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Study on Properties of Coconut Shell Aggregate and Compressive Strength of Coconut Shell Concrete

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Abstract

Concrete is the premier construction material around the world and is most widely used in all types of construction works, including infrastructure, low and high-rise buildings, and domestic developments. It is a man-made product, essentially consisting of a mixture of cement, aggregates, water and admixture(s). Inert granular materials such as sand, crushed stone or gravel form the major part of the aggregates. Traditionally aggregates have been readily available at economic prices and of qualities to suit all purposes. But, the continued extensive extraction use of aggregates from natural resources has been questioned because of the depletion of quality primary aggregates and greater awareness of environmental protection. In light of this, the non-availability of natural resources to future generations has also been realized. Different alternative waste materials and industrial by products such as fly ash, bottom ash, recycled aggregates, foundry sand, china clay sand, crumb rubber, glass were replaced with natural aggregate and investigated properties of the concretes. Apart from above mentioned waste materials and industrial by products, few studies identified that Palm shell and coconut shells, the agricultural by products can also be used as aggregate in concrete. According to a report, coconut is grown in more than 86 countries worldwide, with a total production of 54 billion nuts per annum. India occupies the premier position in the world with an annual production of 13 billion nuts, followed by Indonesia and the Philippines. Limited research has been conducted on mechanical properties of concrete with coconut shells as aggregate replacement. However, further research is needed for better understanding of the behavior of coconut shells as aggregate in concrete.

Thus, the aim of this work is to provide more data on the physical properties of coconut shell and comparing the values with crushed stone aggregate. The result found that coconut shell aggregate shows less crushing strength value, less impact strength value, less abrasion resistance value than the crushed stone aggregate which is advantageous in terms of shock absorbance of concrete.

Key words: Coconut shell aggregate, Fineness modulus, Aggregate Impact value, Aggregate crushing value, Aggregate Impact Value and Compressive strength

1. INTRODUCTION

1.1 Scope of the Work

The aim of this study is to assess the utility and efficacy of coconut shells as a coarse aggregate as an alternative to natural aggregate in concrete. Coconut shells have not been tried as aggregate in structural concrete. Hence as a preliminary work, the physical properties of coconut shell aggregate is studied.

1.2 Waste Materials

In India Almost all over the world various measures aimed at reducing the use of primary aggregates and increasing reuse and recycling have been introduced, where it is technically, economically, or environmentally acceptable. As a result, in developing countries like India, the informal sector and secondary industries recycle 15–20% of solid wastes in various building materials and components. As a part of integrated solid waste management plan that includes recycle, reuse and recovery, the disposed solid waste, representing unused resources, may be used as low cost materials. Presently in India, about 960 MT of solid wastes are being generated annually as by-products from industrial, mining, municipal, agricultural and other processes. Of this, 350 MT are organic wastes from agricultural sources; 290 MT are inorganic wastes of industrial and mining sectors. However, it is reported that about 600 MT of wastes have been generated in India from agricultural sources alone. The coconut palm is one of the most useful plants in the world. Coconut is grown in 92 countries in the world. Global production of coconut is 51 billion nuts from an area of 12 million hectares. South East Asia is regarded as the origin of coconut. The four major players India, Indonesia, Philippines and Sri Lanka contribute 78% of the world production. According to FAO statistics (Food and Agriculture Organization) 2007, global production of coconuts was 61.5 MT with Indonesia, Philippines, India, Brazil and Sri Lanka as the major contributors to coconut production. The total world coconut area was estimated as approximately 12 million hectares and around 93 percent is found in the Asian and Pacific region. The average annual production of coconut was estimated to be 10 million metric tons of copra equivalents. Of the world production of coconut, more than 50 percent is processed into copra. While a small portion is converted into desiccated coconut 5 and other edible kernel products, the rest is consumed as fresh nuts. According to a study done by the Central Plantation Crop Research Institute (CPCRI) at Kasargod, the country's coconut production was headed for an all-time high of 5 14,370 million nuts in 2006-07. Higher productivity in Tamil Nadu was the main reason for the escalation in the production. In India, the southern states account for 90 per cent of the total production. Kerala tops with 5400 million nuts while Tamil Nadu with 4190 million nuts is the second highest producer. Currently, the crop is grown in 1.91 million hectares with an annual production of nearly 14,000,15700&17500million nuts. As per the recent Government of India statistics 2015-16 India has emerged as the largest producer of coconut in the world with a production of 15,840 million nuts. India accounts for 26.9 per cent of the world's production. In India, the four south Indian states namely Kerala, Tamil nadu, Karnataka and Andhra Pradesh account for around 90% of the coconut production in the country.

2. EXPERIMENTAL INVESTIGATION.

2.1 Materials

The materials used in this investigation were procured from local sources. Coconut shell are procured from Thanjavur District, Tamilnadu. Crushed stone are brought from the quarries from Pudukottai, Tamilnadu.

2.2 Coconut Shell

The coconut tree is one of the most useful plants in the world. Coconut is grown in 92 countries in the world. Global production of coconut is 51 billion nuts from an area of 12 million hectares. Coconut shells which were already broken into two pieces were collected from local copra preparing yard; air dried for five days approximately at the temperature of 25 to 30 C; removed fiber and husk on dried shells; further broken the shells into small chips manually using hammer and sieved through 12.5mm sieve. The material passed through 12.5mm sieve was used to replace coarse aggregate with coconut shells. The material retained on 12.5mm sieve was discarded. Fig 1 shows the coconut shell aggregate.

The sugar present in wood may cause incompatibility between wood and cement. Since the coconut shells aggregates are wood based, to estimate the sugar present in coconut shells.

Figure 1. Coconut shell aggregate

Generally, the parameters that determine the compatibility requirements for the coconut shells cement composite are maximum hydration temperature, time taken to attain maximum temperature, ratio of the setting times of coconut shells fines-cement mixture, neat cement and inhibitory index. Inhibitory effect is the measure of the decrease in heat release during the exothermic chemical process of cement hydration. The coconut shells cement compatibility was analyzed with the properties such as normal consistency, initial and final setting times, compressive strength and hydration using the samples of coconut shells fines with cement and neat cement.

2.3. Crushed Stone Aggregate

Aggregate in concrete is structural filler, but its role is more important than what that simple statement implies. Aggregate occupies most of the volume of the concrete. It is the stuff that the cement paste coats and binds together. The composition, shape, and size of the aggregate all have significant impact on the workability, durability, strength, weight, and shrinkage of the concrete. Aggregate can also influence the appearance of the cast surface, which is an especially important consideration in concrete countertop mixes. A Rough, angular shape of aggregate size of 20 mm is used in this study. Fig.2 shows crushed stone aggregate

Figure 2. Crushed stone aggregate

2.4. Experiment

2.4.1.Fineness Modulus

Fineness modulus is an empirical factor obtained by adding the cumulative percentages of aggregate retained on each of the standard sieves ranging from 80 mm to 150 micron and dividing this sum by 100.

2.4.2.Aggregate Crushing value

The aggregate crushing value gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load . With aggregate crushing value 30 or higher the result may be anomalous and in such cases the ten percent fines value should be determined instead.

One of the model in which pavement material can fail is by crushing under compressive stress. A test is standardized by IS: 2386 part-IV and used to determine the crushing strength of aggregates. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied crushing load.

The test consists of subjecting the specimen of aggregate in standard mould to a compression test under standard load conditions (See Fig-1). Dry aggregates passing through 12.5 mm sieves and retained 10 mm sieves are filled in a cylindrical measure of 11.5 mm diameter and 18 cm height in three layers. Each layer is tamped 25 times with at standard tamping rod. The test sample is weighed and placed in the test cylinder in three layers each layer being tamped again. The specimen is subjected to a compressive load of 40 tonnes gradually applied at the rate of 4 tonnes per minute. Then crushed aggregates are then sieved through 2.36 mm sieve and weight of passing material (W2) is expressed as percentage of the weight of the total sample (**W1**) which is the aggregate crushing value.

Fig.3.Aggregate crushing strength Test

2.4.3.Aggregate Impact Value

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal dia 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine. The material is filled in 3 layers where each layer is tamped for 25 numbers of blows (see Fig-3). Metal hammer of weight 13.5 to 14 Kg is arranged to drop with a free fall of 38.0 cm by vertical guides and the test specimen is subjected to 15 numbers of blows. The crushed aggregate is allowed to pass through 2.36 mm IS sieve. And the impact value is measured as percentage of aggregates passing sieve (W2) to the total weight of the sample (W1).

Aggregate impact value = (W1/W2)*100

Aggregates to be used for wearing course, the impact value shouldn't exceed 30 percent. Forbituminous macadam the maximum permissible value is 35 percent. For Water bound macadam base courses the maximum permissible value defined by IRC is 40 percent.

Abrasion Value – Coarse Aggregate

Abrasion test is carried out to test the hardness property of aggregates and to decide whether they are suitable for different pavement construction works. Los Angeles abrasion test is a preferred one for carrying out the hardness property and has been standardized in India (IS: 2386 part-IV).

The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated (see Fig-2). An abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340-445 g is placed in the cylinder along with the aggregates. The number of the abrasive spheres varies according to the grading of the sample. The quantity of aggregates to be used depends upon the gradation and usually ranges from 5-10 kg. The cylinder is then locked and rotated at the speed of 30-33 rpm for a total of 500 -1000 revolutions depending upon the gradation of aggregates.

After specified revolutions, the material is sieved through 1.7 mm sieve and passed fraction is expressed as percentage total weight of the sample. This value is called Los Angeles abrasion value.

A maximum value of 40 percent is allowed for WBM base course in Indian conditions. Forbituminous concrete, a maximum value of 35 percent is specified.

Fig.4. Los Angel Abrasion Test

2.4.5.Specific Gravity and Water absorption Test

The specific gravity and water absorption of aggregates are important properties that are required for the design of concrete and bituminous mixes. The specific gravity of a solid is the ratio of its mass to that of an equal volume of distilled water at a specified temperature. Because the aggregates may contain water-permeable voids, so two measures of specific gravity of aggregates are used:

1. Apparent specific gravity and
2. Bulk specific gravity.

Apparent Specific Gravity, G_{app}, is computed on the basis of the net volume of aggregates i.e the volume excluding water-permeable voids. Thus

$G_{app} = [(M_D/V_N)]/W$

Where,

M_D is the dry mass of the aggregate,

V_N is the net volume of the aggregates excluding the volume of the absorbed matter,

W is the density of water.

Bulk Specific Gravity, G_{bulk}, is computed on the basis of the total volume of aggregates including water permeable voids. Thus

$G_{bulk} = [(M_D/V_B)]/W$

Where,

V_B is the total volume of the aggregates including the volume of absorbed water.

Water Absorption: The difference between the apparent and bulk specific gravities is nothing but the water permeable voids of the aggregates. We can measure the volume of such voids by weighing the aggregates dry and in a **saturated surface dry condition**, with all permeable voids filled with water. The difference of the above two is M_W.

M_W is the weight of dry aggregates minus weight of aggregates saturated surface dry condition. Thus,

Water Absorption = $(M_W/M_D)*100$

The specific gravity of aggregates normally used in road construction ranges from about 2.5 to 2.9. Water absorption values ranges from 0.1 to about 2.0 percent for aggregates normally used in road surfacing.

Mix Methodology

No mix design is available throughout the world for agricultural waste aggregate. Hence a trial Mix is taken for this study from the previous researchers. The mix proportion is as follows

Mix ID	Cement Kg/m^3	Sand Kg/m^3	Coconut Shell Aggregate Kg/m^3	Water cement ratio
CSC	500	750	330	0.4

2.4.6. Slump Test

- Slump is a measurement of concrete's workability, or fluidity.
- It's an indirect measurement of concrete consistency or stiffness.

A slump test is a method used to determine the consistency of concrete. The consistency, or stiffness, indicates how much water has been used in the mix. The stiffness of the concrete mix should be matched to the requirements for the finished product quality.

Three mixes are prepared for slump test and the average slump is taken for the study.

3.Result and Discussion

3.1.Fineness Modulus

Fineness modulus of convention aggregate and Coconut Shell was found by doing Sieve analysis and presented in table 1 and 2. The fineness modulus of crushed stone aggregate is 6.9 and of coconut shell aggregate is 6.87. Both the values are almost same. Hence, as far as Fineness modulus of aggregate concerned, the coconut shell can be used in concrete.

Table 1.Fineness modulus of coarse aggregate

Sl.No.	Sieve Size mm	Weight retained g	Cumulative Weight retained g	% Cumulative Weight	% Passing	Fineness modulus
1	40					**6.9**
2	20	116	116	1.16	98.84	
3	10	8770	8886	88.86	11.14	
4	4.75	1114	10000	100	0	
5	2.36	-		100	0	
6	1.18			100	0	
7	0.6			100	0	
8	0.3			100	0	
9	0.15			100	0	
10	Total			690.02		

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Table 2.Fineness modulus of coconut shell aggregate

Sl.No.	Sieve Size mm	Weight retained g	Cumulative Weight retained g	% Cumulative Weight	% Passing	Fineness Modulus
1	40					**6.87**
2	20	162	162	1.62	98.38	
3	10	8602	8764	87.64	12.36	
4	4.75	996	9760	97.60	2.4	
5	2.36	240	10000	100	0	
6	1.18	0	10000	100	0	
7	0.6	0	10000	100	0	
8	0.3	0	10000	100	0	
9	0.15	0	1000	100	0	
10	Total			686.86		

3.2.Aggregate Crushing value

Aggregate crushing value of convention aggregate and Coconut Shell was found by doing Crushing Strength test Test and presented in table 3 and 4. For getting accuracy, three samples are taken and the result is obtained by finding the mean of the three samples. Aggregate Crushing value of crushed stone aggregate is 34.43 and of coconut shell aggregate is 2.52. the aggregate crushing value of coconut shell aggregate is very well below the values of crushed stone aggregate.

Table.3.Aggregate crushing value – Crushed Stone aggregate

Sample	Weight of sample g	Weight retained g	Weight Passed g	Aggregate crushing Value %	Average Aggregate Cruhing Value
A	3200	2100	1100	34.38	**34.43**
B	3210	2100	1110	34.58	
C	3190	2095	1095	34.33	

Table.4.Crushing value of Coconut Shell aggregate

Sample	Weight of sample g	Weight retained g	Weight Passed g	Aggregate crushing Value %	Average Aggregate Crushing Value
A	1267	1235	32	2.52	**2.52**
B	1270	1240	30	2.42	
C	1265	1232	33	2.61	

3.3. Aggregate Impact Value

Aggregate impact value of convention aggregate and Coconut Shell was found by doing Impact Test and presented in table 5 and 6. For getting accuracy, three samples are taken and the result is obtained by finding the mean of the three samples. Aggregate Impact value of crushed stone aggregate is 46.94 and of coconut shell aggregate is 7.88. the aggregate impact value of coconut shell aggregate is very well below the values of crushed stone aggregate.

Table 5. Aggregate Impact Value – Crushed stone aggregate

Sample	Weight of sample g	Weight retained g	Weight Passed g	Aggregate crushing Value %	Average Aggregate Crushing Value
A	550	300	250	45.45	**46.94**
B	550	295	260	47.2	
C	550	285	265	48.18	

Table 6. Aggregate Impact Value – Coconut Shell Aggregate

Sample	Weight of sample g	Weight retained g	Weight Passed g	Aggregate crushing Value %	Average Aggregate Crushing Value
A	200	184.5	15.5	7.75	**7.88**
B	200	184.0	16.0	8.0	
C	200	184.2	15.8	7.9	

3.4. Abrasion Value

Abrasion value of convention aggregate and Coconut Shell was found by doing Los Angel Abrasion Test and presented in table 7 and 8. Abrasion of crushed stone aggregate is 38.2 and of coconut shell aggregate is 2.2. the abrasion value of coconut shell aggregate is very well below the values of crushed stone aggregate.

Table 7.Abrasion Value – Crushed stone Aggregate

Sieve Size mm Passing	Sieve Size Mm Retaining	Weight of Aggregate g	No.of steel ball	Weight of charge in g	Weight of aggregate retained in 1.7 mm g	Weight of aggregate Passed in 1.7 mm g	Abrasion Value %
20	12.5	2500	11	4584	3090	1910	**38.2**
12.5	10	2500					

Table 8. Abrasion Value – Coconut Shell Aggregate

Sieve Size mm Passing	Sieve Size Mm Retaining	Weight of Aggregate g	No.of steel ball	Weight of charge in g	Weight of aggregate retained in 1.7 mm g	Weight of aggregate Passed in 1.7 mm g	Abrasion Value %
20	12.5	2500	11	4584	4890	110	**2.2**
12.5	10	2500					

3.4. Specific Gravity and Water absorption Test

The values of Specific gravity and water absorption is presented in table 9 and 10 respectively.The specific gravity of Conventional coarse aggregate is 2.64 and that of coconut shell aggregate is found to be very low and is reported as 1.18 respectively. Water absorption of crushed stone is only 0.76 % whereas for coconut shell aggregate it is reported very high value of 23.4 %.

Table 9. Specific gravity

Aggregate	Sample ID	Specific Gravity	Average Specific gravity
Crushed stone Aggregate	A	2.65	**2.64**
	B	2.62	
	C	2.66	
Coconut Shell Aggregate	A	1.2	**1.18**
	B	1.18	
	C	1.17	

Table 10. Water Absorption

	Sample ID	Water absorption %	Average water absorption %
Crushed stone Aggregate	A	0.65	**0.76**
	B	0.80	
	C	0.82	
Coconut Shell Aggregate	A	23.5	**23.4**
	B	23.2	
	C	23.4	

3.5. Slump of fresh Coconut Shell Concrete

Though the outer convex surface of coconut shell aggregate is rough, the smooth concave surface and super plasticizer inclusion facilitate a fair value of slump in coconut shell concrete. True slump is observed in all the three samples. Table 11 shows the slump value of coconut shell concrete. The specimen casted is shown in figure 4. Cube of 150 mm size and cylinders are casted to determine the compressive strength and tensile strength strength of coconut shell concrete.

Sl.No	Mix ID	Slump(mm)	Average Slump (mm)
1	CSC1	50	48
2	CSC2	50	
3	CSC3	45	

Figure 4. Cube specimen

3.6. Compressive Strength

The compression strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine. The cube, cylinder and beam will get fractured at their compressive strength limit. And the given amount of deformation may be considered as the limit for compressive load. The relevant photographs during the testing of concrete are given in table 12 and in figure.5. The compressive strength of the mix at 7days are shown in figure 3. A compressive strength value of 22.4 N/mm^2 is obtained at 7 days.

Figure.5.Testing for Compressive strength

Table 12. Compressive strength at 7 days

Sl.No	Mix ID	Compressive load (kN)	Average Compressive strength (N/mm^2)
1	CSC1	500	22.4
2	CSC2	525	
3	CSC3	490	

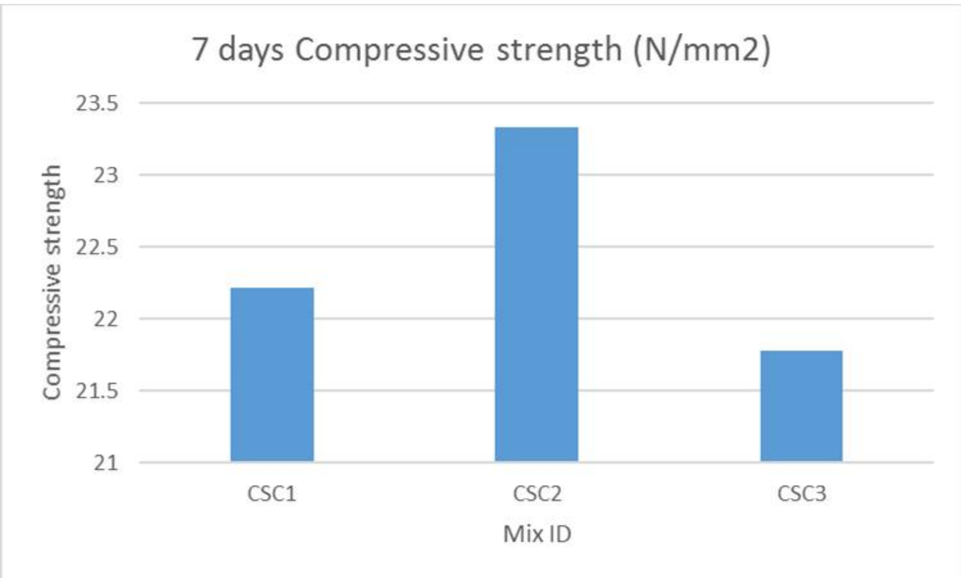

Fig.4. 7 days compressive strength

4. Conclusion

(i). Coconut shell aggregate exhibit a fineness value as close as to a conventional aggregate.

(ii). A very low aggregate crushing value and Aggregate impact value proves the concrete made of coconut shell aggregate is shock absorbent nature and is useful in seismic zone.

(iii) A very low Abrasion value of coconut shell concrete proves the concrete made of coconut shell aggregate can be used for pavement concrete.

(iv) A fair value of slump value of coconut shell concrete proves the concrete made of coconut shell aggregate can be used in heavily reinforced section

(v). A 7 days compressive strength value of 22.4 kN/mm^2 is arrived in coconut shell concrete. As per IS456:2000, coconut shell concrete can be used as a structural concrete.

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