Effect Of Coconut Shell Aggregate On Normal Strength Concrete

Running Title: Coconut Shell As Coarse Aggregate

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Abstract: Abundant availability of natural resources has become a dream for present day engineering society due to large scale consumptions. The unaccountable population growth rate makes problem of availability of coarse aggregate for construction more severe. Due to rapid Urbanization and industrialization, consumption of aggregates increased to manifold. So, the researchers must find the alternatives for the coarse aggregate. The increase in population also increases the industrial by- products, domestic wastes etc. It has been noticed in India that coconut shell (CS) as an agricultural waste, requires high dumping yards as well as an environmental polluting agent. If it can be utilized as a coarse aggregate, then it should be a boon rather than a ban to the civil engineering society. This study aims in development the mix design of lightweight aggregate concrete using CS as coarse aggregate together with cement and river sand. Experimental study is undertaken to investigate the effects of replacement of coarse aggregate by different percentages of coconut shell on mechanical properties of this composite concrete. The test values obtained from experiment was verified with different codes from different countries.

Key words: Coconut Shell; coarse aggregate (CSA), Natural coarse aggregate (NCA), compressive strength; flexural strength and split tensile strength.

Introduction:

The rapid growth rate of the population requires a plenty of natural resources to fetch them a shelter Prasad (2008)[1]. The nature is handicapped to provide its raw materials (aggregates) to the present world of population of 6.3 billion which has risen from 1.6 billion in the 19th century. For building a shelter, concrete is the main component and coarse Aggregates provide 60 percent to 80 percent volume low cost concrete. With increasing concern over the excessive exploitation of natural aggregates, the aggregates produced from industrial wastes and agriculture wastes may be utilized as the coarse aggregate for concrete. India, the land of agriculture produces so many wastes like rice husk, coconut shell, coconut fiber, etc. To save the environment from the pollution of dumped waste and to meet scarcity of raw materials in the construction field to fulfill human desire of having a home, wastes can play a vital role. India is a divine land and in every occasion perhaps coconut is the main item of worshipping. So, India produces a huge amount of waste from coconut. Utilizing coconut shell as aggregate in concrete production not only solves the problem of disposing this solid waste but also helps conserve natural resources. Preservation of environment and conservation of rapidly diminishing Natural resources should be the essence of sustainable development. The strength of concrete is related to its ingredients and water cement ratios. As

According to Olanipekun E.A [2] et.al. a large amount of agricultural waste which was disposed in most of tropical countries if not be disposed properly it would lead to social and environmental problem. Utilized these disposed material was one method of treating the agricultural waste from waste to wealth.

K. Gunasekaran and P.S. [3] reported that as aggregates provide the volume of concrete, industrial wastes and agriculture wastes should be new source for building material. This study was carried out to determine the possibilities of using coconut shell as aggregate in concrete. Utilizing coconut shell as aggregate in concrete production not only solves the problem of disposing this solid waste but also helps conserve natural resources. Their paper highlights physical properties of crushed coconut shell aggregate. They concluded water absorption of the coconut shell aggregate was high about 24 % but the crushing value and impact value was comparable to that of other lightweight aggregates. The average fresh concrete density and 28-day cube compressive strength of the concrete using coconut shell aggregate were 1975 kg/m3 and 19.1 N/mm^2 respectively.

K.Gunasekaran and P.S.Kumar[4] reports development of the mix design of lightweight aggregate concrete using Coconut shell aggregate (CSA) as coarse aggregate together with cement and river sand. The compressive strength after 28 days was found to be in the ranges between 4.9 N /mm^2 - 23.5 N /mm^2 under water curing. The test results shows that concrete using coconut shell aggregate has resulted in acceptable strength required for structural lightweight concrete. It is concluded that the lightweight concrete developed from CSA aggregate can be used for both structural and non-structural applications.

Alida Abdullah, Shamsul Baharin Jamaludin, Mazlee Mohd Noor, Kamarudin Hussin[5] utilized coconut fiber to verify the physical and mechanical properties as well as fracture behavior of composite cement reinforced with coconut fiber.

Saravanan R [6] reported the results of a study undertaken in enhancing properties of fly ash concrete composites with coconut natural fiber. A control mixture of proportions 1:1:49:2.79 with w/c of 0.45 was designed for the normally popular M20 concrete with replacement of cement. Coconut fiber was found to increase the mechanical properties of concrete.

From the literature it was found that coconut fiber has attained its pace in the research activities to be used as a building material, here an attempt was made to utilize coconut shell as a substitution of natural coarse aggregate for making concrete and to verify its strength properties. For this a mix design was prepared with natural coarse aggregate with target mean strength XXXX N/mm2 and then natural coarse aggregate was substituted with coconut shell as a 5% and 10% of natural aggregate(NCA).The mechanical properties such as compressive strength, split tensile strength and flexural strength was found out and the test values are compared with different codal values.

To achieve the above objectives, a mix design was prepared for 35 MPa using Gambhir [7] and IS 10262-1982 [8] and cubes, cylinders and prisms were cast to determine cube strength, split tensile strength and flexural strength respectively with natural coarse aggregate. The same were cast and tested with 10% and 20% replacement of NCA with recycled aggregates (RCA).

The test results were analyzed and compared with theoretical values obtained from various codes.

2.0 Experimental Investigation:

Target mean strength 40.0 N/mm^2 concrete was designed as per [7,8] as control mix with natural coarse aggregate. The mix proportion for the above mentioned target mean strength was found to be 1.0: 1.05: 2.50 with w/c ratio 0.4 after the trial mixes. The control mix was with 100% natural coarse aggregates (NCA). Other mixes were also prepared by substitution of NCA with coconut shell (CSA).The other mixes were 95%NCA+5% CSA and 80% NCA+ 10% CSA as given in Table-1.

Table -1 Percentage of aggregate used in 3 batches of mixes.

Mix Designation → Type of Aggregate ↓	Mix-1(Control Mix)	Mix-2	Mix-3
NCA	100%	95%	90%
CSA	0	5%	10%

2.1 Material Properties:

2.1.1 Cement:

Ordinary Portland cement of 53 grade conforming to Indian Standard IS 12269-1987 [9] was used throughout the experimental program. The standard consistency was 28%, whereas the initial and final setting times were 95 min. and 210 min. respectively. The specific gravity of cement was 3.14 and its compressive strength after 28 days was 57 MPa.

2.1.2 Coarse Aggregate:

In this investigation, two types of coarse aggregates were used for preparation of concrete, Natural Coarse Aggregate. (NCA) and coconut shell Coarse Aggregate. (CSA)

2.1.2.1 NCA.

Crushed hard granite chips of maximum size 20 mm were used in the concrete mixes. The bulk density of aggregate was 1460 kg/m^3 and specific gravity was found to be 2.65.

2.1.2.2 CSA

Available coconut were hammered and crushed to smaller pieces and sieved. The sieved materials were washed with clean water for several times and then dried on sun, made saturated and then required quantity was taken for casting. Physical properties are tabulated in Table-2.The CSA aggregates after crushing and sieving by mechanical means were presented in Fig-1.

Table-2 Physical Properties of NCA and RCA

Properties	NCA 100% NCA	SAND	CSA
Bulk Density(Kg/m^3)	1460	1450	1440
Specific Gravity	2.78	2.76	1.35
Fineness Modulus	7.1	7.11	7.12
Water Absorption (%)	1.0	1.80	20%

2.1.3 Sand:

Fine aggregate (sand) used for this entire investigation for concrete was river sand conforming to zone-II of IS: 383-1970 [10]. The fineness modulus was 2.81.

2.1.4 Water:

Potable water conforming to IS 456-2000 [11] was used for casting and curing.

Table-3 Proportions and weight of each mix material by weight

Batch	1 (Only NCA)		2 (95% NCA+5% CSA)		3 (90% NCA+10% CSA)	
Cement (kg)	26 kg		26 kg		26 kg	
Sand (kg)	27.3 kg		27.3 kg		27.3 kg	
Water (kg)	10.4 kg		10.4 kg		10.4 kg	
Coarse Aggregates (kg)	65		65 Kg		65 Kg	
	NCA	CSA	NCA	CSA	NCA	CSA
	65	0	58.5	6.5	52	13
20 mm – 10mm	39	0	35.1	3.9	31.2	7.8
10mm- 4.75mm	26	0	23.4	2.6	20.8	5.3

2.2 Preparation of Specimens:

Specimens were prepared by batching of materials, preparation of moulds and placing of concrete in the moulds.

2.2.1 Batching:

The performance of coconut shell coarse aggregates concrete is influenced by the mixing. This means that a proper and good practice of mixing can lead to concrete for better performance. A proper mix of concrete is essential for the strength of the concrete and better bonding of cement and aggregate. Before the concreting, all the mix materials were weighed as given in Table-3 and kept ready for concreting as per design mix proportions.

2.2.2 Preparation of Concrete Moulds:

Concrete moulds were such as three cubes (150 mm x 150 mm x 150 mm), cylinders (150 mm x 300 mm) and prisms (400 mm x 100 mm x 500 mm) cleaned first and oiled for easy stripping. The moulds for conducting tests on fresh concrete were made ready and inner surface was oiled.

2.3 Preparation of Concrete:

The average moisture content and water absorption of the crushed coconut shell was found to be 4.20 % and 24.00 % respectively. Since the coconut shells are basically wood based and organic material and therefore moisture retaining capacity would be more compared with the crushed stone aggregates.

Due to the high water absorption of CSA, the aggregates were pre-soaked for 24 hours in potable water prior to mixing and were in saturated surface dry (**SSD**) condition during mixing to prevent absorption of mixing water. The materials in dry condition in the mould was presented in Fig-2. Concrete was prepared in the mixer and dumped in iron tray placed on a flat surface Along with natural coarse aggregate the coconut shells were added for preparation of concrete. Again the concrete was manually mixed properly before placing in the moulds.

2.4 Tests on Fresh Concrete:

In this investigation, the workability tests were conducted on fresh concrete. Workability affects the rate of placement and the degree of compaction of concrete. Slump test, Compaction Factor test and Vee-Bee tests were conducted on fresh concrete and the results are reported on Table-4.

2.5 Preparation of Samples:

During the placing of fresh concrete into moulds, proper care was taken to remove entrapped air by using a table vibrator to attain maximum strength. Vibrators were used after every one third filling of material into the mould and the top surface was properly leveled at the end.

2.6 Demoulding:

After leveling the fresh concrete in the mould, it was allowed to set for 24 hours. The identification marks of concrete specimens were done with permanent markers and the specimens were removed from the mould. The moulds were cleaned and kept ready for next batch of concrete mix.

2.7 Curing:

Curing is an important process to prevent the concrete specimens from losing their moisture while they are gaining their required strength. Inadequate curing is also the cause of unexpected cracks on the surface of concrete specimen. All concrete specimens were cured in water at room temperature for 28 days. After 28 days curing, concrete specimens were removed from the curing chamber to conduct tests on hardened concrete.

2.8 Tests on hardened Concrete:

2.8.1 Compressive Strength:

Compressive strength is defined as the maximum resistance of a concrete cube to axial loading. Three specimens of size 150 mm x 150mm x 150mm were used for compression testing for each batch of mix.

Testing of specimens was carried out as soon as possible after curing. The measurements of specimen dimensions were taken before the testing. Cleaned and surface dried specimens were placed in the testing machine. The platen was lowered and touched the top surface of the specimen. The load was applied at the rate of 14 N/mm^2 and maximum load was recorded. The compressive strength of these samples was recorded in Table-5.

2.8.2 Split Tensile Strength Test:

Split tensile test was conducted on cylinders of size 150mm diameter and 300mm height. The testing of specimens should be carried out as soon as possible after curing. Specimen dimensions were measured before the testing. Cleaned and cured specimens placed in the testing machine. The platen was lowered and was allowed to touch the top surface of the specimen. The force was applied and increased continuously. Maximum load at which the specimen failed was recorded and split tensile strength was calculated and presented in Table-5.

2.8.3 Flexural Strength:

The prisms were tested to evaluate the flexural strength of the concrete. The prism dimensions were measured accurately before testing and marked by a marker for placing in the testing machine.

The test results on hardened concrete are tabulated in Table-5.

Table-4 Test results of Workability

Percentage	Slump (mm)	Compaction Factor	Vee-Bee (seconds)
100% NCA	20	0.9	5
95% NCA + 5 % CSA	18	0.89	4
90% NCA + 10 % CSA	18	0.89	4

Table-5 Test Results on Hardened Concrete

Percentage of coarse aggregate	Compressive Strength(N/mm^2)	Split tensile Strength (N/mm^2)	Flexural Strength(N/mm^2)
100%N.C.A.	40.34	3.05	3.56
95% N.C.A + 5% C.S.A.	30.67	2.06	3.47
90.% N.C.A + 10% C.S.A.	23.17	1.76	3.07

3.0 Interpretation of Test Results:

The test results are reported in Table-5 and compared with the values obtained from various codes, Nevellie [12], Islam [13] and Paramsivam [14]. The test results such as compressive strength, split tensile strength and flexural strength with different proportions of coconut shell coarse aggregate are discussed below.

3.1 Compressive Strength:

Compressive strength is the major parameter which influences other properties of concrete. Compressive strength of concrete specimen with natural coarse aggregate (control specimen) was found to be 40.34 MPa. The mix prepared with 5% replacement of NCA with CSA was found to be 30.67 MPa and that with 10% replacement of NCA with CSA was found to be 23.17 MPa. From the above test results, it is clear that when natural coarse aggregate is substituted with CSA, the compressive strength is found to be reducing. The same was observed by the earlier researchers even when NCA was replaced by recycled aggregate Behera and Behera [14]. This may be due to the fact that the failure of NSC (normal strength concrete) is caused by bond failure of bond between CSA and cement mortar. The bond between mortar and CSA is weaker than that of NCA. The CSA posses lesser crushing value than that of NCA. Compressive strength with 0%, 5% and 10% CSA are plotted in Fig-3. The decrease in compressive strength of 5% and 10% CSA with respect to 100% NCA were plotted in the Fig-4. The percentage of replacement of NCA by CSA is 5% and 10% by weight, but by volume this percentage is more. This may be a cause of decrease in strength. The decrease in strength was found to be high and the variation was not linear.

3.2 Split Tensile Strength:

Split tensile strength of concrete specimen with natural coarse aggregate was found to be 3.05 MPa. The strength of the mix prepared with 5% replacement of NCA with CSA was found to be 2.06

MPa and that with 10% replacement was found to be 1.76 MPa. The theoretical values of split tensile strength were calculated from ACI-1985, ACI-1992 and ACI-1995. Test results along with theoretical values are plotted in Fig-5.The percentage of reduction of split tensile strength with 5% and 10% CSA are plotted in Fig-6. The split tensile strength was found to be reducing with increase of CSA. But this reduction was prominent in 10%.The predicted results overestimates when compared to the test results. According to ACI-1995, the percentages of increase for 0%, 5% and 10% CSA are found to be 22.88, 58.65 and 61.54. The same for ACI-1985 are found to be 4.21, 34.39 and 37.08. The overestimation percentage increases with increase in percentages of CSA and it is more for ACI-1995 and presented in Fig-7.

3.3 Flexural Strength:

Flexural strengths of concrete specimens with natural coarse aggregate only, with 5% CSA and with 10% CSA were found to be 3.56 MPa, 3.47 MPa and 3.07 MPa respectively. The theoretical values of flexural strength were calculated from**,** IS-456-2000[7]; ACI-1985, ACI-1992 and ACI-1995. Test results along with theoretical values are plotted in Fig-8.The percentage of reduction of flexural strength with 5% and 10% CSA were found to 2.62 and 13.86 respectively and plotted in Fig-9. The flexural strength was found to be reducing with increase of CSA. The experimental results are all in good agreement with ACI- 1985 predicted results. Both IS-456-2000 and ACI-1992 overestimate while predicted values by ACI-1995 underestimates. The percentages of overestimation and underestimation are plotted in Fig-.9 From the Fig-.8, it was clear that IS-456-2000 code predicts the test results well.

4.0 Conclusion:

From the test results, the following conclusions are drawn

1. Compressive strength reduces with increase in percentage of coconut shell aggregate. The reduction is prominent even for 10%.
2. ACI-1985 and 1995 overestimate the split tensile strength. The overestimation percentages increase with increase in percentages of CSA.
3. ACI-1992 highly overestimates the split tensile strength.
4. The flexural strength decreases with increase in percentage of coconut shell aggregates. The decrease is not prominent up to 10%.
5. ACI- 1985 well predicts the flexural strength while IS- 456-2000 and ACI- 1992 overestimate the flexural strength. The overestimation percentages increase with increase in percentages of RCA.

6 As strength of the member is reducing with increase in percentage of coconut shell, this can be used for low strength concrete mixes.

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