DEVELOPMENT OF AMBIENT CURED GEOPOLYMER CONCRETE

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ABSTRACT

Greenhouse gas emission reduction of geopolymer concrete is an excellent engineering material. The manufacturing of Portland cement releases approximately an equal amount of carbon dioxide (CO_2) into the atmosphere. In this regard, it is mandatory to find out a solution to avoid the usage of cement in the construction industry. The geopolymer technology is the alternative method to create a binder instead of cement**.** This study aimed to achieve geopolymers suitable for curing without elevated heat. This work presents a concrete that would replace cement in concrete by 100% with fly **ash** and G**round** G**ranulated Blast furnace** S**lag (GGBS)**. Ground Granulated blast furnace slag was added 50%, the mix to enhance the early age properties of concrete. Ambient curing of concrete at r**oom temperature was adopted.** The results indicate that the reaction product and strength of geopolymer depends on the types on source materials and alkali activator. Thus, the geopolymer concrete is considered to be an environmentally pollution free construction material.

*Key Words:*Geopolymer concrete, Ambient curing, Alkaline solution, Construction material,GGBS, Low calcium fly ash.

INTRODUCTION

Concrete is widely used as one of important construction material around the world due to its good engineering properties. The various ingredients of concrete are cement, fine aggregate, coarse aggregate and water. Although the strength and durability of concrete are mainly based on cement, it is the one of the main causes of global warming due to emission of CO_2. Approximately 5% of global $CO_2$are produced by the industry of ordinary Portland cement (OPC). In this aspect, the great scientist, Joseph Davidovits invented a new binding component instead of cement called geopolymer. Geopolymers are chain of minerals containing silica and alumina in association with an alkaline solution. The by-products obtained from thermal power station and steel industries are fly ash and Ground Granulated Blast Furnace Slag (GGBFS) respectively, that contain rich amount of silica and alumina. An alkaline solution is a mixture of sodium silicate and sodium hydroxide. A hardened binder is obtained by mixing minerals such as fly ash, GGBFS and alkaline solution. Due to this chemical reaction, a polymerization process takes place which produces a chain of molecules. The entire polymerization process is taking place in the presence of heat.It is known that the hydration process takes place when cement is mixed with water, which results in binding of aggregates together to form concrete. Polymerization of geopolymer concrete **is** taken place in presence of a curing of room temperature **for** 24 hours. During the polymerization process of geopolymer concrete, water is expelled from concrete. Heat curing of geopolymer concrete can be done in two ways. One is by maintaining 60°C temperature in heat/steam curing chamber and other one is curing under sunlight.

SCOPE AND OBJECTIVE

- To study the properties and characteristics of geopolymer concrete.
- To study the process of production of geopolymer concrete.
- The study on geopolymer concrete is an important factor around the world today.
- The approach on this area will lead to production of innovative concrete by using innovative materials in the future.
- It will lead to find out a proper solution for the high emission of carbon dioxide.
- It will lead to easy disposal of hazardous waste materials from the power plants and other industries.

INTERNATIONAL SCENARIO OF GEOPOLYMER CONCRETE

Kunal Kupwade – Patil and Erez Allouche, conducted test on *the effect of alkali silica reaction in geopolymer concrete.* In their study, alkali silica reaction occurs due to chemical reactions between hydroxyl ions in the pore water within the concrete matrix and certain forms of silica. This reaction could lead to strength loss, cracking, volume expansion and potentially failure of the structure.

Lloyd and Rangan, conducted a *Study on geopolymer concrete with fly ash.* For their study, they used low calcium (ASTM Class F) fly ash as their base material. They concluded that geopolymer possess excellent properties and is well suited to manufacture precast concrete products that are needed in rehabilitation and retrofitting of structures after disaster.

Hardjito and Rangan, studied *Fly ash based geopolymer concrete.* They observed the compressive strength data and concluded that fly ash based geopolymer concrete has good compressive strength and is suitable for structural application. Higher concentration (in terms of molar) of sodium hydroxide solution results in a higher compressive strength of geopolymer concrete.

Rangan et al, carried out experiments on *Reinforced low – calcium fly ash based geopolymer concrete beams and columns.* Heat-cured low-calcium fly ash-based geopolymer concrete has advantages such as excellent structural properties, low creep, very little drying shrinkage, excellent resistance to sulphate attack, and acid resistant.

Antony Jeyasekar and Thirugnanasambandam, carried out *experiments on development of fly ash based geopolymer concrete precast elements.* Geopolymer binders have emerged as one of the possible alternative to OPC binders due to their reported high early strength and resistance against acid and sulphate attack apart from its environmental friendliness. The steam cured geopolymer concrete beams with 8 Molarity NaOH solutions attain higher strength.

Thirugnanasambandam and Antony Jeyasekar, carried out E*xperiments on ambient cured geopolymer concrete products.* It is proved that the geopolymer technology is the alternative method to create a binder instead of cement. In this study, geopolymer concrete is made with fly ash, ground granulated blast furnace slag with alkaline solution as binder. The river sand and granite coarse aggregate are used. The geopolymer concrete specimens are cured in ambient temperature. The test results are compared with conventional cement concrete specimens and it is found that the geopolymer specimens are performing better than concrete specimens.

EXPERIMENTAL WORK

(1) MATERIALS

*Fly ash -L*ow-calcium (ASTM Class F) fly ash is used and it is obtained from the Mettur Thermal Power Station, Mettur, Tamilnadu, India. Fly ash class F has therefore been selected as a good raw material for GPC due to lower reactivity rate, which leads to slower setting time, convenient accessibility, and a reduced water demand. In order improves the mechanical properties of class F fly ash GPC. The Specific gravity of fly ash is 2.15.

GGBFS –Ground granulated blast furnace slag (GGBFS) is one of the most common component in geopolymer concrete, due to improved mechanical and microstructural properties. However, adding GGBFS cause poor workability due to higher viscosity. Specific gravity of Ground granulated blast furnace slag is 2.62.

Fine aggregate -Locally available river sand conforming to the code IS: 383-1970 is used for this study. The specific gravity is 2.67.

Coarse aggregate -The Nominal Size of Aggregate is 12.5mm and 20mm is governed by IS:383-1970.specific gravity of coarse aggregate is 2.70.

Sodium hydroxides – it is available in the form of pellets and flakes.it is recommended to use 94% to 96% purity of NaOH.

Sodium silicate –It is also known as water glass or liquid glass and is available in liquid (gel) form. Sodium silicate solution comprised Na_2O=17.7%, SiO_2=29.4%, Water=55.9% by mass.

Alkaline solution -The alkaline solution is prepared by mixing sodium silicate and sodium hydroxide pellets with water. The alkaline solution dissolves Al^{3+} and Si^{4+}ions from the aluminosilicate sources, which subsequently improves compressive strength by forming sodium alumino silicate hydrate (NASH), calcium alumino silicate hydrate (CASH), and/or calcium silicate hydrate (CSH) gels. High viscosity of sodium silicate in the alkaline solution reduces the slump of geopolymer concrete. it is recommended to leave it for about 24 hours thus the alkaline liquid is get ready as binding agent.

Extra water –Fresh GPC possesses poor workability in comparison with fresh Portland cement concrete due to the higher viscosity of the alkaline solution. A better workability can be obtained by adding extra water to the mixture. However, this will reduce the compressive strength of GPC.

(2) MIX PROPORTION

Geopolymer M20 grade concrete was mixed with the ratio of 1: 2.30: 3.58 with alkaline liquid and fly ash ratio of 0.5. The ratio of Na_2SiO_3/NaOH is 2.5 and different molarity was used. This component of geopolymer concrete mixtures is designed using the tools currently available for Portland cement concrete. M20 grade concrete is made (Table 1).

Table.1 Mix Proportion

Description	Quantity (kg/m^3)				
	6 M	6.5 M	7 M	7.5 M	8 M
Fly ash + GGBFS	348.84	348.84	348.84	348.84	348.84
Fine aggregate	802.33	802.33	802.33	802.33	802.33
Coarse aggregate	1248.85	1248.85	1248.85	1248.85	1248.85
NaOH	10.76	11.66	12.56	13.45	14.35
Na_2SiO_3	112.14	112.14	112.14	112.14	112.14
Water	34.08	33.18	32.48	31.38	30.50

(3) CASTING AND TESTING OF SPECIMENS

The fly ash, GGBFS and fine aggregate are mixed dry until the mixture is thoroughly blended and is uniform in colour. The coarse aggregates were prepared in saturated surface dry condition. The coarse aggregate is added and mixed with the fly ash, GGBFS and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch. The alkaline solution is added and the entire batch was mixed until the concrete appeared to be homogenous and had the desired consistency. Cube mould of size 100mm × 100mm × 100 mm is used. Concrete was placed uniformly over the length of the standard steel mould in three layers and compacted satisfactorily (Figure 1). Demoulding was done after 24 hours and the specimens are cured under sun light (Figure 2). After 3 days, the compressive strength was found (Figure 3) and given in Table 2. The compressive strength of geopolymer concrete with different concentration NaOH is shown in Figure 4.

Fig. 1 Casting of Specimen

Fig. 2 Curing under Sunlight

Fig.3 Testing of Specimen

RESULTS

Table. 2 Compressive Strength of Specimens

Molarity	6 M	6.5 M	7 M	7.5 M	8 M
Compressive Strength (N/mm^2)	22.31	25.71	31.05	38.12	42.30

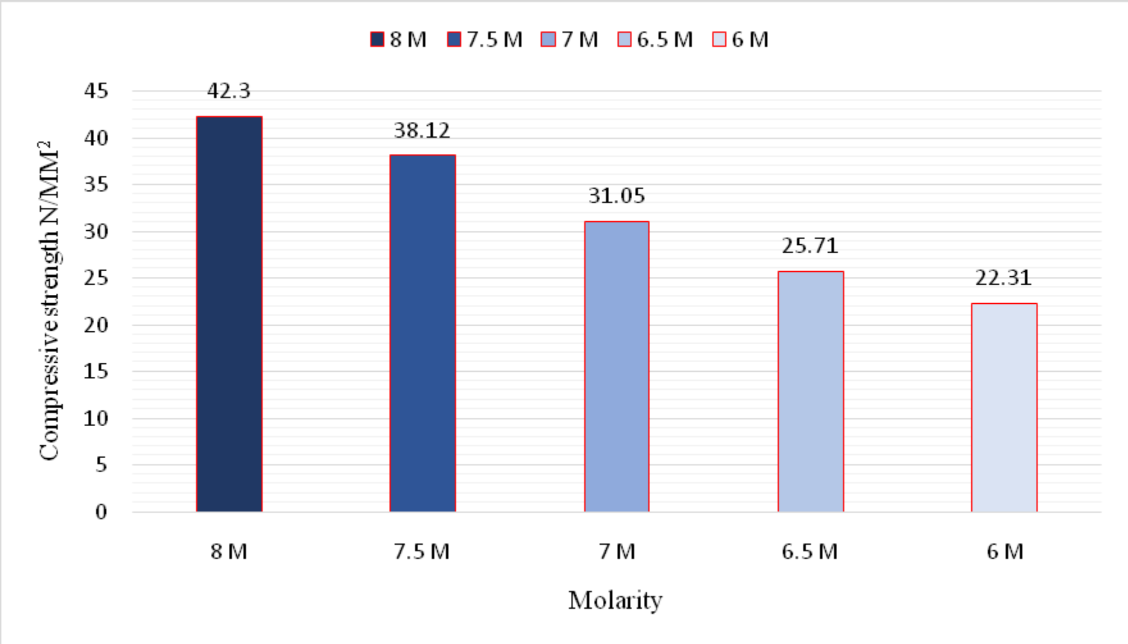

Figure 4. Comparison of Compressive Strength of Geopolymer Concrete

CONCLUSION

The concentration of sodium hydroxide is directly proportional to the compressive strength of geopolymer concrete specimens. In other words, the strength of concrete depends upon the concentration of sodium hydroxide in terms of molarity. The reason for the improvement in compressive strength of geopolymer concrete is the chemical reaction due to the speedy polymerization process and aging of the alkaline liquid.To using GGBS the entire polymerization process is taking place in presence of heat. GGBFS has higher early strength and ambient curing is achieved.

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