# Comparative Study on Strength Characteristics of Geo Grid and Ferro Cement Panel

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***Abstract***

*Definition of ferrocement by ACI Committee 549, 1988 "Ferrocement is a form of reinforced concrete using closely spaced multiple layers of mesh and /or small diameter rods completely encapsulated in mortar. The most common type of mesh used is steel mesh. Other materials such as selected organic, natural or synthetic fibers may be combined with metallic mesh."*

*The present study has made an emphasis for comparing the strength characteristics of ferrocement panels with panels made with HDPE geogrids. Also an attempt has been made to replace cement partially by flyash, one of the residues from thermal power plant, which when partially replaced with cement can be used as a construction material. The rise in cost of river sand used as fine aggregate in concrete have increased the cost of construction significantly in the past few decades. Quarry dust, which is available abundantly from crusher units at a low cost in many areas, provides a viable alternative for river sand in concrete and it is been proposed for partially replacing sand in this study. Different mix proportions using the above materials have been made and panels were prepared for optimum proportion based on the compressive and tensile strength of cube and cylinder specimens. Panels with two layers of steel mesh and geogrid mesh were casted. A comparative study on strength characteristics has been made and failure patterns of the panels have been studied. It was shown that strength of geogrid panels were in par with ferrocement panles and are advantageous to ferrocement panels in corrosion resistance and elasticity.*

**Keywords —** *Ferrocement, geogrid, flyash, quarry dust, compressive strength, flexural strength.*

## I. INTRODUCTION

With the advancement of research technology, use of thin cement composite elements made of cement mortar and layers of continuous and relatively small sized mesh is increasing day by day. Ferrocement is a thin construction element with thickness in the order of 10 -50 mm and uses rich cement mortar; no coarse aggregate is used; and the reinforcement consists of one or more layers of continuous/ small diameter steel wire/ weld mesh netting. It requires no skilled labor for casting, and employs only little or no formwork. At the same time ferrocement is very strong and elegant with very high tensile strength-to-weight ratio and superior cracking behaviour in comparison to conventional reinforced concrete. While of similar durability, it is more elastic than reinforced concrete. This means that thin ferrocement structures can be made relatively light and watertight. In ferrocement, cement matrix does not crack since cracking forces are taken over by wire mesh reinforcement immediately below the surface. Ferrocement has a high tensile strength and stiffness and a better impact and punching shear resistance than reinforced concrete, because of two-dimensional reinforcement of the mesh system. So it undergoes a large deformation before cracking or high deflections before collapse.

Ferrocement is being explored as building materials substituting stone, brick, RCC, steel, prestressed concrete and timber and also as structural components—walls, floors, roofs, beams, columns and slabs, water and soil retaining wall structures. Ferrocement can be fabricated into any desired shape or structural configuration that is generally not possible with standard masonry, RCC or steel. Since the ferrocement uses layers of steel mesh as reinforcement (2 to 8%), the specific surface of reinforcement is considerably higher for ferrocement than for RCC. Also, the reinforcing steel wire mesh has openings large enough for adequate bonding; the closer distribution and uniform dispersion of reinforcement, transforms the brittle mortar into a high performance material which is completely different from reinforced concrete. So it is seen that, ferrocement provides better results in all aspects that R.C.C.

A geogrid is a geosynthetic material used to reinforce soils and similar materials. Geogrids are commonly used to reinforce retaining walls, as well as sub bases or subsoils below roads or structures. Soils pull apart under tension. Compared to soil, geogrids are strong in tension. This fact allows them to transfer forces to a larger area of soil. Geogrids are commonly made of polymer materials, such as polyester, polyethylene or polypropylene. They may be woven or knitted from yarns, heat-welded from strips of material or produced by punching a regular pattern of holes in sheets of material, then stretched into a grid. High density polypropylene (HDPE) geogrids are used in the present study.The structural geogrid shall be an integrally formed grid structure manufactured of a stress resistant polypropylene material with molecular weight and molecular characteristics which impart: (a) high resistance to loss of load capacity or structural integrity when the geogrid is subjected to mechanical stress in installation; (b) high resistance to deformation when the geogrid is subjected to applied force in use; and (c) high resistance to loss of load capacity or structural integrity when the geogrid is subjected to long-term environmental stress.

Quarry dust is a waste obtained during quarrying process. It has very recently gained good attention to be used as an effective filler material instead of fine aggregate. Fly ash is a waste generated from thermal power plants. There is a challenge of disposing the high quantity of fly ash extracted every day, which could be very well used in concrete, meeting the demands in a sustainable manner. In the present study fine aggregate is replaced partially with quarry dust and flyash. An attempt has been made to study the strength characteristics of geogrid panels and compare them with ferrocement panels by partially replacing the sand with quarry dust and cement with flyash.

The proposed system deals with the analysis and comparative study of the strength and flexural properties of steel wire mesh and geogrid in cement sand mortar with three different mortar mixes with partial replacement of cement with flyash and sand with quarry dust in different proportion.The study aims indirectly in pointing out the possibility of producing high strength, more eco-friendly and highly economical geogrid panels which could be very well used in place of ferrocement panels as ferrocement is susceptible to corrosion.

Scaled down panels were prepared and were been tested for its material strength at different loading conditions. The crack distribution and flexural properties of the panels were also examined carefully. A comparison has been made between the two with different mortar combination and thus arriving at a proposal that can nullify the limitations of ferrocement technology to an extent for aiding its application.

## II. LITERATURE REVIEW

Sakthivel P.B, ***et.al*** in his paper, “Ferrocement Construction Technology and its Application”[1] used ferrocement as a building construction material and as well as a repair material. They have shown that ferrocement elements undergo high deformations before collapse. It has high level of impact and cracking resistance, toughness and ductility. The ferrocement structures are thin and light-weight compared to conventional reinforced concrete. Hence there is considerable reduction in self-weight of the structure and saving in foundation cost. Transportation cost is also less. Partial or complete elimination of formwork is possible. Hence there is considerable saving in the cost of formwork, particularly for curved or complicated/ complex shapes/ structures, which is not possible with RCC construction. Ferrocement structures can be easily maintained, and also repaired in the event of structural damage without any major problems.

A. Saleem, et.al, (2008) in their work on “Low Cost Earthquake Resistant Ferrocement Small House”[2] focused on developing a design of small size, low cost and earthquake resistant house. Ferrocement panels are recommended as the main structural elements with lightweight truss roofing system. Earthquake resistance is ensured by analyzing the structure on ETABS for a seismic activity of zone 4. The behaviour of structure is found satisfactory under the earthquake loading. An estimate of cost is also presented which shows that it is an economical solution. It can bear the shock with little or no damage. Catastrophic failure will be avoided in any case thus minimizing the loss of life and property.

Hoe I. Ling, et.al (1998) in their work on “Tensile Properties of Geogrid Under Cyclic Loadings” [3] investigated the tensile behaviour of three commonly used polymeric geogrids (polypropylene, polyester and high-density polyethylene) under cyclic loading. The tests were strain controlled and were conducted for 100 cycles at different load ratios. The stiffness and damping ratios of geogrids at all load cycles were compared with primary loading curve. The stiffness increased while the damping ratio decreased with more loading cycles at any load ratios. A higher load ratio decreased the stiffness ratio and increased the damping ratio. The strength obtained from static tests appears reasonable when used for design considering short term cyclic loading. They concluded that the strength of polypropylene geogrid was not affected significantly by cyclic loading. Whereas, the strength of polyester and polyethylene geogrids was increased by cyclic loading and also increased by load ratios.HDPE geogrid performs well than other two types of geogrid.

Md. Zakaria Hossain, et.al (2005) in their study on “Flexural Behavior of Cement Composites Panels Reinforced with Different Types of Meshes”[4] made an experimental investigation on the flexural behavior of thin cement composite plates reinforced with welded square geogrid mesh and chicken wire mesh with varying number of mesh layers as well as varying percentage of effective reinforcement is presented. A comparison of the load-deflection relationships between the geogrid and chicken mesh composite with 20 and 30 mm thickness is reported. Load carrying capacity of the cement composite elements containing both types of meshes at first crack and ultimate loads is also compared. It is concluded that the first crack and ultimate loads increase with the increase in number of mesh layers for both types of meshes. The load-deflection relationships fluctuate for chicken-mesh-cement composites whereas it is almost smooth pattern for geogrid-mesh-cement composites with any number of mesh layers.

## III. MATERIALS AND THEIR PROPERTIES

All Portland cement OPC grade 53 conforming to IS 12269 (1987) has been used in the present investigation. Coarse aggregate of 20mm maximum size is used in Reinforced cement concrete work of all types of structures. This is obtained by crushing the stone boulders of size 100 to 150mm in the stone crushers. Then it is sieved and the particles passing through 20 mm and retained on 10mm sieve known as course aggregate. The particles passing through 4.75mm sieve are called as quarry dust. The quarry dust was obtained from the local crusher at Tambaram, Kancheepuram District. Fly ash used in the study is Grade-1 class F sourced from North Chennai Thermal Power plant, Chennai and the fine aggregate used is in the experiment is river sand. Table 1 gives the properties of materials used in this study.

IV. TABLE I
PROPERTIES OF MATERIALS

| Materials | Properties |
|---|---|
| Ordinary Portland cement | Specific gravity : 3.15<br>Initial setting time : 30 min.<br>Final setting time : 220 min<br>Fineness : 5 % residue on IS 90 micron sieve<br>Normal consistency: 29% by weight of cement |
| River sand | Specific gravity : 2.64<br>Fineness modulus : 3.0<br>Density : 1.63gm/cc<br>Void ratio : 0.55 |
| Quarry dust | Specific gravity : 2.62<br>Fineness modulus : 2.41<br>Density : 1.85gm/cc<br>Void ratio : 0.42 |
| Fly ash | Grade F<br>Specific gravity : 2.24 |

## V. EXPERIMENTAL INVESTIGATIONS

### A. *Mix Proportions*

Different mixes were used for this research along with the existing ferrocement system (Cement: sand 1 : 2), incorporating two additional ingredients to partially replace the earlier with flyash and quarry dust. The different mixes are,

1. Mix A – C : S = 1:2
2. Mix B – C : F : S = 0.7 : 0.3 : 2
   (i.e 30% replacement of cement with flash)
3. Mix C – C : S : QD = 1 : 1 : 1
   (i.e 50% replacement of sand with quarry dust)
4. Mix D – C : F : S : QD = 0.8 : 0.2 : 1 : 1
   (i.e 50% replacement of sand with quarry dust along with 20% replacement of cement with flyash)
5. Mix D – C : F : S : QD = 0.9 : 0.1 : 1 : 1
   (i.e 50% replacement of sand with quarry dust along with 10% replacement of cement with flyash)

### B. *Selection Of Mortar Mix*

To assess the strength of each mortar mix, specimens like cubes, cylinders and beams were casted and tested for compression, tension and flexure respectively after 28 days of curing. The mix satisfying the strength requirement in all the three aspects was used in casting panels.

### C. *Material Testing:*

#### *1) Compression Test On Cube*

Nine cubes each of size 70mm×70mm×70 mm were casted and cured. The compression test for the specimens was conducted on 7th, 14th, 28th day in the compression testing machine and is shown in fig.1.

**Fig.1 Casting and Testing of Cube**

#### *2) Split Tensile Strength Of Cylinder*

Nine cylinders each of size 100mm diameter and 200mm height were casted and cured. The split tensile strength test of the specimens were conducted on 7th, 14th, 28th day as shown in fig.2

**Fig.2 Casting and Testing of Cylinder**

### 3) *Flexural Test on Beam*

Flexural tests were conducted in the mortar specimens, to get a better view about the mortar proportion when they are casted into panels. Beam moulds of size 40mm×40mm×160mm (three gang mould) pertaining to RILEM standards were used and nine specimens for each mix proportions were casted and cured. The flexural test of the specimens was conducted on 7th, 14th and 28th day as shown in fig.3.

**Fig.3 Casting and Testing of Beam**

Table 2. below gives the results of the tested specimen for compressive strength, split tensile strength and flexural strength.

**Table 2. Test Results On Cube, Cylinder And Beam**

| Mix | Compressive strength ($N/mm^2$) | | | Split Tensile strength ($N/mm^2$) | | | Flexural strength ($N/mm^2$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7th day | 14th day | 28th day | 7th day | 14th day | 28th day | 7th day | 14th day | 28th day |
| A | 34.03 | 37.65 | 41.22 | 1.56 | 1.70 | 2.42 | 4.63 | 4.88 | 5.38 |
| B | 27.43 | 34.69 | 38.78 | 1.02 | 1.29 | 1.85 | 3.75 | 4.25 | 5.25 |
| C | 36.19 | 42.45 | 49.93 | 2.05 | 2.26 | 2.58 | 5.13 | 5.63 | 6.63 |
| D | 24.9 | 29.66 | 39.39 | 1.62 | 1.8 | 2.16 | 4.38 | 4.63 | 5.13 |

## D. *Casting Of Panels*

Based on the results of compression test, tensile test and flexural strength test panels were casted with Mix A (C: S), Mix C (C: S: QD) and Mix D (C: F: S:QD) using one layer of chicken wire mesh and geogrid mesh separately for the comparative study.

### 1) *Panel Specifications*

Wooden panel moulds of sizes 500mm×200mm and 30mm thick were used for casting panels. A clear cover of 5mm was maintained at the bottom (tension) and top (compression) sides. This panel size was recommended after a thorough study of ferrocement documents. Fig.4 to fig.7 below shows the casting of panels with geogrid mesh and steel wire mesh

**Fig.4 Placing of Steel Wire Mesh**

**Fig.5 Placing of Geogrid Mesh**

**Fig.6 Casted Panels**


**Fig.7 Demoulded Panels**

### 2) *Curing And Testing Of Panels*

The samples were cured for 28days and it was allowed to air dry for 48hours in room temperature of about 100 C and then the test was performed.

All the elements were tested with their two edges simply supported over a span of 450 mm under two points loading. The distance between the two loading points is 150 mm with moment arms of 150 mm at both sides of the loading points. The test was performed in universal testing machine and the readings were taken at an interval of 0.2 kN and the corresponding deflections were noted. Before testing, all the elements were painted white so that the cracks could be easily observed and clearly photographed. The ultimate load and the corresponding deflection is noted. Fig. 8 and fig.9 shows the test setup for testing the panels.

**Table: 3 Load and Displacement Values of Panels**

| **Load in kN** | | **0.2** | **0.4** | **0.6** | **0.8** | **1.0** | **4.2** | **1.4** | **1.6** | **1.8** | **2.0** | **2.2** | **2.4** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Displacement in mm | | | | | | | | | | | |
| Mix A | S | 0.07 | 0.12 | 0.21 | 0.28 | 0.35 | 0.42 | 0.49 | 0.59 | | | | |
| | G | 0.15 | 0.30 | 0.43 | 0.54 | 0.62 | 0.82 | 0.97 | 1.05 | 1.18 | | | |
| Mix C | S | 0.09 | 0.16 | 0.24 | 0.32 | 0.40 | 0.46 | 0.52 | 0.60 | | | | |
| | G | 0.06 | 0.11 | 0.17 | 0.24 | 0.30 | 0.39 | 0.47 | 0.55 | 0.69 | | | |
| Mix D (20%flyash) | S | 0.07 | 0.14 | 0.20 | 0.26 | 0.31 | 0.36 | 0.36 | 0.42 | 0.47 | 0.52 | 0.59 | |
| | G | 0.13 | 0.22 | 0.33 | 0.41 | 0.45 | 0.50 | 0.56 | 0.62 | 0.69 | 0.77 | 0.83 | |
| Mix D (10%flyash) | S | 0.08 | 0.13 | 0.18 | 0.24 | 0.29 | 0.35 | 0.41 | 0.49 | | | | |
| | G | 0.06 | 0.10 | 0.18 | 0.24 | 0.3 | 0.36 | 0.42 | 0.48 | 0.55 | | | |

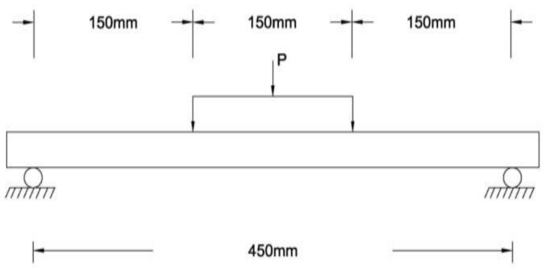


**Fig.8 Test setup**

**Fig.9 Testing of Panel**

## VI. RESULTS AND DISCUSSION

### 1) *Test Results Of Panels*

The results of the tested specimens in flexure are listed in table:3 as shown below.

### 2) *Load Deflection Curves*

The load deflection relationship for specimens reinforced with two layers of geogrid wire meshes and chicken wire meshes are analyzed and presented herein individually. Fig.10 and fig.11 shows the load-deflection curve for steel mesh panels and geogrid panels respectively. Fig.12 shows the load-deflection curve for mix D with 20% fly ash which was considered optimum compared to all other mix. Fig.13 shows load-deflection curve for mix A (steel mesh) and mix D (20% fly ash) geogrid panel where geogrid panels showed good performance compared to ferrocement panels.

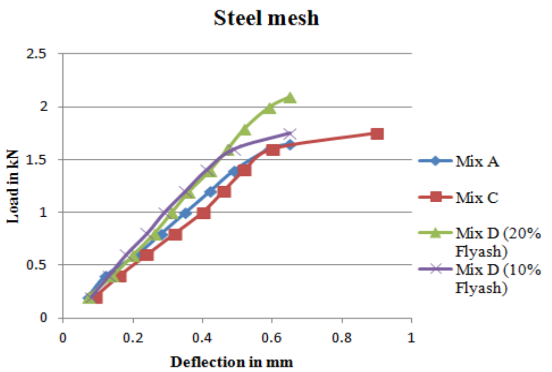


**Fig.10 Load Deflection Curve for Steel Mesh Panels**

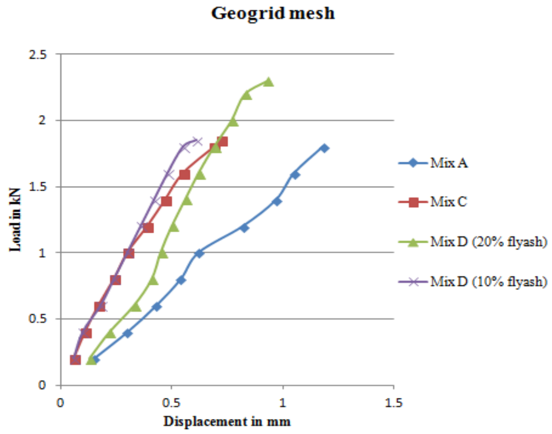


**Fig.11 Load Deflection Curve For Geogrid Panels**

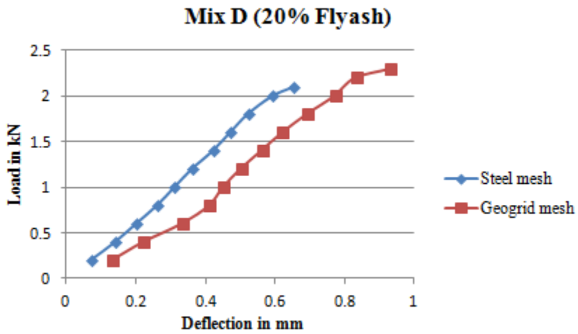


**Fig.12 Load Deflection Curve for Mix D With 20% Flyash**

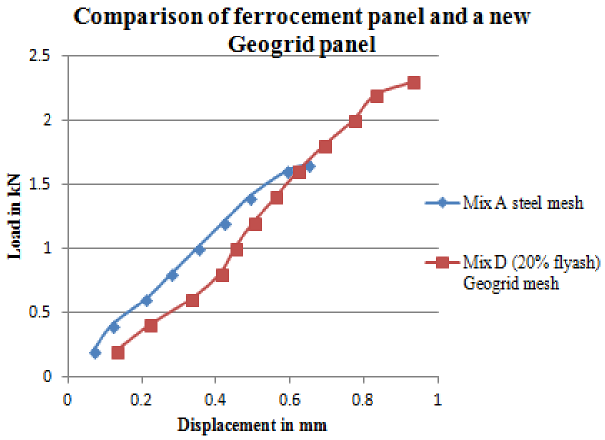


**Fig.13 Load Deflection Curve for Mix a (steel mesh) Panel & Mix D (20% flyash) Geogrid Panel**

### *3) Failure Pattern Of Panels*

It is found that there is a complete collapse at ultimate load in ferrocement panel with steel mesh. But in geogrid panel the crack is initialized at ultimate load and bending occurs without complete collapse of panel, which is shown in fig.13 and fig.14 below.


**Fig.13 Failure of Steel Wire Mesh Panel**


**Fig.14 Failure of Geogrid Mesh Panel**

### *4) Comparitive Study Of Panels*

The ultimate load and the corresponding displacements of all panels with steel and geogrid reinforcement were studied and the details are given below in table 4.

**Table 4 Ultimate Load Values of Panels**

| Type of Mix | | Ultimate load in kN | Displacement in mm |
|---|---|---|---|
| Mix A | Steel mesh | 1.65 | 0.65 |
| | Geogrid mesh | 1.8 | 1.20 |
| Mix C | Steel mesh | 1.75 | 0.80 |
| | Geogrid mesh | 1.85 | 0.72 |
| Mix D with 20% flash | Steel mesh | 2.10 | 0.65 |
| | Geogrid mesh | 2.3 | 0.93 |
| Mix D with 10% flyash | Steel mesh | 1.75 | 0.65 |
| | Geogrid mesh | 1.85 | 0.61 |

From the above table the ultimate load of the panel casted with Mix D (20% flyash) and geogrid mesh is found to be more than the ultimate load of the panel casted with Mix A and steel mesh.

## VII. CONCLUSION

An efficient and eco-balancing revolution of ferrocement technology has been successfully developed, which overcomes the drawbacks of the traditional methods. The results obtained from the experimental study shows that geogrid can successfully replace the chicken wire mesh without sacrificing the strength aspects of chicken wire mesh. Quarry dust has been found to replace sand efficiently in all aspects. Fly ash at an optimum percentage of replacement gives better results than the cement sand mortar combination of existing ferrocement system. Thus a new mortar mix proportion which is economical, efficient and ecobalancing is been proposed in the study. A worthy collaboration of this mortar with an excellent material like geogrid, lime lights a better technology to adopt from the results analyzed. Panels casted can be produced based on the scale on which this technique is to be adopted. Ferrocement construction is usually well known for thin and light weight construction with higher percentage of reinforcement contributing to the strength. A serious limitation of ferrocement is that the steel reinforcement in the existing mortar system is highly prone to corrosion. The effects are even more adverse once the first crack appears in the structure. And this limitation has contributed much to the unawareness of ferrocement technology all these days. And recently this technology has been lime lighted in various research areas. Various methods exists for inhibiting corrosion. But yet a permanent solution for corrosion is not prescribed as far as ferrocement technology is concerned. Geogrid suggested in this project for reinforcement has been used to fabricate strong, durable panels which are corrosion resistant to any extend thus giving solution to the limitation.

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