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LOW MOLARITY GEOPOLYMER CONCRETE –A REVIEW

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ABSTRACT Production of ordinary Portland cement (OPC) results in the emission of greenhouse gases such as carbon dioxide. Several studies have been done in substituting ordinary Portland cement with some other binders in making concrete. Geopolymer concrete is one such solution in which cement is effectively replaced by fly ash, ground granular blast furnace slag (GGBS) etc. which is an industrial waste and thus helps in reducing problems on waste disposal and environmental impact. The use of fly ash, GGBS or combination of both along with alkali activators such as sodium hydroxide and sodium silicate in concrete instead of cement said to have strength equal to the ordinary Portland cement concrete. The Geopolymer concrete should be thermally cured or cured at ambient temperature. This paper concentrates on the effective use of Geopolymer with optimum amount of sodium hydroxide (which is not economical) to make Geopolymer concrete cost effective. Materials used are fly ash,ground granulated blast furnace slag,alkali activator solution,superplasticizer and aggregates.

KEYWORDS : Geopolymer Concrete; flyash; GGBS; Molarity; Compressive strength; Flexural Strength

INTRODUCTION

Manufacturing of Portland cement requires many raw materials, a manufacturing plant etc. It is also an energy intensive process that results in release of large amount of carbon dioxide which contributes to greenhouse effect. Production of one ton of Portland cement requires about 2.8 tons of raw materials, including fuel and other materials. Considering the above scenario several studies have been conducted in replacing Portland cement with some other alternatives. Some materials such as fly ash, burned rice husk, ground granulated blast furnace slag(GGBS),etc. said to have good binding properties when activated with alkali activator solutions such as Sodium hydroxide and sodium silicate, Potassium hydroxide and sodium silicate. When these materials react with Alkali activator solution polymerisation reaction takes place that results in formation of three dimensional polymeric chain and ring with Si-O-Al-O bonds. The product thus formed is called geopolymer and the concrete made with this geopolymer is called geopolymer concrete. The above mentioned geopolymers are waste products thus this project not only helps in replacing cement but also helps in management of these waste materials or byproducts.

Studies shows that use of geopolymer can give higher compressive strength than Portland cement concrete but its compressive strength depend on the ratio of alkali activator solution. If sodium hydroxide concentration is more it is said to give higher strength but Sodium hydroxide is costly and its availability is difficult. Hence this study concentrates on how to reduce the amount or molarity of sodium hydroxide without compromising the strength of concrete by trial mixing and proportionating of materials or by using combination of geopolymers. This paper shows how the use of fly ash alone and combination of both influence the strength of geopolymer concrete and the molarity of sodium hydroxide.

Material Required

Fly Ash:

Fly ash is a toxic waste material produced from coal fired power production. It is produced by burning finely ground coal in a boiler to produce electricity and the waste powder is collected in the chimney of plant by using electric precipitator. There are two types of fly ash, Class C and F, based on the type and source of coal that is burned. The presence of calcium in high amount may interfere with the polymerization process and alter the microstructure and hence low-calcium (ASTM Class F) fly ash is preferred as a source material than high-calcium(ASTM Class C) fly ash. The compounds in fly ash are shown in table 1.

Table 1

Compounds	Fly Ash
SiO_2	49.45
Al_2O_3	29.61
Fe_2O_3	10.72
CaO	3.47
MgO	1.3
Na_2O	0.31
K_2O	0.54
TiO_2	1.76
P_2O_5	0.53
Mn_2O_3	0.17
SO_3	0.27

Ground Granulated Blast Furnace Slag:

GGBS is obtained by quenching molten iron slag from blast furnace to water or steam. This byproduct when ground gives fine glassy powder. It has high binding property. It also helps in improving strength and durability of concrete. The compounds in GGBS are shown in table 2.

Table 2

Components	GGBS
SiO_2	33.45
Al_2O_3	13.46
Fe_2O_3	0.31
CaO	41.7
MgO	5.99
Na_2O	0.61
K_2O	0.29
TiO_2	0.84
P_2O_5	-
Mn_2O_3	0.40
SO_3	2.74

Sodium Hydroxide:

A Sodium hydroxide (commonly known as caustic soda) is an inorganic material, it is white in colour, solid, and highly caustic. It is mainly produced by the chloralkali process. There are three process systems to produce sodium hydroxide, including membrane cells, mercury cells, and diaphragm cells. Sodium hydroxide is used in the activating solution of geopolymer concrete mixtures in combination with either sodium silicate or silica fume. Sodium hydroxide pellets are used to enhance polymerisation process of fly ash and to improve its compressive strength.Sodium hydroxide costly and no other best alternative is found for sodium hydroxide in geopolymer concrete. sodium hydroxide (NaOH) and sodium silicate (Na2SiO3) solutions was used as the activator solution. The physical properties of NaOH are listed in table 3.

Table 3

Property	Value
Appearance/ colour	Pellets/white
Boiling point	102°C for 40% aqueous solution
Molecular weight	39.997 g/mol
Specific gravity	1.5

Sodium Silicate:

Sodium silicate solution is also known as water glass.It is available in both liquid and solid form.Sodium silicate is produced mainly by two processes, hydrothermal production and furnace process for sodium silicate. Sodium silicate can be used in combination with sodium hydroxide as the activating solution in geopolymer concrete. Sodium silicate is a dense material.The physical properties of sodium silicate are listed in Table 4.

Table 4

Property	Value
Appearance/ colour	Liquid(gel)/ light yellow
Boiling point	102°C for 40% aqueous solution
Molecular weight	122.06324 g/mol
Specific gravity	1.7

Aggregates:

Fine and coarse aggregates are used in geopolymer concrete. Fine aggregates can be river sand or manufactured sand (commonly river sand is used) and coarse aggregate is crushed stone. The nominal sizes of coarse and fine aggregates commonly used for geopolymer concrete is 20 and 4.5 mm, and the specific gravity of coarse and fine aggregates were 2.72 and 2.64, respectively.

Super Plasticizer:

They are substances used to increase the workability of geopolymer concrete as it is less workable and sticky in nature. It also helps in reducing amount of water. The commonly used plasticizers arenaphthalene,polycarboxylate and Glenium 51. Both naphthalene and polycarboxylate types of superplasticizer improved the slump of the GC. However, a superplasticizer such as Glenium 51, might be beneficial for both compressive strength and water absorption.

Methodology

Preparation Of Alkali Activator Solution

Sodium hydroxide(NaOH) in pellet form with 98% purity and Sodium silicate solution(Na2O = 16.84%, SiO2 = 35.01% and water = 46.37% by mass) was used.Water available in laboratory was used to prepare NaOH solution. In previous works, sodium hydroxide (NaOH) solution was prepared by dissolving pellets in 1 litre of water to obtain sodium hydroxide solution. In order to avoid evolution of excessive heat due to exothermic reaction during casting it was prepared one day prior to use. Sodium silicate solution is mixed with the sodium hydroxide solution at the time of casting. The ratio of Na2SiO3 to NaOH ranges from 0.17 to 3.It is prepared in different molarities.

Mixing And Casting

The mixing procedure used for geopolymer concrete is similar to that of conventional OPC concrete. Mixing of all the materials have been done in the laboratory at room temperature.

i) Fly Ash Based Geopolymer Concrete

Coarse aggregate and fine aggregate is first dry mixed. After this the alkali activator solution is added and then mixed again. Since there is no code available for mix proportioning trial mixes are taken. Super plasticizer with a dosage of 1.5% by mass of the fly ash can be added into geopolymer paste mixture to improve the workability geopolymer concrete and also to reduce amount of water.

Formould preparationmould releasing agents such as oil or wax is used to remove the sample from mould easily. This makes demoulding easier and provides a smooth surface when concrete becomes hard. It also prevents mould from corroding.For compaction of the concrete specimens, each layer was given 25 to 35 manual strokes using 20 mm rod. After the casting, the concrete specimen was kept at roomtemperature as per the decided rest period.

ii) Fly ash + GGBS

Procedure is same as above but 50% or above GGBS with acombination of flyash is used.

Curing

Water curing is not found to be effective for geopolymer concrete. For geopolymer concrete curing methods such as ambient temperature curing, steam curing, heat curing is commonly used. For the practical application of geopolymer concrete in buildings major studies is done on ambient curing or normal temperature curing. It is found that curing temperature and duration is important in the activation of geopolymer concrete to produce higher compressive strength. The optimum curing temperature to be found is at 80 °C according to research.The fly ash geopolymer shows low reactivity at ambient curing condition and long-term to achieve target strength.

Properties Of Geopolymer Concrete

Fresh Properties

Fresh properties of concrete include workability and setting time.

Workability:

Workability of geopolymer concrete is the property of freshly prepared geopolymer concrete which determines the ease with which it can be mixed, placed and consolidated. It depends on the amount of super plasticiser and the ratio of alkali activator solution added to it. Workability is tested by slump test, flow table test, compaction factor test, Vee Bee consistometer test.

Setting Time:

Setting time of geopolymer concrete depends on many factors such as mix proportion, curing temperature, amount of alkali activator solution, amount of super plasticizer etc.

Hardened Properties:

Hardened properties of geopolymer concrete includes compressive strength, flexural strength, split tensile strength, Acid resistance , Freeze and thaw, durability, fire resistance, modulus of elasticity etc. This study concentrates on compressive strength and flexural strength.

Compressive Strength:

Compressive strength test is conducted using a 1000 kN-3000KN capacity compression testing machine on hardened geopolymer concrete specimens at 3, 7 and 28 days. GPC attains higher early strength when compared with ordinary Portland cement concrete with the use of low molarity alkaline solutions. Some other studies shows that the compressive strength of geopolymer concrete increases with increase in total aggregate content up to a value of 70% . Molarity NaOH is one of the main factors found to be influencing compressive strength of geopolymer concrete. Temperature is another factor that affects compressive strength.

Flexural And Split Tensile Strength:

When Flexural and split tensile strength of GPC also depend on curing temperature, alkali activator ratio aggregate content etc. It is found that similar grades of OPC concrete and GPC when compared,the flexural strength of GPC is found to be 1.4 times higher and split tensile strength 8%-12% greater than that of OPC concrete and applies to both ambient and heat cured geopolymer concrete.

CONCLUSIONS

Fly ash based geopolymer concrete found to attain its strength by 28th day of curing. When temperature is high, the strength of concrete found to be increasing but above certain temperature it was decreasing. It was not much effective in ambient temperature.Workability and setting time was influenced by the super plasticizer and alkali activator solution. Setting time is found to be faster than OPCC.

Fly ash based geopolymer concrete attained its maximum strength when the molarity of NaOH was around 12 or above. But when molarity increases above 14 the strength of GPC was found to be reducing.

GGBS + Fly ash based geopolymer concrete found to attain its Strength developed at 7th day was found to be 86% of 28th day strength which is of a great significance. It attained its maximum strength even in ambient temperature or a lesser temperature than fly ash based GPC.Due to addition of 50% of GGBS the setting of concrete found to be even faster than fly ash based GPC. No considerable change in workability was found with addition of super plasticizer compared to fly ash based GPC.As GGBS is highly cementitious in nature it helped in reducing the amount or molarity of NaOH considerably. High strength was attained under a molarity below 10.

Both the geopolymer concrete was able to attain an early strength compared to ordinary Portland cement concrete. Geopolymer is best alternative for replacing cement. If the molarity of NaOH can be reduced or any alternative substitute can be found, then geopolymer concrete can be made economical and made into use. Further studies are required for the effective replacement of Cement by Geopolymers.

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