Experimental study on strength properties of geopolymer concrete

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Abstract- The Ordinary Portland Cement (OPC), which is widely used material not only consumes significant amount of natural resources and energy but also pollutes the atmosphere by the emission of CO_2, So reduce this ill effect, the search for alternative result is geopolymer concrete. In this work, low calcium class F fly ash is used as the base material. This paper presents the results of an experimental investigation to determine the performance characteristics of geopolymer reinforced concrete. Two kinds of systems are considered in this study using 100% replacement of cement by ASTM class Fly ash.

The beams were made with Geopolymer concrete having compressive strength in the range of M20 - M35 by heat curing. The ratio between sodium hydroxide to sodium silicate solution is 1:2.5. The specimen was cured at 60˚C for 24 hrs. The compressive strength test was performed after the curing period and strain was also measured using LVDT. An empirical formula is derived for fly ash based Geopolymer concrete using the results from experimental work.

Key Words: Geopolymer, Sodium Hydroxide, Sodium Silicate, fly ash,

1.INTRODUCTION

The wood, concrete is the most often used material by the community. Concrete is conventionally produced by using the Ordinary Portland cement (OPC) as the primary binder. The environmental issues associated with the production of OPC are well known. The amount of the carbon dioxide released during the manufacture of OPC due to the calcination of limestone and combustion of fossil fuel is in the order of one ton for every ton of OPC produced. In addition, the amount of energy required to produce OPC is only next to steel and aluminium.

On the other side, the abundance and availability of fly ash worldwide create opportunity to utilise this by-product of burning coal, as partial replacement or as performance enhancer for OPC. Fly ash is itself does not possess the binding properties, except for the high calcium or ASTM Class C fly ash. However, in the presence of water and in ambient temperature, fly ash reacts with the calcium hydroxide during the hydration process of OPC to form the calcium silicate hydrate (C-S-H) gel. This pozzolanic action happens when fly ash is added to OPC as a partial replacement or as an admixture.

The development and application of high volume fly ash concrete, which enabled the replacement of OPC up to 60-65% by mass can be regarded as a landmark in this attempt. In another scheme, pozzolans such as blast furnace slag and fly ash may be activated using alkaline liquids to form a binder and hence totally replace the use of OPC in concrete.

In this scheme, the alkalinity of the activator can be low to mild or high. In the first case, with low to medium alkalinity of the activator, the main contents to be activated are silicon and calcium in the by-product material such as blast furnace slag. The main binder produced is a C-S-H gel, as the result of a hydration process. In the later case, the main constituents to be activated with high alkaline solution are mostly the silicon and the aluminium present in the by-product material such as low calcium (ASTM Class F) fly ash .

The binder produced in this case is due to polymerisation. Davidovits (1999) in 1978 named the later as Geopolymers, and stated that these binders can be produced by a polymeric synthesis of the alkali activated material from geological origin or by-product materials such as fly ash and rice husk ash. However, not a great deal was known regarding using the geopolymer technology to make fly ash-based geopolymer concrete.

The research reported in this thesis was dedicated to investigate the process of making fly ash-based geopolymer concrete and the short-term engineering properties of the fresh and hardened concrete.

2.LITERATURE REVIEW

This chapter presents a background to the needs on the development of a fly ash-based geopolymer technology. The available published literature on geopolymer technology is also briefly reviewed.

The trading of carbon dioxide (CO_2) emissions is a critical factor for the industries, including the cement industries, as the green house effect created by the emissions is considered to produce an increase in the global temperature that may result in climate changes. The climate change is attributed to not only the global warming, but also to the paradoxical global dimming due to the pollution in the atmosphere. Global dimming is associated with the reduction of the amount of sunlight reaching the earth due to pollution particles in the air blocking the sunlight. With the effort to reduce the air pollution that has been taken into implementation, the effect of global dimming maybe reduced, however it will increase the effect of global warming.

In this view, the global warming phenomenon should be considered more seriously, and any action to reduce the effect should be given more attention and effort. The production of cement is increasing about 3% annually. The production of one ton of cement liberates about one ton of CO_2 to the atmosphere, as the result of de-carbonation of limestone in the kiln during manufacturing of cement and the combustion of fossil fuels. The contribution of Portland cement production worldwide to the greenhouse gas emission is estimated to be about 1.35 billion tons annually or about 7% of the total green house gas emissions to the earth's atmosphere .

Cement is also among the most energy-intensive construction materials, after aluminium and steel.

Furthermore, it has been reported that the durability of Ordinary Portland cement (OPC) concrete is under examination, as many concrete structures, especially those built in corrosive environments, start to deteriorate after 20 to 30 years, even though they have been designed for more than 50 years of service life. Public concern will be responsibly addressed regarding climate change resulting from the increased concentration of global warming gases. Strategies to retain concrete as a construction material of choice for infrastructure development, and at the same time to make it an environmentally friendly material for the future have been outlined.

In order to produce environmentally friendly concrete, suggested the use of ever natural resources, less energy, and minimize carbon dioxide emissions. The long-term goal of reducing the impact of unwanted by-products of industry can be attained by lowering the rate of material consumption. Likewise, McCaffrey (2002) suggested three alternatives to reduce the amount of carbon dioxide (CO_2) emissions by the cement industries, i.e. to decrease the amount of calcined material in cement, to decrease the amount of cement in concrete, and to decrease the number of buildings using cement.

3.THE AIM OF THE RESEARCH ARE

1. Finding the compressive strength of geopolymer concrete.
2. Finding the flexural strength of geopolymer concrete.
3. Finding the young's modulus of geopolymer concrete.
4. Finding the deflection behavior of beam.

4. EXPERIMENTAL PROGRAM

4.1MATERIALS

The materials used to making geopolymer concrete were Fly Ash, Sand, Coarse aggregate, and alkaline solution such as sodium hydroxide solution and sodium silicate solution as binders and water as workability measure.

4.1.1 Fly Ash Fly Ash obtained from Mettur power plant was used as 100% replacement of cement.

4.1.2 Fine aggregate Natural river sand with fineness modulus of 2.64. Its gradation meets zone II of IS 383 (1970) requirements. Specific gravity of sand is 2.65.

4.1.3 Coarse Aggregate Crushed blue granite stones were passed through 20mm sieve and meets graduation requirements of IS 2386(1963). The apparent specific gravity is 2.83 and fineness modulus is 6.40.

4.1.4 Sodium hydroxide (NaOH) Generally the sodium hydroxides are available in solid state by means of pellets and flakes. The cost of the sodium hydroxide varied according to the purity of the substance. Since our geopolymer concrete is homogeneous material and its main process to activate the sodium silicate Pellet Sodium Hydroxide is recommended to use the lowest cost i.e. up to 94% to 96 % purity.

4.1.5 Sodium silicate

Sodium Silicate is also known as water glass or liquid glass, available in liquid (gel) form. In present investigation sodium silicate 2.0 (ratio between Na_2O to Sio_2) is used. A per the manufactured, silicate were supplied to the detergent company and textile industry as bonding agent. Same sodium silicate is used for the making of geopolymer concrete.

4.2 Mix Proportion and Mix details The mix design in the case of geopolymer concrete is based on convenient concrete with some modification. In the case of conventional concrete, the materials proportion can be found out of required strength using the code.

4.2.1 Mixing It was found that the fresh fly ash based geopolymer concrete was dark in colour (due to the dark colour of the fly ash). The amount of water in the mixture played an important role on the behavior of fresh concrete when the mixing time was long.

The sodium hydroxide available in pellets form it is dissolved in water. Morality to be used in the concrete is 16 molar in which 444 grams of NaOH solids dissolved in 556 grams of water.

Mix sodium hydroxide solution and sodium silicate solution together at least one day prior to adding to the dry materials. Mix all dry materials in the pan mixer for amount three minutes. Add the liquid compound of the mixture at the end of dry mixing and continue the wet mixing for another 2 minutes.

4.2.2 Curing The Geopolymer specimen were cast and placed inside a jute canvas or tarpaulin. The entire specimen was kept inside the heat curing chamber at 60°C and a temperature indicator was also placed outside the set up. The canvas should be so tight such that the heat can't come out of the heat curing set up. The beams were cured for 24 hours.

Geopolymer specimens should be cured at elevated temperature in a dry environment to prevent excessive evaporation Geopolymer concrete did not harden immediately at room temperature. When the room temperature was less than 30°C the hardening did not occur at least for 24 hours. Also the handling time is a more appropriate parameter (rather than setting time used in the case of OPC Concrete) for fly ash based geopolymer concrete.)

4.3 Test Results and Discussions

4.3.1 Compressive Strength The compressive strength of test cylinder size 300x150mm dia was measured for GPC after 24 hours heats curing at 60°C. The average compressive strength values observed after 24 hours.

4.3.2 Flexural Strength

Tests were carried out conforming to IS 516 (1959) to obtain the flexural strength of various concrete mixtures. Eight beams of beam 100mmx100mmx500mm were cast. The beams were tested by two points loading method in UTM.

4.3.3 Young's Modulus of Elasticity

Young's modulus of elasticity E for the geopolymer concrete investigated was determined at 24 hours. Tests were carried out in accordance with the Indian Standard. For each Mixture, four 100x300 mm concrete cylinders were made. Four of These cylinders were used to determine the elastic modulus and Poisson's ratio. Four other cylinders were tested to determine the average compressive strength. All the specimens were capped in accordance with the Indian Standard. The range of poisons ratio falls between 0.19 and 0.22. For Portland cement concrete, the Poisson's ratio is usually between 0.11 and 0.21, with the most common value taken as 0.15 (Warner et al. 1998) or 0.15 for high strength concrete and 0.22 for low strength concrete (Neville 2000). These ranges are similar to those measured for the geopolymer concrete.

5. CONCLUSIONS

1. For all the mixes considered in this investigation, there was increase in load carrying capacity of beam for increase in grades.

2. The measured values of the modulus elasticity of fly ash-based geopolymer concrete with compressive strength in the range of 20 to 35 MPa were similar to those of OPC concrete. The measured values are at the lower end of the values calculated using the current design Standards due to the type of coarse aggregate used in the manufacture of the geopolymer concrete.

3. The Poisson's ratio of fly ash-based geopolymer concrete with compressive strength in the range of 20 to 35 MPa falls between 0.19 and 0.22. These values are similar to those of OPC concrete.

4. The stress-strain relations of fly ash-based geopolymer concrete in compression fits well with the expression developed for OPC concrete as per IS 456 – 2000.

5. The compressive strength of fly ash-based geopolymer concrete is high, as in the case of Portland cement concrete. The measured values are higher than those recommended by the relevant Indian Standard.

5.1 RECOMMENDATIONS FOR FUTURE RESEARCH

To date, the reaction mechanism of geopolymerisation is still not clear. Fundamental research in this area would increase the potential of the material. For example a study is needed to identify the scientific reason for increase in strength after a longer resting period, and to investigate the role of water in geopolymerisation.

Although the present work identified many salient parameters that influence the properties of fresh and harden fly-ash based geopolymer concrete, a large database should be built on the engineering properties of various mixtures using fly ash from different sources. Such a database may identify additional parameters, and lead to familiarise the utilisation of this material in many applications.

Further research should identify possible applications of geopolymer technology. This would lead to research areas that are specifically oriented towards applications. The geopolymer technology has the potential to go beyond making concrete, there could be possibilities in other areas of infrastructure needed by the community.

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