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STRENGTH STUDY OF ALKALI ACTIVATE GEO-POLYMER CONCRETE USING FLY-ASH AND GROUND GRANULATED BLAST FURNACE SLAG

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Abstract: Concrete is the most commonly used construction material. Customarily, concrete is produced by using Ordinary Portland Cement as a binder a highly energy intensive product which causes pollution to the environment due to the emission of carbon dioxide. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to the environment related. Geopolymer concrete is a new material that does not need the presence of Portland cement as a binder. Research in the field and publications in this field of geopolymer binders, states that this new material is highly potential to replace an alternative to Portland cement. The Durability of these materials is better than OPC which is the main advantage as such it can be replaced. Considering the increasing demand for developing alternative construction materials, due to the growing environmental concerns, this paper discusses the feasibility of alkali activated geo-polymer concrete, as a future construction material. The main objective of this study involves observation of strength behaviours of the fresh fly ash-based and ggbs geo-polymer concrete, understanding the basic mixture proportioning of fly ash-based geopolymer concrete and evaluating various economic considerations

Index Terms - Alkali-Activated Concrete, Ordinary Portland cement, Geopolymer concrete, alkaline activator, Fly-ash/slag

I. INTRODUCTION

Most of the modern constructions worldwide are made of ordinary Portland cement (OPC) based concrete. However, OPC production releases large quantities of carbon dioxide to the atmosphere: approximately 1 tons of carbon dioxide emissions for each ton of OPC produced, corresponding to more than 7% of greenhouse gas emissions worldwide. With this perspective, the study of alternative solutions, such as alkali-activated binders, is quite relevant. Any raw material with reactive silica and alumina in its chemical composition, such as fly ash (FA) or blast furnace slag, can be used to produce alkali-activated concrete (AAC), which together with an alkaline activator and a thermal curing allow binding material with good mechanical properties to be obtained. It is necessary to reduce or replace cement from other cementitious material such as fly ash, GGBS, rise husk ash, etc. Fly ash is made from coal burn in to the boiler of electricity generating power plant. Every year fly ash produce is estimated about 780 million tons in world but out of which only 17-20% are used. In India production are 220 million ton per year and use 35-50% in concrete and stabilization of soil (9). Hence huge amount disposed of in land as waste material In 1978, Davidovits (1999) proposed that binders could be produced by a polymeric reaction of alkaline liquids with the silicon and the aluminium in source materials of geological origin or by-product materials such as fly ash and rice husk ash. He termed these binders as geopolymers. Palomo et al (1999) suggested that pozzolans such as blast furnace slag might be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete. In this scheme, the main contents to be activated are silicon and calcium in the blast furnace slag. The main binder produced is a C-S-H gel, as the result of the hydration process.

II. LITERATURE REVIEW

Davidovits, J. Geopolymer cement, high alkali (K-Ca)-Poly (Sialate-Siloxo) cement, result from an inorganic poly condensation reaction, a so-called geopolymer K-Poly (Sialate-Siloxo) binders, whether used pure with fillers or reinforced are already finding application in all fields of industry. These application are to be found in the automobile and aeronautic industries, non-ferrous foundries and metallurgy, civil engineering, plastic industries, etc.

Djwantoro Hardjito, to reduce greenhouse gas emissions, efforts are needed to develop environmentally friendly construction materials. This paper presents the development of fly ash-based geo-polymer concrete. In geo-polymer concrete, a by-product material rich in silicon and aluminum, such as low-calcium (ASTM C 618 Class F) fly ash, is chemically activated by a high-alkaline solution to form a paste that binds the loose coarse and fine aggregates, and other unreacted materials in the mixture.

The test results presented in this paper show the effects of various parameters on the properties of geo-polymer concrete. The application of geo-polymer concrete and future research needs are also identified.

B.V.Rangan(2008)[1] the Report presented information on heat-cured fly ash-based geopolymer concrete. Low-calcium fly ash (ASTM Class F) is used as the source material, instead of the Portland cement, to make concrete. Low-calcium fly ash-based geopolymer concrete has excellent compressive strength and is suitable for structural applications. The salient factors that influence the properties of the fresh concrete and the hardened concrete have been identified. Data for the design of mixture proportions are included and illustrated by an example. The elastic properties of hardened geopolymer concrete and the behavior and strength of reinforced geopolymer concrete structural members are similar to those observed in the case of Portland cement concrete. Therefore, the design provisions contained in the current standards and codes can be used to design reinforced low-calcium fly ash-based geopolymer concrete structural members. Heat-cured low-calcium fly ash-based geopolymer concrete also shows excellent resistance to sulfate attack, good acid resistance, undergoes low creep, and suffers very little drying shrinkage. The Report has identified several economic benefits of using geopolymer concrete.

V.Ranga Rao(2017)[2] the experimental study on behavior of fly ash based geo-polymer concrete and other parameters like strength properties, concentration of alkaline solution, ratio of NaOH to Na2Sio3, curing time, additional water in mix. In the present study sustainable materials were used such as Fly ash. Combination of Sodium Hydroxide and Sodium silicate is used as activator solution to form geopolymer concrete. The activator solution is prepared 24 hours prior of casting. The mix is designed for 10 Molarity with varying ratios of 1:2, 1:2.5, 1:3. The GPC specimens are tested for compression, flexural and tension tests at the age of 3, 7, 28 days. As the activator ratio increases the compressive strength, Split tensile strength, Flexural strength is also increased. As the time curing is increased the geopolymer specimens also improved.

R.Gopalakrishnan[1] and K. Chinna Raju[2] Concrete is the most commonly used construction material. Customarily, concrete is produced by using Ordinary Portland Cement as a binder a highly energy intensive product which causes pollution to the environment due to the emission of carbon dioxide. Attempts to reduce the use of Portland cement in concrete are receiving much attention due to the environment related. Geopolymer concrete is a new material that does not need the presence of Portland cement as a binder. Geopolymer is an inorganic alumina-hydroxide polymer which is synthesized from predominantly silicon and aluminium materials of geological origin or by product materials such as fly ash, granulated blast furnace slag or rice husk ash, etc. Research in the field and publications in this field of geopolymer binders, states that this new material is highly potential to replace an alternative to Portland cement. The Durability of these materials is better than OPC which is the main advantage as such it can be replaced. This paper presents a review of the literature about the durability of alkali-activated binders. In this paper the durability properties such as resistant to acid, resistance to sulphate, resistance to high temperature and fire has been discussed.

Ammar Motorwala, Ravishankar Kammula, Praveena Nannapaneni, in this paper considered the increasing demand for developing alternative construction materials, due to the growing environmental concerns, this paper discusses the feasibility of alkali activated geo-polymer concrete, as a future construction material. The main objective of this study involves observation of structural behaviours of the fresh fly ash-based geo-polymer concrete, understanding the basic mixture proportioning of fly ash-based geopolymer concrete and evaluating various economic considerations.

III. METHODOLOGY

MATERIALS USED IN THE STUDY

The FA used in the current investigation was obtained from disposal waste resulting from the combustion of powdered coal in the coal-fired furnaces. It complies with the requirements of BS3892: Part 1 (BSI 1992) and is classified as low calcium Class F fly ash in ASTM-C618. Specific gravity of the FA was 2.4 g/cm3. Its Blaine specific surface area was 3500 cm2/g. The slag was delivered from the disposal waste of Helwan steel factory (in Cairo-Egypt) in the form of water quenched fine grains. The slag was then finely ground in a laboratory ball mill to satisfy Blaine specific surface area of 3200 cm2/g. The specific gravity of the slag was 2.8 g/cm3. The slag classified as a category 80 slag according to ASTM C 989 hydraulic activity index. The chemical composition of the FA and slag were evaluated by X-ray fluorescence (XRF) and are given in Table 1. Liquid sodium silicate, which had a density of 1.38 g/cm3 and a composition comprising of 8.2% Na2O, 27% SiO2 and 64% H2O and NaOH in pellet-form with purity of 98% were used as alkali activators. The employed sand was natural siliceous with a fineness modulus of 2.47. Its particle size distribution was within the range of medium grading zone according to the classification of the Egyptian Standard Specification ES 1109/ 2002. The coarse aggregate was crushed limestone; 40% of its particles was in the size range of 10 – 14 mm, and the rest was finer than 10 mm size.

Fig.1 GGBS

Fig.2 Fly-Ash

Table 1 Chemical composition of cementitious materials

Oxides Composition	FA (%)	Slag (%)
SiO_2	60	30.38
Al_2O_3	22.7	9.05
Fe_2O_3	4.6	3.82
CaO	4.5	45.88
MgO	1	5.39
Na_2O	0.7	0.52
K_2O	2	0.31
SO_3	0.5	1.78
L.O.I.	4	1.41

The coarse aggregate was crushed limestone; 40% of its particles were in the size range of 10 – 14 mm, and the rest was finer than 10 mm size.

Alkaline Liquids - The most common alkaline liquid used in geo-polymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. Palomo et al (1999) concluded that the type of alkaline liquid plays an important role in the polymerisation process. Reactions occur at a high rate when the alkaline liquid contains soluble silicate, either sodium or potassium silicate, compared to the use of 14 only alkaline hydroxides. Xu and van Deventer (2000) confirmed that the addition of sodium silicate solution to the sodium hydroxide solution as the alkaline liquid enhanced the reaction between the source material and the solution.

3.2 MIXTURE PROPORTION

The activator was prepared by mixing 15% sodium silicate with 85% 12 M NaOH ($SiO2/Na2O$ ratio = 0.16) and left until the temperature of the solution got down to the room temperature. The ratios of FA (or FA+slag): fine aggregate: coarse aggregate were taken as 1: 1.5: 2; and the alkaline solution/ cementitious materials was adjusted at 0.5. The mixing proportions details are shown in Table 2. In the case of mortar production, the ratio of cementitious materials / sand and the dissolution alkaline / cementitious materials were controlled at 0.5 and 0.4, respectively.

Table 2 Details of alkali-activated concrete mixtures

Mix	%FA	%GGBS	Stone/Slag	C/aggregates	Solution/C
M1	100	0	1.33	0.285	0.5
M2	95	5	1.33	0.285	0.5
M3	90	10	1.33	0.285	0.5
M4	85	15	1.33	0.285	0.5

Fig. 3 various materials used in Geo-polymer concrete

3.3 CASTING. CURING & FINISHING

Cementitious materials and aggregate were mixed in a pan mixer for 5 minutes, then the liquid component of the material was added and mixed for extra 5 minutes. Just after mixing, the slump of fresh concrete was determined in accordance with ASTM C173. Then the mixture was cast into 15 × 15 × 15 cm moulds, cylinders of 15 cm diameter and 30 cm height moulds and prisms of 10 × 10 × 50 cm, in three layers. Each layer was vibrated for 15 seconds using vibrating table. Immediately after casting, the specimens were wrapped with thin vinyl sheet to avoid loss of water then cured at 80 ± 1 °C and 95 ± 5% RH for 48 h. The specimens were then demould and left at room temperature until testing. In similar way, the mortar was mixed. After mixing, the mortar was cast into 2.5 × 2.5 × 28.5 cm moulds in three layers. Each layer was vibrated in similar way. Immediately after casting, the mortar specimens were covered with plastic sheets then cured at 80 ± 1 °C and 95 ± 5% RH for 48 h. The specimens were then demould and left at 20 ± 1°C and 50 ± 5% RH. The compressive strength of cube specimens was measured in triplicate after ages of 3, 7, 28 and 91 days. The testing machine employed for this test complies with British Standard (BS 1881: Part 115). The splitting tensile strength was determined using cylinder specimens according to ASTM C 496 at ages of 3, 7, 28 and 91 days. The flexural strength tests were carried out on the prisms of 10 × 10 × 50 cm at ages of 3, 7, 28 and 91 days using simple beam with center-point loading according to ASTM C293. Three specimens of each mixture were tested and the mean value was reported. Dry shrinkages were determined on mortar specimens in agreement with standard ASTM C596-09. The drying shrinkage measurements started at the third day from casting then repeated every 7 days. The drying shrinkage measurements continued up to 91 days.

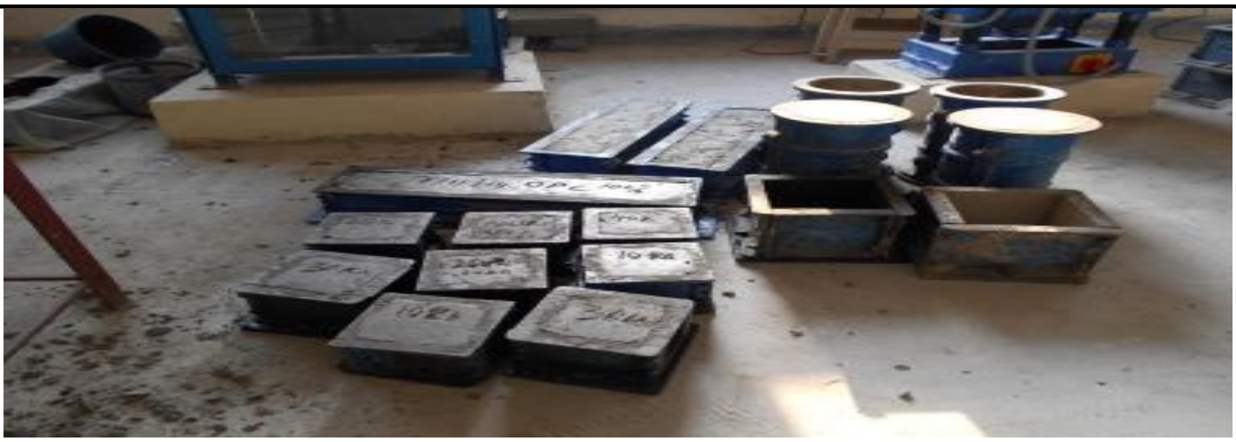

Fig- 4 Demoulded Specimen

The casted specimens were tested as per IS (519:1959) and the strengths were calculated for 3, 7 and 28 days. The Figure 6 shows the testing of geopolymer specimens after demoulding.

Fig 6 Testing of specimens

The various strength tests that are to be done listed as below.

- Compressive Test
- Split Tensile Test
- Flexural Test

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IV. RESULTS AND DISCUSSION

III. Compressive Test:

The compressive test on cubes were conducted as per IS Specifications (IS: 516-1959).The below Figure 6 is the graphical representation of compressive strength. As the activator ratio increases there is increment in compressive strength of the specimens with respect to age of the specimens.

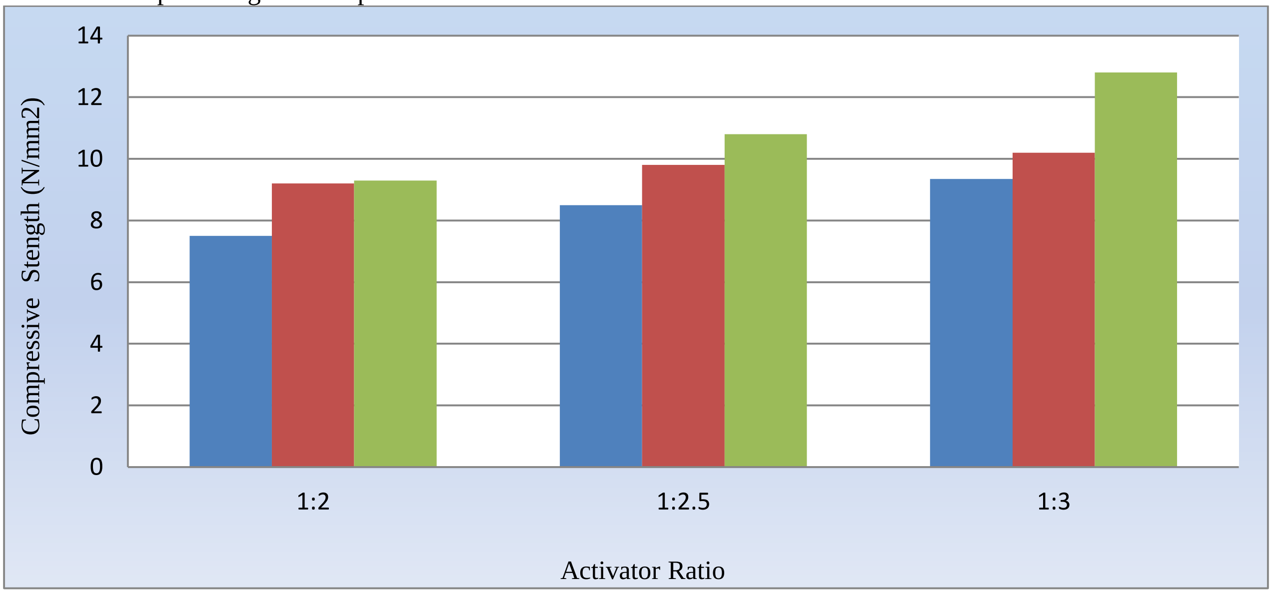

Fig.7 Compressive test conducted at the age of 3,7,28 days for different Activator ratios

Split Tensile Test-

The split tensile test on test specimens is done on the compression testing machine as per IS (5816:1999). Figure 7 shows graphical representation of split tensile strength. As the activator ratio increases there is increment in Split tensile strength of the specimens with respect to age of the specimens.

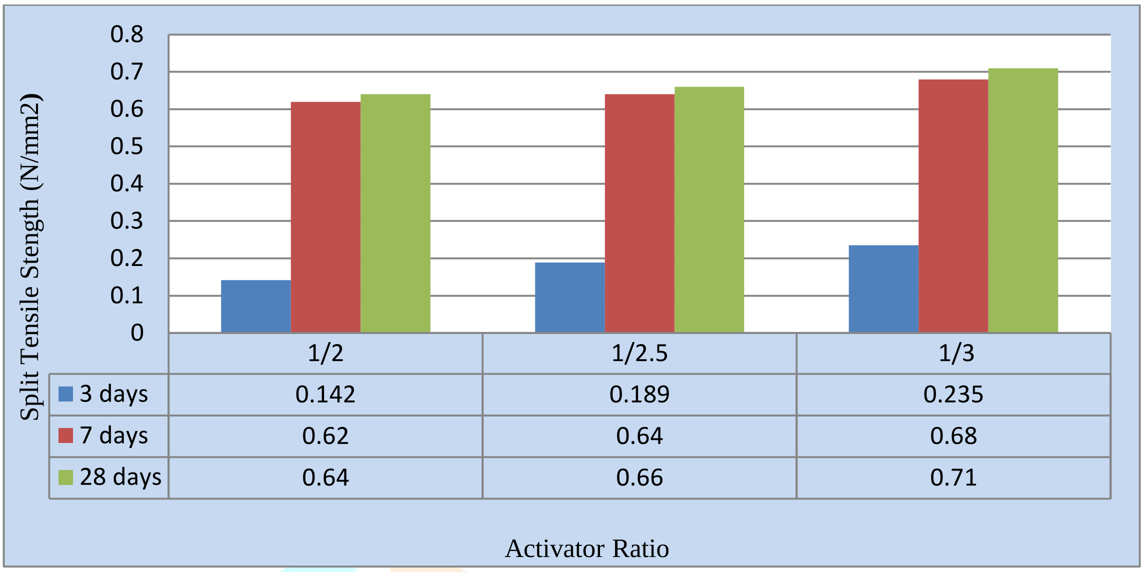

Fig.8 Split tensile strength at the age of 3, 7, 28 days for different Activator ratios

Flexural Test:

The results of flexural Test of concrete at the ages of 3,7,28 days are presented in Figure 8. As the activator ratio increases there is increment in Flexural strength of the specimens with respect to age of the specimens and hence the flexural strength at the age of 28 days, 7 days is observed as same.

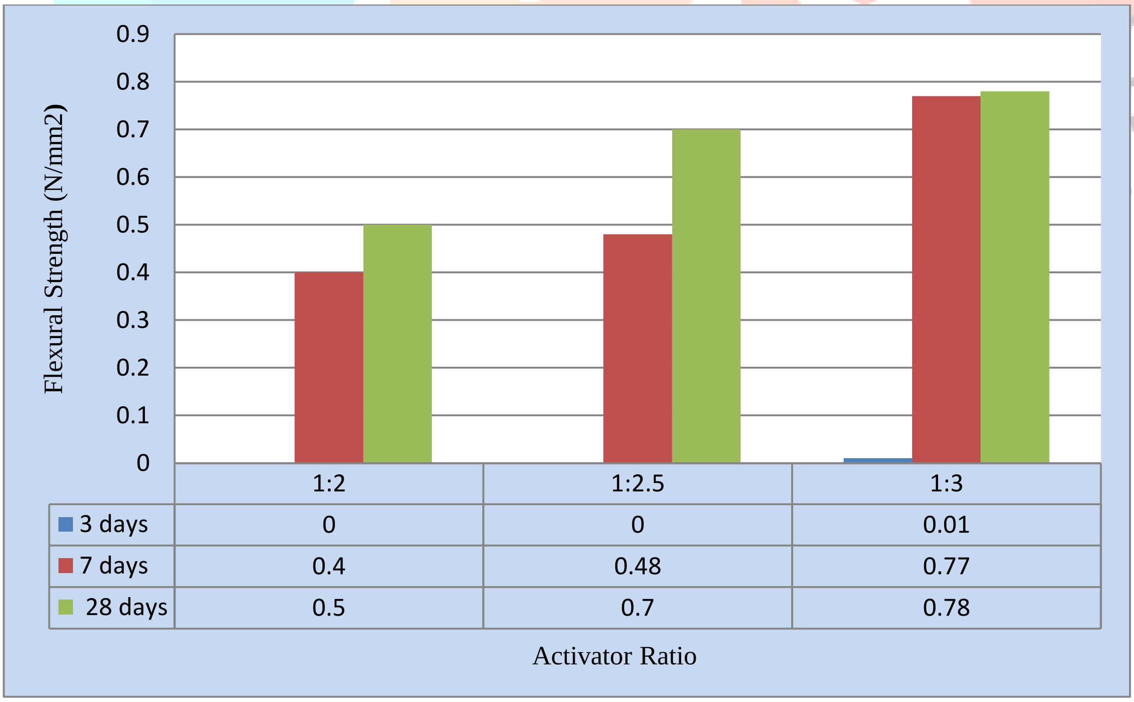

Fig. 9 Flexural strength at the age of 3, 7, 28 days for different Activator ratio

V. CONCLUSION

The compressive strength, Split tensile strength, Flexural strength of fly ash based GPC specimens increased with the increase in Activator ratio i.e., 1:2, 1:2.5 and 1:3. As there is increase in curing time strength of all GPC specimens improved. Some works have been investigated in this area in an attempt to develop mix design methodology for alkali-activated low-calcium fly ash. However, it still used the temperature curing for enhancing the strength development of alkali-activated low-calcium fly ash, but this is limited for construction work. To be useful in practice, alkali-activated binder's concrete cured at ambient temperature has been used to solve this problem. The evolution of products after geo-polymerization is different from the conventional concrete as such it is less susceptible than the concrete in the sulphate attack. Contrary to standard OPC binders alkali-activated binders show a high stability to high temperatures which depends on the silicon/ aluminium ratio. The experimental investigation shows that the behavior of alkali-activated binder show that these materials are specially recommended for works with a fire risk in tall buildings and tunnelling works.

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