EXPERIMENTAL STUDY ON IMPACT RESISTANCE OF GEOPOLYMER FERROCEMENT FLAT PANEL

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Abstract— **This paper deals with the study of impact resistance and energy absorption properties of Geopolymer Ferrocement Flat Panel under impact load. Prefabricated elements are used in construction industry as an alternative system to overcome the formwork problems in addition to getting better quality control. The prefabricated elements made of reinforced concrete are extremely heavy and difficult to transport, placing in position and to construct. Alternatively, ferrocement panels are being used in construction industry due to its good structural performance and low cost. Ferrocement is suitable for the construction of roofing/floor elements, precast units, manhole covers, and construction of domes, vaults, grid surface and folded plates. It can also be used for making water tanks, boats, and silos. An experimental investigation on impact behavior of flat ferrocement panels reinforced with skeletal steel and galvanized iron wire mesh is presented. These panels were subjected to impact loading by drop weight test method. It is concluded that Geopolymer Ferrocement Flat Panels with 10M NaOH solution using higher impact energy absorption capacity as compared other geopolymer mixes.**

*Keywords— **Ferrocement, Geopolymer, Wire mesh, Impact load.***

I. INTRODUCTION

Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh which may be made of metallic or other suitable materials. Since ferrocement possess certain unique properties, such as high tensile strength-to-weight ratio, superior cracking behavior, lightweight, moldability to any shape and certain advantages such as utilization of only locally available materials and semi-skilled labor/workmanship, it has been considered to an attractive material and a material of good promise and potential by the construction industry, especially in developing countries. It has wide range of applications such as in the manufacture of boats, barges, prefabricated housing units, biogas structures, silos, tanks, and recently in the repair and strengthening of structures.

Ferrocement is suitable for low-cost roofing, pre-cast units and man-hole covers. It is used for the construction of domes, vaults, grid surfaces and folded plates. It can be used for making water tanks, boats, and silos. Ferrocement is the best alternative to concrete and steel. Generally, ferrocement shells range from 10 mm to 60 mm in thickness and the reinforcement consists of layers of steel mesh usually with steel reinforcing bars sandwiched midway between. The resulting shell or panel of mesh is impregnated with an extraordinarily rich (high ratio of cement to sand) Portland cement mortar. Ferrocement is a highly versatile construction material and possess high performance characteristic, especially in cracking, strength, ductility, and impact resistance. As its reinforcement is uniformly distributed in the longitudinal and transverse directions and closely spaced through the thickness of the section. There is an ample scope for mass production and standardization together with the economy in construction.

II. LITERATURE REVIEW

In the experimental work carried out by **G.Murali, E. Arun, A. Arun Prasadh, R. Infant raj and T. Aswin Prasanth *et.al,* (2014)[1],** 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, welded mesh light and hexagonal mesh. The dimensions of mortar cube are 5 cmx 5cmx5 cm and cement to sand ratio is 1:2. Polypropylene fiber (0.8%) was used in the mix to produce fibrous concrete to improve the concrete characteristics. The impact energy at initial cracking stage and at failure 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. This could be attributed to the effect of mesh in controlling the developed cracks.

In the experimental work carried out by **S. Nagan and R.Mohana (2014)**[2], they found the resistance of geopolymer mortar slabs under impact load by dropping a steel ball from a considerable height. For this study, they used specimens of size 230 x 230 x 25 mm with different combinations of chicken mesh and rectangular weld mesh and are subjected to impact load by drop weight test and the impact energy required for first crack and final crack were calculated. They found that the combination of chicken mesh and rectangular weld mesh together showed better performance in case of energy absorption and residual impact strength. The compressive strength, flexural strength and split tensile strength of 10M geopolymer mortar specimens are found to be 36.05%, 33% and 27.7% more when compared to cement mortar specimens respectively. Also with increase in volume of reinforcement, energy absorption of geopolymer ferrocement specimen increases compared to cement mortar specimen.

RESEARCH SIGNIFICANCE

In this investigation, the experiments were conducted to understand the structural behavior of Geopolymer Ferrocement Flat Panels under impact loading. The tests were mainly focused on the impact load test of geopolymer Ferrocement Flat Panels with simply supported condition by drop weight test. This paper presents the no. of blows required for first crack stage, ultimate stage, impact load and energy absorption at first crack and ultimate stage.

III. MATERIALS

a. Fly Ash

Fly ash is the most abundantly used mineral admixture as replacement for cement in mortar. It is also the main ingredient for geopolymer mortar due to its active participation in the geopolymerization process. Pozzolanic material exhibits cementitious properties when combined with calcium hydroxide. Fly ash is used as the pozzolana in many concrete applications. Fly ash is used as cement replacement.

b. Fine Aggregate

Fine aggregate used is Trichy River Sand passing through sieve in 4.75mm with specific gravity of 2.62 and having a fineness modulus of 2.80 (IS 383-1971 Zone II).

c. Sodium Hydroxide

Generally, NaOH is available in market in pellets or flakes form with 96% to 98% purity where the cost of the product depends on the purity of the material. The solution of NaOH was formed by dissolving it in water based on the molarity required. It is recommended that the NaOH solution should be made 24 hours before casting and should be used with 36 hours of mixing the pellets with water as after that it is converted to semi-solid state.

d. Sodium Silicate

It is also known as water-glass which is available in the market in gel form. The ratio of SiO_2 and Na_2O in sodium silicate gel highly affects the strength of geopolymer mortar. Mainly it is seen that a ratio ranging from 1 to 1.5 gives a satisfactory result.

e. Wire Mesh

Steel mesh reinforcement is broadly used as the main and characteristic reinforcing for industrial concrete floor slabs, shortcrete. It is also measured for structural purposes in the reinforcement of water tanks, tunnel segments, concrete cellars, meshes help to develop the compressive strength, tensile strength, flexural strength, post peak ductility performance, pre-crack tensile strength, fatigue strength, impact strength and eliminate temperature and shrinkage cracks. The main reason for addition of meshes to mortar is to develop the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent flexure.

V. MIX PROPORTION AND EXPERIMENTAL INVESTIGATION

a. Geopolymer Mix Design

Sodium hydroxide concentration	= 10 M
Na_2SiO_3 to NaOH ratio	= 1:1.50
Fly ash to Sand ratio	= 1:1
Alkaline activator to Fly ash ratio	= 0.45
Curing type	= oven curing
Curing period (oven)	= 24 hrs@72°c -75°c

b. Preparation of Alkaline Activator Solution

The mixture of Na_2SiO_3 solution and NaOH solution can be used as the alkaline liquid. The Alkali activator solution has to be prepared before 24 hours of use because at the time of mixing Na_2SiO_3 and NaOH solution it generates a huge amount of heat and the polymerization takes place by reacting with one another, which will act as a binder in the geopolymer mortar. It should be used within 36 hours of mixing the pellets with water as after that it is converted to semi-solid state. The Sodium hydroxide, available in small flakes, is dissolved in water at different proportions as required molarity of solution.

c. Geometry of mould

Geometry shape of Ferrocement Flat panel will be casted using geopolymer mortar and the size of panels. The tested ferrocement panels consist of two Flat panels. The dimensions of the Flat are shown in Fig. (1) which depicts that the horizontal projection of the trough panel is (350x200mm) dimensions. The thickness of the panels is 30mm.The panels are constructed using the conventional ferrocement materials, which is composed of cement mortar and Galvanizes chicken wire mesh with a hexagonal opening.

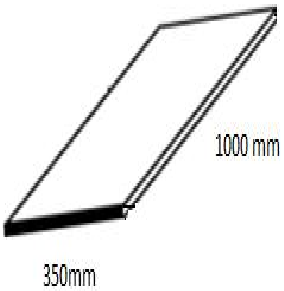

Figure 1. Dimensions of the Flat panel

d. Casting of geopolymer ferrocement panels

Special mould was fabricated in metal sheet to match the required geometry of the flat panel. Each sample is molded after fixing the required wire mesh and skeletal steel in its proper position. For the panels with single wire mesh top of the skeletal steel. Then the panels were cast in sodium hydroxide concentration 10M, sodium hydroxide to sodium silicate ratio 1:1.50, fly ash to sand ratio of 1:1 and alkaline activator to fly ash ratio of 0.45 with proper compaction**.** The moulds were coated initially with oil so as to enable easy removal of the moulds. The moulds were placed on an even surface. The surface was painted with waste oil. Cover blocks were used to ensure a clear cover of 5 mm. Normal mild steel bars steel bars (nominal diameters 6 mm) were used as the reinforcing material. The steel reinforcement mat with required spacing was placed inside the moulds.

e. Impact machine set-up

Geopolymer Ferrocement t flat panels were tested under drop weight impact load the impact was conducted using 4.5 kg hammer that was allowed to fall freely from a constant height of 460mm through a guide at the center of the panel for all the specimens with the simple support conditions as per ASTMD 2794.Specimens were placed in their position. The mass was then dropped repeatedly and the number of blows required to cause first crack was recorded. The number of blows required for failure was also recorded. For each panels the number of blows required to cause the first crack was noted. Then the process was continued further, till the crack propagated further and appeared at the top surface of the specimen. At the point, corresponding number of blows were noted. The no. of impact blows required to develop first visible crack was used to calculate the first crack impact strength. The schematic diagram of impact test experimental setup is shown in Figure 2.

Figure 2. impact machine set-up

VI.RESULTS AND DISCUSSION

a. Energy absorption

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. The number of blows required to cause the crack width of 2mm were also noted down. The total energy absorbed by the Ferrocement panels when struck by a hard impactor depends on the local energy absorbed both in contact zone and by the impactor. The energy absorption can be obtained by using the following formula.

E= N x (w x h) joules

Where,

E= energy in joules

w= weight in Newton

h= drop height in meter

N= blows in numbers

The ratio of energy absorbed up to the failure of specimens to the energy absorbed at initiation of first crack is defined as the 'Residual Impact Strength Ratio' (Irs). The energy absorption capacities of Ferrocement slab specimens at first crack and at ultimate failure stages are presented.

Table 1 Impact Resistance of Geopolymer Ferrocement Flat Panels

S. No.	Specimens ID	First Crack Resistance – FCR (No. of blows)	Ultimate Resistance – UR (No. of blows)	Percent increase in Resistance from FCR to UR
1	GFP FT 01	4	12	2.0
	GFP FT 02	6	16	1.6

Table 2 Impact Energy of Geopolymer Ferrocement Flat Panels

S. No	Specimens ID	Impact Energy Absorbed (Joules)		Impact Strength Ratio (I_{rs})
		At First Crack	At Ultimate	
1	GFP FT 01	77.69	233.08	3.00
	GFP FT 02	116.54	310.78	2.66

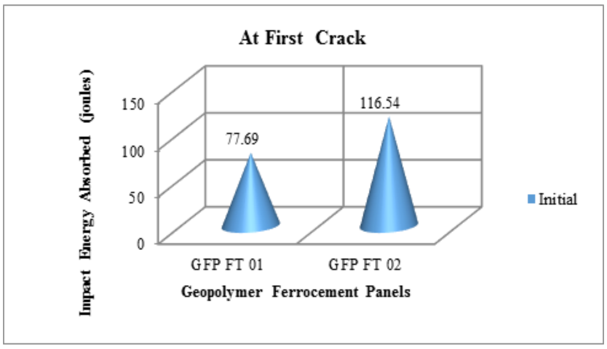

Figure 3 At first crack

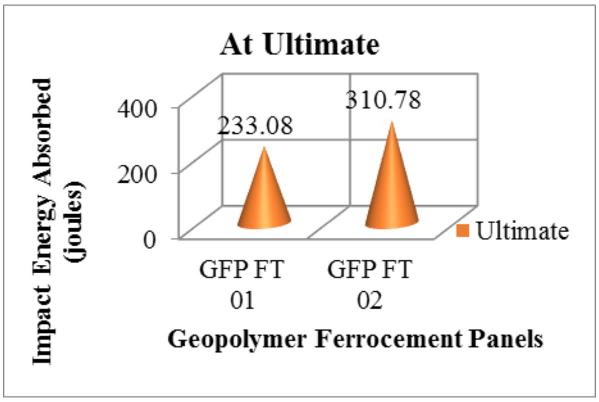

Figure .4 At Ultimate

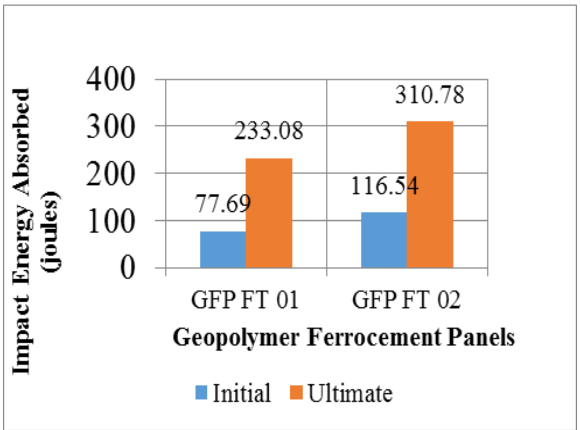

Figure 5. Impact Energy of Geopolymer Ferrocement Flat Panels

b. Failure pattern

From the impact test number of blows required to initiation of first crack was based on visual observation and the ultimate failure was determined based on the number of blows required for the crack to propagate to sides of the panels. The impact energy absorbed by the geopolymer panels specimens were computed based on the number of blows required to cause ultimate failure and impact energy per blow. Moreover, the ultimate crack resistances generally increase with increase in volume fraction of reinforcement of the three types of panels, have absorbed higher energy compare to the other types. This may be due to the higher ductility and lesser susceptibility to embrittlement of reinforcement. It also observed that the failure pattern of the specimens exhibited localized failure at the point of contact of the drop-weight and no fragments detached from the specimens as the various layers of the mesh reinforcement helped to hold the different fragments together. It can thus infer that meshes used as reinforcement play a major role in not only improving the impact energy absorption, but also retain/hold the various fragments together. The Failure pattern of panels is shown in the Fig 6 and 7.

Figure 6. Geopolymer Ferrocement Flat Panels at First crack

Figure 7. Geopolymer Ferrocement Flat Panels at failure

IV. CONCLUSIONS

Based on the above experimental results, the following conclusions are arrived

1) Higher energy absorption is achieved in the Ferrocement panels using meshes then that of the panels using mild steel bars as the reinforcement

materials. This attributed to the effect of mesh in controlling the developed crack s.

2) The failure pattern in the impact tested panels is found to be punching shear due to higher reinforcement. Only pure cracks are propagated up to the edge.

3) The energy absorbed at failure is directly proportional to the volume of the reinforcement provided in the Geopolymer Ferrocement panels.

4) Geopolymer Ferrocement flat Panels exhibit excellent impact resistance characteristics, in terms of higher energy absorption and higher I_{rs} values, indicating excellent post-cracking behavior.

References

1. S. Nagan and R. Mohana (2015) "**Behavior of geopolymer Ferrocement slabs subjected to impact"** *IJST, Transactions of Civil Engineering, Vol. 38, No. C1+, pp 223-233.*

2. Saranyabanu, S.Dharmar, Dr.S.Nagan, **"Flexural Behavior of Trough Shaped Ferrocement Panels"** *International Journal of Innovative Research in Science, Engineering and Technology.*

3. Vincent Prabakar Rajaiah, S.Dharmar, Dr.S.Nagan, **"Experimental Investigation on Flexural Behavior of Folded Ferrocement Panels"** *International Journal of Innovative Research in Science, Engineering and Technology.*

4. R. Padmavathy, S.Dharmar *et.al,* **"Study on Flexural Behavior of Flat Ferrocement Panels "** International Journal of Science and Research (IJSR).

5. Mohamad N. Mahmood & Sura A. Majeed (2009) "**Flexural Behavior Of Flat And Folded Ferrocement Panels**" Al-Rafidain Engineering Volume: 17 No: : 4 August 2009

6. G. Murali, E. Arun, A. Arun Prasadh, R. Infant raj and T. Aswin Prasanth *et.al,* **"Experimental Investigation of Reinforced Ferrocement Concrete Plates under Impact Load"** International Journal of Latest Research in Engineering and Computing (IJLREC).