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EXPERIMENTAL INVESTIGATION ON PAVER BLOCK USING GEOPOLYMER CONCRETE

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Abstract:

Paver block have been in use since many years. Due to rapid infrastructure development the necessity of cement is increasing day by day and it emits large amount of co_2 which leads to global warming. The other major engineering problem today with more stringent environmental law is disposing the solid waste. Today research has combined with waste management leading to an eco-friendly product called geopolymer mortar and concrete. Recently the research is to develop alkali activated fly ash which is complete replacement to conventional cement. An experimental study is made on geopolymer mortar and concrete. The industrial by products like fly ash and GGSS are activated using alkaline solution to get cementitious binder. Similarly, geopolymer concrete is prepared without using conventional cement and it can be self-cured. The primary objective of this research is to understand the properties, economical, technological and environmental benefits of geopolymer concrete. In this research both geopolymer concrete and mortar are prepared which is cured in ambient temperature and compressive strength is analysed.

Key Words: Alkaline Solution, Compressive Strength, Fly Ash Geopolymer Concrete & GGBS.

1. Introduction:

The cement industry is the India's second highest payer of Central Excise. With infrastructure development growing and the housing sector booming, the demand for cement is also bound to be improved. However, the cement industry is extremely energy dependent. After aluminium and steel, the manufacturing of Portland cement is the most energy intensive process as it consumes 4GJ per tons of energy. After thermal power plants and the iron and steel sector, the Indian cement industry is the third largest user of coal in the country. In 2003-04, 11,400 million kWh of power was consumed by our cement industry. The cement industry includes 130 large cement plants and more than 300 mini cement plants. At the beginning of the year 2008-2009, the industry's capacity was about 198 million tonnes. The annual increase in cement demand in India is expected as 10% in the medium term buoyed by housing, infrastructure and corporate capital expenditures. For generating the electricity coal-based thermal power installations in India contribute about 65% of the total installed capacity. In order to meet the growing energy demand of the country, coal-based thermal power generation is expected to play a major role in the future as well, since coal reserves in our country are expected to last for more than 100 years. The ash content of coal used by thermal power plants in India varies from 25 to 45%. However, coal with an ash content of around 40% is predominantly used in our country for thermal power generation. As a consequence, a huge amount of fly ash (FA) generated in thermal power plants, causes several disposal-related problems. In spite of initiatives taken by the government, several non-governmental organizations and research and development organizations are involved in taking precautions related to disposal. India produces 130 million tons of FA but the total utilization of FA is only about 50%. Disposal of FA is a growing problem as only 15% of FA is currently in concrete and building blocks, the remaining being used for land filling. Globally, less than 25% of the total annual FA is utilized. In the USA and China, maximum quantities of FA are produced (comparable to that in India) and its reported utilization levels were about 32% and 40% respectively, during 1995.FA in making cement concretes as it extends technical advantage as well as controls the environmental pollution. Ground granulated blast furnace slag (GGBS) is a by-product from the blast furnaces used for making iron. GGBS is a glassy, granular, non-metallic material consisting essentially of silicates and aluminates of calcium and other bases. Slag when ground to less than 45 microns from coarser, popcorn like friable structure, will have a specific surface of about 400 to 600 m^2/kg. When GGBS is blended with Portland cement it acts as low cost filter, enhances workability, resistance, durability and resistance to alkali-silica reaction. Alternative but promising gainful utility of fly ash and GGBS in construction industry has emerged in recent years in the form of geopolymer cement concretes, which by appropriate process technology utilize all classes and grades of fly ash and GGBS.

2. Geopolymer:

A. Terminology: The term 'geopolymer' was first coined by Davidovits in 1978 to describe a family of mineral binders and its chemical composition similar to zeolites but with an amorphous microstructure. He also suggested the use of 'poly(sialate)' for the chemical designation of geopolymers based on silico-aluminate (Davidovits,1988a, 1988b, 1991; van Jaarsveld et. al., 2002a); Sialate in the abbreviation of silica oxo-aluminate. Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium silicate-hydrates (CSHs) for matrix formation and strength, but utilize the polycondensation of silica and alumina precursors and high alkali content to attain structural strength. Therefore, geopolymers are sometimes referred to as alkali activated alumino silicate binders (Davidovits, 94a; Palomo et. al., 99; Roy, 99; van Jaarsveld et. al., 2002a). However, Davidovits (1999; 2005) stated that using the term 'alkali activated' created significant confusion and generate false thoughts about geopolymer concrete. For example, the use of the term alkali-activated cement' or 'alkali-activated fly ash' can be confused with the term 'Alkali-Aggregate reaction (AAR)' is a harmful property well known in concrete.

B. Source Materials and Alkaline Liquid: There are two main constituents of geopolymers such as the source materials and the alkaline liquids. The source materials for geopolymers based on alumino-silicate must be rich in silicon (Si) and aluminium (Al).

These include natural minerals such as kaolinite, clays, micas, Alou site, spinel, etc whose empirical formula contains Si, Al, and O (Davidovits, 1988c). Alternatively, waste materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc can also be used as source materials. The choice of the source materials for manufacturing geopolymers depends on several factors such as availability, cost and 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. Among the waste or by-product materials, fly ash and slag are the most potential source of geopolymers. Several studies have been reported based on the use of these source materials. Cheng and Chiu (2003) reported the study of manufacturing fire-resistant geopolymer using granulated blast furnace slag combined with meta kaolinite. Alkaline liquid is prepared by using the combination of sodium hydroxide and sodium silicate. Van Jaarsveld et. al., (1997; 1999) identified the potential use of by-products such as fly ash, contaminated soil, mine tailings and building waste to immobilize toxic metals. Palomoet. al., (1999) reported the study of fly ash based geopolymers used the combinations of sodium hydroxide with sodium silicate or potassium hydroxide with potassium silicate as an alkaline liquids wasa significant factor affecting the mechanical strength and the combination of sodium silicate and sodium hydroxide gave the highest compressive strength.

C. Field of Application: According to Davidovits (1988b), geopolymeric materials have a wide scope of applications in the field of industries such as automobile and aerospace, nonferrous foundries, metallurgy civil engineering and in plastic industries. The type of application of geopolymeric materials is identified by the chemical structure in terms of the atomic ratio Si: Al in the polysialate. Davidovits (1999) classified the type of application according to the Si: Al ratio. A low ratio of Si: Al of 1, 2, or 3 initiates a 3D-Network that is very rigid, while Si: Al ratio higher than 15 provides a polymeric character to thegeopolymeric material.

D. Properties of Geopolymer: Previous studies have reported that geopolymer concrete possess high early strength, low shrinkage, freeze-thaw resistance, sulfate resistance, corrosion resistance, acid resistance and no dangerous alkali-aggregate reaction. Geopolymeric cement was superior to Portland cement in terms of heat and fire resistance as the Portland cement experiences a rapid deterioration in compressive strength at 300ºC, whereas they were stable up to 600ºC (Davidovits, 1988b; 1994b). It has also been shown that compared toPortland cement, geopolymeric cement has extremely minimum shrinkage. The presence of alkalis in the normal PPC or concrete could generate dangerous alkali aggregate reaction.

3. Preparation of Alkaline Solution:

- ✓ The sodium hydroxide (NaOH) pellets were dissolved in water to make the solution.
- ✓ The mass of NaOH solids in a solution varied depends on the concentration of solution.
- ✓ For instance, NaOH solution with a concentration of 8M consisted of 8x40=320 grams of NaOH solids per litre of solution, where 40 is the molecular weight of NaOH.
- ✓ Similarly, the mass of NaOH solids per kg of the solution for 12M concentration was measured as 480 grams per litre of solution.
- ✓ Note that the mass of NaOH solids was only a fraction of the mass of the NaOH solution and water was the main component.
- ✓ The sodium silicate solution and the sodium hydroxide solution were mixed together at least one day prior to use to prepare the alkaline liquid.
- ✓ On the day of casting of the specimens, the alkaline liquid was mixed together with the super plasticizer and the extra water to prepare component of the mixture.

4. Mix Design of Geopolymer Concrete:

The quantity of all the materials is same as that of conventional concrete except chemicals. The mix design of chemical is as follows:

- ✓ Assume that normal-density aggregates are to be used and the unit-weight of concrete is 2400 kg/m^3.
- ✓ Mass of combined aggregates as 77% of the mass of concrete, i.e. 0.77x2400=1848 kg/m^3.
- ✓ Mass of fly ash + the alkaline liquid = 2400 – 1848 = 552 kg/m^3.
- ✓ Alkaline liquid-to-fly ash ratio by mass as 0.4; the mass of fly ash = 552/ (1+0.4) = 394.28 kg/m^3.
- ✓ Mass of alkaline liquid = 552 – 394.28 = 157.71 kg/m^3.
- ✓ Take the ratio of sodium silicate to sodium hydroxide solution by mass as 2.5.
- ✓ Mass of sodium hydroxide solution = 157.71/ (1+2.5) = 45.1 kg/m^3.
- ✓ Mass of sodium silicate solution = 157.71 – 45.1 =112.6 kg/m^3.
- ✓ Sodium silicate solution = 112.6 kg /m^3.
- ✓ Sodium hydroxide solution = 45.1 kg/m^3.

Mix Proportion:

Table 1: Mix Proportion of Geopolymer Concrete

Materials	Mix ID		
	$F_{90}\,G_{10}$	$F_{80}\,G_{20}$	$F_{70}\,G_{30}$
Fly Ash (kg/m^3)	354.87	315.44	276.01
GGBS (kg/m^3)	39.43	78.86	118.20
Sodium Hydroxide (kg/m^3)	45.10	45.10	45.10
Sodium Silicate (kg/m^3)	112.60	112.60	112.60
Fine Aggregate (kg/m^3)	554.40	554.40	554.40
Coarse Aggregate (kg/m^3)	1293.4	1293.4	1293.4

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Distilled Water (liters)	39.43	39.43	39.43
Super Plasticizer (liters)	11.83	11.83	11.83
Distilled Water: 10% Cementitious Material Super Plasticizer: 3% of Cementitious Material Mix ratio: 1:1.40:3.27			

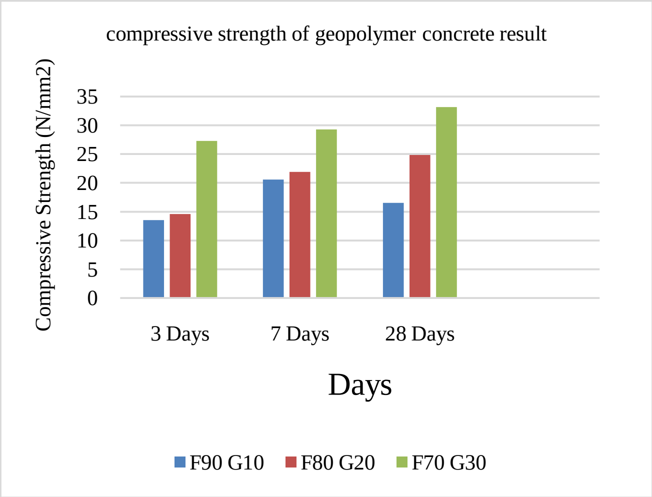
5. Curing of Specimens:

After casting, the test specimens where left in ambient conditions at room temperature for 24 hours and water curing is not required in case of geopolymer concrete.

6. Experimental Results:

A. Compressive Strength: For each batch of geopolymer concrete, standard size of cube where prepared. At least three of the cubes where tested for compressive strength. The average results are presented in Fig.1.

Figure 1: Compressive strength of geopolymer concrete



7. Conclusion:

- ✓ From the test data, it can be concluded that GPC are good materials of constructions from both strength and durability considerations.
- ✓ Geopolymer concrete shows significant potential to be a material for the future; because it is not only ecofriendly but also possesses excellent mechanical properties.
- ✓ Practical recommendations on use of geopolymer concrete technology in precast concrete products and waste encapsulation need to be developed in Indian context.
- ✓ Because of lower internal energy (almost less than 20% to 30 %) and lower CO_2 emission contents of ingredients of geopolymer based composites compared to those of conventional PPC concretes, the new composites can be considered to be eco-friendlier and hence their utility in practical applications needs to be developed and encouraged.

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