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Experimental Investigation on Use of Cockle Shell as Partial Coarse Aggregate Replacement in Concrete

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***Abstract*—** *Preserving natural coarse aggregate for future generation and reducing cockle shell waste has initiated studies on possibility of integrating this waste in concrete production. The main of this research work is to encourage the use of waste products such as cockle shell construction materials in low-cost building. In this research study an experimental investigation was conducted on varying percentages of (0%, 7%, 14%, 21%, and 28%) cockle shell as coarse aggregate replacement for M20 grade of concrete to produce an environment friendly concrete. Tests were conducted to analyse the properties of materials used in concrete. Properties of fresh and hardened concrete were obtained by workability test, strength test, durability test and non-destructive test (NDT). The optimum percentage of replacement of cockle shell as coarse aggregate in M20 grade of concrete was obtained as 21%. The results of the research work show that cockle shell is an effective alternative for partial replacement of coarse aggregate in concrete, which may produce workable and eco-friendly concrete with high strength on optimum percentage of replacement.*

***Keywords*—** *Concrete, Cockleshell, Strength test, Workability, Durability, Non destructive test.*

I. INTRODUCTION

The increase in construction works in the country has increased demand for the construction materials. The insufficiency of the conventional construction materials such as granites, sand, cement etc increases the demand of these construction materials. This increases cost of constructions such as buildings, roads, pavements etc. It is very necessary to make meaningful efforts to save the nation from the housing problem. Scientists, engineers and technologists are continuously are searching for the materials, which can act as substitute for conventional materials in concrete and possess the required properties leads to reduction in the cost of construction.

The growing construction industry had caused the destruction of natural aggregates. The natural sources of aggregates will soon decrease. Aggregates are obtained from two primary sources, viz. quarries and river beds. Environmental issues occur when there is extraction of sand and gravel. The aggregate extraction and processing are the principal causes of environmental problems.

The need for replacement of natural aggregates is a growing requirement to meet the demand for aggregates in concrete. Recent studies aim on the locally available waste to be used as aggregates instead of natural aggregate materials. Such a waste is the seashells obtained from coastal areas, freshwater lakes and riverine areas. Recent investigation of sea shells has indicated greater scope for their utilization as a replacement to cement and aggregate in concrete. Cockleshell is a hard, protective layer, a calcareous exoskeleton which supports and protects the soft parts of an animal. As they grow old, the shells increase in size which becomes a strong compact casing for the mollusc inside. The hard shells are regarded as waste material, which are accumulated in many parts of the country, when dumped and left untreated may cause unpleasant smell .Cockle shell as one of the mixing ingredient in concrete production thus opening a new innovation in concrete research and at the same time offering. Therefore cockle shells are a viable option as partial replacement to coarse aggregate because they contain a large amount of calcium carbonate. Also the calcium carbonate can help improve resistance against heat and chemicals. Cockle shell obtained from dumbing site are washed and cleaned before use as shown in fig. 1. The partial replacement of coarse aggregate with cockle in concrete mix potentially reduces the cost of constructions and makes the concrete industry more environmentally sustainable.

Fig. 1. Washed and cleaned cockle shell

II. OBJECTIVES AND SCOPE OF STUDY

The main objectives of this research work are listed below

- To evaluate the possibility of reducing the quantity of natural coarse aggregate in concrete by partial replacement of coarse aggregate with cockle shell.

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- To investigate the material properties and strength properties of concrete by using cockle shell as partial replacement to coarse aggregate.
- To obtain the optimum percentage of replacement of coarse aggregate with cockle shell in concrete. The percentage of replacement of cockle shell adopted were 0%, 7% , 14% , 21% and 28%.

Concrete is the main constituent material in construction process. Every year, the usage of concrete is increasing at a fast rate. This increased the necessity of finding alternative materials for production of concrete. Possibility in usage of concrete with partial replacement of aggregates with cockle shell to the high rise structures with large load bearing capacity is not analysed yet. The partial coarse aggregate replacement by seashell in concrete is cost effective and environment friendly. It can be investigated by using different types of sea shells to reduce the environmental issues related to their disposal. Cockle shell availability is limited to marine lands that may effect its usage as a partial replacement in concrete as coarse aggregate.

III. METHODOLOGY

Test results analysis and Methodology adopted are as follows

- Selection of materials
- Testing of materials
- Concrete mix design
- Testing of properties of fresh concrete (workability test)
- Preparation of test specimen
- Testing of properties of hardened concrete such as compressive strength test, flexural strength test and split tensile strength test
- Non Destructive test (UPV test)
- Durability test
- Density test
- conclusion.

IV. MATERIALS AND TESTS

Materials used in concrete specimen preparation were cement, fine aggregate, coarse aggregate and water. For experimental work coarse aggregates were replaced with various percentage of cockle shells. Reinforcement bars used in casting of beam specimen in each mix was Fe 415. To analyse material properties various tests were conducted on cement, coarse aggregate, fine aggregate and cockle shell. Properties of all these materials were tested and analyzed. Results are shown in the table I ,table II, table IV and table V. Water used for mixing and curing was clean and free from Oils, Acids, Alkalis, Salts, Sugar and Organic materials. Potable water was used.Mixing and curing with sea water was not be permitted.

TABLE I. Properties of cement

Properties	Values obtained
Fineness	3%
Specific Gravity	3.13
Consistency	30%
Initial Setting Time	78 Minutes
Final Setting Time	253 Minutes

TABLE II. Properties of fine aggregate

Properties	Values obtained
Fineness Modulus	3.61
Specific Gravity	2.3
Grading Zone	II
Water absorption	1%

TABLE III. Properties of coarse aggregate

Properties	Values obtained
Fineness Modulus	3.9
Specific Gravity	2.9
Water absorption	0.5%
Bulk density	1.59
Void ratio	0.83

TABLE IV. Properties of cockle shell

Properties	Values obtained
Fineness Modulus	4.44
Specific Gravity	2.5
Water absorption	0.1%
Bulk density	1.52
Void ratio	0.88

V. DESIGN MIX

The mix design of concrete is done based on properties of cement, fine aggregate, coarse aggregate and water. The mix proportion for concrete is obtained as 1: 1.56: 3.22 and water cement ratio was 0.5

VI. EXPERIMENTAL INVESTIGATION

Experimental investigation have been conducted on concrete specimens in which coarse aggregate were partially replaced with cockle shells at various percentages. The tests were conducted to determine the properties of fresh and hardened concrete

A. Workability Test

Workability test is conducted on fresh concrete mixes to determine its properties. Slump cone test is a method to determine the workability of fresh concrete. Workability grade corresponding to slump value is determined as per IS code IS:456, 2000.

B. Compressive Strength Test

Compressive strength is defined as the load which causes the failure of standard specimen divided by area of cross section in uniaxial compression under given rate of loading [26]. Compressive strength test was conducted on cubes for different percentage of replacement (0%, 7%, 14%, 21%, and 28%) and average of 6 results obtained from 6 identical cubes for each percentage of replacement was reported'

C. Split Tensile Strength Test

Concrete is brittle in nature because of its low tensile strength. It is not capable to take direct tension. That is concrete is strong in resisting compressive force and weak in resisting tensile force. Tensile strength of concrete is determined indirectly by conducting splitting tensile strength test.

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D. Flexural Strength Test

Flexural strength of concrete is the ability to resist deformation under loading. Flexural strength of the specimen was expressed as the modulus of rupture. It is the maximum tensile stress acting on the bottom of the testing beam. Flexural strength reported is the average of 3 results obtained from 3 identical beams.

E. Durability Test

Durability of concrete is referred as the capability of concrete to resist the chemical attack, weathering action, or any other action which destroy its condition. The main chemicals and reactions which effect the durability of concrete is chloride attack, sulphate attack, and alkali aggregate reaction. Durability of concrete replaced with cockle shell is tested based on acid attack test (sulphate attack).

F. Ultrasonic Pulse Velocity (UPV) Test

UPV test is a non-destructive test (NDT). The pulse vibration applied on the test surface of cube are converted to electrical signals by a transducer. Time taken by pulse to travel through the concrete and velocity was displayed on the screen of UPV testing machine. Direct and semidirect transmission test was conducted on cube specimens for each percentage of replacement and compared the grading quality. The quality of concrete is determined based on pulse velocity. Homogenous and uniform concrete specimen provide high pulse velocity. Lower velocity indicate the presence of crack and voids inside the specimen which may cause the discontinuity

G. Density of Cube

In order to find the density of concrete cubes of size (150 X 150 X 150 mm) were casted and cured for 28 days. The weight of the cube was measured on 28th day. Density is obtained as mass by volume of concrete cube casted

VII. Results and Discussion

A. Workability Test

The workability test (slump cone test) results for the concrete mix with various percentage of replacement of coarse aggregate with cockle shell are given in the table V. Variation in slump value for various percentage of replacement is shown in fig. 2.

TABLE V. Workability test result

Percentage of coarse aggregate replaced with cockle shell	Slump value (mm)
0%	120
7%	113
14%	110
21%	107
28%	90

B. Compressive Strength Test

The average compressive strength obtained for each percentage of replacement by testing six concrete cube specimens on 28th day of curing is shown in table VI. Fig. 3 shows the rectangular graph of variation of compressive strength with increase in percentage of replacement.

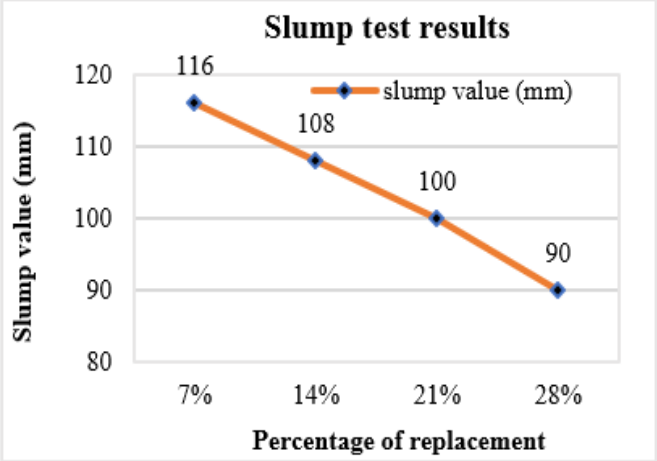

Fig. 2.Variation in slump value with increase in percentage of replacement

TABLE VI. Average compressive strength results

Percentage of Replacement	Average Compressive Strength (MPa)
0%	29.37
7%	30.13
14%	32.1
21%	34.18
28%	29.57

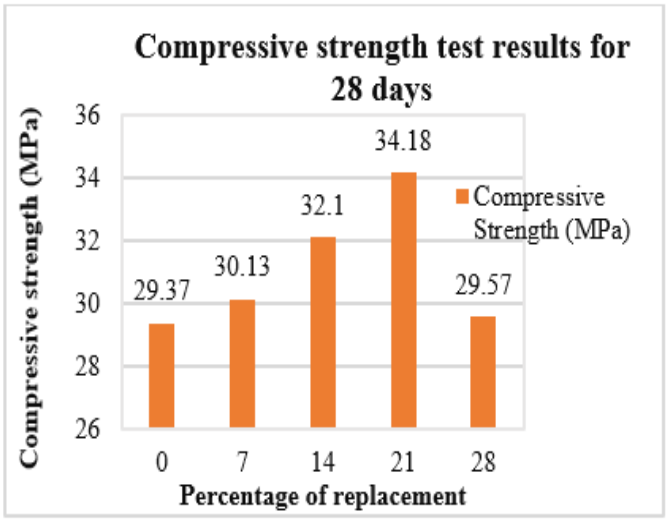

Fig. 3. Rectangular graph of variation in compressive strength with increase in percentage of replacement

C. Split Tensile Strength Test

Six cylindrical specimens were casted for each percentage of replacement and cured for 28 days for conducting split tensile strength test. The cylindrical specimen was subjected to a compressive force on the loading area and a uniform tensile stress along the length of cylindrical specimen. The average split tensile strength obtained for each percentage of replacement on 28th day of curing are shown in Table VII. The rectangular graph of variation of split tensile strength with increase in percentage of replacement is shown in fig. 4.

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TABLE VII. Average split tensile strength results

Percentage of Replacement	Split Tensile Strength (MPa)
0%	3.108
7%	3.04
14%	3.21
21%	3.515
28%	3.03

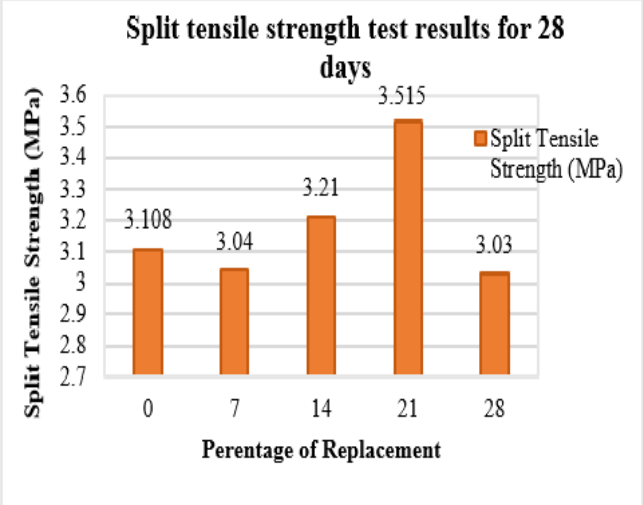

Fig. 4. Rectangular graph of variation in split tensile strength with increase in percentage of replacement

D. Flexural Strength Test

Flexural strength reported is the average of three results obtained from three identical beams. The beam placed for flexural strength test in Universal Testing Machine (UTM) and the cracked beam after test are shown in fig 5 (a) and (b) respectively The average flexural strength obtained for each percentage of replacement specimens on 28th day of curing are as shown in table VII. The rectangular graph of variation of flexural strength with increase in percentage of replacement is shown in fig. 6.

Fig. 5. (a) Split tensile strength test and (b) Cracked cylinder after split tensile strength test

TABLE VII. Average flexural strength test results

Percentage of Replacement	Flexural Strength (MPa)
0	4.16
7	4.22
14	5.32
21	6.72
28	4.15

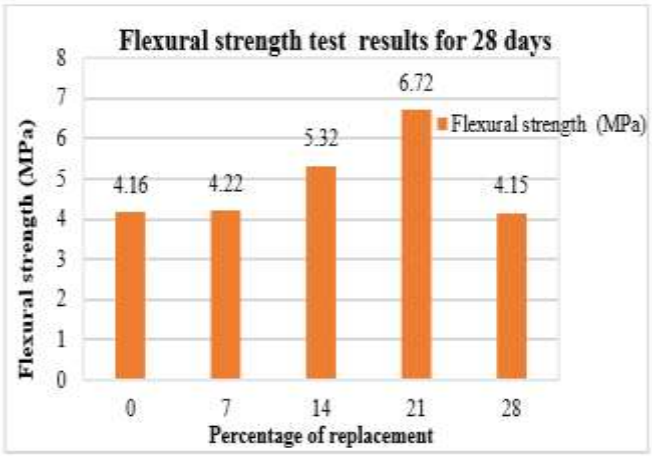

Fig 6. Rectangular graph of variation in flexural strength with increase in percentage of replacement

E. Durability Test

The percentage weight loss obtained for acid attack test for various percentage of replacement of coarse aggregate with cockle shell are given in table IX. The graph of percentage weight loss corresponding to various percentage of replacement are shown in fig. 8. Cubes of standard size are prepared for each percentage of replacement and cured for 7 days .It was kept in atmosphere for 2 days and weighed. Then cubes are kept in 5% sulphuric acid for 60 day. Again kept in atmosphere for 2 days and weighed to find percentage weight loss. Fig. 7 shows the cubes placed for acid attack test.

Fig. 7. Durability test

TABLE IX. Durability test results

Percentage of replacement	Percentage weight loss
0%	0.092 %
7%	0.104 %
14%	0.132 %
21%	0.144 %
28%	0.168 %

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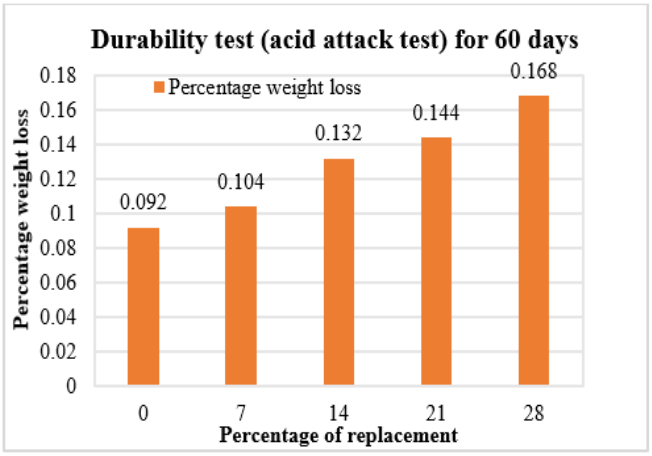

Fig. 8. Rectangular graph of durability test results for increase in percentage of replacement

F. *Ultrasonic Pulse Velocity (UPV) Test*

The pulse velocity and time measured in UPV test are given in table X. The pulse velocity and time were measured in both the direct and semi direct directions for 28th day of curing. Figure 9 shows the rectangular graph of UPV test result for various percentage of replacement.

TABLE X. UPV test results

	Direct transmission		Semi direct transmission	
Percentage of replacement	**Time (micro second)**	**Velocity (m/s)**	**Time (micro second)**	**Velocity (m/s)**
0%	27.72	5434	17.8	8257
7%	28.8	5290	18.4	7825
14%	29.1	5050	19.1	7450
21%	31.4	4580	20.6	6989
28%	32.1	4548	21.8	6746

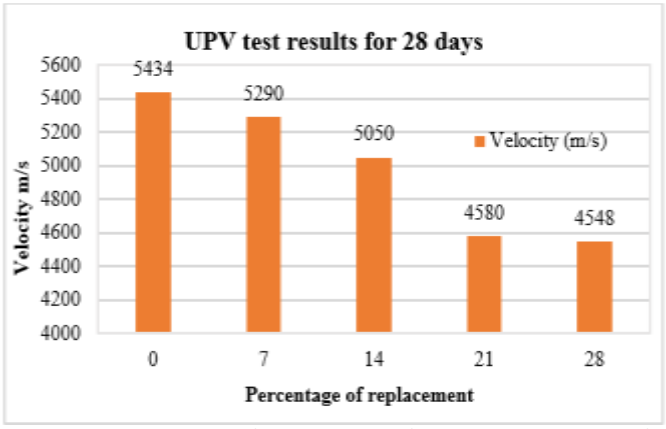

Fig. 9. Rectangular graph of UPV test results for increase in percentage of replacement

G. *Density of Cube*

The weight of cube with 0%,7%,14%,21% and 28% replacement of coarse aggregate was measured. Density of cube was found out on 28th day of curing and it was give in table XI. The rectangular graph of density test results for various percentage of replacement is shown in fig 7

TABLE XI. Density test results

Percentage of replacement of coarse aggregate with cockle shell	Weight of cube (Kg)	Density of cube (KN/m^3)
0%	8.46	25.07
7%	8.42	24.95
14%	8.13	24.09
21%	8.1	24
28%	7.84	23.23

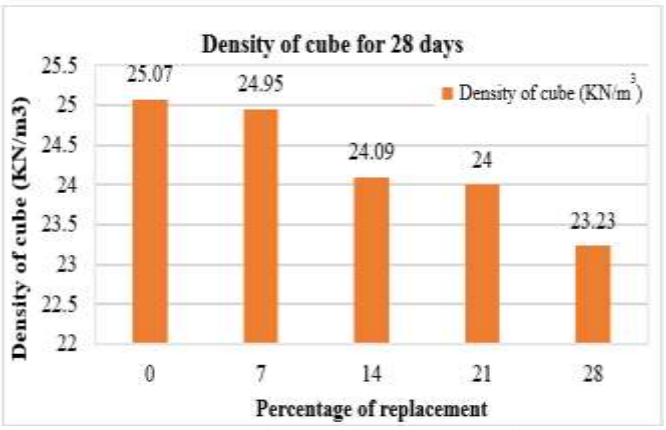

Fig. 7. Rectangular graph of density of cube test results for increase in percentage of replacement

VIII. CONCLUSIONS

Experimental investigation and research study on partial replacement of coarse aggregate with cockle shell in concrete gave the following conclusions

- Cockle shell is one of the effective replacement material as a coarse aggregate in M20 grade of concrete at optimum percentage of replacement
- The test results shows that physical and chemical properties of cockle shells resembles with that of coarse aggregates and are within the IS code limits
- Maximum Compressive strength, Split tensile strength & Flexural strength of optimum percentage coarse aggregate replaced concrete was 34.18MPa, 3.515MPa, 6.72MPa respectively.
- From the percentage of replacement of 0%, 7%, 14%, 21% and 28% optimum percentage of replacement was obtained as 21% based on the strength tests
- Increase in Compressive strength, Split tensile strength & Flexural strength of optimum percentage coarse aggregate replaced concrete was 4.81 MPa, 0.407 MPa, 2.56MPa respectively than that of control mix
- Optimum percentage of replacement gave highly workable mix with a slump value of 107 mm so it can be used for construction purposes
- The percentage weight loss for various percentage of replacement including optimum percentage was less than 1% which is very small. Thus partial replacement of coarse aggregate with cockle shell gave a durable concrete
- UPV test results shows that the pulse velocity for various percentage of replacement including optimum percentage belongs to excellent quality that is free from voids and pores

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- The density of concrete decreases with increase in percentage of cockle shell.
- Cockle shell as a replacement to coarse aggregate would generate an eco-friendly and durable concrete
- The research study proved that partial replacement of coarse aggregate with cockle shell is an better method to reduce the usage of natural coarse aggregate and to reduces the depletion of natural resources.
- It is also an effective solution to reduce disposal of cockle shell as waste in seashore areas

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