International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 09 | Sep 2020 www.irjet.net p-ISSN: 2395-0072

A STUDY ON GEOPOLYMER CONCRETE BEHAVIOURS UNDER AMBIENT CURING

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Abstract - *The main component of preparing concrete, contributes significant amount of greenhouse gas, because the production of one ton of Portland cement releases about one ton of carbon dioxide gas into the atmosphere. Therefore, the introduction of a novel binder called 'geopolymer' by Davidovits promises a good prospect for application in the concrete industry as an alternative binder to Portland cement. In terms of decreasing the global warming, the geopolymer technology can be decrease the CO2 emission to the atmosphere caused by cement and aggregates industries by 80%. Inspired by this novel technology and the fact that fly ash and silica fume is a waste material and fully available, an attempt has been taken to develop an alternative concrete binder by applying the geopolymer technology and utilizing fly ash and silica fume as the source material to prepare the Fly Ash-Based Geopolymer Concrete. The early work on fly ash-based geopolymer concrete concerning with the manufacturing process and the effect of curing time, curing temperature and the age of concrete on the compressive strength of fly ash-based geopolymer concrete. Moreover, the effect of alkaline ratio and the ratio of alkaline to water was also studied. the results on the factors affecting the compressive strength and other properties of fresh and hardened fly ash-based geopolymer concrete Attempts to apply this material as a structural material have geopolymer concrete beams and columns been taken by studying the behavior and strength of reinforced fly ash-based geopolymer concrete beams and columns. This paper presents the study on fly ash-based geopolymer concrete, mix design is focused for three grades i.e. low, medium and higher grades have been arrived and tested for compressive strength.*

Key Words: Fly ash, polymerisation, silica fume, alkaline solution, green concrete.

1. INTRODUCTION

1.1 General

Geo-polymer is a type of amorphous alumina-silicate cementations material. Geo-polymer can be synthesized by poly condensation reaction of geo-polymeric precursor, and alkali poly silicates. Comparing to Portland cement, the production of geo-polymers has a relative higher strength, excellent volume stability, better durability. Geo-polymer concrete based on pozzolana is a new material that does not need the presence of Portland cement as a binder. Fly ash-based concrete has excellent compressive strength, suffers very little drying shrinkage low creep, excellent resistant to sulphate attack and good acid resistance. Given the fact that the fly ash is considered as a waste material, the fly ash based geo-polymer is therefore somehow cheaper than the OPC concrete. Moreover, reduction of one tone of CO2 yields one tone of carbon credit. This carbon credits significantly adds to the economy offered by the Geopolymer. "Fly ash" is preferred as a source material because the presence of calcium in high amount may interfere with the polymerization process and alter the microstructure.

1.2 Scope and objective

➢ To modify/improve the concrete properties by using mineral admixture like Fly ash, Metakaolin, Lime, Silica Fumes.
➢ To conduct various tests on concrete as per IS code to find its properties.

➢ To provide low carbon Geo-polymer concrete with advantages like fire proof, eco- friendly, low permeability.
➢ To find its excellent properties within both acid and salt environments

2. LITERATURE REVIEW

Abhilash P et al. (2006) has done a study on effect of fly ash (FA) and ground granulated blast furnace slag (GGBS) on the mechanical properties of geopolymer concrete (GPC) when they were replaced for cement at different replacement levels (FA50- GGBS50,FA75-GGBS25, FA100-GGBS0) using sodium silicate (Na2SiO3) and sodium hydroxide (NaOH) solutions as alkaline activators. Specimens were casted and cured for different curing periods like 7, 14, 28, 56 and 112 days at ambient room temperature to determine the mechanical properties of geopolymer concrete. Test results shows that as the percentage of GGBS in the mix is increasing, mechanical properties such as compressive strength, split tensile strength and flexural strength were increasing.

Paras S. Pithadiya et al. (2013) has done a research whose objective of the work was to study the effect of GGBS in fly ash based geopolymer concrete and to study the effect of oven curing and ambient room temperature curing on them. And by replacing fly ash from 0 to 100% with GGBS and inspecting the fresh properties and hardened concrete properties at 7 days. The casted cube will be cured at normal room temperature and at 700C Oven heat provision for 24 hours and to ascertain the behavior of concrete mixed with GGBS, thereby examining the changes of properties like strength and durability.

Vignesh P and Vivek K (2009) has done an attempt to study strength properties of geopolymer concrete using low calcium fly ash replacing with slag in five different percentages. Sodium silicate (103 kg/m3) and sodium hydroxide of 8M (41 kg/m3) solutions were used as alkaline solution in all 5 different mixes. The investigations are to be carried for the compressive strength, split tensile strength, flexural strength test on the concrete specimens. Hopefully one day in the near future geopolymer concrete will replace ordinary Portland cement as the most abundant man-made material on earth.

Vaibhav A. Kalmegh et al. (2012) has presented a paper that reviews geopolymer concrete, it"s constituent, environmental benefits and strength also finding some solution to reduce the use of cement by replacing a percentage of it by fly ash

Sonal P. Thakkar et al. (2015) has presented a paper that discussed various combinations of ground granulated blast furnace slag (GGBFS) and fly ash, as source material, to produce geopolymer concrete at ambient temperature. It has been generally accepted that heat treatment is required for producing geopolymer concrete which is considered a drawback affecting its applications. In this paper variation of source material i.e. Various combination of fly ash and GGBFS is done to achieve compressive strength for medium grade of concrete of M-25. Oven and ambient curing is done. It is found that geopolymer concrete with GGBFS in fly ash as increases it gains strength and shows good strength at 3, 7 and 28 days even at ambient curing with increase in GGBFS content. While only slag based geopolymer concrete has higher strength at oven curing while rate of gain of strength is slower at ambient temperature as period increases.

Mehta (2001) suggested that they have strategies to retain concrete as a construction material for the development of infrastructure; mean while they have outlined an alternative eco - friendly material which can be used to manufacture concrete for the future.

McCaffrey (2002) reported that the production of cement is increasing by about 3% per annum. As per the report of Roy (1999), 13 the manufacture of one ton of cement emits about one ton of CO2 to the atmosphere. This is due to de-carbonation of limestone in the kiln during manufacturing of cement and the burning of fossil fuels.

A. Mohd Mustafa Al- Bakari, Omar. A.K.A.Abdul Kareem and San Myint (2009) studied about the Fly ash and a mixture of alkaline activators namely sodium silicate (Waterglass) and sodium hydroxide (NaOH) solution at different Alkaline activator/Fly ash ratio (0.3, 0.35 and 0.4) were used to prepare a fly ash-based geopolymer at constant (NaOH) concentration of 15M, curing temperature, curing time and total additional water content approximately (17%) of the samples weight. Optimum value of the Alkaline activator/Fly ash ratio was determined with respect to the highest compression strength of the 7days aging samples. The effect of the oxide molar ratios of SiO2/Al2O3, Water content of the alkaline activator and the Waterglass % content was studied for each of Alkaline activator/Fly ash ratio, and it showed an important role on the geopolymerization process.

3. METHODOLOGY

The work was carried out by the following order.

- Collection of materials
- Testing of materials
- Mixing of materials
- Casting of specimen
- Curing
- Testing of concrete

4. MATERIALS

- Cement
- Fly ash
- Silica fume
- Alkaline solution
- Fine aggregates
- Coarse aggregates

5. TESTING OF MATERIALS

5.1 Specific Gravity Test

In concrete technology, specific gravity of aggregates is made use of in design calculations of concrete mixes. With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. Specific gravity of aggregate is also required in calculating the compacting factor in connection with the workability measurements. Similarly, specific gravity of aggregate is required to be considered when we deal with light weight and heavy weight concrete. Average specific gravity of the rocks varies from 2.6 to 2.8.

Fig 5.1

5.2 Sieve Analysis

This is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation. A convenient system of expressing the gradation of aggregate is one which the consecutive sieve openings are constantly doubled, such as 10 mm, 20 mm, 40 mm etc. Under such a system, employing a logarithmic scale, lines can be spaced at equal intervals to represent the successive sizes. The aggregates used for marking concrete are normally of the maximum size 80mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron and 150 microns. The aggregate fraction from 80 mm to 4.75 mm is termed as coarse aggregate and those fractions from 4075 mm to 150 micron are termed as fine aggregate. The size 4.75 mm is a common fraction appearing both in coarse aggregate and fine aggregate (C.A. and F.A). Grading pattern of a sample of C.A or F.A. is assessed by sieving a sample successively through the entire sieves mounted one over the other in order of size, with larger sieve on the top. The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above. Sieving can be done either manually or mechanically.

The following limits may be taken as guidance:

Fine sand: Fineness Modulus: 2.2 - 2.6
MEDIUM SAND: F.M.: 2.6 - 2.9
COARSE SAND: F.M.: 2.9 - 3.2

Total weight of sample taken = 1000 grams

Sieve Size	Weight Retained in Grams	% Weight Retained	Cumulative % Weight Retained	% Weight Passing
4.75	24	2.4	2.4	97.6
2.36	38	3.8	6.2	93.8
1.18	148	14.8	21	79
600µ	222	22.2	43.2	56.8
300µ	486	48.6	91.8	8.2
150µ	72	7.2	99	1
pan	10	1	100	0

F=261.4

Fineness modulus of aggregates = F/100 =2.61

RESULT:

Fineness modulus of aggregates = 2.61

6. PREPARATION OF CONCRETE

6.1 General

➢ Concrete has been prepared in three different ratios.

➢ Materials like silica fume and flyash is used as replaced materials for cement.

➢ NAOH solution is mixed with cement to form a gel or paste.

➢ Aggregates are mixed with cement paste to form a geopolymer concrete.

➢ After well mixed the concrete is checked for slump cone test

➢ Finally concrete is filled in prepared moulds (prism, cylinder, cube) for harden test.

6.2 Mix Ratio

SERIAL NUMBER	RATIO NUMBER	CEMENT	FLYASH	SILICA FUME
1	1ST	40%	30%	30%
2	2ND	50%	30%	20%
3	3RD	60%	20%	20%

7. TEST CARRIED OUT ON HARDEN CONCRETE

7.1 Compressive test

Compression test develops a rather more complex system of stresses. Due to compression load, the cube or cylinder undergoes lateral expansion owing to the Poisson's ratio effect. The steel plates do not undergo lateral expansion to some extent that of concrete, with the result that steel restrains the expansion tendency of concrete in the lateral direction. This induces a tangential force between the end surfaces of the concrete specimen and the adjacent steel plates of the testing machine. It has been found that the lateral strain in the steel plates is only 0.4 of the lateral strain in the concrete. The degree of restraint exercised depends on the friction actually developed. When the friction is eliminated by applying grease, graphite or paraffin wax to the bearing surfaces the specimen exhibits a larger expansion and eventually splits along its full length.

Fig 7.1

7.2 Split Tensile Test

The test is carried out by placing a cylindrical specimen horizontally between the loading specimen of a compression testing machine and the load is applied until failure of the cylinder, along the vertical diameter. The loading condition produces a high compressive stress immediately below the two generators to which the load is applied. But the larger portion corresponding to depth is subjected to a uniform tensile stress acting horizontally. In order to reduce the magnitude of the high compression stresses near the points of application of the load, narrow packing strips of suitable material such as plywood are placed between the specimen and the loading platens of the testing machine. The packing strips should be soft enough to allow distribution of load over a reasonable area, yet narrow and thin enough to prevent large contact area. The main advantage of this method is that the same type of specimen and the same testing machine are used for the compression test can be employed for this test. That is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, the modulus of rupture.

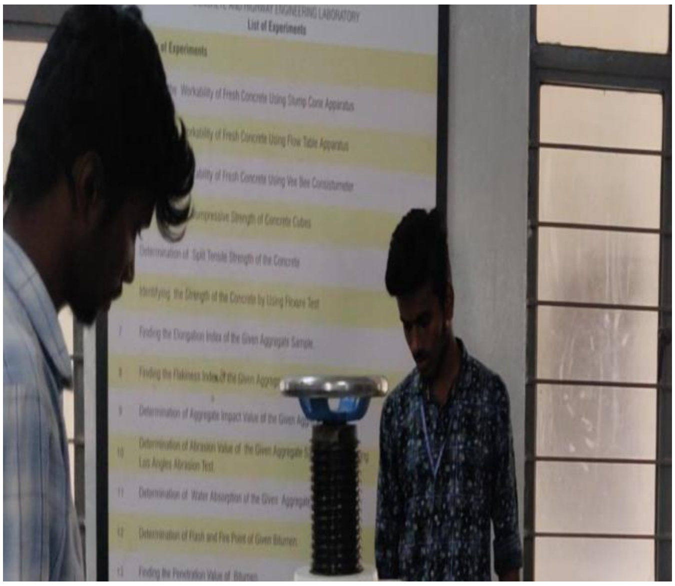

Fig 7.2

8. RESULT

8.1 Compressive strength of concrete on various ratio

Curing Period	Compressive strength N/mm^2		
	1st Ratio	2nd Ratio	3rd Ratio
7 Days	16.74	17.63	22.67
14 Days	20.45	21.63	22.66
28 Days	27.01	28.73	30.25

8.2 Split tensile strength of concrete on various ratio

Curing Period	Stress N/mm^2		
	1st Ratio	2nd Ratio	3rd Ratio
7 Days	2.36	2.876	3.21
14 Days	2.45	3.06	3.35
28 Days	3.16	3.39	4.05

9. CONCLUSIONS

Geopolymer concrete beams has the maximum load carrying capacity compared to the conventional M30 mix. Using higher percent of flyash and lower percent of alkali activator solution as a cement replacement can obtain higher strength

User-friendly geopolymer concrete can be used under conditions similar to those suitable for ordinary portland cement concrete. These constituents of Geopolymer Concrete shall be capable of being mixed with a relatively low-alkali activating solution and must be curable in a reasonable time under ambient conditions.

The production of versatile, cost-effective geopolymer concrete can be mixed and hardened essentially like portland cement. Geopolymer Concrete shall be used in repairs and rehabilitation works.

Due to the high early strength Geopolymer Concrete shall be effectively used in the precast industries, so that huge production is possible in short duration and the breakage during transportation shall also be minimized.

Geopolymer Concrete shall also be used in the Infrastructure works. In addition to that the Flyash shall be effectively used and hence no landfills are required to dump the flyash.

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