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RCA in Base Layer of Roads

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Abstract:
Green Technology a technique to reduce the negative consequences of human activity on the environment. Increasing population and economic development leads to construction and demolition of infrastructures, a larger quantity of waste gets generated and has become a great concern of environment protection. The use of Recycled material has become a viable option to be incorporated into road applications and has reduced pressure on natural material resources. This Paper focuses on using recycled concrete aggregate (RCA) as base material in highway construction in order to gain sustainable and economics benefits. Different samples of Recycled aggregates have been tested to check moisture density characteristics and bearing capacity in accordance to the IS-codes and results were compared with those of standard road materials. The results showed that density of RCA is lower than that of Virgin aggregates (V.A) and CBR test results suggested that CBR values of RCA is significantly higher than those CBR obtained from ordinary sub base.

Keywords: Virgin aggregate (V.A), Recycled Concrete aggregate (RCA), Construction and demolition Waste, water absorption, Aggregate properties, Concrete material properties.

Introduction

Recycling is the process to change waste materials in order to be reused for same or different purposes. Recycling of demolished debris into new construction works is the best way to reduce waste disposal loads to landfills and preserve natural resources. Various laboratory studies and field trials have shown that the RCA can totally or partially replace natural virgin aggregates in road construction and reduces the environmental pollution of solid wastes.

Construction and demolition (CD) activities generated 1.13 billion tones in China in year 2014; and over 530 million tons in United States (US). Construction activities in Europe is the largest producer of waste when compared with other industrial areas, responsible for 35% of the total waste generation which is 2 and 4 times more than the overall household waste produced respectively in US and Europe. European union overall has achieved the horizon of recovery for the year 2020, including backfilling. However, there are still eleven member countries-out of the 19- which need to improve their recovery performance for achieving the EU target. The total production of construction and demolition waste in 28 countries of the European Union plus Britain reached more than 368 million tons in the year 2018.
According to the Building Material Promotion Council (BMPTC), India generates an estimated 150 million tonnes of construction and demolition (C&D) waste every year. But the official recycling capacity is a meager 6,500 tonnes per day (TPD) -- just about 1 per cent.

In Italy, the ratio of construction and demolition waste, which is prepared for re-use, recycled or utilized material recovery was 98% in 2018 compared to 88% of the whole European Union. According to Eurostat figures, at the national level 96% of CDW were recycled in 2018 (90% in 2012), and the amount of CDW which went to landfill was reduced to 1.7% from 2.4% in 2012. In recent years, Circular economy concept attracted an increasing attention. Its goal is to offer an alternative method of traditional dominant model of consuming natural resources. It focuses on three main approaches: reduction, re-use and recycle. Many world countries are trying to decrease their construction and demolition waste by implementing various legislations and improving awareness through different measures to reduce the effects on the environment. Information is available on C&D waste production in each part of world in relation to the recycling activities and existing policies and legislation on disposal of C&D waste. Whilst coarse recycled aggregates generated from construction and demolition waste are permitted by many specifications for various applications in road construction, a necessity exists for developing a high-value market for the recycled aggregate fines. Potential exist for a higher market price for recycled aggregate (RA) fines due to their residual binding properties. In fact, some RA fines possess hardening properties, such as recycled concrete aggregate, whilst others have pozzolanic properties, such as bricks and ceramic wastes. In both cases the binding capacity of these materials will significantly contribute to the cost benefits, for example by reducing the binder requirement in hydraulically bound mixtures. The RCA obtained from construction and demolished wastes when used as road sub bases or base in paving roads has various advantages as listed below

- Improving the workability of road materials
- Increasing the endurance of the material
- Increasing the load bearing capacity
- Enhancing the durability.

Methodology

In order to fulfill the objective of this research work, different tests were conducted to achieve the desired goal. Various analysis and tests were done to check the requirements of the aggregates that were used. These included the gradation tests and physical requirement analysis for virgin aggregates. For the moisture density characteristics and bearing capacity, compaction tests were conducted.

Material Considerations

This research work mainly focused on OMC, dry densities and bearing capacity of mixtures of different percentages of RCA and VA. The main materials used in this project are as follows: i. Virgin aggregates used, conform to the Grade 1 as mentioned in IRC-109-1997 (Guidelines for wet mix macadam). These aggregates were selected after meeting the requirements set by IRC-109-1997 (shown in table 1) for the aggregates to be used in base course. These aggregates were obtained from road research lab Rajbagh Srinagar. Aggregate size ranging from 45mm to 75 micron constitutes the material. RCA used was obtained from crushing of concrete acquired from demolished concrete structures. The size of RCA varies from 37.5mm to 75 micron.

	Test	Test Method	Requirements
1	**Los Angeles Abrasion Value Or Aggregate Impact Value**	IS:2386 (Part IV)	40% (max)
		IS:2386 (Part IV) or IS:564(1))	30% (max)
2	**Combined Flakiness and Elongation Indices**	IS:2386 (Part I)	30% (max)

Table 1: Physical requirement of coarse aggregate for wet mix.

Recycled Concrete Aggregate (RCA)

Virgin Aggregate

Experimental Work:-

In order to complete the objectives, several analyses have to be done on VA to check that they meet the requirements set by Indian Road Congress. After the aggregates are selected, tests to check the moisture-density characteristics and bearing capacity are done in accordance to the IS codes to obtain the results. The analyses and the tests done during this project and the observations obtained are mentioned below.

1. **Gradation test:-**

Performing a sieve analysis is important when analyzing materials because their particle size distribution can affect a wide range of properties such as the strength of concrete, the solubility of a mixture, their surface area properties. Sieve analysis was performed in order to check the particle size distribution of the aggregates and it will help in the gradation of RCA. Both the coarse aggregates and fine aggregates will be blended with RCA at different percentages. Sieve analysis is performed according to the IRC:SP 11-1988 on the RCA and the VA obtained. Gradation of wet mix macadam (WMM) proposed by Ministry of road transportation and highways (MORTH) and Ministry of rural development (MORD) is considered as reference gradation for base material. Gradation of VA (shown in table 2) was done to make Grade 1 material in accordance to IRC-109-1997.

IS Sieve Designation	Percent by weight passing	
	Grading 1	Grading 2
53.00mm	100	-
45.00mm	95-100	-
26.5mm	-	100
22.4mm	60-80	50-100
11.2mm	40-60	-
4.75mm	25-40	35-55
2.36mm	15-30	-
600micon	8-22	10-30
75micron	0-8	2-9

Table 2: Grading requirements of aggregates for wet mix macadam.

IS Sieves

Physical Requirement Test:-

Many tests were conducted in accordance with IS code on VA to check the physical properties as mentioned in table 1. The material to be used should pass these tests so as to be used in the base course of wet mix macadam. The different tests for physical requirement of aggregates are:-

- **Impact Value Test**:-

The property of a material to resist impact is known as toughness. The aggregates should have sufficient toughness to resist their disintegration due to impact. . Impact value test on the VA was done in accordance to IS2386 (Part 4)1963 and the observations and result is given below:-

S. No.	1	2	3
Weight of cylindrical steel cup (w_1)	1365g	1365g	1365g
Weight of cylindrical steel cup with aggregate (W_2)	1938g	1863g	1847g
Weight of aggregate ($W_3=W_2 - W_1$)	573g	498g	482g
Weight of aggregate passing from 2.36mm sieve (W_4)	110g	98g	91g
Impact Value (W_4/W_3)x100	19.19%	19.67%	18.84%

Table 3: Impact Value Test

Average Impact Value = (19.19+19.67+18.84)/3 = 19.23%, which is in accordance to the IS code.

Combined Elongation and Flakiness Test:-

This test was done in accordance with IS-2386(Part 1)1963 and the observations and the results are given below:-

Size of aggregates		**Weight of fraction consisting of at least 200 pieces,g**		**Thickness gauge size, mm**	**Weight of aggregates in each fraction passing thickness gauge, g**		**Length gauge size, mm**	**Weight of aggregatesin each fraction retained on length gauge, g**	
Passing through IS sieve, mm	Retained on IS sieve, mm	1	2		1	2		1	2
63	50	-	-	33.9	-	-	-	-	-
50	40	95	195	27.00	0	65	81.0	95	0
40	31.5	280	150	19.50	90	15	58.5	0	0
31.5	25	770	615	16.95	150	80	-	-	-
25	20	725	1580	13.5	200	310	40.5	235	360
20	16	555	1315	10.8	130	215	32.4	210	445
16	12.5	315	675	8.55	85	160	25.6	160	270
12.5	10	160	225	6.75	40	60	20.2	70	110
10	6.3	90	225	4.89	20	50	14.7	30	95
Total		3000	5000		715	955		800	1280

Table 4: Observations for combined flakiness and elongation index

S. No.	1(g)	2(g)
Total weight of sample,W_1	3000	5000
Total weight of sample passing through thickness gauge, W_2	715	955
Flakiness Index (W_2/W_1)x100	23 %	19 %
Average FlakinessIndex	21.4 %	

Table 5: Flakiness Index

S. No.	1(g)	2(g)
Total weight of sample, W_1	3000	5000
Total weight of sample retained on length gauge, W_2	800	1280
Elongation Index (W_1/W_2)x100	26.6 %	25 %
Average Elongation Index	26. %	

Table 6: Elongation Index

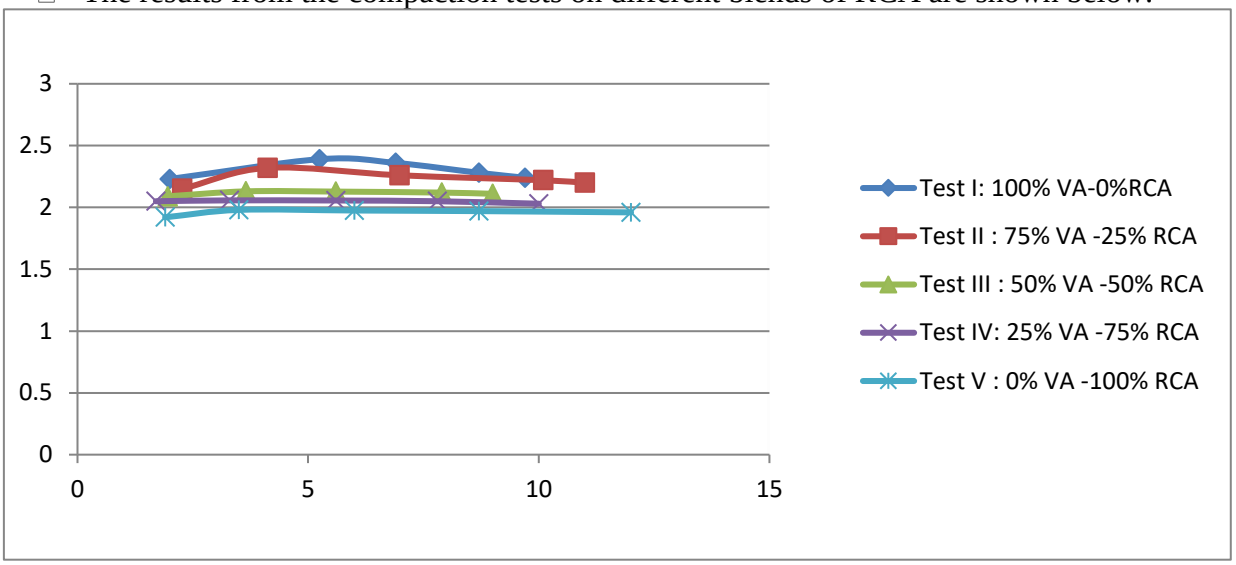
Both the elongation and the flakiness index are in accordance with the IS2386 (Part 1).

Compaction Test:-

Compaction is a mechanical process by which the particles are constrained to be packed more closely together by reducing the air voids. Compaction causes decrease in air voids and consequently an increase in dry density. Compaction, in general is considered most useful in construction of embankments and in the preparation of sub grade and other pavement layers in order to increase the stability and to decrease the future settlement. From the compaction test, the maximum dry density and optimum moisture contents are found for the selected type and amount of compaction. As per IRC and MORTH specifications, during construction of National and State Highways, the dry density achieved in the field for the compacted embankment soil should not be lesser than 95 % of 'Heavy or Modified Proctor compaction' test results and that of sub grade soil should not be lesser than 97 %. Thus, the laboratory compaction test results are made use of for quality control during highway construction.

Modified proctor test done during this project was done according to IS-2720(part 8)1983 using the heavy compaction test and was done on the blends of virgin aggregate and recycled concrete aggregate in the percentages of 100%VA-0%RCA, 75%VA-25%RCA, 50%VA-50%RCA, 25%VA-75%RCA and, 0%VA-100%RCA. The material varied in size from 45mm to 75 micron. The observations and the results of the modified proctor test done on different blends of VA-RCA sample of 6kg, given 55 blows each for 5 layers using a 4.5kg rammer were obtained.

 The results from the compaction tests on different blends of RCA are shown below:



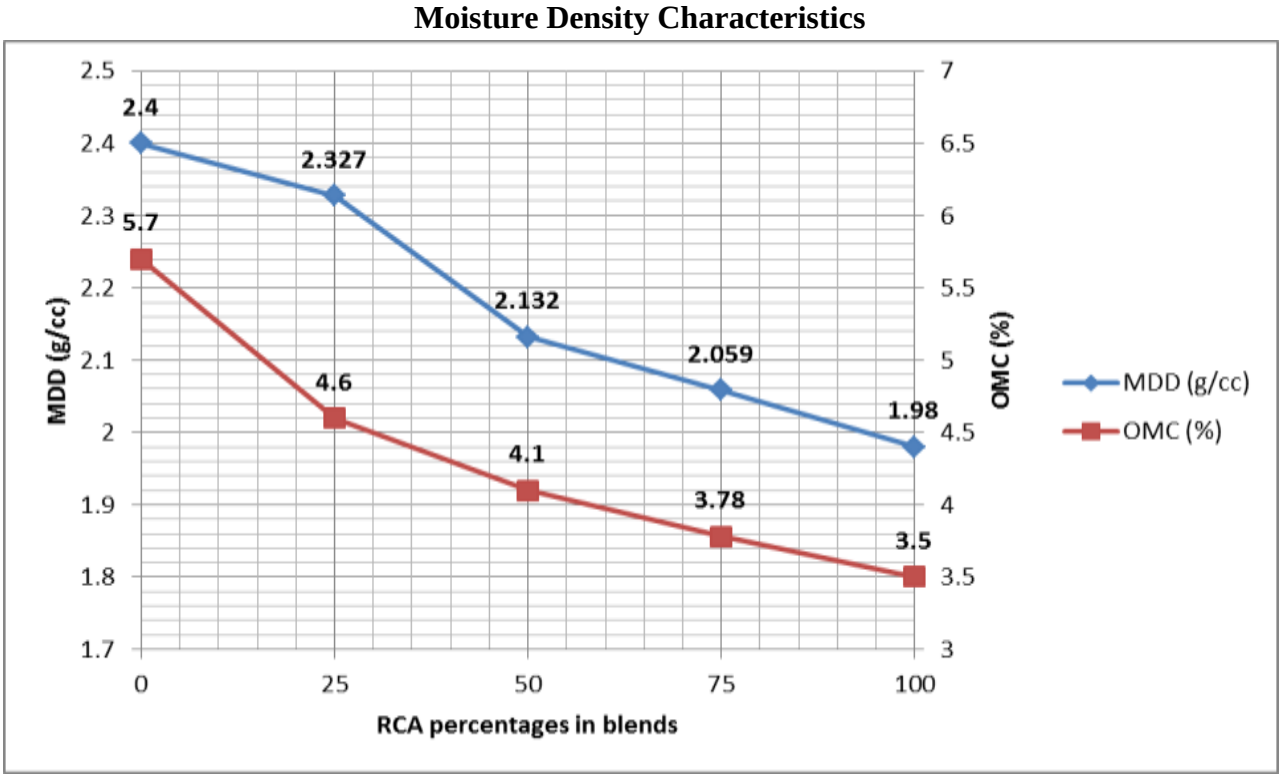


Figure A: Modified Proctor Test results of RCA/VA blends

Modified proctor tests were carried out on blends to determine the moisture density relationships. The density of the RCA varies due to the cement paste that adheres to the surface of the aggregate and has been found to vary between 1.9 g/cc to 2.2 g/cc which is lower than that of virgin aggregates. RCA having high porosity can undergo a high degree of deformation. It is reported that the water absorption values of RCA ranges from 3% to 10% compared to the less than 3% water absorption of natural aggregates. Similarly, it was also reported that RCA possesses higher values of void ratio and porosity than natural aggregate. These values can be explained because of presence of cement mortar in RCA. As shown in

Figure A, due to the cement mortar surrounded the RCA aggregates which inhibit compaction, the compacted dry densities of RCA/VA blends tend to decrease from 2.4 g/cc to 1.98 g/cc with the increase in RCA percentage. OMC also tends to decrease with increase in the RCA percentage due to the binding effect of the concrete particles (75micron to 2.36mm) with the finer particles and the larger particles, reducing the amount of water needed to achieve the required compaction level of the RCA blends. This factor has to be considered when the suitable moisture content of compaction is determined.

California Bearing Ratio

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min. to that required for the corresponding penetration of a standard material. The CBR test is one of the most commonly used methods to evaluate the strength of a sub grade soil, sub base, and base course material for design of thickness for highways and airfield pavement.

The California bearing ratio test is penetration test meant for the evaluation of subgrade strength of roads and pavements. The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavement.

Sieve Size	**Percentage Passing**			
	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
53.00 mm	90	100	100	100
45.00 mm	75	100	100	100
26.5 mm	62	98	100	100
22.4 mm	55	88	100	100
11.2 mm	43	65	98	100
4.75 mm	34	50	78	100
2.36 mm	25	34	60	75
600 micron	18	24	42	49
150 micron	12	20	33	39
75 micron	7	9	12	16
CBR %	110	95	85	40

Sample 1 : 100% VA + 0% RA
Sample 2 : 50% VA + 50% RA
Sample 3 : 25% VA + 75% RA
Sample 4 : 0% VA + 100% RA

The CBR test is performed by measuring the pressure required to penetrate the sample with a plunger of standard area.CBR value of 80% and a high-quality sub-base will have a value between 80–100% (maximum).

Conclusion: -

Results presented in this report allow concluding that, in this case, usage of RCA or constituents of RCA with aggregates or as substitute to the virgin aggregates evidence the reduction in many parameters as mentioned above with slight decrease in the strength values.

Conclusions from laboratory evaluation:

- RCAs have fewer fines but higher percentage of coarse fraction
- A certain replacement percentage of VA (25%) with RCA can be used in¬ aggregate base course without any significant reduction in the MDD.
- RCA is a poor material to be used alone in terms of strength and densities
- MDD's of blends with high percentages of RCA showed significant decrease¬ with increase in the RCA.
- OMC of blends decreased almost linearly with increase in the RCA due to binding effect produced by the concrete particles.
- Sample 3 with 75 % of Recycled Aggregate and 25% of Virgin Aggregate is concluded and looks promising and has a good CBR value of almost 85% and lies between 80-100%. So an economical choice for base layer of roads.

Therefore it could be concluded that the recycled concrete could be used as a sub base material for highways as well as being able to be reusing in base under strict regulations and guidelines to be adopted from experimental results.

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