A REVIEW ON FINITE ELEMENT MODELLING OF STRENGTHENED SIMPLE BEAMS USING ANSYS

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ABSTRACT

An experimental study was undertaken to establish the relationship between compressive strength with Splitting Tensile Strength and Modulus of Elasticity of Geopolymer Concrete. The stress - strain curve of OPC concrete originally proposed by Popovers is validated for Geopolymer concrete with some modification in curve fitting factor. The stress - strain behavior of Geopolymer concrete using sand and M-sand was studied and compared with the experimental investigation. The beams were made with Geopolymer concrete having compressive strength in the range of M20 - M35 by heat curing as well as ambient curing using river sand and M- sand. The experimental ultimate moment was found to be about 40- 60 % higher than the predicted ultimate moment. Due to the high stiffness of reactive Geopolymer concrete, the actual deflections of the beams were found to be slightly lower than the allowable values under service loads. The observed crack widths under service loads were within acceptable limits. It was found that GPC made with sand and M-Sand had better structural integrity. Hence, there is a high potential to produce GPC using sand and M-Sand. Design examples as well as comparison of test results with Numerical Analysis using ANSYS 13.0 are presented in this thesis.

Keywords:- *ANSYS 13.0,Beam section ,Geopolymer concrete*

INTRODUCTION

India is the second-largest cement producing country in the world after China. The country's cement production was 300 million tones during the year 2010 and the figure is expected to double, to reach almost 550 million tones by 2020, as per the estimates by the Cement Manufacturers Association (CMA). On the other hand, global warming has become a major concern due to the climatic changes. The global warming is the increase of Earth's average surface temperature due to the effect of greenhouse gases. Among the greenhouse gases, CO_2 contributes about 65% of global warming. Therefore, efforts are being taken to develop the other forms of cementious materials for producing concrete. One such material, Geopolymer Concrete is produced with activated fly ash as a binder there by eliminating Portland cement. The base material, such as fly ash, is activated by alkaline solution to produce the binder, which is rich in Silica (Si) and Aluminum (Al). The emission of CO_2 to the atmosphere is approximately one tone, and this is due to the production of one ton of Portland cement, and hence, the cement industry is held responsible for CO_2 emissions to a greater extent. In order to address the global warming issues, several efforts are in progress to reduce the use of Portland cement in concrete. These include the utilization of supplementary cementing materials such as fly ash, granulated blast furnace slag, silica fume, metakaolin and rice-husk ash, and the development of alternative binders to Portland cement.

1.2 GEOPOLYMER

The polymerization process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, resulting in a three-dimensional polymeric chain and ring structure consisting of O-bonds. This water, expelled from the Geopolymer matrix during the curing and further drying periods, leaves behind discontinuous nano-pores in the matrix, which provide benefits to the performance of Geopolymers 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. This is in contrast to the chemical reaction of water in a Portland cement concrete mixture during the hydration process.

The source materials for Geopolymers based on alumina-silicate should be rich in silicon (Si) and aluminum (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.

LITERATURE REVIEW

Malhotra (2018) projected that the contribution of Portland cement production worldwide to the greenhouse gas emission is about 1.35 billion tons per annum or about 7% of the total greenhouse gas emissions to the earth's environment. Cement is also one among the most energy-intensive construction materials, after aluminium and steel. Furthermore, Mehta and Burrows (2001) reported that the durability of ordinary Portland cement (OPC) concrete is under examination, as many concrete structures, especially those built in corrosive environments, even though they have been designed for more than 50 years of service life; start to deteriorate after 20 to 30 years.

Mehta (2016) suggested that they have strategies to retain concrete as a construction material for the development of infrastructure; mean while they have outlined an alternative eco - friendly material which can be used to manufacture concrete for the future.

Xu and Van Deventer (2011) investigated the Geopolymerization of 15 natural Al-Si minerals. It was found that the mineral with a higher extent of dissolution, after polymerisation it has been proven that better compressive strength was achieved. The percentage of potassium oxide (K_2O), calcium oxide (CaO), the molar ratio of Si-Al in the source material, the molar ratio of Si/Al in the solution during dissolution and the type of alkali had significant effect on the compressive strength.

Swanepoel and Strydom (2012) conducted a study by mixing fly ash, sodium silica solution, NaOH, kaolinite, and water to produce Geopolymer. The compressive strength was affected by both the curing temperature and the curing time, and the optimum strength occurred when specimens were cured at 60^oC for a period of 48 hours.

Malhotra (2002) estimated that worldwide, the annual production of coal ash was more than 390 million tons in 1998. The major contributors for this amount were India and China. Only about 14 percent of this fly ash was utilized, while the rest was disposed in landfills. The amount of fly ash produced worldwide is estimated to be about 780 million tons annually by the year 2010.

Vimal Kumar et al (2011) observed that Fly ash is a finely divided residue resulting from the combustion of bituminous coal or lignite in a thermal power plant.Indian coals have on an average 45% ash content. Currently India generates around 95 million tonnes of ash per year. It is likely to reach 180 million by 2012.

Cross et al (2005) investigated that in the past Fly ash has been used to replace partially for Portland cement to produce concretes. An important achievement in this regard is up to 60 percent of fly ash was replaced for OPC for the development of high volume fly ash (HVFA) concrete yet possesses excellent mechanical properties with enhanced durability performance. The test results performed well and it shows that HVFA concrete is more durable than ordinary Portland cement concrete. Recently, a research group at Montana State University in the USA has confirmed through field trials of using 100% high-calcium (ASTM Class C) fly ash to replace Portland cement to make concrete. Ready mix concrete equipment was used to produce the fly ash concrete on a large scale. The field trials showed that the fresh concrete can be easily mixed, transported, discharge, placed, and finished.

Palomo et al (2004) investigated the mechanical characteristics of fly ash based Geopolymer concrete. It was found that the characteristics of the material were mostly determined by curing methods, especially the curing temperature and curing time. Their study also reported some limited number of tests carried out on reinforced Geopolymer concrete sleeper specimens.

Brooke et al (2005) reported that the behaviour of Geopolymer concrete beam column joints was similar to that of members made of Portland cement concrete. It was found that the application of Geopolymer concrete structural members was correlated well with the OPC concrete.

Bei Xing Li (2011) investigated the workability, strength and modulus of elasticity, drying shrinkage and creep, and chloride ion permeability as well as freeze-thaw resistance of the C60 high Performance concretes (HPCs) with manufactured sand (MS) containing crushed limestone dust in percents ranging from 3.5% to 14% experimentally. The results were compared with those of river sand (RS) concrete. In addition, the effect of clay amounts at 3% and 5% in MS on properties of C60 HPCs was also investigated

Li Beixing et al (2011) reported that methylene blue value (MBV) is an important index that reflects the quality of manufactured sand. The relation between MBV of manufactured sand and its lime stone fine content, clay content and clay characteristics were investigated. Results showed that MBV of MS was not affected by limestone fine content but by the clay. With an increase in MVB Flexural strength, Workability and 7 day compressive strength had decreased. But 28 day Compressive strength was not affected. Later on, the author also reported that to meet the requirements of construction of concretes filled in the steel tube arches, a C60 grade micro-expansive self-compacting concrete (SCC) was prepared using manufactured sand (MS).

Jiliang Wang et al (2009) reported that the relation between methylene blue (MB) value of MS and its limestone dust content and clay content was investigated. The effects of MB value ranging from 0.35 to 2.5 on the workability of fresh concrete and crack propagation characteristics at the age of 24 hours, and its effects on the mechanical properties, dry shrinkage of the hardened concrete were tested. The experimental results show that the MB value is not related with the limestone dust content of MS, but in direct proportion to clay content. With the increase of MB value, the concrete workability decreases, and the flexural strength and 7 d compressive strength reduced markedly; whereas, the 28 d compressive strength is not affected. When the MB-value is less than or equal to 1.35, the change of the MB-value has a little influence on early plastic cracking and dry shrinkage property of concrete, but when the MB-value is more than 1.35, the tendency of plastic cracking and dry shrinkage is remarkable.

Ilangovan et al (2008) reported that common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. The authors suggested the feasibility of the usage of Quarry Rock Dust as hundred percent substitute for Natural Sand in concrete. Mix design has been developed for three grades using design an approach IS, ACI, USBR, RN.No.4 and BRITISH for both conventional concrete and quarry dust concrete. Tests were conducted on cubes and beams to study the strength of concrete made of Quarry Rock Dust and the results were compared with the Natural Sand concrete.

In order to develop the fly ash-based Geopolymer concrete, a rigorous trial-and-error method was adopted. The focus of this study was to identify the salient parameters that influence the mixture proportions and the properties of low calcium fly ash-based Geopolymer concrete.

As far as possible, the current practice used in the manufacture and testing of ordinary Portland cement (OPC) concrete was followed. The aim of this action was to ease the promotion of this ‘new’ material to the concrete construction industry. In order to simplify the development process, the compressive strength was selected as the benchmark parameter. This is not unusual because compressive strength has an intrinsic importance in the structural design of concrete structures (Neville 2000).

Although Geopolymer concrete can be made using various source materials, the present study used only low-calcium (ASTM Class F) dry flyash. Also, as in the case of OPC, the aggregates occupied 65-75 % of the total mass of concrete. In order to minimize the effect of the properties of the aggregates on the properties of fly ash based Geopolymer, the study used aggregates from only one source.

The present work is carried out in the framework of a project aimed to produce the Geopolymer Mix procedure of different grades of Geopolymer concrete matrices, stronger and denser equal to the cement concrete obtained by using Portland Cement binders, that can be used for the long term stabilization of inorganic toxic waste i.e. fly ash. The particular work presented in this thesis deals with a study investigating the Mix design.

MATERIALS USED

Fly Ash

Fly ash is used as a cementitious material drawn from burning of coal in high temperature. There are two types of Fly ash such as

- ASTM class F
- ASTM class C

Cementitious material used in this experimental programme was low calcium Flyash (ASTM type F). Since the ASTM class F contains calcium of about 5% by mass, where as class C contains more than 5% of calcium which tends to change in micro structure of concrete and properties of concrete. Fly ash (Class-F) was obtained from Mettur Thermal Power Plant (MTTP). The specific gravity and Finesses modulus (passing through 45 µm) of Fly Ash was 2.3 and 7.86. The chemical composition for cementitious material is shown in Table 3.1.

Table 3.1 Composition of Fly Ash

Chemical Properties % by Mass	IS:3812-1981 Specifications	Fly Ash MTPP
$SiO_2+Al_2O_3+Fe_2O_3$	70% min	90.5%max
SiO_2	35%min	58%max
CaO	5%max	3.6%min
SO_3	2.75%max	1.8%min
Na_2O	1.5%min	2%max
L.O.I	12%max	2%min
MgO	5%max	1.91%min

Fine Aggregate (M-Sand)

M-sand is crushed fine aggregates produced from hard granite stone which is cubically shaped with grounded edges, washed and graded with consistency to be used as a substitute for river sand. M-Sand is a superior quality manufactured sand conforming to international standards. The Specific gravity and Fineness modules for manufactured sand were 2.8 and 2.9 respectively.

Fine Aggregate (Sand)

The most important function of the sand is to provide workability and uniformity in the mixture. Clean and dry river sand available locally was used. Sand passing through IS 4.75mm Sieve was used for casting all the specimens. The fine aggregate also helps the cement paste to hold the coarse aggregate particle in suspension. In this investigation sand, which belongs to Zone III was used and the following tests were carried out as per IS: 2386 - 1968 part III. The Specific gravity and Fineness modules for river sand were 2.7 and 2.6 respectively.

Coarse Aggregate

In the present investigation locally available crushed granite stone aggregate of size 20mm passing and retained in 10mm IS sieve used and the various tests were carried out as per IS:2386-1968 part III. The Specific gravity and Fineness modules for coarse aggregate were 2.63 and 2.8 respectively.

CONCLUSION

The basic material of the geopolymer based on fly ash is of prevailingly amorphous character, only seldom containing needle-shaped minority crystals. The depth of the section is 5% less for Geopolymer concrete using sand and 10% less for Geopolymer concrete using M-206 sand when compared to conventional concrete reported in the literature. Moment-curvature curves have the same trend as that of the load-deformation curves. It is observed that when the load is increased, the specimen loses its flexural rigidity due to deflection and reduction in effective moment of inertia due to development of crack. The experimental load deflection results obtained from the test conducted on beam specimens are compared with ANSYS 13.0 results and the graphs are plotted for various mix proportions. Experimental results are found to have good agreement with finite element analysis.

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