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Use of Recycled Concrete Aggregate in Construction: An Overview

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Abstract – Recycled aggregates have germinated towards a valuable preference for virgin aggregates. RA is created from concrete rubble which has undergone years of services; the resulting RAC carries the weakness of lower density, higher water absorption & higher permeability that limit them to lower grade applications. In order to achieve the best ecology-to-quality ratio considering materials, befitting selections should be made. Concrete mix proportioning is enhanced in order to maximize the usage of C&D waste without the reduction of mechanical & enduringness properties.

The experimental follow up were carried out by using detailed strength & durability related tests are explained here for different fusion of recycled aggregates with virgin aggregates. The compressive strength of RAC is found to be higher than the strength of virgin concrete. RAC is in proximity to virgin concrete in terms of split tensile strength, flexural strength and wet density. The slump of RAC is depressed and that can be regenerate by using full substituting of SSD RCA aggregates to the VA. At last it is confirmed that the use of RCA is likely a possible call for structural use.

Index Terms - Recycled concrete aggregate (RCA), recycled aggregate (RA), saturated surface dry (SSD), coarse aggregate (CA), virgin (natural) aggregate (VA), C&D.

1. INTRODUCTION

Indian construction industry nowadays is amongst the five largest in the globe and at the modern rate of culture, it may become to be 2nd top most in the upcoming century. Aggregates supply has also appeared as a problem in some of the principal cities in India. With the shortfall as likely seen today the futurity seems to be in gloom for the construction sector. The demands of natural aggregates are not only required to fulfill the demand for the fore coming projects, but also are the needs of the large repairs or replacements required for the existing infrastructure and damaged buildings built few decades back.

C&D removal has also emerged as a complication in India. India is presently producing C&D waste to the tune of 23.7 million of tons yearly as per the Hindu online of March 2007, which is comparable to some of the advanced nations and these Figures are likely to double fold in the next three fourth decade. The administration of C&D Waste is a dominant interest due to enlarged quantity of demolition stock, continuing shortfall of Dumping grounds, increase in disposal and transportation cost and above all the concern about Environment reduction. Although a significant portion of construction materials could be replaced by recycled construction debris, these selections are not handled in developing countries cause due to lack of consciousness and insufficient administrative frameworks following in waste getting assemblage and causing disposal problems. The growing complications linked with C&D waste have led to a rethinking in advanced countries and most of them have started considering this debris as resource and nowadays have achieved a part of their demand for raw material. India may also have to seriously think of reusing demolished rubble in production of recycled construction material. Work on recycled concrete has been consummate at few places in India but rubble stock and quality of stock formed being site specific, astounding inputs are needed if reprocessed material has to be used in construction for producing high grade concrete.

2. RECYCLED AGGREGATES

Recycling is the undertaking of treating the recycled material for adoption in new product formation. The usage of NA is becoming acute with the leading buildup in the field of infrastructures. In pursuance of reducing the consumption of NA, RA can be taken as the substitute materials. RA includes graded, crushed particles refined from the materials that have been pre-owned in the C&D debris. These materials are generally collected from Roads, Buildings, bridges, and even from cataclysm like disasters and wars. Here are some advantages by using the RA.

The advantages that occur by consumption of RA are listed below.

- Environmental increment
- Cost
- Job Opportunities
- Most inbuilt
- Wide market

2.1 Properties of Recycled Concrete Aggregate

The crushing characteristics of hardened concrete are same as of natural rocks and are not much affected by the quality or grade of the natural concrete. RCA consists of the natural aggregates & hydrated cement paste which results in the decrease in the specific gravity and increases the permeability compared to NA. The concrete formed with RA drops its workability more swiftly than the standard concrete, because RA is more permeable than NA. So concrete with RA may need more water to mix to gain the similar workability as NA. RA formed from well graded concrete can be expected to accomplish the needs for the LA abrasion loss percentage, crushing and impact values.

3. FRESH CONCRETE PROPERTIES

3.1 Workability and consistency

Concrete mixtures with both coarse and fine recycled aggregates can be very harsh and difficult to work due to the highly angular and rough surface of the RCA. Additional water is required in order to obtain the same degree of workability as a mix containing conventional aggregates, especially when both coarse and fine RA are used. Increasing the water content will necessitate an increase in the cement content to produce a cement paste that is equivalent to mixes made with conventional aggregates. The result is a more costly mix design.

Workability can be improved by reducing or eliminating the amount of recycled fines in favor of natural fines, using water reducers, adding fly ash or a combination of all three. Using fly ash alone may not provide a workable mix and a reduction in the percentage or elimination of the recycled fines may be necessary. Slump loss is commonly observed for mixtures containing RCA due to its high absorption characteristics. Solutions include presoaking the aggregates or pre-wetting the stockpile.

3.2 Water Content

Increased water contents are required for mixtures containing RCA due, as mentioned previously, the high absorption capacity of the paste clinging to the aggregates. The higher and more variable absorption capacity also makes it difficult to determine the water content which in turn leads to variation in the strength of the hardened concrete.

3.3 Air Content

Higher and more variable air contents are common in fresh concrete made with RCA. This is due to the higher porosity of the recycled aggregates themselves and to the entrained air in the original mortar. Therefore, the target air content of mixtures containing RCA must be higher to achieve the same durability as conventional mixes.

4. HARDENED CONCRETE PROPERTIES

4.1 Compressive Strength

Compressive strengths of concrete containing RCA are generally slightly lower than concretes made with natural aggregates; however, there is little agreement on the magnitude of the strength reduction. Some studies cite two to ten percent lower compressive strengths, other report similar and sometimes higher strengths depending upon the water-cement ratios for the mixes. The higher air content normally found in mixes containing RCA may also lead to lower strength values.

4.2 Flexural Strength

Reports indicate that the use of recycled coarse aggregate reduces the flexural strength by up to eight percent at the same water-cement ratio, and that this reduction increases if recycled fines are also used. The quality of the concrete used to produce the RCA has a strong influence on flexural strength, which relies most heavily on the paste-aggregate bond strength.

4.3 Modulus of Elasticity

The concrete made with RCA is 20 to 40 percent low in elastic modulus and stiffness than that of standard concrete at the same w/c ratio. This reduction can be even greater when recycled fines are also used. The reduction in modulus of elasticity is due to the fact that RA is typically have lower elastic moduli than NA.

4.4 Splitting tensile strength

The tensile strength is from one of the key properties of the concrete. The concrete is not commonly expected to prevent the absolute tension because it is low in tensile strength and brittle in nature. For all that, the assurance of tensile strength of concrete is unavoidable to determine the capacity at which the concrete section may crack. The cracking is a form of failure in tension point of view. Aside from the flexural tensile test, the other methods to regulate the tensile strength of concrete can be mostly classified as

(a) Direct methods, and

(b) Indirect methods.

The first one go through the number of complications relevant to holding the specimen accordingly in the testing instrument without offering stress absorption, and to the functions of uni-axial tensile load which is free from eccentricity to the model. In these tests in general a compressive force is practiced to a concrete model in a way that it fails by the virtue of tensile stresses produced in the specimen. The tensile stress at which the failure develops is described as the tensile strength of concrete.

4.5 Durability

Cement	**Water**	**Sand**	**Aggregate**
367	147	726	1230
1	0.4	1.97	3.35

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Table: 1

IS Method of Design for M 4 0 Concrete

- Acid Resistance Test

Curing for 28 days, cubes size 150mm is measured and dipped in 3% sulphuric acid solution for 45 days continuously. Then the cubes are removed, weighed and surface dried. The percentage loss in weight and devaluation in compressive strengths are analyzed.

- Saturated water absorption test

Saturated Water Absorption (SWA) tests will be executed on 75, 100 or 150 mm cube specimens at the age of 28 days and more curing as per ASTM C 642. The specimens will be measured before drying. The drying will be executed in a hot air oven at a temperature of 105 degree Celsius. The drying process will be advanced, until the difference in mass between two consecutive measurements at 24 hours spell admitted closely. The dried specimens will then be cooled at room temperature and then dipped in water. The specimens were removed at regular spells of time, surface dried by using cotton cloth and measured. This process will continue till the weights became even (full saturation). The SWA will be determined by the difference between the measured oven dried mass and water saturated mass declare as a percentage of oven dry mass.

- Porosity Test

The hardened concrete test of saturated water absorption is a measure of the porosity which is occupied by water in saturated state. It signifies the volume of water which can be expunged on drying a saturated specimen. The porosity retrieved from absorption tests is termed as effective porosity. It is figured by using the formula:

Effective porosity = (Volume of pores/ bulk volume of model) x 100

The volume of pores is retrieved from the volume of water absorbed by an oven dried model or the volume of water lost on oven drying water saturated specimen at 105oC to consistent mass. The bulk volume of the specimen is accustomed by the difference in weight of the specimen in air & its weight under immersed condition in water.

5. PROPERTIES OF AGGREGATES

5.1 LA abrasion value

The Los Angeles (L.A.) test for abrasion is an accepted test method known to illustrate abrasion and toughness properties of aggregate. These properties are necessary because the essential aggregate in Hot Mix Asphalt (HMA) must prevent disintegration and deterioration in favor of producing a good quality HMA.

Typical L.A. test points a coarse aggregate sample (retained on 1.70 mm (No. 12) sieve to impact, grinding & abrasion in a spinning steel drum consisting of a definite number of steel balls.

After being conducted to the spinning drum, the mass of aggregate which was retained on a No. 12 sieve is deducted from the initial weight to retrieve a proportion of the total aggregate weight that has battered down and passed through the No. 12 sieve. Accordingly, an L.A. abrasion loss value of 40 points out that the original sample passed through No. 12 sieve is 40%.

Grading of test samples

Sieve size (Square hole)		Weight in g of test sample for grade						
		A	B	C	D	E	F	G
Passing through (mm)	Retained on (mm)							
80	63	-	-	-	-	2500*	-	-
63	50	-	-	-	-	2500*	-	-
50	40	-	-	-	-	5000*	5000*	-
40	25	1250	-	-	-	-	5000*	5000*
25	20	1250	-	-	-	-	-	5000*
20	12.5	1250	2500	-	-	-	-	-
12.5	10	1250	2500	-	-	-	-	-
10	6.3	-	-	2500	-	-	-	-
6.3	4.75	-	-	2500	-	-	-	-
4.75	2.36	-	-	-	5000	-	-	-

Table: 2

Grading	No. of spheres	Wt. of charge/spheres (gms)	No. of revolutions
A	12	5000±25	500
B	11	4584±25	500
C	8	3330±20	500
D	6	2500±15	500
E	12	5000±25	1000
F	12	5000±25	1000
G	12	5000±25	1000

Table: 3 No. of spheres & revolutions for different grading

NOTE : Grading E, F & G are ASTM procedures used by Mn/DOT for railroad ballast. The ASTM method (1000 revolutions) has no known consistent relationship to results obtained using the method prescribed for grading A, B, C & D

5.2 Aggregate impact value

The quality of a material to prevent damage from impact is termed as toughness. As vehicles runs on the road, the aggregates are manipulated to strike resulting in their detachment into minor pieces. The aggregates thence have satisfactory toughness to prevent their disintegration by striking. This quality is determined by impact value test. This test is a measure of opposing to frequent impact or strikes, which may be unlike from its resistance to constantly applied compressive load.

The test is executed to regulate the aggregate impact value of coarse aggregates as per IS: 2386 (Part IV) – 1963. The apparatus used for this test is Impact testing machine confirms IS: 2386 (Part IV)- 1963,IS Sieves of sizes – 2.36mm, 10mm and 12.5mm, A cylindrical measure of metal 75mm dia. and 50mm depth, tamping rod of 10mm cross section and 230mm in length with rounded end and an Oven.

5.3 Aggregate crushing value

Aggregates used for construction are advised strongly to resist crushing. If the aggregates are weak, the steadiness of the structure is likely to be negatively afflicted. The strength of coarse aggregates is determined through aggregate crushing test. The aggregate crushing value gives a relative strength of resistance to crushing under constantly applied compressive load. Lesser the aggregate crushing value, stronger the aggregates are.

5.4 Porosity

The tiny holes formed in rocks during solidification of the molten magma, due to air bubbles, are known as pores. Rocks consist of pores are called porous rocks. Water absorption may be defined as the difference between the weight of dry aggregates and saturated surface dry aggregates. Depending upon the amount of moisture present in aggregates, it can exist in any of the given conditions.

- Very dry aggregate
- Dry aggregate
- Saturated surface dry aggregate
- Moist or wet aggregates.

5.5 Bulk density

The bulk density of RA is less than that of NA, thus results are not satisfactory; due to lower Bulk Density the mix proportion gets affected. It is defined as the weight of the aggregate requires filling a unit volume of a container. It is commonly expressed in kg/ltr.

Bulk density of aggregates depends on the following factors.

- Degree of compaction
- grading of aggregates
- Shape of aggregate particles

Aggregate properties	Gravels	Recycled aggregates	Percentage difference (%)
Bulk specific gravity (dry)	2.55	2.09	18
Bulk specific gravity (SSD)	2.56	2.14	16.4
Apparent specific gravity	2.63	2.3	12.5
Absorption (%)	1.56	6.4	4.8
Bulk density (kg/m3)	1469.8	1325.93	9.8
Moisture content (%)	1.9	4.46	2.6

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Table: 4 Comparisons of Properties on Conventional and Recycled Aggregates

6. INTERPRETATION OF TEST RESULTS

6.1 Slump Test Result and Analysis

- First analysis

The slump test indicates a decreasing tendency of workability when the percentage of RA increased. Below shows the average slump recorded all along the test. Figure 1 below shows a graphical representation of slump height.

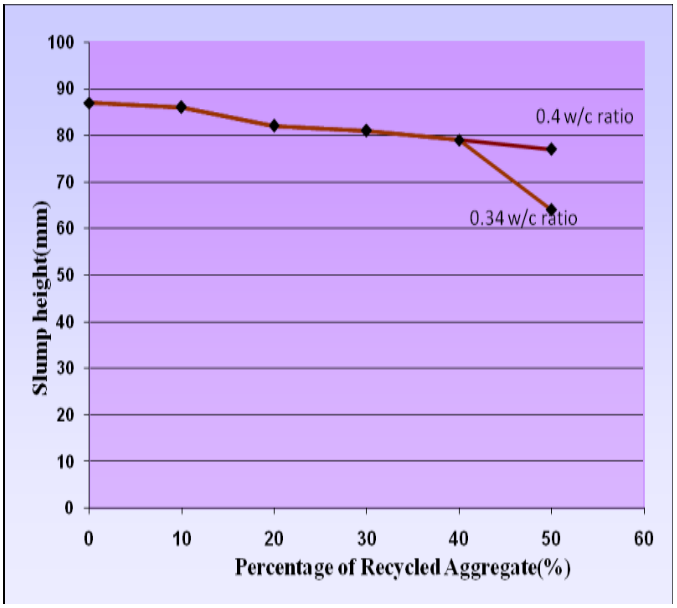

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Figure: 1 Slump Graph

The result shows that, the highest slump obtained was 87mm and the lowest slump was 64mm. The average slump for each set of mix was 80mm. So, required slump has been gained, where the range is from 50mm to 100mm. The workability was favorable and can be satisfactorily handled for 0% to 50% RA. The slump for this replacement was treated as moderate due to the drop in the range of 5mm to 10mm.There was no trouble for the placement and compaction of fresh concrete. The only problem occurred was for the batch with 50% RA (plus 0.34 water cement ratio). The workability was very low due to the slump was 64mm. The reason was due to the large absorption capacity of RA. From the gained results, it appears that the workability was becoming lower when more RA is used.

- Second analysis

The slump results are presented in Table. That concrete mixes at 0.4w/c had a lower slump compared to 0.5 and 0.6w/c concrete mixes. Also, when replacement of RA is incremented in concrete mixtures, the slump of concrete mixes is decreased. It was normal as RA is high in water absorption. Poon C.S. reported that mortar over RA is lead to low slump of RAC.

Here, RA00 stands for 0%recycled aggregates mixed in concrete.

SERIES	W/C RATIO	SLUMP (mm)
RA00	0.4	135
	0.5	173
	0.6	179
RA25	0.4	128
	0.5	165
	0.6	170
RA50	0.4	90
	0.5	165
	0.6	165
RA75	0.4	60
	0.5	160
	0.6	159
RA100	0.4	50
	0.5	153
	0.6	156

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Table 5: Slump for Different w/c Ratio Concrete Mixes

6.2 Compression Test Result and Analysis

- First analysis

The average compressive strengths of cubes casting are determined as per IS 516 using RCA and NA at the age of three, seven, & twenty-eight days and reported in Table 6. As expected, the compressive strength of RAC is slightly less than the conventional concrete made from comparable mixed proportions. The decrease in strength of RAC as compare to NAC is in order of 8-14% and 10-16%for M-30 & M-40 concretes respectively. As per test results the strength of recycled aggregate cube is more than that of target strength, so RCA can be used for construction purpose.

- Second analysis

The compression test demonstrates an increasing phenomenon of compressive strength in the initial age of the concrete specimens. However, it displays that the strength of RA specimens is lower than NA specimens. The target strength for this project/task is 40MPa. From the obtained result, it shows that the only mix which reaches the target strength is the batch with 0% RA. The compressive strength for other batches is below 40MPa.The compressive strength of the concrete specimens for fifty percent RA replacement with 0.34 water/cement ratio is 37MPa, which roughly met the target strength. This shows that up to thirty to forty percent RA replacement may attain high strength by reducing the water/cement ratio. The results also display that the concrete specimens with extra replacement of RA will get the lower strength while compared to the concrete specimens with less RA.

Compressive Strength	Replacement Of Natural Aggregate			
	0%	10%	20%	30%
M30-3Days	20.63 N/mm2	16.38 N/mm2	19.05 N/mm2	18.46 N/mm2
M30-7 Days	33.13 N/mm2	23.83 N/mm2	31.93 N/mm2	28.05 N/mm2
M30-28 Days	47.53 N/mm2	42.28 N/mm2	43.92 N/mm2	40.27 N/mm2
M40-3 Days	31.59 N/mm2	28.44 N/mm2	27.56 N/mm2	25.78 N/mm2
M40-7 Days	56.67 N/mm2	53.69 N/mm2	51.69 N/mm2	49.78 N/mm2
M40-28 Days	64.42 N/mm2	60.44 N/mm2	56.22 N/mm2	54.22 N/mm2

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Table: 6 Compressive strength

7. CONCLUSION

- Despite the fact RA can be applied in the high strength structure, one issue must not be neglected that excess use of RA with reduce w/c would have less workability. Whenever RA is applied, the amount of water added to the concrete mix has to be controlled precisely as the water absorption capacity of RA will vary.
- Use of RA up to 30% does not affect the functional needs of the structure according to the conclusion of the test results.
- Various tests conducted on RA and results in comparison with NA are satisfactory as per IS 2386.
- Due to use of RA in construction, energy & cost of transportation of essential natural resources & excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.

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