

EXPERIMENTAL INVESTIGATION ON RECYCLED AGGREGATES IN CONCRETE

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ABSTRACT - This paper presents the experimental results of recycled coarse aggregate concrete and results are compared with the natural crushed aggregate concrete. The fine aggregate used in the concrete, i.e. recycled and conventional is 100 percent natural. The recycled aggregate are collected from four sources all demolished structures. For both types of concrete i.e. M-20 and M-25, w/c ratio, maximum size of aggregate and mix proportion are kept constant. The development of compressive strength of recycled aggregate concrete at the age of 1,3,7,14,28, 56, and 90 days; the development of tensile & flexural strength at the age of 1,3,7,14 and static modulus of elasticity at the age of 28 days are investigated. The results shows the compressive, tensile and flexural strengths of recycled aggregate are on average 85% to 95% of the natural aggregate concrete. The durability parameters are also investigated for recycled aggregate concrete and are found to be in good agreement with BIS specifications.

Keyword: Concrete, recycled aggregate, natural aggregate concrete, solid waste management

1. INTRODUCTION

The recycling and reuse of construction & demolition wastes seems feasible solution in rehabilitation and new constructions after the natural disaster or demolition of old structures. This becomes very important especially for those countries where national and local policies are stringent for disposal of construction and demolition wastes with guidance, penalties, levies etc.

There is severe shortage of infrastructural facilities like houses, hospitals, roads etc. in India and large quantities of construction materials for creating these facilities are needed. The planning Commission allocated approximately 50% of capital outlay for infrastructure development in successive 10th & 11th five year plans. Rapid infrastructural development such highways, airports etc. and growing demand for housing has led to scarcity & rise in cost of construction materials. Most of waste materials produced by demolished structures disposed off by dumping them as land fill. Dumping of wastes on land is causing shortage of dumping place in urban areas. Therefore, it is necessary to start recycling and re-use of demolition concrete waste to save environment, cost and energy.

Central Pollution Control Board has estimated current quantum of solid waste generation in India to the tune of

48 million tons per annum out of which, waste from construction industry only accounts for more than 25%. Management of such high quantum of waste puts enormous pressure on solid waste management.

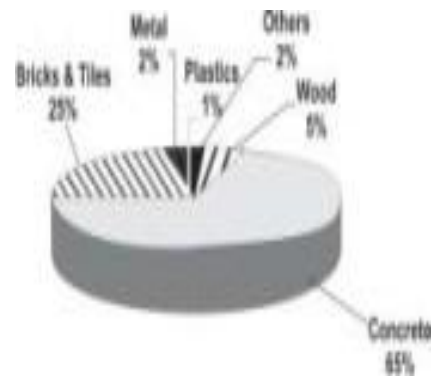


Fig 1 Recycling and Reuse of Construction & Demolition Wastes in Concrete

The properties of RAC has been established and demonstrated through several experimental and field projects successfully. It has been concluded that RCA can be readily used in construction of low rise buildings, concrete paving blocks & tiles, flooring, retaining walls, approach lanes, sewerage structures, sub base course of pavement, drainage layer in highways, dry lean concrete(DLC) etc. in Indian scenario. Use of RCA will further ensure the sustainable development of society with savings in natural resources, materials and energy.

2. Experimental Investigations

In the present paper, an endeavour is made so as to compare some of the mechanical properties of recycled aggregate concrete (RAC) with the natural aggregate concrete (NAC). Since the enormous quantity of concrete is available for recycling from demolished concrete structures, field demolished concrete is used in the present study to produce the recycled aggregates. The concrete debris were collected from different (four) sources with the age ranging from 2 to 40 years old and broken into the pieces of approximately 80 mm size with the help of hammer & drilling machine. The foreign matters were sorted out from the pieces. Further, those pieces were crushed in a lab jaw crusher and mechanically sieved through sieve of 4.75 mm to remove the finer particles. The recycled coarse aggregates were washed to remove dirt, dust etc. and collected for use in concrete mix. The fine aggregate were separated out, and

used for masonry mortar & lean concrete mixes, which is not part of this reported study. But these were found to suit for normal brick masonry mortar and had normal setting and enough strength for masonry work.

3. CONCRETE MIXES

The two different mix proportions of characteristic strength of 20 N/mm² (M 20) and 25 N/mm² (M 25) commonly used in construction of low rise buildings are obtained as per IS 10262 - 1982 or both recycled aggregate concrete and natural aggregate concrete. Due to the higher water absorption capacity of RCA as compared to natural aggregate, both the aggregates are maintained at saturated surface dry (SSD) conditions before mixing operations. The proportions of the ingredients constituting the concrete mixes are 1:1.5:2.9 and 1:1.2:2.4 with water cement ratio 0.50 & 0.45 respectively for M-20 & M-25 grade concrete. The ordinary Portland cement of 43 grade and natural fine aggregates (Haldwani sand) are used throughout the casting work. The maximum size of coarse aggregate used was 20 mm in both recycled and natural aggregate concrete.

The total two mixes are cast using natural aggregate and eight mixes were cast using four types of recycled aggregate concrete for M-20 & M-25. The development of compressive strength is monitored by testing the 150-mm cubes at 1, 3, 7, 14, 28, 56 and 90 days. In one set 39 cubes have to be cast for each mix. The cylinder strength and corresponding strain & modulus of elasticity are measured in standard cylinder of 150x300 mm size at the age of 28 days. The prism of size 150x150x700 mm and cylinder of size 150x300mm were cast from the same batches to measure flexural strength and splitting tensile strength respectively. This paper reports the results of experimental investigations on recycled aggregate concrete.

4. PROPERTIES OF RECYCLED CONCRETE AGGREGATE

4.1 Particle Size Distribution

The result of sieve analysis carried out as per IS 2386 for different types of crushed recycled concrete aggregate and natural aggregates. It is found that recycled coarse aggregate are reduced to various sizes during the process of crushing and sieving (by a sieve of 4.75mm), which gives best particle size distribution. The amount of fine particles (<4.75mm) after recycling of demolished were in the order of 5-20% depending upon the original grade of demolished concrete. The best quality natural aggregate can be obtained by primary, secondary & tertiary crushing whereas the same can be obtained after primary & secondary crushing in case of recycled aggregate. The single crushing process is also effective in the case of recycled aggregate.

The particle shape analysis of recycled aggregate indicates similar particle shape of natural aggregate obtained from crushed rock. The recycled aggregate generally meets all the standard requirements of aggregate used in concrete.

4.2 Specific Gravity and Water Absorption:

The specific gravity (saturated surface dry condition) of recycled concrete aggregate was found from 2.35 to 2.58 which are lower as compared to natural aggregates. Since the RCA from demolished concrete consists of crushed stone aggregate with old mortar adhering to it, the water absorption ranges from 3.05% to 7.40%, which is relatively higher than that of the natural aggregates. Table 4 gives the details of properties of RCA & natural aggregates. In general, as the water absorption characteristics of recycled aggregates are higher, it is advisable to maintain saturated surface dry (SSD) conditions of aggregate before start of the mixing operations.

4.3 Bulk Density:

The loose bulk density of recycled aggregate is lower than that of natural aggregate except recycled aggregate-RCA4, which is obtained from demolished newly constructed culvert. Recycled aggregate had passed through the sieve of 4.75mm due to which voids increased in rodded condition. The lower value of loose bulk density of recycled aggregate may be attributed to its higher porosity than that of natural aggregate.

4.4 Crushing and Impact Values:

The recycled aggregate is relatively weaker than the natural aggregate against mechanical actions. As per IS 2386, the crushing and impact values for concrete wearing surfaces should not exceed 45% and 50% respectively. The crushing & impact values of recycled aggregate satisfy the BIS specifications except RCA2 type of recycled aggregate for impact value as originally it is low grade rubble.

4.5 Compressive Strength:

The average compressive strengths of cubes cast are determined as per IS 516 using RCA and natural aggregate at the age 1, 3, 7, 14, 28, 56 and 90 days and reported. As expected, the compressive strength of RAC is lower than the conventional concrete made from similar mix proportions. The reduction in strength of RAC as compared to NAC is in the order of 2-14% and 7.5 to 16% for M-20 & M-25 concretes respectively. The amount of reduction in strength depends on parameters such as grade of demolished concrete, replacement ratio, w/c ratio, processing of recycled aggregate etc.

The average splitting tensile and flexural of recycled aggregate are determined at the age 1, 3, 7, 14, & 28 days

varies from 0.30 -3.1 MPa and 0.95- 7.2 MPa respectively. The reduction in splitting and flexural strength of RAC as compared to NAC is in order of 5-12% and 4 -15% respectively.

4.6 Modulus of Elasticity:

The static modulus of elasticity of RAC has been reported in Table 4 and found lower than the AC. The reduction is up to 15% .The reason for the lower static modulus of elasticity of RCA is higher proportion of hardened cement paste. It is well establish that E_c depends on E_c value of coarse aggregate, w/c ratio & cement paste etc. The modulus of elasticity is critical parameter for designing the structures, hence more studies are needed.

4.7 Durability:

The following parameters were studied to assess the influence of recycled aggregates on durability of concrete.

4.8 Carbonation:

CO₂ from the air penetrates into the concrete by diffusion process. The pores (pore size>100nm) in the concrete in which this transport process can take place are therefore particularly crucial for the rate of carbonation. The carbonation tests were carried out for 90 days on the specimens (150x150x150mm) of recycled aggregate concrete and natural aggregate concrete in carbonation chamber with relative humidity of 70% and 20% CO₂ concentration. The carbonation depths of recycled aggregate concretes for different grade were found from 11.5 to 14mm as compared to 11mm depth for natural aggregate concrete. This increase in the carbonation depth of RAC as compared to NAC, attributed to porous recycled aggregate due to presence of old mortar attached to the crushed stone aggregate.

4.9 Freeze-Thaw Resistance

In the freeze-thaw resistance test (cube method), loss of mass of the concrete made with recycled aggregate was found sometimes above and below than that of concrete made with natural aggregate. The results were so close that no difference in freeze thaw resistance (after 100 cycles) could be found. The literature also found that the effect of cement mortar adhering to the original aggregate in RAC may not adversely affect the properties of RAC.

4.10 Obstacles in Use of RCA & RAC

The acceptability of recycled aggregate is impeded for structural applications due to the technical problems associated with it such as weak interfacial transition zones between cement paste and aggregate, porosity and transverse cracks within demolished concrete, high level

of sulphate and chloride contents, impurity, cement remains, poor grading, and large variation in quality.

Although, it is environmentally & economically beneficial to use RCA in construction, however the current legislation and experience are not adequate to support and encourage recycling of construction & demolished waste in India. Lack of awareness, guidelines, specifications, standards, data base of utilization of RCA in concrete and lack of confidence in engineers, researchers and user agencies is major cause for poor utilization of RCA in construction. If the Government wishes these obstacles can easily be removed.

5. CONCLUSIONS

Recycling and reuse of building wastes have been found to be an appropriate solution to the problems of dumping hundreds of thousands tons of debris accompanied with shortage of natural aggregates. The use of recycled aggregates in concrete prove to be a valuable building materials in technical, environment and economical respect

Recycled aggregate posses relatively lower bulk density, crushing and impact values and higher water absorption as compared to natural aggregate. The compressive strength of recycled aggregate concrete is relatively lower up to 15% than natural aggregate concrete. The variation also depends on the original concrete from which the aggregates have been obtained. The durability parameters studied at SERC (G) confirms suitability of RCA & RAC in making durable concrete structures of selected types.

There are several reliable applications for using recycled coarse aggregate in construction. However, more research and initiation of pilot project for application of RCA is needed for modifying our design codes, specifications and procedure for use of recycled aggregate concrete. The subject of use of RCA in construction works in India should be given impetus, because of big infrastructural projects are being commissioned.

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