# Flexural Study on Reinforced Geopolymer Concrete Beam with Partial Replacement of Fly Ash by Using Waste Granite Powder

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***Abstract— As $CO_2$ emissions are increasing in the atmosphere and causes global warming with the production of cement, the alternative pozzolanic material is needed. The alternative pozzolanic material for cement in the production of concrete is GGBS. Geopolymer Concrete (GPC) is an alternative material for conventional concrete. Geopolymer concrete is made by mixing GGBS, fine aggregate, coarse aggregate, and alkaline activator solution. GGBS is a by-product of the iron industry. This paper shows the results on experimental investigation done on reinforced geopolymer concrete beams to know the flexural behavior. The alkaline activator solution is prepared by sodium hydroxide NaOH and sodium silicate $Na_2SiO_3$ in 1:2.5 ratio. The flexural behavior of the beams is examined with different molars of NaOH solution. The GPC beams are compared with conventional reinforced concrete beam of M35 grade concrete. The type of curing adopted in the experimental study is ambient. The size of beam is 750 mm × 150 mm × 150 mm. The flexural test is done on the loading frame of capacity 250 tons. The ultimate load, cracking load and the maximum deflection and the crack pattern is determined, and the load Vs deflection graphs are plotted. This experimental study gives a clear conclusion on the flexural behavior of conventional reinforced concrete beam and reinforced geopolymer concrete beam made with GGBS***

***Index Terms—Alkaline Activator Solution, Geopolymer, Ground Granulated Blast Furnace Slag, Molarity, Sodium Hydroxide, Sodium Silicate.***

## I. INTRODUCTION

The demand for concrete increases it also increases the demand for Portland cement. The production of one ton of Portland cement emits approximately one ton of $CO_2$ into the atmosphere. Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. These include the utilization of supplementary cementing materials such as fly ash, silica fume, granulated blast furnace slag, rice-husk ash and metakaolin as the alternative binders to Portland cement. In this respect, the geopolymer technology shows considerable promise for application in concrete industry as an alternative binder to the Portland cement and significantly reduces the $CO_2$ emission to the atmosphere caused by cement industries.

Granite Powder (GP) is the industrial by-product generated from the granite polishing industry in powder form. This by-product is left largely unused and hazardous material to human health because this is an airborne and can be easily inhaled. An experimental investigation has been carried out to explore the possibility of using the granite powder as a partial replacement of fly ash in Geopolymer Concrete (GPC). Thirty-six cubes and four beams of Geopolymer Concrete (GPC) with GP were prepared and tested. The percentages of GP added to replace fly ash were 0%, 5%, 10%, 15%, 20% and 25% of the fly ash by weight. It was observed that substitution of 15% of fly ash by weight with granite powder in Geopolymer Concrete (GPC) was the most effective in increasing the compressive and flexural strength compared to other ratios. The test resulted showed that for 15% ratio of GP in concrete, the increase in the compressive strength was about 25.28% compared to normal concrete. Similar results were also observed for the flexure.

## II. OBJECTIVE

The major objective of this project stands the use of granite powder as fly ash in different variations in low calcium fly ash based geopolymer concrete to evaluate its mechanical properties and studying the flexural strength of the Reinforced Geopolymer Concrete beam.

## III. EXPERIMENTAL DETAILS

In this experiment, Geopolymer Concrete were casted with partial replacement of fly ash by GP upto 25%, and properties were determined. Cement is fully replaced by fly ash and GGBS in the ratio of 60:40 (Fly ash is alone replaced by Granite Powder). In this assessment, physical properties of materials utilized were determined.

### *A. Properties of the Materials:*

The physical properties of the materials utilized in the casting of Geopolymer concrete.

Table 1: Properties of fly ash, GGBS, GP

| Properties | Fly Ash | GGBS | Granite Powder |
|---|---|---|---|
| Fineness | 7% | 8% | 6% |
| Consistency | 43% | 30% | 33% |
| Initial Setting Time | 65 min | 55 min | |
| Specific Gravity | 2.95 | 2.98 | 2.66 |

Table 2: Properties of fine aggregate, coarse aggregate

| Properties | Fine Aggregate | Coarse Aggregate |
|---|---|---|
| Specific Gravity | 2.59 | 2.6 |
| Bulk Density | 1.75 kg/m3 | 1480 kg/m3 |
| Water Absorption | 1.5% | 0.7% |
| Crushing Value | | 248% |
| Impact Value | | 17.46% |

### *B. Geopolymer Concrete Mix Constituents:*

The materials used for manufacturing of geopolymer concrete are fly ash, granite powder, GGBS, fine aggregate, coarse aggregate. The materials are mixed in the pan mixture as shown in figure 1 for making geopolymer concrete

Fig 1: Mixing process in standard pan type mixer.

## IV. EVALUATION OF STRENGTH PROPERTIES

The quality of concrete depends upon the strength property of hardened concrete. Because of this importance, several tests have been conducted and their test results are reported as follows.

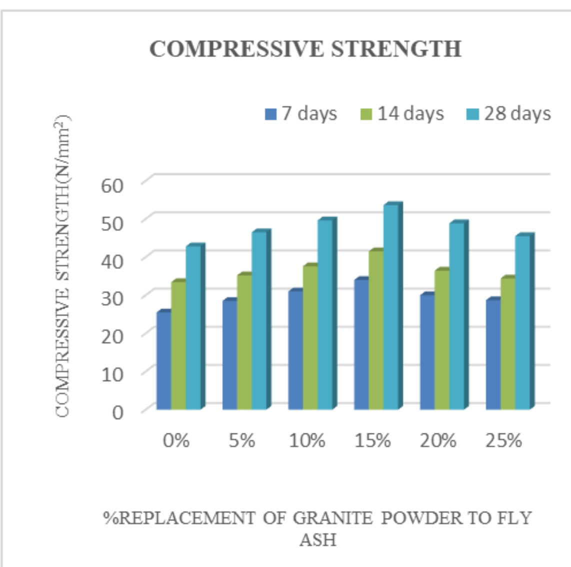
### *A. Compressive Strength Test:*

For this test 100mm×100mm×100mm sized concrete cubes are used. The test is conducted on compressive testing machine. Mechanical behavior of geopolymer concrete was studied. At various proportions of granite powder to fly ash, concrete cubes were casted and used for testing. At last cubes were tested and the outcomes acquired are shown below (In table 3 & graph 1).

Fig 2: Experimental setup for compressive strength

Table 3: Analysis of test results

| Fly ash: GGBS: Granite powder | STRENGTH(N/mm$^2$) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| 60:40:00 | 25.5 | 33.45 | 42.8 |
| 55:40:05 | 28.5 | 35.21 | 46.5 |
| 50:40:10 | 31 | 37.59 | 49.61 |
| 45:40:15 | 34 | 41.5 | 53.62 |
| 40:40:20 | 30 | 36.45 | 48.86 |
| 35:40:25 | 28.75 | 34.4 | 45.5 |




Graph 1- Compressive Strength

This graph 1 result shows that the compressive strength of the geopolymer concrete is gradually increases with respect to the partial replacement of granite powder to fly ash. And it reaches the maximum compressive strength at 15% replacement of granite powder (optimum). After that the compressive strength are getting reduced for more than 15% replacement of granite powder.

## V. DESIGN OF BEAM

The beam size is 150×150×700 mm. 4nos of beam (2nos of 0%, 2nos of 15% partial replacement of granite powder to fly ash) were casted and tested by using the loading frame

### A. *Reinforcement details:*

2nos of 12 mm dia bars are provided at the bottom as a main reinforcement. 2nos of 6mm dia bars are provided at top as a hanger bars. For stirrup reinforcement 8mm dia bar is provided with the spacing of 100mm C/C. 25mm cover block is used for effective cover. Fig 4 represents the reinforcement details of the beam

Fig 3: reinforcement details of the beam

## VI. FLEXURAL STUDY ON BEAM

In this study we have carried out load deflection test and moment curvature test on reinforced geopolymer concrete beam. The two-point loads are applied at 1/3 length of the beam. Deflection of the beam is measured at 1/3 length of the beam from each side & ½ length of the beam.

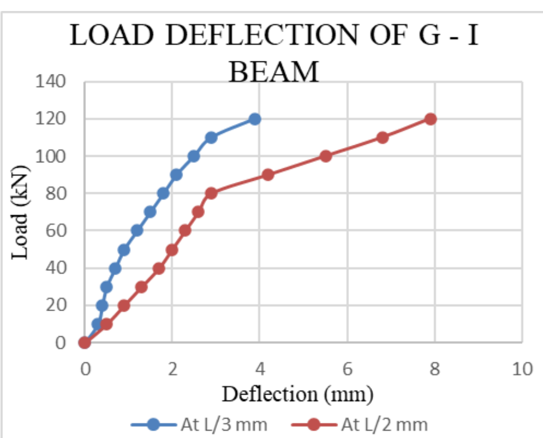
Fig 4: Experimental setup for flexural study

A. *Load deflection test:*

a) *Results of 0% added granite powder reinforced geopolymer beam (G – I):*

Table 4: Load deflection of G-I

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *At L/3 (mm)* | *REMARKS* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | |
| 2 | 10 | 0.3 | 0.4 | |
| 3 | 20 | 0.6 | 0.6 | |
| 4 | 30 | 1 | 0.9 | First crack load |
| 5 | 40 | 1.4 | 1.1 | |
| 6 | 50 | 1.7 | 1.4 | |
| 7 | 60 | 2.1 | 1.5 | |
| 8 | 70 | 2.5 | 1.9 | |
| 9 | 80 | 4.2 | 2.2 | |
| 10 | 90 | 5.1 | 2.6 | |
| 11 | 100 | 6.3 | 2.9 | Ultimate load |

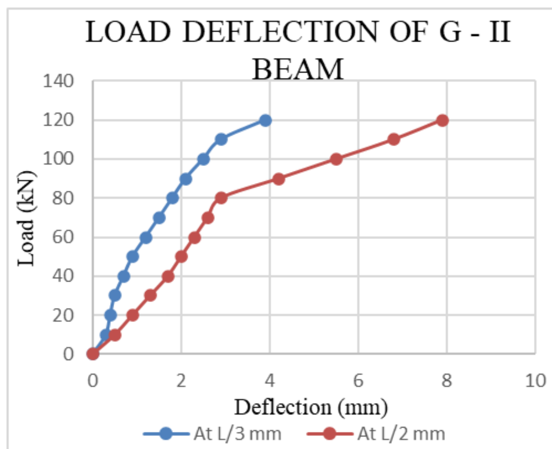



Graph 2- Load Deflection of G-I Beam

b) *Results of 0% added granite powder reinforced geopolymer beam (G – II):*

Table 5: Load deflection of G-II

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *At L/3 (mm)* | *REMARKS* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | |
| 2 | 10 | 0.5 | 0.3 | |
| 3 | 20 | 0.9 | 0.4 | |
| 4 | 30 | 1.3 | 0.5 | |
| 5 | 40 | 1.7 | 0.7 | |
| 6 | 50 | 2 | 0.9 | First crack load |
| 7 | 60 | 2.3 | 1.2 | |
| 8 | 70 | 2.6 | 1.5 | |
| 9 | 80 | 2.9 | 1.8 | |
| 10 | 90 | 4.2 | 2.1 | |
| 11 | 100 | 5.5 | 2.5 | |
| 12 | 110 | 6.8 | 2.9 | |
| 13 | 120 | 7.9 | 3.9 | Ultimate load |



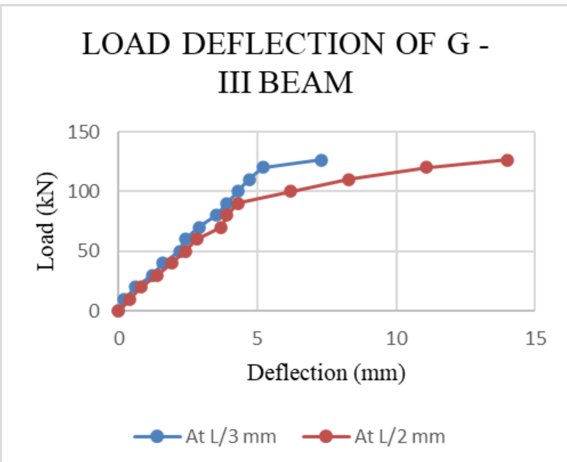

Graph 3- Load Deflection of G-II Beam

c) *Results of 15% added granite powder reinforced geopolymer beam (G – III):*

Table 6: Load deflection of G-III

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *At L/3 (mm)* | *REMARKS* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | |
| 2 | 10 | 0.4 | 0.2 | |
| 3 | 20 | 0.8 | 0.9 | |

| | | | | |
|---|---|---|---|---|
| 4 | 30 | 1.4 | 1.2 | First crack load |
| 5 | 40 | 1.9 | 1.6 | |
| 6 | 50 | 2.4 | 2.4 | |
| 7 | 60 | 2.8 | 2.6 | |
| 8 | 70 | 3.7 | 2.9 | |
| 9 | 80 | 3.9 | 3.5 | |
| 10 | 90 | 4.3 | 3.9 | |
| 11 | 100 | 6.2 | 4.3 | |
| 12 | 110 | 8.3 | 4.7 | |
| 13 | 120 | 11.1 | 5.2 | |
| 14 | 126.4 | 14 | 7.3 | Ultimate load |

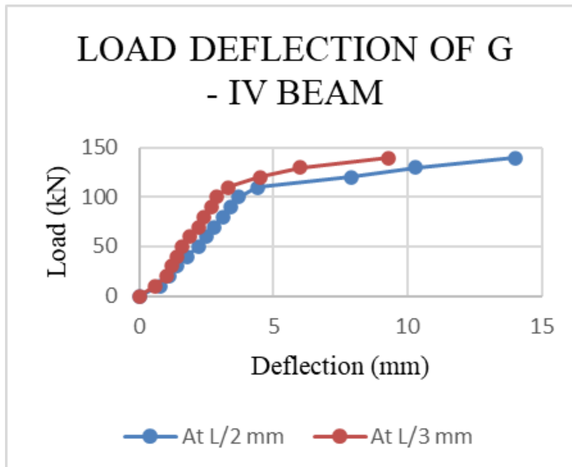



Graph 4- Load Deflection of G-III Beam

d) *Results of 15% added granite powder reinforced geopolymer beam (G – IV):*

Table 7: Load deflection of G-IV

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *At L/3 (mm)* | *REMARKS* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | |
| 2 | 10 | 0.8 | 0.6 | |
| 3 | 20 | 1.1 | 1.0 | |
| 4 | 30 | 1.4 | 1.2 | |
| 5 | 40 | 1.8 | 1.4 | |
| 6 | 50 | 2.2 | 1.6 | |
| 7 | 60 | 2.5 | 1.9 | First crack load |
| 8 | 70 | 2.8 | 2.2 | |
| 9 | 80 | 3.1 | 2.4 | |
| 10 | 90 | 3.4 | 2.7 | |
| 11 | 100 | 3.7 | 2.9 | |
| 12 | 110 | 4.4 | 3.3 | |
| 13 | 120 | 7.9 | 4.5 | |
| 14 | 130 | 10.3 | 6.0 | |
| 15 | 139.5 | 14 | 9.3 | Ultimate load |




Graph 5- Load Deflection of G-IV Beam

B. *Moment curvature relationship:*

a) *Results of 0% added granite powder reinforced geopolymer beam (G – I):*

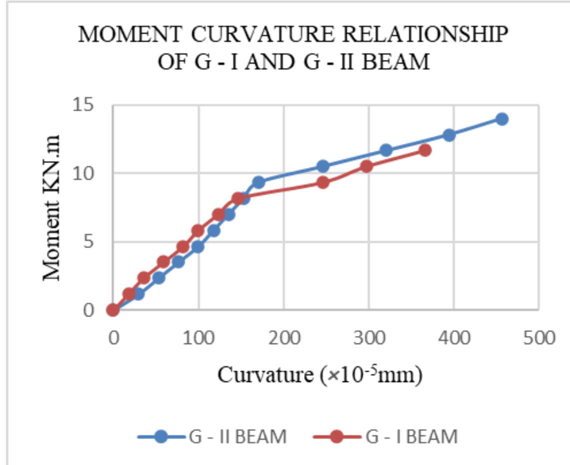
Table 8: Moment curvature of G-I

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *MOMENT (kNm)* | *CURVATURE (× $10^{-5}$ mm)* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 10 | 1.0 | 1.166667 | 17.63219 |
| 3 | 20 | 1.6 | 2.333333 | 35.26158 |
| 4 | 30 | 2.4 | 3.5 | 58.75824 |
| 5 | 40 | 3.0 | 4.666667 | 82.23834 |
| 6 | 50 | 3.4 | 5.833333 | 99.83358 |
| 7 | 60 | 4.0 | 7 | 123.2688 |
| 8 | 70 | 4.5 | 8.166667 | 146.6694 |
| 9 | 80 | 5.1 | 9.333333 | 245.584 |
| 10 | 90 | 5.7 | 10.5 | 297.4812 |
| 11 | 100 | 6.3 | 11.66667 | 366.0165 |

*b) results of 0% added granite powder reinforced geopolymer beam (G – II):*

Table 9: Moment curvature of G-II

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *MOMENT (kNm)* | *CURVATURE (×$10^{-5}$ mm)* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 10 | 0.5 | 1.166667 | 29.3856 |
| 3 | 20 | 1.9 | 2.333333 | 52.88537 |
| 4 | 30 | 2.4 | 3.5 | 76.37023 |
| 5 | 40 | 3.0 | 4.666667 | 99.83358 |
| 6 | 50 | 3.6 | 5.833333 | 117.413 |
| 7 | 60 | 4.1 | 7 | 134.9738 |
| 8 | 70 | 4.7 | 8.166667 | 152.5133 |
| 9 | 80 | 5.1 | 9.333333 | 170.0288 |
| 10 | 90 | 5.4 | 10.5 | 245.584 |
| 11 | 100 | 6.1 | 11.66667 | 320.4169 |
| 12 | 110 | 6.7 | 12.83333 | 394.3152 |
| 13 | 120 | 7.9 | 14 | 455.9637 |




Graph 6- Moment Curvature Relationship of G-I and G-II Beam

*c) Results of 15% added granite powder reinforced geopolymer beam (G – III):*

Table 10: Moment curvature of G-III

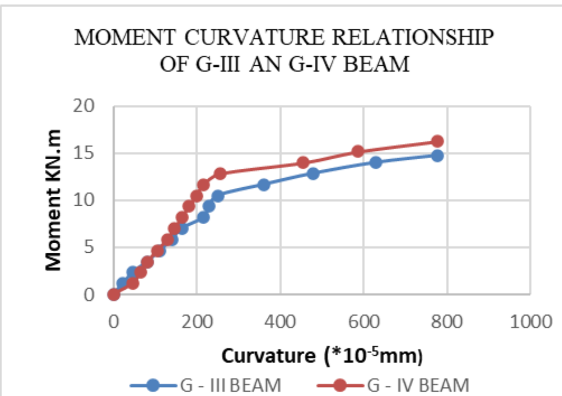
| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *MOMENT (kNm)* | *CURVATURE (×$10^{-5}$ mm)* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 10 | 0.5 | 1.166667 | 23.5091 |
| 3 | 20 | 1.6 | 2.333333 | 47.01157 |
| 4 | 30 | 2.3 | 3.5 | 82.23834 |
| 5 | 40 | 2.9 | 4.666667 | 111.5551 |
| 6 | 50 | 3.6 | 5.833333 | 140.8228 |
| 7 | 60 | 4.0 | 7 | 164.1931 |
| 8 | 70 | 4.4 | 8.166667 | 216.598 |
| 9 | 80 | 5.0 | 9.333333 | 228.2044 |
| 10 | 90 | 5.3 | 10.5 | 251.3688 |
| 11 | 100 | 6.1 | 11.66667 | 360.3376 |
| 12 | 110 | 7.4 | 12.83333 | 478.1564 |
| 13 | 120 | 9.5 | 14 | 629.6108 |
| 14 | 126.4 | 14 | 14.74667 | 778.0419 |

*d) Results of 15% added granite powder reinforced geopolymer beam (G – IV):*

Table 11: Moment curvature of G-IV

| *S.NO* | *LOAD (KN)* | *At L/2 (mm)* | *MOMENT (kNm)* | *CURVATURE (×$10^{-5}$ mm)* |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| 2 | 10 | 0.7 | 1.166667 | 47.01157 |
| 3 | 20 | 1.1 | 2.333333 | 64.63008 |
| 4 | 30 | 1.4 | 3.5 | 82.23834 |
| 5 | 40 | 2.4 | 4.666667 | 105.6953 |
| 6 | 50 | 3.3 | 5.833333 | 129.1225 |
| 7 | 60 | 3.9 | 7 | 146.6694 |
| 8 | 70 | 4.3 | 8.166667 | 164.1931 |
| 9 | 80 | 5.0 | 9.333333 | 181.691 |
| 10 | 90 | 5.5 | 10.5 | 199.1601 |
| 11 | 100 | 5.9 | 11.66667 | 216.598 |
| 12 | 110 | 6.3 | 12.83333 | 257.1492 |
| 13 | 120 | 8.0 | 14 | 455.9637 |
| 14 | 130 | 9.8 | 15.16667 | 587.084 |
| 15 | 139.5 | 14.0 | 16.275 | 778.0419 |




Graph 7- Moment Curvature Relationship of G-III and G-IV Beam

## VII. CONCLUSION

- The GPC cube with 15% partial replacement of G.P has 25.28% more compressive strength than the 0% partial replacement of G.P
- Load Deflection test
  - First crack load of the reinforced GPC beam with 15% partial replacement of G.P is 12.5% higher than the 0% partially replaced G.P reinforced GPC
  - Ultimate load of the reinforced GPC beam with 15% partial replacement of G.P is 20.86% higher than the 0% partially replaced G.P reinforced GPC
- Moment Curvature test
  - It shows the same behaviour as load deflection test
  - Moment resistance of the reinforced GPC beam with 15% partial replacement of G.P is 20.86% higher than the 0% partially replaced G.P reinforced GPC

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