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Study on the Partial Replacement of Demolished Concrete from Natural Aggregate in Rigid Pavement

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I. INTRODUCTION

Nowadays concrete has been the leading road pavement material since it was first used and is bound to maintain its significant role in the upcoming future due to its durability, maintenance free service life, adaptability to any shape and size, wide range of structural properties plus cost effectiveness. The concrete is the most important construction material which is manufactured at the site. It is the composite product obtained by mixing cement, water and an inert matrix of sand and gravel or crushed stone. It undergoes a number of operations such as transportation, placing, compaction and curing. The distinguishing property of concrete is the ability to harden under water. The ingredients can be classified into two groups namely active and inactive. The active group consists of cement and water, whereas the inactive group consists of fine and coarse aggregates. The inactive group is sometimes also called inert matrix. Concrete has high compressive strength but its tensile strength is very low.

The main reasons for increase of volume of demolition concrete / masonry waste are as follows:-

A. Many old buildings, concrete pavements, bridges and other structures have overcome their age and limit of use due to structural deterioration beyond repairs and need to be demolished;
B. The structures, even adequate to use are under demolition because they are not serving the needs in present scenario;
C. New construction for better economic growth;
D. Structures are turned into debris resulting from natural disasters like earthquake, cyclone and floods etc.
E. Creation of building waste resulting from manmade disaster/war.

II. SCOPE OF INVESTIGATION

The concrete obtained from the demolition sites can be used for the production of aggregate of acceptable quality which in turn reduces the consumption of the natural aggregate and hence reduces the ever rising costs of construction. Also it saves energy used in the manufacturing process. Hence the present work involves systematic study of fresh and hardened state properties of concrete using aggregates obtained from fresh demolition operations. The properties (Compressive Strength) of the concrete made from demolished concrete are compared with properties of the concrete made from natural aggregate. In the present work the use of recycled aggregate in varying proportions of 0%, 10%, 20%. 30%, 40%, 50%, 60%, 70%, 80 %, 90% & 100% as a replacement of natural coarse aggregates has been done for & and 28 days curing. It includes the study of concrete property i.e. Compressive Strength.

III.LITERATURE REVIEW

Following are some of the important studies and researches already done regarding the demolition of concrete:

Buyle-Bodin, F. et. al. (2002) drew a comparison between the behaviour of RAC and that of ordinary natural aggregate concrete. The influence of both the composition and the curing conditions was discussed. It was observed that durability of RAC is controlled by flow properties of high total W/C ratio and air permeability. The diffusion of the carbon dioxide is faster, that leads to a weaker resistance of RAC to environmental attacks. Hendriks, F. Ch. et. al. (2003) developed the approach called Design for Recycling can be used to optimize design of constructions for later reuse and the Design for Disassembly can be used for demolition. For the technical aspects two models were developed concerning degradation processes and high-graded applications. These models were based on Life Cycle Assessment method. Poon et. al. (2004) studied Influence of moisture states of natural and recycled aggregates on the compressive strength of concrete, and concluded that the concrete mixtures prepared with the incorporation of recycled aggregates, the air dried (AD) aggregate concretes exhibited the highest compressive strength. The surface dried density (SSD) recycled aggregates seemed to impose the largest negative effect on the concrete strength, which might be attributed to ‘‘bleeding’’ of excess water in the pre-wetted aggregates in the fresh concrete. Based on the results of his study, aggregates in the ADstate and contain no more than 50%recycled aggregate should be optimum for normal strength recycled aggregate concrete production.

Levy, Salomon M. et. al. (2004) studied three properties water absorption, total pores volume and carbonation of recycled concrete. They made concrete with recycled aggregate (0%, 20%, 50% & 100% replacement) from recycled sources and achieved compressive strength in the range of 20-40 MPA at 28 days which is same as natural aggregate. It was found that the carbonation depth decreased when the replacement was 20% or 50% which shows that carbonation depth depends strongly on the chemical composition of the concrete and not only on the physical aspects. Xiao, Jianzhuang et. al. (2005) studied the bond behavior between recycled aggregate concrete (RAC) and steel rebar. The conducted 36 pull out tests with 3 recycled coarse aggregate (RCA) replacement percentages (0%, 50% & 100%) and two types of steel rebar's (plain & deformed). They found that under equivalent mix proportions with an increase of RCA replacement percentage, the bond strength between the RAC and plain rebar decreases. The bond strength between RAC and deformed rebar has no obvious relation with the RCA replacement percentage.

Khatib (2005) found that the absorbed water in the recycled aggregate may have helped with internal curing by providing a source of water to react with the cement. The relative compressive strength of recycled aggregate concrete decrease with the increase of relative water absorption of aggregate and the relative compressive strength can also be significantly affected by the water cement ratio and curing condition.

Pan, J. et. al. (2006) investigated the effect of aggregates on the bond capacity. Ten different compositions of concrete have been used to prepare specimens for the direct shear test. An empirical expression was derived to calculate the interfacial fracture energy in the shear test using ANN. The bond capacity can then be calculated according to fracture mechanics based model. Good agreement was obtained between the simulation and experimental results.

Rao, Aakash et. al. (2006) studied the effect of recycled aggregate concrete can be used in lower end applications of concrete. It was concluded that recycled aggregate can be used for making normal structural concrete with the addition of fly ash, condensed silica fume etc.

Debs, Mounir, k. el. et. al. (2007) analyzed the bond behavior of self-compacting concrete (SCC), in comparison to vibrated concrete (VC), using pull-out and beam tests according to the Rilem procedures. The main analyzed parameters were the concrete compressive strength, the steel bar diameter, the concrete type and the test adequacy to provide a value for bond strength. Also, a comparison between Code provisions and empirical equations was done. The analytical results showed satisfactory approach compared to the experimental ones. It was concluded that the same parameters adopted for VC can be extended for SCC.

Zhang, Xue-bing et. al. (2007) developed a formula for additional water requirement in recycled concrete. They found that the specific absorption of coarse aggregate increases as the time of absorbing water goes on. In the first 10 minutes, the water absorption speed is the greatest and then it decreases and changes very little. The specific absorption and water absorption speed of RCA are greater than those of crushed stone and pebble, within the same time.

Yang et. al. (2008) observed that the normalized splitting tensile strength ofRecycled aggregate concrete decreased with the increase of relative water absorption and it was less than 0.53 for most specimens having relative water absorption larger than approximately 2.25%.

Tabsh, Sami W. et. al. (2008) studied the strength of concrete made with recycled concrete coarse aggregate. The two variables considered in the study were the source of the recycled concrete and recycled concrete strength. Test results indicated the losses as 50% for toughness and 12% for soundness tests which are within acceptable limits. They found that the recycled concrete mix requires more water than the conventional concrete to maintain the same slump without the use of admixtures. The strength of recycled concrete can be 10-25% lower than that of concrete made with natural coarse aggregate.

S. R. Yadav et. al. (2009) has investigated that India is presently generating construction and demolition (C &D) waste to the tune of 23.75 million tons annually and these figures are likely to double fold in the next 7 years. C&D waste and specifically concrete has been seen as a resource in developed countries. 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. 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.

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IV. MIX DESIGN

The selection of mix materials and their required proportion is done through a process called mix design. There are number of methods for determining concrete mix design. The methods used in India are in compliance with the BIS (Bureau of Indian Standards). The objective of concrete mix design is to find the proportion in which concrete ingredients-cement, water, fine aggregate and coarse aggregate should be combined in order to provide the specified strength, workability and durability and possibly meet other requirements as listed in standards such as IS: 456-2000. The specification of a concrete mix must therefore define the materials and strength, workability and durability to be attained. IS: 10262-1982 gives the guidelines for concrete mix designs. In this study, six batches of mixes were determined. The mixes was taken with (1:1.38:2.41 , w/c=0.04) .The natural coarse aggregate was replaced by recycled coarse aggregate in the ratio of 10% to 100%. The properties of designed concrete was studied i.e compressive strength.

V. PROPERTIES OF MATERIALS

The mechanical and physical properties of cement, sand, natural coarse aggregate and coarse aggregate from demolished concrete as per IS: 2386-1963 were determined which are discussed below:

VI. CEMENT

Ordinary Portland cement of 43 grade (Source: Shree Ultra Cement) conforming to IS: 8112-1989 was used. The cement was tested as per IS 4031-1968. The test results of the cement are shown below in Table 1.

Table 1 Physical properties of cement 43-grade

S. No.	Properties	Values obtained	Standard Values as per IS:8112-1989
1.	Fineness % (90 µm I.S. Sieve)	4	Not more than 10
2.	Soundness (mm) (Le Chatelier Method)	1.0	Not more than 10
3.	Normal Consistency (%)	29	
4.	Initial Setting Time (minutes)	220	>=30
5.	Final Setting Time (minutes)	300	<=600
6.	Compressive Strength (MPa) i) 3 days ii) 7 days	 26.07 31.40	 >23 >33
7.	Specific gravity (Le-Chatelier's Method)	3.87	

VII. NATURAL FINE AGGREGATE

Yamuna Coarse sand was used as a fine aggregate. The grading of sand and other properties are given in the table 2. The sand conforms to zone II as per IS:383-1970.

Table 2 Sieve Analysis of Natural Fine Aggregate (Yamuna River Sand)
Weight of Sample Taken=1000gm

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative percentage of Weight Retained	Percentage Passing
4.75	152	152	15.2	84.8
2.36	51	203	20.3	79.7
1.18	116	319	31.9	68.1
.6	114	433	43.3	56.7
.3	379	812	81.2	18.8
.15	144	956	95.6	4.4
0.75	25	981	98.1	1.9
Pan	-	-	-	-

∑F=385.6
Fineness Modulus (F.M.)=3.86
Sand conform to grading zone II of I.S. 383-1970

Table 3 Physical Properties of Natural Fine Aggregate

S. No.	Property	Values Obtained
1.	Bulk Density (Loose), kg/m^3	1682
2.	Bulk Density (Compacted), kg/m^3	1886
3.	Specific Gravity	2.54
4.	Free Moisture %	1.48
5.	Water Absorption %	14.3

VIII. NATURAL COARSE AGGREGATE

Coarse aggregate of 10mm and 20mm sizes were used. The grading and properties of the coarse aggregate are given in the tables 4 and 5 respectively.

Table 4 Sieve Analysis of Coarse Aggregate (10mm)
Weight of Sample Taken = 2000gm

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative percentage of Weight Retained	Percentage Passing
20	0	0	0	100
16	0	0	0	100
12.5	8	8	.4	99.6
10	541	549	27.45	72.55
4.75	1414	1963	98.15	1.85
2.36	32	1995	99.75	.25
Pan	-	-	-	-

$\sum C=125.6$
Fineness Modulus (F.M.)=6.2

Table 4 (a) Physical Properties of Coarse Aggregate (10 mm)

S. No.	Property	Values obtained
1.	Bulk Density (Loose), kg/m^3	1307
2.	Bulk Density (Compacted), kg/m^3	1469
3.	Specific Gravity	2.61
4.	Free Moisture %	0
5.	Water Absorption %	.5

Table 5 Sieve Analysis of Coarse Aggregate (20mm)
Weight of Sample Taken = 2000gm

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative percentage of Weight Retained	Percentage Passing
20	72	72	3.6	96.4
16	740	812	40.6	59.4
12.5	577	1389	69.45	30.55
10	546	1935	96.75	3.25
4.75	54	1989	99.45	0.55
Pan	-	-	-	-

$\sum C=199.8$
Fineness Modulus (F.M.)=6.99

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Table 5 (a) Physical Properties of Coarse Aggregate (20 mm)

S. No.	Property	Values obtained
1.	Bulk Density (Loose), kg/m^3	1415
2.	Bulk Density (Compacted), kg/m^3	1478.2
3.	Specific Gravity	2.66
4.	Free Moisture %	0
5.	Water Absorption %	1.84

IX. COARSE AGGREGATE FROM DEMOLISHED CONCRETE

The aggregate was produced by crushing the old concrete slab at Ambala city. All the aggregate sizes were screened to give the combined coarse aggregate size higher than 4.75mm but lower than 20mm. coarse aggregate of sizes 20mm-10mm and 10mm-4.75mm were separated. The different size aggregate fill each other and thus increase the strength. The particle shape of the demolished concrete aggregate (recycled aggregate) was round and surface textures porous and rough. This was expected owing to the presence of attached mortar of the old natural aggregate. The specific gravity of the demolished concrete coarse aggregate was lower than the corresponding value of natural coarse aggregate and water absorption higher due to presence of low density porous mortar. The resistance against crushing was slightly lower than that of natural aggregate. The properties of the demolished concrete coarse aggregate are given in the Table 6.

Table 6 Sieve Analysis of Recycled Aggregate
Weight of Sample Taken =2000gm

IS Sieve Size (mm)	Weight Retained (gm)	Cumulative Weight Retained (gm)	Cumulative percentage of Weight Retained	Percentage Passing
20	30	30	1.5	98.5
16	289	319	15.95	84.05
12.5	491	810	40.5	59.5
10	904	1714	85.7	14.3
4.75	261	1975	98.75	1.25
2.36	7	1982	99.1	0.9
Pan	-	-	-	-

$\sum C=185.95$
Fineness Modulus (F.M.)=6.86

Table 6 (a) Physical Properties of Recycled Aggregate

S. No.	Property	Values obtained
1.	Bulk Density (Loose), kg/m^3	1128
2.	Bulk Density (Compacted), kg/m^3	1294.92
3.	Specific Gravity	2.32
4.	Free Moisture %	2.03
5.	Water Absorption %	5.6

A. Water

Water used for mixing and curing was free from deleterious materials as per clause no 5.4 of IS 456-2000. Potable water is generally considered satisfactory for mixing and curing of concrete.

B. Mix Proportion

The ratio of recycled to total aggregate (by weight) is termed as the RCA percentage replacement (%R). The mix proportion of the concrete are given in Table:7

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Table 7 Mix proportion

S. No.	R%	Cement (kg/m^3)	FA (kg/m^3)	NCA (kg/m^3)	RCA (kg/m^3)	Water (kg/m^3)	Remark
1.	0	450	624	1085	0	180	%R=0
2.	10	450	624	975.5	108.5	180	%R=10
3.	20	450	624	868	217	180	%R=20
4.	30	450	624	759.5	325.5	180	%R=30
5.	40	450	624	651	434	180	%R=40
6.	50	450	624	542.5	542.4	180	%R=50
7.	60	450	624	434	691	180	%=60
8.	70	450	624	335.5	759.5	180	%R=70
9.	80	450	624	217	868	180	%R=80
10.	90	450	624	108.5	975.5	180	%R=90
11.	100	450	624	0	1085	180	%R=100

C. Casting of Specimens

The mix types chosen was 1:1.38:2.41, w/c=0.4. The concrete mix was prepared using 10mm & 20mm coarse aggregate obtained from demolished concrete from an old building material in Ambala city. Mix with equal amount of natural coarse aggregate i.e. equal weights of both ((NCA=100%) + (RCA=0 to ((NCA=0%) + (RCA=100%)) were prepared and used to cast the specimens.

In all the above mixes workability was measured by slump test, compaction factor test and flow table test. The test specimens were 150mm x 150mm cubes for compressive strength. The specimens were cast according to IS: 516-1959. The specimens were tested at the age of 7 and 28 days. The aggregates used were in saturated, surface-dry condition. The test procedures were followed as per relevant Indian standard specifications. The batching was done by weight.

Table 8 Size of Moulds

S. No.	Moulds	Size (mm^3)	Specimen Casted
1.	Slump	100x200x300	Workability
2.	Cube	150x150x150	Compressive Strength

D. Preparation of Concrete from Demolished Concrete Aggregate

Research on the usage of waste construction materials is very important because material waste is gradually increasing with the increase in population and increase in urban development. Recycled aggregate is easy to obtain and costs cheaper than natural aggregate. Natural aggregate needs to be mined but recycled aggregate can be easily obtained.

E. Source of Demolished Concrete Aggregate

In the present investigation, old concrete pieces of building beams from Ambala city were used for preparation of demolished aggregate.

F. Preparation of Aggregate from Demolished Concrete

The Recycled or Demolished concrete obtained from demolition of the buildings is bound to have variety of foreign matter like finishes, cladding materials, dirt, steel, hardware, wood, plastics etc. which are attached directly or indirectly to the concrete. These are impurities and hence need to be removed to obtain the final foreign material free aggregate. In the present investigation, the recycled aggregates were produced by crushing old building material, from Ambala city, in a jaw crusher with the opening set at 20 mm in the closed position. The crushed products were then sieved and recombined to obtain the required grading.

G. Processing of Demolished Concrete Aggregate

Old concrete pieces of RCC were crushed first using 200 tones capacity compression testing machine and later 5 kg hammer was used for further breaking it into smaller pieces. These smaller pieces were fed in a jaw crusher with the opening set at 20mm in the closed position. The crushed products were then sieved and recombined to obtain desired grading conforming to IS 383-1970. In the present investigation, coarse aggregate obtained from demolished concrete had the grading as per IS: 383-1970.

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H. Mixing and Compaction

The component materials were weighted on the weighting machine. The mixing was done manually. Cement, fine aggregate and coarse aggregate were thoroughly mixed in dry condition to get the homogeneous mix. Water was then added slowly to get a uniform mix. The mixing time was in the range of 4-5 minutes for all the mixes. Cast iron moulds were used for casting specimens. The specimens were cast according to IS: 516-1959. The compaction was done by vibrating the moulds for about 2 minutes using the table vibrator. Excess material was struck off using a rod. Top surface was given smooth finish using suitable floats and trowel. The concrete specimens were removed from the moulds after 24 hours. Specimens were kept in clean and fresh water for curing in water tanks and cured till testing. The cubes were tested at the age of 7 and 28 days.

I. Curing

The test specimen should be stored in a place at a temperature of 27° +/- 2°C for 24 +/- 0.5 hrs. from the time addition of water to the dry ingredients. After this period the specimen should be marked and removed from the woulds and immediately submerged in clean fresh water or saturated lime solution and kept there until taken out just prior to the test. The water or solution in witch the specimen s are kept should be renewed every seven days and should be maintained at a temperature of 27° +/- 2°c.

J. Properties of Concrete (Workability)

A number of different methods are available for measuring the workability of fresh concrete, but none of them is wholly satisfactory. Each test measures only a particular aspect of it and there is really no method which measures the workability of concrete in its totality. However, by checking and controlling the uniformity of the workability it is easier to ensure a uniform quality of concrete and hence uniform strength for a particular job. In the present work, following tests were performed to find workability.

1) The Slump Test
2) The Compaction Factor Test

The values obtained from above tests have been given:

Table 9 Properties of Concrete

S. No.	Mix	W/C	%R	Slump Value (mm)	Compaction Factor Value
1.	1:1.38:2.41	0.4	0	26	0.85
2.	1:1.38:2.41	0.4	10	25	0.82
3.	1:1.38:2.41	0.4	20	23	0.79
4.	1:1.38:2.41	0.4	30	21.5	0.76
5.	1:1.38:2.41	0.4	40	19.5	0.73
6.	1:1.38:2.41	0.4	50	19	0.72
7.	1:1.38:2.41	0.4	60	18	0.71
8.	1:1.38:2.41	0.4	70	16	0.70
9.	1:1.38:2.41	0.4	80	14	0.69
10.	1:1.38:2.41	0.4	90	12	0.68
11.	1:1.38:2.41	0.4	100	11	0.67

K. Testing Procedure

After the specified period of curing the specimens were taken out of the curing tank and their surfaces were wiped off. The various tests were performed as described below: Compressive Strength of Cubes at 7 & 28 days.

Compressive Strength The specimens were tested at the age of 7 and 28 days. The cubes were tested on universal testing machine after drying at room temperature according to IS 516-1959. The load was applied continuously without impacts and uniformly @140N/$cm^{2/}$minute. Load was continued until the specimen failed and maximum load carried by the specimen was recorded. The cube compressive strength was obtained by considering the average of three specimens at each age.

In the above experimental program, the various properties of recycled aggregate concrete and natural aggregate concrete such as workability (slump and
compaction factor), compressive strength are determined for the period of 7and 28 days, and results were obtained. The average values of all the test specimens were taken.

X. CONCLUSION

Research on the usage of waste construction materials is very important because material waste is gradually increasing with the increase in population and increase in urban development. Recycled aggregate is easy to obtain and costs cheaper than natural aggregate. Natural aggregate needs to be mined but recycled aggregate can be easily obtained. The aim of present work is to determine the comparison of compressive strength of natural coarse aggregate and compressive strength of recycled coarse aggregate with different percentages in mix design. The study shows that recycled concrete aggregate increased strength when its mix in 50% proportion with natural aggregates. This is classified as medium strength concrete and they can be applied in the infrastructures, which need compressive strength up to 40MPa. Recycled aggregate is cheaper in comparison to natural aggregate. So, the work on rigid pavements can be carried with lesser material costs. It was observed in this study that increment and reduction in RCA with natural coarse aggregate gave different compressive strengths and 50% gave maximum strength. Whenever recycled aggregate is applied, water content in the concrete mix has to be monitored carefully as the water absorption capacity of recycled aggregate varies.

Following conclusions have been drawn based on the observations and discussion of test results:

A. Compressive strength of Natural aggregate is more than Recycled concrete aggregates. The compressive strength decrease 20.27% for 7 days curing and 15.75% for 28 days.

B. Compressive strength of recycled concrete aggregate is more than natural aggregate when 50% natural aggregate added with 50% RCA w.r.t. strength of natural aggregate. The compressive strength increases 2.89 % for 7 days curing and 3.90% for 28 days curing samples days curing samples.

C. Compressive strength of recycled concrete aggregate is more than natural aggregate when 50% natural aggregate added with 50% RCA w.r.t. compressive strength of recycled aggregate. the compressive strength increases 29.6% for 7 days curing and 23.33% for 28 days curing samples.

XI.SCOPE FOR FURTHER STUDY

The strength characteristics of recycled aggregate concrete can be further studied by taking into account the following parameters:

A. Using rusted (deformed or mild steel) bars in place of non rusted steel bars.

B. With different type and grading of sand.

C. The mix proportion and water cement ratio.

By using the fine aggregate also as a recycled concrete aggregate.