Mechanical Properties of Geopolymer Concrete Made With Partial Replacement of Coarse Aggregate by Recycled Aggregate

T. Srinivas, G. Sukesh Reddy

Abstract: Construction is the one the fast growing field in the worldwide. There are many environmental issues connected with the manufacture of OPC, at the same time availability of natural coarse aggregate is getting reduced. Geopolymer binder and recycled aggregates are promising alternatives for OPC and natural coarse aggregates. It is produced by the chemical action of inorganic molecules and made up of Fly Ash, GGBS, fine aggregate, coarse aggregate and an alkaline solution of sodium hydroxide and sodium silicate. 10 M sodium hydroxide and sodium silicate alkali activators are used to synthesis the geopolymer in this study. Recycled aggregates are obtained from the construction demolished waste. The main focus of this work is to find out the mechanical properties of geopolymer concrete of grade G40 when natural coarse aggregate (NCA) is replaced by recycled coarse aggregate in various proportions such as 0%, 10%, 20%, 30%, 40% and 50% and also to compare the results of geopolymer concrete made with recycled coarse aggregates (RAC) with geopolymer concrete of natural coarse aggregate (GPC) and controlled concrete manufactured with recycled aggregates (RAC) and controlled concrete of natural coarse aggregates (CC) of respective grade. It has been observed that the mechanical properties are enhanced in geopolymer concrete, both in natural coarse aggregate and recycled coarse aggregate up to 30% replacement when it is compared with the same grade of controlled concrete.

Key words: Geopolymer Concrete, Recycled Aggregate, Alkaline Solutions, controlled concrete.

I. INTRODUCTION

Carbon dioxide (CO₂) is the iminical greenhouse gas in the world. One ton of OPC releases one ton of CO₂ into atmosphere. Now a day’s natural resources like coarse aggregate are depleted and construction and demolish waste increased. This cause to increase the land filling globally. Geopolymer is a promising alternative binder to Portland Cement. Recycled aggregate are promising alternative for coarse aggregate. This paper presents experimental results of geopolymer concrete of grade G40 when natural coarse aggregate is replaced by recycled coarse aggregate up to 50% at the interval of 10% and also to compare the results of geopolymer concrete made with recycled coarse aggregates with geopolymer concrete of natural coarse aggregate and controlled concrete of respective grade.

II. MATERIALS

A. Ordinary Portland Cement (OPC)

In this program, 53-grade of OPC is used. The physical properties of cement tested in accordance with IS: 4031 1968.

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B. Fine Aggregate

In this investigation, fine aggregate used is collected from the local suppliers. It belonging to Zone-II IS 383:1970. The physical properties are tested in accordance with IS: 2386-1963.

C. Coarse Aggregate

Locally available aggregate 20mm size were used in this study. The physical properties were tested in confirming to IS: 2386-1963.

D. Fly Ash

In this study of work, low calcium Fly Ash is used, which is acquired from Dr Narla Tata Rao Thermal Power Plant from Andra Pradesh.

E. Ground Granulated Blast Furnace Slag (GGBS)

GGBS acquired from the Lafarge RMC plant from bachupally Telangana. It is replaced by 15% of weight of binder.

F. Recycled Aggregate Concrete (RAC)

Recycled aggregates are collected from the CT lab, Osmania university. Utilizing RCA can result in 50 percentages less mineral depletion per m³ of concrete produced.

Fig 1: Recycled Coarse Aggregate (Source: Laboratory)

G. Water

Portable water is used for the curing in this work. which is easily available in the lab environment.

H. Sodium Hydroxide

NaOH is one of the major ingredients of geopolymer concrete. The following are the specifications of Sodium hydroxide pellets and this material is procured from the local laboratory chemical vendors in Hyderabad. Specifications of sodium hydroxide are shown in table 1.

Table 1: physical properties of NaOH
i. Compressive Strength of CC and GPC
This experiment is the direct measure of the strength of concrete. Compressive strength test has been conducted on the cubes of sizes 100mmx100mmx100mm accordance with IS 516-1969. Compressive strength of CC and GPC are shown table 3.

Table 2: Compressive strength of CC & GPC

|          | CC (N/mm²) | GPC (N/mm²) |
|----------|------------|-------------|
| 3 days   | 28.75      | 46.71       |
| 7 days   | 40.25      | 53.91       |
| 28 days  | 56.72      | 58.30       |

ii. Compressive Strength of Conventional Concrete manufactured with Recycled Aggregate (RAC)
Compressive strength test is performed on conventional concrete made with recycled aggregate up to 50% replacement at the interval of 10%. In this regard, the compressive strength value has been slightly decreasing up to 30% of replacement with recycled aggregate and thereon it started to decrease drastically. From table 3, it can be summaries that, 30% replacement is the optimum percentage of utilization of recycled aggregate in the concrete, because at this percentage the strength is higher than target mean strength.

Table 3: Compressive strength (N/mm²) of RAC

| percentage | DAYS |
|------------|------|
|            | 3    | 7    | 28   |
| 0%         | 28.45| 39.51| 56.72|
| 10%        | 26.80| 37.66| 53.81|
| 20%        | 24.91| 35.50| 51.04|
| 30%        | 24.56| 34.65| 49.75|
| 40%        | 23.26| 32.70| 46.72|
| 50%        | 21.98| 31.50| 45.08|

iii. Compressive Strength of Geopolymer Concrete made by Recycled Aggregate (RAGPC)
Compressive strength test is performed on RAGPC up to 50% at the interval of 10%. In this regard, the compressive strength value has been slightly decreasing up to 30% of replacement with recycled aggregate and thereon it started to decrease drastically. From the results given in table 4, it can be summaries that, 30% replacement is the optimum percentage of utilization of recycled aggregate in the concrete, because at this percentage the strength is higher than target mean strength.

Table 4: Compressive strength (N/mm²) of RAGPC

| percentage | DAYS |
|------------|------|
|            | 3    | 7    | 28   |
| 0%         | 28.75| 40.25| 56.72|
| 10%        | 26.80| 46.71| 53.91|
| 20%        | 24.91| 51.04| 53.81|
| 30%        | 24.56| 49.75| 51.04|
| 40%        | 23.26| 46.72| 49.75|
| 50%        | 21.98| 45.08| 49.75|
iv. Compressive Strength Test Results

From Table 5, it is evident that the strength of GPC is more than that of Conventional concrete. When the conventional and geopolymer concrete replaced with recycled aggregate the strengths have been slightly decreased up to 30% and thereon decreased drastically. In RAC and RAGPC, the strength has been decreased slightly but still it is above the target mean strength, so optimum strength results at 30% replacement of recycled aggregate geopolymer concrete can be considered.

Table 5: Compressive Strength Test Results

| percentage | 3   | 7   | 28  |
|------------|-----|-----|-----|
| 0%         | 46.71 | 53.91 | 58.30 |
| 10%        | 45.56 | 51.18 | 56.25 |
| 20%        | 43.65 | 48.44 | 53.24 |
| 30%        | 40.77 | 46.31 | 50.34 |
| 40%        | 38.24 | 43.98 | 47.81 |
| 50%        | 38.02 | 42.72 | 46.95 |

B. Split Tensile Strength

It is the experiment to know the tensile strength of the concrete in the indirect way. This test has been conducted on the cylinders of sizes 100 mm x 200 mm accordance with IS 5816-1970.

i. Comparisons of Split Tensile Strength Test Results

From Table 6, the tensile strength of GPC is more than that of CC. When the conventional and geopolymer concrete replaced with recycled aggregate the strengths have been slightly decreased up to 30% and thereon decreased drastically. The results shows that 30% is the optimum replacement among all replacements.

Table 6: Split Tensile Strength Test Results

|          | 3 | 28 |
|----------|---|----|
| CC       | 3.34 | 4.90 |
| GPC      | 5.97 | 6.62 |
| RAC -30% | 2.81 | 4.28 |
| RAGPC -30% | 5.3  | 5.82 |

C. Flexural Strength

It is the experiment to know the bending strength of the concrete in indirect way, it was conducted on the prisms of sizes 500mmx100mmx100mm accordance with the IS 519-1959. The systems of loading used in finding the flexure strength was central point loading and third point loading. In this study third point loading is used.

i. Comparison of Flexural Strength Test Results

From Table 7, bending strength of GPC is more than that of CC. From the results it is observed that 30% replacement is optimum among all replacements.
Comparison of Flexural Strength Test Results

V. CONCLUSIONS

The conclusions are drawn from the above results are as follows

i. From the results, it is concluded that the compressive, tensile and flexural strength of Geopolymer concrete made with Natural Aggregate (GPC) is 2.79%, 3.5% and 6.9% greater than that of Conventional concrete made with Natural Aggregate (CC) respectively.

ii. It is distinguished that the compressive, tensile and flexural strength of RAC is 12.29%, 13.17% and 10.13% less than that of CC respectively at 30% replacement. However, it can be considerable, since compressive strength is still above the target mean strength.

iii. The compressive, tensile and flexural strength of RAGPC is 13.65%, 12.89% and 10.16% less than that of GPC respectively at 30% replacement. However, it can be considerable, since compressive strength is still higher than the target mean strength.

iv. The replacement of recycled aggregate in concrete gives better results till 30% replacement, so it is an alternative solution for disposal of C & D waste.

v. The geopolymer concrete gives an early strength when cured in an oven, so it can be preferred wherever early strength is required.

REFERENCES

1. Nella shiva kumar, Gone punneshwar(2011) “strength properties of recycled aggregate” International Journal Of emerging technologies in engineering research 6(2), Pp.63-68.

2. O. sanusi, B. Tempest and V. O. Ogunro(2011) “Mitigating Leachability Flyash based Geopolymer concrete using Recycled Coarse Aggregate” Geo-Frontiers, pp.1315-1324.

3. Dr.T.Srinivas and Dr.N.V.Ramana Rao (2019) "Studies on the Behaviour of Sulphate Attack Resistance of Low Calcium Fly Ash and Slag Based Geopolymer Concrete" International Journal of Civil Engineering and Technology (IJCIET), Volume 10, Issue 02, February 2019, pp. 510-518

4. V S Reddy, “Performance of Microbial Concrete Developed Using Bacillus Subtilis J3”, Journal of The Institution of Engineers (India: Series A, Springer India, Print ISSN 2250-2149, Online ISSN 2250-1257.

5. Pawan Anand Khanna, Durga Kelkar (2017) “Study on the Compressive Strength of Flyash based Geopolymer Concrete”, Journal of Materials Science and Engineering, 263,pp.1-5.

AUTHOR’S PROFILE

Dr. T.Srinivas is working as a professor in the Department of Civil Engineering, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad, Telangana, India. His areas of research interest are mainly focused on the utilization of coal ash (fly ash ), special concrete, structural analysis and design of different structures.

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