Blending of Recycle Concrete Aggregates for Use in Base Course Construction

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Abstract— This paper presents an examination of the self-cementing phenomenon of the road construction material known as recycled concrete aggregate .The aggregates resulting from the recycling of the products of demolition lie within the scope of local materials replacement and this study contributes to their valorization in the field of civil engineering, particularly in roads. This study aims to develop the best economic solution by blending of recycled concrete aggregates for use in base coarse construction. Therefore, the objective of this project is to investigate the properties of blended Recycled Concrete Aggregate including optimum moisture content, maximum dry density, and bearing strength. In this study, six different types of RCA samples were subjected classification tests such as particle size distribution, plasticity, compaction test and California Bearing Ratio (CBR). Results were compared with those of the MORTH and found that “RA01-100/RA02-0” and “RA01-80/RA02-20” samples are sitting in the margin of the minimum required specifications of base materials while others are lower than that.

Keywords: Recycling, Concrete Aggregate, Demolished concrete

I. Introduction

Aggregate is one of the most vitally important materials in use for concrete production as it profoundly influences concrete properties and performance. Regarding aggregate usage in concrete, a conservative estimate is that at least 4.5 billion tons of concrete aggregates per year are consumed worldwide.

The research conducted for the Industry Commission Report indicated that about 3 million tons of waste aggregate has been created in the Australia alone. The disposal of all this waste has become a harsh social and environmental problem. This is a large burden on the world’s natural resources and an increasingly expensive problem for solid waste management. Therefore, a possible alternative aggregate method to overcome this issue may be using recycled concrete aggregates instead of natural aggregate in construction tasks.

The recycling process of concrete involves crushing, removing and separation into various sizes and bulks. Reclaimed aggregate may be designated according to its origin and its quality.

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.

II. Materials Used

In this research, two main commercially material available RCA products, namely RA01 and RA02, collected from a leading concrete recycle plant in Yamuna nagar, Haryana. Sources of materials are demolished building (slabs, floors, columns and foundations), bridges, airport runways and concrete road pavement. The taken sample has been undergone to the specified crushing process to produce “RA01” and “RA02”.As it is shown in table no. 1, the maximum percentage of the constituents that is considered in “RA01” and “RA02” at plant output. These two materials were blended in different percentage by weight to form another four samples to present various combinations of constituents. New sample are shown in table no. 1 and table no. 2 with their blending percentage.

Recycle Material	Maximum Limit of reach constituent(Percentage by mass)		
Type	Reclaimed concrete	RAP	Brick
RA01	100	-	-
RA02	100	25	10

RAP= Reclaimed Asphalt Pavement

Table 1: Percentage Limit of Constituents of Two Main RCA Materials

Material Name	Mixing percentages by mass (%)	
	RA01	RA03
RA01-100/RA03-0	100	0
RA01-80/RA02-20	80	20
RA01-60/RA02-40	60	40
RA01-40/RA02-60	40	60
RA01-20/RA02-80	20	80
RA-01-0/RA02-100	0	100

Table 2: New RCA Samples with Blending Percentage

III. Laboratory Test Perform and Methods

A. Grain Size Distribution

Particle size distribution of a particular pavement aggregate type affects its compressibility, permeability, density.Grain size distribution curves of all six testing RCA samples obtained from sieve analyses are shown in “Fig. 1”. Further the maximum and minimum grading curves of material subtype 2.1 have been drawn in same figure. Material subtype 2.1 is applied for base layers by MORTH and its gradation curves are drawn as their specifications. These demarcating lines are showing that fine content of the six samples are within required range but close to the minimum curve, while the course particles have exceeded the maximum gradation curve at the top. But all the curves show that a greater fraction of their curves are laid within the specified range.

According to the unified soil classification system (USCS), except "RA01-0/RA02-100", other five samples are categorized as 'well graded gravel'. The "RA01-0/RA02-100" present approximately half of sand and half of gravel with slightly susceptible to gravel.

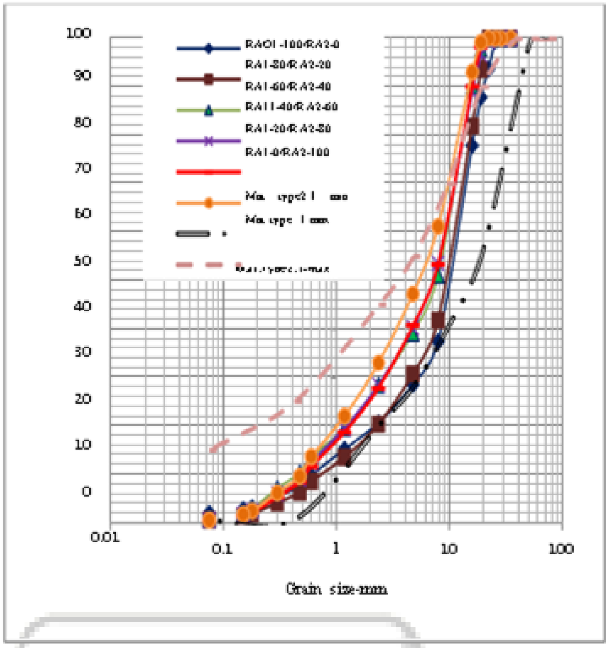

Fig. 1: Gradation curves for six samples and maximum & minimum curves of subtype 2.1 materials.

B. Plasticity

Cone-penetrometer method was used to deter-mine the liquid limit (LL) as well as plastic limit test was done for plastic limit (PL) for the sample of fines passing IS 0.475 mm sieve. Fines sample of "RA01-100/RA02-0" and "RA01-0/RA02100" were tested since other four samples are blended of these two. The LL values and mean values of plastic limit (PL) test (Atterberg limit test) were shown in Table 3. As per the MORTH, the maximum plasticity index (PI) is 6 and liquid limit 25 percent for material subtype 2.1. "RA01-100/RA02-0" is within that range but "RA01-0/RA02-100" having PI of material subtype 2.3 which is given maximum PI as 8. The subtype 2.3 is applied for upper sub base layers by Main Roads.

Fine sample	RA01-100/RA02-0	RA01-2/RA02-100
LL	22	26
PL	14.6	21
PI	5.6	8

Table 3: Plasticity Index of Two Main Materials

C. Modified Procter Test

The Procter test is carried out to determine the optimal water content "W_{opt}" and the maximum dry density "γ_{dmax}". The proctor curves are drawn up taking into account of the added brick, cement or sand. The results will be then compared with those obtain on natural aggregates.

The modified Procter test was developed to represent heavier compaction. The test is used to stipulate the field conditions where heavy rollers are used. This test was standardized by the American Association of State Highway Officials and therefore also known as modified AASHO test.

The Indian Standard Code IS: 2720 (Part VIII) gives the specifications for heavy compaction based on this test.

In the modified Procter test, the rammer used is much heavier i.e. mass is 4.89 kg and free drop is 450 mm. The face diameter is 50 mm. The soil is compacted in five equal layers; each layer is being given 25 blows. The compactive energy for the rest is thus increased to "27260 kg cm/ 1000 cm^3" that are about 4.5 times that of Standard Proctor Test. The sample taken from proctor test for getting results of optimum moisture content and dry density is being dried in oven for 24 hours.

The dry densities, γ_d obtained in a series of determinations should be plotted against the corresponding moisture contents, w. A smooth curve should be drawn through the resulting points and the position of the maximum on the curve is to be determined in "Fig. 2".

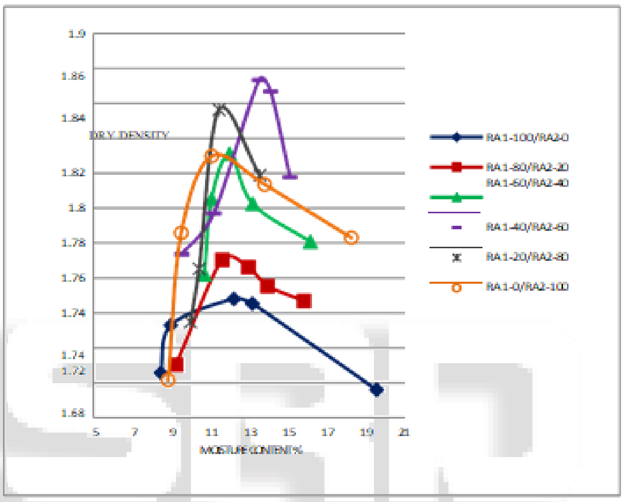

Fig. 2: Compaction curve of six sample.

Sample Type	Optimum Moisture Content %	Maximum dry density (g/cm^3)
RA01-100/RA0-0	12.11	1.701
RA01-80/RA02-20	13.1	1.778
RA01-60/RA02-40	13.2	1.842
RA01-40/RA0-60	13.6	1.866
RA01-20/RA02-80	14.1	1.816
RA01-0/RA02-100	14.3	1.856

Table 4: Optimum Moisture Content and Maximum Dry Density of Six Samples

As shown in "Fig. 2" and related in table 4, its shown the connection between OMC and MDD and how each other effect each other. The range of the variation of MDD and OMC are relatively small as "1.701-1.856 g/cm^3" and "12.11-14.3%", respectively. It can be seen that with the increase in fines contents of a material, both OMC and MDD increase as fines can absorb more water and can reduce the void volume by filling the voids between larger particles.

According to MORTH specification, MDD should be more than "1.700 gm/cm^3" and OMC should be minimum 8 percent.

In addition, with the increment of fine aggregate in the samples the curves are more pointed showing the sensitivity of mixture of water. And it is also interesting to note that all the samples are more

Sensitive to the moisture variation on the dry side of the OMC curves than the west side ofthe OMC.

D. California Bearing Ratio Test

California Bearing Ratio (CBR) test is a type of test developed by California Division of Highways in 1929. The test is used for evaluating the suitability of sub grade and the materials used in sub-base and base coarse.

CBR characterization is widely used to provide a relative measure of strength, elastic modulus and moisture durability. CBR tests were performed as specified in AS 1289.6.1.1 – 1998 and MORTH on the six samples compacted at their corresponding OMC.

To find OMC homogenization period that is time between material mixing with water and compaction and for this a series of CBR tests were done on RCA samples at different periods 0, 3 and 8 hours. The main components of crushed concrete are aggregates; cement mortar, sand need specific time period for uniformly moisture distribution. The results of these CBR tests are tabulated in Table 5.

	CBR %		
Sample type	No moisture homog-enizati0n period	3hrs moisture homogenization period	8hrs moisture homogenization period
RA01-100/RA02-0	62	75	54
RA01-80/RA02-20	58	64	-
RA01-60/RA02-40	54	67	-
RA01-40/RA02-60	51	62	-
RA01-20/RA02-80	49	61	-
RA01-0/RA02-100	47	52	54

Table 5: Variation of CBR Values with Different Moisture Homogenization Periods

CBR was conducted only for two samples to observe the strength gaining pattern

As shown in above table, no moisture homogenization period shows less CBR value in six sample because they did not have enough time for homogenization of moisture. Three hours curing period showed higher CBR values since the materials have taken sufficient time for uniformly moisture distribution which helps for properly compaction of the samples. But "RA01 100/RA02-0" showed lower CBR values for 8 hours curing period while "RA01-0/RA02-100" had its highest CBR value than previous conditions. "RA01-0/RA02-100" consists on more fines, clay bricks, and RAP particles which need more time and three hours insufficient for uniformly moisture distribution. In the "RA01-100/RA02-0" neither clay bricksnor RAP , but when check at the higher curing time that is 8 hours, mortar with cement shows less strength and poor bonding between RCA and cement along with poor compaction. Therefore 3 hours moisture homogenization compaction was followed for the next CBR test series.

1) CBR test for un soaked samples

Now, next step taken to do CBR test on un soaked curing periods on compacted six sample and effect on this CRR values. Every sample was prepared following the three hours curing period and followed standard compaction procedure. The sample compacted into the mould was cured (un soaked) in a sealed container for different periods that is 4 and 8 days along with 4.5kg surcharged load before applying testing. The changing of CBR values in curing periods for each RCA are shown in Table 6. Four days curing for compacted samples were followed and it is done as per MORTH. Eight days curing period for compacted samples were applied to observe the strength gaining with time.

"RA01-100/RA02-0" and "RA01-80/RA02-20" had little bit lower values of their CBR after eight days curing of the compacted samples. Fine particles of these compacted samples were fix themselves below 4.5 kg surcharge load for eight days. Due to this cause, they form little voids between irregular shapes recycled aggregates because these two samples have low quantity of fines comparatively with other samples. And that cause weak inter connection in the upper part of the compacted samples during load transfer and result for low CBR values.

"RA01-60/RA0-40", "RA01-40/RA02-60" and "RA01-20/RA02-80" are almost equal but slightly higher values .Due to high fine fraction values; it has very increased compact ability and increased water absorption for cement mortar strength gaining affect on its load bearing strength.

"RA01-0/RA02-100" had its lowest CBR values and this is due to the lower intrinsic particle strength of crushed bricks and reclaimed asphalts (RAP) which led to lower overall bearing strength of RCA. Also the poor interlocking system due to the crushed clay brick and sand decrease the load transfer capacity of the compacted samples.

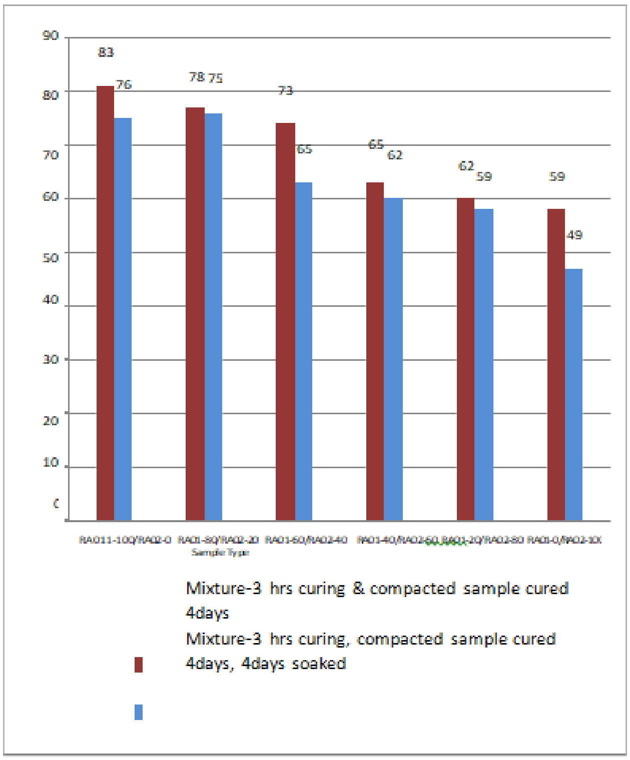

Fig. 3: Summary of CBR values for best un soaked and soaked results

	CBR%	
Sample type	Mixture-3 hrs curing and compacted sample cured 4 days	Mixture 3 hrs curing and compacted sample cured 8 days.
RA01-100/RA02-0	83	80
RA01-80/RA02-20	78	76
RA01-60/RA02-40	73	76
RA01-40/RA02-60	65	65
RA01-20/RA02-80	62	62
RA01-0/RA02-100	59	43

Table 6: CBR Values for Different Curing Period of Compacted Samples

2) CBR test for soaked samples

To perform the test of CBR values under soaking sample plays an important role for the strength of base course under fully saturated condition. This is recommended for flood areas in material selecting and base course designing. As per MORTH, it has introduced minimum required soaked CBR value as 80 for base layers. The soaked CBR results and the best CBR values which were shown by the mixture cured three hours and compacted samples cured 4 days are shown in "Fig." . For the soaked test, sample were cured 3 hours prior to compaction and the compacted samples also cured for four days with 4.5kg surcharged load prior to testing. It shows that soaked CBR values not reached the minimum requirement of the Main Road's specifications.

IV. Conclusion

The objective of this study is to develop the best economic solution by blending of recycled concrete aggregates for use in base coarse construction.

Therefore, the objective of this project is to investigate the properties of blended Recycled Concrete Aggregate including optimum moisture content, maximum dry density, elastic modulus, moisture durability and bearing strength.. For determining the above properties, the blending of the recycled aggregate has been done in different proportions of 100 %, 80%, , 60%,40 % and 20% in six samples of recycled concrete aggregate name RA01 and RA02 with the varying percentage of sand. Laboratory trails were conducted to investigate the possibility of using percentage of recycled concrete aggregate (100%, , 80%, 60%, 40%and 20%) with 3% and 5% of cement to replace the part of sand in mix. The heavy compaction tests were conducted to determine the optimum moisture content and dry density of the recycled aggregates.

RCAs have fewer fines but higher percentage of coarse aggregates. The six curves shows minimum required particles size distribution of material subtype 2.1.

The proctor tests show that there is great change of the granular structure according to the number of blows and presence of water. The addition of the sand, recycled concrete aggregate and cement varies considerably the behavior of the recycled concrete aggregates at compaction. OMC decreases with increasing the percentage of recycled concrete aggregates (RCA) as shown in "Fig. 5".

Proctor test provide higher water absorption for maximum dry density. However the density varied in a small range giving the lowest value for "RA01-100/RMA02-0" which represents only crushed concrete aggregate.

"RA01-100/RA03-0"sample has certainly very appreciable results at CBR test at the both soaked and un soaked. "RA01-80/RA02-20"sample also has come close to "RA01-100/RA02-0" with CBR results but lesser value.

The above inevitably impacts on the environment due to the great huge quantity of general and construction waste materials or from building demolition sites generated in developed countries. The research conducted for the Industry Commission Report indicated that about three million tons of waste aggregate has been created in the Australia alone. The disposal of all this waste has become a harsh social and environmental problem. This is a large burden on the world's natural resources and an increasingly expensive problem for solid waste management. Therefore, a possible alternative aggregate method to overcome this issue may be using recycled concrete aggregates instead of natural aggregate in construction tasks. This solution not only can help to conserve and extend natural resources but also can reduce the cost.

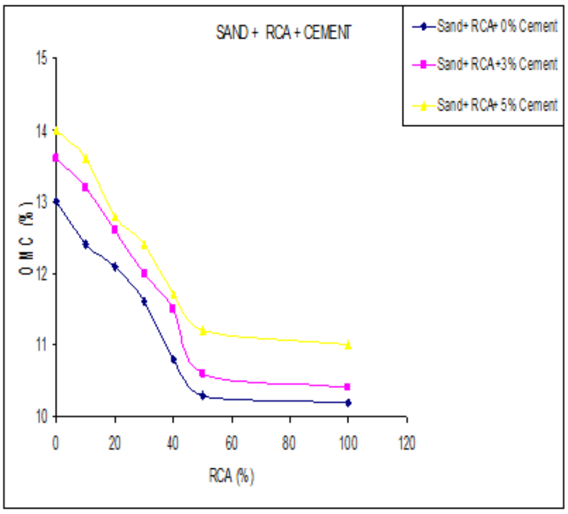

Fig. 5: OMC vs RCA at different proportions of cement

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