Influence of Granite Cutting Waste on Mechanical Properties of Recycled Aggregate Concrete

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Abstract. Solid waste disposition has been a growing problem in many developed and under-developing nations. Major part of development was constituted by construction and infrastructure; on the contrary these industries also lead to release of carbon dioxide into the atmosphere. To overcome these disadvantages; in this research, recycled aggregates from construction waste and granite cutting waste were adopted as a replacement of coarse aggregate and cement respectively. Mechanical properties of recycled aggregate (RA) concrete are tested by replacing coarse aggregate varying from 0% to 100% with a difference of 25% and cement is replaced with Granite cutting waste (GCW) varying from 0% to 20% with a difference of 5%. Mix designation and fresh properties were also presented. Results were plotted and compared with the normal concrete to predict the most optimal values of the replacement. Mix containing 25% of RA and 15% of GCW replaced has shown a notable difference in strength comparing with the normal aggregate concrete.

Keywords. Construction waste, Granite cutting waste, recycled aggregate concrete, hardened properties.

1. Introduction

It is very evident that concrete is one of the most used construction material and has an increasing demand every year. With increase in demand there is chance of depletion of naturally available material, that could let down to worst scenarios[1]. To reduce, the depletion of natural resources and increasing carbon dioxide values in the atmosphere, construction waste from demolition is used as recycled aggregate and such concrete is called recycled aggregate concrete[2][3]. Recycled aggregates are usually made by crushing plain and rounded cementitious aggregates. Past studies revealed that recycled aggregate concrete has less flowing ability and compensatory cementitious material were added to
increase the workability[4], [5]–[8]. Usually silica fume, flyash were taken as super plasticizers to increase the workability and increase in mechanical strength also observed in such investigations[9]. In this paper GCW is used as partial replacement to investigate strength properties. GCW is usually replaced with cement in normal aggregate concrete to yield a notable strength values and was adopted in this study to evaluate the strength[10].

2. Experimental Methodology

2.1. Materials

Ordinary Portland cement of 53grade, stored in permissible condition as per is.4082.1996[1]. Physical and chemical properties of cement were given in Table 1. Granite cutting waste is obtained from quarry site of chimakurthy town, Andhra Pradesh, India. A large amount of waste was observed to be accumulated at the quarry sites which has a highest impact on air pollution. Highest amount of sample collected can pass through 25m sieve and finer to the limits of cement particles. Chemical properties of granite cutting waste are shown in Table 2. River sand is taken as fine aggregate and 20mm sized gravel is taken as coarse aggregate. Recycled aggregates are taken from the demolition site near Ongole and were manual graded to obtain the required size and shape. Admixture used in the study is conplast sp430g8.

### Table 1. Chemical and Physical properties of cement

| Chemical property | Composition | Physical property       | value  |
|-------------------|-------------|------------------------|--------|
| Cl                | 0.04        | Specific Gravity       | 3.2    |
| MgO               | 1.0         | Standard Consistency   | 31.21  |
| CaO               | 64.23       | Initial setting time   | 30min  |
| Na2O              | 0.33        | Final Setting time     | 225min |
| SiO2              | 22.54       |                        |        |
| SO3               | 2.45        |                        |        |
| FeO3              | 3.82        |                        |        |
| Loss of ignition  | -           |                        |        |

| Chemical property | Composition |
|-------------------|-------------|
| SiO2              | 76.38       |
| Al2O3             | 11.86       |
| Fe2O3             | 2.01        |
| MnO               | 0.02        |
| MgO               | 0.21        |
| CaO               | 0.43        |
| Na2O              | 2.95        |
| K2O               | 5.05        |
| TiO2              | 0.14        |
| P2O5              | 0.19        |
| Loss of Ignition  | 0.77        |
2.2. Mix Design

20 mixes were prepared in this study to replace coarse aggregate with recycled aggregate in proportion of 0%, 25%, 50% and 100%. Cement is replaced with granite cutting waste by 0%, 5%, 10%, 15% and 20%. Designation of each mix along with fresh properties is shown in Table 4. Water to cement ratio by trial and error can be adopted as 0.37 and mix proportions were shown in Table 3.

Table 3. Mix proportion of Normal Aggregate concrete.

| Cement (kg/m³) | Water (kg/m³) | Coarse aggregate (kg/m³) | Fine aggregate (kg/m³) |
|----------------|---------------|--------------------------|------------------------|
| 450            | 166.5         | 1152                     | 855                    |

2.3. Workability tests on concrete

To test the workability of concrete slump cone and compaction factor tests are done on all the mixes of concrete and results were plotted in Table 4. From the test results it is observed that when recycled aggregate is increasing there is decrease in the workability values of recycled aggregate concrete with 0% of granite cutting waste. This may be due to irregular arrangement and roughness of recycled aggregate. After increasing the values of granite cutting waste, a change in workability is observed to a certain limit, this may be due to filling the voids with granite cutting waste and settling of particles.

Table 4. Mix designation and workability test values.

| Mix Designation | % of RA replaced | % of GCW replaced | Slump (mm) | Compaction Factor |
|-----------------|------------------|--------------------|------------|------------------|
| RA₀GCW₀         | 0                | 0                  | 69         | 0.954            |
| RA₀GCW₅         | 0                | 5                  | 71         | 0.956            |
| RA₀GCW₁₀        | 0                | 10                 | 73         | 0.958            |
| RA₀GCW₁₅        | 0                | 15                 | 78         | 0.956            |
| RA₀GCW₂₀        | 0                | 20                 | 70         | 0.953            |
| RA₂₅GCW₀        | 25               | 0                  | 65         | 0.943            |
| RA₂₅GCW₅        | 25               | 5                  | 64         | 0.945            |
| RA₂₅GCW₁₀       | 25               | 10                 | 64         | 0.956            |
| RA₂₅GCW₁₅       | 25               | 15                 | 65         | 0.955            |
| RA₂₅GCW₂₀       | 25               | 20                 | 71         | 0.945            |
| RA₅₀GCW₀        | 50               | 0                  | 61         | 0.933            |
| RA₅₀GCW₅        | 50               | 5                  | 63         | 0.935            |
| RA₅₀GCW₁₀       | 50               | 10                 | 63         | 0.937            |
| RA₅₀GCW₁₅       | 50               | 15                 | 62         | 0.932            |
| RA₅₀GCW₂₀       | 50               | 20                 | 59         | 0.933            |
| RA₁₀₀GCW₀       | 100              | 0                  | 55         | 0.922            |
| RA₁₀₀GCW₅       | 100              | 5                  | 58         | 0.925            |
| RA₁₀₀GCW₁₀      | 100              | 10                 | 58         | 0.927            |
| RA₁₀₀GCW₁₅      | 100              | 15                 | 56         | 0.927            |
| RA₁₀₀GCW₂₀      | 100              | 20                 | 53         | 0.921            |

*RA: Recycled Aggregate *GCW: Granite Cutting Waste
3. Mechanical Properties Tests

Compressive strength, split tensile strength and flexural tests were conducted to determine the mechanical properties of recycled aggregate concrete incorporated with granite cutting waste.

Table 5. Mechanical properties

| Mix Designation | Compressive strength (MPa) | Split Tensile strength (MPa) | Flexural strength (MPa) |
|-----------------|-----------------------------|------------------------------|-------------------------|
|                 | 7days | 28days | 7days | 28days | 7days | 28days |
| RA₀GCW₀         | 41.21 | 51.43  | 4.49  | 5.00   | 5.98  | 6.52  |
| RA₀GCW₅         | 44.13 | 59.65  | 4.49  | 5.09   | 5.99  | 6.59  |
| RA₀GCW₁₀        | 46.14 | 60.32  | 5.01  | 5.12   | 6.12  | 7.21  |
| RA₀GCW₁₅        | 47.13 | 61.12  | 5.13  | 5.22   | 6.25  | 7.25  |
| RA₀GCW₂₀        | 44.12 | 58.63  | 4.55  | 5.02   | 6.02  | 7.18  |
| RA₂₅GCW₀        | 40.13 | 50.12  | 4.24  | 4.63   | 5.71  | 6.49  |
| RA₂₅GCW₅        | 41.33 | 51.03  | 4.33  | 4.69   | 5.73  | 6.51  |
| RA₂₅GCW₁₀       | 43.33 | 53.15  | 4.39  | 4.72   | 5.75  | 6.53  |
| RA₂₅GCW₁₅       | 44.16 | 59.15  | 4.42  | 4.77   | 5.77  | 6.55  |
| RA₂₅GCW₂₀       | 42.11 | 49.16  | 4.22  | 4.59   | 5.70  | 6.48  |
| RA₅₀GCW₀        | 39.33 | 42.11  | 3.93  | 4.42   | 5.57  | 6.33  |
| RA₅₀GCW₅        | 39.96 | 44.11  | 3.96  | 4.45   | 5.59  | 6.37  |
| RA₅₀GCW₁₀       | 40.13 | 49.14  | 3.99  | 4.49   | 6.01  | 6.42  |
| RA₅₀GCW₁₅       | 41.11 | 51.13  | 4.01  | 4.52   | 6.15  | 6.48  |
| RA₅₀GCW₂₀       | 38.33 | 42.14  | 3.93  | 4.41   | 5.58  | 6.35  |
| RA₁₀₀GCW₀       | 33.43 | 39.18  | 3.50  | 3.92   | 5.09  | 5.36  |
| RA₁₀₀GCW₅       | 35.15 | 39.36  | 3.50  | 3.96   | 5.11  | 5.39  |
| RA₁₀₀GCW₁₀      | 35.56 | 40.12  | 3.51  | 3.98   | 5.12  | 5.44  |
| RA₁₀₀GCW₁₅      | 36.33 | 41.11  | 3.53  | 3.99   | 5.16  | 5.49  |
| RA₁₀₀GCW₂₀      | 33.12 | 38.16  | 2.99  | 3.34   | 4.92  | 5.22  |

Duration for testing mechanical properties is considered as 7 and 28 days. Tests results were shown in Table 5. A comparative graph was plotted for all the 25 mixes as shown in Figure 1 to Figure 6.
Figure 1: 7 days compressive strength of Recycled Aggregate Concrete

Figure 2: 28 days compressive strength of Recycled Aggregate Concrete
Figure 3: 7 days Split Tensile Strength of Recycled Aggregate Concrete

Figure 4: 28 days Split Tensile Strength of Recycled Aggregate Concrete
Figure 5: 7 days Flexural Strength of Recycled Aggregate Concrete

Figure 6: 28 days Flexural Strength of Recycled Aggregate Concrete
It is observed from the Table 5 that compression test values are gradually increased to a certain limit ranging to a replacement of granite cutting waste at 15%. Also increase in recycled aggregate content increase may cause segregation of particles irregularly. Decrease in mechanical properties may be also due to highest void ratio.

4. Conclusions

From the workability and mechanical test results following conclusions can be drawn

- Compressive strength of concrete has a drop of nearly 15% with increase in RA volume in the concrete, though granite cutting waste has an effect on porosity. This may be due to uneven shape and size of the recycled aggregates.
- Split tensile and flexural strength has the also shown same impact like compression strength.
- Most suitable proportions can be considered as RA$_{25}$GCW$_{15}$. With increase in percentage of recycled aggregates, there is nearly a decrease of 35 to 40% in strength of concrete.

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