iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 Issue: III Month of publication: March 2025

DOI: https://doi.org/10.22214/ijraset.2025.67489

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Experimental Study on Strength of Concrete by using Partial Replacement of Coarse Aggregate with Cockle Shells

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Abstract: The growing emphasis on eco-friendly buildings in the construction industry necessitates innovative solutions for sustainable material use. This study explores the potential of incorporating waste materials, specifically cockle shells (a byproduct of the seafood industry) and ground granulated blast furnace slag (GGBS), into concrete production. The aim is to reduce both natural resource depletion and marine waste, while addressing the increasing demand and decreasing availability of traditional concrete aggregates. In this research, cockle shells were used to partially replace coarse aggregate in M25 grade concrete at replacement levels of 0%, 8%, 16%, and 24%, utilizing Ordinary Portland Cement (OPC) 43 grade. The performance of the resulting concrete mixes was evaluated through compressive strength and split tensile strength tests after 7, 14, and 28 days of curing. The results demonstrate that incorporating appropriate percentages of cockle shells yields workable concrete with satisfactory strength, comparable to conventional concrete. This study highlights the viability of utilizing marine waste for sustainable construction practices.
Keywords: Cockle shells, GGBS, coarse aggregate replacement, M25 concrete, OPC 43, compressive strength, split tensile strength, eco-friendly buildings.

I. INTRODUCTION

A. General

The escalating use of concrete in infrastructure development has driven the search for cost-effective and sustainable alternatives. Traditional concrete production is environmentally detrimental, prompting the exploration of waste materials like fly ash, recycled aggregates, and marine shells. This study focuses on utilizing cockle shells and lime powder as partial replacements for coarse aggregate and cement in concrete, addressing both waste management and resource scarcity.

1) Concrete Fundamentals

Concrete, a composite of water, aggregates, and cement, is essential for construction. Its versatility allows for diverse applications, from buildings to pavements. Achieving desired properties involves precise mixing and potential use of additives. Historically, the Romans pioneered large-scale concrete use, and it remains the most widely used man-made material.

2) Material Replacement and Testing

This research investigates the impact of replacing coarse aggregate with 8%, 16%, and 24% cockle shells in M25 grade concrete. The performance of these mixes was evaluated through compressive and split tensile strength tests after 7, 14, and 28 days of curing. The objective is to analyze the strength variations resulting from different percentages of waste materials.

3) Environmental and Economic Benefits

Utilizing cockle shells offers environmental and economic advantages. It reduces marine pollution by repurposing waste and lowers concrete production costs due to the low cost and availability of these materials. Furthermore, the use of waste materials promotes sustainable construction practices.

4) Concrete Properties

Fresh concrete requires good workability, preventing segregation and bleeding. Workability, the ease of mixing and placing, is influenced by water content, aggregate-cement ratio, and aggregate size. Segregation, the separation of concrete constituents, can be minimized through proper mix proportions and handling. Bleeding, the upward migration of water, can be reduced by adjusting the mix design.

5) Temperature Effects and Solid Waste

Elevated temperatures can cause spalling, strength loss, weight reduction, and color changes in concrete. The increasing volume of solid waste, including marine waste like cockle shells, necessitates innovative recycling solutions. This study aims to demonstrate the viability of incorporating such waste into concrete, reducing environmental impact and promoting resource efficiency

B. Objectives Of Project

1) The main objective is to encourage the use of these products as construction material in building
2) To evaluate the cockle shells and lime powder, compressive strength and split tensile strength at 7 days, 14days and 28 days by replacing in concrete.
3) These should reduce the usage of natural products like aggregates.
4) To encourage the use of waste.
5) Environmental friendly disposal of cockle shells. Hence this should controls the pollution of environment.

II. MATERIALS AND PROPERTIES

A. Materials Used

The ingredients used in this concrete mix are,

1) Ordinary Portland Cement of53 Grade cement conforming to IS: 169-1989.
2) Fine aggregate and coarse aggregate conforming to IS: 2386-1963.
3) Water.
4) Cockle shells as partial replacement to coarse aggregate
5) Fly ash as partial replacement of cement

B. Cement

Cement is the most important material used in constructions. It has adhesive and cohesive properties so as to render it to form a good bond with other materials. As it is a binder material in concrete, when it is mixed with aggregates and water it tums the particles in to a whole compound and solidifies. Cement is most important and costliest ingedients of concrete, and it is obtained by burning a mixture of the siliceous, argillaceous and calcareous material in a definite proportions.

Fig Cement

C. Fine Aggregates

Sand is a natural granular material which is mainly composed of finely divided rocky material and mineral particles. The most common constituent of sand is silica (silicon dioxide, or Si02), usually in the form of quartz, because of its chemical inertness and considerable hardness, isthe most common weathering resistant mineral. Hence, it is used as fine aggregate in concrete.

Fig Fine aggregate

D. Coarse Aggregate

Crushed aggregates of 20mm size produced from local crushing plants were used. The aggregate exclusively passing through 16mm sieve size and retained on 20mm sieve is selected. The aggregates were tested for their physical requirements such as gradation, specific gravity in accordance with IS: 2386-1963. The individual aggregates were mixed to induce the required combined grading.

Fig Coarse Aggregate

E. Water

Water plays a vital role in achieving the strength of concrete. For complete hydration it requires about 3110th of its weight of water. It is practically proved that minimum water-cement ratio 0.35 is required for conventional concrete. Water participates in chemical reaction with cement and cement paste is formed and binds with coarse aggregate and fine aggregates. If more water is used, segregation and bleeding takes place, so that the concrete becomes weak, but most of the water will absorb by the fibers. Hence it may avoid bleeding. If water content exceeds permissible limits it may cause bleeding. If less water is used, the required workability is not achieved. Potable water fit for drinking is required to be used in concrete and it should have PH value ranges between 6 to 9.

F. Cockle Shells

A cockle is an edible, marine bivalve mollusc. Although many small edible bivalves are loosely called cockles. true cockles are species in the family Cardiidae. True cockles live in sandy, sheltered beaches throughout the world. The distinctive rounded shells are bilaterally symmetrical, and are heart-shaped when viewed from the end. Numerous radial, evenly spaced ribs are a feature of the shell. There are more than 205 living species of cockles, with many more fossil forms.

Seashell is a waste obtained near the seashore area as the result of disintegration of dead animals. Seashell consists of three layers outer, intermediate and inner layer .0uter layer is made up of calcite material whereas inner layer is otherwise known as nacre which is made up of calcium carbonate. Since 95% of calcium carbonate present in seashell, it has the strength nearly equal to coarse aggregate. The sieve analysis for seashell is executed to find out its size.

Fig Cockle shells

G. Properties Of Cockle Shells

1) Specific gravity and water absorption of cockle shells
2) Crushing strength of cockle shells

H. Specific Gravity And Water Absorption Of Cockle Shells

Specific gravity test of aggregates is done to measure the strength or quality of the material. Specific Gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It is the measure of strength or quality of the specific material. Aggregates having low specific gravity are generally weaker those with higher specific gravity values. Higher specific gravity of material will corresponds to

1) Enough strength against impact load i.e., toughness
2) Higher value of Abrasion and attrition i.e., Los Angeles Test
3) Better soundness i.e. less impact of seasonal weathering
4) Lesser water absorption

In general specific gravity of an aggregate varies from 2.5 to 2.90.

I. Crushing Value Of Cockle Shells

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. With aggregate of aggregate crushing
value 30 or higher, the result may be anomalous, and in such cases the ten percent fines value should be determined instead. The principal mechanical properties required in stones are (i)
Aggregates used in road construction, should be strong enough to resist crushing under traffic wheel loads. If the aggregates are weak, the stability of the pavement structure is likes to be adversely affected. The strength of coarse aggregates is assessed by aggregates crushing test. The aggregate crushing value provides a relative measure of resistance to crushing under gradually applied compressive load. To achieve a high quality of pavement, aggregate possessing low aggregate crushing value should be preferred.
The aggregate crushing value for cement concrete pavement shall not exceed 30%. The aggregate crushing value for wearing surfaces shall not exceed 45%.

J. Ground Granulated Blast Furness Slag (GGBS)

The ground granulated blast furnace slag (GGBS) is a by-product of iron manufacturing which when added to concrete improves its properties such as workability, strength, and durability. This material is obtained by the heating of the iron ore, limestone, and coke at a temperature of about 1500°C. The process is carried out in a blast furnace. The formation of GGBS is not direct. The by-product of iron manufacturing is molten iron and molten slag. The molten slag consists of silica and alumina, also with a certain amount of oxides.
The slag is later granulated by cooling it. For this, it is allowed to pass through high-pressure water get. This results in the quenching of the particles which result in granules of size lesser than 5mm in diameter. The main constituents of blast furnace slag are Cao, SiO, Al2O3 and MgO. These are the minerals that are found in most of the cementitious substances. The particles are further dried and ground in a rotating ball mill to form a fine powder, known as ground granulated blast furnace slag. Now different methods can be employed to perform the main process called the quenching.

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K. Chemical Composition of GGBS

Chemical Constituent	Percentage by Mass (%) GGBS	Percentage by Mass (%) PC
Sio2	35.3	18.8
Fe2o3	12.3	3.3
Al2O3	14.1	5
CaO	40	63.3
MgO	8.2	1.5

Mix Prapoertions for Cubes

S.NO	MIX DESIGNATION	CEMENT IN KG	FINE AGGREGATE IN KG	COARSE AGGREGATE	COCKLE SHELLS IN KG (8%, 16%, 24%)	W/C RATIO
1	C_0	12.15	20.95	34.44	0	0.45
2	C_{10}	11.54	20.95	31	3.44	0.45
3	C_{20}	10.93	20.95	27.55	6.88	0.45
4	C_{30}	10.32	20.95	24.11	11.48	0.45

Mix praportions for Cylinders

S.NO	MIX DESIGNATION	CEMENT IN KG	FINE AGGREGATE IN KG	COARSE AGGREGATE IN KG	COCKLE SHELLS (20%, 30%)	W/C RATIO
1	C_0	19.08	32.913	54.09	0	0.45
2	C_{1O}	18.12	32.913	48.68	5.4	0.45
3	C_{20}	17.17	32.913	43.27	10.81	0.45
4	C_{30}	16.218	32.913	37.86	16.22	0.45

III. EXPERIMENTAL METHODOLOGY

A. Material Collection

Gather raw materials: cement, coarse aggregate, fine aggregate, cockle shells, and GGBS.

B. Material Characterization

Conduct physical property tests on raw materials:

- Fineness test (cement)
- Water absorption (aggregates)
- Fineness modulus (aggregates)
- Specific gravity (all materials)
- Normal consistency (cement)
- Initial and final setting time (cement)

Verify test results against relevant standards.

C. Mix Design

- Develop an M25 grade concrete mix design based on the obtained physical properties.
- Establish the control mix proportions.

D. *Partial Replacement*

Prepare concrete mixes with partial replacements:

- GGBS: 2%, 4%, and 6% replacement of cement.
- Cockle shells: 8%, 16%, and 24% replacement of coarse aggregate.
- Create a control mix with 0% replacement of both materials.
- Label each mix variation for identification.

E. *Specimen Preparation:*

Cast concrete specimens

- Cubes (150×150×150 mm) for compressive strength tests.
- Cylinders (300 mm diameter) for split tensile strength tests.
- For each mix design, cast 9 cubes and 3 cylinders.

F. *Curing*

Cure all specimens for 7, 14, and 28 days in a controlled environment.

G. *Hardened Concrete Testing*

- Conduct compressive strength tests on the cube specimens at each curing age.
- Conduct split tensile strength tests on the cylinder specimens at each curing age.

H. *Data Analysis and Comparison*

- Record and analyze the compressive and split tensile strength results.
- Compare the strength results of the modified concrete mixes with the control mix.
- Evaluate the effects of varying percentages of cockle shells and GGBS on the concrete's strength.
- Draw conclusions based on the comparative analysis.

IV. RESULTS AND DISCUSSIONS

Table:Results of Cement Tests

S.NO	TESTS ON CEMENT	RESULTS
1	Fineness of cement	25%
2	Standard consistency of cement	34%
3	Soundness of cement	0
4	Initial setting time of cement	0
5	Final setting time of cement	5mm
6	Specific gravity of cement	3.16

Table: Results Of Fine Aggregate Tests

S.NO	TESTS ON FINE AGGREGATE	RESULTS
1	Specific gravity of fine aggregate	2.6
2	Water absorption of fine aggregate	1.6%
3	Sieve analysis of fine aggregate	3.78

TABLE : RESULTS OF COARSE AGGREGATE

S NO	TESTS ON COARSE AGGREGATE	RESULTS
1	Specific gravity of coarse aggregate	2.64
2	Water absorption of coarse aggregate	0.62%
3	Sieve analysis of coarse aggregate	3.49
4	Impact value of coarse aggregate	18.06%
5	Aggregate crushing value	16.6%
6	Flakiness of coarse aggregate	36.8%
7	Elongation of coarse aggregate	48.9%

TABLE RESULTS OF COCKLE SHELLS TESTS

S.NO	TESTS ON COCKLE SHELLS	RESULTS
1	Specific gravity of cockle shells	2.6
2	Water absorption of cockle shells	0.82%
3	Crushing value of cockle shells	16%

Fig: Mixing of concrete and curing of specimens

A. Workabilty

1) Slump Cone Test

The test was conducted for fresh concrete prepared before the moulding process. A total mix proportions of replaced concrete are prepared at different times.


Fig: Slump Monitoring

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue III Mar 2025- Available at www.ijraset.com

Workability Results from slump cone test for M30 grade of concrete is shown in table:

TABLE: Workability Of Concrete

S.NO	MIX DESIGNATION	SLUMP CONE (mm)
1	C_0	50
2	C_{1O}	65
3	C_{20}	73
4	C_{30}	79

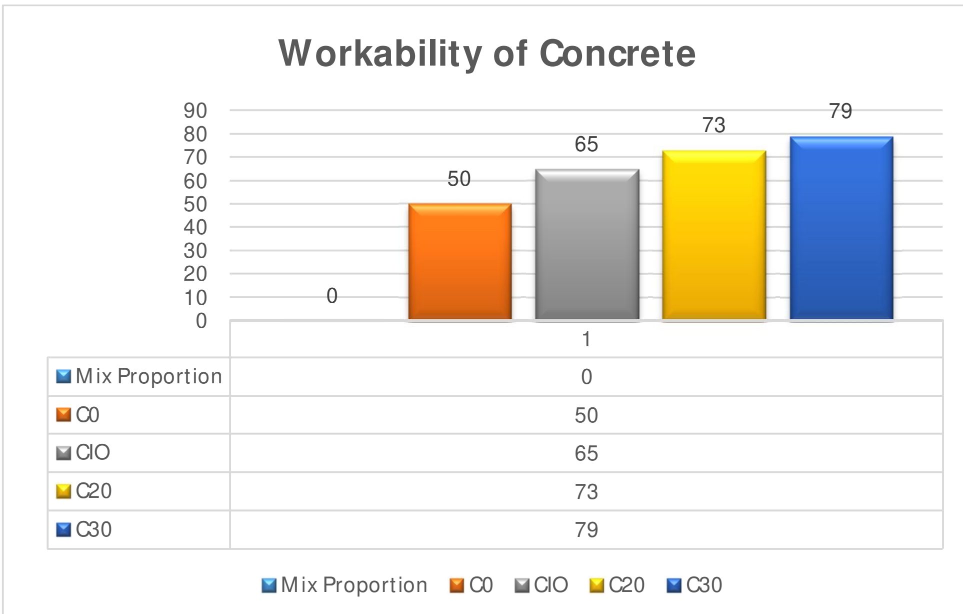
Where

Co = Conventional concrete for M25 grade.

C_{10} =Concrete with 2% replacement of GGBS in cement and 8% replacement of cockle shells in coarse aggregate

C_{20} = Concrete with 4% replacement of GGBS in cement and 16% replacement of cockle shells in coarse aggregate

C_{30} = Concrete with 6% replacement of GGBS in cement and 24% replacement of cockle shells in coarse aggregate



Graph Workability of concrete

The above graph shows the workability of M25 grade of concrete by slump cone method. The result shows that decrease in workability of concrete by replacing cement with GGBS and coarse aggregate with cockle shells with different proportions. The workability of concrete decreased with increasing the proportion of GGBS and cockle shells. The workability of concrete decreased because of rough texture of cockle shells.

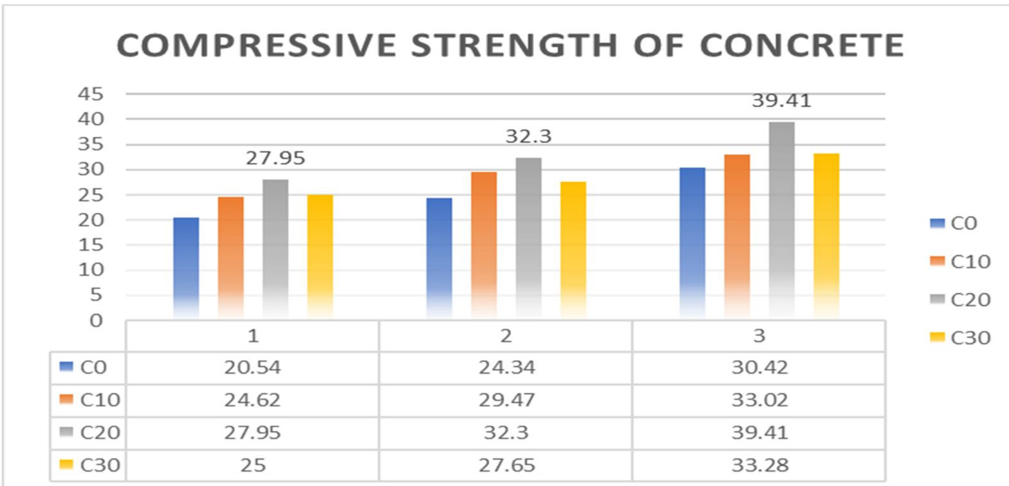
2) Compressive Strength

A total of 36 cubes of size 150 x 150 x 150mm were casted and tested for 7 days, 14 days and 28 days testing each specimen after conducting the workability tests. The results are tabulated below:

TABLE: Compressive Strength Of Concrete

S.NO	MIX DESIGNATION	REPLACED CONCRETE %		COMPRESSIVE STRENGTH N/mm^2		
		GGBS %	COCKLE SHELLS%	7 DAYS	14 DAYS	28 DAYS
1.	C_0	0	0	20.54	24.34	30.42
2.	C_{10}	2	8	24.62	29.47	33.02
3.	C_{20}	4	16	27.95	32.30	39.41
4.	C_{30}	6	24	25	27.65	33.28

Where
C_0 = Conventional concrete for M25 grade.
C_{10} = Concrete 2% replacement of GGBS in cement and 8% replacement of shells in coarse aggregate
C_{20} = Concrete with 4% replacement of GGBS in cement and 16% replacement of Cockle shells in coarse aggregate
C_{30} = Concrete with 6% replacement of lime powder in cement and 24% replacement of cockle shells in coarse aggregate



Graph compressive strength for M25 grade of concrete

The above graph shows the compressive strength of M25 grade of concrete. The result shows that increase in strength of concrete by replacing cement with lime powder and coarse aggregate with cockle shells with different proportions. It clearly shows that strength increased by replacing the materials compared to conventional concrete. The optimum strength is obtained for 8% and 16% replacement of GGBS and cockle shells in cement and concrete.

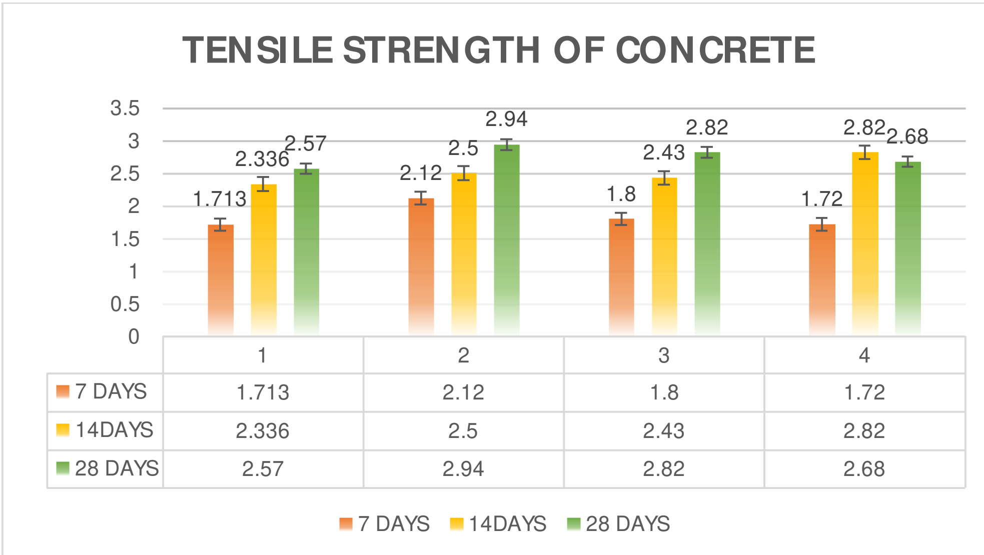
3) *Tensile Strength*

A total of 36 cylinders of size 150mm diameter and 300mm height were casted tested for 7 days, 14 days and 28 days testing each specimen after conducting the Workability tests. The results are tabulated below:

Table Tensile Strength Of Concrete

S.no	MIX DESIGNATION	REPLACED CONCRETE %		TENSILE STRENGTH N/mm^2		
		GGBS	COCKLE SHELLS	7 DAYS	14 DAYS	28 DAYS
1.	C_0	0	0	1.713	2.336	2.57
2.	C_{10}	2	8	2.12	2.5	2.94
3.	C_{20}	4	16	1.8	2.43	2.82
4.	C_{30}	6	24	1.72	2.39	2.68

C_0 = Conventional concrete for M25 grade.
C_{10} = Concrete with 8% replacement of GGBS in cement and 2% replacement of cockle shells in coarse aggregate
C_{20} = concrete with 16% replacement of GGBS in cement and 4% replacement of cockle shells in coarse aggregate
C_{30} = concrete with 24% replacement of lime powder in cement and 6% replacement of cockle shells in coarse aggregate



Graph Tensile Strength for M25 grade of concrete

The above graph shows the tensile strength of M25 grade of concrete. The result shows that increase in strength of concrete by replacing coarse aggregate with cockle shells with different proportions. It is clearly shows that strength is increased by replacing the materials compared to conventional concrete. The optimum strength is obtained for 4% and 6% replacement of GGBS and cockle shells in cement and concrete.

V. CONCLUSION

A. *Summary*

The need to study the role of replaced materials Cockle shells in concrete have been justified. concrete cubes and cylinders were casted, cured and tested for compressive strength and tensile strength with OPC 43 grade cement. The results have been presented in the form of tables and graphs in detail.

B. *Conclusion*

1) Strength of concrete is more Cockle shells blended concrete than the conventional concrete.
2) Comparative study on Cockle shells replaced concrete with various replacement percentages of Cockle shells (0%, 8%, 16%, 24%) shows that , a replacement level of 8% and 16% Cockle shells in concrete performs and shows increase in strength as 12.94% than the other replacements.
3) For M25 grade of concrete 8% and 16% replacement of cockle shells respectively shows optimum compressive strength as 16.49% than normal concrete.
4) For M25 grade of concrete 8% and 16% replacement of cockle shells respectively shows optimum tensile strength as 11.39% than normal concrete.
5) As the replacement coarse aggregate by cockle shells by 0%, 8%, 16%, 24% in concrete, the workability of concrete decreases by 15mm, 23mm and 29mm respectively compared to conventional concrete. The workability of replaced concrete decreases due to Rough and Smooth texture of cockle shells.
6) The cockle shells replaced in coarse aggregate helps in the reduction of pollution in environment and usage of Natural and Marine solid waste.
7) Hence the optimum replacement level of Cockle Shells obtained from the studies is 16% Cockle Shells for M25 grade of concrete.

VI. SCOPE FOR FUTURE STUDY

Although several studies were conducted on behavior of normal concrete and by replacing cement with lime powder and coarse aggregate with cockle shells. Different physical and mechanical properties on lime powder and cockle shell concrete were also studied to find the optimum dosage of lime powder and cockle shells. Following few avenues may be studied further to understand the behavior and to deliver guidelines useful for design of concrete structure.

1) Effects of different admixtures to improve the strength of lime powder and cockle shell concretes further.
2) The grade of cement used in present study is 43. The study can be further investigated with 33 grades.
3) Studies on reinforced lime powder and cockle shell concretes exposed to acid and alkaline.

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