EXPERIMENTAL STUDY ON THE COMPRESSIVE STRENGTH OF NORMAL CONCRETE CUBES & FLY ASH BASED GEOPOLYMER CONCRETE

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***ABSTRACT**: The use of supplementary cementitious materials as partial replacements for the cement in concrete will play a significant role with respect to the environmental control of greenhouse effects and global temperature reduction. The development of geopolymer concrete (GPC), in which all of the Portland cement is replaced with fly ash. Fly Ash, a byproduct of coal obtained from the thermal power plant is plenty available worldwide. Fly ash is used as ingredients in concrete which enhance the properties of concrete and utilization of fly ash is helpful for consumption strengthening of concrete specimen in compression by replace the cement in concrete ingredients has been investigated in this research study. Eight cubes of size 6"x 6"x 6" were prepared and cured properly in curing tank and tested for compressive strength after 7,14,21,28 days. For this purpose 2 types of concrete were used GPC & OPC. The cement used were ordinary Portland cement, Fly ash used as compare to OPC., the coarse aggregate were locally avail, and the sand used were local Chenab sand,. These cubes were designed by ACI mix design method. Eight cubes casted Four of GPC & Four of OPC and compared in compressive strength after 28 days with each other the eight combination containing locally available materials. The mix designed ratio is established on the basis of the properties of respective materials. These combinations were tested in compressive testing machine by applying loading rate of 250 Kpa/s. Comparative study between concrete cubes was carried out in terms of compressive strength. The findings of this experimental study show that to use proper material for construction in order to gain maximum strength using economical materials. Future research studies are recommended to be carried out to investigate the durability of these concrete cubes.*

Keywords: Constituents of concrete; Concrete cubes; eight combinations; Compressive strength

1. INTRODUCTION

Geopolymer concrete is an innovative, eco-friendly construction material. It is used as replacement of cement concrete. In geopolymer concrete cement is not used as a binding material. Fly ash, silica-fume, or GGBS, along with alkali solution are used as binders there are many ways to strengthen concrete structure these days like adding different admixtures, providing reinforcement, fiber polymer but in this project we tried to find the most suitable combination of concrete constituents to empower the concrete in compression. In this case we casted the two type of concrete cubes 1St type of GPC and 2nd is OPC total casted eight cubes of concrete and then compare to each other The concrete is majorly made up of three kinds of constituents except water first one is binder or cement and Fly ash and, second one is major part of the concrete that is Coarse aggregate and the third and probably the last one is filler like sand. Sometimes admixture is also added like accelerator, retarder, water reducer and strength improver. Other admixture describe in the above study. Cubes casted with the ratio of 1:2:4 and curing period is 28 days in curing tank In Pakistan, there are a lot of brands of Geopolymer concrete like that Rock based geopolymer, Fly ash based geopolymer, Alkali activated geopolymer, Slag based geopolymer, Ferro-silicate based geopolymer, material available that can be used in concrete construction. The available famous quarries of coarse aggregate are locally, mostly are Sargodha crush. The famous sand that are majorly used are Chenab sand. These are the materials we usually used in our local area of Punjab. By using these mention materials we have to find the suitable combination securing both economical and strength benefits. By this we will be able to gain our desired result with simple ingredients without using any economically expensive admixture. In further dealing with mega projects locally the results enables us to choose the best material that will be strong and durable as well. Concrete cubes are casted and tested in the compressive testing machine to check the property of the specific material.

1.2. Literature Review

M.I.Abdul Aleem, P. D.Arumairaj(2012) [1]: Geopolymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Fly Ash, a by- product of coal obtained from the thermal power plant is plenty available worldwide. Fly ash is rich in silica and alumina reacted with alkaline solution produced aluminosilicate gel that acted as the binding material for the concrete. It is an excellent alternative construction material to the existing plain cement concrete.

Shankar H. Sanni and R. B. Khadiranaikar [2] carried out investigation on the variation of alkaline solution on mechanical properties of geopolymer concrete. The grades preferred for the investigation were M30, M40, M50 and M60; the mixes were designed for 8 molar. The alkaline solution used was the combination of sodium silicate and sodium hydroxide solution with the varying ratio of 2, 2.5, 3 and 3.5. The test specimens were 150x150x150 mm cubes and 100x200 mm cylinders heat-cured at 60°C in an oven. The results revealed that the workable flow of geopolymer concrete was in the range of 85 to 145mm and was dependent on the ratio by mass of sodium hydroxide and sodium silicate solution. The freshly prepared geopolymer mixes were cohesive and their workability increased with the increase in the ratio of alkaline solution. It was concluded that the strength of geopolymer concrete can be improved by decreasing the water/ binding and aggregate/binding ratios. Compressive strength and split tensile strength obtained were in the range of 20.64-60N/ mm2 and 3-4.9 N/mm2.

Yasir Sofi and Iftekar [3] Gull intended to study the properties of fly ash based Geopolymer concrete. M20 grade GPC can be formed by adopting nominal mix of 1:1.5:3 (fly ash: fine aggregates: coarse aggregates) by varying alkaline liquid to fly ash ratio from 0.3 to 0.45. The compressive strength, tensile strength and flexural strength tests were conducted on geopolymer concrete and parameters that affect it are analyzed and proved experimentally. The durability properties like permeability and acid attack are also studied. From the test results, it was concluded that geopolymer concrete possesses good compressive strength and offers good durability characteristics. With the increase of alkaline liquid to fly ash ratio strength decreases and alkaline liquid to fly ash ratio less than 0.3 is very stiff.

P. K. Jamdade and U. R. Kawade [4] studied the strength of Geopolymer concrete by using oven curing. In this study Geopolymer concrete is prepared by mixing sodium silicate and sodium hydroxide with processed fly ash. The concrete is cured at different condition and different temperatures i.e.; 600C, 900C and 1200C so as to increase the strength of concrete. It was observed that higher curing temperature resulted in larger compressive strength of Geopolymer concrete, even though an increase in the curing temperature beyond 600C did not increase the compressive strength substantially. Also longer curing time improved the polymerization process resulting in higher compressive strength of Geopolymer concrete.

S. Jaydeep and B. J. Chakravarthy [5] prepared an optimum mix for Geopolymer concrete using admixtures. Concrete cubes of size 150×150×150mm were prepared to find out compressive strength at 7 and 28 days. Results showed that the addition of sodium silicate solution to the sodium hydroxide solution as an alkaline activator enhanced the reaction between the source material and solution. Oven cured specimen gives the higher compressive strength as compared to direct sunlight curing. It was also observed that geopolymer concrete is more advantageous, economical and ecofriendly method when compared with conventional concrete.

Benny Joseph and George Mathew [6] carried out the influence of aggregate content on the engineering properties of Geopolymer concrete. Influence of other parameters such as curing temperature, period of curing, ratio of sodium silicate to sodium hydroxide, ratio of alkali to fly ash and molarities of sodium hydroxide were also discussed. Based on the study carried out, it can be concluded that a geopolymer concrete with proper proportioning of total aggregate content and ratio of fine aggregate to total aggregate, along with the optimum values of other parameters, have better engineering properties than the corresponding properties of ordinary cement concrete. Compared to ordinary cement concrete, 14.4% enhancement in modulus of elasticity and 19.2% enhancement in Poisson's ratio could be achieved in geopolymer concrete.

Monita and Hamid R. Nikraz [7] studied the strength characteristics, water absorption and water permeability of low calcium fly ash based geopolymer concrete. Mixtures with variations of water/ binder ratio, aggregate/binder ratio, aggregate grading, and alkaline/fly ash ratio were investigated. Results showed that a good quality concrete was obtained by reducing the water/binder ratio and aggregate/binder ratio; and the water absorption of low calcium fly ash geopolymer was improved by decreasing the water/binder ratio, increasing the fly ash content, and using a well-graded aggregate. No significant change was observed in water permeability coefficient for the geopolymer with different parameters.

Aminul Islam Laskar and Rajan Bhattacharjee [8] investigated the variation of workability of fly ash based Geopolymer concrete with the variation of lignin based plasticizer and poly-carboxylic ether based super plasticizer. It has been observed that there exists a critical value of molar strength of sodium hydroxide beyond which super plasticizer and plasticizer have adverse effect on workability of fly ash based geopolymer concrete. There is an increase in slump below the critical molar strength of sodium hydroxide. Lignin based first generation plasticizer shows better performance in terms of workability over third generation super plasticizer below the critical value of molar strength. It was also observed that there is a good correlation between the rheological parameters and slump for fly ash based geopolymer concrete incorporating plasticizer and super plasticizer.

Davidovits (1988b) [9] geopolymeric materials have a wide range of applications in the field of industries such as in the automobile and aerospace, nonferrous foundries and metallurgy, civil engineering and plastic industries. The type of application of geopolymeric materials is determined by the chemical structure in terms of the atomic ratio Si: Al in the polysialate.

Xu and Van Deventer (1999; 2000) [10] have also studied a wide range of aluminosilicate minerals to make geopolymers. Their study involved sixteen natural Si-Al minerals which covered the ring, chain, sheet, and framework crystal structure groups, as well as the garnet, mica, clay, feldspar, sodalite and zeolite mineral groups

Kamlesh. C. Shah [11] conducted research on strength parameters and durability of fly ash based Geopolymer concrete. In this study, two concrete mixes are to be worked out; GPC Mix-1 fly ash concrete and OPC Mix-2 Concrete mix having OPC equivalent to amount of cementitious material used in GPC Mix

Steenie Edward Wallah [12] used low-calcium fly ash as its source material, alkaline activators and aggregates normally used for Ordinary Portland cement concrete. Four series of test specimens with different compressive strength were prepared to study the drying shrinkage of this concrete. Results obtained were compared with the calculated results of drying shrinkage as predicted by Gilbert Method which is normally used for Ordinary Portland cement concrete. Results showed that the heat cured fly ash-based geopolymer concrete undergoes very low drying shrinkage. The drying shrinkage strain at one year as calculated using Gilbert Method was much higher, about five to seven times, compared to the measured drying shrinkage strain.

1.3 Objective

The main target of this study is to analyze the carbon dioxide free cementitious material, various properties and their effects on Geopolymer concrete.

2. EXPERIMENTAL PROGRAM

2.1. Preparation of Test Specimens

Concrete mix prepared from the material chosen with respect to combination by the ratio derived from the ACI mix design and cast in the laboratory. First of all concrete mix of local materials like Ordinary Portland cement locally avail crush and Chenab sand were mixed with the ratio designed 1:2:4 and water added according to the mix design (W/C = 0.50) and added quantity of Sodium Hydroxide and Sodium Silicate. Oiled the mould of size 6"x6"x6" and poured the materials in 3 layers compacting each by 25 strokes of tempering.

Eight other cubes were also casted by repeating the same procedure as described above. The ingredients of all these combinations are shown in the Table 1.

Fig.1: Prepared compacted sample

Table. 1 : Combinations

Sr.	TEST	CEMENT	AGGREGATE	SAND
1	OPC	Ordinary Portland	Locally	Chenab
2	OPC	Ordinary Portland	Locally	Chenab
3	OPC	Ordinary Portland	Locally	Chenab
4	OPC	Ordinary Portland	Locally	Chenab
5	GPC	Fly ash	Locally	Chenab
6	GPC	Fly ash	Locally	Chenab
7	GPC	Fly ash	Locally	Chenab
8	GPC	Fly ash	Locally	Chenab

2.2. Test Performed

After 24 hours of casting the cubes were demolded and properly cured for 28 days in curing tank. After the each 7 day of curing the cubes were dragged out of the curing tank and allowed to dry for 24 hours to make them ready for testing. After that, the cubes were tested in the compressive testing machine of 3000 KN Capacity. The machine was manually set to apply the load at the rate of 250 Kpa/s while the area of the cube was 23230 mm^2 as shown in the Fig 2. The compressive strength of GPC cubes was found to be less than the designed because the GPC required oven curing and we used sample water curing that's why GPC have low strength as compare OPC.

Fig.2: Setting loading rate and area of sample

Fig.3: Compression Testing Machine

3. RESULTS AND DISCUSSION

3.1 Experimental observations

Recorded data in terms of loads was used to plot bar chart to represent the values of compressive strength which is shown in Fig.4, where it is obvious that the maximum load of OPC in compression carried by the concrete cube was to represent the values of compressive strength which is shown in Fig.4, where it is obvious that the maximum load of OPC in compression carried by the concrete cube was 27.3Mpa 636.2 (KN).Moreover, the behavior of concrete cube up to failure was noticed to be almost linear. As well as the failure mode of concrete cubes is concerned, it was due to de-bonding of the cement mortar and aggregate as shown in Fig.5 (b) which resulted in the brittle failure of the concrete cube.(Strength of all types of cubes in Mpa).

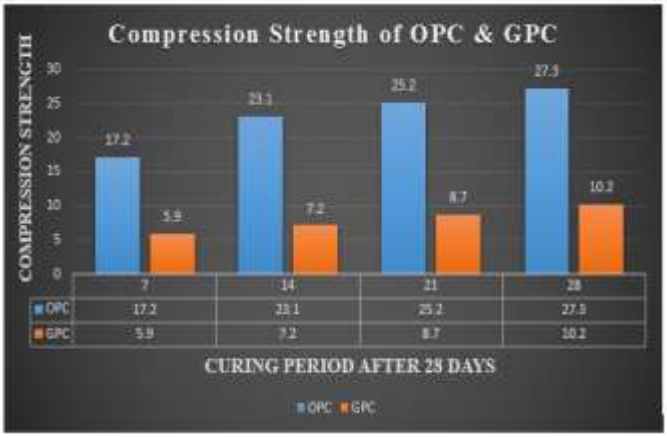

Fig.4: Bar chart between strength of concrete cubes

(a) **(b)**

Fig.5:
(a) Prepared Cubes (b) Failure Pattern of Cubes

Fig.6: Cubic Mould

ANALYTICAL PROCEDURE TO CALCULATE COMPRESSIVE STRENGTH

3.1 Design of concrete cubes

The concrete cubes are designed using ACI mix design method for cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of egate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.

3.2 Finding properties

Properties and characteristics of materials which used in GPC & OPC concrete.

1. Properties of cement concrete
2. Properties of Coarse Aggregate
3. Properties Of Sand
4. Properties of Geopolymer
5. Study on the physical and mechanical property of OPC & fly ash paste

After calculating these properties carefully used them in ACI mix design.

3.3 Establishing Ratio

Using ACI mix design the ratio of materials and w/c ratio is calculated this involves following steps

1. Required material information

The properties like cement concrete, coarse aggregate, fine aggregate, properties of geopolymer were determined.

2. Maximum aggregate size

The maximum aggregate size that confirms the limitations given in the ACI

In our case we used 40 mm max that fulfills the conditions as well.

3. Estimation of mixing water and Alkaline Liquid

A table is given in ACI mix design to calculate the water content & alkaline solution in this study.

4. Water to cement ratio

In our case we choice the 0.5 w/c ratio.

5. Calculation of Cement content

When the water content and the w/c ratio is determined, the amount of cement per unit volume of the concrete is found by dividing the estimated water content by the w/c ratio.

6. Estimation of coarse aggregate content

The percentage of coarse aggregate to concrete for a given maximum size 40mm and minimum 20 mm.

7. Estimation of Fine aggregate content

The volume of fine aggregates is found by subtracting the volume of cement, coarse aggregate, water and air from the total concrete volume.

3.4Comparison with Experimental Results

The maximum strength of the concrete cube obtained experimentally is 27.3 Mpa after 28 day of OPC and 10.2 Mpa obtained of GPC after 28 days in our this report GPC have low strength as compare to OPC in actual GPC have greater strength as compare to OPC actually we used sample curing that's why we achieved 10.2 Mpa due to sample curing otherwise GPC have greater strength.

3.5 Comparison of the strength each cube

As early described that we casted 8 cubes so our aim is to compare their strength of GPC & OPC, concrete cube sample so now start one by one.

1. Cube (OPC)

In the first cube, the combination of a material selected was Ordinary Portland cement, Chenab sand (locally available) and coarse aggregate. This is our so-called ideal cube because it's easily availability and cost-effective.. The compressive strength gained after 7 days was found to be 17.2 Mpa (400.4kN).

2. Cube (OPC)

In the 2nd cube the combination of material selected was Ordinary Portland cement, this is our so called ideal cube because it's easily availability and cost effective. The compressive strength gained after 14 days was found to be 23.1 Mpa 537.1 (KN).

3. Cube (OPC)

In this 3rd cube of OPC which made of ordinary Portland cement The compressive strength gained after 21 days was found to be 25.2 Mpa 587.4 (kN).

4. Cube (OPC) In this 4th cube of OPC which made of ordinary Portland cement The compressive strength gained after 28 days was found to be 27.3 Mpa 636.2 (kN).

5. Cube (GPC)

In this cube only the Ordinary Portland cement was replaced Fly ash s but our purpose was to check whether the compressive strength increases or decreases while working with Fly ash. So our experimental results shows that the compressive strength decrease as compare to OPC. The compressive strength gained after 7 days was found to be 5.9 Mpa 138.8(kN).

6. Cube (GPC)

In this 2nd cube of geopolymer concrete only the Ordinary Portland cement was replaced Fly ash but our purpose was to check whether the compressive strength increases or decreases while working with Fly ash. So our experimental results shows that the compressive strength decrease as compare to OPC. So our goal is to compare its compressive strength with Ordinary Portland cement concrete cube's strength the compressive strength gained after 14 days was found to be **7**.2 Mpa (168.9kN).

7. Cube (GPC)

In this 3nd cube of geopolymer concrete only the Ordinary Portland cement was replaced Fly ash in this cube the compressive strength increase as compare to 2nd cube of GPC means that after 21 days. our experimental results shows that the compressive strength decrease as compare to OPC .The compressive strength gained after 21 days was found to be 8.7 Mpa (203.0kN).

8. Cube (GPC)

In this 4nd cube of geopolymer concrete only the Ordinary Portland cement was replaced Fly ash in this cube the compressive strength increase as compare to 3rd cube of GPC means that after 28 days. our experimental results shows that the compressive strength decrease as compare to OPC .The compressive strength gained after 28 days was found to be 10.2 Mpa (238.9kN).

3.6 Cost Comparison

After designing of Concrete cubes, the cost comparison between the materials used for same application was carried out. In the cements, only the actual cost is taken into account due to locally availability and other materials the cost of per 100cft is taken which includes material and carriage cost both.

Table. 2 : Metarial cost and availabilities

Material	**Cost/unit**	**Availability**
Ordinary Portland cement	525/50kg bag	Easily available and have less carriage cost
Sand	1000/100cft	Easily available
Aggregate	3000/100cft	Easily available
Sodium Hydroxide	450/ltr	Easily available
Sodium Silicate	450/ltr	Easily available
Fly ash	20/kg	It is not easily available and have more carriage cost in this project we used fly ash of SAHIWAL thermal power plant.

4. CONCLUSIONS AND RECOMMENDATION

Based on the test results, the following conclusions are drawn:

1. In this study we worked on the compressive strength of Fly ash based Geopolymer Concrete with alkaline solution.
2. Geopolymer Concrete have greater strength as compare to ordinary Portland cement but in our experimental work GPC have low strength as compare to OPC. Ordinary Portland cement have greater strength in this study in actual GPC have greater strength .Because GPC required oven curing but we used sample curing that's why GPC have low compression strength which is main reason.
3. GPC 28 days strength range 45 MPA-50 MPA but in this study GPC have low strength we achieved 10.2 Mpa after 28 days (Due to simple curing).
4. High early strength, low creep and shrinkage, acid resistance, fire resistance makes it better in usage than OPC.
5. Geopolymer concrete is a promising construction material due to its low carbon dioxide emission.
6. Wide spread applications in precast industries due to
    a) its high production in short duration
    b) less breakage during transportation
7. Geopolymer concrete has excellent properties within both acid and salt environments.
8. The reduced CO2 emissions of Geopolymer cements make them a good alternative to Ordinary Portland Cement.
9. Low-calcium fly ash-based geopolymer concrete has excellent compressive strength and is suitable for Structural applications.

5. RECOMMENDED FUTURE WORK

In continuation of present research study, following research works related to Compressive strength of Fly ash based Geopolymer Concrete may be carried out in future in Civil Engineering Department, U.C.E.T Sargodha.

This study recommends the following future research:

1. It has been observed that fly ash from different sources may vary the compressive strength of the geopolymer concrete. Thus, the effect of fly ash from different sources in the compressive strength needs to be further explored.
2. In this research, the alkaline liquid used in the geopolymerization is the combination of sodium hydroxide and sodium silicate. Hydroxide solutions greatly influence the compressive strength of the geopolymer concrete. Therefore, there is a need to research the effect of other hydroxide solutions like barium hydroxide, lithium hydroxide, and magnesium hydroxide in the compressive strength.

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