An Experimental Study on Geopolymer Concrete with Partial Replacement of fine Aggregate Using Steel Slag

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Abstract— This research work aims to study further sustainability to the cement less geopolymer concrete by partially replacing fine aggregate by iron Steel slag. Geopolymer concrete is one of the building materials that has become more popular in recent years since it is significantly more environmentally friendly than standard concrete. Geopolymer concrete usually includes fly ash, fine aggregate and coarse aggregate activated by means of alkaline liquids like sodium silicate and sodium hydroxide which is effective in oven curing. Further the Steel slag which is a byproduct obtained from Steel manufacturing industry can be used as a replacement to fine aggregate. By using this in construction purpose, it reduces the environmental pollution. Geopolymer concrete of grade M25 with Steel slag as a partial replacement to fine aggregate was studied for its compressive behaviour and compared with conventional cement concrete. The study derived that in all stages, the performance of the geopolymer beam with Steel slag was marginally better than the conventional beam with fine aggregate. This investigation work encourages the use of Steel aggregate ash in concrete with its inherent structural advantage, easy availability.

Key words: Geopolymer Concrete, Water absorption, Acid resistance, Sulphate resistance, Sorptivity, Flyash, GGBS, Flexural strength, sodium hydroxide (NaOH), sodium silicate (Na_2SiO_3), fine aggregate, coarse aggregate.

I INTRODUCTION

Geopolymer concrete is one of the building materials that has become more popular in recent years since it is significantly more environmentally friendly than standard concrete. Geopolymer concrete is a type of concrete that is made by reacting aluminate and silicate bearing materials with a caustic activator. Commonly, waste materials such as fly ash or slag from iron and metal production are used, which helps lead to a cleaner environment. This is because the wastematerial is encapsulated within the concrete, and it also does not have to be disposed of as it is being used. Steel slag is an industrial by product obtained from the steel manufacturing industry of iron or steel. Steel slag can be used in the construction industry as aggregates in concrete by replacing natural aggregates.

II. DURABILITY TEST

A. Water absorption test

Cubes of size 100mm were cast for two different mixes. All specimens were removed 24 hours after casting and subsequently water cured for 15 and 30 days. Samples were removed from water and wiped out the water with damp cloth and difference in weight was measured.

FIG 1 Water absorption test

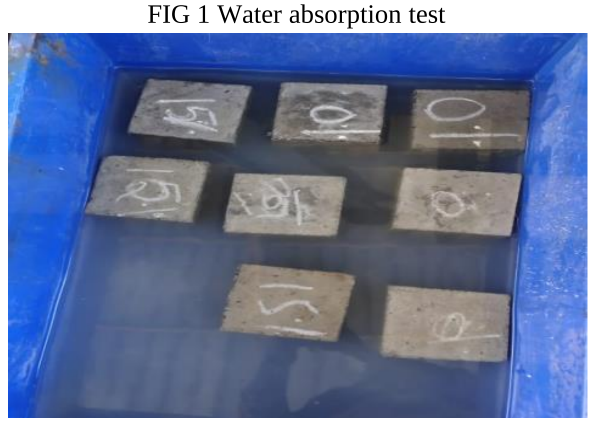
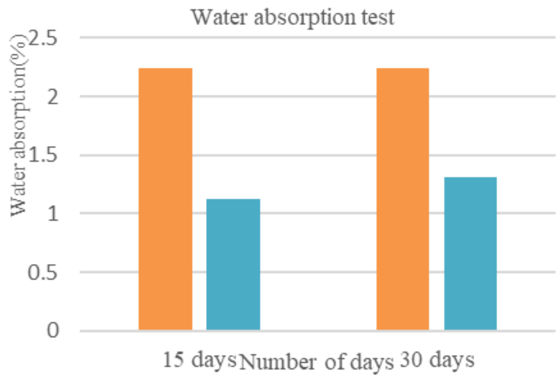


TABLE 1 Water absorption Test

Specimen	Age Of Concrete	Average Of Water Absorption(%)
GPC 0%	15 days	2.24
	30 days	2.30
GPC 15%	15 days	1.13
	30 days	1.31



B. Acid Resistance test

The concrete cube specimens of various concrete mixtures of size 100 mmwere cast and cured and the specimens were removed from the curing tank and allowed to dry for one day. The weights of concrete cube specimen were taken. The acid attack test on concrete cube was conducted by immersing the cubes in the acid water for the age of 15and 30 days. Hydrochloric acid (HCl) with 5% weight of water was added to water in which the concrete cubes were stored.

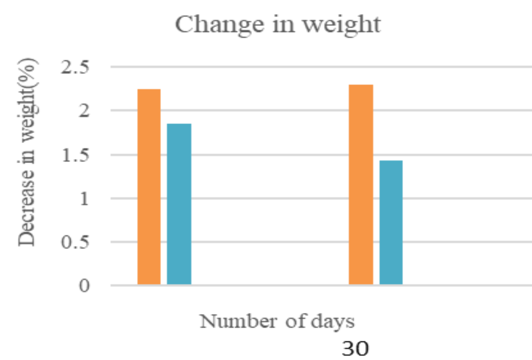
FIG 2 Acid attack test

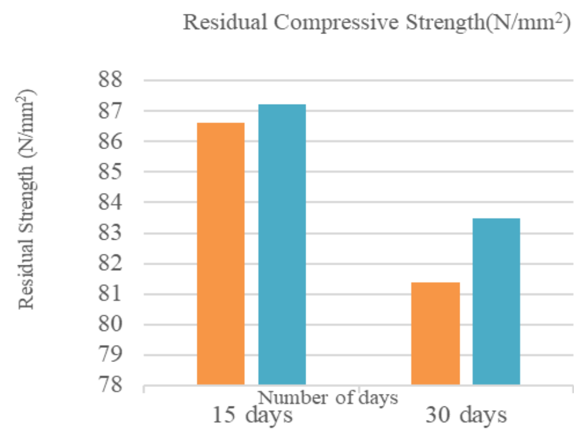
TABLE 2 Acid Resistance Test

Specimen	Age Of Concrete	Average Decrease in weight (%)
GPC 0%	15 days	2.24
	30 days	2.39
GPC 15%	15 days	1.85
	30 days	1.95

TABLE 3 Compressive strength for acid resistance Test

Specimen	Age of concrete	Decrease in strength after attack (N/mm²)	Residual strength (N/mm²)
GPC 0%	15 days	13.37	86.63
	30 days	18.60	81.40
GPC 15%	15 days	12.77	87.23
	30 days	16.50	83.50





C. Sulphate resistance test

The resistance of concrete to sulphate attacks was studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 5% of sodium sulphate (Na_2SO_4) by weight of water and those which are not immersed in sulphate water. The concretecubes of 100mm size were cured and dried for one day were immersed in 5% Na2SO4.The concentration of sulphate water was maintained throughout the period.

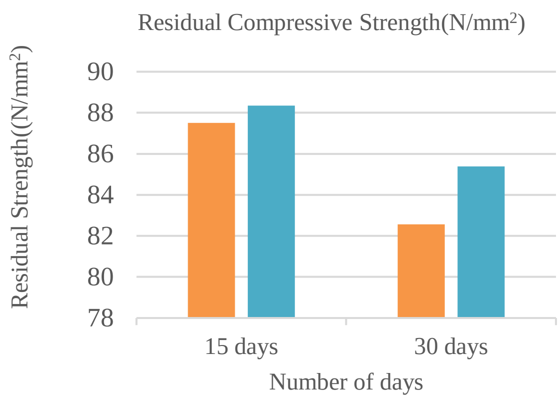
FIG 3 Sulphate attack test

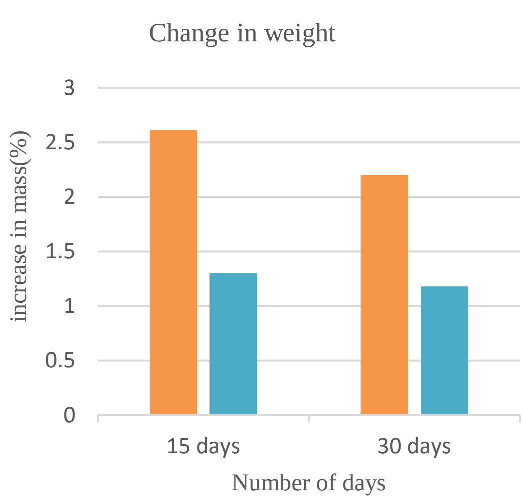
TABLE 4 Sulphate resistance Test

Specimen	Age Of Concrete	Average increase in weight (%)
GPC 0%	15 days	2.61
	30 days	2.80
GPC 15%	15 days	1.30
	30 days	1.48

TABLE 5 Compressive strength in sulphate resistance test

Specimen	Age of concrete	Decrease in strength after attack (N/mm²)	Residual strength (N/mm²)
GPC 0%	15 days	12.50	87.50
	30 days	17.44	82.56
GPC 15%	15 days	11.65	88.35
	30 days	14.61	85.39





D. Sorptivity test

sorptivity test for cylinder disc at 30days for four specimens were conducted as per ASTM C1585-13.

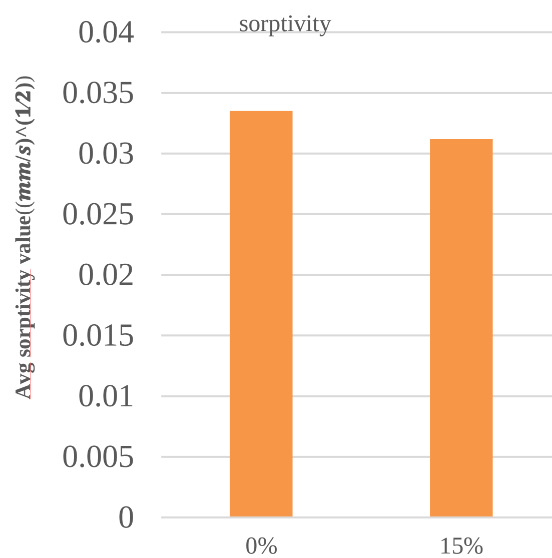
$S = I/t^{1/2}$.

Here S= Sorptivity in mm, t = elapsed time in minutes I=Δw/Ad ; Δw = change in weight = W2-W1;A = surface area of the specimen referencethrough which water penetrated; d= density of water.

FIG 4 Sorptivity test

TABLE 6 sorptivity test

Percentage(%)	Sorptivity ($mm/s^{1/2}$)	Sorptivity ($mm/s^{1/2}$)	Average ($mm/s^{1/2}$)
GPC 0%	0.0355	0.0315	0.0335
GPC 15%	0.0320	0.0305	0.0312



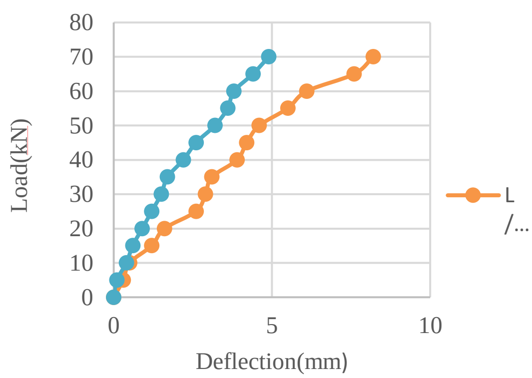
III FLEXURAL STRENGTH TEST

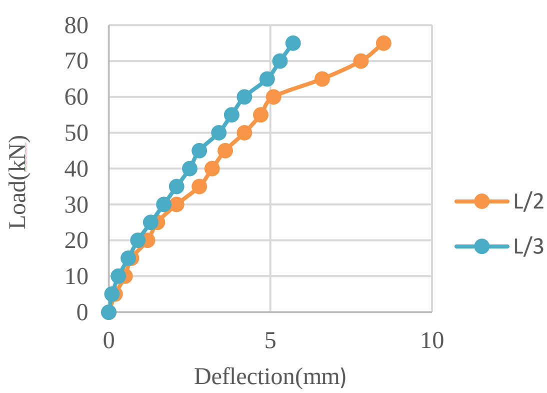
All the beam specimens were tested on actuator of capacity 250KN.The load was applied until complete failure took place. The support conditions were partially fixed on both the sides. Deflections were noted down at L/2 and L/3 at each side of specimen with deflectometer. First crack is noted down. Then ultimate load and corresponding deflections were noted down. Then the load- deflection curve was plotted.

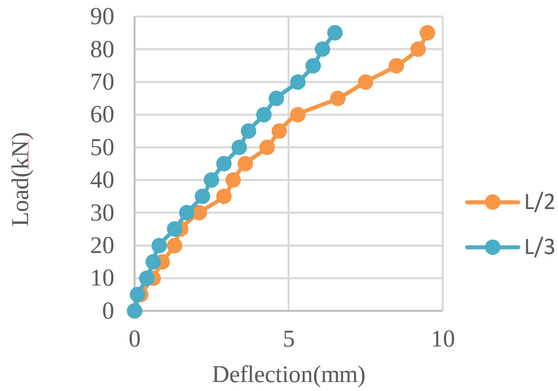
FIG 5 Crack Pattern on Beam

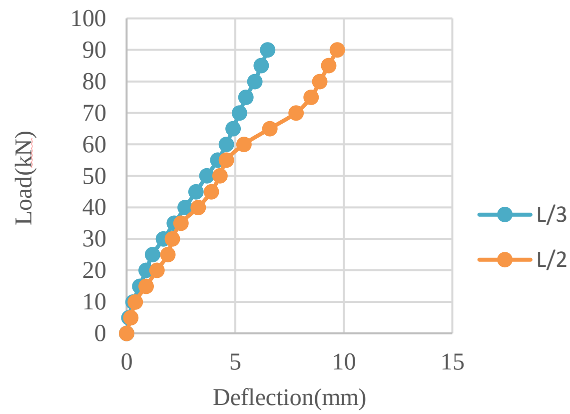
TABLE 7 Test Results For Beam

Specimen	Average of first crack load (kN)	Average of ultimate load (kN)	Average of max deflection (mm)
GPC 0%	27.5	72.5	8.35
GPC 15%	37.5	87.5	9.6









IV. CONCLUSION

In water absorption test, GPC 15% Specimen shows water absorption 40% less than conventional concrete for 30 days.

In Acid resistance test, the GPC 15% Specimen found to be 2.6% higher compressive strength than conventional concrete for 30 days.

In Sulphate Resistance test, the GPC 15% Specimen found to be 3.5% higher compressive strength than conventional concrete for 30 days.

Sorptivity results shows that concrete with GPC 15% steel slag found to be 10% less capillary rise than conventional concrete for 30 days.

The initial crack load arrived at 0% GPC is less than 15% steel slag GPC beam. The load obtained for 15% steel slag GPC is 3.63 times the initial crack in 0% GPC beam.

The ultimate load obtained by 15% steel slag GPC beam is 20% increased than the 0% GPC beam.
The ultimate load at failure was higher for geopolymer reinforced beam with 15% steel slag than the conventional geopolymer reinforced beam.
This gives the scope that the Geopolymer concrete with fly ash and GGBS in proportion with steel slag be employed in construction for better achievement of strength and flexural characteristics.

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