AN EXPERIMENTAL STUDY ON THE USE OF RECYCLED AGGREGATES IN RIGID PAVEMENT

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Abstract: Concrete is one of the most widely used construction materials in the world, mainly due to its favorable features such as durability, versatility, satisfactory compressive strength, cost effectiveness. But with the depleting natural resources and the huge amount of concrete waste produced, it becomes essential to identify an effective way to solve the need of the moment. In this rapid industrialized world, recycling construction material plays an important role to preserve the natural resources. In this research, Recycled Coarse Aggregates (RCA) from demolished slab pieces was used. These demolished slab pieces are crushed to suitable size and reused as recycled coarse aggregate. Natural sand used as fine aggregate. Concrete industry, uses 12.6 billion tons of raw materials each year, is the largest user of natural resources in the world. The environmental impact of production of raw ingredients of concrete (such as cement and coarse and fine aggregates) is considerable. In this paper The mix design has been done by trial and error method. The mix proportions are calculated as per IS code. The design procedure as per IS code and IRC: 44-2008 is used in mix design of M30 grade cement concrete. The w/c ratio is taken 0.5% for all the mixes. Hence, Coarse aggregates was replaced in percentages of 0%, 20%, 40 %, 60 %, 80 %, 100 % with recycled coarse aggregates 150 × 150 × 150mm, Beam and Cylinder moulds were used for casting.

Keywords: Recycled Aggregates, Compressive strength, Fresh Concrete, Waste management.

1.1 INTRODUCTION

The use of crushed aggregate from either demolition concrete or from hardened leftover concrete can be regarded as an alternative coarse aggregate, typically blended with natural coarse aggregate for use in new concrete. The use of 100% recycled coarse aggregate in concrete, unless carefully managed and controlled, is likely to have a negative influence on most concrete properties – compressive strength, modulus of elasticity, shrinkage and creep, particularly for higher strength concrete. Also the use of fine recycled aggregate below 2 mm is uncommon in recycled aggregate concrete because of the high water demand of the fine material smaller than 150 μm, which lowers the strength and increases the concrete shrinkage significantly. Many overseas guidelines or specifications limit the percentage replacement of natural aggregate by recycled aggregate. In general leftover concrete aggregate can be used at higher replacement rates than demolition concrete aggregate. With leftover concrete aggregate, information will generally be known about the parent concrete – strength range and aggregate source etc., whereas for demolition concrete very little information may be known about the parent concrete, and the resulting aggregate may be contaminated with chlorides or sulphates and contain small quantities of brick, masonry or timber which may adversely affect the recycled aggregate concrete. Often the sources of material from which a recycled aggregate came (and there could be more than one source), are unknown and the variability and strength of the recycled aggregate concrete could be adversely affected in comparison with a recycled aggregate concrete where the recycled aggregate came from one source with a known history of use and known strength. It is therefore necessary to distinguish between the properties of recycled aggregate concrete made using demolition concrete aggregate and that using leftover concrete aggregate. Aggregates have to bear stresses occurring due to the wheel loads on the pavement and on the surface course they have to resist wear due to abrasive action of traffic. These are used in pavement construction in cement concrete, bituminous concrete and other bituminous construction and also as granular base course underlying the superior pavement layers. Most of the road aggregates are prepared by crushing natural rock. Natural materials are of limited availability and its quantities are declining rapidly creating an acute shortage.

Nevertheless, recycled aggregate concrete can be manufactured using recycled aggregate at 100% coarse aggregate replacement where the parent concrete, the processing of the recycled aggregate and the manufacture of the recycled aggregate concrete are all closely controlled.

However as target strengths increase, the recycled aggregate can limit the strength, requiring a reduction in recycled aggregate replacement.

1.2 LITERATURE REVIEW ON RECYCLED AGGREGATES

Gurukanth S et al studied the Effect of Use of recycled concrete aggregates in bituminous concrete surface course. Today, science and technology has a responsibility of innovating new trends which are both economical and ecofriendly. Old demolished concrete structures can be recycled to obtain recycled aggregate (RA). This can be used along with the natural aggregates effectively in various infrastructure need so that we attain a balance between demand and supply of construction material thereby reducing the impact on nature. In this investigation , the strength variation of bituminous concrete surface course in which recycled aggregates are used in partial or full replacement of natural aggregates. Marshall's method is used to study the strength variations in bituminous concrete surface course with replacement of natural aggregates with recycled aggregates. It was found that replacement of natural aggregates by recycled aggregates upto 20% is possible in bituminous concrete surface course without significant impact on the strength characteristics. However there is an increase in the binder content for which there is a need to study the economic value of the replacement.

S R Yadav et al studied the use of recycled concrete aggregate in making concrete. This paper deals with the review of the existing literature work for the use of recycled concrete as aggregates in concrete in respect of mainly the compressive strength and proposes an approach for use of recycled concrete aggregate without compromising the strength. Works on recycling have emphasized that if old concrete has to be used in second generation concrete, the product should adhere to the required compressive strength. Literature survey reveals that compressive strength primarily depends upon adhered mortar, water absorption, Los Angeles abrasion, size of aggregates, strength of parent concrete, age of curing and ratio of replacement, interfacial transition zone, moisture state, impurities present and controlled environmental condition. Some of the studies have suggested the mix design procedure for recycled aggregates in concrete, yet a simple and cost effective method of using demolished concrete, taking into account % adhered mortar and thus calculating mix composition needs to be developed. Though there has been extensive research carried out on recycling yet construction industry does not have a simple and cost effective method to use the recycled aggregates in second generation concrete.

López-Gayarre F et al studied the influence of recycled aggregate quality and proportioning criteria on recycled concrete properties. This paper presents the results of experimental research using concrete produced by substituting part of the natural coarse aggregates with recycled aggregates from concrete demolition. The influence of the quality of the recycled aggregate (amount of declassified and source of aggregate), the percentage of replacement on the targeted quality of the concrete to be produced (strength and workability) has been evaluated. The granular structure of concrete and replacement criteria were analyzed in this study, factors which have not been analyzed in other studies. The following properties of recycled concretes were analyzed: density, absorption, compressive strength, elastic modulus, amount of occluded air, penetration of water under pressure and splitting tensile strength. A simplified test program was designed to control the costs of the testing while still producing sufficient data to develop reliable conclusions in order to make the number of tests viable whilst guaranteeing the reliability of the conclusions. Several factors were analyzed including the type of aggregate, the percentage of replacement, the type of sieve curve, the declassified content, the strength of concrete and workability of concrete and the replacement criteria. The type of aggregate and the percentage of replacement were the only factors that showed a clear influence on most of the properties. Compressive strength is clearly affected by the quality of recycled aggregates. If the water-cement ratio is kept constant and the loss of workability due to the effect of using recycled aggregate is compensated for with additives, the percentage of replacement of the recycled aggregate will not affect the compressive strength. The elastic modulus is affected by the percentage of replacement. If the percentage of replacement does not exceed 50%, the elastic modulus will only change slightly.

Tushar R Sonawane et al studied the use of Recycled Aggregate Concrete**.** The application of recycled aggregate has been started in a large number of construction projects of many European, American, Russian and Asian countries. Many countries are giving infrastructural laws relaxation for increasing the use of recycled aggregate. This study reports the basic properties of recycled fine aggregate and recycled coarse aggregate & also compares these properties with natural aggregates. Basic changes in all aggregate properties are determined and their effects on concreting work are discussed at length. Similarly the properties of recycled aggregate concrete are also determined. Basic concrete properties like compressive strength, flexural strength, workability etc. are explained here for different combinations of recycled aggregate with natural aggregate. Codal guidelines of recycled aggregates concrete in various countries are stated here with their effects, on concreting work. In general, present status of recycled aggregate in India along with its future need and its successful utilization are discussed here.

Paine, K. A et al to develop this performance-related approach, concrete mixes were cast and tested using combinations of unbound stone, crushed concretes and crushed bricks. From the results, three classes of recycled aggregates have been derived based on Los Angeles coefficient, aggregate absorption, density and drying shrinkage of the combined coarse aggregate. The concept is that the highest quality recycled aggregates will be suitable for high-performance applications, meeting the relevant standards and specifications, while the two lower classes will be more appropriate for lower performance applications. Given this approach, material that is currently not fully specified for use in BS 8500 may be classified and considered for relevant applications. This should remove the main technical barrier that is preventing the uptake of recycled aggregates in concrete, and lead to greater confidence in specifying and using recycled aggregates.

Janani Sundar et al studied the Impact of Chemical Admixture on Recycled Aggregates concrete. This research deals with reclamation of the aggregates obtained from the old concrete, and using them in creating a durable and normal strength concrete with 100% of the recycled concrete aggregate with addition of chemical admixtures of specific gravity 1.19. For this purpose the old concrete debris is broken into required aggregate size and some basic tests are carried out, then the compressive strength of this recycled aggregate concrete is compared to that of the concrete made with normal aggregate. The concept of direct percentage replacement is followed. The test results show that the density of the recycled aggregate is low compared to the normal natural aggregates, thus resulting in the decrease in density of concrete. The chemical admixture at 1.5, 1.8 and 2% of weight of cement is added and the compressive strength for 1.8% was found to be similar to that of normal aggregate concrete.

Ozbakkaloglu T et al studied the Use of recycled plastics in concrete. This paper summarizes the current published literature until 2015, discussing the material properties and recycling methods of plastic and the influence of plastic materials on the properties of concrete. To provide a comprehensive review, a total of 84 studies were considered, and they were classified into sub categories based on whether they dealt with concrete containing plastic aggregates or plastic fibers. Furthermore, the morphology of concrete containing plastic materials is described in this paper to explain the influence of plastic aggregates and plastic fibers on the properties of concrete. The properties of concretes containing virgin plastic materials were also reviewed to establish their similarities and differences with concrete containing recycled plastics.

Jitender Sharma et al studied on recycled concrete aggregates. This paper describes the introduction and production of recycled concrete aggregates and its various applications in the construction industry. In this paper, properties of recycled aggregates and its comparison with the natural aggregates are also mentioned. From past studies it is concluded that the recycled aggregate has rough – textured, angular and elongated particles where natural aggregate is smooth and rounded compact aggregate and Recycled aggregate is well graded as natural aggregate. The water absorption capacity of coarse recycled aggregate is about two times or more than natural coarse aggregates. The dry density of coarse recycled aggregate is lower than dry density of natural aggregate.

Marinković S et al studied on the Comparative environmental assessment of natural and recycled aggregate concrete. The main purpose of this study is to determine the potentials of recycled aggregate concrete (concrete made with recycled concrete aggregate) for structural applications and to compare the environmental impact of the production of two types of ready-mixed concrete: natural aggregate concrete (NAC) made entirely with river aggregate and recycled aggregate concrete (RAC) made with natural fine and recycled coarse aggregate. Based on the analysis of up-to-date experimental evidence, including own tests results, it is concluded that utilization of RAC for low-to-middle strength structural concrete and non-aggressive exposure conditions is technically feasible. The Life Cycle Assessment (LCA) is performed for raw material extraction and material production part of the concrete life cycle including transport. Assessment is based on local LCI data and on typical conditions in Serbia. Results of this specific case study show that impacts of aggregate and cement production phases are slightly larger for RAC than for NAC but the total environmental impacts depend on the natural and recycled aggregates transport distances and on transport types. Limit natural aggregate transport distances above which the environmental impacts of RAC can be equal or even lower than the impacts of NAC are calculated for the specific case study.

1.3 MIX PROPORTION

The mix design has been done by trial and error method. The mix proportions are calculated as per IS code. The design procedure as per IS code and IRC: 44-2008 is used in mix design of M30 grade cement concrete. The material required in the design of M 20 grade concrete is as follows and shows the test result of material which is generally required in the mix design of M20. The raw materials are mixed through hand mixing and compacted through the vibrators of casted cubes and beams. The total mixing time was 3 minutes; the samples were then casted and left for 24 hrs before demoulding .They were then placed in the curing tank. The w/c ratio is taken 0.5% for all the mixes. Hence, Coarse aggregates was replaced in percentages of 0%, 20%, 40 %, 60 %, 80 %, 100 % with recycled coarse aggregates 150 × 150 × 150mm, Beam and Cylinder moulds were used for casting. The concrete was left in the mould and allowed to set for 24 hours before the cubes were demoulded and placed in curing tank. The concrete cubes were cured in the tank for 7, 28 days. . The mix design of the concrete is shown in Table 1

Table 1: Mix Specification for 1 cubic meter Concrete

DESIGNATIONS	M 0	M 1	M 2	M 3	M 4	M 5
Particulars	Plain concrete mix	20 %	40 %	60 %	80 %	100 %
Cement in kg/m³	375	375	375	375	375	375
Sand in kg/m³	562.50	562.50	562.50	562.50	562.50	562.50
Coarse aggregate in kg/m³	1125	900	675	450	225	0
Recycled Aggregates	0	225	450	675	900	1125

1.4 COMPRESSIVE STRENGTH TEST

Compressive strength of concrete can be defined as the measured maximum resistance of a concrete to axial loading. The strength of the concrete specimens with different percentage of recycled aggregate replacement can be indicating through the compression test. The compressive strength of recycled aggregate concrete is shown in figure 1.

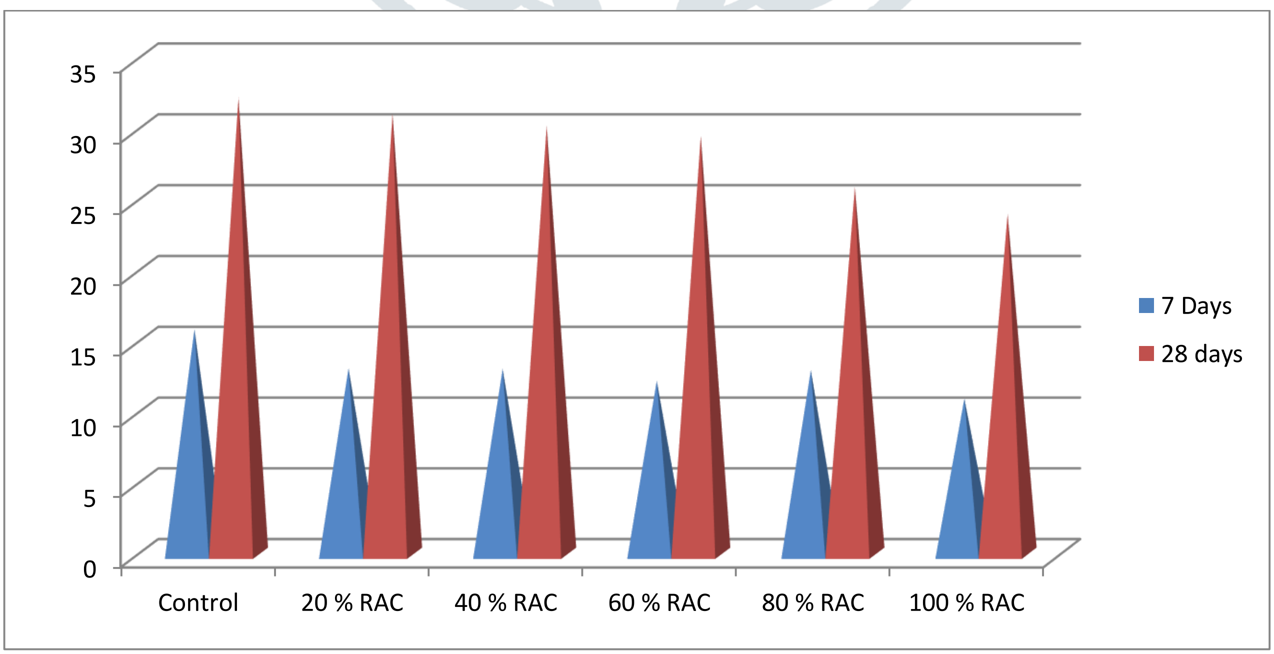

Figure 1: Compressive strength of various mixes

1.5 SPLIT TENSILE STRENGTH TEST

Split cylinder test was carried out to ascertain tensile strength of standard cylinders cast from each mix. The Split strength of recycled aggregate concrete are shown in figure 2.

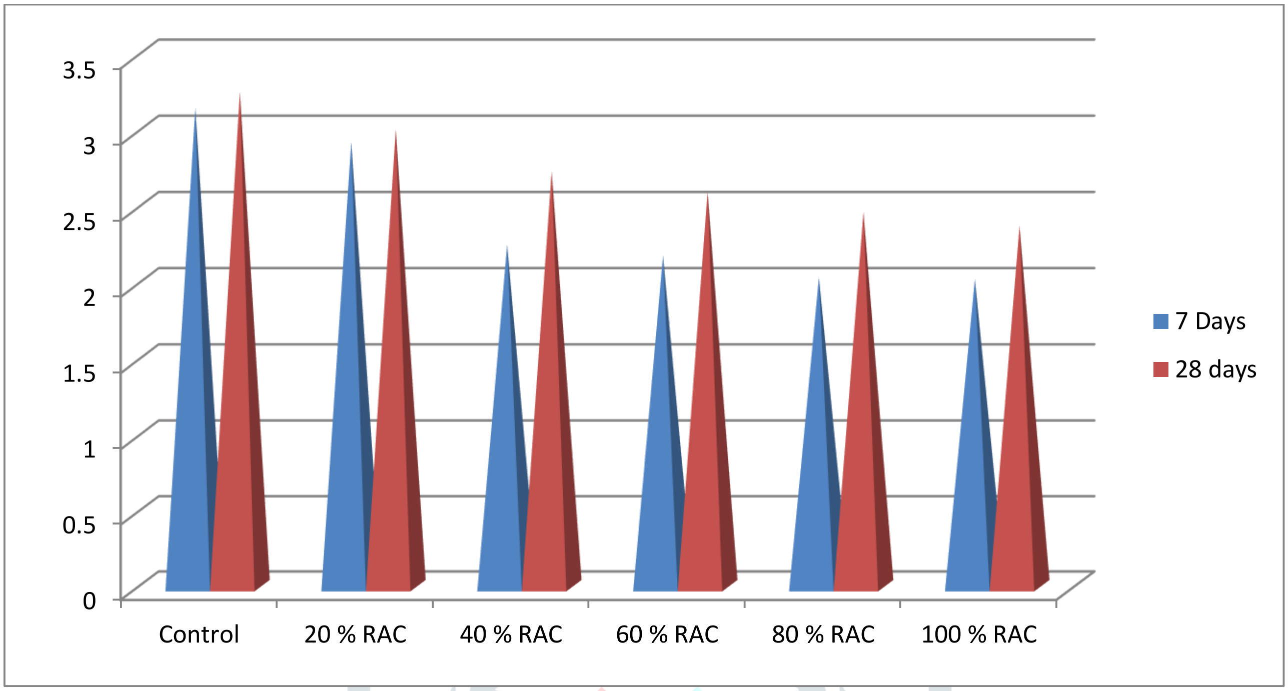

Figure 2: Split tensile strength of various mixes

1.6 FLEXURAL STRENGTH TEST

Test resulted that the beams with 100% replacement of RCA obtained higher cracks and lower in deflection. Flexural Strength of recycled aggregate concrete are shown in figure 3.

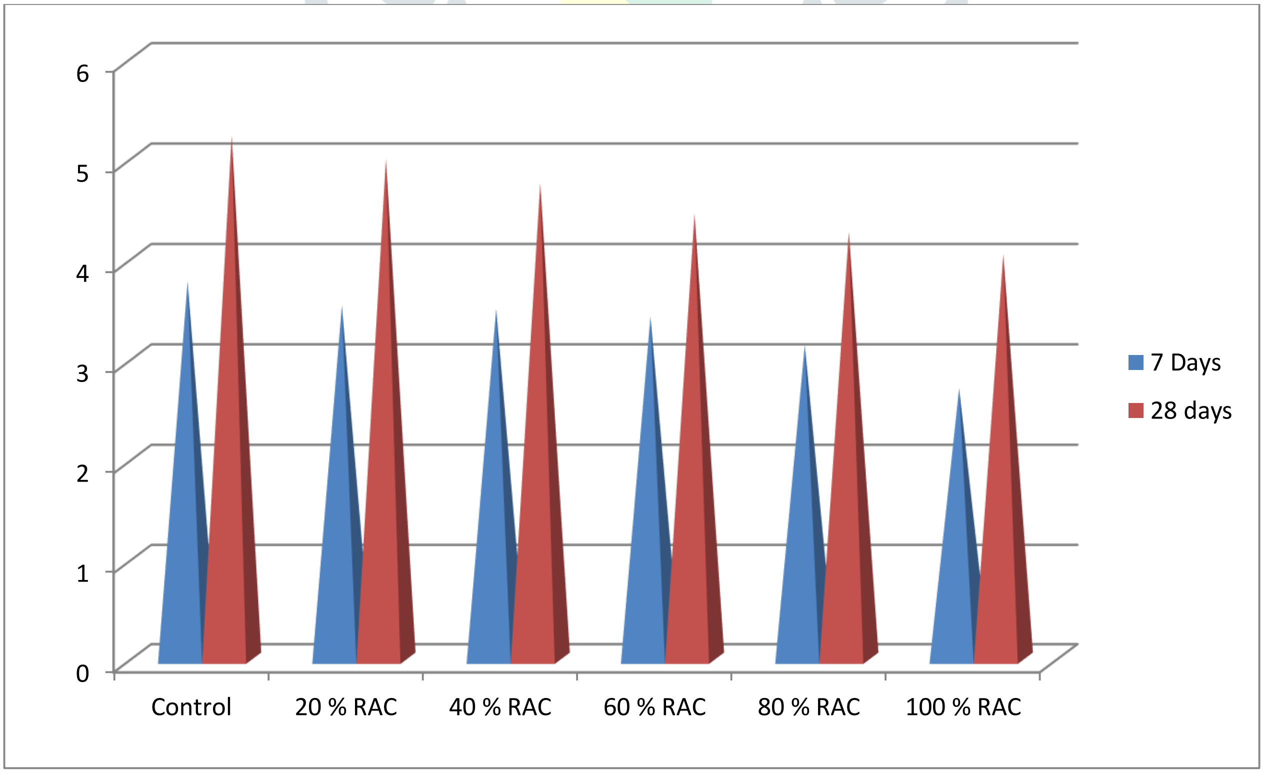

Figure 3: Flexural strength of various mixes

CONCLUSION

Based on the analysis and evaluation of the findings presented, the following set of general conclusions is drawn

1. The slump is also found to decline in the recycled aggregate concrete
    - The use of RCA decreases workability of fresh concrete at a given water content, increases the water requirement at a given consistency,
    - Increases shrinkage at a given water/cement ratio.
2. The slump is also found to decline in the recycled aggregate concrete but admixture has improved the slump.
3. It is observed that mixing of RAP reduces the rate of gain of compressive strength as compared to fresh aggregate.
4. Due to use of recycled aggregate in construction, energy & cost of transportation of natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.
5. RA extracted from good quality concrete without impurities impart higher strength than normal aggregates.
6. Use of recycled aggregate up to 25% does not affect the functional requirements of the structure as per the findings of the test results.
7. When the water cement ratio used in recycled aggregate mix is reduced, tensile strength and modulus of elasticity are improved.
8. New standards should be introduced for recycled aggregates so that these materials can be used successfully in future.
9. Recycled aggregate materials produce harsh mixes with lower workability than NAs.
10. The 100% replacement of NA by RCA in concrete mixture may effect on chloride ions resistance, if proper design is not adopted.
11. The workability tests it is observed that the optimum workability achieved in fresh concrete mix with 40% replacement of RCA.

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