# Experimental Investigation on Characteristic Strength of Recycled Aggregate Concrete with Admixtures

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***Abstract:-* The usage of natural aggregate is getting more and more intense with the advanced development in infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as replacement materials. Three series of mixes with 25%, 50% and 75% replacement of natural aggregate(NA) with recycled aggregate(RA) were prepared to study the strength and durability characteristic of concrete. In each series fly ash(FA) were replaced with 10% by the weight of cement and silica fume(SF) were replaced with 7.5% by weight of cement and glass fiber with 0.3% is added to the concrete by weight of fine aggregate. The effect of above said replacements on various properties of concrete such as compressive strength, tensile strength, flexural strength test were investigated. These results were compared to the same properties of a control concrete mixture and an acceptable percentage of replacements of NA were obtained. Test results show that concrete containing optimal amount of recycled aggregate and mineral admixture resulted in a good structural concrete in strength and durability aspects.**

***Keywords: Recycled aggregate, Fly ash, Silica fume, Glass fiber***

## 1. INTRODUCTION

### *1.1RECYCLING OF CONSTRUCTION AND DEMOLITION WASTE*

Environment preservation and reduction in the rate of rapidly diminishing natural resources are the key requirement for sustainable development. Many steps have been taken to conserve the natural resources. The large amount of depletion of natural aggregate (NA) and the increased amounts of wastes from construction and demolition going to landfill sites are causing serious problems to handling and safe disposal without causing significant damage to the environment.Therefore efforts are made for conversion of C&DW and industrial wastes into utilizable raw materials for beneficial uses. This phenomenon is discussed by using the principle of 3R i.e. Reduce, Reuse and Recycle.

It is estimated that the global production of concrete is at an annual rate of 1 $m^3$ per capita. As per the research by Fredonia group, World construction aggregates demand is forecast to 28 billion metric tonnes by the year 2013. India is also one among the top ten users of construction materials.

Over 1 billion tonnes of C&DW is generated every year worldwide. From environmental point of view, for production of natural aggregates of 1 ton, emissions of 0.0046 million ton of carbon exist where as for 1ton recycled aggregate (RA) produced only 0.0024 million ton carbon is produced. Considering the global consumption of 10 - 12 billion tons/year of aggregate for concrete production (Tsung et al. 2006), the carbon footprint can be determined for the NA as well as for the RA.

### *1.2 RECYCLING OF INDUSTRIAL WASTES*

Industrial wastes like fly ash (FA) and silica fume (SF) are also available in abundant quantity and create lot of disposal problem. Formation of land-fills in thermal industries is an inevitable problem. To solve the above issues, these waste materials can be used as partial replacer to cement in construction industry. However, the use of FA and SF in construction is nothing new and has a long history of use in concrete. The reduction of Ordinary Portland cement production will reduce carbon dioxide (CO2) emissions, reduce energy consumption and reduce the rate of global warming. Utilization of FA and SF usually provides cost savings as well as improved concrete properties.

## 2. REVIEW OF LITERATURE

The RCA has 3-10% lower density and 3-5 times higher water absorption than the corresponding NA because of the adhered cement paste in the RCA. They also suggested giving prior importance to the density and water absorption; avoid large variations in properties of hardened concrete as well as in achieving fresh concrete of adequate workability, stability and cohesiveness [Limbachiya et al. 2004]. The use of upto 30% RA to replace NA will not have significant adverse effects on RAC cube strength. For higher RA contents, minor alterations to the mix proportions may be needed to ensure that equivalent performance to NAC is achieved.[Dhir et al. 1998]. The addition of steel and polypropylene fibers provide better performance for the concrete. The addition of fly ash in the concrete mixture may adjust the workability and strength losses caused by fibres. [Topcu and Canbaz, 2007]. The investigations carried out in China on performance of RAC on mechanical, durability and structural characteristics for the past 15 years (1996–2011). They concluded that microstructure of RAC is much more complex than that of conventional concrete and mechanical property and durability gets affected when percentage of RA increases [Xiao et al. 2012].An experimental study on the effect of fly ash and silica fume on the properties of concrete subjected to acidic attack and sulphate attack.Changes in physical and chemical properties in the mortars with different replacements by fly ash and silica fume when immersed in 2% H2SO4, 10% Na2SO4 and 10% MgSO4 solutions for 3 years were investigated [Kazuyuki Torii and MitsunoriKawamura ,1994]. They tried with two series of concrete mixtures. Series one consists of replacement of NA with 0, 20, 50 and 100% of RA and cement with 0, 25 and 35% of FA for constant water-cement ratio of 0.55. In series two, water-binder ratio was modified to 0.42 for concrete prepared with FA. They used Class F fly ash to mitigate the lower quality of RA. Specimens were subjected to different tests like compressive strength, drying shrinkage, creep, chloride penetration, carbonation depth and capillary water absorption. They concluded that though the addition of RA reduces strength and affects durability properties, addition of 25 to 35% of fly ash minimizes the drawbacks induced by RA. They encouraged the use of RA in concrete with considerable percentage of FA [Kou and Poon, 2012].

## 3. OBJECTIVES

- To reduce the impact of waste materials on environment
- To study the behavior of recycled aggregate concrete with flyash, silica fume and glass fiber as a replacement to cement and fine aggregate
- To find out the % use of RCA feasible for construction
- To investigate the strength and durability of hardened concrete
- To reduce cracks and shrinkages in concrete
- To find out the ways of cost saving

## 4. MATERIALS AND ITS PROPERTIES

### *4.1. CEMENT*

The cement used in the present research work was Ordinary Portland Cement with 43 grade. The specific gravity of cement was found out by density bottle method and its value is 3.15, which confirms the permissible value as per IS: 8112.

| S.no. | Parameter | Test results |
|---|---|---|
| 1. | Normal Consistency | 28% |
| 2. | Fineness of cement (%) | 6 |
| 3. | Specific Gravity | 3.15 |
| 4. | Initial setting time | 70 min |
| | Final setting time | 300 min |

Table 1: Properties of cement

### *4.2. FLY ASH*

Fly ash is a by product obtained during the process of combustion of pulverized coal in electric power generating plant. Low calcium fly ash equivalent to ASTM Class F fly ash which was collected from the thermal power plant.The physical and chemical composition of fly ash are shown in table 4.1.2 and 4.2.

| Properties of Fly ash | Results |
|---|---|
| Fineness modulus ash (passing through 75μ) | 7.5 |
| Specific surface ($cm^2/g$) | 3950 |
| Specific gravity (g/cc) | 2.4 |

Table 2: Physical properties of fly ash

| Description | NA (%) | RA (%) | FA (%) | Cement (%) | Silica fume (%) |
|---|---|---|---|---|---|
| $SiO_2$ | 58.54 | 56.89 | 56.6 | 24.5 | 92.1 |
| $Al_2O_3$ | 17.81 | 10.57 | 33.71 | 7 | 0.5 |
| CaO | 6.17 | 19.93 | 1.07 | 63 | 0.5 |
| $Fe_2O_3$ | 6.07 | 3.85 | 3.97 | 0.55 | 1.4 |
| $Na_2O$ | 4.2 | 1.92 | 0.16 | 0.4 | 0.3 |
| MgO | 2.91 | 0.6 | 0.42 | 0.2 | 0.3 |

Table 3: Chemical composition of concrete materials

### *4.3. SILICA FUME*

The primary chemical and physical composition of silica fume are shown in table 4.1.2 and 4.3.

| Property | Result |
|---|---|
| Particle size | 0.5 µm - 1µm |
| Pack density | 0.76 gm/cc |
| Moisture content | 0.058% |
| Specific gravity | 2.6 |

Table 4: Physical Properties of Silica fume

### *4.4. GLASS FIBRE*

E-Glass fibres was used and the properties of glass fibres is shown in Table 4.4

| Diameter µm | Specific gravity | Failure strain % | Elasticity (GPa) | Tensile strength (GPa) |
|---|---|---|---|---|
| 12 | 2.6 | 3.0 | 80 | 2.5 |

Table 5: Properties of glass fiber

### *4.5. NATURAL AGGREGATE (NA)*

Crushed granite natural aggregate of size 20 mm (max) which was proven to produce excellent natural aggregate concrete and their particle size distribution satisfying the requirements of IS 2386 – 1997 was used in the present research work. The physical, mechanical properties and the chemical composition of coarse aggregate are given in Table 4.1.2 and Table 4.5Physical and Mechanical properties of Coarse Aggregates

| S.no | Description | Coarse aggregate | | |
|---|---|---|---|---|
| | | Natural aggregate | Recycled aggregate | Permissible range as per IS2386 (1997) |
| 1 | Specific gravity | 2.7 | 2.6 | 2.5 to 3 |
| 2 | Fineness modulus | 7.24 | 6.99 | 6.00 to 8.00 |
| 3 | Water absorption(%) | 0.6 | 2 | 0.1 to 2 |
| 4 | Crushing value (%) | 17.77 | 33.54 | 45 |
| 5 | Impact value (%) | 12.88 | 18.5 | 45 |
| 6 | Abrasion value (%) | 17 | 14 | 30 |
| 7 | Density(g/cc) | 2.60 | 2.56 | -- |

Table 6: Physical and Mechanical properties of Coarse Aggregates

### *4.6. RECYCLED AGGREGATE (RA)*

Recycled aggregates were obtained from the demolished building. The physical and mechanical properties of recycled aggregates are shown in table 4.5

Fig 1: Natural Aggregates

Fig 2: Recycled Aggregates

### *4.7 FINE AGGREGATE*

River sand which passes through 4.75mm sieve and retained on 150 µm sieve, which satisfies IS 383 -1970 was used as the fine aggregate. The specific gravity and water absorption of fine aggregate was 2.65 and 0.44%.

### *4.8. WATER*

The water used for casting and curing concrete test specimens was free of acids, organic matter, suspended solids and impurities which when present can adversely affect the strength of concrete.

### *4.8. SUPERPLASTICIZER*

To enhance the workability and strength of concrete chemical admixture known as Sulphonated Naphthalene Formaldehyde based polymer was used.

## 5. METHEDOLOGY


## 6. EXPERIMENTAL DETAILS

### *6.1 MIX PROPORTION*

A mix M25 grade was designed as per IS 10262:2009 and the same was used to prepare the test samples. The design mix proportion is shown in Table 6.1

Table 7 Different type of mix

| Types | Constituent materials and percentage replacement |
|---|---|
| R-0 | Conventional concrete |
| R-25 | Concrete containing 25% of RA, 10% of FA, 7.5% of SF, 0.3% of GF |
| R-50 | Concrete containing 50% of RA, 10% of FA, 7.5% of SF, 0.3% of GF |
| R-75 | Concrete containing 75% of RA, 10% of FA, 7.5% of SF, 0.3% of GF |

( RA- Recycled aggregate, FA- Fly ash, SF- Silica fume, GF- Glass fiber)

### *6.2 COMPRESSIVE STRENGTH TEST*

The steel mould of size 150x150x150 mm is well tightened and oiled thoroughly. The fresh mixed concrete is placed and well compacted through mechanical vibrators and after 24 hours they were allowed for curing in a period of 3, 7, 28 days and they were tested. After the curing period the specimen is taken out from the curing tank and wipes it clean. The dimensions of the specimens and the weight of the specimens were noted down with accuracy. Then the specimen is placed between the loading the surface of the CTM and the load is applied till the specimen fails. The ultimate load at the time of failure is noted down. The test procedures were adopted as per ASTM standards. The load was applied at the rate of 140 $kg/cm^2/min$ till the cube breaks.The compressive strength of the specimen was calculated by using the formula

$$f_c = P/A \ (N/mm^2)$$

Where,

P = Load at which the specimen fails in Newton (N)

A = Area over which the load is applied in $mm^2$

$f_c$ = Compressive Stress in $N/mm^2$

### *6.2. SPLIT TENSILE STRENGTH*

Split tensile strength of concrete is usually found by testing concrete cylinder of size 100mm × 200mm. The specimens were tested for its strength as per IS: 516-1959 using a calibrated compression testing machine of 2000KN capacity.The tensile strength of the specimen was calculated by using the formula

$$f_t = 2P/\pi dl \ (N/mm^2)$$

Where,

P = Maximum load in N applied to the specimen

d = Measured length in cm of the specimen

l = Measured diameter in cm of the specimen

ft = Tensile strength $N/mm^2$

### *6.4 FLEXURAL STRENGTH*

The normal tensile stress in concrete, when cracking occurs in a flexure test is known as modulus of ruptures, i.e. flexural strength. The standard test specimen is a beam of size 500mm × 500 mm × 100mm size. The specimen should be should be cast and cured in the same manner as for casting of cubes. The specimens should be immediately tested on removal from the water. The flexural strength can be finding out by calibrated flexural machine. The flexural strength can be find out by central loading as well as the load is applied through two similar rollers mounted at the third point of the supporting span. The flexural strength can be found out by formula as follows

$$F_{cr} = (PL)/bd^2$$

Where,

P = Fracture load for beam

L = Span

b = Width of the beam

d = Depth of the beam

## 7. RESULT AND DISCUSSIONS

The mix proportion for M25 is 1: 1.18: 2.86 and W/C ratio of 0.45 was casted. The cubes, cylinders and beams were tested for compressive strength, split tensile strength and flexural strength. These tests were carried out at the age of 7 days, 14 days, 28 days and 56 days.

### *7.1 COMPRESSIVE TEST*

The compressive strength of RAC is slightly higher than the conventional concrete made from similar mix proportions.But the extent of reduction in strength depends on the source of recycled aggregate, degree of replacement, water cement ratio as well. As per test results the strength of recycled aggregate cube is more than target strength, so RCA can be used for construction purpose.

Fig 3: Compressive strength test

| Mix design | Compressive strength ($N/mm^2$) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| R-0 | 22.32 | 25.36 | 30.96 |
| R-25 | 26.67 | 29.33 | 33.33 |
| R-50 | 25.33 | 24.89 | 24.44 |
| R-75 | 24.10 | 21.78 | 20.89 |

Table 9: Compressive strength test

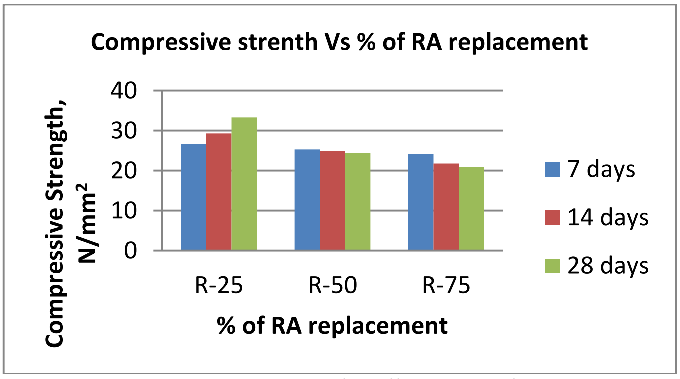


Fig 4: Compressive strength for different types of mix

### *7.2 SPLIT TENSILE STRENGTH*

The split tensile strength of RAC is slightly lower than the conventional concrete made from similar mix proportions.

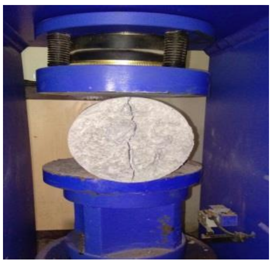

Fig 5: Split tensile strength test

| Mix design | Split tensile strength ($N/mm^2$) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| R-0 | 2.68 | 3.5 | 3.75 |
| R-25 | 1.76 | 2.97 | 4.24 |
| R-50 | 1.84 | 3.11 | 4.38 |
| R-75 | 1.79 | 2.82 | 4.10 |

Table 10: Split tensile strength test

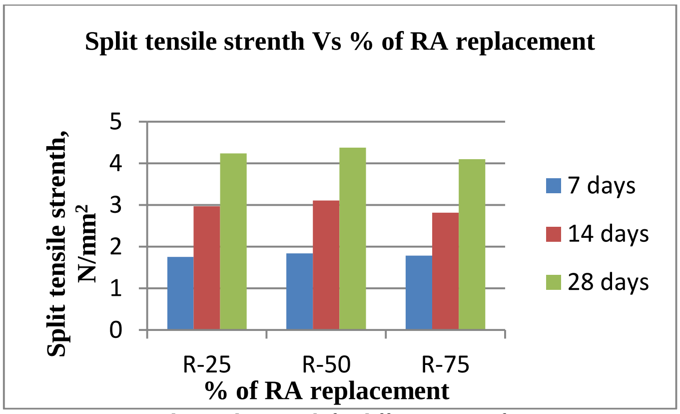


Fig 6: Split tensile strength for different types of mix

### *7.3 FLEXURAL STRENGTH*

The flexural strength of RAC is higher than the conventional concrete and the strength gets decreasing when replacement of RA increases.

| Mix design | Compressive strength ($N/mm^2$) | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| R-0 | 2.84 | 3.34 | 3.92 |
| R-25 | 3.61 | 3.79 | 4.04 |
| R-50 | 3.52 | 3.49 | 3.46 |
| R-75 | 3.44 | 3.27 | 3.19 |

Table 11: Flexural strength test

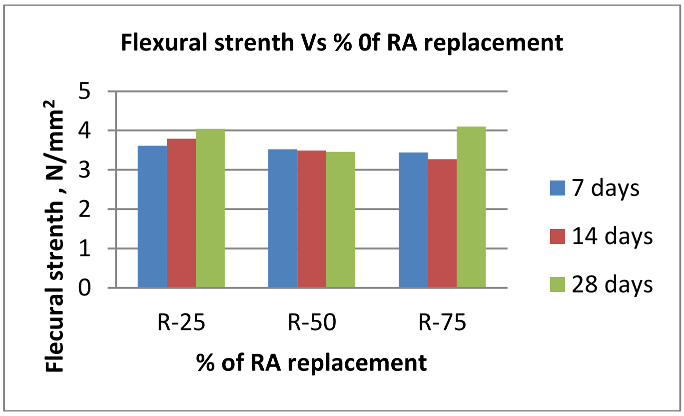


Fig 7: Flexural strength for different types of mix

## CONCLUSION

Based on experimental investigation concerning the compressive, split tensile, flexural strength of concrete, the following conclusions are drawn

- RA content increases compressive strength decreases, but combined effect of admixture and glass fiber gives better performance.
- The optimum value of compressive strength can be achieved in 25% replacement of RA.
- The split tensile strength of RAC has been found to be lesser than NAC at all ages of concrete and for all percentage of NA replacements.
- Use of recycled aggregate up to 25% does not affect the compressive strength and flexural strength as per the findings of the test results.
- The addition of glass fiber of 0.3% increases the split tensile strength and flexural strength.
- From this it is concluded that replacement of 25% of RA is suitable for structural construction.

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