IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

AN EXPERIMENTAL INVESTIGATION OF GEOPOLYMER CONCRETE AT ELEVATED TEMPERATURE AND AGAINST AGGRESSIVE CHEMICAL ENVIRONMENT

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A B S T R A C T

The current research discusses the findings of an exploratory programme aimed at revising the behavior of GEOPOLYMER concrete when subjected to harsh environmental circumstances. The grades used in the study were M-30, M-40, M-50, and M-60, with the mixes prepared for molarities of 8M and 12M. The alkaline solution employed in this investigation is a mixture of sodium silicate and sodium hydroxide solution in the proportions of 2.50 and 3.50. GEOPOLYMER concrete cubes with dimensions of 150×150×150 mm were cast. Three cubes were evaluated for compressive strength by universal testing equipment at 7 and 28 days of age. The specimen was then treated to increased temperatures of 200o C, 6000c, 800o C, and 1000o C in an electric air heated muffle before being tested for compressive strength after cooling. Six cubes were soaked in Sodium Sulphate, sulfuric acid, and sodium chloride solutions for 30 and 60 days, respectively.

Keywords: Geopolymer, Steel, compressive strength, elevated temperature, sodium chloride, sulphuric acid

1. Introduction

Davidovits originally introduced GEOPOLYMER technology in 1978. His research clearly demonstrates that the application of GEOPOLYMER technology might significantly cut CO2 emissions caused by cement industry. GEOPOLYMERS are inorganic polymer family members. The GEOPOLYMER material's chemical makeup is similar to that of natural zeolitic materials, but its microstructure is amorphous. Any substance containing mostly silicon (Si) and aluminium (Al) in amorphous form is a potential source material for the production of GEOPOLYMER. As source materials, metakaolin or calcined Kaolin, low calcium ASTM Class F fly ash, natural Al-Si minerals, combinations of calcined minerals and non-calcined minerals, fly ash and metakolin, and granulated blast furnace slag and metakaolin have all been investigated. A combination of sodium hydroxide or potassium hydroxide and sodium silicate or potassium silicate is the most frequent alkaline liquid used in GEOPOLYMERISATION.

Since the development of GEOPOLYMER binders by Davidovits in 1978, there has been a great deal of interest in the realm of engineering as well as chemistry. It has arisen as a prospective alternative to OPC binders in recent decades due to its reported high early strength and resilience to acid and sulphate attack, as well as its environmental friendliness. Though GEOPOLYMERS can be made from a variety of silica and alumi na-rich materials, including fly ash, silica fume, powdered granulated blast furnace slag, and metakaolin, fly ash-based GEOPOLYMERs have received the most attention. GEOPOLYMER binders may be a promising alternative in the creation of acid resistant concrete since they rely on alumina-silicate bonds for structural stability rather than calcium silicate hydrate linkages.

The American Association of State Highway and Transportation Officials provides design and detail specifications for median barriers (AASHTO). These have been adjusted on a regular basis to reflect changes in the vehicle type and loading mandated on federal and state routes. AASHTO amended its Load Resistance Factor Design (LRFD) in 2009, which is a design reference for bridges and related fixtures11. The NCHRP Report 35012, which had been the recognized approach for safety hardware device testing and acceptance since 1993, was superseded by this update. The LRFD (2009) incorporates multiple vehicular loads and accident circumstances to ensure the functionality of traffic barriers at the roadside.

2. Experimental Investigation

The following materials have been used in the experimental study (Veeresh, 2011)

1. Fly Ash (Class C) collected form Raichur Thermal power plant having specific gravity 2.00.
2. Fine aggregate: Sand confirming to Zone –III of IS: 383-1970 having specific gravity 2.51 and fineness modulus of 2.70.

   Coarse aggregate: Crushed granite metal confirming to IS: 383-1970 having specific gravity 2.70 and fineness modulus of 5.85.
3. Water : Clean Potable water for mixing
4. Alkaline Media: Specific gravity of

a. Sodium Hydroxide (NAOH) = 1.16

b. Sodium Silicate (Na_2SiO_3) = 1.57

Tests were conducted on specimen of standard size as per IS: 516-1959. Details of tests conducted and specimens used are given in table 1.

Table 1: Details of specimen used and tests conducted

Type of tests conducted	Size of specimen	No. of specimen cast for different grades
Compressive strength	150x150x150mm	5
Split tensile strength	100x200mm	5

Mix design of GEOPOLYMER concrete

In the design of GEOPOLYMER concrete mix, coarse and fine aggregates together were taken as 7% of entire mixture by mass. This value is similar to that used in OPC concrete in which it will be in the range of 75 to 80% of the entire mixture by mass. Fine aggregate was taken as 30% of the total aggregates. The density of GEOPOLYMER concrete is taken similar to that of OPC as 2400 kg/m3 (Rangan, 2008).

Mixing, Casting, Compaction and Curing of GEOPOLYMER Concrete

GPC can be manufactured by adopting the conventional techniques used in the manufacture of Portland cement concrete. In the laboratory, the fly ash and the aggregates were first mixed together dry on pan for about three minutes. The liquid component of the mixture is then added to the dry materials and the mixing continued usually for another four minutes. In preparation of NAOH solution, NAOH pellets were dissolved in one litre of water in a volumetric flask for two different concentration of NAOH (8 and 12M). Alkaline activator with the combination of NAOH and Na_2SiO_3 was prepared just before the mixing with fly ash. The addition of sodium silicate is to enhance the process of geopolymerization (Hua Xu, J.S.J.van Deventer, 2000). The ratio of fly ash/ alkaline activator and Na_2SiO_3 / NAOH used in the current study was 2.5 and 3.5 for all the mixes. The fly ash and alkaline activator were mixed together in the mixer until homogeneous paste was obtained. This mixing process can be handled within 5 minutes for each mixture with different molarity of NAOH. Fresh fly ash based GEOPOLYMER concrete was usually cohesive. The workability of the fresh concrete was measured by means of conventional slump test. Heat curing of GPC is generally recommended, both curing time and curing temperature influence the compressive strength of GPC. For easy working of fresh GPC mixes super plasticizer Conplast SP-430 was used. After casting the specimens, they were kept in rest period for two days and then they were de molded. The de molded specimens were kept at 60°C for 24 hours.

3. MATERIALS AND METHODS

Cement

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. English masonry worker Joseph Aspdin patented Portland cement in 1824; it was named because of its similarity in colour to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture.

A. Portland Cement: Portland cement is made from four basic compounds, tricalcium silicate (C3 S), dicalcium silicate (C2 S), tricalcium aluminate (C3 A), and tetracalcium aluminoferrite 31 (C AF). The cements used in Minnesota are made either from limestone and clay, 4 limestone and shale, or limestone and slag

B. Blended Cements: These blended cements are composed of one of five classes of hydraulic cement for general and special applications, using slag, fly ash or other pozzolan with Portland cement, or Portland cement clinker with slag.

C. Ground Granulated Blast Furnace Slag (GGBFS): In the blast furnace, magnetic iron ore (Fe O) and haematic iron ore (Fe O) 3 4 2 3 are fed along with limestone into a high temperature chamber containing coke. Coke is partially oxidized to carbon monoxide, which reduces the ores to iron.

D. Fly Ash: Fly ash is the most widely used pozzolana in concrete. It is a fine residue resembling cement that is a by-product of burning coal in an electric power generating plant.

Water

Combining water with a cementations material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it and allows it to flow more freely.

Aggregates

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel and crushed stone are used mainly for this purpose.

Chemical admixtures

Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing.

4.Experimental Investigation and Comparison of Results

THE SLUMP TEST

The slump test is done to make sure a concrete mix is workable. The measured slump must be within a set range, or tolerance, from the target slump.

COMPRESSION TEST

There are two common tests that are performed to determine strength of Portland cement concrete. Flexural strength tests are typically used for concrete paving; and compressive strength tests are typically used for structures. The compression test shows the compressive strength of hardened concrete. The testing is done in a laboratory off-site. The only work done on-site is to make a concrete cylinder for the compression test. The strength is measured in Mega Pascals (MPa) and is commonly specified as a characteristic strength of concrete measured at 28 days after mixing. The compressive strength is a measure of the concrete's ability to resist loads which tend to crush it.

REBOUND HAMMER TEST

Rebound hammer test is done to find out the compressive strength of concrete by using rebound hammer as per IS: 13311 (Part 2) – 1992.The underlying principle of the rebound hammer test is: The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.

5. RESULTS AND DISCUSSIONS

Workability

The workability of the GEOPOLYMER concrete decreases with increase in the grade of the concrete as presented in Table 2, this is because of the decrease in the ratio of water to GEOPOLYMER solids. As the molarity of the NaOH solution increases the workability of the GEOPOLYMER concrete decreases, because of the decrease in the water content. Thus we can say that as the grade of the concrete increases, the mix becomes stiffer decreasing the workability.

Sulphuric acid and magnesium sulphate attack on GPC and PPCC specimens

Visual appearance

The below figure it can be seen that the specimens exposed to sulphuric acid undergoes erosion of the surface. In the case of ordinary Portland cement, sulphuric acid attack manifests itself by deposition of a white layer of gypsum crystals on the acid-exposed surface of the specimen.

6. Experimental Investigation and Comparison of Results

Crack analysis of the barrier's FE model predicted the first crack to appear at a load of 30 Kip, whereas the initiation of cracking during the test was observed to occur at 26 Kip. This suggests a close agreement with the FE approximation. The load characteristics of the GPC barrier are shown in Figure

As the load reached 30 Kip, the first crack fully propagated on the tensile face of the barrier with the development of a second crack. When the applied load reached 32 Kip, a crack was observed at the right support while the crack at the central tensile zone(first crack) developed further. The flexural load was completely transferred to the rebar 41 Kip, when the concrete fully cracked, which was accompanied with loud sound. The steel was visible at this point and the load dropped to 22 Kip. As the load further, the rebar failed when the load reached 26 Kip. This marked the end of the test.

7 Conclusions

Based on results obtained during the experimental investigations, following conclusions were drawn:

Fly ash was used in the present study to produce GEOPOLYMERIC reactions with the help of sodium hydroxide-silicate based alkaline activator solutions. Conventional methods of mixing, compaction, molding and demolding can be adopted for GPCs mixes. Fly ash based GPC specimens prepared with different alkali content showed varying degree of deterioration when exposed to sulphuric acid. Specimens received white deposits on the surfaces during exposure to magnesium sulphate solution which gradually transformed from soft and flaky shape to hard and rounded shape. The GPC and PPCC mixes indicated minor changes in weight and strength when the specimens were exposed to sulphuric acid and magnesium sulphate. The split tensile strength loss for the specimens exposed in magnesium sulphate was in the range of 4 to 15% in PPCC, whereas it was about 7 to 30% in GPCs.

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