

REPLACEMENT OF AGGREGATE BY C&D WASTE CONCRETE

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ABSTRACT:- Construction and demolitions activities have increased phenomenally for the past two decades. With these construction activities going up, we are falling short for the construction materials, especially aggregates, therefore finding an alternate resource is the need of hour. Using recycled aggregate will not only conserve rapidly depleting non-renewable resource but also provide a sustainable disposal solution for already accumulated waste. The aggregates can either be reused directly by giving proper dressing or it can be combined with virgin aggregates in certain proportions and used for different construction activities especially in pavement constructions. The aim of this study is to evaluate the strength and economic characteristics of M20 concrete prepared by replacing natural aggregates with demolished concrete coarse aggregates. Each replacement mix was compared with characteristic properties exhibit by concrete mix prepared using virgin aggregate. In this study replacement of recycled aggregate was done in three proportions i.e. 10%, 20% and 30%. Each sample was tested for compressive strength, flexural strength and splitting tensile strength for 7 & 28 days and compared with standard concrete, each test was replicated with three samples.

KEYWORDS: Demolished concrete coarse aggregate, Compressive strength, split tensile strength, flexural strength, sustainable development

1. Introduction:

Sustainability can be defined as satisfying today's need without compromising the capability of future generations to meet their needs. Sustainable construction is accomplished by using less natural materials, causing low pollution, and reducing waste while achieving the same advantages that can be achieved through the use of traditional materials [1][14]. Recycling is the processing the used material for use in creating new product. The usage of natural aggregate is getting increasing with advanced development in

infrastructure area. In order to reduce the usage of natural aggregate, recycled aggregate can be used as the replacement materials. Recycled aggregate are comprised of crushed, graded inorganic particles processed from the materials that have been used in the constructions and demolition debris. These materials are generally obtained from buildings, roads, bridges and sometimes from wars and earthquakes. Recycled aggregate have been used in the road industry for the last 100 years in Australia [13]. In 2012, the global market for construction aggregates was expected to increase 5.2% per year until 2015, up to 48.3 billion tonnes, and is expected to expand even further to 66.3 billion tonnes by 2022 [2]. As per Rahul, K. (2007), recycled aggregate concrete and normal aggregate concrete (NAC) showed similar trends in development of compressive strength, with relatively faster gain of strength in NAC upto age of 7 days. The RCA which can be obtained from the site tested concrete cubes can be very useful since it shows good potential as coarse aggregate for the new production of concrete [15]. Concrete up to 30% of coarse aggregate was replaced by demolished waste which gave strength closer to the strength of plain concrete cubes and strength retention was recorded in the range of 86.84-94.74% for recycled concrete mix [16].

1.1 Application of Recycled Aggregates

Recycled aggregate have been used as concrete kerb and gutter mix in Australia. According to Building Innovation & Construction Technology (1999), the 10mm recycled aggregate and blended recycled sand are used for concrete kerb and gutter mix in the Lenthall Street project in Sydney.

According to Market Development study for Recycled Aggregate Products (2001), recycled aggregate are

used as granular base course in the road construction and proved to be better than natural aggregates on wet subgrade in terms of stabilizing the base and improved working surface for pavement structure construction. Recycled aggregate can be used in embankment fill. The reason for being able to use in embankment fill is same as it is used in granular base course construction. Recycled aggregate have been used as paving blocks in Hong Kong. According to Housing Department recycled aggregate are used as typical paving blocks (2002). Mehus and Lillestl found that Norwegian Building Research Institute mentioned that recycled concrete aggregate can be used as backfill materials in the pipe zone along trenches after having testing in laboratory. Figure 1 shows the diagrammatic representation of natural and recycled aggregates.



Figure 1. Natural and Recycled Aggregates

1.2 Advantages of Recycled Aggregates

There are many benefits to using recycled aggregates.

- Use of recycled aggregates over natural materials can save money as they are less expensive to produce.
- Producing recycled aggregate for resale is more cost-effective than sending un-wanted materials to landfill and incurring landfill tax.
- Recycled Aggregate is regarded to be a 'green' construction material. Using recycled aggregate reduces the amount of virgin aggregates which are created and therefore means less use of natural resources.
- There is increasing pressure on landfill capacity, and pressure on construction sites to divert waste away from landfill to meet sustainability targets. So use of recycled aggregates conserves landfill space, reduces the need for new landfills.

- Studies proved that Recycled Aggregate is as structurally reliable as natural aggregate and is as safe to use.

1.3 Indian Status

There is severe shortage of infrastructural facilities like houses, hospitals, road etc. in India and the need of quantities of construction materials for creating these facilities is large. The planning Commission allocated approximately 50% of capital outlay for infrastructure development in successive 10th and 11th five year plans. Central Pollution Control Board has estimated current quantum of solid waste generation in India of 48 million tons per annum out of which, waste from construction industry only accounts for more than 25%. The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum out of which 7-8 million tons are concrete and brick waste. According to findings of a survey, 70% of the respondent have given the reason for not adopting recycling of waste from construction industry is "Not aware of the recycling techniques" while remaining 30% have indicated that they are not even aware of recycling possibilities.

1.4 Necessity for the use of recycled concrete aggregates

The major reasons for the increase of demolition concrete waste are:

- Many old building and other structures have overcome their limit of use and need to be demolished.
- Structures, even adequate to use, are under demolition, becomes there are new requirements and necessities such as new earthquake zones.
- Creation of building wastes which result from natural destructive phenomena such as earthquakes, storms etc.

The basic composition of demolition waste according to Meddah (2017) is shown in figure 2.

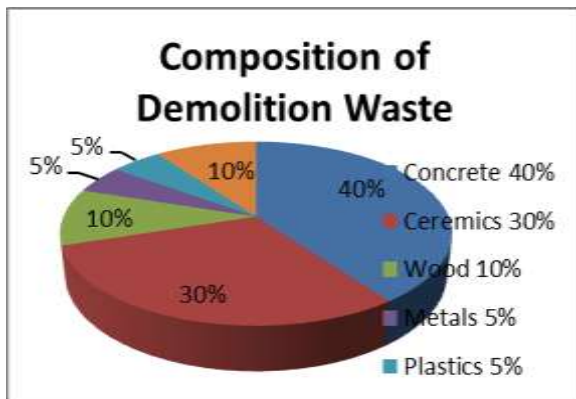


Figure 2. Composition of Demolition Waste.

2. MATERIALS AND METHODS

In the design of conventional concrete the selection of proper ingredients, evaluating their properties and understanding the interaction between different materials plays a major role in performance of the concrete. The ingredients used in the study are cement, natural sand, coarse aggregate, demolished concrete waste in the form of coarse aggregate.

2.1 Demolished concrete waste

The concrete obtained using demolished waste aggregate satisfies the minimum requirements of new bought aggregates. Concrete using demolished waste aggregates resulted in acceptable strength required for structural concrete. The Demolished waste-cement composite is compatible and no pre-treatment is required.

The demolished waste was obtained from a construction site. They are dried for few days before being crushed manually. The crushed materials are later transported to the laboratory where they were washed and allowed to dry under ambient temperature for several hours. Coarse aggregates show a wide diversity in size, weight, shape, and colour, depending on the crushing.

2.2 Recycled Aggregate

Aggregate typically processed by the crushing of parent or old concrete such as demolished waste concrete is regarded as recycled concrete aggregate (RCA). Generally RCAs are mixed with bricks, tiles, metals and other miscellaneous such as glass, wood, paper, plastic and other debris [17].

Figure 3 shows the clear difference between the recycled coarse aggregate and natural virgin coarse aggregate. In recycled coarse aggregate it contains old attached adhered mortar on the surface of aggregate but surface of natural virgin coarse aggregate is free from adhered mortar.



Figure 3: Process of using recycled Aggregate in Concrete [17]

2.3 Preparation of Specimens

Concrete mix proportions of ratio 1:1.5:3 (M20) is used for the preparation of specimens. Conventional specimens were casted. Recycled aggregate specimens is prepared where the coarse aggregate is replaced by the recycled coarse aggregate from concrete waste of about 10%, 20%, 30%. The specimens were cured by using tap water at room temperature and tested at the age of 7 and 28 days.

3. MIX DESIGN

A mix design is a method of calculating the amount of coarse aggregate, fine aggregate, cement content and water content is calculated by using the experimental values obtained.

DESIGN STIPULATIONS:

Mix of concrete is M20. The f_{ck} value is 20 N/mm². Consider maximum aggregate size is 20mm. Degree of workability = 0.90 (compaction factor)
Type of Exposure = Mild exposure

TEST DATA OF MATERIAL:

Specific gravity of cement = 3.15
Specific gravity of CA = 2.63
Specific gravity of RFA = 2.45

Water absorption:

CA = 0.5 %
 RFA = 1.8 %
 Free (surface) moisture:
 CA = nil
 RFA = 1%
 Sand conforming to Zone I.
 (RFA- RECYCLED FINE AGGREGTAE)

MIX DESIGN CALCULATIONS:

TARGET MEAN STRENGTH:
 $f_{ck}' = f_{ck} + (t*s)$
 $f_{ck}' = 20 + (1.65*4)$
 S, t obtained from IS 10262-2009
 Target mean strength = 26.6 Mpa

WATER CEMENT RATIO:

From IS 10260-2009 the water/cement ratio is obtained as 0.50
 From the above values the amount of water content is 186 kg and the percentage of sand is 34.5%

Concrete Mixes

Conventional Cubes:
 Volume of each cube = $3.375 \times 10 \text{ m}^3$
 Volume of 3 cubes = $10.125 \times 10 \text{ m}^3$
 Quantity of materials required (considering 10 % loss)
 Cement = 5 kg
 Sand = 7.7 kg
 Coarse aggregates = 15.7 kg
 Water = 2.5 lit

The mix design is calculated and the amount of aggregate need for 9 cubes is calculated. The mix is done by hand by adding water at different interval. Table 1 shows proportion of each mix materials for six cubes.

Table 1: Proportion of each mix materials for six cubes

	Cement	Sand	N.A.	R.A.	Water
30%	9.9kg	21.72kg	14.09kg	9.40kg	5.5 lit
20%	9.9kg	21.72kg	18.79kg	4.7kg	5.5 lit
10%	9.9kg	21.72kg	21.31kg	2.8kg	5.5 lit
0%	9.9kg	21.72kg	23.49kg	-	5.5 lit

4. TESTS ON AGGREGATE

I) Impact Strength Test (IS: 2386 (Part IV) – 1963)

Aggregates Impact strength is determined by impact testing machine. Impact value of fresh aggregates and recycled aggregate are shown in table 2.

Table 2: Impact Value of Fresh Aggregates and Recycled Aggregate.

S.NO.	Particulars	Impact Value
1	Fresh Aggregates	20
2	Recycled Aggregates	23

II) Crushing Strength Test (IS: 2386 (Part IV) – 1963)

Aggregates Crushing strength is determined by compressive testing machine. Crushing value of fresh aggregates and recycled aggregate are shown in table 3.

Table 3: Crushing Strength of Fresh Aggregates and Recycled Aggregate.

S.NO.	Particulars	Crushing Strength N/mm ²
1	Fresh Aggregates	25
2	Recycled Aggregates	29

III) Specific Gravity Test (IS: 2386 (Part IV) – 1963)

Aggregates Specific Gravity is determined by Pycnometer. Specific Gravity of fresh aggregates and recycled aggregate are shown in table 4.

Table 4: Specific Gravity of Fresh Aggregates and Recycled Aggregate

S.NO.	Particulars	Specific Gravity
1	Fresh Aggregates	2.65
2	Recycled Aggregates	2.53

5. TESTS ON CONCRETE

5.1 Compressive Strength Test (IS: 516-1959)

Compressive strengths were attained as a result of the compressive tests conducted on the cube specimens of size 150mm x 150mm x 150mm. Cube was placed on the platform of the compression testing machine. The load was applied gradually till specimen failure. The specimens are subjected to compressive loads in compression testing machine as per IS: 516-1969 and the crushing load is noted which gives the compressive strength of that cube. The compressive strength is the ratio of crushing load to the surface area of the specimens expressed in N/mm². Similarly the compression strength values of all the cubes are found for 7 days and 28 days.

5.2 Split Tensile Strength Test (IS: 5816-1999)

Split tensile strength of concrete is usually found by testing cylinders specimen of size 150mm x 300 mm were casting using M20 grade concrete. Specimens of two different percentages were casted. During casting the concrete cubes were manually compacted using tamping rods. After 24hours, the specimens were removed from the mould and subjected to water curing for 7, 28 days. After curing, the specimens were tested for compressive strength as per IS: 5816-1999 using a calibrated compression testing machine of 2000KN capacity. The specimen was placed on the plywood strip and aligned so that, the central horizontal axis of the specimen is exactly perpendicular to the load applying axis. The second plywood strip was placed length wise on the cylinder and the top platen was brought down till it touched the plywood. The load was applied without shock and increased continuously until the resistances of the specimen to the increasing load broke down and no greater load can be sustained.

$$\text{Tensile strength of concrete } f_t = \frac{2P}{\pi DL}$$

Where, P = Maximum load in N applied to the specimen
 L = Measured length in cm of the specimen
 D = Measured diameter in cm of the specimen

5.3 Flexural Strength Test (IS: 516-1959)

The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol f_{cr} . The flexural strengths of the respective specimens have been obtained from the flexural tests performed on the prism specimens of size 100mm x 100mm x 500mm. The flexural strength are tested using a two point loading frame machine as per standard. The modulus of rupture can be determined by using the below given formula:

$$f_{cr} = \frac{P_{max} l}{bh^2}$$

Where,

- f_{cr} = Flexural strength
- P_{max} = maximum load in (N) kg.
- b = width of the prism in mm
- h = depth of the prism in mm
- l = span of the prism in mm

6. RESULTS AND DISCUSSION

The results obtained from the various experiments conducted to access mechanical properties. The aim of the study is to determine the compressive strength, flexural strength and split tensile strength so the results of test specimens are presented. The mechanical properties of concrete such as compressive strength, flexural strength and split tensile strength are determined from the standard experiments.

6.1 Compressive Strength

After preparing the cube, Compressive strength is determined by compression testing machine. Compressive strength of cubes after replacement of the recycled coarse aggregate in different proportions for 7 days and 28 days are shown in Table 5.

Figure 4 shows the Bar Chart for Characteristic Compressive strength and replacement percentage of recycled aggregate as proportion of 0%, 10%, 20% and 30%.

Table 5: Compressive Strength of Recycled Coarse Aggregate at Different Replacement % for 7 And 28 Days.

S.NO.	Replacement of recycled Aggregates (%)	Compressive strength (N/mm ²) for 7 days	Compressive strength (N/mm ²) for 28 days
1	0	12.72	19.42
2	10	9.96	18.33
3	20	12.88	18.11
4	30	13.92	19.35

Table 6: Tensile Strength of Recycled Coarse Aggregate at Different Replacement % for 7 And 28 Days.

S.NO.	Replacement of recycled Aggregates (%)	Tensile Strength (N/mm ²) for 7 days	Tensile Strength (N/mm ²) for 28 days
1	0	2.50	3.14
2	10	2.43	3.37
3	20	2.39	3.25
4	30	2.35	2.94

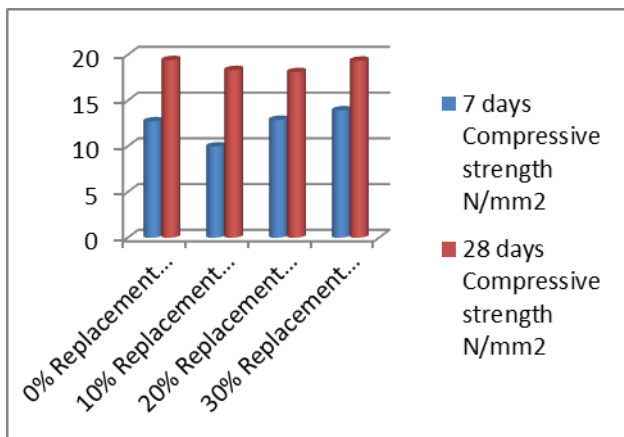


Figure 4: Characteristic Compressive strength and replacement percentage of recycled aggregate

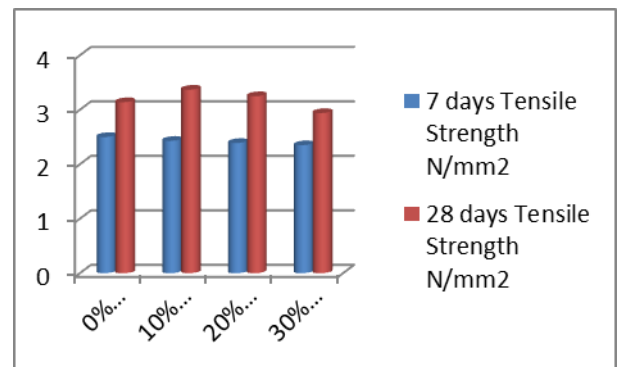


Figure 5: Tensile Strength and replacement percentage of recycled aggregate

6.2 Tensile Strength

After preparing the cube, Tensile strength is determined for 7 days and 28 days. Tensile strength of cubes after replacing the recycled coarse aggregate in different proportions for 7 days and 28 days is shown in Table 6.

Figure 5 shows the Bar Chart for Tensile Strength and replacement percentage of recycled aggregate as proportion of 0%, 10%, 20% and 30%.

6.3 Flexural Strength

After preparing the cube, Flexural strength is determined for 7 days and 28 days. Flexural strength of cubes after replacing the recycled coarse aggregate in different proportions for 28 days is shown in Table 7. Figure 6 shows the Bar Chart for Flexural Strength and replacement percentage of recycled aggregate as proportion of 0%, 10%, 20% and 30%.

Table 7: Flexural Strength of Recycled Coarse Aggregate at Different Replacement % for 28 Days.

S.NO.	Replacement of recycled Aggregates (%)	Flexural Strength (N/mm ²) for 28 days
1	0	3.91
2	10	3.85
3	20	3.67
4	30	3.74

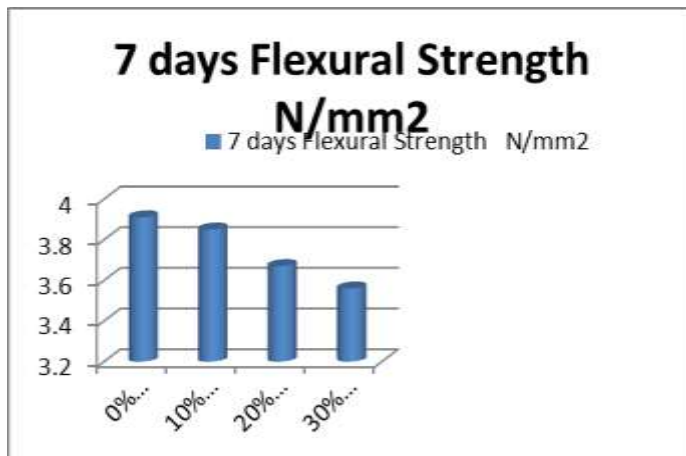


Figure 6: Flexural Strength Split and replacement percentage of recycled aggregate

7. CONCLUSION

M20 grade of concrete is used in this study and tests are conducted on different proportion of recycled aggregate 0%, 10%, 20% and 30% in concrete. Based on study below conclusion are drawn:

1. The 28 days compressive strength of the concrete increases with the increases in the percentage of the recycled aggregate replacement. The value of the compressive strength is found to be maximum at 30% replacement of the aggregates by the recycled aggregates. At 20% replacement of coarse aggregate compressive strength is decreased, the problem can be overcome by adding mineral admixture.

2. The Flexural strength and splitting tensile strength of all three sets of replaced concrete is decreasing as proportion of recycled aggregate is increased.
3. Replacement of demolished concrete waste in new concrete will decrease the cost of making concrete and reduce the waste generated from the old demolished concrete.
4. By the analysis it is clear that the individual properties of the recycled coarse aggregates are slightly lower than the natural aggregates but does not affect the strength characteristics at high extent.
5. Recycled aggregate must be used at higher replacement levels, maximum benefit in terms of compressive strength and bond strength is achieved.

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