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Performance of Recycled Coarse Aggregate in Concrete Mix

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Abstract

Extensive amount of concrete materials is used in building industries. The scarcity of natural coarse aggregate along with enhances demand, the recycling coarse aggregate has become a necessary and demand oriented work. The aim of this project work is to evaluate the performance of the recycled coarse aggregate by performing a comparative study of compressive and bond strength of both fresh and recycled concrete. Results indicate that compressive and bond strength of concrete prepared by using recycled coarse aggregate is 87.49% and 77.58% respectively of the average compressive and bond strength of concrete prepared by using fresh coarse aggregate. Therefore, concrete with recycled coarse aggregate may be suitably used for the construction work, such as light grade concrete, ordinary concrete, sub-base of foundation, bridge abutments etc.

Keywords: *Recycling Materials, Construction Materials and Aggregates as construction Materials, Compressive Stress of Concrete, Bond Stress of Concrete.*

1. Introduction

Concrete is an important versatile construction material used in wide variety of situations [1]. It is like an artificial stone manufactured from a mixture of binding material with water. Coarse aggregate and fine aggregate are used as inert materials. Concrete is being widely used in construction works. The need for inert materials is also increasing. Due to the growing demand of coarse aggregate as inert material now, it becomes important to recycle the used coarse aggregate. In the growing wake of scarcity of natural aggregate and geometric rise in its price structure the need to recycle coarse aggregate from demolished waste obtained from non-functional and obsolete buildings, debris obtained from earth quake or natural calamity such as flood and cyclone has become necessary and demand oriented work. The concrete yard of pre-fabricated units also contributes concrete waste. Since concrete accounts for about 75% by weight of all construction materials used in building industries, the demolished concrete is expected to constitute [3].

2. Objectives of the study:

i. To compare the compressive strength of concrete between concrete prepared from fresh coarse aggregate and concrete prepared from recycled coarse aggregates.
ii. To ascertain the extent of the use of recycled coarse aggregate in concrete from the above comparison study.

3. Research methodology

3.1 Recycled aggregate

Among the engineering materials the aggregate (sand & khoa) play an important role for construction purposes. When a construction work is completed with passage of long time it may collapse or damage by their ages or any hook or by crook. When building collapse or damage then many coarse & fine aggregate are rejected [2]. But by various ways, the aggregate may be recycled the important road material (C.A & F.A.) used in their construction can be recycled after use to produce materials to height quality possible in order to have a minimum effect on the supply of natural resources.

3.2 Importance of recycled coarse aggregate

Construction &demolition is two twin sisters. The building and urban areas where we live have had to change in harmony with the needs of the age in these circumstances it is natural to consider demolition work as being as important as construction work in the sound development of urban areas. In congested in particular the quality of the demolition technique becomes as essential element which determines the success of city. In addition to efficiency in demolition, strategies must be adopted to avoid noise, vibration and dust which affect the surrounding environment and there must be efficient disposal of the waste product. The effective reuse of these waste products can be of great importance socially as well as economically.

3.3 Beneficiary of recycling: The benefits of recycle aggregate are as follows;

i. Save money for local governments and other purchasers.
ii. Create additional business opportunities.
iii. Conserve diminishing aggregate resources.
iv. Save energy when recycling is done on site.
v. Help local government meet their goal of reducing disposal by 50 percent.

3.4 Need utility of recycled coarse aggregate

i. The distinct utility of the use of concrete with recycled coarse aggregate are as follows;
ii. Reduced external transport of waste to relatively side i.e. Reduction of traffic density.
iii. Reduce transportation cost of natural coarse aggregate at the demolished sites.
iv. This lessens the environment pollution considerably.
v. With lower replacement of N.C.A by R.C.A replacement no substantial decrease in compressive strength.
vi. R.C.A can be used in pre-fabricated units such as concrete blocks, PVC fabricated roofing materials.

4. Specification of materials to be used for test specimen

The whole project was performed with Portland cement, sand, fine aggregate and coarse aggregate. The Specific gravity of cement is 3.15 and compressive strength of cement is 3500 psi [4]. Local sand was used. The finnes modulus and unit weight of sand was determined as 2.42 and 2.78 respectively. The fresh coarse aggregate was used and its finnes modulus is 5.57 and unit weight 80 pcf. The recycled coarse aggregate was used and its finnes modulus is 5.96 and unit weight 82pcf.

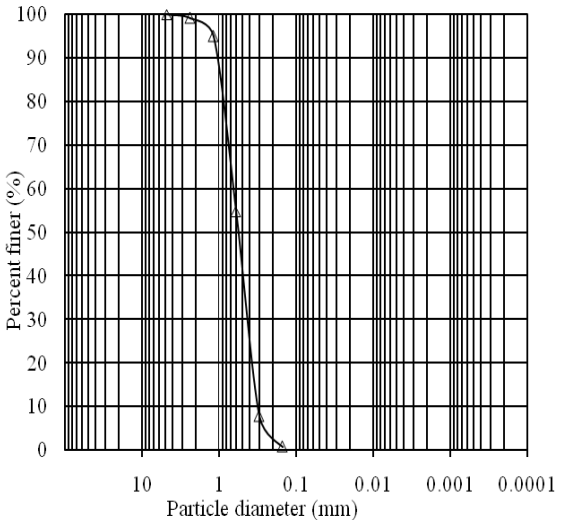

Figure 1: Particle Size Distribution Curve for Sand

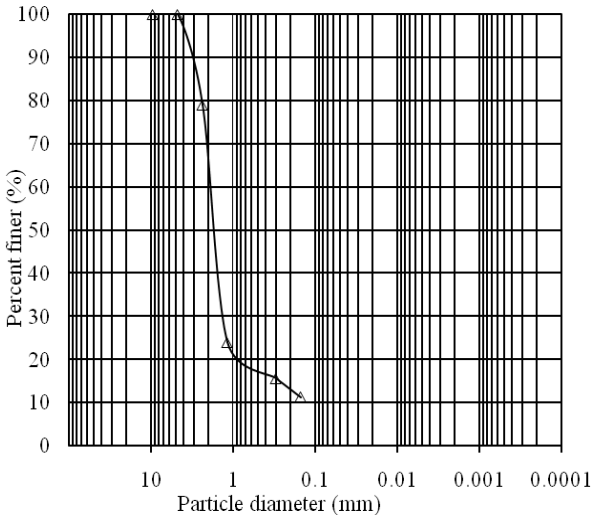

Figure 2: Particle Size Distribution Curve for Fresh C.A

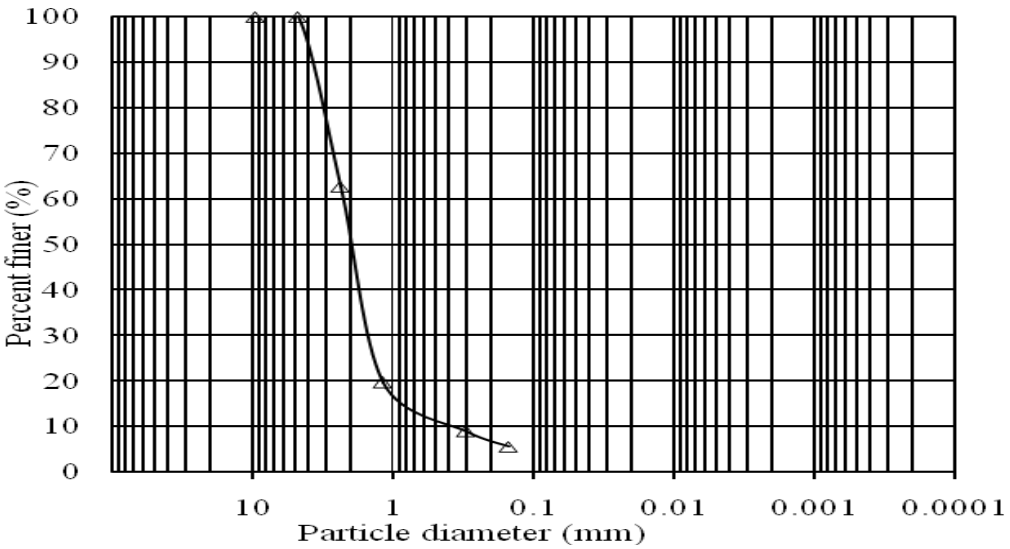

Figure 3: Particle Size Distribution Curve for Recycled C.A

4.1 Mix design

It will be worthwhile to recall that at this stage the relationship between aggregate and paste, which the two essential ingredient of concrete. Workability of the mass is provided by the lubricating effect of the paste and is influenced by the amount of dilution of paste [5]. The strength of concrete is limited by the strength of paste, since mineral aggregate with rate exception are for stronger than the paste compound. Essentially the permeability of concrete is governed by the quality and continuity of the paste, since little water flows through aggregate either under pressure or by capillary. Further the predominant contribution to drying, shrinkage of concrete is that of paste. Since the properties of concrete are governed to a considerable extent by the paste, it is helpful to consider more closely the structure of the paste. The fresh paste is a suspension, not a solution of cement in water. The more dilute the paste, the greater the spacing between cement particles and thus the weaker will be the ultimate paste structure. Since the quality of water required also depends upon almost of paste, it is important that as a little paste as possible should be used and hence the importance of grading.

4.1.1 Various methods of proportioning:

i. Arbitrary proportion, ii. Maximum density method, iii. Fineness modulus method, iv. Surface area method**,** v. A.C.I curve method and, vi. Grading curve method

4.1.1.1 Design of concrete mixes by ACI method

This method of proportioning was recommended by A.C.I. committee 212 [6], having gone into the details about the various methods of mix designing procedures. The A.C.I. committee mix methods assume certain basic facts, which have seen substantiated by field experiments on large work. They are;

a) The method makes use of the established fats, that our a considerable range of practical proportions by fresh concrete of given slump are containing a reasonably well graded aggregate for given maximum size will have practically a constant total water content regardless of variations in water cement ratio and cement content which are necessarily interrelated.

b) It makes use of relation that the optimum day rotted volume of coarse aggregate per unit volume of concrete depends on its maximum size and fineness modulus of the fine aggregate regardless of shape of pastilles.

c) Irrespective of the compaction even after complete compactions done, a define percentage of air remain which is inversely proportional to the maximum size of the aggregate.

4.1.1.2 Required data

For mix design the data to be required are as follows;

i. Fineness modally of selected fine aggregate.

ii. Unit weight of dry coarse aggregate.
iii. Specific gravity of coarse and fine aggregate.
iv. Absorption characterizes of both coarse and fine aggregate.
v. Specific gravity of cement.

4.1.1.3 Design of concrete mixes for the project work by ACI method (FCA)

Specification:

Desired strength = 20.71N/mm^2. Max. Size of coarse aggregate =19.05 mm.
Slump desired =50.8 mm. Sp. Gravity of coarse aggregate = 1.89
Fineness modulus of fine aggregate =2.42 Sp. Gravity of fine aggregate = 2.78
Sp. Gravity of cement = 3.15 Bulk density of coarse aggregate = 79.8 pcf.

Solution:

Water requirement =300 lb per cubic yard of concrete
Water cement ratio = 0.55
So, Quantity of cement = 545.5 lb
Bulk volume of coarse aggregate = 0.665 per unit vol. of concrete
Hence the wt. of coarse aggregate per cubic yard of concrete = 0.665×79.8×27 = 1432.81 lb
The total absolute vol. of mix ingredient per cubic yard of concrete-
Cement = 545.5/(3.15×62.4) = 2.78 cft
Water = 300/62.4 = 4.81 cft
Coarse aggregate = 1432.81/(1.89×62.4) = 12.15 cft
Air entrapped = 27/100 = 0.27 cft
Total vol. = 2.78+4.81+12.15+0.27 = 20.01 cft
So the vol. of fine aggregate = 27-20.01 = 6.99 cft
Wt. of fine aggregate = 6.99×2.78×62.4 = 1212.57 lb
So, the wt. of material per cubic yard of concrete = 3490.88 lb
Hence the density of concrete = 3490.88/27 = 129.29 lb/cft
And the ratio of Cement: Sand: Khoa = 1:2.22:2:3

4.1.1.4 Design of concrete mixes for the project work by ACI method (RCA)

Desired strength = 20.71N/mm^2. Slump desired = 50.8 mm.
Max. Size of coarse aggregate = 19.05 mm. Sp. Gravity of coarse aggregate = 1.92
Fineness modulus of fine aggregate = 2.42. Sp. Gravity of fine aggregate = 2.78
Sp. Gravity of cement = 3.15. Bulk density of coarse aggregate = 81.6 pcf.

Solution:

Water requirement = 300 lb per cubic yard of concrete
Water cement ratio = 0.55
So, Quantity of cement = 545.5 lb
Bulk volume of coarse aggregate = 0.665 per unit vol. of concrete
Hence the wt. of coarse aggregate per cubic yard of concrete = 0.665×81.6×27 = 1465.13 lb
The total absolute vol. of mix ingredient per cubic yard of concrete-
Cement = 545.5/ (3.15×62.4) = 2.78 cft
Water = 300/62.4 = 4.81 cft
Coarse aggregate = 1432.81/(1.92×62.4) = 12.23 cft
Air entrapped = 27/100 = 0.27 cft
Total vol. = 2.78+4.81+12.23+0.27 = 20.09 cft
So the vol. of fine aggregate = 27-20.09 = 6.91 cft
Wt. of fine aggregate = 6.91×2.78×62.4 = 1198.69 lb
So, the wt. of material per cubic yard of concrete = 3509.32 lb
Hence the density of concrete = 3505.32/27 = 129.97 lb/cft
And the ratio of Cement: Sand: Khoa = 1:2.19:2:69

4.1.1.5 Preparation of specimens

i. At first sand and khoa were screened by the sieve according to their requirements.
ii. Concrete constructions (sand, cement, khoa) were measured to dry separately by weight according to required proportions.
iii. The khoa were soaked thoroughly 24 hours and then made them surface dry saturated before use.
iv. Sand and cement were mix to dry on a clean platform until the mix was uniform.

v. The coarse aggregate then added to mix of cement and sand admixture and the whole were mixed thoroughly.

vi. The moulds were oiled by lubricating oil, before placing concrete in the mould.

vii. The concrete was compacted by vibrator till the water appeared on top and no khoa was then left uncover by mortar.

viii. The cast specimens were then left for 24 hour of moist curing.

4.1.1.6 Casting and curing of specimens

The specimens were stripped from moulds after 24 hours of casting as shown in Figure 4(a) for compressive strength test and Figure 4(b) for bond strength test. All the specimens were carefully cured by immersing in clean water on the water bath of the laboratory. Most concrete gains strength most rapidly during the first days and weeks. Structural design is generally based on the 28 days strength and 70% of which is reached at the end of first week after casting. The test specimens were cured 28 days.

(a)

(b)

Figure 4: Cylinder for (a) Compressive Strength& (b) Bond Strength.

5. Results and discussions

The compressive strength of which is obtained from this is given in the table 1 for F.C.A and for R.C.A. The result of bond strength which is recorded during test from the universal testing machine is listed in the table 2 for F.C.A and for the R.C.A. For fresh concrete cylinders, from test result the average compressive strength of those cylinders was obtained 0.0124 Mpa and bond strength is 4.34×10^{-3} Mpa. For recycled concrete cylinders, from the test result the average compressive strength and bond strength of that cylinder was obtained 0.0098 Mpa and 3.37×10^{-3} Mpa respectively, which was about 83.49 % and 77.58% of the average compressive and bond strength of the fresh concrete cylinders. If compressive strength of recycled concrete is compared well with the fresh concrete and the value of compressive strength for recycled concrete is very near the value of compressive strength for fresh concrete, then it can be said that the recycled concrete is performing well. Ten fresh concrete cylinders were casted with medium workability, for compressive and bond strength. From the test result the average compressive strength of the cylinders was obtained 0.0124 Mpa. Again ten recycled concrete cylinders were casted for compressive and bond strength. The compressive strength of the recycled concrete was 0.0098 Mpa, which is about 83.49 % of the compressive strength of the fresh concrete and the average bond strength is $3.37\times10^{-}$ Mpa which is 77.58% of the average bond of the fresh concrete. However, from the above discussion, it can be concluded that the recycled coarse aggregate can be suitably used as coarse aggregate for concrete.

Table 1: Compressive Strength of Concrete When Used Fresh Aggregate (FCA) and Recycled Aggregate (RCA)

Sam-ple No.	Curing Period (day)	Crushing Load (kN) For FCA	Compressive Strength (Mpa) For FCA	Ave. compressive Strength (N/mm^2)	Crushing Load (kN) For RCA	Compressive Strength (Mpa) For RCA	Ave. compressive Strength (Mpa)
1	28	205	0.014	0.0124	160	0.009	0.0098
2	28	230	0.013		195	0.011	
3	28	250	0.014		200	0.011	
4	28	195	0.011		180	0.010	
5	28	180	0.010		150	0.008	

Table 2: Bond Strength of Concrete When Used Fresh Aggregate (FCA) and Recycled Aggregate (RCA)

Sample No.	Curing Period (day)	Crushing Load (kN) For FCA	Bond Strength (Mpa) For FCA	Ave. Bond Strength (N/mm^2)	Crushing Load (kN) For RCA	Bond Strength (Mpa) For RCA	Ave. Bond Strength (Mpa)
1	28	30	3.94×10^{-3}	4.34×10^{-3}	22	2.89×10^{-3}	3.37×10^{-3}
2	28	36	4.74×10^{-3}		36	4.74×10^{-3}	
3	28	27	3.55×10^{-3}		20	2.63×10^{-3}	
4	28	32	4.21×10^{-3}		27	3.55×10^{-3}	
5	28	40	5.26×10^{-3}		23	3.03×10^{-3}	

6. Conclusions

The following conclusion can be drawn from the investigation;

i. The compressive strength of concrete prepared by using fresh coarse aggregate is 0.0124 Mpa and that for recycled coarse aggregate is 3.37×10^{-3} Mpa.

ii. The compressive strength of concrete prepared by using recycled coarse aggregate is 83.49% of the average bond strength of concrete prepared by using fresh coarse aggregate.

iii. The recycled coarse aggregate can be successfully used in concrete as a replacement of fresh C.A in the construction work like bridge abutment, light grade concrete, ordinary concrete sub-base of foundation etc.

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