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An Experimental Investigation on Partial Replacement of Coarse Aggregate with Coconut Shell

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ABSTRACT

In this study, coconut shell is used as lightweight aggregate in concrete. The properties of coconut shell and coconut shell aggregate concrete is examined and the use of coconut shell aggregate in construction is tested. Moisture content and water absorption are more compared to conventional aggregate. Coconut shell exhibits more resistance against crushing, impact and abrasion compared to conventional aggregate. Density of coconut shell is in the range of 550 - 650 kg /m3 and these are within the specified limits for lightweight aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption.

Coconut shell cement ratio has been optimized to satisfy the criteria of structural lightweight concrete. An experimental study has been done in order to reduce the Coarse aggregate content in concrete by replacing it with the Coconut shell in various percentages ie.(5-30%) for M30 & M40 mix to determine compressive strength, flexural strength, splitting tensile strength were determined and a comparison made with control concrete. and durability of concrete and are compared for both grades and results are tabulated and the optimum percentages are concluded.

Coconut shell aggregate is a potential construction material and simultaneously reduces the environmental problem of solid waste.

INTRODUCTION

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 [1]. 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.

The mixtures when placed in forms and allowed to cure, hardens into a rock-like mass known as concrete. The hardening is caused by chemical reaction between water and cement and it continues for a longtime, and consequently the concrete grows stronger with age. The hardened concrete may also be considered as an artificial stone in which the voids of coarse aggregates are filled by fine aggregates and the voids of fine aggregates are filled with cement [2].

Coconut shell

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 is51 billion nuts from an

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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. Thetotal 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 [3]. Of the world production of coconut, more than 50 percent is processed into copra. While a small portion is converted into desiccated coconut and other edible kernel products, the rest is consumed as fresh nut

Fig 1.1 Coconut shell

Fig 1.2 Coconut shell as aggregates

Applications of coconut shell

- CS has good durability characteristics, high toughness and abrasion
- Resistant properties; it is suitable for long standing use. CS is mostly used as an
- Ornament, making fancy items, house hold utensils, and as a source of activated
- Carbon from its charcoal. The powdered shell is also used in the industries
- plastics, glues, and abrasive materials and it is widely used for the manufacture of insect repellent in the form of mosquito coils and in agarbathis
- The study of CS as an alternative for aggregates is another way of using the contributions a coconut tree will provide. The whole entity could be called coconut shell aggregate concrete (CSAC) [4].
- The studyof CS will not only provide a new material for construction but will also help in the preservation of the environment in addition to improving the economy by providing new use for the CS.
- Therefore attempts have been taken to utilize theCS as coarse aggregate and develop the new structural LWC

MATERIALS USED

Cement, fine aggregates, coarse aggregates, coconut shells were used in preparation of concrete The detailed specifications of the materials are given below.

Cement

Ordinary Portland cement available in the local market of standard brand of 53 grade confirming to IS 12269 - 1987 was used for the concrete mix. The cement should be fresh and of uniform consistency and there is no evidence of lumps or any foreign matter in the material. The cement should be stored under dry conditions and for as short duration as possible. The physical properties obtained from various tests are listed in Table 3.1. All tests are carried out in accordance to procedure laid in IS 1489 (Part 1): 1991.

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Coconut shell

CS is discarded at coconut industries ashalf-shell rounds. CS was collected from the local coconut oil mills to analyse the properties of CS in this study. CS have maximum thickness in range of 2-8mm they were crushed to the required sizes (Fig.3.3) in the range 3-12 mm inlength using the specially developed crusher.

Fine Aggregate:

Aggregates of size ranges between 0.075mm – 4.75mm are generally considered as fine aggregate. In this experimental work two types of Fine aggregate were used. They are River sand and (Bottom ash). The Fine aggregate are selected as per IS-383 specifications.

Coarse Aggregate:

Aggregate of size more than 4.75mm are generally considered as Coarse aggregate. The maximum size of Coarse aggregate used in this experimental work are 20 mm and 12 mm. A good quality of Coarse aggregate is obtained from nearest crusher unit. The Coarse aggregate are selected as per IS-383 specifications

Water:

Water is a liquid at standard temperature of 273.15k (0°C, 32°F). The intrinsic color of water and ice is a very slight blue hue. Water is a good polar solvent and is often referred to as the universal solvent. Water is used in concrete should be free from acids and alkalis and PH value is in between 6.5 – 8.5.

MIX DESIGN – M30

The steps involved in the design of concrete mix as per IS: 10262-2009, IS: 456-2000.

Stipulations for proportioning:

Grade designation	: M30
Type of Cement	: OPC 53 grade confirming to IS 12269:1987
Maximum nominal size of aggregate	: 20 mm
Exposure condition	: Severe (for reinforced concrete)
Degree of supervision	: Good
Minimum Cement content	: 320 Kg/m^3
Type of aggregate	: Crushed angular aggregate
Maximum cement content	: 450 kg/m^3
Workability	: 75mm

MIX DESIGN – M40

The steps involved in the design of concrete mix as per IS: 10262-2009 is a follows,

Stipulations for proportioning:

Grade designation	: M40
Type of Cement	: OPC 53 grade confirming to IS 12269:1987
Maximum nominal size of aggregate	: 20 mm
Exposure condition	: Severe (for reinforced concrete)
Degree of supervision	: Good
Minimum Cement content	: 320 Kg/m^3
Type of aggregate	: Crushed angular aggregate
Maximum cement content	: 450 kg/m^3
Workability	: 75mm

CASTING OF SPECIMENS

After completing the mix proportioning of materials concreting is done to represent the characteristics. Three types of concrete specimens are prepared in respective moulds in casting procedure. The types of specimens are Cubes, Beams and Cylinders [5]

CASTING PROCEDURE

Preparation of moulds:

The moulds for concreting are need prepare carefully before casting. All the moulds should be fitted properly. Oiling is done on the surface of the moulds for an easy removal of specimens.

Calculation of materials

The required materials are calculated for casting. The materials should be dry and well graded.

Mixing Concrete:

In mixing of concrete we are using hand mixing process. In concrete mixing process we are mixing cement, fine and coarse aggregates with required water content as per the design mix proportions.

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Compacting:

The testing cube specimens are made as soon as possible after mixing and in such a manner to produce full compaction of the concrete with either segregation or excessive bleeding. The concrete is filled into mould in layers approximately 5cm deep. In placing each scoopful of concrete, the scoop is required to be moved around the top edge of mould as the concrete slides from it in order to ensure a symmetrical distribution of the concrete within the mould. Each mould is compacted either by a needle vibrator or table vibrator. After the top layer has been compacted the surface of the cube up to the top of the mould is smoothed using a trowel. The top is covered with a glass or metal plate to prevent evaporation [6].

Casting of Specimens:

After mixing of concrete we can cast the specimens. In our project we are casting 3 types of specimens i.e., Cube, Cylinder, Prism moulds. Concrete is poured into the mould in three layers for cubes, prisms and five layers for cylinders and is compacted uniformly and compacting 25 blows per each layer by tamping rod.

Cube

Cylinder

Prism

Fig. 5 Casting of specimens

Curing:

The test specimens are stored in a place free from vibration in moist air of atleast 90% relative humidity and at a temperature of 270^{c} for 24 hours from the time of addition of water to the dry ingredients. After this period, the specimens are marked and removed from the moulds. Unless required for testing within 24 hours, they are immediately submerged in clean fresh water or saturated lime solution and are kept there until they are taken out just prior to test [7]. The water or solution, in which the specimens are submerged, are renewed every seven days and are maintained at a temperature of $270^{c} + 20^{c}$. The specimens are not to be allowed to become dry at any time until they have been tested

TESTING OF SPECIMENS

TESTS ON FRESH CONCRETE:

WORKABILITY:

Workability is defined as the property of concrete which determines the amount of useful internal work necessary to produce full compaction. Tests conducted for workability are compacting factor test and slump cone test.

Compaction Factor Test:

- The compacting factor test works on the principle of determining degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height.
- The degree of compaction called the compacting factor is measured by the density ratio.
- The ratio of the density actually achieved in the test to density of same concrete fully compacted.

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- The sample of concrete to be tested is placed in the upper hopper up to the brim.
- The trap door is opened so that concrete falls into lower hopper.
- Then the trap door of the lower hopper is opened and the concrete is allowed to fall in the cylinder.
- Then measure the weight of the cylinder which is known as "weight of partially compacted concrete".
- The cylinder is emptied and then refilled with the concrete from the same sample in three equal layers. The layers are heavily rammed to obtain full compaction.
- This weight is known as "weight of partially compacted concrete".
- Compacting factor is the ratio of "weight of partially compacted concrete" to "weight of partially compacted concrete".

Fig.6.1 Compaction factor apparatus

Slump Cone Test:

- The apparatus for conducting the slump test essentially consists of a metallic mould in the form of frustum of a cone have internal dimensions, bottom diameter 20 cm, top diameter 10 cm and height 30 cm.
- Before conducting test the internal surface of the mould is thoroughly cleaned.
- Then mould is placed on a smooth, horizontal, rigid and non- absorbent surface.
- The mould is then filled in four equal layers with prepared concrete. Each layer is tamped 25 times by tamping rod.
- After the top layer has been rotted the concrete has been struck off level with a trowel and tamping rod.
- The mould is removed from the concrete immediately by raising it slowly and carefully in vertical direction.
- This allows the concrete to subside. The subsidence is referred as slump of concrete.
- The difference in level between height of the mould and that of the highest point of subsided concrete is measured.

Fig.6.2 Slump cone apparatus

TESTS ON HARDENED CONCRETE:

COMPRESSIVE STRENGTH TEST:

- Concrete specimen cubes were used to determine the compressive strength of concrete as per IS 516-1959.
- The compression testing machine (microprocessor based) used for testing the cube specimens is of standard make.
- The capacity of the testing machine is 2000 tons. The machine has a facility to control the rate of loading with a control valve.
- The plates are cleaned and oil level is checked, and kept ready in all respects for testing.
- After the required period of curing, the cube specimens are removed from the curing tank and cleaned to wipe off the surface water.
- It is placed on the machine such that the load is applied centrally.

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- The smooth surfaces of the specimen are placed on the bearing surfaces.
- The top plate is bought in contact with the specimen by rotating the handle.
- The oil pressure valve is closed and the machine is switched on.
- Then the load shall be applied without shock and increased continuously at a rate of approximately 140 kg/sq cm/min until the resistance of the specimen to the increasing load breaks down and no greater load can be sustained.
- The maximum load applied to the specimen shall then be recorded and the appearance of the concrete and any unusual features in the type of failure shall be noted.
- Then compressive strength is measured by dividing maximum load applied to the specimen to cross sectional area.

Fig.6.3 Compressive testing machine

SPLIT TENSILE STRENGTH TEST :

- Test for split tensile strength consists was conducted according to IS: 5816-1999.
- Split tensile strength is conducted on specimens of diameter 15 cm diameter and 30 cm length.
- Specimens when received dry shall be kept in water for 24 hours before they are taken for testing.
- Unless other conditions are required for specific laboratory investigation specimen shall be tested immediately on removal from the water whilst they are still wet.
- Surface water and grit shall be wiped off the specimens and any projecting fins removed from the surfaces which are to be in contact with the packing strips.
- Central lines shall be drawn on the two opposite faces of the cube using any suitable procedure and device that will ensure that they are in the same axial plane.
- The test specimen shall be placed in the centering jig with packing strip and/or loading pieces carefully positioning along the top and bottom of the plane of loading of the specimen.
- Then the load shall be applied without shock and increased continuously at a nominal rate within the range 1.2 N/ (mm2/min) to 2.4 N/ (mm2/min).
- The failure load applied on the specimen was recorded. Finally the split tensile strength of the specimen was computed as mentioned below.

$$\text{Split Tensile Strength} = 2P / (\pi \times l \times d)$$

Where P = maximum load recorded

l = length of cylinder

RESULTS

COMPRESSIVE STRENGTH

Compressive strength is obtained by applying crushing load on the cube surface. So it is also called as Crushing strength. Compressive strength of concrete is calculated by casting 150mm x 150mm x 150mm cubes. The test results are presented here for the Compressive strength of 7 days and 28 days of testing.

The water cured specimens are eliminated from moisture content by surface drying before testing in CTM [8]. The detailed test results are summarized as follows

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Table 7.1 Compressive strength results of M30 and M40 Grade

Mix	Compressive Strength (N/mm²)			
	M30 Grade		M40 Grade	
	7 Days	28 Days	7 Days	28 Days
C_1-0%	25.2	35.35	31	41.02
C2-5%	25.8	35.82	32.32	41.63
C3-10%	26	36.84	32.54	41.75
C4-15%	26.25	37.52	32.92	42.82
C5-20%	26.84	38.34	32.6	43.85
C6-25%	27.1	38.52	32.81	44.92
C7-30%	25.2	26.23	26.6	32.25

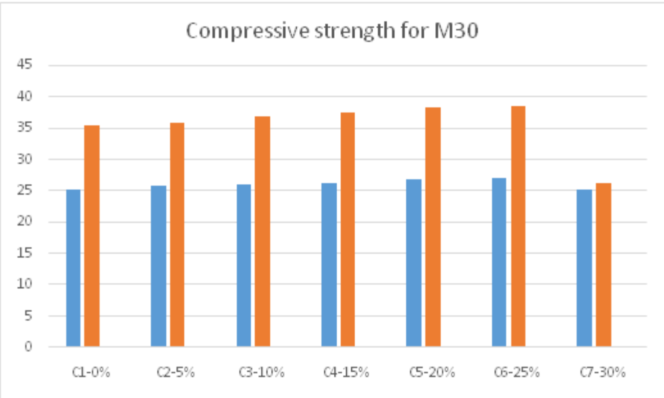

Fig7.1.1 Compressive strength variation for M30 grade at 7 & 28 days

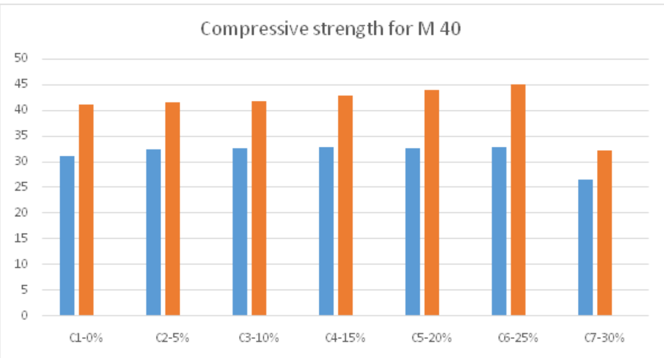

Fig 7.1.2.Compressive strength variation for M40 grade at 7 & 28 days

SPLIT TENSILE STRENGTH

Out of all the properties of concrete, tensile strength is very important one. The tensile strength is calculated by testing cylindrical specimens of size 300mm height and 150mm diameter. Here each set of specimens are tested for 7 days and 28 days of curing. The details of test results are summarized below

Table 7.2 Split tensile strength results of M30 and M40 Grade

Mix	Split tensile Strength (N/mm²)			
	M30 Grade		M40 Grade	
	7 Days	28 Days	7 Days	28 Days
C_1-0%	2.28	2.44	3.20	3.82
C2-5%	2.29	2.63	3.24	3.9
C3-10%	2.32	2.70	3.26	3.92
C4-15%	2.38	2.38	3.32	3.94
C5-20%	2.40	2.64	3.48	3.98
C6-25%	2.41	2.48	3.52	4.02
C7-30%	2.43	2.31	2.82	2.26

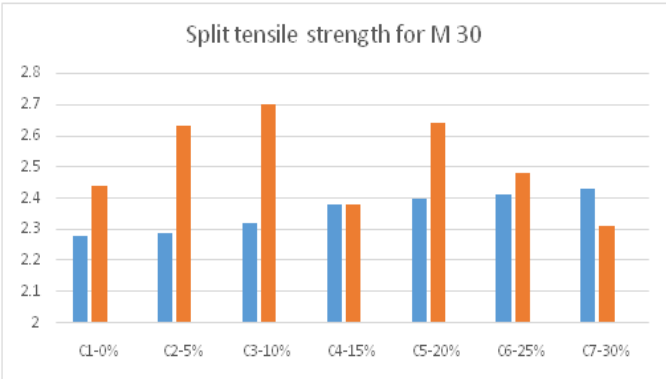

Fig 7.2.1Split tensile strength variation for M30 grade at 7 & 28 days

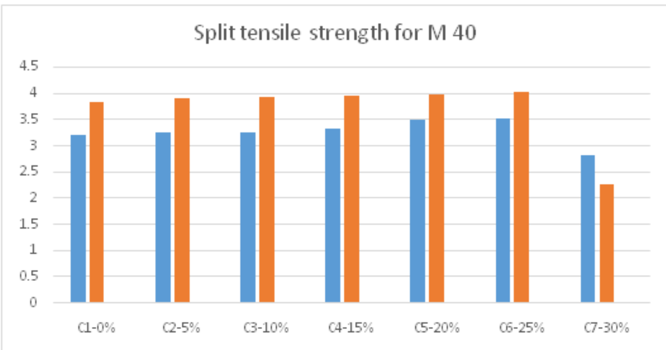

Fig 7.2.2Split tensile strength variation for M40 grade at 7& 28 days

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CONCLUSIONS

After the analysis of the result of the experimental programme the following conclusions were arrived.

- The possibility of recycling and reuse of coconut shells which are discarded as waste led to studies into its possible use as coarse aggregate in the development of lightweight concrete
- The test results obtained from this study also provide significant understanding on basic properties, bond behavior, and durability properties, flexural and shear behavior of coconut shell aggregate concrete
- Coconut shell exhibits more resistance against crushing, impact and abrasion, compared to crushed granite aggregate. Coconut shell can be grouped under lightweight aggregate. There is no need to treat the coconut shell before use as an aggregate except for water absorption.
- Coconut shell is compatible with the cement. The 28-day air-dry densities of coconut shell aggregate concrete are less than 2000 kg/m3 .
- By seeing the compression strength results, there is a nominal increase in the strength up to 25%of coconut shell replacement and decreasing in the case of above 25 %coconut shell replacement with reference to conventional concrete at 28 days.
- By seeing the split tensile strength results, there is a nominal increase in the strength up to 25%of coconut shell replacement and decreasing in the case of25 %coconut shell replacement with reference to conventional concrete at 28 days.
- By seeing the Flexural strength results, there is a nominal increase in the strength up to 25%of coconut shell replacement and decreasing in the case of25 %coconut shell replacement with reference to conventional concrete at 28 days.
- The resulting values of flexural strength and splitting tensile strength of CSAC [9] were comparable to other concretes. Impact resistance of CSAC is more compare to CC. Modulus of elasticity of coconut shell aggregate concrete is approximately one-third of control

SCOPE FOR FUTURE WORK

- CSAC may be beneficial for use in earthquake prone areas, since it is light weight and has shown good ductility. By reducing the self weight of the structure, catastrophic earthquake forces and inertia forces that influence the structures can be also be reduced ultimately, as these forces are proportional to the weight of the structures.
- Therefore, the behavior of CSAC subjected to earthquake loadings can be explored
- Drying shrinkage characteristics of CSAC can be studied, since this is also the important part especially for structural lightweight concrete.
- Effect of admixtures on CSAC can be studied. CS can be also used to produce non-load bearing elements and particle board and the properties can be studied.

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