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Effect of Recycled concrete aggregate on the strength Properties of new concrete

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Abstract - The compressive strength of old (made with natural aggregate) concrete was 30 MPa at 28-day, which was crushed at the ages of 1, 3 and 28 days to replace the natural (new) aggregate by the recycled aggregate (which obtained by destruction of old concrete structure) for new concrete. The precast concrete plants, and the destruction of the building structure after the reaching the end of service life or design life and changing in the Bylaws of building results the crushed concrete (recycled aggregate). The various properties of the recycled aggregate and the concrete produced with the recycled aggregate are tested, with almost complete replacement of the aggregate. There are considerable differences between the properties of recycled aggregates of different groups of particle sizes, while the age of grinding has about no effect. The properties of the concrete made with recycled aggregates are more scarce than the concrete produced with natural aggregates. The effects of the age of grinding are moderate: the concrete made with crushed aggregates at the age of 3 days showed improved properties compared to those produced with aggregates of other crushing ages (1 and 28 days), when a strong matrix of cement was used. cement. An opposite tendency was observed when a weaker cement matrix was used.

***Key Words*: RAC - Recycled Aggregate concrete , Old Concrete - Made with Natural Aggregate, New Concrete - Made with Recycled Aggregate, RA - Recycled Aggregate, NA - Natural Aggregate**

1.INTRODUCTION

More concrete structures which were constructed near the 1970s and before, those structures are now required of either high maintenance or possible replacement in India. It is required, because some of the concrete structures are now have reached at the end of their design service life, or may not be constructed as per the specification and design criteria, or did not done the proper maintenance during the service life of the structure. Additionally, some natural disasters such as India/Nepal Earthquake (April 2015), Kashmir Earthquake (2005),Bhuj, Gujrat earthquake (2001), Earthquake in Uttarkashi, Uttrakhand (1991) and Earthquake in Cachar district of Assam (1984) and many more in India have resulted in a great quantity of waste concrete. The repairing and the replacement work of the civil work results from a large quantity of waste concrete in the form of dust or rubble of concrete mass that is usually dumped in the deserts.

Construction waste and destruction (C & D) might be the broken concrete, building bricks, bridges or broken road paving. Therefore, the Recycled Aggregate (RA) can come from the destruction of buildings, bridge, airport runways and concrete floors. Concrete made with this type of aggregate is said to be recycled aggregate concrete (RAC).

The continuous industrial development creates a serious issue of discharge of construction and demolition waste. While on the one hand, there is the problem of the scarcity of natural aggregates (NA) for the production of new concrete, on the other, the enormous quantities of dismantled concrete waste form due to the deterioration of the reinforced concrete structure and obsolete structures create a ecological criticism. There is only a solution to this problem is to reuse this "concrete waste" like an aggregate in the new concrete production. The use of old destructive building materials in new construction projects is not a new idea. Recycling of construction and demolition waste used in Roman times, often reusing stones to rebuild roads before new roads. At first, the idea of recycling cement demolition waste was carried out for the first time after the Second World War. Since then, there has been much research in many countries are conducting to increase the use of construction waste for the production of new concrete.

2. MATERIALS AND EXPERIMENTAL DETAILS

2.1 Materials

In the following, "old concrete" will end up if it is returned to the waste used to turn out the recycled aggregates, while "recycled concrete" indicates the concrete, which prepared with recycled aggregates. '' The recycled aggregate '' is the aggregate that was prepared by dismantling the old concrete structure, while '' natural aggregate '' said the aggregate, which is obtained by crushing the natural stone.

The old concrete consists of concrete constituents (ordinary portland cement, Aggregate and water) . The mix composition of concrete constituents and compressive strength of the old concrete are listed in Table 1.

Table -1: The compressive strength and Composition of constituents of the old concrete-M30 (Kg/m^3)

Components	Quantity (Kg)
Coarse aggregate (10– 25 mm)	**1155 kg**

Fine aggregate (<4.75 mm)	**743 kg**
Ordinary Portland cement (43grade)	**382 kg**
Water	**191 kg**
Compressive strength (MPa) at 7 days 28 days	 **20N/mm²** **30N/mm²**

The old concrete was filled with 150 mm-sized cubes and subsequently tested for the compressive strength at the age of 7 and 28 days, like the standard compression test procedure. Instantly after the compression tests, the cubes were broken by the mill and dried in an oven at 105° C to inhibit any other hydration.

2.2 Experimental details

In this paper a comparative study of the properties of the recycled aggregate and of the concrete produced with the recycled aggregate (prepared with the crushing of the old partially hydrated concrete) is concluded.

In this study, recycled concrete was studied by recycled aggregates from the crushing of old concrete, with the addition of natural sand necessary to maintain good workability. Furthermore, a new concrete produce with the natural aggregates with the same mixing ratio of aggregates and cement and the cement-to-water weight ratio similar to the reference concrete. The detailed composition of concrete elements of the recycled aggregated concrete are listed in Table 2.

The grinded mixture of concrete was separated into some fractions of the subsequent dimensions: coarser (more than 10 mm), medium (less than 10 mm higher than 2.36 mm) and fine (less than 2.36 mm). Thus the effect of the size of the aggregate on the property of recycled aggregate concrete can be studied. Each size groups were tested for size distribution, apparent density, bulk specific gravity, water, crushing value (only of the large fraction, according to the Indian standard 456: 2000) and cement content.

Table-2: Composition of concrete elements for new concrete (Kg/m³)

Components	**Quantity (Kg)**
Crushed aggregate (10– 25 mm)	907 kg
Crushed aggregate (2.36– 10 mm)	454 Kg
Crushed dust	215 kg
ordinary Sand	427 Kg
Ordinary Portland cement (43grade)	298 kg
Water	163kg

For each mixing batch, 150 mm cube samples are made and stored in their molds for 24 hours. After splitting, they were stored in the 100% humidity at room temperature of 21 ° C upto 2 hours before testing the cubes at 7 days and 28 days. The compressive strength of concrete cubes were determined on the basis of what established in IS: 516-1959.

3. RESULTS AND DISCUSSION

3.1. property of the recycled aggregates produced from crushed old concrete

The recycled aggregates from the crushing of the prior crushed concrete at many times is presented in Figure 1. The three curves shown in Figure 1 depicts the distribution that confirms no significant change in the size of aggregates.
fine, medium and coarse aggregated shown in table-3 that presents the bulk specific gravity, the evident density, the crushing value and the cement content of the recycled aggregates of the different sizes of the aggregation and at the different age of crushing.

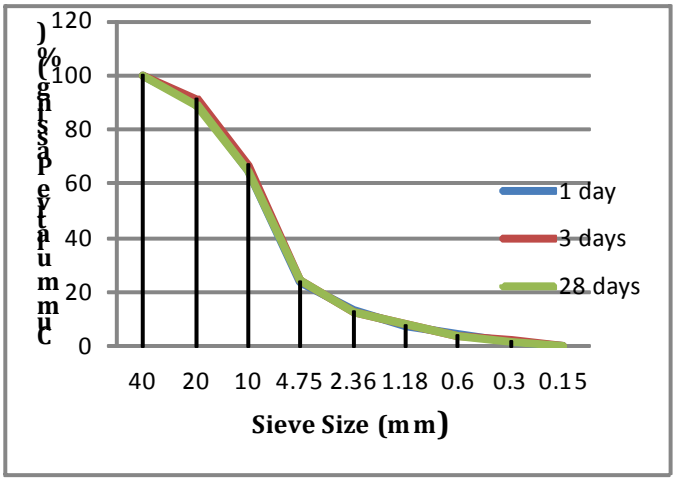

Fig. -1: Size distribution curve for recycled aggregates at various crushing ages (1, 3 and 28 days)

The normalized values were calculated comparatively to the value of the coarsest fraction, crushed at the age of 28 days and presented in Fig. 2, 3 and 4.

Table -3: The Various properties of the recycled aggregates

Crushing age	Mass specific gravity	Mass density (KN/m³)	Crushing value (%)	Cement content (%)
1 Days				
Coarse	2.57	14.64	24.7	6.9
Medium	2.33	12.23	-	15.7
Fine	2.23	13.28	-	25.7
3 Days				
Coarse	2.60	14.33	25.2	6.1
Medium	2.38	12.34	-	15.5
Fine	2.25	13.42	-	25.4
28 Days				
Coarse	2.55	14.34	24.6	6.9
Medium	2.32	12.77	-	13.4
Fine	2.23	13.23	-	24.6

As discussed in pervious sections depicts in Table 3, the content of the cement (hydrated and not hydrated) increases significantly from about 6.5% in the coarse fraction to about 25% in the fine fraction.

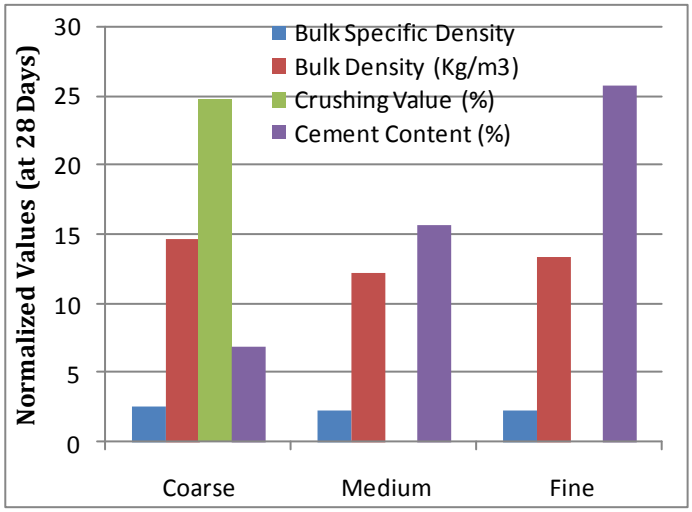

Fig.- 2: Various property of recycled aggregates normalized with the coarser fraction (crushed at age 28 days) for 1 Day Crushing Age

The parameters, such as the specific gravity of the volume and the apparent density, which are correlated to the properties of the natural aggregates and of the cement paste, change only fairly with the size of the particles, since the cement paste forms only a small portion of the recycled aggregate (28% for smaller aggregate sizes).

Taking into account the comparison of aggregate size distributions and some different parameters broken into different ages, Further it was concluded that partition of the cast-off aggregates into various size fractions is avoidable for the preparation of the new compositions concrete.

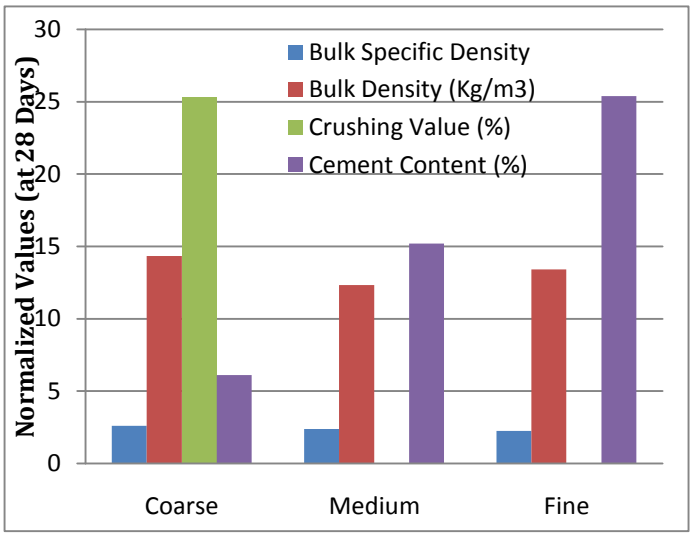

Fig. -3: Various property of recycled aggregates normalized with the coarser fraction (crushed at age 28 days) for 3 Days Crushing Age

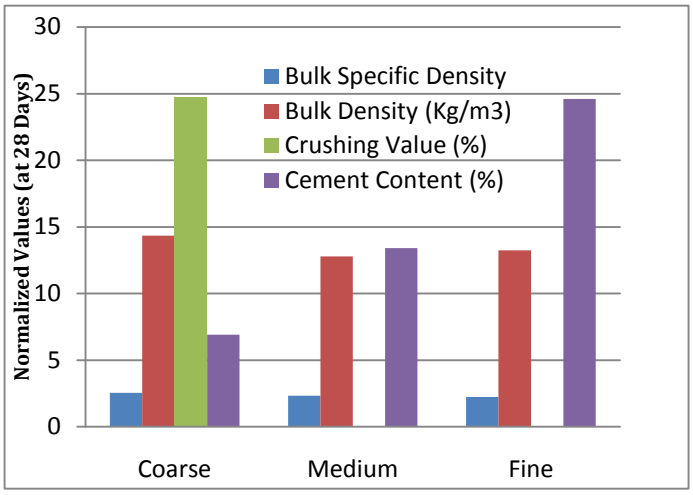

Fig. -4: Various property of recycled aggregates normalized with the coarser fraction (crushed at age 28 days) for 28 Days Crushing Age

3.2. property of novel concrete prepared from recycled aggregates

3.2.1 Green concrete

Tble-4 shows the various property of the novel concrete with apparent density of green concrete produced that is prepared by natural aggregates, while the concrete produced with recycled aggregates it was noticeably lighter, around 2150 kg/m³, apart from the type of cement or the age of the grinding. Density lowers due to the consequence of specific volume density of the aggregates analyzed above (2.60, 2.30 and 2.20 for coarse, medium and finely ground aggregates, respectively, compared to 2.63-2.74 for natural aggregates). Furthermore, a higher air content was observed, which led to a further reduction in the density of fresh concrete.

Slump of the mixture ranges from 135-185 mm. This decrease reports with as good as quantities of free water, which indicates that the water requirement for a given workability is not influenced by the type of aggregate or by the age of the grinding. This is due to fact that the inadequate quantity of recycled aggregates, some quantity of usual sand were still necessary to maintain adequate workability.

Table -4: Property of new and Hardened concrete

Properties		Crushing Age of old concrete		
	Reference	1 Day	3 Days	28 days
Bulk density (kg/m³)	2463	2175	2145	2156
Slump (mm)	140	180	175	135
Compressive strength (MPa)				
7 Days	21.6	18.3	17.0	17.1
28Days	34.6	24.6	25.8	28.5
Flexural strength (MPa)	6.1	6.1	5.4	5.4
Splitting strength (MPa)	3.3	3.4	2.9	3.1
Modulus of elasticity (GPa)	22.7	14.2	13.3	11.3

3.2.2 Hardened concrete

3.2.2.1. Compressive strength:- The compressive strengths of the various mixes are shown in Table 4 for ages of 7 and 28 days. The use of recycled aggregates led to a reduction in the compressive strength of the concrete, whether OPC was used (see Fig. 5). The loss of strength of the recycled OPC concrete was more sensible, about to 24%.

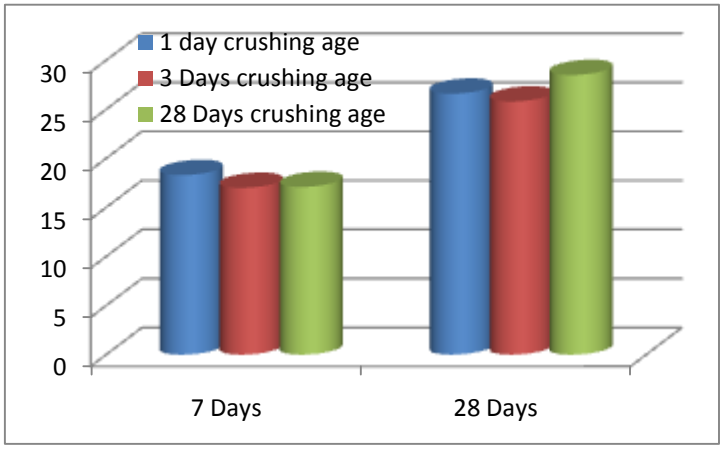

Fig. -5: The compressive strength of recycled concrete crushed at different ages

Crushing age seems to have a significant effect on the compressive strength of the recycled OPC concrete, The effect of the crushing age was much smaller; the differences between the lower and the higher strengths were 7% and 13% at testing ages of 7 days and 28 days, respectively. A slightly higher compressive strength was observed in recycled OPC concrete made with aggregates crushed at the age of 1 day, and there was no significant difference between crushing ages of 3 and 28 days.

3.2.2.2. Flexural and splitting strength:- The flexural and splitting strengths of the new concrete are listed in Table 4. The flexural and the splitting strengths to the compressive strength were in the ranges of 16–23% and 9–13%, respectively as per IS 456 2000. Although these values are within a reasonable range, they are relatively high when comparing them with the recommendations found in IS:456 2000. The following equations are recommended by IS:456 2000 and ACI 318-95 for the relationships between the compressive strength (fck) and the flexural (fcr) and splitting (ft) strengths respectively, for concrete of compressive strength in the range of 20–85 MPa:

Flexural strength

$$Fcr = 0.7\sqrt{Fck}\ \text{N/mm}^2. \quad (1)$$

Split tensile strength or Modulus of Rupture

$$Ft = 0.56\sqrt{Fck}\ \text{N/mm}^2 \quad (2)$$

and also recommends the modulus of rupture . . .

$$Ft = 0.62\sqrt{Fck}\ \text{N/mm}^2 \quad (3)$$

where *Fck* is the characteristic cube compressive strength of concrete in N/mm²

The relationships between the compressive strength and the flexural and splitting strengths are shown in Fig. 6, together with the lines representing the IS:456 & ACI relationships noted above. The higher values of the flexural and splitting strengths relative to the predicted ones are clearly seen in the figure, for the OPC recycled concrete.

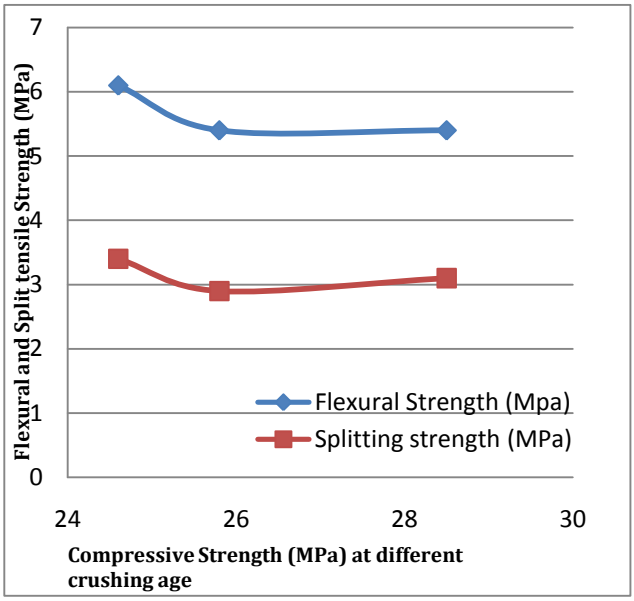

Fig. -6: Flexural and splitting strengths vs. compressive strength(at different Crushing age)

3.2.2.3. Modulus of elasticity:- Relatively low values of modulus of elasticity (Ec) were obtained from the test results (Table 4) of the recycled concrete. However, the values for the recycled concretes, are still lower by approximately 42% -50% than the values predicted by Eq. (4) (adopted from IS:456-2000)

$$Ec = 5000\sqrt{Fck}. \quad (4)$$

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3. SUMMARY AND CONCLUSIONS

1. The properties of the recycled aggregates crushed at ages of 1, 3 and 28 days were quite similar. The size distribution of the aggregates was the same for the different ages of crushing, as well as other properties such as bulk-specific gravity, bulk density, cement content and crushing value of the coarse fraction. These observations indicate that at these strength levels and structure of the old concrete, the aggregates that are made of it have fairly similar properties. However, some additional cementing capacity still remains in the aggregates crushed at 1 day, but it rapidly decreases within a few days.
2. Concrete made with recycled aggregates was weaker than concrete made with natural aggregates at the same water to cement ratio. When the new concrete was made from the same type of OPC and the same water to cement ratio as the old concrete, the strength reduction was 25 - 30%, despite the crushing age of the old concrete. Other properties like flexural and splitting strengths, exhibited similar trends.
3. Two differing mechanisms seem to affect the properties of the new concrete: the physical properties of the old concrete and the presence of unhydrated cement in the recycled aggregate. These effects are well-known when the new cement matrix is significantly stronger than the one in the old concrete. In such type of concrete, the combination of strengths and cementing capacity of the recycled aggregates crushed at 3 days enhanced strength over crushing ages of 1 or 28 days. In a weaker new cement matrix, this effect is inverted and the new concrete made from recycled aggregates crushed at 3 days was slightly weaker than concrete made from recycled aggregates crushed at 1 or 28 days.
4. The properties of aggregates made from crushed concrete and the effect of the aggregates on the new concrete (strength, modulus of elasticity, etc.) are similar to those of lightweight aggregate concrete, and similar considerations apply when dealing with this type of aggregates.

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