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Original Research Paper

Study on Fly Ash Geopolymer Concrete to Reduce Global Warming Gases

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ABSTRACT

The climate change due to global warming, one of the greatest environmental issues, has become a major concern during the last decade. The global warming is caused by the emission of greenhouse gases such as CO_2 to the atmosphere by human activities. In recent years, attempts to increase the utilisation of fly ash to partially replace the use of Portland cement in concrete are gathering momentum. Geopolymer concrete is a new material that does not need the presence of Portland cement as a binder. Instead, activating the source materials such as fly ash that are rich in silicon (Si) and aluminium (Al) using high alkaline liquids produces the binder required to manufacture the concrete. Hence, concrete with no cement can be achieved. In this study M20 grade geopolymer concrete was designed and two trial mixes have been compared with the control specimen. This paper presents information on fly ash-based geopolymer concrete, material and the mixture proportions, the manufacturing process, and the influence of various parameters on the properties of fresh and hardened concrete.

INTRODUCTION

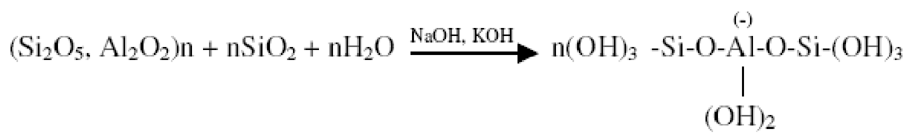
In this work, low-calcium (Class F) fly ash-based geopolymer is used as the binder, instead of Portland or other hydraulic cement paste, to produce concrete. The fly ash-based geopolymer paste binds the loose coarse aggregates, fine aggregates and other un-reacted materials together to form the geopolymer concrete. The manufacture of geopolymer concrete is carried out using the usual concrete technology methods. Geopolymer concrete can be manufactured by using the low-calcium fly ash obtained from coal-burning power stations (Davidovits 1994). Most of the fly ash available globally is low-calcium fly ash formed as a by-product of burning anthracite or bituminous coal. Although coal burning power plants are considered to be environmentally unfriendly, the extent of power generated by these plants is on the increase due to the huge reserves of good quality coal available worldwide and the low cost of power produced from these sources. Low-calcium fly ash has been successfully used to manufacture geopolymer concrete when aluminium oxides constituted about 80% by mass, with the Si-to-Al ratio of about 2. Coarse and fine aggregates used by the concrete industry are suitable to manufacture geopolymer concrete. The aggregate grading curves currently used in concrete practice are applicable in the case of geopolymer concrete.

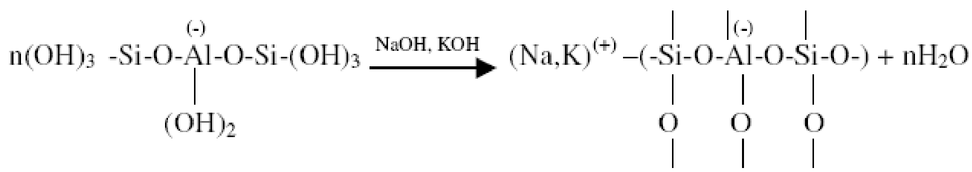
MATERIALS AND METHODS

Ordinary Portland cement OPC 53 grade confirming to IS 12269-1987 was used in the investigation. Locally available river sand conforming to zone II of IS 383-1970 was used as fine aggregate.

Twenty mm downgraded crushed granite stone, obtained from local quarry, was used as the coarse aggregate. Potable water was used for casting specimens. In this investigation a sulphonated naphthalene polymer SUPAFLO superplasticizer was added as admixture. Fly ash procured from Mettur Thermal Power plant was used as 100% replacement of cement. The technology and the equipment currently used to manufacture ordinary Portland cement concrete were used to make the geopolymer concrete. Chemical properties of fly ash are given in Table 1.

Geopolymers: Davidovits (1988) proposed that an alkaline liquid could be used to react with the silicon (Si) and the aluminium (Al) in a source material of geological origin. Because the chemical reaction that takes place in this case is a polymerization process.





The last term in equation 2 reveals that water is released during the chemical reaction that occurs in the formation of geopolymers. This water is expelled from the geopolymer matrix during curing and further drying periods. The water in a geopolymer mixture, therefore, plays no role in the chemical reaction that takes place; it merely provides the workability to the mixture during handling. For the current study the combination of sodium hydroxide (NaOH) and sodium silicate is used.

Alkaline liquids: The alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The sodium hydroxide solids must be dissolved in water to make a solution with the required concentration. The concentration of sodium hydroxide solution used is 8 molar. The mass of NaOH solids was measured as 262 g per kg of NaOH solution with a concentration of 8 molar.

Mixing, Casting and Compaction of Geopolymer Concrete: In the laboratory, the fly ash and the aggregates were first mixed together dry for about three minutes. The alkaline liquid was mixed with the super plasticizer. The liquid component of the mixture was then added to the dry materials and the mixing continued usually for another four minutes. The workability of the fresh concrete was measured by means of the conventional slump test.

It was found that the fresh fly ash-based geopolymer concrete was dark in colour (due to the dark colour of the fly ash), and was cohesive. Sodium hydroxide solution and sodium silicate solution were mixed together at least one day prior to adding the liquid to the dry materials (Fig.1). The mix ratio of M20 grade was cement : F.A:C.A:W/C (1:1.475:3.35:0.5).

Fresh geopolymer concrete: The fresh concrete (Fig. 2) was cast into the moulds immediately after

Fig. 1: Mixing.

Fig. 2: Fresh geopolymer concrete.

Fig. 3: Workability test-slump cone.

Table 1: Properties of fly ash.

Chemical properties % by mass	IS:3812-1981	Fly ash MTPP
$SiO_2+Al_2O_3+Fe_2O_3$	70	90.5
SiO_2	35	58
CaO	5	3.6
SO_3	2.75	1.8
Na_2O	1.5	2
L.O.I	12	2
MgO	5	1.91

Table 2 a: Compressive strength.

Specimen Description	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
CCM	12	19	24.85
CC1	7	15.25	21.25
CC2	8.2	17	24.4

Table 2b. Split tensile strength.

Specimen Description	7 Days (MPa)	14 Days (MPa)	28 Days (MPa)
CCM	1.96	2.95	3.24
CC1	1.85	2.88	3.18
CC2	2.12	2.98	3.18

CCM = Conventional concrete (M20 grade)
CC1 = Geopolymer concrete with 0.5 w/b ratio with superplasticizer
CC2 = Geopolymer concrete for M20 grade.

mixing. The size of the mould was 150 mm, tested for compressive strength, 150 × 300 mm cylinders for splitting tensile strength in three layers for both the specimens. For compaction of the specimens, each layer was given 60 to 80 manual strokes using a rodding bar, and then vibrated for 12 to 15 seconds on a vibrating table. Before the fresh concrete was cast into the moulds, the slump value of the fresh concrete was measured (Fig. 3). For the current investigation curing at ambient temperature was followed.

RESULTS AND DISCUSSION

Compressive and split tensile strengths after different days of curing are given in Table 2a and Table 2b.

Compressive strength: The compressive strength of the concrete was determined at the age of 7 days, 14 days, 28 days using cubes (Fig. 4). The test was carried out on 100mm × 100mm × 100mm size cube as per IS: 516-1959 (BIS 1959). A 2000 kN capacity standard compression testing machine was used to conduct the test. For the studies on compressive strength, cubes were tested with a replacement of 100% of mass of cement with fly ash. Three cubes were cast for each proportion.

At the age of 7, 14, and 28 days, strength of geopolymer concrete with superplasticizer achieved 58.3%, 80.26% and 90.91% when compared to the conventional concrete. For geopolymer concrete the strength variation was 63.33%, 89.47% and 94.39% when compared to the control specimen.

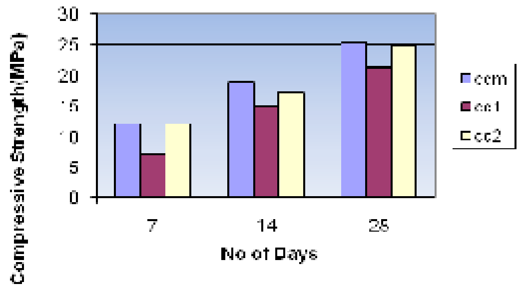


Fig . 4: Comparison of conventional concrete and geopolymer concrete for compressive strength.

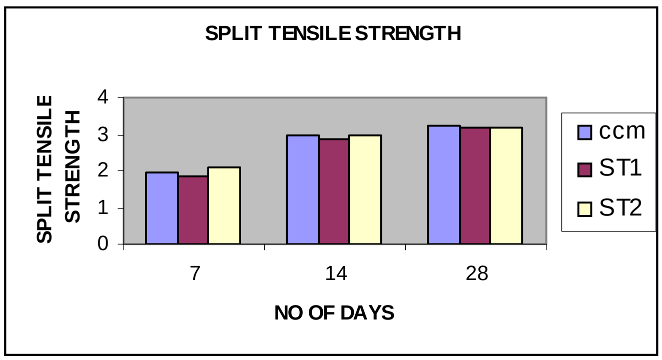


Fig . 5: Comparison of conventional concrete and geopolymer concrete for split tensile strength.

Split tensile strength: The split tensile strength of concrete was determined at the age of 7 days, 14 days and 28 days (Fig. 5). The test was carried out on 100 × 200 mm size cylinder. The load was applied till the failure of the cylinder specimens.

At the age of 7, 14 and 28 days, strength of geopolymer concrete with superplastsicer achieved 91.18%, 97.62% and 98.15% when compared to the conventional concrete. The strength variation for geopolymer concrete was 139%, 110% and 134% when compared to the control specimen. Following observations were made from the results.

- Higher the ratio of sodium silicate-to-sodium hydroxide ratio by mass, higher is the compressive strength of fly ash-based geopolymer concrete.
- Longer curing time in ambient temperature, in the range of 7 to 28 days, produces higher compressive strength of fly ash-based geopolymer concrete.
- The addition of naphthalene sulphonate-based superplasticiser, up to approximately 4% of fly ash by mass, improves the workability of the fresh fly ash-based geopolymer concrete; however, there is a slight degradation in the compressive strength of hardened concrete when the superplasticiser dosage is greater than 2%.
- The slump value of the fresh fly-ash-based geopolymer concrete increases with the increase of extra water .
- The fresh fly ash-based geopolymer concrete is easily handled up to 120 minutes without any sign of setting and without any degradation in the compressive strength.
- As the H_2O-to-Na_2O molar ratio increases, the compressive strength of fly ash-based geopolymer concrete decreases .

- As the ratio of water-to-geopolymer solids by mass increases, the compressive strength of fly ash-based geopolymer concrete decreases.
- The effect of the Na_2O-to-Si_2O molar ratio on the compressive strength of fly ash-based geopolymer concrete is not significant.
- The price of one ton of fly ash is only a small fraction of the price of one ton of Portland cement. Therefore, after allowing for the price of alkaline liquids needed to the make the geopolymer concrete, the price of fly ash-based geopolymer concrete is estimated to be about 10 to 30 percent cheaper than that of Portland cement concrete.

CONCLUSIONS

The study has proved that the replacement of cement with hundred percentage of fly ash content shows that the 7th day strength of ambient-cured specimens depends on the average ambient temperature during the first week after casting; higher the average ambient temperature higher is the strength. Fly ash-based geopolymer concrete cured in the laboratory under ambient conditions gains compressive strength with age. Effective use of fly ash can reduce pollution, energy consumption and saves the environment.

REFERENCES

Davidovits, J. 1988. Geopolymeric reactions in archaeological cements and in modern blended cements. Paper presented at the Geopolymer' 88, First European Conference on Soft Mineralurgy, Compiegne, France.

Davidovits, J. 1994. High-alkali cements for 21st century concretes. In: Concrete Technology, Past, Present and Future, Proceedings of V. Mohan Malhotra Symposium, Editor, P. Kumar Metha, ACI SP- 144, 383-397.

Hardjito, D. and Rangan, B.V. 2005. Development and Properties of Low-Calcium Fly Ash-based Geopolymer Concrete. Research Report GC1, Faculty of Engineering, Curtin University of Technology, Perth. Available at espace@curtin.

BIS 1959. IS 516- 1959. Methods of Tests for Strength of Concrete. Bureau of Indian Standards, New Delhi, India.

BIS 2000. IS 456- 2000. Code of Practice for Plain and Reinforced Concrete. Bureau of Indian Standards, New Delhi, India.

INNOVATIONS, NEW ENVIRONMENTAL TECHNOLOGIES

Energy Storage Flywheels

Energy storage flywheels are currently being developed as a viable solution for megawatt-scale back-up power and for frequency regulation on the grid. LaunchPoint Technologies' magnetically- levitated 'Power Ring' flywheel will rotate in a complete vacuum at tip speeds faster than Mach 2. Such speeds are extremely demanding on a system that require precise control of five levitation axes. LaunchPoint engineers are currently developing innovative adaptive control techniques that will enable the cost-effective and reliable operation of maglev high-speed energy storage flywheels.

To be effective, energy storage flywheels must be able to generate power on the megawatt scale which requires high rotational speeds and results in high centripetal forces. To achieve these speeds, the flywheel is constructed of a carbon composite material and is levitated using a magnetic bearing. It is claimed that research will also be applicable to reducing energy consumption in many of the high speed machines.

Launchpoint Technologies,Inc, August 5, 2009

Antimicrobial Surfaces

European scientists have created light-activated antimicrobial surfaces by modifying a material used in medical devices with tiny amounts of commonly used dyes. Silicone is used in medical equipment, such as catheters. But bacteria can colonise its surface so the infections associated with catheter-use are very common. Ivan Parkin, Mike Wilson, at University College London, and their colleagues in the UK and Spain have modified the polymer so that it kills bacteria when it is irradiated with a laser or visible light.

The researchers covalently bound organic dye molecules, methylene blue or toluidine blue O, to silicone surfaces. The process involves dipping a modified silicone in a solution of the dye for 24 hours, washing and drying it. It uses only small amounts of the dyes (picograms per mm2) but is very effective. After a few minutes' exposure to a low power laser, levels of viable Escherichia coli and Staphylococcus epidermidis on the polymeric surfaces dramatically drop: up to 99.999 percent in the case of S. epidermidis.

The dyes work by generating reactive oxygen species under light irradiation and it is these that are toxic to the bacteria. The work is an interesting and novel strategy in developing effective antimicrobial coatings for medical surfaces. Research is attributed as significant advancement in functional coatings.

Europe-Chemical Technology, July 15, 2009