Durability Characteristics of Hybrid Fiber Reinforced Geopolymer Concrete with M-Sand

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Abstract

Concrete is considered to be the excellent building material. The major ingredients of concrete are cement, water, fine and coarse aggregates. The demand of these materials keeps on increasing now-a-days as we are depleting the resources of the earth. For instance, the availability of river sand is less which leads to increase in the cost of the material. During the manufacturing process of the cement toxic gases such as carbon monoxide and carbon dioxide release which is dangerous to environment. Moreover, the concrete is very good in compression but the tensile strength is just one-tenth of the compressive strength. In order to eliminate these draw backs, several research works are in practice. This paper tries to investigate the durability behaviour of the concrete with the implementation of such innovative works. This paper attempts to investigate the durability characteristics of the geopolymer concrete with hybrid fibres and also it includes the usage of M- sand. This paper completely eliminates the usage of cement thus it is environmental friendly. This paper completely eliminates the river sand thus it is economical and this paper uses the hybrid characteristics of fibres as well. Thus in overall sense making the concrete more durable

Keywords - *Geopolymer concrete, Manufactured sand, Hybrid fibers, Durability characteristics.*

I. INTRODUCTION

Concrete is considered to be the excellent building material because of its phenomenal properties. Although it is a great building material, it has some major drawbacks. One of them is the usage of cement. The manufacturing process of cement is considered to be highly against the environment, since it releases harmful gases like carbon di oxide and nitrous oxide in to the atmosphere. In order to replace or eliminate the use of cement in the construction industry several research works are carried out as partial replacement of cements. This will reduce the usage of cement to some extent. But the geo polymer concrete completely eliminates the use of cement. The main binders used are fly ash and GGBS which are the waste products from the electrical power plants and iron industry.

The another major drawback of the concrete is its tensile strength. Concrete is excellent in compression but very weak in tension. The tensile strength is just one tenth of its compressive strength. In order to eliminate this drawback, addition of fibers as reinforcement has been introduced. Normally steel fibers has given some better results in strength characteristics but it may be subjected to corrosion. Some natural fibers are also used as reinforcement in the concrete to improve its tensile characteristics. In that way, it has trended to use the hybrid fibers. Collecting the desirable characteristics of two or more fibers and adding it into the concrete on definite proportion is called hybrid fibers.

The another major drawback which is in economical point of view, is the availability of river sand as fine aggregates. River sand has been used as fine aggregates in the concrete which performs excellently. But now-a-days the demand for the river sand has increased enormously which leads to the increase in the cost of river sand. There comes the use of M sand. This is nothing but the manufactured sand, obtained by grinding the large mass of rocks to the suitable particle size.

This paper attempt to use all these hybrid innovations such as geopolymer concrete, hybrid fiber reinforced concrete and use of M sand in the concrete.

II. LITERATURE SURVEY

Various research papers have been published in the fields of geo polymer concrete, concrete with M sand and fiber reinforced geo polymer concrete. The hybrid characteristics of all these research papers have been gathered and are as follows.

C. Sudha et al (2016) conducted experiments on strength characteristics of high-performance concrete with M sand [5][6] and proposed that 100% replacement of M sand with river sand can be a best substitute for the preparation of concrete. Hence the full replacement of M sand with river sand for fine aggregates has intensified the strength characteristics also.

S.A. Balachander et al (2013) has investigated the geo polymer concrete with glass fibers [3]. According to their research addition of 0.03% of glass fibers by volume increases the compressive and flexural strength of concrete to a great extent.

A. Suriya Prakash and G. Senthil kumar (2015)[7] has conducted experiments on steel fiber reinforced geo polymer concrete [8] and revealed that 1% addition of steel fibers by weight of cement has shown increase in the compressive and split tensile strength and it is considered to be the optimum dosage.

Aradhana Mehta and kuldeep kumar(2016) conducted experiments on strength and durability characteristics of geo polymer concrete[1] and compared the characteristics of OPC based concrete and geo polymer concrete and concluded that 2%, 4%, 6% of acid solution doesn't make any significant change in mass and shape whereas OPC based concrete would have been deteriorated.

R.R. Singh and himanshu bansal (2014) conducted experiments on [2] strength and durability characteristics of geopolymer concrete and revealed that there is no significant change in the shape and weight of the concrete on exposure to chemical attacks.

Thus it is clear from the literatures that the usage of glass fiber and steel fibers has shown intensification in the strength of concrete and the full replacement of river sand with M sand as fine aggregate has also considered to be the best substitute. This paper tries to attempt all these hybrid characteristics of research in the concrete technology.

III. EXPERIMENTAL PROGRAMME MATERIALS USED

A. Coarse aggregate

Coarse aggregate is the aggregate which is passing 80mm sieve and retained on 4.75mm sieve. Cube specimens casted for M40 mix using coarse aggregates of maximum sizes 20 mm. The physical properties were tested as per IS2386 (part 1) – 1963[8]. The fineness modulus of coarse aggregate used is 7.22 with a specific gravity of 2.80.Figure 1 shows the sieve analysis curve for coarse aggregate and it is confirming to IS383:1970[9].

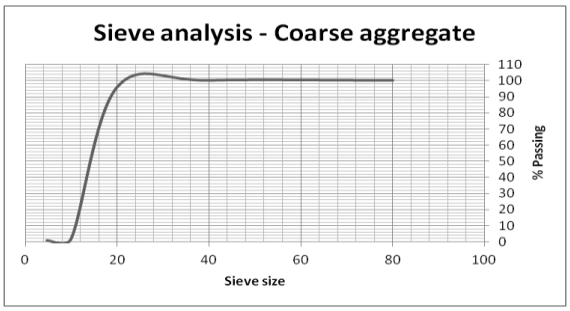

Figure 1 Sieve analysis curve

B. Binders

Fly ash is one of the effluents from the electric power generation plants. These are formed due to the pulverization of coal. These are directly collected from the electrostatic precipitators. Ground granulated blast furnace slag, popularly known as GGBS, is obtained from the process called quenching which leads to the formation of a glassy, granular product and then these are grained in the form of powder. A suitable proportion of fly ash and GGBS is used as a binder in this experimental process.

B. Solvents

Geopolymer concrete replaces the use of water with catalytic liquid system. The solutions, which are known as alkaline activator solution, used here are sodium hydroxide and sodium sulphate solutions. These are dilute in nature since it should not be harmful to the labors preparing the concrete at the construction site.

C. M Sand

Manufactured sand, popularly known as M sand, is manufactured by crushing the coarse rocks to the particle size of a fine aggregate. This experiment involves the 100 % replacement of M sand with fine aggregates and it is conforming to zone II of IS 383.

D. Fibers:

The type of fibers chosen for this experimental purpose is steel fibers, polypropylene fibers and glass fibers. The steel fibers are of hooked ended type. These are particularly chosen for their excellent strength intensification. The properties of the fibers are shown in the table 1.

Table 1: Properties of fibers

S.No	Properties	Steel fiber	Polypropylene fiber	Glass fiber
1	Diameter (mm)	0.75	0.2	0.25
2	Length (mm)	50	12	15
3	Aspect ratio	67	60	60

4	Bulk density (g/cc)	7.8	0.9	2.6

E. Superplasticizers

The super plasticizers generally used for the preparation of geo polymer concrete is sulphonated – naphthalene formaldehyde. The same has been used for this experimental purpose. The main aim of using the superplasticizers is to produce homogenous concrete and cohesive moreover it should avoid the concrete from bleeding and segregation.

F. Testing procedure

It is planned to prepare the concrete specimens in the forms of cubes. As far as the literatures are concerned, the full replacement of M sand with fine aggregates gives better results when compared to partial replacement. This it is adopted to use 100% M sand as fine aggregates. Based on their excellent contributions, the following fibers are chosen to test their hybrid characteristics, steel fibers, polypropylene fibers and glass fibers. The various mix proportions are explained in the table 2. Average of 3 specimens are casted per mix proportion. After the preparation of the concrete, it is air cured for 28 days. Then these cubic specimens are immersed in the chloride and sulphate solutions for 28 days, the testing procedure is explained in the further context and then these cubes are again tested for its compressive strength. The values of the compressive strength and weight of the specimens, before and after exposure to chloride and sulphate solutions are compared and it is finally concluded.

Mix proportions	Percentage of River sand	(%) of M sand	(%) of steel fibers	(%) of polypropylene fibers	(%) of Glass fibers
MPC 0	100	0	0	0	0
MPC 1	0	100	0	0	0
MPC 2	0	100	1	0.5	0.5
MPC 3	0	100	0.5	1	0.5
MPC 4	0	100	0.5	0.5	1

Table 2 Mix Proportions

IV. EXPERIMENTAL TEST

A. Chloride attack test

In this test, the behavior of the concrete is examined when it is exposed to the chloride attack. The cubic specimens of size 0.15m x 0.15m x 0.15m were casted and it is air cured for 28 days. After 28 days of air curing the weight and compressive strength of the concrete specimens are noted. Then these specimens are immersed in 5% Nacl solution for 28 days. The dilution ratio of the solute to the solvent is 5% i.e., 500 mg of solute (sodium chloride) is added and mixed in 10 liters of water (solvent). The concrete specimens are remained undisturbed in the solution for 28 days. then these specimens are removed, the surface is cleaned, dried and the weight is noted down. The compressive strength of these specimens should then be noted. The compressive strength test of the specimens is carried out with the universal testing machine [12]. The ultimate load at which the concrete specimen fails is noted and the compressive strength is calculated using the formula

compressive strength = $\frac{P}{A}$.

B. Sulphate attack test

In this test, the behavior of the concrete is examined when it is exposed to the sulphate attack. The cubic specimens of size 0.15m x 0.15m x 0.15m were casted and it is air cured for 28 days. After 28 days of air curing the weight and compressive strength of the concrete specimens are noted. Then these specimens are immersed in 5% Na_2SO_4 and 5% $MgSO_4$ solution for 28 days. the dilution ratio of the solute to the solvent is 5% i.e., 500 mg of solute (500 mg of sodium sulphate and 500 mg of magnesium sulphate) is added and mixed in 10 liters of water (solvent). The concrete specimens are remained undisturbed in the solution for 28 days. then these specimens are removed, the surface is cleaned, dried and the weight is noted down. The compressive strength of these specimens should then be noted. The compressive strength test of the specimens is carried out with the universal testing machine [12]. The ultimate load at which the concrete specimen fails is noted and the compressive strength is calculated using the formula compressive strength = $\frac{P}{A}$.

V. RESULTS AND DISCUSSION

A. Chloride attack test

Table 3 gives the test results of various mix proportions of the hybrid fibers. The weight of the concrete specimen after 28 days of air curing is taken and then exposed to the 5% Nacl solution for 28 days and the strength and weight of the concrete specimens are again noted. The weight loss and strength loss of the concrete specimens are noted. As

far as the mix proportions are concerned, the proportions in which glass fiber and polypropylene fibers dominate, shows better results when compared to the proportion where steel fiber dominates. The weight and strength of the concrete has been reduced to nearly 2% and 2.4% respectively, for steel fiber domination whereas it is only nearer to 1.5% and 2% for glass fiber and polypropylene fiber domination proportions, which is acceptable. Figure 2 and 3 shows the percentage variation in terms of weight and compressive strength

before and after exposure to chloride attack.

Mix Proportion	Weight (Kg)		% Reduction	Average Compressive Strength		% Reduction
	Air Curing (28 Days)	5% Nacl Solution (28 Days)		Air Curing (28 Days)	5% Nacl Solution (28 Days)	
MPC 1	7.53	7.45	0.91	48.7	47.7	2.01
MPC 2	7.46	7.32	1.87	50.6	49.3	2.38
MPC 3	7.35	7.23	1.68	48.3	47.4	1.97
MPC 4	7.34	7.21	1.72	49.2	48.3	1.92

Table 3 Test results before and after chloride exposure

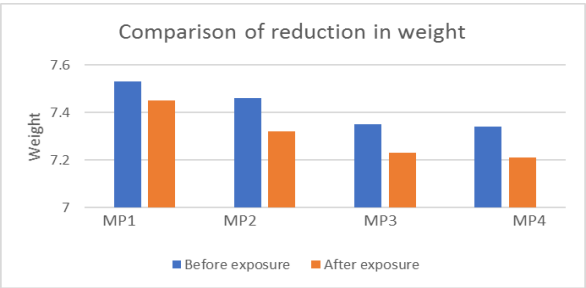

Figure 2Comparison of % reduction in weight before and after chloride exposure

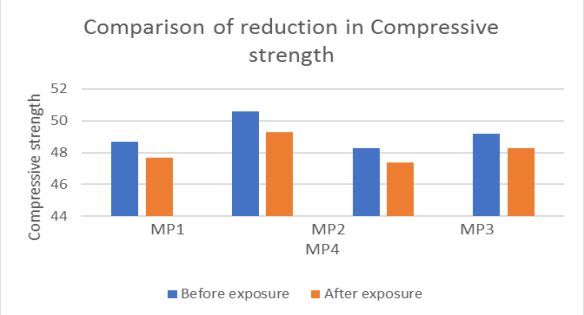

Figure 3Comparison of % reduction in compressive strength before and after chloride exposure

B. Sulphate attack test

Table 4 gives the test results of various mix proportions of the hybrid fibers. The weight of the concrete specimen after 28 days of air curing is taken and then exposed to the 5% Na_2SO_4 and $MgSO_4$ solution for 28 days and the strength and weight of the concrete specimens are again noted. The weight loss and strength loss of the concrete specimens are noted. As far as the mix proportions are concerned, the proportions in which glass fiber and polypropylene fibers dominate, shows better results on sulphate attack also when compared to the proportion where steel fiber dominates. The weight and strength of the concrete has been reduced to nearly 0.85% and 2.4% respectively, for steel fiber domination whereas it is only nearer to 0.8% and 1.8% for glass fiber and polypropylene fiber domination proportions, which is acceptable. Figure 4 and 5 shows the percentage variation in terms of weight and compressive strength before and after exposure to sulphate attack.

Table 4Test results before and after sulphate exposure

Mix Proportion	Weight (Kg)		% Reduction	Average Compressive Strength		% Reduction
	Air Curing (28 Days)	5% Nacl Solution (28 Days)		Air Curing (28 Days)	5% Nacl Solution (28 Days)	
MPC 1	7.53	7.47	0.75	48.7	47.8	1.79
MPC 2	7.46	7.39	0.84	50.6	49.4	2.34
MPC 3	7.35	7.29	0.81	48.3	47.4	1.85
MPC 4	7.34	7.28	0.79	49.2	48.3	1.72

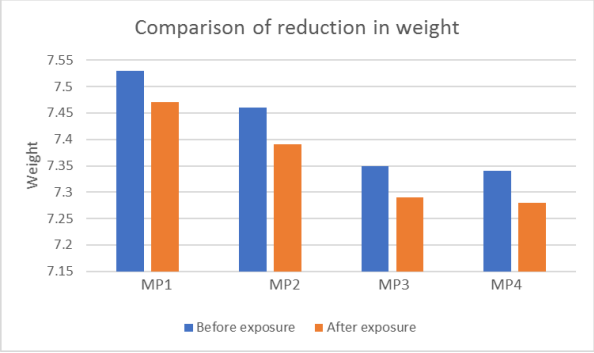

Figure 4Comparison of % reduction in weight before and after sulphate exposure

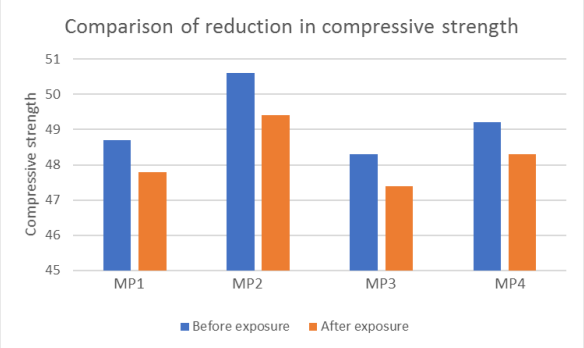

Figure 5Comparison of % reduction in compressive strength before and after sulphate exposure

V. CONCLUSION

In this experimental attempt, several replacements have been done such as addition of M sand as fine aggregates, usage of hybrid fibers in geo polymer concrete etc. mechanical properties of the concrete has been investigated and test results are already discussed. In this research attempt, the following conclusions can be derived.

- It is obvious that the addition of M sand in the concrete increases its strength characteristics in conventional concrete. Here it is again proved that the M sand can also be used a best substitute for fine aggregates in geo polymer concrete also.
- With reference to various literature reviews, it is evident that the steel, glass and polypropylene fibers has shown some significant intensification in terms of strength characteristics, now it is also proved that the hybrid nature of these fibers also improves the durability characteristics.
- As far the proportions of hybrid fibers and the reduction in weight on exposure is concerned, Domination of Steel fibers (1%) over the polypropylene and glass fibers (0.5% each) has resulted in huge loss in weight in case of chloride as well as sulphate attack.
- As far the proportions of hybrid fibers and the reduction in compressive strength on exposure is concerned, Domination of Steel fibers (1%) over the polypropylene and glass fibers (0.5% each) has resulted in huge loss in compressive strength also, in case of chloride as well as sulphate attack.
- Overall, when there is suspect of exposure of concrete to chloride and sulphate attack, mix proportion MP4 gives better results. i.e., percentage of glass fibers are dominated over the other fibers. Hence this proportion is suggested for construction over these areas.
- Since this method eliminated the use of cement it is highly eco-friendly.

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