36.05%,33%,27.7%. The energy absorbed at failure is directly proportional to the volume fraction of reinforcement provided in the geopolymer ferrocement slab. The performance of geopolymer ferrocement slab is the highest when the volume fraction is 1.6% and the number of layers of reinforcement is 5(1 layer of weld mesh and 4 layers of chicken mesh), within the range of parameters considered.

K.Mounika *et.al,* to study of impact resistance and flexural performance of reinforced ferrocement specimens with layers of welded mesh and varying percentages of steel fibers. The major objective of this work is to study the effects on specimens casted by means of single and double layers of welded mesh and varying percentages of steel fibers such as 0.5%, 1 %, 1.5%, 2%. The dimension of impact test specimens is 500x500x25mm and the flexural test specimens are 700x300x25mm.Flexural specimens were tested under two point loading system in UTM machine and impact specimen were experienced by carry out a low velocity impact test. The results indicated that impact energy increases with increase in steel fibers and flexural strength increases with increase in number of mesh layers and presence of steel fibers (0.5%-2%).was a nominal amount of increase in impact energy absorption capacity of welded mesh reinforced specimen when the layers were increased from 1 to 2 layers. Incorporation of steel fibers in welded mesh reinforced ferrocement specimens have contributed significantly in improving the cracking behavior under flexure.

V.Sreevidya *et.al,* this study carried out experimental investigation is to study the flexural behavior of fly ash based geopolymer ferrocement elements. Ferrocement composite is a rich Geopolymer mortar mix of flyash to sand ratio is 1:3 with alkaline solution to flyash ratio is 0.416. The alkaline activators used consist of Sodium hydroxide and sodium silicate. The length of ferrocement elements was selected as 760 mm, width 150 mm and depth of the section was 30 mm, nine number of rectangular slab were casted with different meshes such as Square woven, Square welded and Expanded metal mesh. Different number of layer mesh was used from 1,2 and 3 layers. The specimens were cured for 28 days by ambient curing. Based on the test results, load vs. deflection curves were down. The efficiency of the Square woven, square welded and expanded metal mesh was compared.

Increasing the number of steel mesh layers from one to three caused a substantial increase in flexural strength and energy absorption to failure.It was also observed that the flexural strength of the section increasing the number of wire mesh layers. This study it can be considered the Weld mesh is resulted in significant improvement in their flexural behavior compare to woven and expanded mesh. The use of weld mesh in the ferrocement structure gives more strength and significant improvement to the ferrocement.

AnjuViswan *et.al,* one of the environmental friendly building material technologies for cost effective housing is ferrocement wall panel. Ferrocement wall panel is used by Building Materials and Technology Promotion Council to achieve a low cost building construction effectively. Precast wall panels were casted using ferrocement and Ferro-Geopolymer to study its effectiveness. The test program consists of casting and testing the panel having standard size 900x720x30 with normal ferrocement and with geopolymer cements. Wire mesh of hexagonal shape is used with 22 gauge and 12 mm hexagonal opening.Normal ferrocement wall panel is casted and cured for 28 days and geopolymer Ferro panels for ambient curing .The strength of the specimen were tested using 100t loading frame. The ultimate load carrying capacity of ferro geopolymer panels are high. In geopolymer panels cement is totally replaced with flyash and it utilizes geopolymer technology .So there will be larger reduction in cost when we consider binder part. No utilization of coarse aggregate, hence there will be much reduction in self weight. These precast members are easy to place on the site .Economy and reduction of weight in panels depends on the replacement of reinforced concrete with ferrocement. For geopolymer panels water curing is not require. So this technique is more economical compared to the normal ferrocement panels.

III. CONCLUSION

Based upon the experimental test results of the ferrocement panels the following conclusions can be drawn:

1. 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.
2. The cracking load was not significantly affected by the number of the wire mesh layer.
3. Flexural strength of Geopolymer Panel With Fiber is more when compared with Geopolymer Panel of without fiber.
4. Increasing the thickness also affected the final breaking load for slab panels. Therefore increasing the thickness of ferrocement panels from 20 mm to 50 mm significantly increases the ductility and capability to absorb energy the panels.
5. Finally increasing the number layers significantly increases the ductility and capability to absorb energy of both types of the panel.

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