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Experimental Investigation On The Strength Aspects Of Flyash Based Geopolymer Concrete

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ABSTRACT
Ordinary Portland Cement (OPC) becomes an important material in the production of concrete which act as itsbinder to bind all the aggregate together. However, the utilization of cement causes pollution to the environment andreduction of raw material (limestone). The manufacturing of OPC requires the burning of large quantities of fuel anddecomposition of limestone, resulting in significant emissions. As such, alternative materials had been introduced toreplace OPC in the concrete. Geopolymer concrete had been introduced to reduce this problem. This paper discussesabout the strength properties of fly ash based Geopolymer concrete. Fly ash based Geopolymer concrete offersseveral economic benefits over Portland cement concrete. The results obtained were far better than conventionalconcrete.
Keywords-Geopymer Concrete,Flyash .

I. INTRODUCTION

Although the use of Portland cement is unavoidable in the foreseeable future, many efforts are being made to reduce the use of Portland cement in concrete. In this respect geopolymer concrete is very promising technique. The term geopolymer describes a family of mineral binders with chemical composition same as zeolite. Hardened geopolymer concrete has an amorphous microstructure.Geopolymer is produced by a polymeric reaction of alkaline liquid with source material of geological origin or by product material such as fly ash.The polymerisation process involves a substantially fast chemical reaction under alkaline condition on Si-Al minerals, that results in a three dimensional polymeric chain and ring structure consisting of Si-O-Al-O bonds. In terms of reducing global warming, geopolymer technology could reduce approximately 80% of CO_2 emission to the atmosphere caused by cement and aggregate industry. Compared with ordinary Portland cement concrete, geopolymersshow many advantages. Geopolymers show substantially superior resistance to fireand acid attackand much less shrinkage than OPC concrete. Geopolymer concrete can obtain 70% of the final compressive strength in the first four hours of setting. The tensile strength of geopolymer concrete falls within the range predicted for OPC based concrete. It has been reported that the stress strain relationship of fly ash based geopolymer concrete is almost similar to that of ordinary Portland cement concrete.

These advantages make the geopolymer concrete a strong substitute for replacing ordinary portland cement based concrete composites in construction. Fly ash is residue from combustion of coal which is widely available worldwide and lead to waste management proposal. Hence, fly ash-based geopolymer concrete is a good alternative to overcome the abundant of fly ash. The curing process of geopolymer concrete play shows a great influence on the development of microstructure, and subsequently on the mechanical characteristics of geopolymer.In addition, the appropriate usage of one ton of fly ash earns approximately one carbon-credit that has a significant redemption value. One ton low-calcium fly ash can be utilized to manufacture approximately three cubic meters of high quality fly ash-based geopolymer concrete, and hence earn monetary benefits through carbon-credit trade.

II. MATERIALS

1.1.Fly Ash (Source Material)

One constituent of geopolymers is the source material. In this study fly ash is used as sourcematerial. Low calcium (ASTM class F) fly ash is used as source material than high calcium (ASTM class C) fly ash. The presence of calcium in high amount may be interfering with the polymerization process. The other characteristic that influence the stability of fly ash to be a source material for geopolymer are particle size , amorphous content, as well morphology, and origin of fly ash.

1.2 Alkaline Liquid (AL)

The most common alkaline liquid used in geopolymerisation is a combination of sodium hydroxide (NAOH) or potassium hydroxide (KOH) and Sodium Silicate or Potassium Silicate. The Sodium hydroxide (NaOH) solution was prepared by dissolving either the flakes or the pellets in water. It is recommended that the alkaline liquid is prepared by mixing both the solutions together at least 24 hours prior to use. The Ratio Sodium Silicate Solution to Sodium Hydroxide Solution by mass of 2.5**.**The sodium silicate solution is commercially available in different grades. The sodium silicate solution with SiO_2-to-Na_2O ratio by mass of approximately 2 is generally used.The solids must be dissolved in water to make a solution with the required concentration. The concentration of Sodium Hydroxide solution can vary in the range between 8 Molar and 16Molar; however 8 M solution is adequate for most applications.Ratio of activator solution to fly ash, by mass, in the range of 0.3 and 0.4.

1.3. Aggregates (A)

A combined aggregate is used in geopolymer concrete i.e.,local aggregates comprising 20mm, 12.5mm and 6.3mm coarse aggregates and fine aggregates in saturated surface dry (SSD) condition were used. The coarse aggregate (CA) were crushed granite type aggregates and the fine aggregates (SA) was fine sand. Coarse and fine aggregates used by the concrete industry are suitable to manufacture geopolymer concrete.Coarse and fine aggregates of approximately 75% to 80% of the entire mixture by mass. This value is similar to that used in OPC concrete.

1.4**.**Super Plasticizer (SP)

In order to improve the workability of fresh concrete high-range. Water-reducing napthalene based Super plasticizer was added to the mixture. In this studyCeraplast 300 is used as the superplasticizer, which is a black coloured liquid.

III. EXPERIMENTAL PROCEDURE

3.1. Mix Proportions

The Curtin University has suggested several mixproportions for the development and manufacture of geopolymer concrete. In this study one of them was selected and is given per m^3 of concrete in Table 3.1.

Table 3.1 General Mixture Proportion

Materials		Mass Kg/m^3
Coarse Aggregates	20mm	277
	14mm+	370
	7mm	647
Fine sand		554
Fly ash (class F)		408
Sodium Silicate Solution (Sio_2/Na_2o = 2)		103
Sodium hydroxide solution (8M)		41
Super plasticizer		8
Water		0

3.2.Manufacture Of Test Specimens

3.2.1Preparation of Liquids

The Sodium hydroxide (NaOH) solids were dissolved in water to make the solution. The mass of NaOH solids in a solution varied depending on the concentration of solution expressed in terms of molar M. 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 the specimens, the alkaline liquid was mixed together with the Super plasticizer and the extra water (if any) to prepare the liquid component of the mixture.

3.2.2 Test Specimens

Cube specimens of size 150 mm x150 mm x 150 mm for measuring compressive strength.cylinderspecimens of 150 mm dia x 300 mm height for indirect splitting tensile strength and modulus of elasticity were casted in our study.

3.3Manufacture of fresh concrete and casting

Mixing of all the materials were done manually in laboratory at room temperature. The fly ash and aggregate first mixed homogenously and then alkali solutions which were made one day before and super plasticizer is added to mixture of fly ash and aggregate. The mixing of total mass were continue until binding paste cover all the aggregate and become homogenous and uniform in colour. The mixing of geopolymer concrete involves two phases. sInitially the mixing of flyash along with combined aggregate in dry condition was done.Later alkaline solution is added to commence the wet mixing. Hence the mixing was continued for about 4 minutes to get fresh geopolymer concrete. Before casting into moulds the slump value of concrete was tested. Then cube were casted. Each cube specimen was casted in two layers by compacting. Each layer receives 25 strokes compaction by standard compaction rod.

3.4 Curing of Geopolymer Concrete

Setting time of geopolymer concrete depend on many factors such as composition of alkaline solution and ratio of alkaline liquid to fly ash by mass. However the curing temperature is the most important factor for geopolymer concrete. As the curing temperature increases, setting time of concrete decreases. During curing process, geopolymerconcrete experiences polymerization process. Due to the increase of temperature, polymerization process becomes more rapid. The curing time may varied from 4 hours to 96 hours (4 days). The rate of increase in strength was rapid up to 24 hours of curing time; beyond 24 hours, the gain in strength is only moderate. Therefore, heat curing time need not been more than 24 hours in practical applications.In this study two types of curing has been done i.e., sunlight curing and oven curing at 80^0C. It has been found that strength increases as temperature increases.

IV. EXPERIMENTAL RESULTS

4.1. Compressive Strength

First the conventional concrete specimens were prepared and tested for compressive strength for an age of 7 & 28 days after casting. The geopolymer concrete specimens were prepared for 2 types of curing (sunlight curing &oven curing.) and they also tested for the compressive strength at an age of 7 &28 days after casting.

4.2 Conventional Concrete

In this study, for conventional concrete, 150 x 150 mm cubes specimens were prepared. At least three of these cubes were tested for compressive strength at an age of 7 & 28days after casting. The Tables 4.1 given below shows the compressive strengths of conventional concrete.

Table 4.1 Compressive Strength Of Conventional Concrete For 7^{th} Day and 28 th day

Specimen	Method of curing	7^{th} day Compressive Strength(N/mm^2)	28^{th} day Compressive strength (N/mm^2)
1	Water Curing	27.55	41.77
2		27.33	41.77
3		29.33	36.00
Average		28.07	39.68

4.3Geopolymer Concrete

For each batch of geopolymer concrete made in this study, 150 x 150 mm cubes specimens were prepared. At least three of these cubes were tested for compressive strength at an age of 7 & 28days after casting. The Tables 4 given below shows the compressive strengths of sunlight cured geopolymer concrete for 7 & 28 day. The Tables 4.2 given below shows the compressive strengths of sunlight cured geopolymer concrete for 7 & 28 day.

Table 4.2 Compressive Strength Of Sunlight Cured Geopolymer Concrete For 7^{th} Dayand 28^{th} Day

Specimen	Method Of Curing	7^{th} Day Compressive Strength (N/mm^2)	28^{th} Day Compressive Strength (N/mm^2)
1	Sunlight	38.63	41.16
2		37.06	42.14
3		38.5	42.50
Average		38.06	41.93

Table 4.3Compressive Strength Of Oven Cured Geopolymer Concrete For 7^{th} Day and 28^{th} Day

Specimen	Method Of Curing	7^{th} Day Compressive strength (N/mm^2)	28^{th} Day Compressive strength (N/mm^2
1	Oven	38.63	44.17
2		39.45	44.65
3		39.20	43.12
Average		39.12	43.98

4.4.Split Tensile Strength

The cylindrical specimens of size 150 x 300 mm were prepared & tested for splitting tensile strength on conventional &geopolymer concrete.

4.5Conventional Concrete

Table 4.4 given below shows the split tensile strengths of conventional concrete for 7^{th}& 28^{th}day .

Table 4.4Split Tensile Strength Of Conventional concrete

Specimen	Method of Curing	Age Of Testing Days	Split Tensile Strength (N/mm^2)
1	Water Curing	7	1.4995
2		28	2.365

4.6 Geopolymer Concrete

Tables 4.5 given below shows the split tensile strengths of geopolymer concrete for 7^{th} & 28^{th} day

Table 4.5Split Tensile Strength Of Geopolymer Concrete

Age of test day	Split Tensile Strength (N/mm^2)	
	Sunlight	Oven
7	2.569	2.598
28	2.679	3.043

4.7 Modulus Of Elasticity

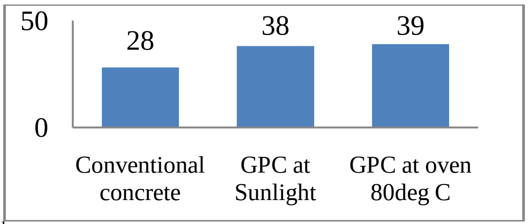
For testing modulus of elasticity ,cylindrical specimens of 150 x 300 mm were used.

Table 4.6 Modulus of Elasticity Of Geopolymer Concrete

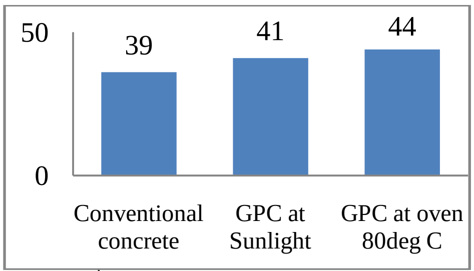
Modulus of elasticity (N/mm^2)			
Age of test day	Conventional	GPC sun curing	GPC Oven curing
7	35000	36500	39444
28	37600	38962	40290

4.7 Comparison OfGeopolymer Concrete And Conventional Concrete

The experimental results obtained were keenly observed and studied well, so as to compare the strength parameters of geopolymer concrete and conventional concrete. On compairing the strength aspects, the GPC was found to be far better than conventional. The strength parameters included compressive strength, tensile strength, and modulus of elasticity. The strength attaining ratios of (7th/28th) days were found to be 0.7,0.9,0.8 for conventional concrete, GPC in sunlight curing, and oven curing respectively. Heat cured GPC resulted in better strength than water cured normal concrete. Compared with ordinary Portland cement concrete, Geopolymers show many advantages. Fly ash-based geopolymer concrete has excellent compressive strength, suffers very little drying shrinkage and low creep, excellent resistance to sulfate attack, and good acid resistance.



7th DAY Compressive Strength



28th DAY Compressive strength

V. CONCLUSIONS

Fly ash (as a basic Si – Al ingredient) based geopolymer concrete was investigated and the following conclusions are made.

- The alternative ranges of constituents of mixture proportions, curing time and curing temperature shall be used to improve the compressive strength of geopolymer concrete.
- As the curing temperature increases, the compressive strength of fly ash based geopolymer concrete also increases.
- Curing time, in the range of 7 – 28 days produces higher compressive strength of fly ash based geopolymer concrete.
- The production of geopolymers may have a relative higher strength and one can easily replace ordinary concrete with geopolymer concrete for precast applications compared to Portland cement.
- Geopolymer concrete helps in the complete replacement of Portland cement.
- The fly ash is considered as a waste material, the low calcium fly ash-based geopolymer concrete is, therefore, cheaper than the Portland cement concrete.
- Geopolymer concrete is a promosing technique in the field of construction field. On behalf of environmental aspects, it didn't utilises cement which produces CO_2 during its production and hence there will not be any effects on the environment.

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