Experimental Investigation on the Propertiesof Recycled Concrete and Coconut Shell Aggregate Concrete

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Abstract: In this experimental study, the properties of recycled aggregate and coconut shell aggregate concrete are examined and the scope of recycled aggregate and coconut shell aggregate in construction is investigated. The basic properties of recycled and coconut shell aggregate concrete are examined wrtthe natural aggregate concrete. Basic changes in all aggregate properties were determined and their effects on concreting work were discussed. Basic concrete properties like compressive strength, split tensile strength, workability etc. are conducted here for different combinations of recycled and coconut shell aggregate.

The paper aims at analyzing and comparing split tensile strength and compressive strength characteristics with partial replacement of recycled aggregate as well as coconut shell aggregate concrete using M25 grade concrete.

Keywords: Ordinary Portland cement (43 Grade), recycled aggregate, coconut shell aggregate, natural aggregate, fine aggregate, workability, compressive strength, split tensile strength.

1. INTRODUCTION:

To minimize the adverse environmental effects on the human surrounding, extensive investigations on wastage recycling are being undertaken. The cost of building materials are increasing day by day. As the main ingredient of concrete is coarse aggregate, it is observed that, the use of recycled aggregate and coconut shell aggregate can be useful in concrete for environmental protection and economic use of materials.

The application of recycled aggregate has been initiated in construction projects in many European, American and Asian countries with relaxation of infrastructural lawsfor increase the use of recycled aggregates. India is the third largest coconut producing country in the world. Huge amount of waste is generated by coconut. The waste coconut shell may be used to replace conventional coarse aggregates. It may help to produce concrete economically and at the same time , will also help to reduce its disposal problem. In this study, coconut shell is used as light weight aggregate in concrete. The properties of split tensile strength and compressive strength with partial replacement of recycled aggregate and coconut shell aggregate concrete are investigated.

2.LITERATURE REVIEW:

2.1. Recycled Aggregate:

M Etxeberria et al (2006)used specified recycled coarse aggregates obtained by crushed concrete for concrete production. Four different recycled aggregate concretes were produced; made with 0%, 25%, 50% and 100% of recycled coarse aggregates, respectively. The mix proportions of the four concretes were designed in order to achieve the same compressive strength. In general ,the workability of recycled aggregate concretes is affected by the absorption capacity of the recycled aggregates. The shape and texture of the aggregates can also affect the workability of the concrete. Concrete crushed by an impact crusher achieves a high percentage of recycled coarse aggregates without adhered mortar. Concrete made with 100% of coarse recycled aggregate requires high amount of cement to achieve a high compressive strength and consequently is not an economic proposition as it is not cost effective. Concrete made with 100% of recycled coarse aggregates has 20–25% less compression strength than conventional concrete at 28 days, with the same effective w/c ratio and cement quantity.

YasumichiKoshiroetal (2014) investigated an entire concrete waste reuse model for producing recycled aggregate concrete established with the objective of recycling concrete waste generated during anticipated demolition of older buildings in urban areas. In a redevelopment project of Obayashi Technical Research Institute, a 24-year old building was demolished and concrete waste was used to produce high-quality recycled coarse aggregate using a heat grinder system. Then the quality of concrete using these recycled materials was tested and applied to fair-faced concrete structures of a new building. This model enabled all the concrete waste to be recycled.

2.2. Coconut Shell:

B.Damodhara Reddy (2014) studied the use of coconut shell as coarse aggregate by replacing 25%, 50%,75% and 100% of coarse aggregate with coconut shell. A nominal mix of 1:2:4 was used and free constant water cement ratio was maintained at 0.6. Tests were conducted for workability, flexure, and compression and split tensile strength. Increase in CS percentage decrease densities of the concretes. The overall strength decrease with increase in CS replacement. Replacement of 25% CS gives higher strength compared to other percentage.

Parag S. Kambli (2014) investigated the maximum compressive strength which was foundto be 19.7 N/mm^2at a coconut shell replacement percentage of 20%. From the experimental results and discussion, it is found that, the coconut shell has very high potential to be used as lightweight concrete. Also, coconut shell as coarse aggregate in concrete can reduce the material cost in construction.

3. MATERIALS:

3.1. Cement:

The cement that used is of Ramco cement, Ordinary Portland Cement (OPC) 43 grade as per standard specification. Ramco Cement OPC 43 confirms to IS 8112. The grade is based on the 28-day compressive strength of the cement mortar, which in this case is not less than 43 MPa.

3.2. Aggregate:

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. One of the most important factors for producing workable concrete is good gradation of aggregates. Good grading implies that a sample fractions of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste means less quantity of cement and less water, which are further mean increased economy, lower shrinkage and greater durability.

3.2.1. Natural Coarse Aggregate (NCA):

Natural coarse aggregateswere obtained in crushed form were of granite-type. The natural coarse aggregate is of angular shaped crushed granite with maximum size of 20mm.

3.2.2. Fine aggregate (FA):

The natural fine aggregatesare the river sand which is the most commonly used natural material for the fine aggregates. For this study, the river sand Zone-III is used.

3.2.3. Recycled Coarse Aggregate (RCA) :

Recycled coarse aggregatecan be generated from demolished construction structure which comprises of broken members or components likes the slab, beam, brick wall and others. Recycled concrete aggregatesproduced from all but the poorest quality original concrete can be expected to pass the same tests required for conventional aggregates. Recycled concrete aggregates contain not only the original aggregates, but also hydrated cement paste. This paste reduces the specific gravity and increases the porosity compared to similar natural aggregates. Higher porosity of RCA leads to a higher absorption. The maximum size of RCA is 20mm.

3.2.5. Coconut Shell Aggregate (CSA):

Available coconut shells were hammered, crushed to smaller pieces, sieved and used for preparation of the concrete. Maximum size of coconut shell aggregate is 20mm.

3.3. Water:

Water used for both mixing and curing is required to be free from deleterious materials; potable water is generally satisfactory for mixing and curing of concrete. Dark colored or bad smell water may be used if they do not possess deleterious substances.

3.4. Super Plasticizers:

(*High Range Water Reducing Admixture - Sika*)

Sika can be used for all levels of water reduction in various types of concrete ranging from dry cast applications, conventional concrete to SCC (Self-Consolidating Concrete). Sikadelivereswater reduction up to 45%. The special formulation of Sika increases compressive strength of concrete and helps maintain the plasticity of the concrete over prolonged period of time. Sika extends concrete workability time in high temperature weather , when slump loss and fast stiffening of the fresh concrete can be a concern. The superplasticizing action of Sika provides high slump/ flowing concrete that can be placed with minimal or no vibration even at very low water cement ratios as low as 0.25.

3.5. Plasticizing effect:

The superplasticizing action of Sika provides high slump, flowing concrete that maintains excellent workability and may be placed with minimal vibration even at very low water cement ratio as low as 0.25. Sika plasticized concrete is highly fluid while maintaining complete cohesion within the concrete matrix to eliminate excessive bleeding or segregation.

4.METHODOLOGY AND EXPERIMENTAL INVESTIGATION:

Before the start of the experimental program, the physical properties of cement and aggregate was tested.The physical tests was conducted according to the Indian Standard and all the test results are given in the Table 1 and Table 2.

Table 1.Physical properties of cement:

Characteristics	OPC 43 Grade cement
Initial setting time	84 minutes
Final setting time	272 minutes
Specific gravity	3.12
Normal consistency	35%

Table 2. Physical properties of aggregates:

Characteristics	**NCA**	**RCA**	**CSA**	**FA**
Specific Gravity	2.62	2.27	1.33	2.62
Water Absorption, %	1.65	5.64	7.6	0.806

The concrete mixture proportions for M25 grade of concrete are found to be 1:1.8:3.2 calculated as per IS: 10262-2009 and the water cement ratio is 0.45.

In total, 9 types of mixes are prepared. The properties of fresh concrete i.e. the slump value is evaluated for TM1(NCA or 0% replacement),TM2(5% RCA), TM3(10% RCA),TM4(15% RCA), TM5(20% RCA), TM6(5% CSA), TM7(10% CSA),TM8(15% CSA) and TM9(20% CSA) and the properties of hardened concrete i.e. compressive strength and split tensile strength of concrete are investigated with different mixes as mentioned above at 7 days and 28 days. Then the strength of concrete is compared with natural course aggregate (NCA).

Mix proportions:(For M25 grade)

Various input data related to the mix proportions for M25 concrete are noted below. The design mix proportion is shown in Table 3.Concrete mixture proportions for M25 grade of concrete are 1:1.8:3.2.

- Target mean strength (f'ck) = 31.6 N/mm^2
- Water content For 50-75mm slump = 191.6 lit
- As superplasticizer is used, the water content can be reduced 13%.
- Water content = 191.6 x 0.87 = 167 lit.
- Cement content = 167/0.45 = 372 kg/m^3
- Volume of coarse aggregate = 0.64 (For Zone – III Sand, 20mm CA)
- Volume of fine aggregate = 1 – 0.64= 0.36

Table 3: Trial Mix Calculation

Trial mix no.	Cement in (kg/m^3)	FA in (kg/ m^3)	CA in (kg/ m^3)	Water in (kg/ m^3)	Sika in (%)
TM1	372	670	1186	167	0.8% of Cement
Proportion	1	1.8	3.2	-	-

6. RESULTS AND DISCUSSION:

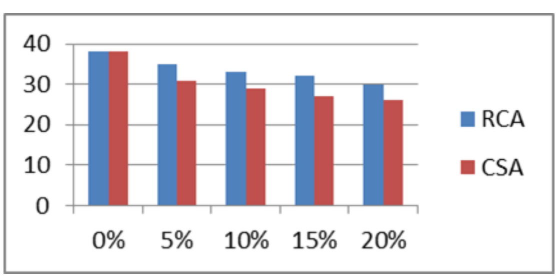
6.1.FreshConcrete Properties

Workability Test: The replacement of coarse aggregate by RCA and CSA affects the workability of the concrete. The workability of RCA concrete shows a decrease in slump with increase of recycled aggregate content of total aggregate volume and the workability of CSA concrete shows also decrease in slump with increase in coconut shell aggregate content of total aggregate volume. The low slump may be due to high absorption of water during the mixing process. The results of the slump test are shown in Table 4 and Figure 1.

Table 4. Slump Test

% replacement	w/c ratio	Slump in mm	
		RCA	CSA
0%	0.45	38	
5%		35	31
10%		33	29
15%		32	27
20%		30	26

Figure.1 Workability of concrete in terms of slump value



6.2. Harden Concrete Properties:

6.2.1. Compressive Strength Test:

Concrete specimens are cast and tested under the action of compressive loads to determine the strength of concrete. In very simple words, compressive strength is calculated by dividing the failure load with the area of application of load, usually after 28 days of curing. The strength of concrete is controlled by the proportioning of cement, coarse and fine aggregates, water, and various admixtures. The ratio of the water to cement is the main factor for determining the concrete strength. The lower the water-cement ratio, the higher is the compressive strength.

The compressive strength tests were carried out after 7 days and 28 days for the concrete cubes. The specimen of size 150×150×150 mm cubes were cast according to IS: 516-1969.The compressive strength of specimen was observed to decrease with an increase in the percentage of the RCA and CSA concrete with NA. The results of compressive strength of cubes for 7 days and 28 days are given in Table 5, Table 6 and figure 2, 3 respectively.

Stress = Load of cube / area of cube

6.2.2. Split Tensile Strength test:

The split tensile strength tests are conducted for M25 grade of concrete with different percentages of RCA and CSA replacement by the NA concrete at the age of 7days and 28days. Concrete cylinders (100mm diameter x 200mm height) are caste. Once the curing is over for the specific duration, , the cylinders are cleaned and dried properly, before placing it in Universal Testing Machine (U.T.M). The plate is lowered and allowed to touch the top surface of the cylinder. The force is applied with gradual increase in load. The load at which splitting of the cylinder takes place is recorded and the split tensile strength is calculated as per formula. The concrete does not resist the direct tension because of its low tensile strength and brittle nature. However, determination of split tensile strength is necessary to determine the load at which the concrete members may fail.

The results of split tensile strength test of cylinder for 7 days and 28 days are given in Table 7 and 8 and are also shown in Figure 3 and 4. The split tensile strength was computed by the expression;

$$f_{sp} = 2P / \pi L d$$

Where,

P: - Maximum Load on cylinder in Newton.

*f*sp: - The split tensile strength of concrete in MPa.

L: - Length of the cylinder in mm.

d: - Diameter of the cylinder in mm.

Table 5. 7 days Compressive Strength Test Results

Sample	w/c	Weight(Kg)		Area (mm^2)	Load(KN)		Compressive Stress (N/mm^2)	
		RCA	CSA		RCA	CSA	RCA	CSA
TM1 (0%)	0.45	8.86		22500	500		22.22	
TM2 (5% RCA)		8.80			483		21.46	
TM3 (10% RCA)		8.82			488		21.68	
TM4 (15% RCA		8.83			468		20.79	
TM5 (20% RCA)		8.85			447.5		19.88	
TM6 (5% CSA)			8.41			465		20.67
TM7 (10% CSA)			8.20			387.5		17.22
TM8 (15% CSA)			7.84			361		16.04
TM9 (20% CSA)			7.73			347.5		15.45

Figure.2 – 7 days Compressive strength test

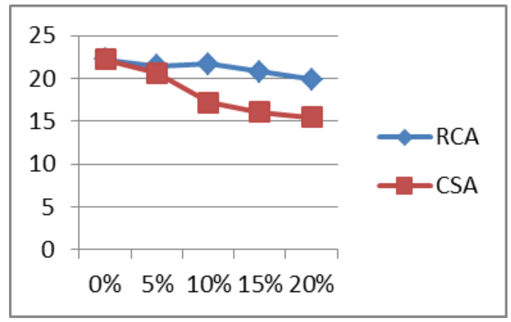


Table 6. 28days Compressive Strength Test Results

Sample	w/c	Weight(Kg)		Area (mm^2)	Load(KN)		Stress (N/mm^2)	
		RCA	CSA		RCA	CSA	RCA	CSA
TM1 (0%)	0.45	8.87		22500	722		32.08	
TM2 (5% RCA)		8.81			710		31.56	
TM3 (10% RCA)		8.90			694		30.84	
TM4 (15% RCA)		8.92			675		29.56	
TM5 (20% RCA)		8.95			645		28.67	
TM6 (5% CSA)			8.62			705		31.33
TM7 (10% CSA)			8.50			630		28.00
TM8 (15% CSA)			7.91			560		24.89
TM9 (20% CSA)			7.94			495		22.00

Figure.3 – 28 days Compressive strength test

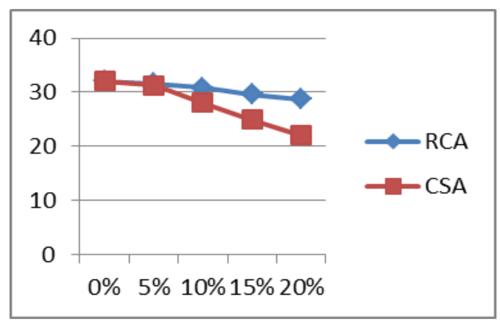


Table.7- 7 days split tensile strength of concrete

Sample	w/c	Weight in Kg		Load in KN		Stress in MPa	
		RCA	CSA	RCA	CSA	RCA	CSA
TM1 (0%)	0.45	3.965		9.45		3.005	
TM2 (5% RCA)		4.05		9.2		2.92	
TM3 (10% RCA)		3.975		8.8		2.81	
TM4 (15% RCA)		4.25		7.5		2.38	
TM5 (20% RCA)		4.30		6.2		1.97	
TM6 (5% CSA)			3.74		6.75		2.15
TM7 (10% CSA)			3.72		6.60		2.10
TM8 (15% CSA)			3.57		6.50		2.06
TM9 (20% CSA)			3.625		6.05		1.92

Figure.3- 7 days split tensile strength test

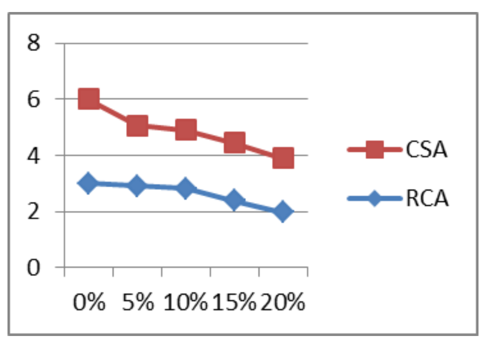
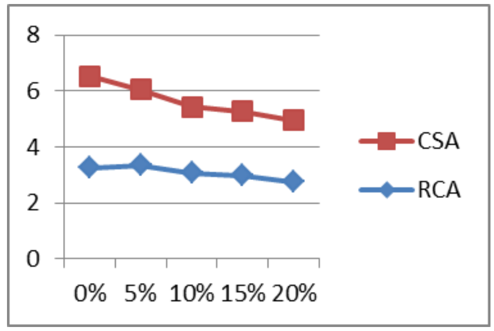


Table. 8. 28days split tensile strength of concreteFigure 4- 28 days split tensile strength test

Sample	w/c	Weight in Kg		Load in KN		Stress in MPa	
		RCA	CSA	RCA	CSA	RCA	CSA
TM1 (0%)	0.45	3.95		10.25		3.26	
TM2 (5% RCA)		3.985		10.5		3.34	
TM3 (10% RCA)		4.045		9.62		3.06	
TM4 (15% RCA)		4.32		9.40		2.99	
TM5 (20% RCA)		4.45		8.70		2.76	
TM6 (5% CSA)			3.93		8.50		2.70
TM7 (10% CSA)			3.75		7.50		2.38
TM8 (15% CSA)			3.72		7.15		2.27
TM9 (20% CSA)			3.65		6.90		2.19



6.3. DISCUSSION:

- The CSAconcreteis observed to have low slump. The slump values of the concrete are between26 - 31mm, whereas RCA concreteis having high slump, when compared to CSA concrete. The slupvalues of CSA concrete vary from 30-55mm.Observation shows that, the workability decreases with increase in the CSA and RCA percentage.In CSA concrete, the slump is quiet low as compared to RCA concrete, but in both the concrete, slump goes down with the increase in the percentage of replacement.
- The compressive strength of CSA concrete is little low when compared to RCA concrete. The reason is that, the CSA is unable to make proper bonding. The compressive strength is decreased with the increase in percentage of replacement in both CSA and RCA concrete. Thestrength of CSA concrete at the age of 7days is having 49-65% strength, while in RCA concrete, the strength value is 63 - 68%.
- Increase in percentage replacement by CSA and RCA reduces the split tensile strength of concrete.
- The weight of CSA concrete is decreased when the replacement percentage is increased, but in case of RCA concrete, the weight is increased with increase in percentage replacement.
- The CSA is having higher water absorption capacity because of higher porosity in its shell structure while in RCA, little low water absorption is observed compared to CSA.
- As per the investigation result, both RCA and CSA concrete are useable, but in comparison, it is preferable to use RCA concrete.

6. CONCLUSION:

The following conclusions are made based on the experimental invesrtigation of the study.

- With the same w/c ratio, the slump value decreases, if percentage of RCA and CSA is increased.
- The compressive strength of RCA and CSA concrete was lower than that of Natural Aggregate Concrete.
- The split tensile strength of RCA and CSA concrete was lower than that of NA concrete.
- Generally, the recycled aggregate, in comparison to the aggregates obtained from natural resources, is characterized by: higher water absorption, lower density, higher content of organic and possibly harmful substances, higher level of crushability, reduced abrasion resistance and reduced resistance to frost. Recycled aggregate can be grouped under heavyweight aggregate.
- The coconut shell aggregates have higher water absorption because of higher porosity in its shell structure. The aggregate impact value of coconut shell aggregates are much lower compared to crushed stone aggregate which indicates that this aggregates have good absorbance to shock.
- Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate. Coconut shell can be grouped under lightweight aggregate.
- strength of CSA concrete at the age of 7days is having 49-65% strength, while in RCA concrete, the strength value is 63 - 68%.
- Increase in percentage replacement by CSA and RCA reduces the split tensile strength of concrete.
- The weight of CSA concrete is decreased when the replacement percentage is increased, but in case of RCA

- concrete, the weight is increased with increasein percentage replacement.
- The CSA is having higher water absorption capacity because of higher porosity in its shell structure while in RCA, little low water absorption is observed compared to CSA.

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