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COMPARISON OF GEOPOLYMER CONCRETE WITH CEMENT CONCRETE

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ABSTRACT

Cements which are used for construction work are generally OPC or PPC and the production of this kind of cement not only consumes huge amount of the natural resources i.e., limestone and fossils fuel but also produces almost 0.9 tons of CO_2 for 1 ton cement clinker production. Also, world cement production generates 2.8-billion-ton man-made greenhouse gas annually. Geo-polymer concrete is totally different in materials and chemistry which is synthesized from waste material like fly-ash (Class F or C). It is an inorganic 3D polymer which is synthesized by activation of aluminosilicate source like fly ash (waste materials). Due to its high mechanical properties combined with substantial chemical resistance, low shrinkage and creep and environment friendly nature (very less amount of CO, production in comparison with OPC), it is a novel construction material for future. It was seen that geo-polymer concrete made of fully Fly-ash or partial replacement results with 80% reduction in CO, emission compared to OPC. Exhaustive studies in various processes and parameters show that geopolymer concrete is superior to cement concrete, which is a very good candidate material for future.

INTRODUCTION

1.1 GENERAL

The production of one ton of cement emits approximately one ton of carbon dioxide to the atmosphere which lends to global warming conditions. A need of present status is, should we build additional cement manufacturing plants or find alternative binder systems to make concrete? On the other scenario huge quantity of fly ash are generated around the globe from thermal power plants and generally used as a filler material in low level areas. Alternative binder system with fly ash to produce concrete eliminating cement is called "Geopolymer Concrete"

Geopolymers are a type of inorganic polymer that can be formed at room temperature by using industrial waste or by-products as source materials to form a solid binder that looks like and performs a similar function to PPC. Geopolymer binder can be used in applications to fully or partially replace PPC with environmental and technical benefits, an 80-90% reduction in CO_2 emissions and improved resistance to fire and aggressive chemicals.

Geopolymer cement is made from aluminium and silicon, instead of calcium and silicon. The sources of aluminium in nature are not present as carbonates and therefore, when made active for use as cement, do not release any quantities of CO. The most readily available raw materials containing aluminium and silicon are fly ash and slag.

The main process difference between PPC and geopolymer cement is that PPC relies on a high-energy manufacturing process that imparts high potential energy to the material via calcination. This means the activated material will react readily with a low energy material such as water. On the other hand, geopolymer cement uses very low energy materials, like fly ashes, slags and other industrial wastes and a small amount of high chemical energy materials (alkali hydroxides) to bring about reaction only at the surfaces of particles to act as a glue.

Geopolymer binders are used together with aggregates to produce geopolymer concretes which are ideal for building and repairing infrastructures and for precasting units, because they have very high early strength, their setting times can be controlled and they remain intact for very long time without any need for repair. The properties of geopolymer include high early strength, low shrinkage, freeze-thaw resistance, sulphate resistance and corrosion resistance.

1.2 WHAT IS A GEOPOLYMER?

The term geopolymer was coined by Davidovits in 1978 to represent a broad range of materials characterized by chains or networks of inorganic molecules (Geopolymer Institute 2010). There are nine different classes of geopolymers, but the classes of greatest potential application for transportation infrastructure are comprised of alumino silicate materials that may be used to completely replace Portland cement in concrete construction (Davidovits 2008). These geopolymers rely on thermally activated natural materials (e.g., kaolinite clay) or industrial by-products (e.g., fly ash or slag) to provide a source of silicon (Si) and aluminium (AI), which is dissolved in an alkaline activating solution and subsequently polymerizes into molecular chains and networks to create the hardened binder. Such systems are often referred to as alkali-activated cements or inorganic polymer cements.

As stated by Rangan (2008), "The polymerization process involves a substantially fast chemical reaction under alkaline conditions on silicon-aluminium minerals that results in a three-dimensional polymeric chain and ring structure...."

The ultimate structure of the geopolymer depends largely on the ratio of Si to Al (Si:Al), with the materials most often considered for use in transportation infrastructure typically having an Si:Al between 2 and 3.5 (Hardjito et al. 2004; Davidovits 2008). This type of geopolymer will take one of the following three basic forms (where "sialate" is an abbreviation for silicon-oxo-aluminate) (Davidovits 2008):

- Poly (sialate) Si:Al = 1, which has [-Si-O-AIO-] as the repeating unit.
- Poly (sialate-siloxo) Si:Al = 2, which has [-SIO-Al-O-Si-O-] as the repeating unit.
- Poly (sialate-disiloxo) Si:Al = 3, which has [-Si-O-Al-O-Si-O-Si-O-] as the repeating unit.

Although the mechanism of polymerization is yet to be fully understood, a critical feature is that water is present only to facilitate workability and does not become a part of the resulting geopolymer structure. The geopolymer can be in the form of -Si-O-Al-O- or -Si-O-Al-O-Si-O- or Si-O-Al-O-Si- O-Si-O-. The chemical reaction behind the formation of geopolymer areas is as follows

$n(Si_2O_5,Al)+2nSiO_2+4nH_2O+NaOH$ or KOH-Na,K-n(OH)-Si-O-Al-O-SI-$(OH)_3$,
(Si-Al materials) |
$(OH)_2$
(Geopolymer precursor)

| | |
(OH),-Si-O-Al-O-Si-(OH); + NaOH or KOH (Na,K)-(-Si-O-Al-O-Si-O)$+4nH_2O$ $(OH)_2$;

| | |
O O O
| | |

From the above equation it's clear that water doesn't plays any role in the polymerization process because it was expels from the chemical reaction.

In other words, water is not involved in the chemical reaction and instead is expelled during curing and subsequent drying. This is in contrast to the hydration reactions that occur when portland cement is mixed with water, which produce the primary hydration products calcium silicate hydrate and calcium hydroxide. This difference has a significant impact on the mechanical and chemical properties of the resulting geopolymer concrete, and also renders it more resistant to heat, water ingress, alkali-aggregate reactivity, and other types of chemical attack (Davidovits 2008; Lloyd and Rangan 2009).

Conceptually, the formation of geopolymers is quite simple. In the case of geopolymers based on alumino silicate, suitable source materials must be rich in amorphous forms of Si and Al, including those processed from natural mineral and clay deposits (e.g., kaolinite clays) or industrial byproducts (e.g., low calcium oxide ASTM C618 Class F fly ash or ground granulated blast furnace slag) or combinations thereof. In the case of geopolymers made from fly ash, the role of calcium in these systems is very important, because its presence can result in flash setting and therefore must be carefully controlled (Lloyd and Rangan 2009).

The source material is mixed with an activating solution that provides the alkalinity (sodium hydroxide or potassium hydroxide are often used) needed to liberate the Si and Al and possibly with an additional source of silica (sodium silicate is most commonly used). The temperature during curing is very important, and depending upon the source materials and activating solution, heat often must be applied to facilitate polymerization, although some systems have been developed that are designed to be cured at room temperature (Hardjito et al. 2004; Davidovits 2008, Rangun 2008; Tempest et al. 2009).

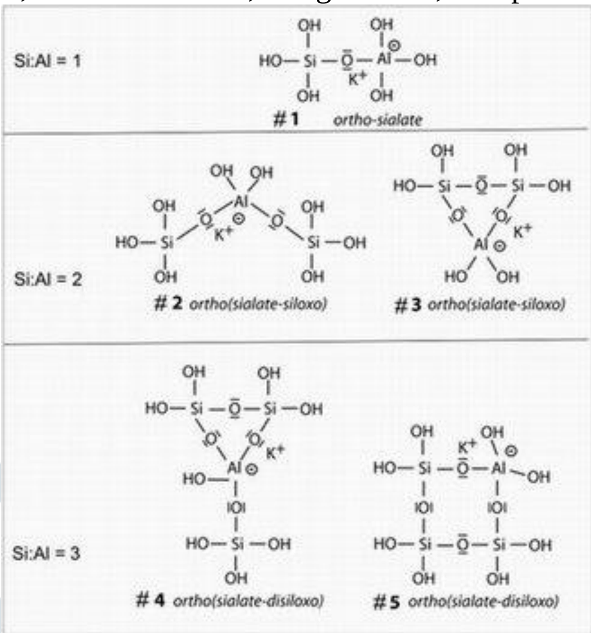


Fig: - 1 Structure of Geopolymer

1.3 OBJECTIVE

- To replace cement in concrete and make it eco friendly and cost efficient.
- To compare the compressive strength between a normal PPC concrete and a Geopolymer concrete.
- To compare the split tensile strength between a normal PPC concrete and a Geopolymer concrete.
- To verify and check whether the Geopolymer concrete can be used for construction purposes.

LITERATURE REVIEW

A literature review was conducted in order to gain a deeper understanding of the topic of this research. GPC broadly is investigated, including the materials, reactions and curing requirement. The strength-influencing parameters were researched and the theoretical similarities and differences between PPC concrete and GPC were examined. PPC concrete mix design is outlined then the requirement for a GPC mix design process is investigated.

RAJAMANE,2012

Results indicated that the water absorption decreased with an increase in the strength of the concrete and the fly ash content. Based on summary of extensive studies conducted, a simple trial and error method was suggested to design the geopolymer concrete mixes (Rangan, 2008). The geopolymer concrete (GPC) was superior to plain Portland cement concrete (PPCC) when these mixes were subjected to sodium sulphate and magnesium sulphate solutions (Rajamane et al., 2012)

WALLAH, 2006

Wallah have shown that geopolymer composites possesses excellent durability properties in a study conducted to evaluate the long term properties of fly ash based geopolymers (Wallah, 2006). The geopolymer has a very good resistance in acid media in terms of weight loss and residual compressive strength (Suresh Thokchom et al., 2009). The performance on geopolymer concretes in aggressive environments was studied using tests on absorption and acid resistance (Manu Santhanam et al., 2008).

DAVIDOVITS, 1994

Davidovits found that geopolymer cements has very low mass loss of 5%- 8% when samples were immersed in 5% sulphuric acid and hydrochloric acid solutions. In contrast, Portland cements were completely destroyed in the same environment (Davidovits, 1994). Bakharev studied the resistance of geopolymer materials prepared from fly ash against 5% sulphuric acid up to 5 months exposure and concluded that geopolymer materials have better resistance than ordinary cement counterparts (Bakharev 2005 (a) and (b)).

In contrast to portland cement, most geopolymer systems rely on minimally processed natural materials or industrial byproducts to provide the binding agents. Since portland cement is responsible for upward of 85 percent of the energy and 90 percent of the carbon dioxide attributed to a typical ready-mixed concrete (Marceau et al. 2007), the potential energy and carbon dioxide savings through the use of geopolymers can be considerable. Consequently, there is growing interest in geopolymer applications in transportation infrastructure.

Although geopolymer technology is considered new, the technology has ancient roots and has been postulated as the building material used in the construction of the pyramids at Giza as well as in other ancient construction (Davidovits 1984; Barsoum and Ganguly 2006; Davidovits 2008). Moreover, alkali-activated slag cement is a type of geopolymer that has been in use since the mid-20th century

PRELIMINARY TESTING

3.1 SPECIFIC GRAVITY OF SAND

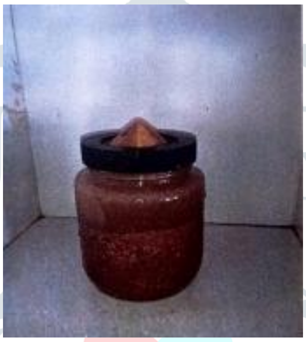


FIG 2: SPECIFIC GRAVITY TEST ON SAND

TRAIL 1

Empty bottle (W_1) = 0.701 kg
Sand + bottle (W_2) = 1.33 kg
Sand + bottle (W_3) = 1.98 kg
Bottle + Water (W_4) = 1.59kg

TRAIL 2

Empty bottle (W_1) =0.0.698 kg
Sand + bottle (W_2) =1.368 kg
Sand + bottle (W_3) = 1.98 kg
Bottle + Water (W_4) = 1.59kg

TRAIL 3

Empty bottle (W_1) = 0.702 kg
Sand + bottle (W_2) = 1.393 kg
Sand + bottle (W_3) = 1.98 kg
Bottle + Water (W_4) = 1.561 kg

CALCULATION

Weight of sand in pycnometer (W_2-W_3) = 1.33-0.70
=0.629

Weight of equal volume of Water (W_4-W_1) – (W_3-W_2)
= 0.239kg

$$\text{Specific gravity} = \frac{\text{Weight of sand in Pycnometer}}{\text{Weight of equal volume of water}}$$

Specific gravity = 2.65

3.2 SPECIFIC GRAVITY OF 20MM AGGREGA

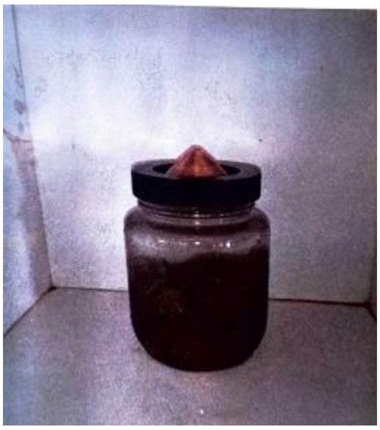


FIG 3: SPECIFIC GRAVITY TEST ON COARSE AGGREGATE

TRAIL 1

Empty bottle (W_1) =0.702 kg
Sand + bottle (W_2) =1.438 kg
Sand + bottle (W_3) = 2.05 kg
Bottle + Water (W_4) = 1.58 kg

TRAIL 2

Empty bottle (W_1) = 0.702 kg
Sand + bottle (W_2) =1.418 kg
Sand + bottle (W_3) = 2.03 kg
Bottle + Water (W_4) = 1.5 kg

TRAIL 3

Empty bottle (W_1) = 0.701 kg
Sand + bottle (W_2) =1.458 kg
Sand + bottle (W_3) = 2.07 kg
Bottle + Water (W_4) = 1.56 kg

CALCULATION

Weight of aggregate in Pycnometer(W_2-W_1) = 1.438-0.702
= 0.736 kg

Weight of equal volume of water (W_4-W_1) - (W_3-W_2) = 0.266kg

Specific gravity= Weight of sand in Pycnometer / Weight of equal volume of water

Specific gravity = 2.8

3.3 CONSISTENCY TEST ON CEMENT

FIG 4: VICAT APPARATUS

Cement – 500 grams
Initial amount of water 28% = 140 ml

TABLE 1: CONSISTENCY TEST ON CEMENT

Percentage of water	Weight of water	Reading
28	140	130
29	145	27
30	150	15
31	155	9
32	160	4

3.4 SETTING TIME TEST

500 grams of cement
160 x 0.85= 136 ml

TABLE 2: SETTING TIME TEST ON CEMENT

Time	Penetration (mm)
0	0
5	2
10	2
15	2
20	3
25	3
30	3
35	3
40	4
42	4
44	4
46	7

Initial time = 45 minutes

3.5 WATER ABSORPTION TEST ON COARSE AGGREGATE

Weight of oven dried (W_1) =200g
Weight of saturated specimen (W_2) = 205g
Weight of water absorbed (W_2- W_1) = 5g
Percentage of water absorption = (W_2- W_1)/W, x 100 = 2.5%

Therefore, water absorption of coarse aggregate = 2.5%

3.7 Water absorption test on Fine aggregate

Weight of oven dried (W_1) =200g

Weight of saturated specimen (W_2) =205g
Weight of water absorbed (W_2- W_1) = 5g
Percentage of water absorption =(W_2-W_1)/W, x 100
= 2.5%

Therefore water absorption of fine aggregate = 2.5%

3.8 CHEMICAL TESTING

Preparation of sodium hydroxide solution.

AIM

To prepare 16 M concentration of sodium hydroxide (NaoH)
Molarity of sodium hydroxide (NaoH) = 40
Amount of sodium pellets required for one litre - 40 x16 =640 g
Sodium hydroxide solution was prepared for 2.129 kg
Therefore amount of solid required is 945g
Amount of water content in solution is 1.18 kg

FIG 5: PREPARATION OF SODIUM HYDROXIDE SOLUTION

METHODOLOGY

4.1 COLLECTION OF MATERIALS

The following materials have been used in the experimental study (Veeresh, 2011)
1. Fly Ash (Class F) collected from Ennore Thermal power plant.
2. Fine aggregate: Sand confirming to Zone-III of IS:383-1970.
3. Coarse aggregate: Crushed granite metal confirming to IS:383-1970.
4. Water: Clean Potable water for mixing.
5. Alkaline Media: Specific gravity of
   a. Sodium Hydroxide (NaOH) = 1.16
   b. Sodium Silicate (Na2SiO3) = 1.57

Tests were conducted on specimen of standard size as per IS: 516 (1959)- **Method of Tests for Strength of Concrete**.

SODIUM HYDROXIDE

Generally, NaOH is available in market in pellets or flakes form with 96% to98% purity where the cost of the product depends on the purity of the material. The solution of NaOH was formed by dissolving it in water with a molarity of 16M. It is recommended that the NaOH solution should be made 24 hours before casting and should be used with 36 hours of mixing the pellets with water as after that it is converted to semi-solid state.

SODIUM SILICATE

It is also known as water glass which is available in the market in gel form. The ratio of SiO, and Na_2O in sodium silicate gel highly effects the strength of geopolymer concrete. Mainly it is seen that a ratio ranging from 2 to 2.5 gives a satisfactory result.

ALKALINE LIQUID

According to Prof. J. Davidovits the alkaline liquid should be made prior to one day before mixing because at the time of mixing of Na-SiO, with NaOH solution it generates a huge amount of heat and the polymerization takes place by reacting with one another, which will act as a binder in the geopolymer concrete

COARSE AGGREGATE

Coarse aggregates used in case of cement concrete can be used in case of Geo-polymer concrete (GPC) also where the coarse aggregate should conform to IS-383-1970.

4.2 MIXING PROCEDURE

Rattanasak et al [1] proposed that the mixing of geopolymer is of two types i.e. normal mixing & separate mixing. In case of normal mixing fly ash, sodium hydroxide solution & sodium silicate solution and aggregate are mixed at a time but in case of separate mixing the fly ash was first mixed with the sodium hydroxide solution for the first 10 minutes and then the sodium silicate solution with aggregate is mixed with the above mix. Different test results show that the separate mix gives a higher strength in comparison with the normal mix. Although many authors consider that the mixing should be as follows:- first the fly ash, coarse aggregate and fine aggregate should be mixed properly and after proper dry mix then the sodium hydroxide and the sodium silicate solution should be added to the dry mix according to the proper proportions required to attain a good compressive strength and then the mix should be properly compacted in three layers using the standard tamping rod and by vibrating table.

Type of test conducted	Size of Specimen (mm)	No of Specimen casted
Compressive Strength	150x150x150	9
Split tensile test	100x200	6

FIG 6: CASTING OF CUBES

4.3 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 of NaOH (16M). Alkaline activator with the combination of NaOH and Na,SiO, 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 SiO/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 (Hardjito, 2004 and Mustafa Bakri, 2011). For easy working of fresh GPC mixes superplasticizer Conplast SP-430 was used. After casting the specimens, they were kept in rest period for two days and then they were demoulded. The demoulded specimens were kept at 60° C for 24 hours in an oven.

Mixing of all the materials were done manually in the laboratory at room temperature. The fly-ash and aggregates were first mixed homogeneously as shown in fig. 1 and then the alkaline solutions which were made one day before and superplasticiser were added to the mixture of fly ash and aggregates. The Potassium Hydroxide and the sodium Hydroxide solutions were first mixed with each other and stirred to obtain a homogeneous mixture of the solutions before adding them to the solids. Fig.2 shows adding of alkaline solution into the dry mixtures.The mixing of total mass was continued until the binding paste covered all the aggregates and mixture become homogeneous and uniform in colour.

A Pan Type concrete mixer that offers mechanical sharing action can be used for obtaining uniform mixture with less effort. The fresh geopolymer concrete was used to cast cubes of size 150 x 150 x 150mm to determine its compressive strength. The specimens were prepared according to the method followed by Hardjito et. al.[2]. Each cube specimen was cast in three layers by compacting manually as well as by using vibrating table. Each layer received 25 strokes of compaction by standard compaction rod for concrete, followed by further paction on the vibrating table. The specimens were wrapped by plastic sheet to prevent loss of moisture and placed in an oven. Since the process of geopolymerisation needs curing at high temperature, the specimens were cured at temperature of 60° C for 24 hours in the oven, as shown in fig. 4 They were temperature cured for 24 hours then left to open air (room temperature 25°C) in the laboratory until testing.

FIG 7: CURING OF GEO POLYMER CONCRETE

4.4 MIX DESIGN OF M-40 GRADE CEMENT

Test data materials

1. Specific gravity of cement = 3.15
2. Compressive strength of cement =36.3
3. Specific gravity of aggregate =2.8
4. Specific gravity of sand =2.65

STEP 1

TARGET MEAN COMPRESSIVE STRENGTH

As per IS code 10262(1982) RECOMMENDED GUIDELINES FOR CONCRETE MIX DESIGN

$F_{ckt} = f_{ck} + t_s$

fax = 40 N/mm² t_s= 1.65 x 6.6

=50.89

Target mean compressive strength = 50.89 N/mm²

STEP 2

SELECTION OF WATER CEMENT RATIO

As per IS code 10262 (1982) RECOMMENDED GUIDELINES FOR CONCRETE MIX DESIGN

The water cement ratio corresponding to target mean strength of 45.39 n/m² is 0.35

Water cement ratio = 0.3

Therefore water cement ratio = 0.3

STEP 3

QUANTITY OF WATER

Approximate sand water content w/c = 0.35

Workability=0.8 c.f.

Since we use 20 mm aggregate, so the water content = 180 kg

STEP 4

WEIGHT OF CEMENT

W/C= weight of water / weight of cement

0.3=180/Weight of cement

Therefore weight of cement = 600 kg/m³

STEP 5

AMOUNT OF AIR CONTENT

Maximum size of aggregate = 20mm

Entrapped air as percentage of concrete -2.0

Hence, the amount of voids in Im^3 of concrete using 20 mm aggregate is 2%. **Therefore the amount of air content = 2% per m^3.**

STEP 6

VOLUME OF CONCRETE IN 1 M³

V=Vc +VA + Vw + Vv

V=Ve+ VA + Vw + 0.02

Density of cement = Mass / Volume

Specific gravity of cement = density of cement/ density of water

3.1 = Ve/1000

Density of cement = 3.1 x 1000

=3100

Therefore the volume of concrete (V_c) is density of cement = mass / V_c

V_c=600/3100

Therefore volume of concrete Vc=0.193 m^3.

STEP 7

VOLUME OF WATER

Density of water = Mass/Volume

1000 =180/Volume

Vw = 180/1000

= 0.18 m^2

Therefore volume of water (Vw)=0.18 m³

STEP 8

VOLUME OF AGGREGATE

V=Vc + VA +Vw + Vv

VA=0.607

Therefore volume of aggregate (V)=0.607 per m^3

STEP 9

VOLUME OF FINE AGGREGATE

VFA =25% of volume of aggregate

=25/100 x 0.607

= 0.25 x 0.607

= 0.152 m^3

STEP 10

VOLUME OF COARSE AGGREGATE

V.C.A.= $V_A - V_{FA}$

=0.607-0.512

= 0.455 m^3

Therefore volume of coarse aggregate (Ve) = 0.455 per m^3.

STEP 11

WEIGHT OF FINE AGGREGATE

Density of fine aggregate = Mass / Volume

Density = Specific gravity of F.A. x 1000

= 2.65 x 1000

= 2650 kg/m^3

Density of fine aggregate = Mass/Volume

2650 = Mass/0.152

Mass =2650 x 0.512

Therefore weight of fine aggregate = 402.8 kg/m^3.

STEP 12

WEIGHT OF COARSE AGGREGATE

Density of coarse aggregate = Mass / Volume

Density = Specific gravity of C.A. x 1000

= 2.8 x 1000

= 2800 kg/m^3

Density of C.A. =Mass / Volume

2800 = Mass/0.455

Mass = 2800 x 0.455

= 1247 kg/m^3

Weight of coarse aggregate = 1274 kg/m^3.

Step 13

Ratios

W: C: F.A.: C.A.

Weight of water : Weight of cement : Weight of F.A. : Weight of C.A. Weigh of cement Weight of cement Weight of cement Weight of cement

$\frac{180}{600} : \frac{600}{600} : \frac{402.8}{600} : \frac{1274}{600}$

0.3 : 1 : 0.67 : 2.12

4.5 MIX DESING PROCEDURE OF G.P.C. MIX

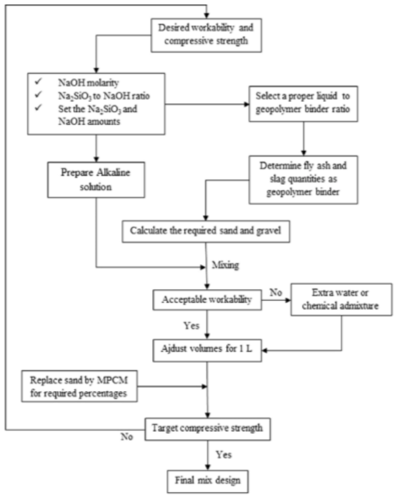


FIG 8: MIX DESING PROCEDURE FOR GPC

Assume density of aggregate as unit weight of concrete-2400 kg/m
Mass of combined aggregate = 75%-80%
= 2400 x 0.77 =1848 kg/m
Remaining Mass =2400-1848-552 kg/m³
Alkaline/liquid ratio = 0.4;
Mass of fly ash =552/(1+0.4) = 394.28 kg
Mass alkaline liquid =552-394.28 kg/
Mass of sodium hydroxide = 112.64 kg/m³

Table 3: Mix Proportion of GPC

Materials	**Mass (kg/m^3)**
Fly- Ash	394.3
Fine aggregate	646.8
Coarse aggregate	1201.2
Sodium Hydroxide	45.06
Sodium Silicate	112.64
Super Plasticizer	5.91
Extra water	39.42

TEST RESULTS

5.1 COMPRESSIVE STRENGTH TEST ON PPCC

COMPRESSIVE STRENGTH TEST ON 7" DAY FOR PPCC

FIRST CUBE

Ultimate load =550 KN
Area of specimen = 150 x 150 mm
Compressive strength =Ultimate load/Area
=550 x 10/150 x150

COMPRESSIVE STRENGTH = 24.44 N/mm²

SECOND CUBE

Ultimate load = 500 KN
Area of the specimen = 150 x 150 mm
Compressive strength = Ultimate load/ Area
=500 x 10/150 x 150

COMPRESSIVE STRENGTH = 22.22 N/mm²

THIRD CUBE

Ultimate load= 530 KN
Area of the specimen = 150 x 150 mm
Compressive strength = Ultimate load/Area
= 530 x 102/150 x 150

COMPRESSIVE STRENGTH = 23.52 N/mm²

COMPRESSIVE TEST ON 14TH DAY FOR PPCC

FIRST CUBE

Ultimate load = 800 KN
Area of specimen = 150 x 150 mm
Compressive strength = Ultimate load / Area
= 800 x 10^3/ 150x150

COMPRESSIVE STRENGTH= 35.55. N/mm²

SECOND CUBE

Ultimate load= 780 KN
Area of the specimen = 150 x 150 mm
Compressive strength = Ultimate load / Area
=780 x 10^3/150 x 150

COMPRESSIVE STRENGTH = 34.66 N/mm2

THIRD CUBE

Ultimate load = 820 KN
Area of the specimen = 150 x 150 mm
Compressive strength = Ultimate load/Area
= 820 x 10/150 x 150

COMPRESSIVE STRENGTH =36.44 N/mm²

COMPRESSIVE STRENGTH TEST ON 28 DAY FOR PPCC

FIRST CUBE

Ultimate load=950 KN
Area of specimen = 150 x 150 mm
Compressive strength = Ultimate load/Area
=950 x 10^3/150 x150

COMPRESSIVE STRENGTH =42.22 N/mm²

SECOND CUBE

Ultimate load =920 KN

Area of the specimen = 150 x 150 mm
Compressive strength= Ultimate load / Area -920 x 10^3/150 x 150

COMPRESSIVE STRENGTH =40.88 N/mm²

THIRD CUBE

Ultimate load=915 KN
Area of the specimen =150 x 150 mm
Compressive strength = Ultimate load/Area
=915 x 10"/150 x 150

COMPRESSIVE STRENGTH = 40.66 N/mm²

FIG 9: COMPRESSIVE STRENGTH TESTING ON PPCC

TABLE 4: COMPRESSIVE STRENGTH OF PPCC

S.NO	Days of curing	Load (KN)	Calculation (Ultimate load/ Area)	Compressive Strength N/mm^2	Average
1.	7	550	550 / (150x150)	24.44	25.03
2.	7	500	500/ (150x 150)	22.22	
3.	7	530	530 / (150 x 150)	23.52	
4.	14	800	800 / (150x150)	35.55	29.47
5.	14	780	780 / (150 x 150)	34.66	
6.	14	820	820 / (150 x 150)	36.44	
7.	28	950	950 / (150 x 150)	42.22	37.47
8.	28	920	920 / (150 x 150)	40.88	
9.	28	915	915 / (150 x 150)	40.66	

5.2 COMPRESSIVE STRENGTH TEST ON GEOPOLYMER CONCRETE
COMPRESSIVE STRENGTH TEST ON 7TH DAY FOR GPC
FIRST CUBE

Ultimate load-550 KN
Area of specimen 150 x 150 mm
Compressive strength = Ultimate load/Area
=550 x 102/150 x150.

COMPRESSIVE STRENGTH = 24.44 N/mm²
SECOND CUBE

Ultimate load 560 KN
Area of the specimen = 150 x 150 mm
Compressive strength = Ultimate load/Area
=560 x 102/150 x 150

COMPRESSIVE STRENGTH= 24.88 N/mm²
THIRD CUBE

Ultimate load=580 KN
Area of the specimen = 150 x 150 mm

Compressive strength = Ultimate load/Area

=580 x 10"/150 x 150

COMPRESSIVE STRENGTH = 25.77 N/mm²

COMPRESSIVE TEST ON 14TH DAY FOR GPC

FIRST CUBE

Ultimate load= 650 KN

Area of specimen = 150 x 150 mm

Compressive strength = Ultimate load/Area

= 650 x 10 / 150x150

COMPRESSIVE STRENGTH = 28.88 N/mm²

SECOND CUBE

Ultimate load =680 KN

Area of the specimen = 150 x 150 mm

Compressive strength = Ultimate load/Area

= 680 x 102/150 x 150

COMPRESSIVE STRENGTH = 30.22 N/mm²

THIRD CUBE

Ultimate load = 650 KN

Area of the specimen = 150 x 150 mm

Compressive strength = Ultimate load/Area

= 650 x 10^3/150 x 150

COMPRESSIVE STRENGTH = 28.88 N/mm²

COMPRESSIVE STRENGTH TEST ON 28TH DAY FOR GPC

FIRST CUBE

Ultimate load=820 KN

Area of specimen = 150 x 150 mm

Compressive strength = Ultimate load/Area

=820 x 103/150 x150

COMPRESSIVE STRENGTH = 36.44 N/mm²

SECOND CUBE

Ultimate load =860 KN

Area of the specimen = 150 x 150 mm

Compressive strength =Ultimate load/Area

= 860 x 10^3/150 x 150

COMPRESSIVE STRENGTH=38.22 N/mm²

THIRD CUBE

Ultimate load=850 KN

Area of the specimen = 150 x 150 mm

Compressive strength = Ultimate load/Area

= 850 x 10^3/150 x 150

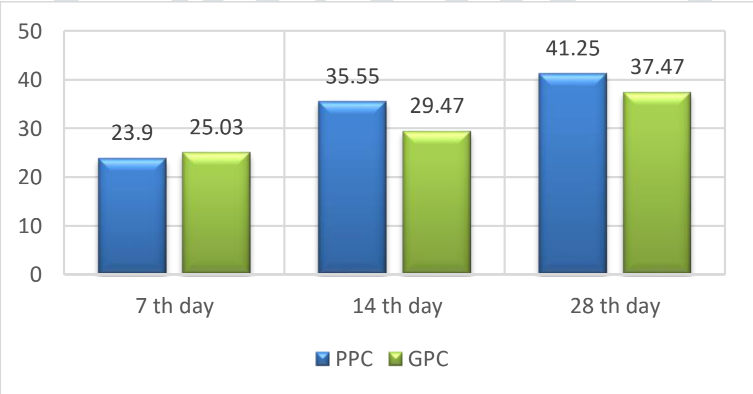
COMPRESSIVE STRENGTH = 37.77 N/mm²

FIG 5: COMPRESSIVE STRENGTH OF GPC

TABLE 5: COMPRESSIVE STRENGTH OF GPC

S.NO	Days of curing	Load (KN)	Calculation (Ultimate load/ Area)	Compressive Strength N/mm^2	Average
1.	7	550	550 / (150x150)	24.44	25.03
2.	7	560	560/ (150x 150)	24.88	
3.	7	580	580 / (150 x 150)	25.77	
4.	14	650	650 / (150x150)	28.88	29.47
5.	14	680	680 / (150 x 150)	30.22	
6.	14	660	660 / (150 x 150)	29.33	
7.	28	820	820 / (150 x 150)	36.44	37.47
8.	28	860	860 / (150 x 150)	38.22	
9.	28	850	850 / (150 x 150)	37.77	

FIG 11: COMPRESSIVE STRENGH OF GPC VS PPC



5.3 SPLIT TENSIL TEST

TABLE 6: SPLIT TENSIL STRENGTH TEST OF PPCC

S.NO	DAYS OF CURING	LOAD (KN)	Calculation (Ultimate load / area	Split tensile strength (N/mm^2)	Average
1.	28	420	420/ (3.14 x 150 x 300)	2.9	2.76
2.	28	400	400/ (3.14 x 150 x 300)	2.8	
3.	28	380	380/ (3.14 x 150 x 300)	2.6	

TABLE 7: SPLIT TENSIL STRENGTH TEST OF GPC

S.NO	DAYS OF CURING	LOAD (KN)	Calculation (Ultimate load / area	Split tensile strength (N/mm^2)	Average
1.	28	420	360/ (3.14 x 150 x 300)	2.5	2.33
2.	28	400	330/ (3.14 x 150 x 300)	2.3	
3.	28	380	320/ (3.14 x 150 x 300)	2.2	

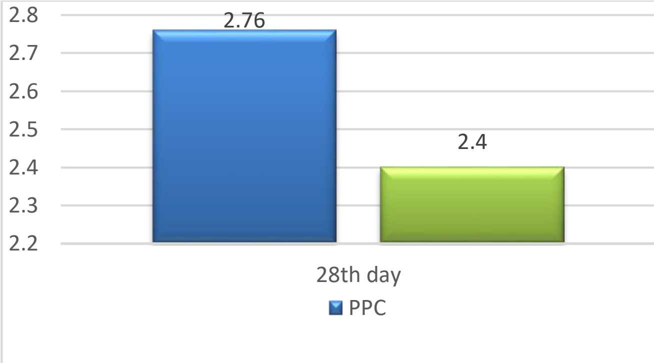


FIG 12: SPLIT TENSILE STRENGTH OF PPCC VS GPC

DISCUSSIONS

1. Compressive strength of GPC is almost the same as M40 grade concrete
2. Split Tensile Strength of GPC decreases over cement concrete by 3 N/mm²
3. It has been observed that geopolymer concrete obtains 67% of its strength within 7 days where as compared to cement it obtains 56%.
4. The curing process of geopolymer is quite simple and can be done both in ambient as well as in heating process which is quite simpler process compared to cement concrete.

6.1 ECONOMIC ANALYSIS

Low calcium fly ash based geopolymer concrete has several benefits over conventional cement concrete. First is the price of one ton fly ash is just a fraction of the price of one ton cement. The price of the alkaline solution a little bit high but the overall price of GPC is almost 10% to 20% less than the same quantity of cement concrete. In accordance with the above fact the full use of fly ash also curbs down the carbon dioxide release to the atmosphere. Furthermore, it is very little drying shrinkage, low creep, excellent sulphate and magnesium resistance and good acid resistance which properties yield additional benefits when it is used in infrastructure applications.

6.2 EXISTING APPLICATIONS

To date, there are no widespread applications of geopolymer concrete in transportation infrastructure, although the technology is rapidly advancing in Europe and Australia, One North American geopolymer application is a blended portland-geopolymer cement known as Pyrament, variations of which continue to be successfully used for rapid pavement repair. Other portland-geopolymer cement systems may soon emerge. In addition to Pyrament, the US. military is using geopolymer pavement coatings designed to resist the heat generated by vertical takeoff and landing aircraft (Hambling 2009).

In the short term, there is potential for geopolymer applications for bridges. such as precast structural elements and decks as well as structural retrofits using geopolymer-fiber composites Geopolymer technology is most advanced in precast applications due to the relative case in handling sensitive materials (eg high- alkali activating solutions) and the need for a controlled high temperature curing environment required for many current geopolymer systems. To date, none of these potential applications has advanced beyond the development stage. but the durability attributes of geopolymers make them attractive for use in high-cost severe-environment applications such as bridges. Other potential near-term applications are precast pavers and slabs for paving.

6.3 FUTURE DEVELOPMENTS

User-friendly geopolymer cements that can be used under conditions similar to those suitable for Portland cement are the current focus of extensive world-wide research efforts. These cements must be capable of being mixed with a relatively low-alkali activating solution and must cure in a reasonable time under ambient conditions (Davidovits 2008). Until such cements are developed. geopolymer applications in transportation infra- structure will be limited. The production of versatile, cost-effective geopolymer cements that can be mixed and hardened essentially like portland cement would represent a "game changing" advancement, revolutionizing the construction of transportation infrastructure.

COST ANALYSIS

7.1 COST ESTIMATION OF CEMENT

Materials	**Kg/m^3**	**Rs/Kg**	**Rate**
Cement	552	10	**Rs 5520/-**

7.2 COST ESTIMATION OF GEOPOLYMERS

Materials	**Kg/m^3**	**Rs/Kg**	**Rate**
Fly Ash	394.28	4	1577.12
Sodium Hydroxide	22.53	65	1464.45
Sodium Silicate	112.3	21	2364.4
Total			**Rs 5402/-**

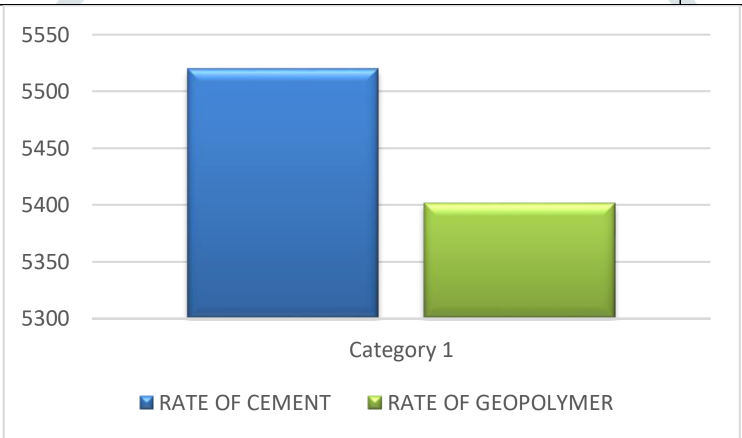


FIG 13 : PRICE CHART COMPARISON OF GEOPOLYMERS & CEMENT

CONCLUSION

This paper presented a brief overall review on comparison of geopolymer concrete with cement concrete and also its different ingredients, mixing proportions of them, mixing procedure and economical benefits. With a higher Na_2O/SiO_2 gives a higher strength, generally with a ratio of 2.5. Generally heat cured geopolymer concrete gives higher strength but it can be obtained at ambient temperature by replacing fly ash content. Geopolymer concrete has excellent properties as discussed earlier so it can be very useful for rehabilitation and retrofitting works. It can also be used in road works because of its very early attainment of strength. The economic benefits of geopolymer concrete have also been discussed. As because the geopolymer concrete is a whole new concept of structural concrete with a new technology and since no Indian Standards are available so a detailed study on the chemistry behind the polymerization is needed. So a new method can be there rather than the conventional mixing procedure which is obtained for the mixing of geopolymer concrete.

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