

CHARACTERISTICS STUDY ON MECHANICAL PROPERTIES OF SLAG BASED GEOPOLYMER CONCRETE

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Abstract - As the issue of global warming and climate change is increasing, it is time that the construction industries switch to environment friendly materials. Thus the substitution of Portland cement by industrial waste materials like Ground Granulated Blast Furnace Slag (GGBS) makes the concrete more environmental friendly and economical too, as it does not emit Carbon dioxide (CO₂) which is a major greenhouse gas. Formation of geopolymer concrete is involved by replacing cement entirely with slag (GGBS) along with Sodium Hydroxide (NaOH) of 8 Molarity. The test results of compressive, split tensile and flexural strength of GGBS based Geopolymer concrete adopted by M30 grade mix design. The results indicated rapid strength gain and rapid hardening process while mixing the concrete (38.05MPa). The paper also deals with the comparison of strength results with the use of different admixtures in developing the concrete.

Key Words: Geopolymer, GGBS, NaOH, Compressive Strength, SEM and EDX.

1. INTRODUCTION

The term "Geopolymer" was first introduced to the world by Davidovits of France resulting a new field of research and technology. Geopolymer is an inorganic polymer resulting from the reaction of amorphous aluminosilicates with alkali hydroxide and silicate solutions. The manufacturing of Portland cement causes liberation of carbon di oxide (CO₂) a major greenhouse gas. Thus industrial wastes are used as substitution for Portland cement and one of them is slag (GGBS). Slag is a by-product waste generated in blast furnace of iron industries. It contains silica and aluminium which are the major constituents of binder in manufacturing of concrete. [1]. In 1970 Joseph Davidovits coined the term "Geopolymer" to classify the newly discovered "geosynthesis" material that produces inorganic polymeric materials, now used for a number of industrial applications. He also set a logical scientific terminology based on different chemical units for silicate and alumino-silicate materials, [2]. The first Slag based geopolymer concrete was developed in 1980 by Davidovits by using poly-sialate compound. Ordinary Portland cement undergoes hydration reaction whereas geopolymer concrete undergoes polymerisation

reaction which involves reaction between GGBS and Sodium Hydroxide (NaOH) solution forming 3 dimensional structure of alumina-silicate. Sodium Hydroxide is used as an alkali activator, [3]. Sodium hydroxide, Potassium hydroxide and sodium silicate solution are mostly used as alkali activators, but sodium hydroxide gave better results hence it is used. Alkali solutions and source materials like GGBS are the main constituents of formation of geopolymer concrete. [4] Several efforts have been taken to address this issue. They used different supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, these are the alternative binders to Portland cement. The geopolymer concrete has so many advantages such as the rapid setting time and does not require water for curing, fire resistance, and lower shrinkage. [5] Geo-polymers have the chemical composition similar to Zeolites but they can be formed an amorphous structure. For binding of materials the silica and the alumina present in the source material are induced by alkaline activators. The most common alkaline liquid used in the geopolymerization is the combination of Sodium hydroxide and Sodium silicate. This combination increases the rate of reaction. Ground granulated blast furnace slag (GGBS) is a by-product from the blast-furnaces used to make iron. During the process, slag was formed and it is then dried and ground to a fine powder. The strength of the concrete would depend on the nature and type of samples used in the formation of concrete.

2. MATERIALS USED

The main constituent source material slag (GGBS) was obtained from Sasthra dealers, Chennai, India. The brand name of GGBS was JSW, which has a specific gravity of 2.83. Sodium Hydroxide (NaOH) used was obtained from the locality in Vellore; it was obtained as commercially used pellets which has a specific gravity of 1.53. Coarse aggregate was also obtained in the locality, which was angularly shaped and was sieved by passing through 12.5mm sieve along with Fine aggregate which was sieved by passing through 4.75mm sieve. The specific gravity of Coarse and Fine aggregate was 2.62 and 2.6 respectively. Admixtures were also used in the formation of concrete, Admixtures were ordered from Kalpakkam, Chennai. Hyper plasticizer

and Super plasticizer were used as an admixture in the making of concrete. GGBS was subjected to SEM (Scanning electron microscope) analysis to find the composition of the sample. The SEM image is given in the fig 1 and EDX analysis is shown in table 1.

3. MIX DESIGN

As there are the codes for preparing mix design for geopolymer concrete, M30 grade mix design was adopted to the specimens according to IS 10262:2009. The ratio obtained was 1:1.54:2.36 and 0.35 water/cement ratio. The ratio for compressive strength of mortar cube was taken to be 1:3 as in 1 part of slag and 3 parts of fine aggregate (sand). The proportion for the mix design is given in the table 2

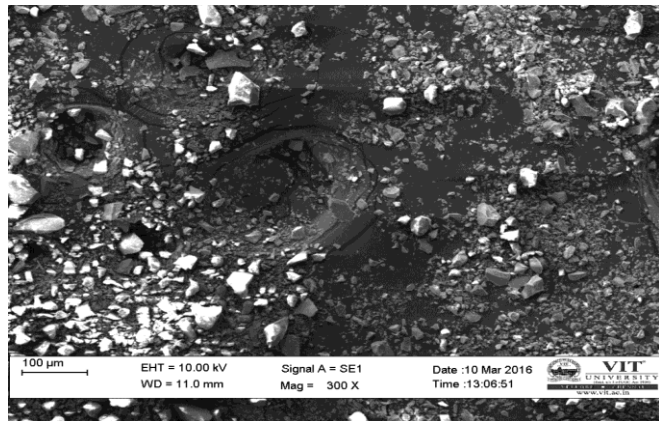


Fig -1: Slag sample image under 100µm

Table 1: Chemical composition of GGBS

Elements	Weight %	Atomic %
Carbon	35.56	49.09
Oxygen	34.49	35.74
Magnesium	1.69	1.15
Aluminium	4.61	2.83
Silica	8.00	4.72
Calcium	15.65	6.47

Table 2: Mix design proportion for M30 grade

Ingredients	Proportion (kg/m ³)
GGBS	422
Fine aggregate	612
Coarse aggregate	1276
Water	147.6

3.1 MIXING

Sodium Hydroxide pellets used is taken of 8 Molarity, the calculated amount of sodium hydroxide is taken in a water solution which is calculated by water/binder ratio which is 0.35. Hyper plasticizer and Super plasticizer were taken as admixtures and the admixture detail is given in the table 3. The constituents were thoroughly hand mixed until the mixture becomes uniform. The mixing process should be done in a fast pace because of the rapid setting time of the constituents because of the addition of sodium hydroxide and admixtures

Table 3: Admixture usage

Tests	Ratio	Admixture	Percentage
Mortar test	1:3	-	-
Compressive strength	1:1.54:2.36	HP	2%
Compressive strength	1:1.54:2.36	SP	0.5%
Split Tensile strength	1:1.54:2.36	SP	0.5%
Flexural strength	1:1.54:2.36	SP	0.5%

Note: SP - Super Plasticizer, HP - Hyper Plasticizer

3.2 CURING

After the mixture is transferred into the moulds, the moulds were carefully kept in oven with temperature around 80-85°C for 8 hours. Then the specimens were removed from the moulds and kept in room temperature for the rest of the days as shown in fig 2.



Fig -2: Geopolymer concrete specimens.

4. RESULTS AND DISCUSSION

The geopolymer mortar cubes have casted on the proportion of 1:3(one part of cement and 3 part of sand) and according to the calculation of mix design of M30 the concrete cubes, cylinder and prism have been casted in the proportion of 1:1.54:2.36(one of part of cement, 1.54 part of F.A, 2.36 part of C.A) for better bonding purpose we have used alkali activator which is nothing but NaOH with 8M. In the concrete cubes we have been used two different types of plasticizer like hyper plasticizer and super plasticizer. Super plasticizer gives 4-5% of result higher than the hyper plasticizer. So we have adopted to super plasticizer for further process. Those compressive strength, split tensile strength, flexural strength value are higher than M30 mix design value what we expected. So it can be used as a replacement of cement in some places.

4.1 Compressive strength of Mortar cube

The cube specimens for mortar test were casted with dimensions 70.6mm x 70.6mm x 70.6mm. Specimens of 5 numbers were made for 1, 3, 14 and 28 days each respectively. Their average compressive strength was found and the strength increased gradually along with the no of days, the details are given in chart 1 and table 4.

Table 4: Compressive strength results of mortar cube

Day of testing	Compressive strength (N/mm ²)
1	12.11
3	19.41
14	21.03
28	25.43

4.2 Compressive test

The cube specimens for compressive strength test were casted with dimensions 100mm x 100mm x 100mm according to IS 516-1959. Specimens of 5 numbers were made for 3, 7 and 28 day each respectively. Hyper plasticizer (HP) and Super plasticizer (SP) were used as admixtures to the specimens separately and the comparison of their strengths is given in the chart 2. Use of superplasticizer yielded higher strengths than usage of hyper plasticizer; hence super plasticizer was used for the rest of the tests. The compressive strength results for both the admixtures are given in the table 5.

Table 5: Compressive strength of slag based geopolymer concrete with various plasticizers

Days of testing	Strength using Hyperplasticizer (N/mm ²)	Strength using Superplasticizer (N/mm ²)
3	27	29.64
14	31.3	33.17
28	34.28	38.05

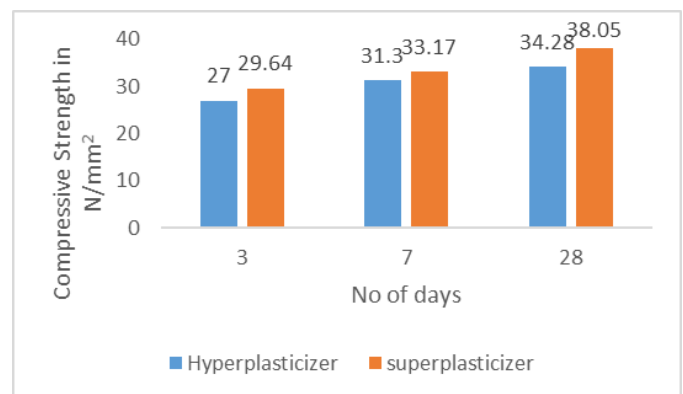


Chart 1: Comparison of compressive strengths.

4.3 Split tensile strength

The Cylinder specimens of diameter 100mm and depth of 200mm were casted according to IS 5816-1999. Super plasticizer was used as an admixture and M30 mix design was adopted for this test too. The cubes were oven cured for 8 hours at 80°C and tested for its split tensile strength for 3rd, 14th and 28th days. The test results are given in table 6.

Table 6: Split tensile strength of slag based geopolymer concrete with superplasticizers

Days of testing	Tensile strength (N/mm ²)
3	1.8
14	2.5
28	3.01

4.4 Flexural strength

The prism specimens of dimensions 100mm x 100mm x 500mm were casted according to IS 516-1959 and oven cured for 8 hours at 80°C. The prism specimens were tested for 14 and 28 days for its flexural strength. The test results are given in the table 7.

Table 7: Flexural strength of slag based geopolymer concrete with superplasticizers

Days of testing	FLEXURALSTRENGTH(N/mm ²)
14	5.5
28	8



Fig -3: Flexural strength testing machine setup.

4.5 Ultra sonic pulse velocity

The prism specimens of dimensions 100mm x 100mm x 500mm were casted according to IS 516-1959 and oven cured for 8 hours at 80°C. The prism specimens were tested for 14 and 28 days for its ultra-sonic pulse velocity. The test results are given in the table 8.

Table 8: Ultrasonic pulse velocity of slag based geopolymer concrete with superplasticizers

Days of testing	Ultrasonic pulse velocity (m/s)
14	6990
28	7090

5.CONCLUSIONS

1. GGBS is cheaper than cement which makes it economical to use and also environmental friendly.
2. Polymerization reaction needs Sodium Hydroxide as an alkali activator and hence 8M is nominal strength provided the rapid setting time.
3. The casting process such as mixing and compacting has to be done quickly since the hardening process is rapid.
4. Use of admixtures makes the hardening faster and hence can increase the strength of the concrete.
5. Geopolymer concrete attains early strength in around 7th and 14th day hence it can be applied for structures where early strength is required such as road repair works and plastering damaged structures.
6. The specific gravity of GGBS was found to be 2.83 and the setting time is 18 mins.
7. The production of geopolymer concrete needs extensive care and should be done with necessary precautions.

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