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ENHANCING THE PROPERTIES OF CONCRETE BY USING ALKALINE SOLUTION AND ITS COMPARATIVE STUDY WITH CONVENTIONAL CONCRETE

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Abstract - The main aim of this study was to reduce the use of cement so as to produce a CO_2 emission free cementitious material and Geopolymer Concrete (GPC) was the best alternative solution present out there. GPC utilizes industrial waste material such as fly ash from thermal power station to provide practical solution to waste management as well as environmental protection method. In this study we have used low calcium fly ash (ASTM class F), along with fly ash, water was enable to bind effectively. Therefore we also have replaced water completely with alkaline solution to hold fly ash, aggregate and sand together. The alkaline solutions we have used are – sodium hydroxide (NaOH) and sodium silicate (Na_2SiO_3). The main purpose to introduce alkaline solution was polymerization. That is the reason scientist Davidovits named this mix as geopolymer concrete.

GPC required high temperature for curing to happen the polymerization, to neglect this necessity we also have used Ground Granular Blast Furnace Slag (GGBS) in the proportion FA:GGBS as 60:40. Thus, the curing of GPC was done at ambient temperature without keeping it in water unlike the conventional concrete. Amongst both the alkali solutions i.e. NaOH and Na_2SiO_3, sodium hydroxide was used in different molar concentration of 10M, 12M and 14M with keeping silicate to hydroxide ratio constant as 1.5, three different sets of 9 cubes and 3 cylinders were casted. It was observed that the specimen of 12M concentrated solution has the maximum compressive strength, split tensile strength.

Index Terms - Geopolymer, Flyash, Alkaline solution, compressive strength, split tensile strength

I. INTRODUCTION

The major problem that the world is facing today is the environmental pollution. In the construction industry mainly the production of ordinary Portland cement (OPC) will cause the emission of pollutants which results in environmental pollution. The emission of carbon dioxide during the production of ordinary Portland cement is tremendous because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere.On the other hand, the climate change due to global warming and environmental protection has become major concerns. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO_2), to the atmosphere by human activities. Among the greenhouse gases, CO_2 contributes about 65% of global warming. The cement industry is held responsible for some of the CO_2emissions, because the production of one ton of Portland cement emits approximately one ton of CO_2 into the atmosphere.

The environment must be protected by preventing dumping of waste/by-product materials in un-controlled manners.The geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement. In terms of global warming, the geopolymer concrete significantly reduce the CO_2 emission to the atmosphere caused by the cement industries. Davidovits (1988; 1994) proposed that an alkaline liquid could be used to react with the Silicon (Si) and Aluminum (Al) in a source material of geological origin or in by product materials such as fly ash and GGBS to produce binders. Because the chemical reaction that takes place in this case is a polymerization process, he coined the term geopolymer to represent these binders.Several efforts are in progress to address these issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin, and the development of alternative binders to Portland cement.

There are two main constituents of geopolymers, namely the source materials and the alkaline liquids. The source materials for geopolymers based on alumina-silicate should be rich in silicon (Si) and aluminium (Al). These could be natural minerals such as kaolinite, clays, etc. Alternatively, by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc could be used as source materials. The choice of the source materials for making geopolymers depends on factors such as availability, cost, type of application, and specific demand of the end users.The alkaline liquids are from soluble alkali metals that are usually Sodium or Potassium based. The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NaOH) or potassium hydroxide (KOH) and sodium silicate or potassium silicate. According to Davidovits, geopolymeric materials have a wide range of applications in the field of industries such as in the automobile and aerospace, non-ferrous foundries and metallurgy, civil engineering and plastic industries.

II. LITERATURE REVIEW

Geopolymer concrete with fly ash by N A Lloyd and B V Rangan at Marche Polytechnic University, Ancona, Italy in June 2020. The paper presented brief details of fly ash-based geopolymer concrete. A simple method to design geopolymer concrete mixtures has been described and illustrated by an example. Geopolymer concrete has excellent properties and is well-suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after a disaster. To ensure further uptake of geopolymer technology within the concrete industry, research is needed in the critical area of durability.

GPC an eco-friendly construction material by L. Krishnan, S. Karthikeyan, S Nathiya, K. Suganyaat IJRET: International Journal of Research in Engineering and Technology, in June 2019. The Alkaline liquids used in this study for the polymerization process are the solutions of sodium hydroxide (NaoH) and sodium silicate (Na2SiO3). A 12 Molarity solution was taken to prepare the mix. The cube compressive strength was calculated for 12M solution for different mix Id i.e. F90G10, F80G20, F70G30, and F60G40 (Where F and G are, respectively, Fly Ash and GGBS and the numerical value indicates the percentage of replacement of cement by fly ash and GGBS).The cube specimens are taken of size 100 mm x 100 mm x 100 mm. Ambient curing of concrete at room temperature was adopted. In total 36 cubes were cast for different mix Id and the cube specimens are tested for their compressive strength at age of 1 day, 7 days and 28 days respectively. The result shows that geopolymer concrete cubes gains strength within 24 hours without water curing at ambient temperature. Also the strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix. It was observed that the mix Id F60G40 gave maximum compressive strength of 80.50 N/mm2. The geopolymer concrete gained strength within 24 hours at ambient temperature without water curing. The necessity of heat curing of concrete was eliminated by incorporating GGBS and fly ash in a concrete mix. The strength of geopolymer concrete was increased with increase in percentage of GGBS in a mix.

A Review on Strength and Durability Studies on Geopolymer Concrete by Shriram Marathe, Mithanthaya I R, N Bhavani Shankar Rao at Department of Civil Engineering, NMAMIT, Nitte, India 2018. This paper briefly reviews the constituents of geopolymer concrete, its strength and potential applications. The production of OPC requires large amount of energy consumption, also leading to an enormous emission of carbon di-oxide to the atmosphere, which is being a great challenge to the sustainable development. Efforts are needed to develop a environmental friendly civil engineering construction material for minimizing emission of green-house gases to the atmosphere. A review summary of the extensive literature survey conducted to know about one such environmental friendly concrete namely geopolymer concrete is presented in this paper. And conclusions were as followed. The load capacity and behaviour of geopolymer columns are similar to the conventional concrete. The bond strength of GBS is observed to be significantly higher than that of conventional OPC concrete.

Study of the Strength Geopolymer Concrete with Alkaline Solution of Varying Molarities by A. Maria Rajesh, M. Adams Joe, Roy Mammen at ACEW, Nagercoil, Tamilnadu, India 2017. Finding a suitable alternative solution to mitigate the environmental degradation caused by using Portland cement is very important for environmental sustainability. The use of geopolymer concrete as an alternative material over Portland cement concrete to reduce the adverse effects on the environment is investigated in this paper. The paper also critically analyses the economic and environmental benefits of geopolymer concrete and address the financial and environmental issues associated with the production and use of Portland cement. Geopolymer cement utilizes industrial waste materials such as fly ash from thermal power stations to provide a practical solution to waste management as well as environmental protection methods.

GPC for green environment by B. Vijaya Rangan at The Indian Concrete Journal in April 2014. The paper describes the results of the tests conducted on large-scale reinforced geopolymer concrete members and illustrates the application of the Geopolymer concrete in the construction industry. Some recent applications in the precast construction and the economic merits are also included. Extensive studies conducted on fly ash-based geopolymer concrete are presented. Salient factors that influence the properties of the geopolymer concrete in the fresh and hardened states are identified. Test data of various short-term and long-term properties of the geopolymer concrete are then presented. Geopolymer concrete offers environmental protection by means of up cycling low-calcium fly ash and blast furnace slag, waste/by-products from the industries, into a high value construction material needed for infrastructure developments. The paper presented information on 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. 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. Simple guidelines for the design of mixture proportions are included.

III OBJECTIVES OF INVESTIGATION

- To study the different properties of fly ash and different types of alkaline solutions like NaOH and Na2SiO3, GGBS, etc.
- To cast the concrete blocks, beams and cylinders using geopolymers in different proportions and with appropriate molar solutions.
- To perform test on the concrete blocks and cylinders in order to check it's strength.
- To compare the testing results with the OPC i.e. conventional concrete.

IV. MATERIALS

1. Fly ash: The first reference to the idea of utilizing coal fly ash in concrete was by McMillan and Powers in 1934 and in subsequent research (Davis et al., 1935, 1937). In the late 1940s, UK research was carried out (Fulton and Marshall, 1956) which led to the construction of the Lednock, Clatworthy and Lubreoch Dams during the 1950s with fly ash as a partial cementitious material.Fly ash, the most widely used mineral admixture in concrete, is a by-product of combustion of pulverized fuel coal in electric furnace power generating plants at 1250°C to 1600° C. Upon ignition in the furnace, most of the volatile matter and carbon in the coal are burned off. During combustion, the mineral impurities of coal (such as clay, feldspar, quartz and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called 'FLYASH'. The particle sizes in fly ash vary from less than 1µm to more than 100µm with the typical size measuring less than 20µm. Only 10 to 30% of the particles by mass are larger than 45µm. The relative density of fly ash normally ranges between 1.9 and 2.2 and the colour is generally grey.Fly ash-Fly Ash is available in dry powder form and is procured from Dirk India Pvt. Ltd., Nashik. It is available in 30Kg bags, color of which is light gray under the product name "**Pozzocrete 63**" Confirming to IS: 3812 Part 1-2003 as mineral admixture in dry powder form.

2. Alkali Solution: The alkali solution is used for alkalination of GGBS thus leading to polymerization which results in geopolymer binder. Sodium hydroxide and sodium silicate is used as mediums to form alkali solutions. Sodium hydroxide and sodium silicate was purchased from Abhay chemicals, Ahmadnagar. Different concentrations of sodium hydroxide solution were prepared in the Lab. Sodium silicate of 40% concentration and required grade was added to sodium hydroxide solution and the alkali solution was prepared.

This solution was prepared 1 day prior to be used and consumed within 36 hours. The solution was prepared and kept covered at room temperature for gel formation.

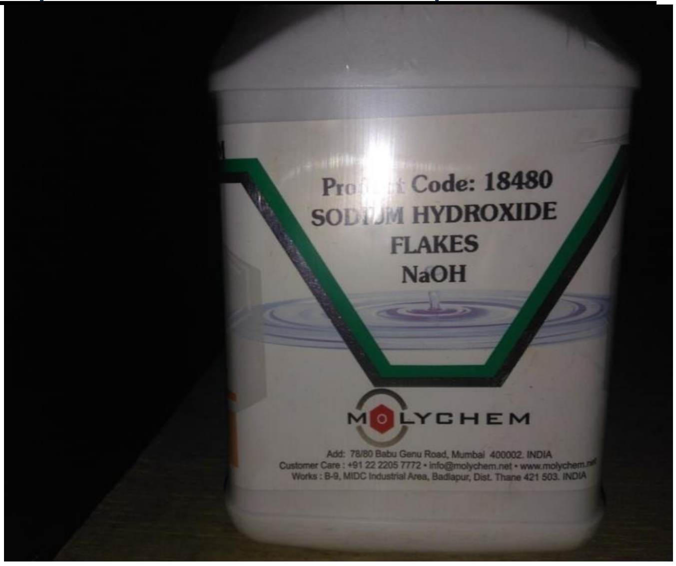


Fig 1: Sodium hydroxide pellets.

3. Coarse aggregate: Aggregates provide about 75% of the total volume. They should meet certain requirements with respect to grading, shape, size and strength. Though they are considered inert, they exhibit certain reactivity which is popularly known as AAR (alkali aggregate reactivity or reaction). Since our geo-polymer concrete is highlyalkalineduetosodiumhydroxidehenceAARmarkssignificanceimportance.Here fine and coarse aggregates were procured from local contractor working on our college site. Various lab tests are conducted on these aggregates to ensure that they are well graded along with other properties essential for in corporating into mix design of concreteMost concretes contain aggregates of maximum size 40mm or 20mm and grading going down to 150 microns or even smaller. At times, maximum aggregate size of 10mm is also used. For massive work or large unreinforced pours, MSA of 150mm or above is used. In and around Pune crushed downgraded aggregates are generally screened through rotating screens having a rounded mesh of 1 to 0.5 inch in diameter. Hence crushed aggregates are available with maximum size of 30mm and 15mm respectively. Economical concrete is produced by using as large as MAS as possible as this reduces the amount of cement required in concrete due to reduction of surface area per unit weight of the aggregates. It is therefore recommended to use as large as MAS as possible (depending upon the condition of concreting).

4. Fine aggregates: Fine aggregates are finer in size less than 4.75mm. Its size ranges from 4.75mm to 150 microns. A fraction finer than 150 microns is considered as dust or silt. Due to development in construction and infrastructure, fine aggregates are available in various categories like manufactured sand - famously known as M-Sand, river or natural sand, Gujarat sand, etc. Gujarat sand was procured from a local contractor from our college site. Fineness of aggregate plays a key role. It is very important to know the fineness of aggregate as they significantly influence the water demand of the concrete mix or in other words strength. Fine aggregates are classified in four zones. While zone 1 represents coarsest sand, zone 4 represents finest sand. Zone 2 and zone 3 represents medium fineness. When fine aggregate particles, generally 600 microns passing are in high percentage, the surface area of aggregate increases per unit weight. Larger surface area will require more cement paste to bind the aggregate particles together. Due to increase in surface area of aggregates, mix will require more water.For selection of proportion of fine aggregates, the method given by DoE is adopted. From the percentage passing through 600-micron sieve, Zone of sand is determined. Fine aggregate requirement should be such that coarse and fine aggregates combined should produce minimum voids. This should necessitate minimum cement paste requirement. The properties of coarse and fine aggregates will vary from place to place depending upon particle size distribution of locally available materials. The efforts should be directed to arrive at the optimum ratio to coarse aggregate to arrive at the best particle packing of aggregate.Gradation of fine aggregate is also required and an important parameter in designing pump able concrete.

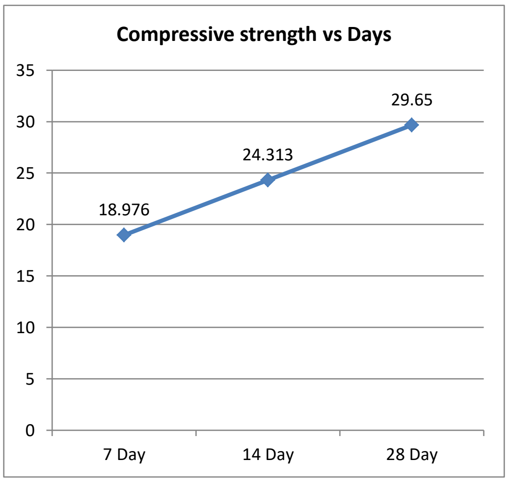
V. TESTING PROGRAM

1. Compressive strength: Compressive strength of geopolymer concrete specimens was determined at 7, 14, 28 days, following all the IS specification. Result of conventional concrete and geopolymer was compared and concluded. Cement is replaced 100% by fly ash and GGBS at a proportion of 60:40 respectively, and water is 100 % replaced by alkaline solution. Result of same are illustrated below in graphical representation.

Fig 2: Compression testing

Table 1 :Compressive strength of OPC

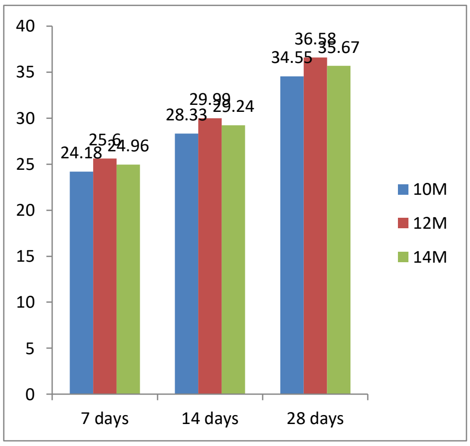
Sr. No	Notation	No of days	Compressive Strength (N/mm^2)
1	OPC	7 days	18.976
2		14 days	24.313
3		28 days	29.65



Graph 1: Compressive strength of conventional concrete

Table 2 : Compressive strength of Geopolymer Concrete

Sr. No	Notation	No of days	Compressive Strength (N/mm^2)		
			10M	12M	14M
1	GPC	7 days	24.18	25.60	24.96
2		14 days	28.33	29.99	29.24
3		28 days	34.55	36.58	35.67



Graph 2:Compressive strength of Geoplymer concrete with varying molarities

2. Split tensile strength: Cylinder specimens with dimensions of 150 mm diameter and 300 mm length were produced for the Split tensile strength test. After 24 hours of casting, the specimens were demolded and moved to a curing tank, where they were allowed to cure for 28 days. These specimens were put through their paces on a compression tester. Three cylinders were tested in each category, and the average value is provided

Split Tensile strength was calculated as follows as split tensile strength:

Split Tensile strength (MPa) = 2P / π DL,

Where, P = failure load

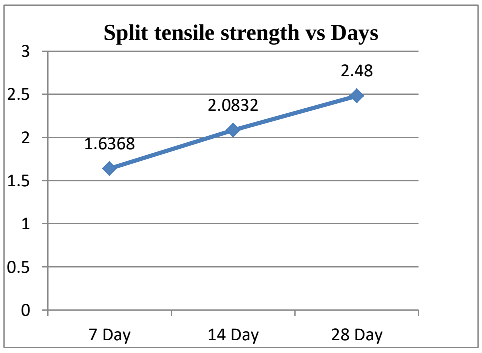
D = diameter of cylinder

L = length of cylinder

Fig 3: Split Tensile testing

Table 3: Split tensile strength of OPC

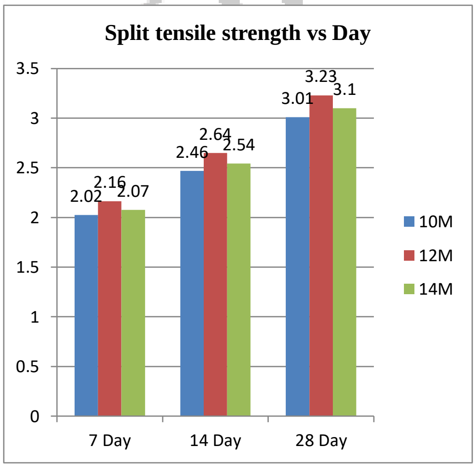
Sr. No	Notation	No of days	Split Tensile Strength (N/mm^2)
1	OPC	7 days	1.6368
2		14 days	2.0832
3		28 days	2.48



Graph 3: Split tensile strength of conventional concrete

Table 4: Split tensile strength of Geopolymer concrete

Sr. No	Notation	No of days	Split Tensile Strength (N/mm^2)		
			10M	12M	14M
1	GPC	7 days	2.02	2.16	2.07
2		14 days	2.46	2.64	2.54
3		28 days	3.01	3.23	3.10



Graph 4: Split tensile strength of Geopolymer concrete with varying molarities

VI. CONCLUSIONS

- 12M Geopolymer concrete has maximum compressive strength amongst 10M, 10M and 14M Geopolymer concrete, which is 18.94% greater than conventional concrete. i.e. at 28th day it gives 37.4KN/m2

- 12M Geopolymer concrete has maximum split tensile strength amongst 10M, 12M and 14M Geopolymer concrete. It is 23.21% greater than conventional concrete.

- Initial setting time of Geopolymer concrete is decreased with increased in molarity of sodium hydroxide which can be improve by addition of super plasticizers.

- Workability of Geopolymer concrete is decreased with increased in molarity of sodium hydroxide.

- As our aim was, cement can be completely replaced with flyash in order reduce the use of cement.

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