HIGH PERFORMANCE SELF-COMPACTING CONCRETE USING RECYCLED COARSE AGGREGATE AND ECO SAND

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ABSTRACT

- In this article, attempt has been made to improve the performance of self compacting concrete (SCC) using recycled coarse aggregate with eco sand. SCC represents one of the most significant advances in concrete technology for decades. SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. SCC has significant environmental advantages in compaction to the vibrated concrete. In large variation in the strength of concrete is due to the variation in the quality of aggregates used. (RAC) use is necessary in order to decrease the environmental impact of the construction industry. In general, there is a scarcity of coarse aggregate throughout the world. Consumption of large amount of coarse aggregate affects the environment. For the purpose of reducing the consumption of coarse aggregate there is a need for an alternative coarse aggregate arises. Recycled aggregates are obtained from the demolition of buildings, culverts and also by-products from the industries. The SCC must meet the filling ability and passing ability with uniform composition throughout the process of transport and placing. Hence concrete with partial or full replacement of coarse aggregate by recycled aggregate, we need to add certain percentage of eco sand as a partial replacement of fine aggregate to satisfy the filling ability and passing ability. Hence, partial or full replacement of coarse aggregate by recycled coarse aggregate and partial replacement of fine aggregates by eco sand is researched in this article, in view of consuming the ecological balance. The fresh and hardened properties of SCC using recycled coarse concrete with eco sand were evaluated. SCC mixtures were prepared with maximum of 100% of recycled coarse aggregates. The cement was kept constant for all concrete mixtures. The SCC mixtures were prepared with 0% up to 100% of recycled coarse aggregate and 30% replacement of fine aggregate by using eco sand. The strength tests namely, Compressive Strength Test, Split Tensile Strength Test and Flexural Strength Test were carried out in this investigation. To test the characteristics of SCC, Slump cone test, J – ring test and L – box test were conducted.

Keywords: Self Compacting Concrete, Recycled Coarse Aggregate, Eco Sand, Fresh Properties, Mechanical Strength

INTRODUCTION

Usage of SCC has become very widely present and varied in recent years. SCC is such that after casting into the formwork does not require vibrating. The filling ability and stability of SCC in the fresh state can be defined by four characteristics: flow ability, viscosity, passing ability and segregation resistance. The concrete mixture will be classified as a self compacting one, if all the mentioned characteristics are present [1-2].

Recycled aggregates are produced from the re-processing of mineral waste materials, with the largest source of construction and demolition waste. The coarse portion of the recycled aggregates has been used as a replacement of the natural aggregates for concrete production. The potential benefits and drawbacks of using recycled aggregates are well understood and extensively documented. The use of SCC has gained a wider acceptance in recent years. The coarse portion of the recycled aggregates is lower than the natural aggregates and the recycled aggregates have a greater water

absorption value compared to the natural aggregates. As a result a proper mix design is required for obtaining the desired qualities for concrete made with recycled aggregates [3-5].

In recycled aggregates, mortar gets attached to it. The physical and mechanical properties of the recycled aggregates relate to the quality and quantity of mortar adhered to the aggregates. The quality of the adhered mortar depends on the water cement ratio employed in original concrete and the quantity of adhered mortar influences the strength of concrete, size and crushing procedure adopted [6]. High percentage of recycled coarse aggregates without adhered cement mortar may be produced from the concrete crushed by impact crusher. The water absorption and density of recycled aggregates are affected by the adhered cement mortar [7]. In addition, the water absorption of recycled aggregates increases with an increase in strength of concrete from which the recycled coarse aggregates are derived [8].

The recycled coarse aggregates have relatively finer particles than the natural coarse aggregates due to the crushing of old concrete. However, the grading limits of recycled coarse aggregates are within the limits specified by IS: 383 [9] for aggregates of normal concrete. Not much significant difference is observed in compressive strength of recycled coarse aggregate and replacement of coarse aggregate, where as considerable difference is observed in case of split tensile strength and modulus of elasticity values at 50% replacement [10].

In practice the recycled aggregates are obtained from different types of demolished structures. The recycled aggregates are directly supplied by an industrial crushing plant from which building demolition are suitably selected grounded, cleaned and sieved. The properties of recycled aggregates obtained from the structures are varying from structure to structure and hence the properties of RAC. As there is no much information available on the properties of recycled aggregates and RAC in India, it is very essential to study the basic properties of recycled coarse aggregates and its use in RAC.

Eco sand are very fine particles ranges between 100 micron to 1mm and it is the by product of cement obtained when the excess silica in the cement is removed by froth floatation process, the residue is dumped as eco sand. It is cheaper than conventional river sand and hence saves the cost. It can be mixed with sand to get better grading of aggregates, increases the efficiency of concrete, increases the SCC properties and reduces pores in concrete and also it provides moisture resistivity and durability of concrete.

The aim of this present work is to check the possibility of preparing SCC by using recycled aggregate instead of natural aggregates and also study the properties of eco sand for replacement of natural river sand. From the above literature it is found that split tensile strength and strength of concrete value is equal to normal concrete when the recycled coarse aggregate is replaced up to 50% and eco sand is replaced up to 30% of natural river sand.

ORIGIN OF THIS WORK

The recycling of the construction and demolition waste has been increasing gradually since there is a necessity to control the depletion of natural resources and to protect the environmental pollution. However, not much information is available for the quality of RAC from the recycled aggregates in India. The selection of eco sand rather than natural river sand gives more workability and improves the property particularly in the SCC, provided that the former is finer than the latter. In order to find out the correct mix proportion of eco sand, there is a need to generate systematic information in this particular area for coding purpose.

EXPERIMENTAL STUDY

MATERIALS

PORTLAND CEMENT

Ordinary Portland Cement (OPC) of 53 grade conforms to the Bureau of India Standard (BIS) specifications with specific gravity 3.14. The compressive strength of cement obtained at 28 days is 53MPa. The chemical composition of cement is reported in Table 1.

Table 1 Chemical Composition of Ordinary Portland Cement

Characteristics	Percentage

$SiO_2+Al_2O_3+Fe_2O_3$	30.90
CaO	62.75
MgO	0.4
SO_3	2.5
Na_2O	1.3
Loss of ignition	2.12

NATURAL COARSE AGGREGATE

The natural coarse aggregate, obtained from the locally available quarries with size in between 10mm and 12mm satisfy the grading requirements of BIS. The specific gravity and fineness modulus of coarse aggregate used were 2.67 and 5.51respectively.

NATURAL FINE AGGREGATE

The natural fine aggregate, obtained from the local river is passed through 4.75 IS sieve. Fine aggregates shall be such that not more than 5 percent shall exceed 5mm in size, not more than 10% shall pass IS sieve No.150, not less than 45% or more than 85% shall pass IS sieve No.1.18mm and not less than 25% or more than 60% shall pass IS sieve No.600 micron. Properties of natural fine and coarse aggregates were arrived and listed in Table 2.

Table 2 Properties of fine and coarse aggregates

Property	Fine aggregate	Coarse aggregate
Specific gravity	2.62	2.67
Fineness modulus	2.80	5.51
Bulk Density (Kg/m^3)	2620	2670

ECO SAND

Limestone, Bauxite ore and iron ore are some of the ingredients in manufacture of cement. All these compounds contain silica and hence the composition of silica in cement may go higher. Hence the excess silica is removed from cement by using some techniques like “Froth Floatation” which is dumped out as Eco Sand. Eco Sand is very fine particles ranges between 100 micron and 1mm. So it can be mixed with sand at an optimum level to get a better grading of aggregates or 100% of replacement of natural sand (zone III to IV). Eco Sand, by-product from cement manufacture and it can be used to increase the efficiency in concrete. Eco Sand ensures a comparatively denser concrete/mortar than those made only with conventional sand with or without quarry fines. Its micro-filling effect reduces pores in concretes and provides better moisture resistivity and thus durability. Eco Sand is substantially cheaper than conventional Sand and hence provides adequate cost saving potential. The non-absorbent nature and smooth surface texture of Eco Sand has been tested safe against limits of deleterious materials and soluble silica for alkali aggregate reactivity. Properties of Eco Sand were arrived and listed in Table 3 and 4.

Table 3 Properties of Eco Sand

Sl.No	**Properties**	**Eco Sand**
1.	Water absorption	1.0%
2.	Fineness Modulus	1.11
3.	Bulk Density	1726 Kg/m^3
4.	Specific Gravity	2.56

Table 4 Chemical Composition of Eco Sand

Characteristics	Percentage
SiO2	74.12%

CaCO3	18.74%
Al2O3	3%
Fe2O3	1%
MgO	0.8%
Mn2O3	0.04%
Na2O	1.3%
K2O3	0.5%
BaO	0.5%
Total	100%

FLY ASH

Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electric precipitator. Fly ash is the most widely used pozzolanic material all over world. ASTM broadly classifies fly ash into two classes, that are, Class F and Class C. In this study Class F fly ash was used.

The fly ash meets the general requirements of ASTM Class F fly ash that has relatively high CaO content of 8.70% and alkali content (Na_2O equivalent) of 0.60% and the specific gravity is 2.1. The chemical and physical properties of fly ash used in this study are given in Table 3 and 4 respectively.

Table 3 CHEMICAL PROPERTIES

Chemical compound	Class F fly ash
SiO_2	54-90%
Al_2O_3	25-80%
Fe_2O_3	6-90%
CaO	8-70%
MgO	1-80%
SO_2	0-60%
Na_2O & K_2O	0-60%

Table 4 PHYSICAL PROPERTIES

Physical Compound	Properties
Colour	Whitish grey
Specific gravity	2.1
Specific surface	2000 to 2200 cm^2/g
Moisture	Nil

CHEMICAL ADMIXTURES

Chemical admixture is a substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. A high range water reducing admixture is also referred as superplasticizer. Each type of superplasticizer has defined ranges for required quantities of concrete mix ingredients, along with corresponding effects. Dosages needed vary by the particular concrete mix and type of super plasticizer used.

A water-reducing admixture, constitute of a Poly Carboxylic Ether (PCE). It is free of chloride and low alkali. In this study Glenium B233 is used as super plasticizer for producing SCC. The property of Glenium B233 used in this study is given in Table 5.

Table 5 PROPERTIES OF GLENIUM B233

Physical and Chemical Compound	Properties
Aspect	Light brown liquid
Relative density	1.09±0.01 at 25 □ C
PH	≥6

Chloride ion content	<0.2 %
Solid content	Not less than 30 % by weight
Optimum dosage	0.5 – 1.5% by weight of cementitious materials

VISCOSITY MODIFYING AGENT

The sequence of addition of superplastizer and Viscosity Modifying Agent (VMA) into concrete mix is very important. If VMA is added before the super plastizer, it swells in water and becomes difficult to flow concrete. To avoid this problem VMA should be added after the super plastizer has come into contact with the cement particles.

In this study Glenium Stream 2 admixture was used and it enhanced viscosity, exhibits superior stability and controlled bleeding characteristics, thus increasing resistance to segregation and facilitating placement. The property of Glenium Stream 2 used in this study is given in Table 6.

Table 6 PROPERTIES OF GLENIUM STREAM 2

Physical and Chemical Compound	Properties
Aspect	colourless free flowing liquid
Chloride content	<0 .2 %
Optimum dosage	0.1%

RECYCLED COARSE AGGREGATE

The recycled coarse aggregates were obtained from the demolished building of 10 years old. It was not exposed to any chemicals. The large pieces of slab [free from impurities] are transported to the laboratory and broken into pieces smaller than 20mm and sieved through 12mm. The pieces greater than 20mm are crushed through a crusher to the maximum of 12mm size and then both the materials are mixed and sieved again. The property of the recycled coarse aggregate is shown in Table 7.

The density and absorption, the most important properties of recycled aggregates are directly related to the quantity of adhered mortar. The procedure adopted for the production of recycled aggregates in the present study may not truly represent the field conditions. But by adopting the combinations of both manual as well as crusher, the quantity of adhered mortar can be minimized upto certain extent. Therefore this process will improve the quality of recycled aggregates.

Table 7 PROPERTIES OF RECYCLED COARSE AGGREGATE

Property	Recycled coarse aggregate
Specific gravity	2.58
Fineness modulus	6.86
Bulk Density (Kg/m^3)	2460

WATER / CEMENT RATIO

Strength of cement primarily depends upon the strength of cement paste. The strength of cement paste depends upon the water/cement ratio. Adjustment of the water/cement ratio and super plasticizer dosage is one of the main key properties in proportioning of SCC mixtures. In this study, different ages of aggregates were tested for determining the exact water absorption value for recycled coarse aggregate. The results are shown in figure (1).

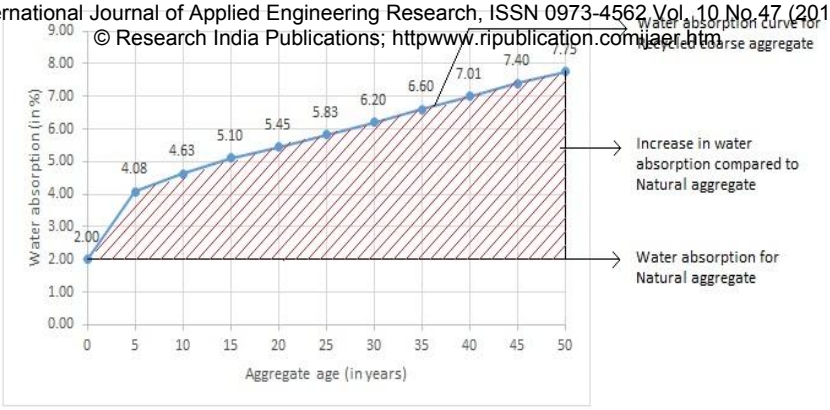

Fig. 1. Water Absorption Curve

The above graph gives the water absorption value which is measured directly based on the age of aggregate. Normally water absorption value for natural aggregate is 2% but recycled coarse aggregate value is greater than natural aggregate which is proved by the excess water absorption values shown in graph for different age of aggregate.

MIX PROPORTION

The term Coarse aggregate Replacement Ratio (CRR) is defined as the ratio of weight of recycled coarse aggregate to the total weight of coarse aggregate used in the mix. In this study, ten concrete mixes namely RCA 0% to 100% were used.

The trial mix details used for M_{30} grade SCC with replacement of coarse aggregate by recycled aggregate is shown in Table 8. Mix proportion used for the specimen preparation is shown in Table 9.

Table 8 TRIAL MIX FOR M_{30} GRADE CONCRETE

S.NO	Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	F.A (kg/m^3)	C.A (kg/m^3)	Water (kg/m^3)	S.P (%)	VMA (%)
1	TR1	380	137	906	796	233	1.4	0.1%
2	TR2	382	136	903	798	234	1.4	0.1%
3	TR3	382	136	905	796	234	1.4	0.1%
4	TR4	384	134	903	798	235	1.4	0.1%
5	TR5	386	132	901	800	236	1.4	0.1%
6	**SCC**	**386**	**132**	**901**	**800**	**236**	**1.4**	0.1%

Table 9 MIX PROPORTION FOR M_{30} GRADE OF CONCRETE

Mix	Cement (kg/m^3)	Fly ash (kg/m^3)	Sand (kg/m^3)		C.A (kg/m^3)		Water (Lit/m^3)	S.P (Lit/m^3)	VMA (Lit/m^3)
			NFA	ECO Sand	NCA	RCA			
SCC	386	132	901	0	800	0	236	7.252	0.518
10% of RCA	386	132	901	0	720	80	236	7.252	0.518
10% of RCA & 10% of FA	386	132	810.9	90.1	720	80	236	7.252	0.518
20% of RCA	386	132	901	0	640	160	236	7.252	0.518
20% of RCA & 20% of FA	386	132	720.8	180.2	640	160	236	7.252	0.518
30% of RCA	386	132	901	0	560	240	236	7.252	0.518
30% of RCA & 30% of FA	386	132	630.7	270.3	560	240	236	7.252	0.518

40% of RCA	386	132	901	0	480	320	236	7.252	0.518
40% of RCA & 40% of FA	386	132	630.7	360.4	480	320	236	7.252	0.518
50% of RCA	386	132	901	0	400	400	236	7.252	0.518
50% of RCA & 50% of FA	386	132	450.5	450.5	400	400	236	7.252	0.518
60% of RCA	386	132	901	0	320	480	236	7.252	0.518
60% of RCA & 60% of FA	386	132	360.4	540.6	320	480	236	7.252	0.518
70% of RCA	386	132	901	0	240	560	236	7.252	0.518
70% of RCA & 70% of FA	386	132	270.3	630.7	240	560	236	7.252	0.518
80% of RCA	386	132	901	0	160	640	236	7.252	0.518
80% of RCA & 80% of FA	386	132	180.2	720.8	160	640	236	7.252	0.518
90% of RCA	386	132	901	0	80	720	236	7.252	0.518
90% of RCA & 90% of FA	386	132	90.1	810.9	80	720	236	7.252	0.518
100% of RCA	386	132	901	0	0	800	236	7.252	0.518
100% of RCA & 100% of FA	386	132	0	901	0	800	236	7.252	0.518

PREPARATION AND CURING OF SPECIMENS

All the concrete mixtures were mixed for 5mins in a laboratory mixer. Before casting, a variety of tests were conducted on the concrete mixtures to determine their properties at it fresh state including the slump flow, flow time, segregation resistance and wet density. For each concrete mixture, 9 numbers of 150mm cubes were cast for the determination of compressive strength, 9 numbers of 150 ϕ x300mm cylinder were cast for the determination of split tensile strength. Furthermore, 3 numbers of 150mm x 150mm x 700mm prisms were cast for measuring the flexural strength. After casting, all the specimens were covered with plastic sheets in the laboratory at 27 □ C until the time of testing.

TESTING METHODS

In this experiment, the following test methods were used to characterize the workability properties of SCC for the final acceptance of the self compacted concrete mix proportions: slump-flow test for flow ability, L-box test and J-ring test for testing passing ability.

The slump flow test was used to evaluate the free deformability and flow ability of the SCC in the absence of any obstruction. A standard slump cone was used for the test and the concrete was poured in the cone without compaction. The slump flow value is represented by the mean diameter (measured in two perpendicular directions) of concrete testing by using the standard slump cone.

The L-box test was performed; this test has been used to access the flow ability of concrete. During the test, SCC was allowed to flow upon the release of a trap door from the vertical section to the horizontal section via few reinforcement bars of an L shape box. The height of the concrete at the end of the horizontal section was compared to the height of concrete remaining in the vertical section.

The properties of concrete for each mix on various sizes of specimen are conducted at different ages of curing according to the procedures given in Indian Standard Code of practices and ASTM. The details of property, age at test, size of specimens along with test methods are presented with the help of fig.2 to fig.6.

ANALYSIS OF TEST RESULTS AND DISCUSSION

For Fresh Concrete

Figure 2, 3 & 4 provides a summary of the properties of the recycled coarse aggregate SCC mixes in the fresh state. As it is evident, the basic requirements of high flowability and segregation resistance, as specified by guidelines on SCC by EFNARC, are satisfied. The workability values are maintained by adding suitable quantities of superplasticizers.

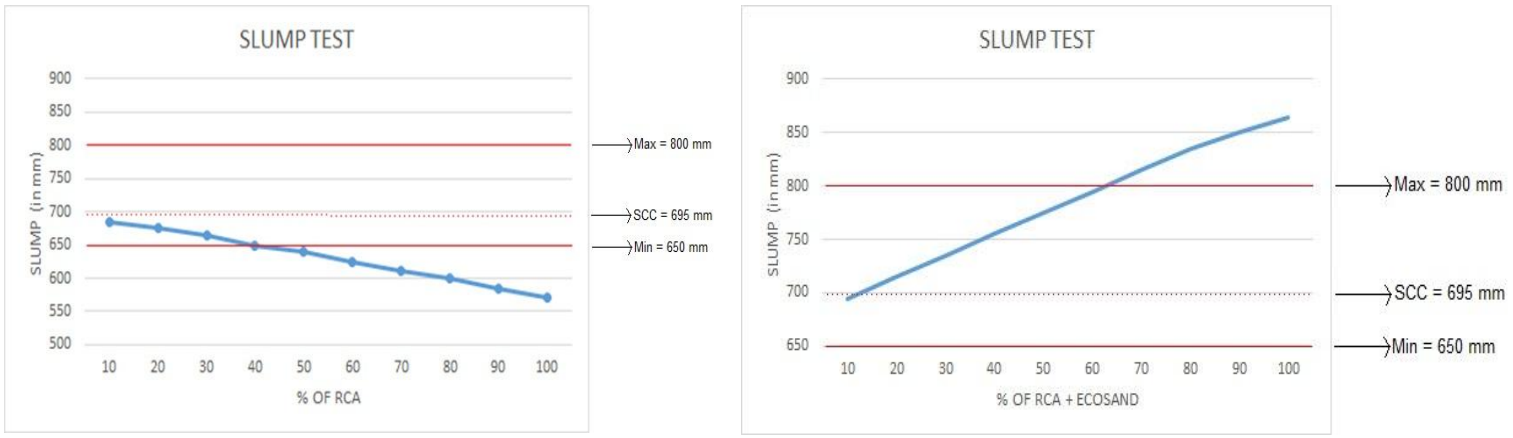

Fig. 2. Slump Test

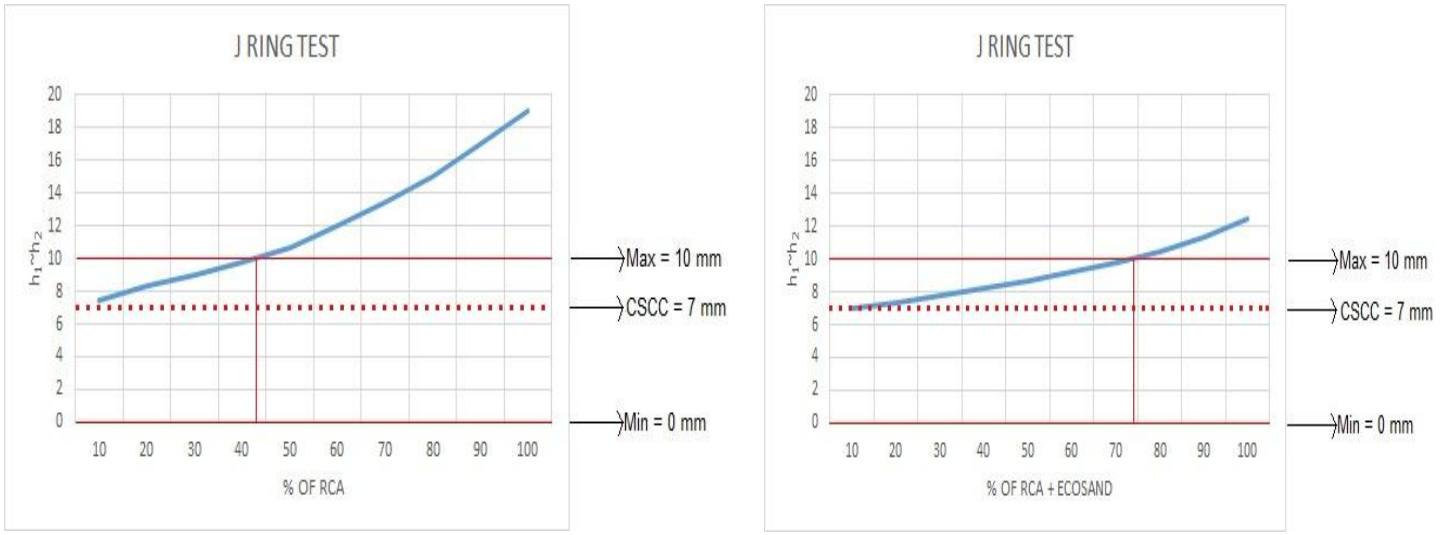

Fig. 3. J Ring Test

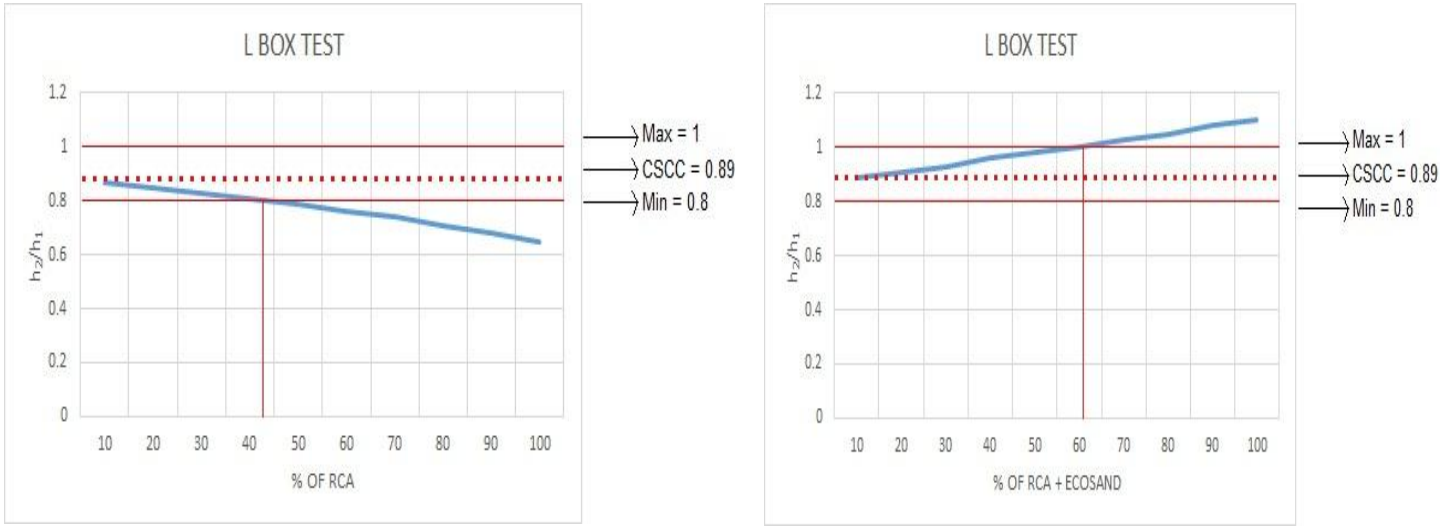

Fig. 4. L Box Test

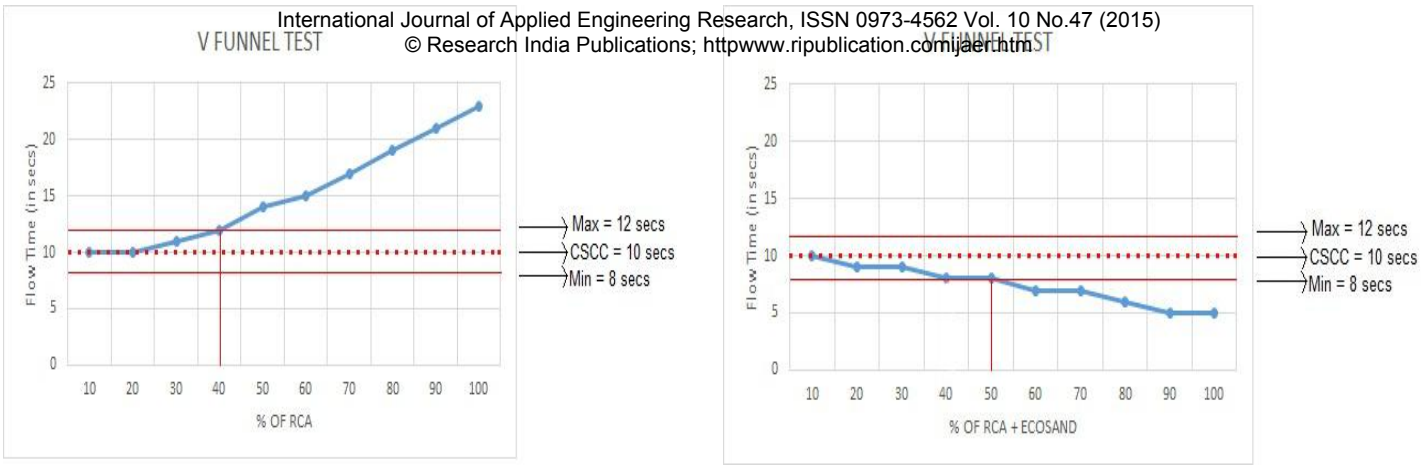

Fig.5. V FUNNEL TEST

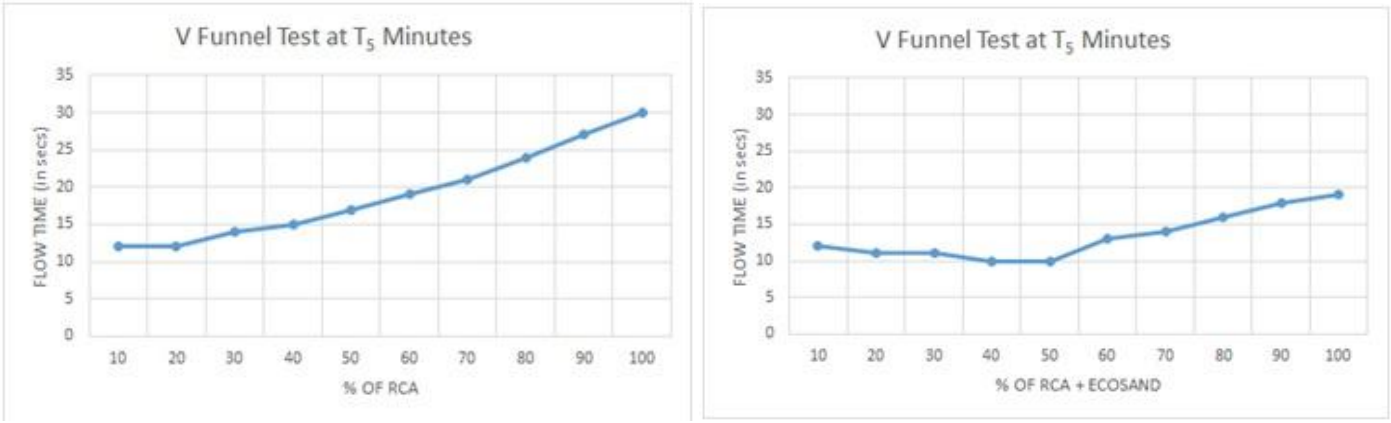

Fig.6. V FUNNEL TEST @ T_5 MINUTES

Several test methods have been developed in attempts to characterise the properties of SCC. The above graph gives the characteristic of SCC. However the figures (2, 3, 4, 5 & 6) give the list of test methods for workability properties of SCC based on EFNARC specification and guidelines. In this study, SCC properties are thoroughly tested for utilization of recycled coarse aggregate along with Eco sand. SCC properties were satisfied up to 40% replacement of recycled coarse aggregate with Eco sand.

For Hardened Concrete

COMPRESSIVE STRENGTH TESTING:

A comparative study on properties of a recycled coarse aggregate and Eco sand in SCC for M_{30} grade of concrete is studied. Tests of compressive strength 28 days yielded the results are shown in fig (7). All the mixtures quickly gain strength, and after 7 days they achieve more than 90% of the strength they have at the age of 28 days. Compressive strength of SCC value is equal to conventional SCC when the replacement ratio is 50% of recycled coarse aggregate with Eco sand.

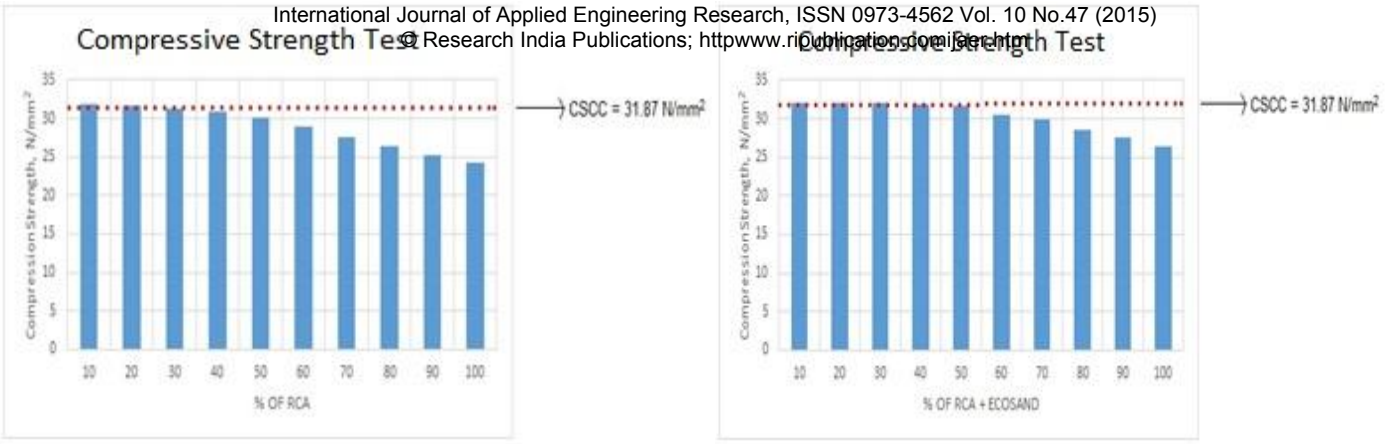

Fig. 7. Compressive Strength Test

Split tensile strength:

In this investigation, the Split tensile strength test of SCC is carried out with 0% to 100% replacement of recycled aggregate with coarse aggregate and Eco sand with natural river sand for M_{30} grade of concrete. The tests are carried out after 28 days of curing. The results are shown in figure (8). All three mixtures quickly gain strength, and after 7 days they achieve more than 90% of the strength at the age of 28 days. Split tensile strength value is gradually decreased to the percentage of recycled coarse aggregate replaced in the concrete.

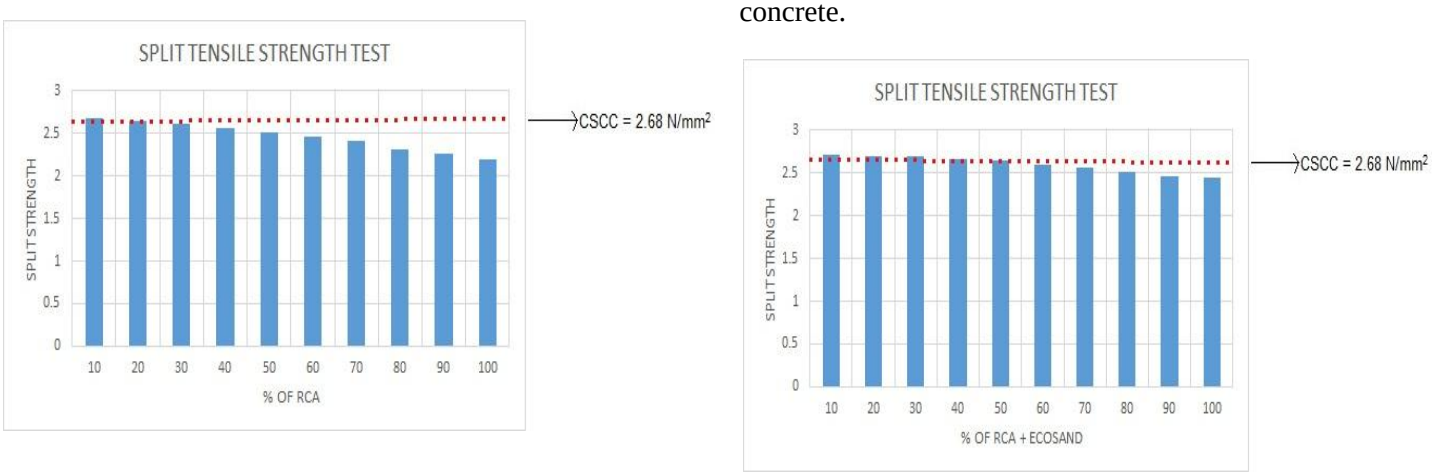

Fig. 8. Split Tensile Strength Test

Flexural strength

In this investigation, the flexural strength test of SCC is carried out with 0% to 100% replacement of recycled aggregate with coarse aggregate and Eco sand with natural river sand. The tests are carried after 28 days of curing. The results are shown in figure (9). Flexural strength of recycled coarse aggregate SCC is equal to the conventional SCC when the replacement ratio is 40% of recycled coarse aggregate with Eco sand.

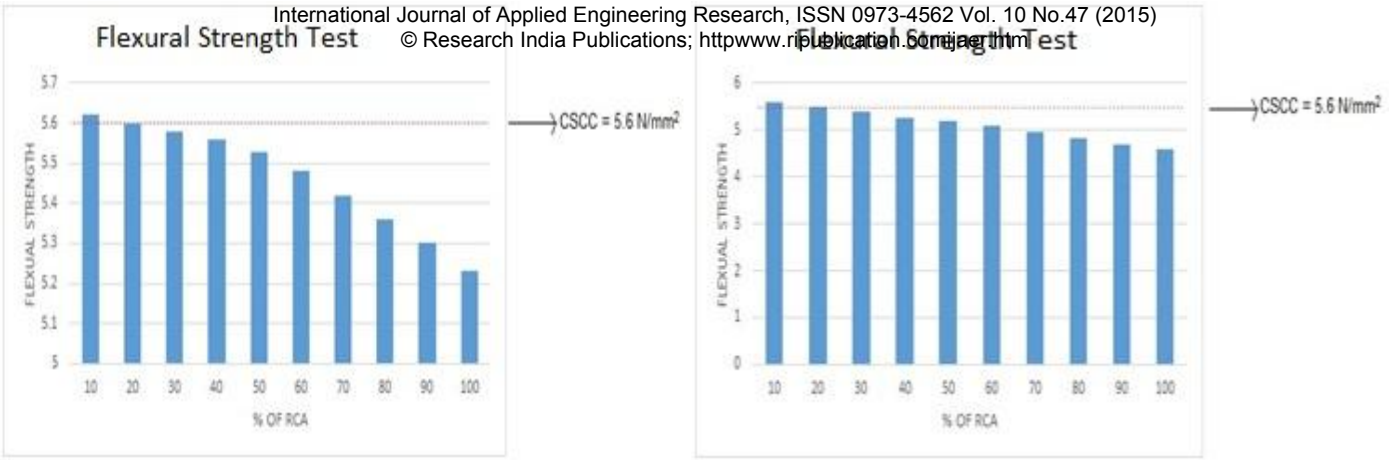

Fig. 9. Flexural Strength Test

ANALYSIS OF TEST RESULT AND DISCUSSION

Use of recycled coarse aggregate and eco sand in SCC, there is a small improvement in the strength and the same is reported. The tests are carried at 7, 14 & 28 days. Compressive strength of recycled coarse aggregate SCC value is decreased compare to conventional SCC. But, it is found that the compressive strength at 28 days has equal up to 50% of replacement of recycled coarse aggregate with eco sand.

In this investigation, the split tensile strength test values are equal to the ordinary SCC when the replacement ratio is 40%.

It is observed from the results that the flexural strength is equal with 40% of recycled aggregate with eco sand.

CONCLUSION:

Studies on different properties of eco sand with RAC are carried out in this paper. Based on the results obtained and interpertation the following conclusions are drawn from the study:

- The recycled coarse aggregates have relatively fine particles than natural coarse aggregates due to the crushing of old concrete. The surface texture of recycled coarse aggregate is more porous and rough due to the adherence of old porous mortar. This may increase the water demand and reduce the workability.
- In this study, different ages of aggregates were tested for determining the exact water absorption value for recycled coarse aggregate. Water absorption values are directly taken from the graph.
- Eco sand increased the workability of SCC and also excess amount of eco sand gives segregation and bleeding.
- The details of the various mixes of both normal and RAC along with eco sand obtained the properties of fresh concrete are satisfy the SCC properties.
- Not much significant is observed in compressive strength of recycled coarse aggregate with eco sand up to 50% replacement of coarse aggregate and sand.
- Considerable difference is observed in case of split tensile strength values at 50% replacement of aggregate and sand.
- Allowable difference is observed on case of flexural strength value at 40% replacement of aggregate and sand.
- Density of RCA is less than of concrete with natural aggregates. This is an advantage in the design of structures where the light weight concrete is performed.
- Overall strength gain rate for eco sand with RAC is better than concrete with natural aggregates up to 40% replacement.

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