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Evaluation of Strength Performance of Concrete by Partially Replacing Fine Aggregates with Coir Dust

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Abstract - *Concrete is the most important engineering material and the addition of some other materials may change the properties of concrete. Studies have been carried out to investigate the possibility of utilizing a broad range of materials as partial replacement materials for cement keeping in mind the increasing cost of construction material and environmental effects. Due to the high material consumption of the construction industry, the utilization of coir dust as a partial replacement for fine aggregate in non-structural concrete is particularly attractive. The study is aimed at investigating the effect of use of coir dust as partial replacement of fine aggregates in various percentages*

Key Words: Concrete, Coir dust, Compressive Strength, Split Tensile Strength, Fine Aggregate,

1. INTRODUCTION

The adverse effects of the construction industry can be controlled by coming up with alternate environmental conscious solutions in the construction space. Present day developments in technology have revealed that the organic and inorganic resources in solid waste materials are very valuable and can be used to produce various beneficial products. Therefore, in the current scenario it becomes more significant and the need of the hour to find a substitute material for it in the manufacture of concrete. Coconut fibre or coir, when dried, contains cellulose, lignin, pentosanes and ash in varying percentages. In Asia, the construction industry is yet to realize the advantages of light weight concrete in high rise buildings. Coconut dust is an agricultural waste whose applications as a substitute in fine aggregate is a viable prospect which can be further explored. The aim of this research is to spread awareness of using coir dust as partial replacement of fine aggregates in concrete and determining its compressive strength, split tensile strength and workability. The obtained results are compared with that of a conventional mix. Tests are conducted as per our Indian Standards.

1.1 Coir Dust

Coir is a natural fiber, extracted from the husk of coconut. Technically, coir is the fibrous material found between the hard internal shell and the outer coat of a coconut. Coir dust is a by-product of coir fiber production which is an important Industry in most countries where there are coconuts. Coir dust strongly absorbs liquids and gases. This property is due to the honeycomb like structure of the mesocarp tissue which gives it a high surface area per unit volume.

Coir dust has a similar dry density, water holding capacity (WHC) and available water content as sphagnum peat. The air-filled porosity (AFP) is slightly lower but this is compensated for by a more even distribution of moisture in the mix.

Production of coir dust: Husk is separated from the inner hard-shelled nut and it is soaked in water to soften the pith and loosen the fibres. The moist husk is then held against a revolving drum studded with metal spikes that comb the fibres out. During this operation, the long fibres are separated from the pith which accumulates with the unwanted short fibres beneath the machine. Coir dust is normally air dried and compressed into blocks or bails before it is exported to reduce transport costs. Before it can be used, the bale must be broken up. Compressed coir increases in volume by 3-4-fold on breakout.

1.3 Objective

This project mainly focuses on the effective utilization of the by-products from the coir industry and to reduce the problem of disposal of the industrial by-products. Also to check the feasibility of using the by-products from the coir industries as a partial replacement for fine aggregates. The objective of this study is to investigate the effect of use of coir dust as:

- Partial replacement of fine aggregates in various percentages (0–50%).
- To determine the concrete properties such as compressive strength, workability and split tensile test.
- To recycle industrial by-products and understand the effectiveness of coir dust in strength parameters.

2. MATERIALS AND ITS PROPERTIES

2.1 Cement

Ordinary Portland cement, conforming to I.S l2269-l987 is the most commonly used binder for the concrete production. Portland cement is the basic ingredient of concrete. Concrete is formed when Portland cement creates a paste with water that binds with sand and rock to harden.

Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients.

Portland cement clinker is made by heating a mixture of raw materials to a calcining temperature of above 600 °C (l,ll2 °F) in a cement kiln and then a fusion temperature, which is about l,450 °C (2,640 °F) for modern cements, to sinter the materials into clinker.

Sl. No.	**Characteristics**	**Values Obtained**	**Standard values**
1.	Normal Consistency	32%	-
2.	Initial Setting Time	40 min	Not less than 30 min
3.	Final Setting time	325 min	Not greater than 600 min
4.	Fineness	2.7%	<10
5.	Specific gravity	3.05	-

2.2 Coarse aggregates

Construction aggregate, or simply aggregate is a broad category of coarse to medium grained particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates. Aggregates are composite of materials such as concrete and asphalt concrete; the aggregate serves as reinforcement to add strength to the overall composite material. Due to the relatively high hydraulic conductivity value as compared to most soils, aggregates are widely used in applications of drainage Aggregates are also used as base-materials for foundations, roads, and railroads.

The size of aggregates bigger than 4.75mm is considered as coarse aggregates. Coarse aggregates used in the project is crushed angular stone with a maximum size of 20mm. The aggregates were tested as per Indian Standard Specifications IS: 383-l970. The results of various tests conducted on coarse aggregate are given in table below.

IS Sieve Designation	Cumulative Percentage		Specification as per IS:383-1970 (Percentage Passing)		
	Retained	Passing	Zone I	Zone II	Zone III
4.75 mm	0.06	99.94	90-100	90-100	90-100
2.36 mm	0.82	99.18	60-95	75-100	85-100
1.18 mm	15.34	84.66	30-70	55-90	75-100
600 μm	47.58	52.42	15-34	35-59	60-79
300 μm	92.52	8.48	5-20	8-30	12-40
150 μm	98.62	1.38	0-10	0-10	0-10

2.3 Fine aggregates

The size of the aggregates lesser than 4.75mm are considered as fine aggregates. IS specifications label the fine aggregate into four types of fine aggregate, consistent with its grading as grading zone-1 to grading zone-4. The four grading zones become progressively finer from grading Zone-1 to grading Zone-4. The aggregates were sieved through a set of sieves to obtain sieve analysis. The fine aggregates belonged to grading zone II. The properties of the fine aggregates are listed in table below.

Sl. No.	**Characteristic**	**Value**
1.	Specific Gravity	2.65
2.	Total water absorption	1%
3.	Fineness Modulus	2.62
4.	Grading	Zone II

IS Sieve Designation	Cumulative Percentage		Specification as per IS:383-1970 (Percentage Passing)		
	Retained	Passing	Zone I	Zone II	Zone III
4.75 mm	4.74	95.3	90-100	90-100	90-100
2.36 mm	7.37	92.63	60-95	75-100	85-100
1.18 mm	27.75	72.25	30-70	55-90	75-100
600 μ	47.70	52.3	15-34	35-59	60-79
300 μ	81.59	18.41	5-20	8-30	12-40
150 μ	92.34	7.66	0-10	0-10	0-10

2.4 Coir Dust

The coir dust was bought from Kachohalli near Magadi road. The physical properties of coir dust were tested with the same test procedure as that of fine aggregates. Coir dust was sieved through 4.75mm IS sieve. Coir dust requires no pre-treatment, except for water treatment. Coir dust has high water absorption. Due to this property, coir dust was pre-soaked in potable water for 24 hours before use. The characteristics of the coir dust are listed in the table 4 below.

Sl. No.	Characteristic	Value
1.	Specific Gravity	1.33
2.	Fineness Modulus	2.62
3.	Grading	Zone II

2.5 Water

The amount of water in concrete controls properties in concrete including workability, compressive strengths, permeability and water tightness, durability and weathering, drying shrinkage and potential for cracking. Water is added to wet the surface of aggregates and to develop adhesion because the cement pastes adheres quickly and satisfactory to the wet surface of the aggregates than to a dry surface. The function of water in concrete is to prepare a plastic mixture of the various ingredients and to impart workability to concrete to facilitate placing in the desired position and water is also needed for the hydration of the cementing materials to set and harden during the period of curing.

For the project, tap water was used for mixing and curing.

3. METHODOLOGY

Requirements of concrete mix design:

- The minimum compressive strength required from structural consideration.
- The adequate workability necessary for full compaction with the compacting equipment available.
- Maximum w/c ratio and/or maximum cement content to give adequate durability for the particular site conditions
- Maximum cement content to avoid shrinkage cracking due to temperature cycle in mass concrete.

Factors affecting the choice of mix proportions are workability, compressive strength of concrete, size, shape and grading of aggregates and durability.

Mix designing was done as per IS: 10262 – 2009 and the concrete was designed for M25 grade.

3.1 Volumetric Analysis of Coir Dust

Since the specific volume of fine aggregates and coir dust are different and the mix design is based on weight batching, the equivalent amount of coir dust to be replaced was determined using volumetric analysis. The volumetric ratio was found to be 1: 0.85.

3.2 Casting of Specimens

For the compressive strength test, concrete specimens were cast in 150mm x 150mm x 150 mm cube and for split tensile strength cylinders were casted. Three concrete cubes were casted at 3 days, 7 days, 14 days and 28 days and two cylinders at 28 days for each percentage replacement of coir dust (0, 12.5, 25 and 50%).

3.3 Curing of Specimens

The specimens were allowed to remain in the steel mould for the first 24 hours at ambient condition. After 24 hours specimens were demoulded by loosening the screws of the steel moulds with care and placed in the curing tank for curing till the date of testing

3.4 Workability Tests on Fresh Concrete

Concrete is said to be workable when it is easily placed without bleeding or Segregation and is assessed by Slump cone test. The workability of concrete was found to be decreasing as the percentage of the coir was increasing.

Sl. No	Type Of Concrete	Obtained Slump Value (Mm)
1	CC	72
2	CCD-12.5%	68
3	CCD-25%	66
4	CCD-50%	65

3.5 Compressive Strength Test On Hard Concrete

The compressive strength of concrete is the load which causes failure of the specimen divided by the area of the cross section in uni-axial compression, under a given rate of loading and expressed in N/mm^2. The compressive strength test was conducted on a direct compression testing machine with a capacity of 2000 KN. The load was applied on a uniform rate without any shock.

COMPRESSIVE STRENGTH= LOAD/AREA [N/mm^2]

3.6 Split Tensile Strength on Hard Concrete

Cylindrical specimens of size 150 mm dia x 300 mm height were cast. The test was conducted at the end of 28 days of curing and the average of 2 samples was taken as the representative split tensile strength of the mix.

SPLIT TENSILE STRENGTH= $2P/\pi DL$ [N/mm^2]

4. TEST RESULTS AND DISCUSSIONS

Type of concrete	Compressive strength (N/mm^2)				Split tensile strength (N/mm^2)
	3 days	7 days	14 days	28 days	28 days
CC	13.75	23.2	29.2	34.37	2.98
CCD-12.5%	9.5	15.4	18.93	23.66	2.25
CCD-25%	7.31	9.62	11.48	13.78	1.88
CCD-50%	3.3	4.44	5.56	7.11	0.90

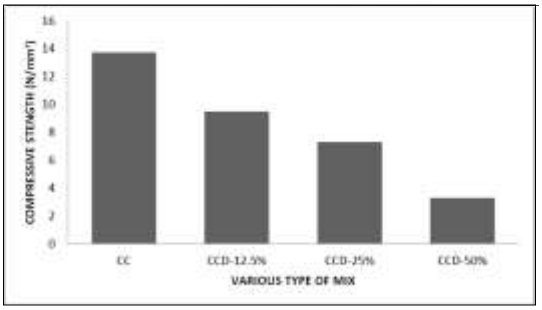

Fig -1: Third day compressive strength

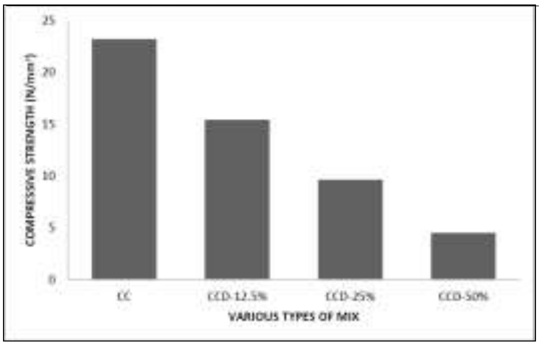

Fig -2: Seventh day compressive strength

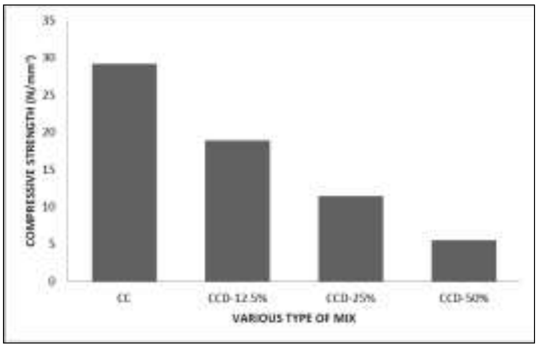

Fig -3: Fourteenth day compressive strength

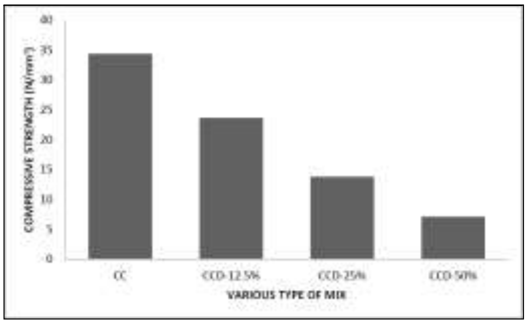

Fig -4: Twenty Eighth day compressive strength

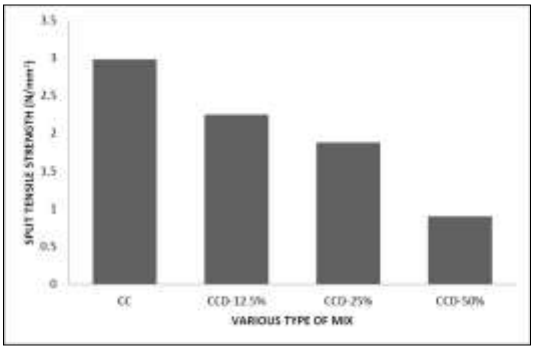

Fig -5: Graph for 28th day split tensile strength

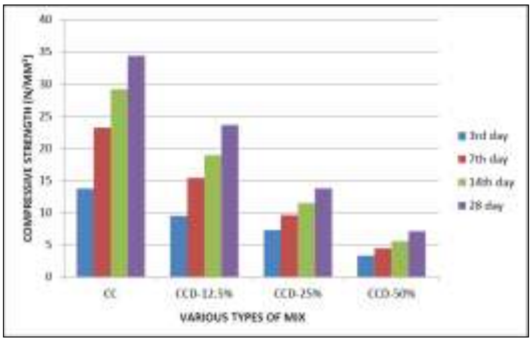

Fig -6: Comparison of compressive strength

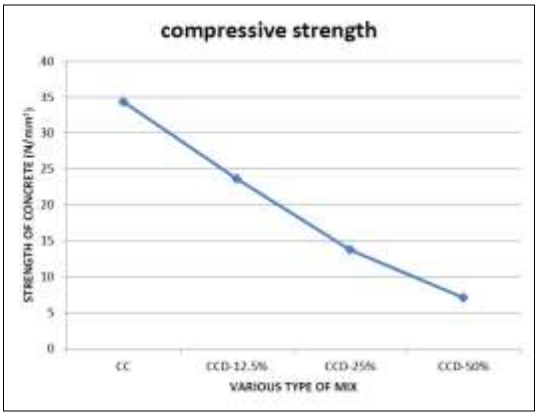

Fig -7: Twenty Eighth day split tensile strength

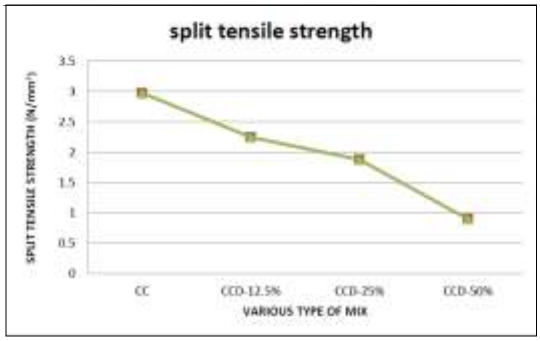

Fig -8: Twenty Eighth day split tensile strength

4.1 Cost Analysis

NATURAL RIVER SAND

Quantity of river sand in one load of truck = 18 tonnes

Cost of natural river sand per load = Rs.55000/-

Cost of natural river sand per tonne = Rs.3055.56/-

Therefore Cost of 1kg of river sand = Rs.3.055/-

COIR DUST

Coir dust was bought in bags, each bag weighing 25kgs

Cost of one bag of coir dust = Rs.40/-

Therefore Cost of 1kg of coir dust = Rs.1.6/-

Cost of fine aggregates in conventional concrete per cubic meter

Quantity of natural river sand per cubic meter = $800kg/m^3$

Cost of 800kgs of river sand = Rs.2444/-

Therefore total cost of fine aggregates without coir dust replacement per cubic meter = Rs.2444/-

Cost of fine aggregates for 12.5% replacement of coir dust per cubic meter

Quantity of natural river sand per cubic meter = $700kg/m^3$

Quantity of coir dust per cubic meter = $100kg/m^3$

Cost of 700kgs of river sand = Rs.2138.5/-

Cost of 100kgs of coir dust = Rs.160/-

Total cost of fine aggregates with 12.5% replacement of coir dust per cubic meter = Rs.2298.5/-

From the analysis it is observed that the cost of fine aggregates with 12.5% replacement by coir dust is found to be 6% lesser than the conventional concrete per cubic meter.

3. CONCLUSIONS

Based on the results obtained it can be concluded that coir dust is not an effective replacement of fine aggregates, but it is observed that density reduces as the percentage of coir dust increases. So, we can use the concrete having 12.5% replacement of coir for non- structural members since the strength is almost equal to conventional concrete.

The workability of the concrete decreases by 2-3mm when the percentage of coir dust increases by 12.5%. The compressive strength of the concrete decreases almost linearly as the coir percentage increases. The cost of fine aggregates with 12.5% replacement of coir dust is nearly 6% lesser than conventional concrete per cubic meter.

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