Durability Behaviour of Geopolymer Concrete with Metakaolin and GGBS

Ganesan Nagalingam, **Ramesh Babu Chokkalingam**, **Meyyappan PL**

Abstract*: This study consists of preparation of Geopolymer concrete mix with Ground Granulated Blast furnace Slag (GGBS) which is followed by the usage of Metakaolin in replacement of GGBS with 5% variation from 0 to 25%. From previous researches on geopolymer concrete with GGBS, an optimized mix is selected and tested for durability behaviour. A 12 Molarity sodium hydroxide solution along with sodium silicate in the ratio of 1:2.5 is used as activator in this study. La Hypercrete S25 which belongs to the category of carboxylic is used as admixture for escalating the workability. Water absorption, Acid resistance, and Rapid Chloride Penetration (RCPT) are the durability tests performed on the specimens. The prepared specimens are water cured at room temperature for the required days in accordance with the codal guidelines and tested for durability. For water absorption test, concrete cylinders of 50mm dia and 100mm height are prepared. 100 mm size cube specimens prepared for acid resistance test. The specimens for RCPT include preparation of discs of 100 mm dia and 50 mm height. In all the test specimens, GGBS is replaced by Metakaolin. It is believed from the test results that geopolymer concrete with Metakaolin and GGBS performs well in durability aspects.

***Keywords :* activator, admixture, Geopolymer concrete, GGBS, Metakaolin,**

I. INTRODUCTION

To minimize the depletion of natural resources, many researchers started using the industrial waste materials as construction material either an additive or partial replacement of the conventional material and achieved with good solutions. The main cause of atmospheric pollution is the emission of green house gases during the cement manufacture. This pollution can be minimized only by restricting the manufacture and usage of cement. Geopolymer concrete is one which completely eliminates the usage of cement. Many research works has proved that geopolymer concrete has excellent mechanical and durability properties.[1, 2] Poly condensation in silica and alumina is responsible for the strength development of geopolymer concrete.[3] When Sodium Hydroxide and Sodium Silicate mixture is used as an activator, the thermal activation takes place and gives strength the concrete[4,5]. Similarly, Metakaolin has high reactivity with alkali solutions [6], in this work, steps have been taken to use both Metakaolin and GGBS in geopolymer concrete for the response of durability behaviour. Experiments prove that the rate of absorption of geopolymer is less.[10,11,12]

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II. MATERIALS

A. Ground Granulated Blast furnace Slag(GGBS)

Ground Granulated Blast furnace Slag (GGBS) is collected from the blast furnace in iron manufacturing industries. From the physical properties, it is found that the specific gravity of GGBS used in this study is about 2.8. XRD analysis was performed on GGBS to determine its oxide composition and the details are presented in Fig 1.

B. Metakaolin

Metakaolin is a pozzolanic material and it is obtained by calcinations of Algerian kaolin at 700° C for 7 hours. The silica and alumina content of Metakaolin reacts with free lime and forms C-S-H gel and alumina silicates which are responsible for the strength improvement. Metakaolin is a white coloured fine particle. The specific gravity of Metakaolin used in this study is 2.7.

C. Fine aggregate

The fine aggregate used in this study belongs to Zone 2 -IS 382- 2016. The sand which passes through 2.36 mm sieve is used in this work. The fine aggregate has the specific gravity of 2.80 with fineness modulus 3.28[7]

D. Coarse aggregate

The coarse aggregate used in this study satisfies the guidelines of IS 383- 1970. The crushed granite stone aggregate which passes through 4.75 mm sieve is used in this work. The coarse aggregate has the specific gravity of 2.808 with fineness modulus 7.05.

E. Activator

A 12 Molarity Sodium Hydroxide solution and sodium silicate mixed in the ratio of 1: 2.5, prepared 24 hours before casting the specimens is used as activator.

F. Admixture

La-Hypercrete - S25 (HTS code 38244090), a modified carboxylic based ether is used in this study to increase the workability of geopolymer concrete. [8]

G. Mix proportion for the experimental work

The proportions of materials used in this experimental work is tabulated in Table I below.[9]

Table- I: Materials for the experimental work

Materials	GG BS	FA	CA	Na OH	Na_2SiO_3	Ad-mixture
Quantity (kg/m^3)	550	689.10	1113.2	55	137.5	5.5

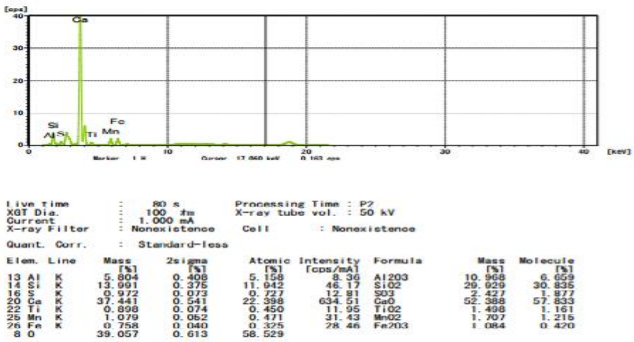

Fig.1. XRF Analysis of GGBS

III. EXPERIMENTAL WORK

A. Metakaolin and GGBS quantities for Mixes

The Metakaolin and GGBS quantities used in various mix combinations are tabulated in Table II below.

Table- II: Metakaolin and GGBS quantities

Mix ID	S1	S2	S3	S4	S5	S6
Metakaolin (%)	0	5	10	15	20	25
GGBS (%)	100	95	90	85	80	75

B. Water absorption test and test results:

Cylinders of 50mm diameter and 100 mm height are prepared for water absorption test. Specimens are cast for each mix ID mentioned in Table 2. The specimens are cured for 28 days and kept in oven at 110° C for 24 hours. This dry weight is W1. Then the specimens are kept inside the warm water at 90°C for 3 ½ hours. The wet weight is taken as W2. The percentage of water absorption is determined by [(W2-W1)/W1] x 100. The water absorption test results are tabulated in Table III.

Fig.2.Specimens for water absorption test

Table- III: Water absorption test results

Specimen ID	Dry weight of specimens in gms (W1)	Wet weight of specimens in gms (W2)	Water absorption (%)
S1	572	586	2.45
S2	580	593	2.24
S3	610	623	2.13
S4	608	620	1.97
S5	612	624	1.96
S6	625	614	1.79

C. Rapid Chloride Penetration test and test results:

To calculate this Chloride penetration, two discs of 100mm dia with 50mm height are cast for each mix ID and cured for 28 days and tested as per ASTM C 1202 (2017) standards. The concrete disc is sealed in between the two-glass container and the space between the disc and the glass containers are sealed using the sealant. The cathode terminal has 3% sodium chloride solution and the anode terminal has 0.3M sodium hydroxide solution. The wires of the voltage box and glass containers are connected. Now the RCPT setup is complete. Set the voltage of 60 Volts in the DC power supply. The initial reading is taken after the voltage setup. The solution is passed through the disc and gave the value of rate of transported chloride ions. Readings are noted for every 30minutes continuously and the log time is set as 6hrs. 60 Volts current is charged continuously till this log time gets over. The chloride permeability is calculated by 2 x 900 x Cumulative coulombs. Where, Cumulative coulombs = I 0 + I 30 + I 60 + I 90 + I 120 + I 150 + I 180 + I 210 + I 240 +I 270 + I 300 + I 330 + I 360. From this experimental work, it is concluded that since chloride ion permeability values falls between 2000 – 4000 coulombs, it is under Moderate range of acceptability. The experimental set up is shown if Fig_ 3. The test results are shown in Fig.4 and the average RCPT test results are shown in Table IV .

Table- IV: RCPT test results

Mix ID	S1	S2	S3	S4	S5	S6	Remarks
Charge passed (Coulombs)	3189.6	3137.4	3139.2	3047.4	2802.6	3004.2	As per ASTM C 1202- 2017 ratings, the values lies in between 2000-4000 which indicates the Chloride ion permeability is Moderate.
Chloride permeability	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	
>4000 – High, 2000-4000 – Moderate, 1000-2000 – Low, 1000-100- Very Low, <100 - Negligible							

D. Acid resistance test (Sulphate Attack) and test results:

In this test, concrete cubes of 100mm size are cast[9]. The cube specimens are immersed in 1% sulphuric acid for 28 days. Six cubes are cast for each mix ID in which 3 cubes are subjected to water curing and 3 cubes are subjected to acid curing. The specimens are tested after 28 days as per the codal provisions of IS: 516-1959. The cube specimens are shown in Fig 4 and the acid resistance test results are tabulated in Table V.

Fig.3.RCPT test set up

Fig.4. Cube specimens for acid resistance test

Table- V: Average compressive strength results of acid resistance test

Mix ID	28 days Average compressive strength of water curing (N/mm^2)	28 days Average compressive strength of acid curing (N/mm^2)	% Reduction
S1	38.22	32.46	15.07
S2	40.61	34.85	14.18
S3	42.90	37.14	13.42
S4	44.21	38.45	13.02
S5	46.33	40.57	12.43
S6	40.77	34.96	14.25

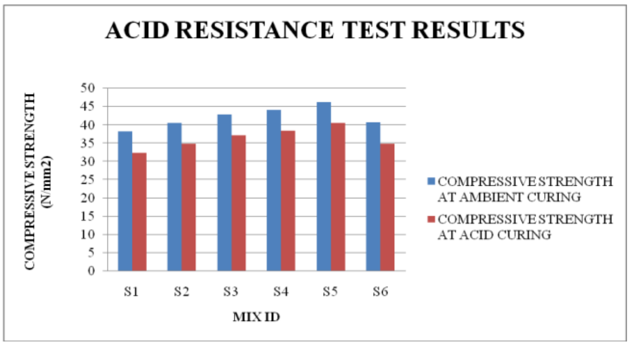

Fig.5. Acid resistance test results

IV. DISCUSSION ON TEST RESULTS

A. Water absorption test:

The water absorption for S1 specimen (0% Metakaolin and 100% GGBS) is 2.45%. When the GGBS is replaced by Metakaolin gradually, the water absorption also decreases and reached the value of 1.79% for S6 specimens. (25% Metakaolin and 75% GGBS). From the test results, it has been concluded that the water absorption decreases with increase in Metakaolin quantity.

B. Rapid Chloride Penetration test:

The RCPT test result of all the mix specimens gives MODERATE result. It shows that the geopolymer concrete with Metakaolin and GGBS performs uniformly for all replacements.

C. Acid resistance rest:

The 28 days average compressive strength value of S1 specimens is 38.22 N/mm^2 for ordinary curing and it is 32.46 N/mm^2 for acid curing. This value is approximately 84% value of the ordinary water cured specimens.. When the GGBS is gradually reduced by the addition of Metakaolin in 5 to 25%, with a variation of 5%, the compressive strength value also increases from the value of S1 specimens.

All the acid treated specimens are having nearly 80% of the compressive strength value of ordinary water cured specimens.

V. CONCLUSIONS

The conclusions based on the limited observations from the present investigation on properties of Metakaolin and GGBS based Geopolymer concrete is as follows.

(i)The water absorption value decreases for increased quantity of Metakaolin in the GGBS based geopolymer concrete.

(ii) Geopolymer concrete with GGBS performs uniformly with MODERATE chloride permeability for all the replacement ratios of GGBS by Metakaolin from 5 to 25% with a variation of 5%.

(iii) The acid treated geopolymer concrete specimens gives nearly 80% compressive strength of the normal water cured specimens.

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