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Appraisal of Processing Techniques for Recycled Aggregates in Concrete

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Abstract: ***Due to depletion of natural aggregates the need for the usage of recycled aggregate in concrete has gained significance. In this regard, the present study is an attempt to evaluate the performance of M20 grade of concrete made with 100% recycled aggregate processed using various techniques. Handpicked aggregate from concrete rubble is used to prepare recycled aggregate concrete. The use of chemical admixture is mandatory to compensate the extra water (3 to 6%) required by the RCA (Recycled Aggregates). RCA treated with calcite mineral precipitating bacterial suspension enhances its surface permeability. RCA exposed to different acid concentrations improved the surface of the aggregate with the removal of the loosely adhered mortar. In thermal – mechanical method the recycled aggregates from rubble are heated in microwave to 300°C to remove adhered mortar from the aggregate and placed in a rotating drum containing iron balls. In chemical–mechanical method the recycled aggregate is exposed to Na_2So_4 and is subjected to freeze-thaw cycles to create mechanical to separate adhered mortar from RCA. In acid soaking beneficiation method the mortar around RCA is removed by immersing them in 5% HCl and H_2SO_4 for 24 hours. All the above mentioned recycled aggregate processing techniques are however to be tested in full scale to study the efficiency of these treatment techniques. Compressive strength and water absorption capacities of various concrete samples made with recycled aggregate prepared using above discussed processing techniques are evaluated.***

Index Terms- Recycled aggregate concrete, processing techniques, recycled aggregate, CWD.

I. INTRODUCTION

Construction and demolition (C&D) rubble management is a matter of great concern in construction industry due to dumping problem, its availability in huge quantities and the transportation cost involved for disposal. Central Pollution Control Board of India (CPCB) reports nearly 60 million tons of solid waste produced every year of which 40 % is from construction rubble. At present the construction debris is used as landfill or infill material but still it remains environmental hazard so a proper solid waste management is required for appropriate disposal. It is suggested that a combined and universal approach of design and construction strategy is required to reduce this construction and demolition waste production. Recycling is one such option to address this concern of disposal of C&D waste.

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Using demolished waste in concrete after proper processing has been an innovative way of developing concrete using recycled aggregate than natural aggregates. Developing the high strength recycled aggregate concrete is always a challenge due to disparities in the quality of recycled aggregate collected from various sources. Past studies suggested that recycled aggregate usage is concrete is limited to 20-30% based on the grade of concrete. But research on recycled aggregate concrete has demonstrated that 50% pre- processed recycled aggregate replacing natural aggregate has improved the performance of the concrete. Many researchers proposed various processing techniques such as soaking RCA in acids and cleaning with water, heating RCA to certain temperature so that temperature stresses are developed which loosens the adhered mortar on the aggregate, and some researchers suggested even ultra-sonic cleaning and PVC coating methods for RCA. In the present work authors demonstrated various pre-processing techniques for recycled aggregates in concrete. But these techniques are yet to be tested for full-scale experimentation of Recycled aggregate concrete.

II. AIMS

The main aim of the present project study is to realise the compressive strength and water absorption properties of 100% recycled aggregate concrete of M20 grade. To achieve the above mentioned objectives, the experimental investigations are planned as shown below–

(1) Determine the mix proportions for M20 grade 100% recycled aggregate concrete (RAC)
(2) Evaluation of workability in terms of slump for M20 100% recycled aggregate concrete (RAC)
(3) Assessment of compressive strength and water absorption capacities of natural and 100% recycled aggregate M20 grade concrete at 28 days age of curing.

III. MATERIALS

A. Cement

Ordinary Portland cement (OPC)

B. Fine Aggregate

Manufactures sand conforming to IS: 383.

C. Coarse Aggregate

Crushed stone coarse aggregate of angular in shape.

D. Recycled aggregates

Recycled aggregates are extracted from demolished and construction waste. The C&D waste collected from locally available, poured water on C&D to remove silt and clay then removed other foreign materials such as broken brick bats, reinforcement, mortar etc. About 100mm size concrete samples separated and fed in the feeding unit of the laboratory jaw crusher of capacity 250 kg/hr. Fig 1 shows the jaw crusher.

The jaw of the crusher is adjusted to obtain aggregates of desired size.

The material passing through the feeder unit of the laboratory jaw crusher is broken to appropriate sizes of 20 mm (Fig 2 (b)). The crushed aggregates received from the feeder unit are then sieved through a series of IS sieves as per IS: 2386 (Part I)-1997 to segregate them in various sizes by discarding the material smaller than 20 mm size. The material in size larger is subjected to re-crushing so as to obtain the aggregates of appropriate size. The sieving process also help for the removal of adhered mortar traces loosened during the crushing process. It was observed that the jaw crushers provide the best grain-size distribution of recycled aggregate to be used in making concrete.

E. Super Plasticizer

Conplast SP 430, a Sulphonated Naphthalene based Formaldehyde (SNF) super plasticizer manufactured by Fosroc is used. Dosage range of 0.5 to 1.5% by weight of cement is normally recommended.

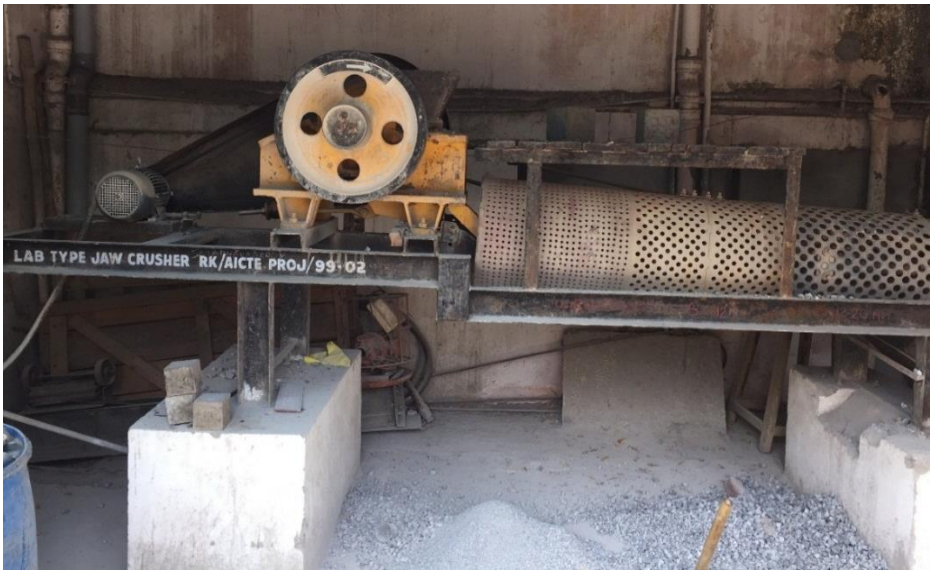

Fig 1: Jaw Crusher

Fig 2: a) Construction Demolition Waste b) Recycled Aggregate after crushing

IV. RECYCLED AGGREGATE PROCESSING TECHNIQUES

The table 1 below gives various recycled aggregate processing techniques used in the present study to treat construction demolition waste.

V. CONCRETE MIX DESIGN

The grade of the concrete used in the present investigation is M20 made with 100% recycled aggregate (RCA). The quantity of materials per one cubic meter of concrete are designed using IS: 10262-2009 (Table -2).

Table 1 – Various recycled aggregate processing techniques adopted in the present study

Type of specimen	Designation	Recycled aggregate processing technique	Description
M20 grade (Natural coarse aggregate)	Method 1	-	Naturally available crushed angular coarse aggregate
M20 grade (100% Recycled coarse aggregate)	Method 2	Hand-picked	Hand-picked coarse aggregate from concrete rubble
	Method 3	Microbial carbonate precipitation (MCP)	Hand-picked coarse aggregate from concrete rubble are pre-soaked in S. pasteurii bacterial suspension of 10^5 cells/ ml concentration
	Method 4	Acid soaking beneficiation method	Hand-picked coarse aggregate from concrete rubble are pre-soaked in 0.1 M HCl for 24 hours
	Method 5	Acid soaking beneficiation method	Hand-picked coarse aggregate from Construction and demolition waste are pre-soaked in 0.1 M H_2SO_4 for 24 hours
	Method 6	Thermal – mechanical method	Hand-picked coarse aggregate from concrete rubble are heated to 300°C in microwave which loosens the adhered mortar by placing the heated aggregate in the los angles abrasion testing machine
	Method 7	Chemical–mechanical method	Hand-picked coarse aggregate from concrete rubble are exposed to 1% sodium sulfate solution and subjected to repeated freeze-and-thaw action (7 cycles)
	Method 8	Jaw crusher	Construction and Demolition waste is crushed in Jaw crusher into recycled coarse aggregate

Table 2 – Dry Quantities of concrete ingredients per one m^3

Grade	Cement kg	Fine aggregate kg	Coarse aggregate kg		Water L	W/C ratio
			20 mm	10mm		
M20	333	739.11	464.34	703.28	160.02	0.50

VI. WORKABILITY

Slump test on recycled aggregate concrete is carried out in fresh state to evaluate the workability of the concrete made with treated concrete rubble.

VII. COMPRESSIVE STRENGTH

This investigation is carried out to study the compressive strength of M20 grade concrete mix made with 100% recycled coarse aggregate (RCA) at 28 days. For this concrete cubes of 150mm are cast and tested to study the compressive strength of M20 grade rubble concrete and conventional concrete at 28 days as per IS: 516-1999.

VIII. WATER ABSORPTION CAPACITY STUDIES

This study is to evaluate the total water absorption capacity of M20 grade rubble concrete (RCA) and conventional concrete as per ASTM C642-13.

IX. TEST RESULTS AND DISCUSSIONS

A. Workability

In this study, workability of concrete is assessed using slump cone test.

Slump values for M20 grade concrete made with treated and recycled concrete rubble and natural crushed aggregate are presented in table 3.

To enhance workability, mineral admixtures such as GGBS can be added in suitable quantity so that the desired strength and workability can be achieved.

For concrete made with rubble, workability in terms of slump values decreases due to the highly porous mortar attached on the surface of the concrete rubble. So some quantity of mixing water, calculated during mix design trials intended for desired workability and strength, may get absorbed by the recycled aggregate reducing the workability of the concrete mix and prolongs the mixing time. This limitation can be overcome by admixing the recycled aggregate concrete with pozzolans.

A. Compressive Strength and Water absorption Studies

Compressive strengths of M20 grade rubble concrete mixes are tabulated in table 4. For this concrete cubes of 150x150x150 mm are cast and tested as per IS: 516-1999 to study the compressive strength under axial compression on completion of 28 days. Similarly the water absorption capacity of M20 grade rubble concrete mixes as per ASTM C642-13 are presented in table 4.

Table 3 – Slump values of recycled aggregate concrete

Grade of concrete	Type of Concrete	Slump mm
M20	Natural Aggregate	90
	Recycled aggregate	45

Table 4 - Compressive strength and water absorption capacity of M20 grade concrete made with 100% recycled aggregate prepared using various processing techniques

Designation	Recycled aggregate processing technique	Compressive Strength (MPa) @ 28 days Age of Curing	% increase / decrease of Compressive strength	Water absorption capacity %
Method 1	-	27.86	-	5.62
Method 2	Hand-picked	17.86	-35.89	11.79
Method 3	Microbial carbonate precipitation (MCP)	35.91	28.89	2.79
Method 4	Acid soaking beneficiation method	26.13	-6.21	6.43
Method 5	Acid soaking beneficiation method	27.19	-2.40	6.55
Method 6	Thermal – mechanical method	22.17	-20.42	8.56
Method 7	Chemical–mechanical method	24.89	-10.66	7.75
Method 8	Jaw crusher	22.19	-20.35	7.87

The following observations were made-

1. When compared to conventional concrete, in 100% handpicked recycled aggregate concrete strength under compression decreases by about 36%. If the handpicked recycled aggregate is treated with bacterial solution then the compressive strength increases by 29% and water absorbtion is reduced by 11.8%.
2. The decrease in compressive strength in rubble concrete is due to high absorbent mortar adhered to the surface of the rubble aggregate. Interfacial Transition Zone (ITZ) in rubble concrete is weak than in conventional concrete. Strength of ITZ depends on the bond between aggregate and cement paste which is not poor in rubble based concrete.
3. In rubble concrete, bond between recycled aggregate and cement paste surrounding is weak so development of CSH crystals in this zone are structured weakly which leads to failure in compression. This phenomenon reduces the compressive strength of rubble concrete drastically. It is understood that porous nature of rubble makes the concrete permeable. Inclusion of mineral admixtures will address this problem suitably.
4. In concrete made with treated rubble, cement content is increased for strength requirement. This may not be a sustainable justified solution so the use of optimally admixed rubble concrete is encouraged to achieve equivalent compressive strength corresponding to natural aggregate concrete.
5. Of all the recycled aggregate processing techniques, recycled treated with mineral precipitating bacterial solution yields maximum compressive strength and has less water absorption capacity.

X. CONCLUSIONS

On the basis of the key findings during the experimental investigations, the following conclusions are drawn:

1. Recycled aggregates are angular in shape with rough surface texture.
2. In rubble concrete, workability decreases due to loss of water in the form of absorbtion by recycled aggregates.
3. Recycled aggregates absorb more water due to its porous nature. So while mixing concrete appropriate correction to water mixed to concrete is to be made to prevent drying shrinkage and increase the volume of void space. This may affect the workability and may lead to higher creep strains on loading.
4. There is a significant increase in the compressive strength of concrete made with bacteria treated recycled aggregate due to formation of calcite mineral precipitation changing the concrete pore structure within the cement-sand environment.
5. Untreated handpicked recycled aggregate yield very less compressive strength and has more water absorption capacity.

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