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Strength Characteristics Of Concrete With Recycled Aggregates And Artificial Sand

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ABSTRACT

Growing concern of the planet due to heavy consumption of sand and rock in concrete made it a necessity to find way through sustainable construction practices. A possible solution to these problems is to use of C& D waste in concrete. Recycled concrete can produce an alternative aggregate for structural concrete as partial or total replacement. In this paper an attempt is made to utilize recycled concrete aggregates and artificial sand (machine made sand) in concrete, using IS10262:2009 as guideline for designing the concrete with grade M25. Use of machine made sand will allow replacement to conventional sand. The fresh and hardened properties of new concrete are studied and compared with concrete made using conventional materials. A comparison with control mix mainly their compressive strength, split tensile strength & flexural strength, will allow assessing the suitability of using Recycled aggregate in concrete with replacement to sand with conventional or artificial sand.

Keywords – Recycled Concrete Aggregate, Artificial Sand, Convetional Coarse aggregate, Concrete ,control mix

I. INTRODUCTION

Sustainable construction rather than a fancy idea now is a necessity. Concrete industry, which uses 12.6 billion tons of raw materials each year, is the largest user of natural resources in the world.[1]. On the other side when a building is demolished after its use, for repairs or for deterioration it generates large amount of C &D, which conventionally and till today is used for land filling. In recent years, the recyclable potential of construction and demolition(C&D) waste has made it a target of interest and the main focus of waste management policies on encouraging minimization, reuse, recycling, and valorization of the waste as opposed to its final disposal in landfills. [2,3].

Recycled aggregate is generally produced by two stages crushing of demolished concrete, screening and removal of contaminants such as reinforcement, wood, plastic etc. [4]

RILEM Committee 121-DRG has published recommendations for the use of recycled aggregates, classifying them into three groups.

Group I-Aggregates mainly from masonry rubble

Group II- Aggregate obtained mainly from concrete rubble

Group III-A mixture of natural aggregates (>80%) and rubble from the other two groups (with upto 10% of group I).

The quality of the adhered mortar and properties of recycled aggregates depends on the w/c ratio employed in original concrete and the quantity of adhered mortar influences the strength of concrete, size and crushing procedure adopted [6, 7].Excessive paste content due to high AC of recycled aggregates will cause poor workability and large slump loss of concrete. Such poor quality further hinders the strength development of the resulting concrete.[8-10]. The strength characteristics of concrete are not affected by the quality of recycled aggregate at higher water cement ratio; it was only affected when the water cement ratio is low. Recycled aggregates need typically 5% more amount of water for making concrete. [11-16]. An experimental study concluded that compressive strength does not seem to be affected by the fine aggregate replacement ratio at least up to 30%.The same study showed that both tensile splitting and modulus of elasticity is reduced with increase in the replacement ratio.[14]. In Italy, the use of 30% recycled concrete instead of virgin aggregate is definitively allowed for producing concretes (C30/37 class) since July 2009[17]. In a study over treatment on recycled aggregates proposed, Impregnation with a solution of silica fume and Ultrasonic cleaning of recycled aggregate, were done to remove the loose particles and improve the bond between the new cement paste and the recycled aggregate. The results showed that silica fume improves the properties of new concrete made from recycled aggregates in two ways: a) by improving the interface between the R-aggregate and the new cement matrix i) By strengthening the structure of the old paste that is still adhered to the R-Aggregate, which cracked during the crushing process. Ultrasonic cleaning of recycled aggregates yielded a moderate increase of strength [18-20].

II. EXPERIMENTAL PROGRAMME:

An experimental program was undertaken which consisted of testing Recycled aggregates – Coarse and fine and properties with fresh and hardened concrete specimens. The materials used were:

a. Conventional materials- Cement (C), fine aggregates (NFA)- 4.75mm and below, Artificial Sand (AS)-4.75mm and below with approx..14% dust and coarse aggregates,Convetional-(NCA-20mm),Recycled Concrete Aggregates (RA-20mm, RA-10mm) were purchased from the local vendors.

b. Recycled aggregate were derived from demolished parking area (concrete rubble) and cubes casted and tested in the laboratory. The concrete rubble and cube remains were broken initially manually and then sieving was done using IS sieves. The process generated, Fine recycled concrete aggregate, recycled concrete aggregate-10mm and recycled concrete aggregate-20mm.(Fig:1 to Fig:4).

c. Superplasticiser: Fosroc –Conplast SP500 complies with IS: 9103:1999 and BS: 5075 Part 3 .Conplast SP500 conforms to ASTM-C-494 Type 'G'.

Fig:1All in one Aggregate

Fig:2 Recycled Fine Aggregate(RFCA)

Fig:3 Recycled Aggregate -20mm

Fig:4 Recycled Aggregate-10mm

Table 1: Properties of NCA-20mm and RCA-20mm and RA-20mm

Property of Aggregate	NFA	RFCA	AS
Specific Gravity	2.75	2.29	2.89
Fineness Modulus	2.748	4.89	3.05
Moisture Content	2.83 %	3.18 %	2.8%
Loose Bulk Density (Kg/Lit)	1.48	1.35	1.94
Water Absorption	3.18%	8.52%	3.12 %
Material finer than 75µ	2.35%	3.60%	-

III. PROPERTIES OF AGGREGATES

Recycled Concrete Aggregates are characterised with irregular shape and better bond between mortar and aggregate. The structure of RCA mainly depends upon the parent source of concrete rubble. The properties of aggregates are as shown in Table 1 and Table 2. The results indicate that RCFA is much coarser with FM as 3.98 and will not be a suitable material for producing concrete which have more amounts of fine aggregates which have mortar and cement paste as fine aggregates. .The properties of aggregates indicate that RCA-20mm can be considered to be used in concrete however RCA-10mm has limitation, thus a mixed gradation of aggregates is required to be considered for producing workable concrete with economy**.**

The recycled aggregates have less specific gravity and high water absorption as compared to the conventional aggregates. The main reason for this is existence of mortar on the aggregates. Bulk density of the Recycled aggregate sample for RFCA and RCA-20mm is less as compared to NFA and NA-20mm.The lesser value of loose bulk density of recycled aggregate is attributed to the adhered mortar on aggregate which increases the size of the aggregate and will have better interlocking which in turn reduces the voids in rodded condition and the higher porosity than that of natural aggregates. The crushing value of Recycled aggregate is less due to the adhered mortars on the surface of aggregate makes the RCA weaker towards impact resistance and crushing.

Table 2: Properties of NFA, AS and RFCA

Property of Aggregate	NCA-20mm	RCA-20mm	RCA-10mm
Specific Gravity	2.86	2.58	2.59
Elongation Index	34.82%	26.25%	24%
Flakiness Index	14.7%	7.15%	6.9%
Bulk Density	1.41kg/lit	1.4 kg/lit	1.17kg/lit
Water Absorption	1.37 %	4.68 %	4.52 %
Impact Value	16.22 %	16.88%	11.15 %
Crushing Value	21.67%	26.8%	29.8%

IV.PROPORTIONING OF MIX FOR THE DESIGN

M25 Concrete mix was designed with 28-days target strengths as 31.6 Mpa and slump of 75mm using IS 2009:10262. Various mixes which were designed are as follows:

a. Concrete (C, NFA, NCA-20mm):-Mix 1

b. Concrete (C, AS, NCA-20mm):– Mix 2

c. Concrete (C, NFA, RCA-20mm &10mm):-Mix 3
d. Concrete (C, AS, RCA-20mm, RCA-10mm):-Mix 4.
e. Concrete (C, RFCA, and RCA-20 mm and RCA-10mm):-Mix 5

Table 3 shows a summary of the mix proportions for the different proportions of materials for target strength.Use of Superplasticiser reduced the need of excess water however as compared to conventional materials the amount of water required for recycled aggregates is more (about 22 % more).

V. RESULTS AND DISCUSSION

1. Workability

As Table 3 describes the workability for all the mixes are same.owever. The water requirement for all the mixes is different and specially for mix with recycled aggregates coarse. The water once mixed, the dry mix starts absorbing the water by recycled aggregate and thus the slump goes reducing with time. However use of a superplasticer can prove to be effective to reduce the water content and increase the workability.

2. Compressive strength

The important aspect of designing the concrete and it getting accepted is the compressive strength. In the given set of mixes an attempt was made to check the acceptability of recycled aggregate for M25grade concrete. The table 3 shows the values for compressive strength for various mixes. The compressive strength for mix with conventional sand is higher than the mix with artificial sand. However the reason for decrease of strength in mix 2 is the presence of dust in AS.Also for attaining the target strength of 31.6 N/mm2 and use of AS, more amount of cement is required. The results in table 3 shows that 100% replacement of conventional coarse and fine aggregates by Recycled coarse-20mm and Recycled fine aggregates could not meet the Concrete grade requirements. There is an approximate decrease of 6.12 % of compressive strength than the target strength. Concrete with 100% replacement of RCA-20mm and RCA-10mm with AS showed a decrease as compared to Mix 2 but increase of 3.82% to the target strength requirement. Use of AS in concrete to attain the strength also requires more amount of water due to the presence of dust and excessive water absorption of recycled aggregates. In Recycled aggregate two interfaces exists the interface between adhered mortar and the original aggregate, and the new interfacial zone between the new mortar and the recycled aggregate. When a recycled aggregate is not adhered by in the old mortar the transition zone is similar to original transitional zone. However in the recycled aggregates with adhered mortar makes the transitional zone weak. [19].Super plasticser plays a major role ,where it makes it denser, close textured concrete which reduces porosity. This is a factor which contributes towards increase of compressive strength. Meanwhile, the more angular shape of RA and its rougher surface texture are what contribute to a better interfacial bond and thus higher compressive strength in recycled aggregate concrete (Ridzual et. al., 2001). The fig 5 shows the tested specimen of concrete –Mix 4. A good bond can be seen in the crushed specimen as we can see an aggregate broken through and which are not in excess too.[20].Use of 10mm and 20mm aggregate sizes also contribute towards strength of concrete with good grading curves, which provides appropriate surface area for formation of gel bonds.

Fig4: Tested Specimen

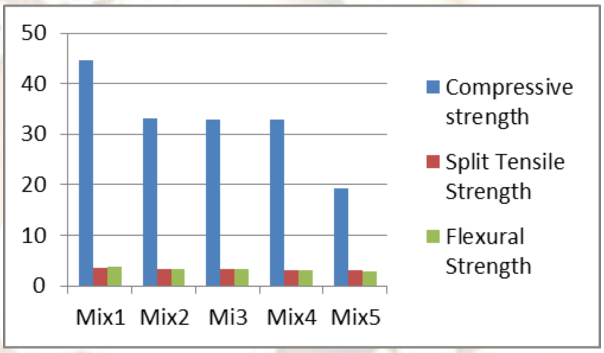

Fig:4 Strength details of Control Mixes

3.Split Tensile strength and flexural strength

The split tensile strength of concrete with conventional aggregates and use of conventional coarse aggregates with AS is similar. A clear reduction in the split tensile strength of concrete with recycled aggregates is seen. A reduction in split tensile strength of 0.29% is seen in Mix 2 as compared to Mix1.Mix 3 shows a reduction of 6.43% in split tensile strength as compared to the mix 1. and 9.64% ,as compared to mix 4.By visual inspection, it was observed that the failure happened through the recycled aggregates (the recycled aggregates being the weakest point) producing two similar symmetric faces. It typically did not happen in the interfacial transition Zone. RAC represents the weakest component and the strength controlling link of the composite system. (19)

Flexural strength of concrete as per BIS, IS 456:2000(20) the flexural strength is given by

$F_{cr} = 0.7\sqrt{Fck}$ ………………1

F_{ck} – Characteristic Compressive strength.

For M25 grade concrete the flexural strength as per eq 1 is 3.5N/mm^2.In the above mixes Mix 1 i.e conventional materials satisfies the requirement with 3.76N/mm2. However Mix 2 to Mix 5 does not satisfy the requirement and thus care must be taken during designing the flexural members. Concrete with total recycled aggregates shows less flexural strength and so does the concrete with AS and recycled aggregates where a difference of 17.97% is noted with control mix. A difference of 11.80% is reported In flexural strength of Mix 2 and Mix1,and thus the fact that use of AS in concrete itself shows a reduction in flexural strength is important from designing perspective.

4. Density of Concrete

Density of concrete is another important factor. The results above indicate that all the concrete mixes with recycled aggregate have less density as compared to Concrete with conventional materials. A reduction in density is also seen with concrete with AS and RCA as compared to concrete with conventional aggregates. However the reduction in density for concrete with conventional aggregates and concrete with NCA and recycled aggregate is 2.86% and concrete with AS and recycled aggregate is 6.89%. This indicates lesser density due to the adhered mortar to the aggregates.

5.Conclusion

1. The experiments done showed large values of water absorption and moisture content for all the Recycled aggregates and more for RCFA. The fact that the mortar adhered which is weak and more porous and thus absorbs more water is the main factor contributing towards decrease of compressive strength of concrete with RCA.
2. The lower value of specific gravity of recycled aggregates is an indication that recycled concrete aggregates are lighter than that of natural aggregates. The main reason for this is existence of loose paste in the demolished wastes.
3. The physical and Mechanical properties of Recycled Concrete aggregates are important factors governing the strength characteristics of the concrete. And the properties of Recycled Concrete Aggregates are governed by the Parent source of recycled aggregates.
4. Target strength of 31.6 N/mm2 can be achieved for M25 grade of concrete by 100% replacement of recycled coarse aggregates.100% replacement of recycled coarse aggregate with river sand exhibited a increase of 3.82% in compressive strength and concrete with RCA-20mm and RCA-10mm and AS showed a increase of 4.20% as compared to target strength. A mix grading of 20mm and 10mm of aggregates can be done for economic perspective and also higher strength. Thus use of river sand and artificial sand with 100% replacement of recycled coarse aggregate can be used for low strength applications. Use of artificial sand in concrete can be a viable option due to the scarcity of river sand.
5. Split tensile test and Flexural strength both are tests for tensile strength of concrete. Concrete made by using recycled aggregates showed slightly lower values of tensile strength as well as flexural strength, hence the loss in tensile strength should be considered while designing members using recycled aggregate concrete.

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Table 3: Strength of concrete with various proportions of materials

ID	Mix proportions (M25)	Slump	28 day Compressive Strength	Split Tensile Strength	Flexural Strength 28 days	Density
Kg/cum		mm	N/mm2	N/mm2	N/mm2	Kg/m3
Mix 1	C – 320 NFA–737.35 NCA-20mm– 741.74 NCA-10mm-494.46 Water – 189 Lit	70	44.58	3.42	3.76	2709.64
Mix 2	C – 325 AS–742.746 NCA-20mm– 1034.274 Water – 183.86 Lit	70	33.05	3.41	3.316	2715.06
Mix 3	C- 320 NCA-791.76 RCA-20mm-629.38 RCA-10mm-419.6 Water-236.36	60	32.81	3.20	3.26	2632.099
Mix 4	C-325 AS-774.53 RCA-20mm – 670.79 RCA-10mm-447.196 Water – 223.82	70	32.93	3.09	3.084	2528.39
Mix 5	C-348.27 RFCA- 655.35 RCA-1029.55 Water-191.58	70	19.38	3.12	2.76	2334.15