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Exploring the Properties of High Strength Lightweight Concrete through A Systematic Investigation

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Abstract— High strength lightweight concrete made by coconut shell as coarse aggregate offers a sustainable alternative for conventional coarse aggregate. This paper presents the mechanical properties of high strength lightweight concrete. The coconut shell is used as a partial replacement for conventional coarse aggregate in the production of concrete. The coconut shell was added by 0, 10%, 20%, 30% and 40% by weight of coarse aggregate. Alccofine is added 15% by weight of cement, as a mineral admixture for improving the strength of concrete. The concrete is designed for M50 grade. The cube and cylinder specimen were casted and tested after 7, 14 and 28 days. The maximum compressive strength achieved is 55.9 MPa.

Key words: Alccofine, Coconut shell, High Strength Concrete, Lightweight Concrete, Mechanical Properties

1 INTRODUCTION

1.1 General

Concrete is a composite material made of fine and coarse aggregate bonded together with cement and water. Aggregates are large chunks of material in a concrete mix, generally coarse gravel or crushed rock along with finer material such as rock. A fluid slurry is formed at the time that aggregates are blended with dry cement and water. The mixture thus formed is easily poured and molded into shape. Often, additives such as superplasticizers are included in the mixture to improve the physical properties of the mix. High demand for concrete in construction using normal weight aggregate, has drastically reduced natural stone deposits and this has caused irreparable damage to the environment. Also, due to the increased population and modern living habits, the production of waste material is increasing and its disposal has become a genuine problem. In view of these issues, the reuse of various type of waste material in the production of concrete has been investigated. Using alternative materials like industrial slag, waste plastic, over burnt bricks, coconut shell, oil palm shell, waste rubber tyres, waste glass, recycled coarse aggregate, papercrete etc. in place of natural aggregate in the concrete production make concrete as sustainable and environmentally friendly construction material. The present study focuses on the use of waste coconut shell as partial replacement for conventional coarse aggregate forthe production of concrete.

1.2 Lightweight Concrete

Lightweight concrete mixture is made with a lightweight coarse aggregate and sometimes a portion orentire fine aggregate may be lightweight instead of normal aggregate. Structural lightweight concrete has unit weight of 1440 to 1840 kg/ m ^{3}. Lightweight aggregates used in lightweight concrete are, expanded clay, shale, coconut shell etc.

1.3 High Strength Lightweight Concrete

Structural lightweight concrete with a minimized density at a definite strength level is called high strength lightweight concrete. High strength lightweight concrete has unique performance characteristics: low density (less than 1500 kg/m^3) and high compressive strength (more than 70 MPa). Mineral and chemical admixtures have been used to produce highstrength lightweight concrete to increase strength.

1.4 Coconut Shell Concrete

Coconut shell concrete is a mixture of cement, sand aggregate and crushed coconut shell aggregate. In this type of concrete, crushed stone is replaced partially or fully with crushed coconut shell to utilize the environmental sources and protect the environment. Thus the main aim is to utilize the coconut shell and to achieve the strength with different percentage of coconut shell aggregate in concrete. The bulk density of coconut shell is about 500 to 600

kg/m^3, making the concrete with weight of less than 2000 kg/m^3. The coconut shell concrete straight forwardly achieve the strength of around 17 N/mm^2.

1.5 Need for this Study

Since structural concrete is used extensively in the construction of various kinds of building and aggregate contribute significantly to the structural performance of concrete, high demand for concrete using normal weight aggregate such as gravel and granite drastically minimize the availability of naturalstone resources and damages the environment thereby causing ecological imbalance. Therefore there is a need to explore and find suitable replacement material to substitute the natural stone aggregate.

2 MATERIALS USED

2.1 Cement

Ordinary Portland cement confirming to IS 8112-1989 is used for experimental work. It is composed of calcium silicate sand, aluminate sand, and alumina ferrite. Cement is hygroscopic material meaning it absorbs moisture, in presence of moisture it undergoes chemical reaction termed hydration. Laboratory test were conducted on cement to determine specific gravity, consistency, initial and final setting time and fineness.

2.2 Alccofine

Alccofine is a new generation microfine material of particle size much finer than other hydraulic materials like fly ash, cement, silica etc. being manufactured in India. Alccofine has unique characteristics to enhance the performance of concrete in fresh and hardened stages due to its optimized particle size distribution. It is manufactured in the controlled conditions with special equipments to produce optimized particle distribution which is its unique property. Due to the ultra-fineness of alccofine 1203, it reduces the demand of water for a given workability, even up to 70%replacement level as per requirement.

2.3 Fine Aggregate

Aggregate which is passing through 4.75 IS sieve is termed as fine aggregate. Fine aggregate is added to concrete to aid workability and to bring uniformity in the mixture. Usually river sand is used as fine aggregate for producing concrete. The locally available good quality M sand was used in this project. M sand is a substitute for river sand in the production of concrete. Due to the depletion of good quality river sand for the use of construction, the manufactured sand has been used. These, manufactured sand is produced from hard granite stone by crushing. The size of M sand is in between 4.75mm to 150 micron. The fine aggregate was tested in laboratory to determine the different physical properties.

2.4 Coarse Aggregate

The size of aggregate bigger than 4.75 mm is considered as coarse aggregate crushed stone obtained bycrushing of granite that could pass through 20 mm sieve and retained on 4.75mm IS sieve and contained only so much of five materials as is permitted by specification along were produced. Coarse aggregate is used mainly for providing bulk to the concrete to the strength of concrete depends also on the strength of the coarse aggregate and hence selection of suitable aggregate is very essential. It should be hard, strong, dense, durable, rough and free from salt and organic matters. Well graded aggregate provided denser concrete with lessvoids. The coarse aggregate was tested in laboratory to determine various physical properties.

2.5 Coconut Shell Aggregate

Waste coconut shells are collected from various places. They were dried under sun for 30 days before being crushed manually. Shells were broken by hammer into smaller size. The crushed shells were then washed and permitted to dry under ambient temperature for another 30 days. The range of the particle sizes of coconut shell was kept between 5 to 20 mm for use in concrete. The shell should be submerged in water for 24 h before using it as aggregate. The surface texture of the shell was fairly smooth on concave face and rough on convex face. The laboratory tests are conducted to identify the physical properties of coconut shell.

Figure 2.1 Coconut Shell Aggregate

2.6 Water

Water is an important ingredient of concrete as it actively participates in the chemical relation with cement. The quantity and quality of water is required to be watched into carefully so that it can form the strengthgiving cement gel. Portable water is used for making mortar. The pH value of water is between 6 and 8 that shows the water is free from organic matters. The water is required to chemically act with the cement and to provide workability to the concrete. The amount of water poured in the mix compared with the amount of cement is called the water/cement ratio. The strength of concrete increases as the w/c ratio reduces (higher strength, less permeability).

The various physical properties of materials used in this project are tabulated in the table 2.1.

Table 2.1 Properties of materials used

Properties	Cement	Alcco fine	Fine aggregate	Coarse aggregate	Coconut shell
Specificgravity	3.15	2.7	2.56	2.67	1.2
Fineness	6	_	2.56	6.4	6.84
Consistency	32%	_	_	_	_
Intial settingtime	30 minutes	_	_	_	_
Final settingtime	185 minutes	_	_	_	_
Water absorption	_	_	1.5%	1.1%	15%
Impactstrength	_	_	_	7.6%	2.7%

EXPERIMENTAL PROGRAM

In this experimental program compression and split tensile test were carried out for various percentage replacement of conventional coarse aggregate by coconut shell aggregate at 7, 14 and 28 days. Before mixing the concrete, aggregates were prepared to the saturated surface dry condition. The coconut shell aggregates were soaked in water for 24 hrs before mixing the concrete. Cube (150mm X150mm X 150mm) and cylinder (150mmX 300mm) specimen were casted for conducting the tests. Indian standard methods were used for sampling and testing the concrete.

3. RESULT AND DISCUSSION

3.1 Compressive Strength

Compressive strength at 7, 14 and 28 days were conducted on cube specimen of size 150mm X 150mm X 150mm. The test was carried out by initially clean the bearing surface of the testing machine. Then, put the specimen in the compression testing machine in such a way that the load shall be applied to the opposite sides of the cube. Position the specimen in the center on the base plate of the machine. After aligning, apply the load gradually till the specimen fails. Finally, record the maximum load. The test results were tabulated in table 4.1. The compressive strength of coconut shell concrete gradually increases up to 20% replacement of coconut shell with coarse aggregate and then decreases. The maximum compressive strength achieved was 55.9 N/ mm^2.

Table 4.1 Compressive Strength

Sl. no	Specimen type	Replacement ofcoconut shell (%)	Average strength at7 days (N/mm^2)	Average strength at 14 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	Cube	0	43.1	51.3	59.4
2	Cube	10	24.1	28.1	35.6
3	Cube	20	36	44.6	55.9
4	Cube	30	32.3	43.1	50.2
5	Cube	40	15.7	18.9	22.1

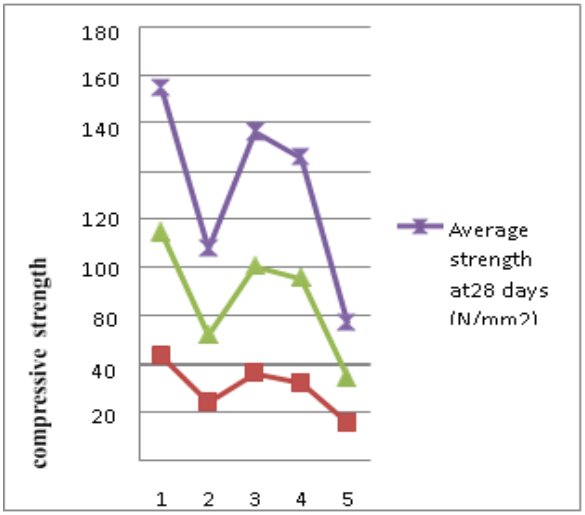

Figure 4.1 Graph showing Compressive Strengthfor Various % Replacement of Coconut Shell

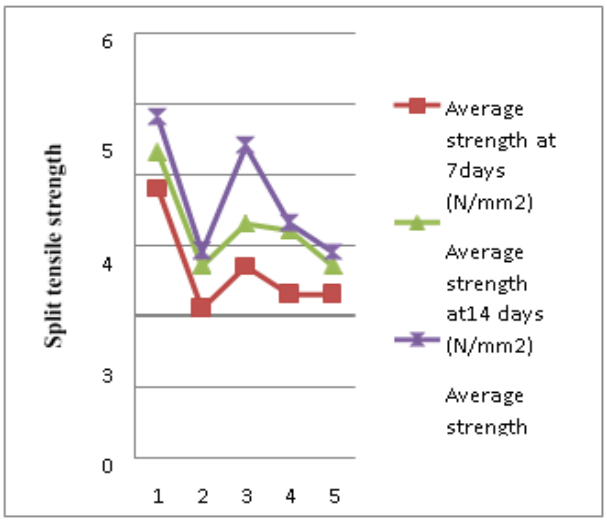

Figure 4.2 Graph showing Split Tensile Strength for Various % Replacement ofCoconut Shell

3.2 Split Tensile Strength

Split tensile strength was carried out by using Compression testing machine using the cylinder specimen of size 150mm X 300 mm. To evaluate the splitting strength of the specimen, first of all clean thebearing surface of the testing machine. Then, the cylindrical specimen is placed in a manner that the longitudinal axis is perpendicular to the load. Apply the load gradually till the specimen fails. Finally, record the maximum load. The results were tabulated in table 4.2. The split tensile strength of coconut shell concrete with various percentage was calculated and compared with the conventional concrete. The maximum strength was achieved at 20 % replacementof coarse aggregate by coconut shell.

Table 4.1 Split tensile Strength

Sl. no	Specimen type	Replacement of coconut shell (%)	Average strengthat 7 days (N/mm^2)	Average strength at 14 days (N/mm^2)	Average strength at 28 days (N/mm^2)
1	Cylinder	0	3.8	4.3	4.8
2	Cylinder	10	2.1	2.7	2.9
3	Cylinder	20	2.7	3.3	4.4
4	Cylinder	30	2.3	3.2	3.3
5	Cylinder	40	2.3	2.7	2.9

4. CONCLUSION

From all the test results, it can be seen that the maximum compressive and split tensile strength was achieved at 20% replacement of coarse aggregatewith coconut shell. It can be concluded that, the coconut shell can be used as coarse aggregate up to 20% by weight of the conventional coarse aggregate.

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