International Journal of Scientific & Engineering Research, Volume 8, Issue 3, March-2017 1317
ISSN 2229-5518

# Effect of Glass Powder on Geopolymer Concrete

Nimisha Sasindran C, Vidya Jose

**Abstract**— Cement production process is one of the major cause of $CO_2$ emission into the atmosphere which leads to global warming. In order to reduce the environmental effects associated with these, there is a need to develop an alternative binder for producing concrete. Geopolymer concrete (GPC) is an innovative construction material synthesized predominantly from alumino silicate material activated by alkaline solution which emits lesser green house gas to the atmosphere. Waste glass, when ground to very fine powder shows pozzolanic properties which can be used as a partial replacement for binder in concrete. In this work an attempt has been made to study the effect of utilization of glass powder as partial replacement for fly ash in Geopolymer concrete. The fly ash in Geopolymer concrete was replaced by glass powder in the range of 5 to 25% with an increment of 5%. All the specimens were tested for its workability, compressive strength and split tensile strength, then the values are compared with those of normal fly ah based Geopolymer concrete. The test results indicated that the workability increased with increase in amount of glass powder. Also the maximum compressive strength was obtained for samples with 15% replacement of glass powder. The maximum tensile strength was obtained for 10% replacement of glass powder.

**Index Terms** — Cement, Alternative binder, Geopolymer concrete, Alumino silicate material, Alkaline solution, Fly ash, Glass powder.

## 1 INTRODUCTION

Concrete is the one of the most widely used construction material in the world due to its versatility, durability and economy [1]. Concrete is a blend of coarse aggregate, fine aggregate, cement and water. The production of Portland cement which is an essential part of concrete leads to the emission of significant amount of $CO_2$ to the atmosphere [2]. Cement industry produces 5 to 8% of atmospheric $CO_2$ in the world. This $CO_2$ is largely responsible for the increases in the green house gas effect which leads to global warming [3]. Although there is much reduction in the environmental impact of concrete with the use of other supplementary material for cement replacement, the carbon footprint of concrete remains high [4]. One of the best alternative to develop a new cement free binder is through the alkali activation of waste material known as Geopolymer concrete [5].

Geopolymer concrete is an innovative environmental friendly inorganic binder produced by activation of alumino silicate material [6]. The polymerization of the Si-O-Al-O bond which develops when Al-Si source material like fly ash is mixed with alkaline activating solution is the main concept behind the geopolymer concrete. NaOH or KOH solution with $Na_2SiO_3$ or $K_2SiO_3$ are commonly used for alkali activation of alumino silicate material [7].

Generally fly ash is used as source material for geeopolymer concrete due to its availability around the world. Fly ash is classified as class C and class F depending on their chemical composition [8]. Alternatively other byproduct materials such as silica fume, rice husk ash, red mud, slag etc. can be used as source material for Geopolymer concrete. The selection of these source material for making geopolymer concrete depends on the availability, cost, type of construction etc [9].

• *Nimisha Sasindran. C is currently pursuing masters degree program in civil engineering in KTU,India, E-mail: topazz.nimi@gmail.com*
• *Vidya Jose is assistant professor in civil engineering department in TIST, Ernakilam,KTU,India, E-mail: vidyabreen@gmail.com*

Geopolymer concrete shows improved properties such as compressive strength, good acid resistance, low creep, low shrinkage etc [10]. So the development of geopolymer concrete not only to reduce the $CO_2$ emission from the cement industries, but also utilizes the waste materials such as fly ash, rice husk ash, red mud which leads to sustainable construction with improved properties [11].

Furthermore interest of the construction industry to utilize recycled material such as waste glass in concrete is increasing because of the emphasis placed on sustainable construction [12]. Unlike other forms of recycled waste material like, paper sludge, waste glass will remain stable after their disposal. Glass is an amorphous material consist of high amount of silica. Due to its silica content finely ground glass can be considered as a pozzolanic material and can be exhibit similar properties as other pozzolanic material used for concrete production [13].

A significant number studies based on the utilization of glass powder in geopolymer concrete have been conducted in the previous years itself. In contrast there is a limited number of studies based on the temperature curing of glass powder incorporated fly ash based geopolymer concrete. Due to the contradiction and variations in the available test results corresponding to the utilization of glass powder in geopolymer concrete, this work presents a detailed investigation on the effect of glass powder incorporated geopolymer concrete. Therefor the prime objective of the of this investigation is to find the behaviour of fly ash based GPC containing different percentage of glass powder and which is then compared to pure fly ash based geopolymer concrete free from glass powder.

Here workability test, compressive strength test, and split tensile strength test have been conducted on different concrete mixes. The fly ash is replaced by glass powder at percentage ranging from 0% to 25% with an increment of 5%.

## 2. EXPERIMENTAL PROGRAM

### 2.1 Material

Any material which consist of alumino silicate composition is a potential source of the material for geopolymer binder. A geopolymer concrete is a mixture of geopolymer binder and aggregate. Several waste material and other industrial byproducts such as fly ash, silica fume, rice husk ash etc can be used as source material for geopolymer binder.

In this study fly was used as the main source material as geopolymer binder. The fly ash for the investigation was collected from local source. The fly ash had a specific gravity of 1.78.

Manufactured sand with specific gravity of 2.73 and water absorption of 2.08% was used as fine aggregate. Natural crushed stone of specific gravity 2.85 and water absorption of 0.50% was used as coarse aggregate.

A mixture of sodium hydroxide (NaOH) and sodium silicate ($Na_2SIO_3$) were used as activating solution.

Waste glass was collected from a local glass recycling plant and which were ground to desired size.

### 2.2 Mix design

The manufacture of geopolymer concrete includes the preparation of alkaline solution, dry mixing, wet mixing, casting and curing. The ratio of $Na_2SiO_3$ to NaOH was fixed at 2.5. The molarity of NaOH was fixed as 8M. The mixture proportion of geopolyme concrete was given in table 1.

TABLE I
MIXTURE PROPORTION

| Material | Fly ash | Fine aggregate | Coarse aggregate | NaOH | $Na_2SIO_3$ |
|---|---|---|---|---|---|
| Quantity ($kg/m^3$) | 444.44 | 540 | 1260 | 44.45 | 111.11 |

### 2.3 Experimental details

The experimental investigation of this work was mainly focused on the replacement of fly ash in geopolymer concrete by glass powder at percentage ranging from 0% to 25% with an increment of 5%. The casting procedure was similar to that of ordinary concrete. All the specimens were oven cured for 24 hours. After 24 hours they were stored at ambient condition.

### 2.4. Testing

A series of tests were conducted on the normal fly ash based geopymer concrete and geopolymer concrete modified with glass powder. In order to evaluate the fresh properties of the concrete, slump test was conducted on fresh geopolymer concrete mixture with different percentage of glass powder. To assess the mechanical properties of modified geopolymer concrete, compressive strength test and split tensile strength test were conducted. Then all the test results were compared with normal fly ash based geopolymer concrete.

## 3. TEST RESULTS AND DISCUSSION

Different concrete specimens of fly ash based geopolymer concrete were designed to study the effect of glass powder on the workability, compressive strength, and split tensile strength. The test results are following.

### 3.1 Workability

Fig 1 shows the variation of slump values of geopolymer concrete having different percentages of glass powder. From the figure it can be observed that glass powder has a significant effect on the workability of geopolymer concrete. The workability increases with the addition of glass powder. The maximum workability was obtained for geopolymer mix having glass powder content as 25% of fly ash. The slump value obtained for normal fly ash based geopolymer concrete was 48mm while the slump value obtained for 25% glass powder replacement was 79mm which was 65% higher than normal fly ash based geopolymer concrete.

The increase in workability with the increase in glass powder content coluld be attributed to the glassy surface of the glass powder which has less water absorption characteristics.

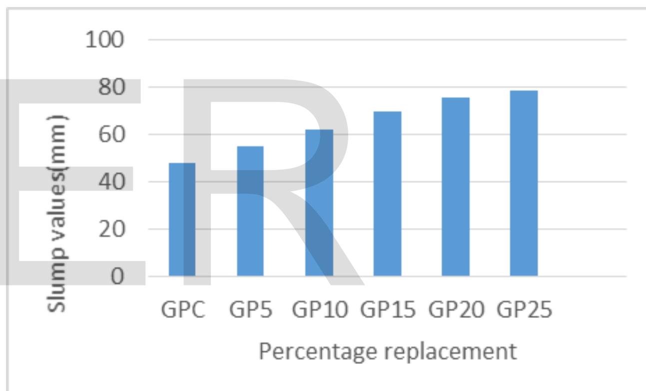


Fig 1. Variation of slump values

### 3.2 Compressive strength test

The compressive strength development of the various hardened geopolymer concrete with different percentage of glass powder content are shown in the figure 2. From the figure it is clear that the glass powder has a significant influence on compressive strength. The compressive strength was increased with glass powder content up to 15%. Beyond 15% the compressive strength was decreased. The 7 day compressive strength obtained for normal fly ash based geopolymer concrete was 31.7MPa and for 15% replacement of glass powder the compressive strength was 34.1MPa. The increase in strength was 7.5% compared to normal fly ash based geopolymer concrete. For 25% replacement of glass powder the compressive strength was obtained as 31.3MPa which was 8.2% less than 15% replacement. The 28 day compressive strength of normal fly ash based geopolymer was 32.1MPa and for 15% replacement of glass powder was 35.9. For 25% replacement of glass powder it was 32.4MPa. The increase in strength for 15% replacement was 11.8% compared to normal fly ash based geopolymer concrete.

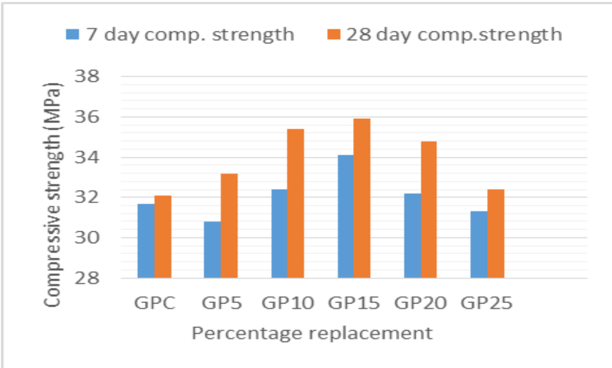


Fig 2. Variation of compressive strength

The improvement in the compressive strength was mainly because of glass powder has more tendency to fill the micro pores inside the geopolymer concrete to form more compacted structure. Also the high pozzolanic characteristics lead to increase the strength. The reduction in the compressive strength beyond 15% replacement of glass powder may be due to the brittle poroperties of glass powder.

### 3.3. Split tensile strength test.

The effect of glass powder on fly ash based geopolymer concrete tensile strength is presented in the figure 3. From the test results it can be found that the the geopolymer tensile strength was also slightly influenced by glass powder. The 7 day tensile strength obtained for normal fly ash based geopolymer concrete was 3.12MPa Then with the addition of glass powder up to 10% the strength was increased. The tensile strength obtained for 10% replacement was 3.27MPa. Beyond 10% the tensile strength was decreased. The 28 day tensile strength for normal fly ash based geopolymer concrete and for 10% replacement were 3.17MPa and 3.32MPa respectively. The increase in the strength was 4.7%. Beyond 10% replacement the strength was decreased.

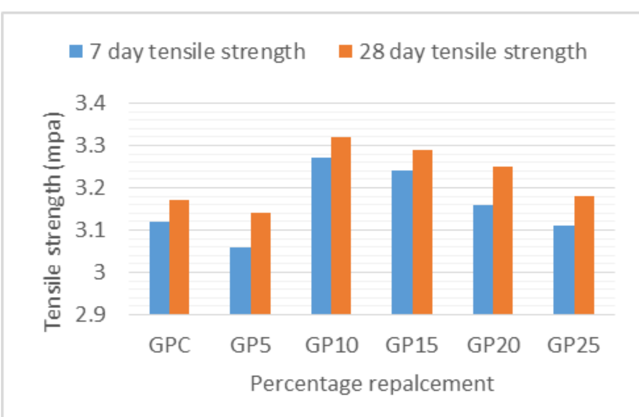


Fig 3. Variation of split tensile strength

The increment in tensile strength up to 10% was mainly due to the pozzolanic charactetristics of glass powder. Also glass powder possess high silica content. The decrease in strength could be attributed to increase in amount of glass powder in geopolymer concrete

## 4. CONCLUSION

This paper presents the possibility of using glass powder as a replacement for fly ash in geopolymer concrete. Based on a the different experimental works the following conclusions are drawn;

- The increase in glass powder content has a significant effect on the workability of geopolymer concrete. The workability increases with the increase in the amount of glass powder.
- The compressive strength of geopolymer concrete increases with the increase in the amount of glass powder up to 15% replacement of fly ash. Beyond 15 % replacement the compressive strength is decreases.
- The maximum tensile strength of geopolymer concrete is obtained for the mixture having 10% replacement of fly ash by glass powder. Beyond 10% the tensile strength is decreases.

## REFERENCES

[1] Bhupendra Singh Shekhawat1, Dr. VanitaAggarwal (2014) "Utilisation of Waste Glass Powder in Concrete – A Literature Review" International Journal of Innovative Research in Science, Engineering and TechnologyVol 3 PP 14822-14826

[2] Shilparaju, Dr. P.R Kumar (2014) "effect of using glass powder in concrete" International journal of innovative research in science, engineering and technologyVol 3 PP 421-429

[3] Paras S.Pithadiya, Abhay V. Nakum (2015) "Experimental study on geopolymer concrete by using GGBS" International Journal of Research in Engineering and Technology Vol 4 PP 185-187

[4] Ana Balaguer Pascual, Monique Tohoue Tognonvi, Arezki Tagnit-Hamou (2014) "Waste glass powder based alkali activated mortar" International journal of research in engineering and technology, Vol 03, PP 32-36

[5] Lateef N. Assi , Edward (Eddie) Deaver , Mohamed K. ElBatanouny , Paul Ziehl (2016) "Investigation of early compressive strength of fly ash-based geopolymer concrete"Construction and building material, Vol 112, PP 807-815

[6] Alaa M. Rashad, Ahmed A. Hassan , Sayieda R. Zeedan(2016) "An investigation on alkali-activated Egyptian metakaolin pastes blended with quartz powder subjected to elevated temperatures" Construction and building material

[7] Ali A. Alibado, AbdElmoaty M. AbdElmoaty, Hazem A. Salem (2016) " Effect of water addition, plasticizer and alkaline solution constitution on fly ash based geopolymers concrete performance"

[8] Construction and building materials,Vol 121, PP 694-703

[9] PattanapongToparkNgar,PrinyaChindaprasirtand VanchaiSata (2014) "Setting Time, Strength, and Bond of High-Calcium Fly Ash GeopolymerConcrete"Journal of Materials in Civil Engineering, PP 1-7

[10] B. Vijaya Rangan (2014) "Geopolymer concrete for environmental protection" The Indian Concrete Journal PP 41-59

[11] Garcia Lodeiro, A Palomo, A Ferenadez Jimenez (2007) " Alkali aggregate

reaction in activated fly ash system" Cement and concrete research 37 PP 175-183

[12] Ali A. Alibado, AbdElmoaty M. AbdElmoaty, Hazem A. Salem (2016) " Effect of cement addition, solution resting time, and curing characteristics on fly ash based geopolymer concrete performance" Construction and Building Materials PP 581-593

[13] Dr. Vijayakumar G, Vishaliny M, Dr. Govindarajulu D (2013) "Studies on Glass Powder as Partial Replacement of Cement in Concrete Production" International Journal of Emerging Technology and Advanced EngineeringVol 3 PP 153-157

[14] Khatib J M, Negim,E M, Sohl H SM, Chileshe N(2012) "Glass powder utilisation in concrete production"EuropeanJournal of Applied Sciences" Vol4: PP 173-176

[15] Shankar H. Sanni, R. B. Khadiranaikar (2013) "Performance of alkaline solutions on grades of geopolymer concrete" International Journal of Research in Engineering and Technology PP 366-371