# Experimental Study on Recycled Concrete Aggregates

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**Abstract** –*Waste arising from construction and demolition (C & D) constitutes one of the largest waste streams within India and many other developing countries. Of this a large proportion of potentially useful material disposed of as landfill. The environmental and economic implications of this are no longer considered sustainable and, as a result, the construction industry is experiencing more pressure than ever before to overcome this practice. On the other hand, in recent years the wisdom of continued wholesale extraction and use of aggregates from natural resources has been questioned at an international level. This is mainly because of the depletion of quality primary aggregates and greater awareness of environmental protection. The results of an extensive experimental programme aimed at examining the performance of Portland-cement concrete produced with natural and coarse recycled aggregates are reported in this paper.*
*The mass production of construction and demolition are creating serious problems in India. In most of the countries applicability of construction and demolished wastes are restricted to non-structural concrete, pavements and backfilling. In present day Demolished Concrete waste handling and management is challenging one in all over the countries in the world. Recycle the demolished concrete has reduces the environmental pollution and protect the natural resources. In this research paper an experimental study is carried out to investigate the recycling of demolished waste concrete for new contraction. This research included a collecting a Demolished Concrete from waste and is separated with different sizes using sieve analysis. Various sizes of aggregate is treated with heating process. Finally the demolished concrete aggregate DCA is replaced by various percentage of 10%, 20%, 30%, 50%, 100% and test can be conducted and compared with nominal concrete.*

***Key Words*: Demolished, concrete waste, recycle, new concrete, fresh coarse aggregate**

## 1. INTRODUCTION

Increased concern for environmental protection and for promotion of the principles of sustainable development has led some governments to introduce legislation to encourage the use of recycled aggregates. A favored method is to lower the selling price of recycled aggregates in relation to natural aggregate, and this is largely achieved by increasing landfill costs. Demolition sites and restoration schemes are sources of large amounts of solid waste, which today is being used as mere landfill. On the other hand, building practices are such that reusable materials also become mixed with rubble, stone and soil, reducing their value and making recycling difficult or uneconomical. This waste material too, is rendered suitable only as infill for construction work, or as landfill. A Building waste recycling as aggregates is a modern approach for preventing environmental pollution through both reducing the stocks of waste and decreasing the use of natural aggregates.

**Present Scenario of Demolished Waste used in India:**
Construction and demolition waste (C&DW) management is gaining attention from policy makers in India. Study shows C&DW generation from urban building, rural building, and non-building sectors in India and calculates material, energy, and emissions savings from C&DW recycling. The review results indicate that India generated between 112 and 431 million tonnes of C&DW in 2016 depending upon the assumptions, which are orders of magnitude higher than official records indicate. Although per capita waste generation from rural area is less than urban areas, rural areas as a whole generate more waste than urban areas, as rural population is still over two times the urban population in India. Additionally, it was estimated that formal C&DW recycling can save upto 2–8% of natural minerals, such as sand and aggregate in urban areas, energy and emissions savings were negative, implying that recycled C&DW materials are likely to be more resource and environmentally intensive as compared to natural materials.

**Demolished waste of concrete as a material:**
Recycling of concrete debris can make a contribution to reducing the total environmental impact of the building sector. To increase the scope for recycling in the future, aspects of recycling have to be included in the design phase. Besides, aggregate sources are almost depleted, so aggregates have to be brought from far quarries. Consequently, reclaiming aggregates from concrete debris would lead to environmental and economic benefits.

## 2. LITERATURE REVIEW

•**Patil.et.al. (2013),** this study aimed to evaluate physical properties of concrete using recycled coarse aggregate. In this research, concrete waste from demolished structure has been collected and coarse aggregate of different percentages is used for preparing fresh concrete (0%, 25%, 50%, 75% & 100%). The compressive strength of recycled coarse aggregate (RCA) is found to be higher than the compressive strength of normal concrete when used upto a certain percentage. Recycled aggregate concrete is in close proximity to normal concrete in terms of split tensile strength. The slump of recycled aggregate concrete is more than the normal concrete. At the end, it can be said that the RCA upto 50 % can be used for obtaining good quality concrete.

•**Osei.et.al. (2013),** in this study, the compressive strength properties of concrete were investigated by completely replacing Natural Aggregate (NA) with recycled concrete aggregate (RCA). Densities of both RCA concrete and NA concrete were within the range of normal weight concrete. Both RCA concrete and NA concrete showed the similar trends in the variation of strength and density with time. Reduction in the 28-day compressive strength of concrete due to complete replacement of natural aggregates with recycled concrete aggregate ranges from 11% to 33%. RCA can replace NA in the production of both non-structural and structural concrete.

•**Garg and Jain (2014),** studied on green concrete: efficient & eco-friendly construction materials. It presents the feasibility of the usage of by product materials like fly ash, quarry dust, marble powder/granules, plastic waste and recycled concrete and masonry as aggregates in concrete. It concluded that, it focuses on known benefits and limitations of a range of manufactured and recycled aggregates. Use of concrete product like green concrete in future will not only reduce the emission of $CO_2$ in environment and environmental impact but it is also economical to produce.

•**Dhoka (2013),** carried out "green concrete: using industrial waste of marble powder, quarry dust and paper pulp" The green concrete is prepared by using industrial waste of marble powder, quarry dust with proper proportions". The versatility of green concrete& its performance derivate will satisfy many future needs.

•**Wangchuk et.al. (2013),** studied that green concrete for sustainable construction. It is characterized by application of industrial wastes to reduce consumption of natural resources and energy and pollution of the environment. Replacement of materials over nominal concrete is what makes green concrete more environmental friendly concrete. Marble sludge powder, quarry rocks, crushed concrete and fly ashes are some of the materials used for making green concrete, a sustainable construction. With green concrete technology we can save the natural materials.

•**Prof. Pratap Krishnan** discussed the results of an experimental investigation FLY ASH and BLAST FURNACE SLAG are used in equal proportion (50% each). The green concrete gains about 60-70% of the total compressive strength within 7days.

•**Palaniappan. A, S. Vasantha** concluded the experimental investigation and compare on the mechanical properties of different binder composition (17 TO 20 % replacement of cement by ground granulated blast furnace slag (GGBS)) of Green Concrete Composites (GPCC). The test results show that GGBS concrete shown increase in compressive strength of 13.82% as compared with conventional concrete.

•**Gokulram .H, R. Anuradha** presented the results of an experimental investigation and compare on the mechanical properties of different binder composition (100% replacement of cement by ASTM class F Fly ash (FA) and ground granulated blast furnace slag (GGBS)) of Green Concrete Composites (GPCC).

•**Ganapati Naidu. P, A. S. S. N. Prasad** reported in this paper that an attempt is made to study strength properties of green concrete using low calcium fly ash replacing with slag in 5 different percentages. Higher concentrations of G.G.B.S (Slag) result in higher compressive strength of green concrete. 90% of compressive strength was achieved in 14 days.

•**Tafheem, Z et al (2011)** provided an overview of the status of green concrete which reduced the environmental impact and emphasized that the use of green concrete embodied low energy costs, lower green house gas emission, and low maintenance cost leading to sustainable construction materials. Furthermore, as far as resource conservation is concerned, the reuse of post consumer wastes and industrial byproducts usedas a partial replacement for Portland cement clinker, makes concrete more durable and eco-friendly as well.

•**Jain, N.et al 2015** studied evolution of green concrete (M30 grade) using recycled coarse aggregates for sustainable development and found coarse aggregates with physical and mechanical properties are of inferior quality and progress in properties was noticed after washing, due to removal of old mortar on its surface. The compressive strength of 28-day hardened concrete containing 100% washed recycled aggregate was slightly lower (7%) than concrete prepared with natural aggregates. Water absorption, carbonation, and rapid chloride penetration test were also conducted to assess the durability of concrete. Concrete was found permeable for chloride ions.

•**Aiyewalehinmi E.O and Adeoye T.E (2016)** estimated that about 15% to 20% of construction waste materials join land fills and dumping pits. They performed testing of four different mixes 0.5, 0.55, 0.60 and 0.65 water cement ratios on total of 96 concrete cubes casted, cured and crushed and found that at lower percentage water/cement ratios, the compressive strength of used aggregates after 28 days were much lower than virgin aggregates i.e. 16.89 N/mm2 against 19.93 N/mm2 while at higher percentage water/cement ratios it was very near to that of virgin aggregates i.e. 18.07 N/mm2 and 18.37 N/mm2 . The researchers investigated that the used aggregates could attain the same compressive strength as that of virgin at higher water/cement ratios.

**OBJECTIVES OF THE STUDY:**

- To produce a concrete with the use of locally available materials (i.e. Recycled aggregate concrete).
- To study the strength properties of green concrete with partial replacement of natural aggregates.
- To investigate the effect of recycled coarse aggregate on the strength of concrete.
- To investigate the effect of recycled coarse aggregate on the workability of concrete.
- To determine the optimum percentage of recycled coarse aggregate in the concrete.

**SIGNIFICANCE OF RESEARCH**

The following listed are potential benefits from this research work to the construction industry and the environment.
These are;
1) Reduction of pressure on landfills from construction and demolition debris;
2) Potential to increase the use of recycled coarse aggregate beyond the maximum recommended 30%;
3) Conservation of natural resources through reduction in the use of natural coarse aggregate for concrete work;
4) Mitigation of performance issue like low strength associated with recycled aggregate
5) Potential application of recycled coarse aggregate in structural concrete.

**Materials:**

**Portland cement**
Cement used is Ordinary Portland cement. (OPC). The colour of the cement is due to iron oxide. In the absence of impurities, the colour of cement is gray. Ordinary Portland cement (OPC) – 53 grade (Birla Shakti Cement) is used. Following tests will be conducted, on cement:

1. Consistency limit test:- Three samples were tested
2. Initial setting time and final setting time

**Sand**
The sand used in the investigation will be ordinary river sand. The sand passing through 4.75 mm sieve will be used in the preparation of specimens. Sieve analysis for the sand will be carried out in the laboratory as per the procedure mentioned in IS2386 (part-I)-1963. The sizes of sand vary between 2 mm to 4.75 micron

**Coarse aggregate**
**i) Fresh crushed coarse aggregate**
The coarse aggregate used in the investigation will be 20 mm size crushed granite stone obtained from quarries. The physical properties will be determined as per IS: 3286-1963.

**ii) Recycled coarse aggregate**
The recycled aggregate used in this project are taken from the demolished concrete members. These concrete wastes are crushed and Recycled coarse aggregates were produced. Recycled coarse aggregate used in the investigation will be 20 mm size.

**Water**
The water used in the mix design was potable water from the water supply and is free from suspended solids and organic materials, which might have affected the properties of the fresh and hardened concrete. The presence of tannic acid or iron compounds is objectionable. The general required of water for mixing and curing concrete shall be as per IS: 456-2000.

**Impurities in Recycled Coarse Aggregate:**
The performance of recycled coarse aggregate can be reduced due to the presence of impurities, which emanated from demolition process including porous mortar and cement paste attached to the parent aggregate. The effect could also lead to general reduction in characteristics of recycled aggregate concrete. Some of the impurities identified through visual inspection from the recycled coarse aggregate. The average percentage impurities present in the recycled coarse aggregate amounted to about 5% of the total mass of the sample. Although there is visual evidence to show the presence of adhered mortar on the parent material, it was practically impossible to estimate their percentage. However, the adhered mortar does not seem to be of significant quantity but its impact on the characteristics of recycled coarse aggregate concrete cannot be neglected.

**Fig-1 Batching of Aggregates**

**EXPERIMENTAL PROGRAM**

- Concrete mixes were made, NAC and RAC were produced using natural sand as fine aggregate.

- NAC mixes were used fully Natural Aggregate as coarse aggregate in concrete mix.
- Mean while RAC mixes were used demolished waste concrete aggregate as partially or fully replacement of Natural Aggregate ascoarse aggregate.
- These mixes were designed according to concrete mix design.
- The concrete mixtures were prepared with a water-cement (w/c) ratio 0.4, 0.45, 0.50
- The slump target is between 70mm to 190mm for NAC and RAC mixes.
- Fresh concrete testing (slump test), (compaction factor test);
- Filling of steel moulds (cube, cylinder and beam) and compaction using tamping rod and vibrating table
- Covering fresh concrete filled moulds with polyethylene bag to prevent loss of moisture due to evaporation;
- De-moulding of concrete sample after 24 hours;
- Storage of hardened concrete sample in the curing tank about 20oCfor maximum 28 days;
- Testing of hardened concrete at 28 days curing age

The combination in concrete mixes after this will be called as RA00, RA10, RA20, RA30, RA50 and RA100.
Table below showed the details of concrete mixes.

**Table-1: Mix Designs**
**(N-A Natural Aggregates/ R-A Recycled Aggregates)**

| Mix Designation | Description |
|---|---|
| RAC-0 | 100% N-A + 0% R-A |
| RAC-10 | 90% N-A + 10% R-A |
| RAC-20 | 80% N-A + 20% R-A |
| RAC-30 | 70% N-A + 30% R-A |
| RAC-50 | 50% N-A + 50% R-A |
| RAC-100 | 0% N-A + 100% R-A |

## 4. RESULTS AND DISCUSSIONS

### Workability

The slump results are presented in Table below. It can be observed that concrete mixes at 0.4 had a lower slump compared to 0.45 and 0.50 concrete mixes. On the other hand, when replacement of RA is increased in concrete mixes, the slump of concrete mixes is decreased. It was expected because recycled aggregate is high in water absorption.

| Mix Designation | W/C RATIO | SLUMP (mm) |
|---|---|---|
| RAC-0 | 0.40 | 129 |
| | 0.45 | 131 |
| | 0.50 | 160 |
| RAC-10 | 0.40 | 120 |
| | 0.45 | 128 |
| | 0.50 | 169 |
| RAC-20 | 0.40 | 115 |
| | 0.45 | 125 |
| | 0.50 | 168 |
| RAC-30 | 0.40 | 100 |
| | 0.45 | 115 |
| | 0.50 | 165 |
| RAC-50 | 0.40 | 80 |
| | 0.45 | 85 |
| | 0.50 | 164 |
| RAC-100 | 0.40 | 42 |
| | 0.45 | 48 |
| | 0.50 | 155 |

**Table-2: W/C ratio & Slump values**

### Compressive strength

Compressive strength on M20 and M25 grade of concrete made with the different percentages of natural aggregate and recycled aggregates are performed. For each concrete mix, the compressive strength is determined on three 150x150x150 mm cubes at 7 & 28days of curing.

W/C ratio adopted for M20 grade is 0.50 were as for M25 grade 0.45 W/C ratio is adopted. Following table gives the compressive strength test results of recycled aggregate concrete with different percentages of aggregates.

**Fig.2: Performing Compressive Strength Test**

| MIX | GRADE | Compressive Strength ($N/mm^2$) | |
|---|---|---|---|
| | | 7 days | 28 days |
| RAC-0 | M-20 | 17.11 | 20.1 |
| | M-25 | 18.13 | 25.89 |
| RAC-10 | M-20 | 14.30 | 18.23 |

| | | | |
|---|---|---|---|
| | M-25 | 16.41 | 23.40 |
| RAC-20 | M-20 | 17.10 | 21.14 |
| | M-25 | 19.12 | 26.22 |
| RAC-30 | M-20 | 15.12 | 17.80 |
| | M-25 | 16.95 | 23.22 |
| RAC-50 | M-20 | 14.95 | 16.09 |
| | M-25 | 15.53 | 22.71 |
| RAC-100 | M-20 | 14.01 | 15.44 |
| | M-25 | 14.21 | 24.55 |

**Table-3: Compressive strength values**

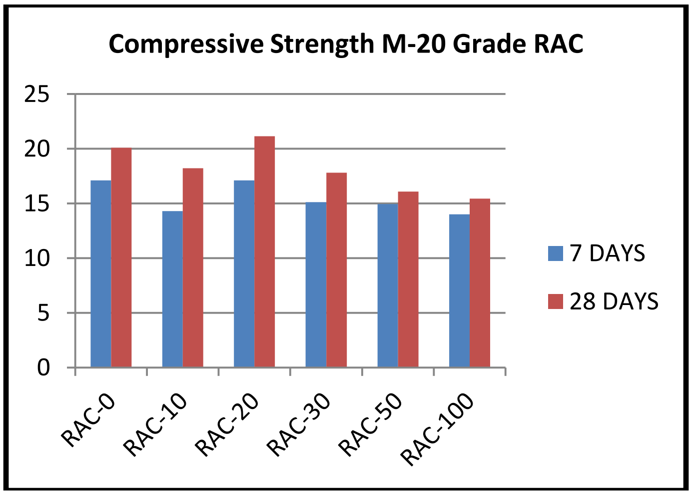


**Fig-2: Analysis of Compressive strength for M-20 Grade RAC**

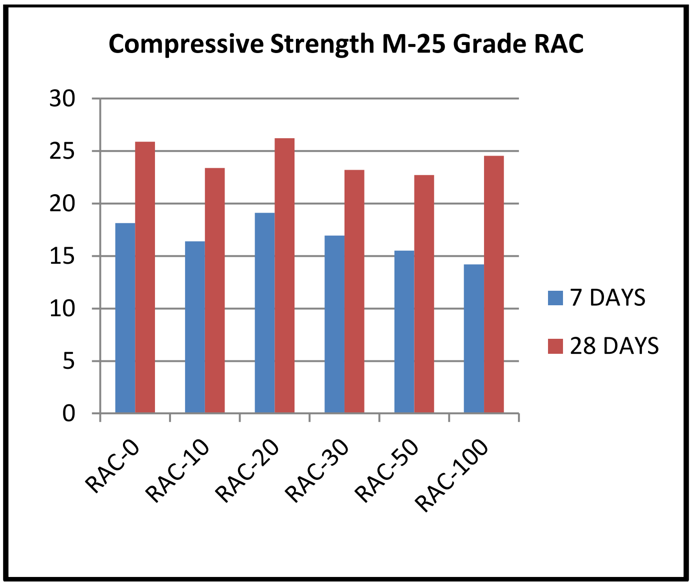


**Fig-3: Analysis of Compressive strength for M-20 Grade RAC**

## 5. SUMMARY AND CONCLUSIONS

The following conclusions have been made based on the results of this study:
1. With the same w/c ratio, the slump value decreases if percentage of demolished aggregates is increased.
2. The compressive strength of Recycled Aggregate Concrete was lower than that of Natural Aggregate Concrete but if 20% demolished waste is used then it will give more characteristics strength to that of natural aggregate used concrete.
3. Strength decreases with 30% replacement and with 10% and 20% of demolished waste it gives more result as compared to normal aggregate concrete.
4. The relationship of w/c ratio and compressive strength of demolished waste concrete is inversely proportional.
5. Recycled concrete can be effectively used in low cost housing where slab load is not high , it can also be used in the construction of boundary wall columns and for other construction where compressive load is not too much .
6. By using recycled aggregates in concrete problem of dumping demolished waste can be minimized.
7. Using recycled aggregates in concrete also reduces environmental pollution, which would otherwise would have been produced during crushing of gravels as coarse aggregate for concrete

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## BIOGRAPHIES

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