STUDY OF MECHANICAL PROPERTIES OF LIGHTWEIGHT AGGREGATE CONCRETE BY USING PUMICE STONE, CERAMIC TILES AND CLC LIGHTWEIGHT BRICKS

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Abstract - *Over thousands of years, by the time these materials were improved upon, combined with other materials and change into modern concrete. Now days, concrete are made by using Portland cement, coarse aggregates, fine aggregates and water. The performance characteristics of concrete can be observed with change according to the different forces that the concrete will need to resist. Time after time, lots of invention have been made to improve the quality of concrete in the concrete technology. With the improvement that they had made, the superstructure size in the construction can be reduce such as beam and column. In modern construction, structural lightweight concrete have been used because of flexibility, less dead load, durability and cost savings.*

In this, pumice stone is a lightweight aggregate used for light weight concrete. This light weight is due to escaping of gas from the molten lava. Like this, ceramic tile is a tile made of clay and permanently hardened by heat. These have excellent properties like durability, low water absorption, high breaking strength, light weight and fire resistance. Also, clc lightweight bricks are used because it offers light in weight, durability, low water absorption and high abrasion resistance.

In this project, we have used pumice stone, ceramic tiles waste and light weight bricks waste because of their individual properties as discussed above. These are used as partial replacement of 10%, 20% and 30% as coarse aggregate and fine aggregate used as individually to study the mechanical properties of lightweight aggregate concrete.

Key Words: CLC lightweight bricks, foaming agents, insulation, versatile material, Pumice stone, Ceramic tiles.

1. INTRODUCTION

Concrete is a product obtained by hardening the mixture of cement, sand, gravel and water in predetermined proportions. These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. The disadvantage of conventional concrete is due to its high self-weight. The density of the normal concrete is in the order of 2200 to 2600 kg/m^3. This heavy self-weight is some extent uneconomical structural material. Attempts have been made in the past to reduce the self weight of concrete and to increase the efficiency of concrete as a structural material. The weight of a building on the foundation is an important factor in design, particularly in the case of weak soil and tall structures. In framed structures, the beams and columns have to carry loads of floors and walls. If floors and walls are made up of lightweight concrete it will result in considerable economy.

1.1 Lightweight concrete

The lightweight concrete is defined as a concrete whose density from 300 to 1900kg/m^3. Structural lightweight aggregate concrete is an important and versatile material in modern construction. It had many and varied applications including multistorey building frames and floors, bridges, offshore oil platforms, and prestressed or precast elements of all types. Many architects, engineers and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found today throughout the world. Structural lightweight aggregate concrete solves weight and durability problems in buildings and exposed structures. Lightweight concrete has strengths comparable to normal weight concrete, yet is typically 25% to 35% lighter.

1.1.1 Advantages of lightweight concrete

i) Rapid and relatively simple construction.

ii) Economical interms of transportation as well as reduction in manpower.

iii) Most of the lightweight concrete have better nailing and sawing properties than heavier and stronger conventional concrete.

1.1.2Disadvantages of lightweight concrete

i) Very sensitive with water content in the mixtures.
ii) Difficult to place and finish because of the porosity and angularity of the aggregate.
iii) In some mixes the cement mortar may separate the aggregate and float towards the surface.
iv) Mixing time is longer than conventional concrete to assure proper mixing.

1.2 Types of lightweight aggregates:-

Table – 1: Types of lightweight aggregates

Natural Lightweight aggregate	Artificial lightweight aggregate
Pumice	Artificial cinders
Diatomite	Coke breeze
Scoria	Foamed slag
Volcanic cinders	Expanded shale
Sawdust	Expanded perlite
Rice husk	Thermocole beads

2. EXPERIMENTAL INVESTIGATION

Cube specimen dimension is of 10cmx10cm x10cm, cylinder specimen dimension is 15cmx30cm and prism specimen is 50cmx10cm x10cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes, cylinders and prisms are moved to the curing tank carefully. They are cured for a period of 7, 14 and 28 days.

2.1 MATERIALS AND ITS PROPERTIES

The constituent materials used in this study are given below:
(i) Cement
(ii) Coarse aggregate
(iii) Fine aggregate
(iv) Pumice stone
(v) Ceramic tiles
(vi) Cellular lightweight concrete(CLC) bricks
(vii)

2.2.1 CEMENT

The cement used was ordinary Portland cement of 53-grade in accordance with IS: 12269-1987. The cement should be fresh and of uniform consistency. The cement should be stored under dry conditions and for as short duration as possible.

Table – 2: Approximate Oxide Composition Limits of Ordinary Portland Cement

Oxide	Percent content
CaO	60 – 67
SiO_2	17 – 25
Al_2O_3	3.0 – 8.0
Fe_2O_3	0.5 – 6.0
MgO	0.1 – 4.0
Alkalies (K_2O, Na_2O)	0.4 – 1.3
SO_3	1.3- 3.0

2.2.1.1 Normal or standard consistency of cement (IS: 4031-Part 4 – 1988):-

Normal or standard consistency is defined as that percentage water requirement of the cement paste, the viscosity of which will be such that the vicat plunger penetrates up to a point 5 to 7mm from the bottom of the vicat mould.The water content of the paste is expressed as a percentage by weight of dry cement. The usual range of values 26% and 33%.

2.2.1.2 Setting Time of cement (IS: 4031-Part 5 – 1988):-

It is defined as the time at which the cement paste mortar or a fluid concrete changes to a solid but in a weak state. When water is added to the cement, the resulting paste starts stiffening and gaining strength, simultaneously losing its consistency. Two stiffening stages are identified as

- ✓ Initial setting time and
- ✓ Final setting time.

Initial setting time is defined as the period elapsing between the time when the water is added to the cement and the time at which a needle of 1mm square section fails to pierce the test bock to a depth of about 5mm from the bottom of the vicat mould.

Final setting time is defined as the period elapsing between the time when water is added to the cement and the time at which the needle of 1mm square section(with 4mm diameter attachment) makes an impression on the test block, which the attachment fails to make an impression on the test block.

2.2.1.3 Fineness test (IS: 4031- Part 1 – 1996):-

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gaining of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence the faster and greater the development of strength.

Observations and calculations:-

Weight of the cement taken = 100gm.
Weight of the residue left on the sieve = 3gm.
Fineness of cement = (Weight of residue left on the sieve / Weight of the cement taken) X100
= (3/100) X100
= 3%.

2.2.1.4 Soundness Test:-

Once the concrete hardened it is necessary to ensure that no volumetric change takes place. The cement is said to be unsound, if it exhibits volumetric instability after hardening. IS code recommends Le Chatelier mould should be used for testing of soundness.

Table - 3: Properties of cement

S. No	Property of cement	Values
1	Grade of cement	53
2	Specific gravity	3.15
3	Normal consistency	30%
4	Initial setting time	45 min
5	Fineness of cement	3%

2.2.2 AGGREGATES

2.2.2.1 Coarse aggregates

Machine crushed hard granite chips of 86% passing through 20mm sieve and retained on 12 mm sieve and 14% passing through 12mm and retained on 10mm sieve was used as coarse aggregate throughout the work.

2.2.2.2 Fine aggregates

Aggregates which are passing through 4.75mm sieve is termed as fine aggregate. Generally river sand is suitable for construction purpose which is obtained from banks or beds of rivers. It is usually available in clean condition. It is fine and consists of fine rounded grains. Colour of river sand is almost white and greyish. It should be free from silt and clay.

2.2.3 Water

Water used in the mixing is to be fresh and free from any organic and harmful solutions which will lead to deterioration in the properties of the mortar. Salt water is not to be used. Potable water is fit for use mixing water as well as for curing of specimens. It is an important ingredient of concrete as it is actively participates in chemical reaction with cement.

2.2.4 Fresh concrete properties:-

Workability:-

Workability of fresh concrete is an important characteristic of concrete. It can be defined as the ease with which the concrete can be worked. Working includes mixing, placing, compacting and finishing.

A) Slump Test:-

To assess the workability of given fresh concrete mix slump test is done. Vertical settlement of a standard cone of fresh concrete (actually frustum of a cone) under its own weight is called slump. It indicates consistency or workability of concrete. It gives an idea of w/c ratio needed for concrete to be used for different works.

Fig – 1: Slump cone Test

B) Compaction factor Test:-

The compaction factor test is designed primarily for use in the laboratory but it can also be used in the field. This test works on the principle of determining the 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 compaction factor is measured by the density ratio.

Compaction factor = [(Weight of partially compacted concrete)/(Weight of fully compacted concrete)]

= 0.785

Fig – 2: Compaction factor test

2.2.3 Pumice stone

Pumice are rocks of volcanic origin occurs in many parts of the world. They are light enough and yet strong enough to be used as lightweight aggregate. Their lightness is due to the escaping of gas from the molten lava. Pumice is nearly white in color and has a fairly even texture. Pumice is one of the oldest kinds of lightweight aggregates which have been used in roman structures also. Pumice is the only rock which floats on water, although it eventually becomes waterlogged and sinks. It is a lightweight aggregate of low specific gravity. It is a highly porous material with a high water absorption percentage.

Fig – 3: Pumice Stone

2.2.3.1 Applications of Pumice stone:-

1. Used in industries as a filler, abrasive, filteration and concrete applications. It is even used as an consumer products.
2. Pumice stone is mostly an ideal lightweight aggregate which is used in the construction of concrete blocks.
3. It acts as an good filler which is non-crystalline, non-toxic and non-hazardous. It acts as functional filler in paint industry which gives low density and stain resistance.

Table -4: Chemical composition of pumice stone

Silicon dioxide SiO_2	71.91%
Aluminium Oxide Al_2O_3	12.66%
Ferric Oxide Fe_2O_3	1.13%
Calcium Oxide CaO	1.46%
Magnesium Oxide MgO	0.32%
Sodium Oxide Na_2O	3.45%
Potassium Oxide K_2O	4.30%
Sulphur Trioxide SO_3	0.03%
Calcification loss	4.53%
Indefinable content	0.21%

2.2.3.2 Sieve Analysis of Pumice stone

Fineness modulus = $\sum\frac{\text{Cumulative \% weight retained}}{100}$

$= \frac{265.4}{100}$

= 2.65

2.2.4 Ceramic Tiles

Ceramic is one of the most ancient industries on the planet. The word ceramics from the Greek word *keramikos* meaning "potters" clay. According to (Mustafa et al., 2008) the particle shape analysis of ceramic waste coarse aggregate has diverse particles shape with the crushed stone normal concrete. These are made from a mixture of clay, sand and other natural materials. These are produced when the products are combined and molded into shape and then fired at a high temperature upto 1250^{0}C in a kiln. These are very popular as both wall tiles and flooring tiles.

Table- 5: Chemical composition of ceramic tiles

Oxides	Wt.(%) content
SiO_2	67.35
Al_2O_3	19.79
Fe_2O_3	2.52
Na_2O	0.15
K_2O	4.13
TiO_2	0.92
MgO	2.00
CaO	2.32

2.2.4.1 Properties of Ceramic tiles:-

Ceramic tile is a tile made of clay and permanently hardened by heat. These have excellent properties which are being enumerated below:

(i) Very high breaking strength of 350-400kg/cm^2.

(ii) It has light weight of about 14 kg/m^2.

(iii) Ceramic tiles are fired at 1900^{0}C and are highly fire proof.

(iv) These are stain free, acid and alkali resistance.

(v) Very long life.

(vi) Does not require any polishing over it.

(vii) It has very good thermal insulation capacity which improves air conditioning efficiency significantly.

(viii) Low water absorption.

Fig – 4: Ceramic Tiles

Fineness modulus = $\sum\frac{\text{Cumulative \% weight retained}}{100}$

$= \frac{258.5}{100}$

= 2.58

2.2.5 Cellular Lightweight Concrete (CLC) Bricks

Cellular lightweight concrete (CLC) is one of the recent emerging technology in making concrete and it has more advantages when compared to the conventional concrete. Flyash is a nuisance waste product obtained from thermal power plants that cannot be easily disposed. It solves the problem of disposal of flyash and at the same time it reduces cost of the construction. Hence, flyash based CLC is considered as eco friendly.

2.2.5.1 Properties of cellular lightweight concrete:-

1. It has low weight.
2. It has good fire resistance.
3. It has good thermal insulation property.

2.2.5.2 Uses of Cellular Lightweight Concrete:-

1. It is used for the construction of partition walls.
2. It is used for partitions for heat insulation purposes.
3. It is used for the construction of hollow filled floors.

Fineness modulus = $\sum\frac{\text{Cumulative \% weight retained}}{100}$

$$= \frac{287.9}{100}$$

$$= 2.87$$

2.3 Moulds:-

Moulds of required size and shape were prepared for casting process. The dimensions of the moulds for casting cubes, cylinders and prisms are 100mmx100mmx100mm, 150mm x 300mm & 500mmx100mmx100mm respectively are used. All the moulds are applied lubricant before concreting. After a day of casting, the moulds are demoulded and then cubes, cylinders and prisms are moved to the curing tank carefully for curing.

2.4 Compacting concrete:-

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 neither segregation nor excessive bleeding.

2.5 What is curing:-

When water is added to cement chemical reactions takes place (hydration of cement) which result in the setting and hardening of cement. Mixing water is usually sufficient for the initial hydration of cement. If however, there is insufficient water in the concrete during the setting period for the complete hydration of the cement, the concrete does not develop its full strength.

Fig – 5: Curing of specimens

3.1 Testing:-

(i) Compressive strength :-

In design of RCC Section allowable stress is taken for the design. This allowable stress is a fraction of the ultimate (crushing) strength of concrete. As per IS456, a factor of safety of 3.0 is adopted for obtaining allowable compressive stresses in working stress design. The permissible stresses are specified with reference to cube strength.

Fig – 6: Compressive Testing Machine

(ii) Split tensile strength:-

In normal structural design of members in flexure, the tensile strength of concrete is important to estimate the cracking loading. The absence of cracking is important in maintaining the continuity of a concrete structure for diminishing the corrosion of reinforced concrete for a liquid retaining structure.

Tensile Strength = $2P/\pi dl$

Fig – 7: Split Tensile Test

(iii) Flexural strength:-

Flexural strength is used to determine the bending properties of a material. Direct measurement of tensile strength of concrete is difficult. Neither specimens nor testing apparatus have been designed which assure uniform distribution of the pull applied to the concrete while a number of investigations involving the direct measurement of tensile strength have been made, beam tests are found to be dependable to measure flexural strength property of concrete.

Flexural strength = Pl / bd^2

Fig – 8 : Flexural strength Tesing Machine

TEST RESULTS AND DISCUSSIONS

Nominal or Control mix Test results

Mix Designation	No. of days	Compressive strength Mpa	Tensile Strength Mpa	Flexural Strength Mpa	Density of concrete
M20 (1:1.7:3.0)	7 14 **28**	16 21.5 **27.1**	2.12 2.23 **2.71**	3.5 4.2 **3.01**	2750 2680 **2570**

Replacement of coarse and fine aggregate by Pumice stone of 10%, 20% and 30% used individually in concrete

Mix Designation	No. of days	Compressive strength Mpa	Tensile strength Mpa	Flexural strength Mpa	Density of concrete
M20 (10% PC)	7 14 **28**	12.87 14.74 **23.50**	2.09 1.99 **1.78**	3.20 3.00 **2.80**	2400 2365 **2330**
M20 (20% PC)	7 14 28	11.50 13.68 21	1.98 1.68 1.63	2.95 2.73 2.60	2230 2175 2080
M20 (30% PC)	7 14 28	10.9 12.93 17.98	1.88 1.56 1.45	2.85 2.63 2.54	1985 1960 1925
M20 (10% PF)	7 14 **28**	14.00 19.50 **24.5**	2.52 2.36 **2.12**	3.40 3.33 **3.20**	2320 2375 **2410**
M20 (20% PF)	7 14 28	12.50 16.00 23	2.46 2.22 1.83	3.38 3.22 3.10	2395 2340 2290
M20 (30% PF)	7 14 28	10.50 14.00 22.50	2.38 2.12 1.73	3.15 3.12 3.08	2295 2240 2180

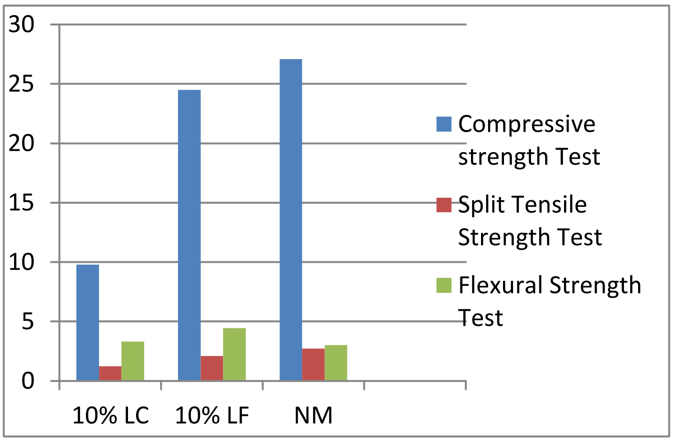
Replacement of coarse and fine aggregate by Ceramic Tiles of 10%, 20% and 30% used individually in concrete

Mix Designation	No. of days	Compressive strength Mpa	Tensile Strength Mpa	Flexural Strength Mpa	Density of concrete
M20 (10% CC)	7 14 **28**	27.5 33.25 **34.23**	1.75 2.12 **2.33**	5.00 4.00 **3.80**	2840 2775 **2730**
M20 (20% CC)	7 14 28	25.5 31.25 32.26	1.82 1.99 2.26	2.00 1.83 1.78	2790 2755 2700
M20 (30% CC)	7 14 28	19.75 28.5 30.56	1.48 2.33 2.20	1.98 1.82 1.66	2735 2670 2635
M20 (10% CF)	7 14 **28**	28.75 28.90 **30.10**	2.12 2.54 **2.80**	4.50 3.50 **3.30**	2685 2605 **2560**
M20 (20% CF)	7 14 28	28 28.75 29.36	1.68 2.12 2.55	3.50 3.00 2.85	2630 2550 2460
M20 (30% CF)	7 14 28	27.50 28.10 29.50	1.50 2.06 2.33	3.00 2.83 2.75	2580 2530 2440

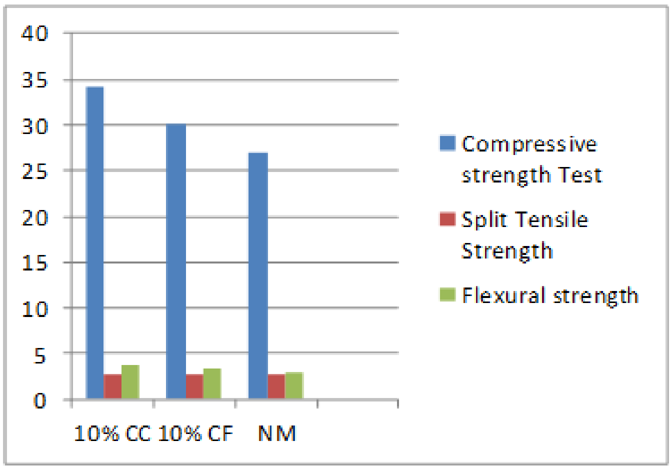
Replacement of coarse and fine aggregate by CLC Lightweight Bricks of 10%, 20% and 30% used individually in concrete

Mix Designation	No. of days	Compressive strength Mpa	Tensile strength Mpa	Flexural strength Mpa	Density of concrete
M20 (10% LC)	7 14 **28**	10.5 10 **9.80**	1.82 1.40 **1.22**	4.00 3.50 **3.30**	2055 1960 **1875**
M20 (20% LC)	7 14 28	7.50 4.75 3.75	0.84 0.7 0.65	3.5 2.75 2.55	1945 1860 1740
M20 (30% LC)	7 14 28	2.55 1.2 0.5	0.4 0.2 0.1	1.00 0.5 0.2	1820 1730 1640
M20 (10% LF)	7 14 **28**	20.50 22 **24.50**	1.26 1.96 **2.10**	3.00 4.00 **4.45**	2560 2460 **2395**
M20 (20% LF)	7 14 28	19.00 21.50 23.00	1.16 1.72 1.93	2.80 3.25 3.50	2445 2350 2245
M20 (30% LF)	7 14 28	17.50 19.00 22.75	1.03 1.52 1.76	2.65 3.20 3.00	2360 2275 2180

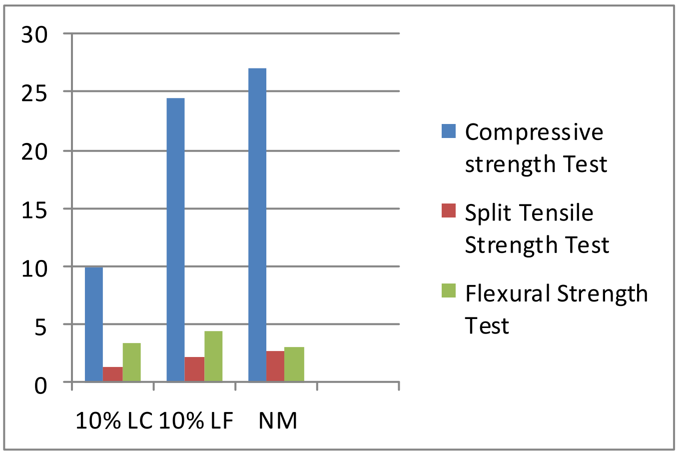
Optimum graph of different strength values of Pumice stone



Optimum graph of different strength values 5of Ceramic Tiles



Optimum graph of different strength values of CLC Lightweight Bricks



CONCLUSIONS:

Based on the experimental investigations conducted on the casted cubes, cylinders and prisms, the following conclusions were drawn.

Pumice stone:-

1. By observing above results it is understood that using pumice stone as a fine aggregate gives better results than that of coarse aggregate.
2. The increase in percentage of pumice stone as replacement will show negative impact on strength of concrete (strength decreased).
3. Finally, the density of the lightweight aggregate concrete is found to be 1925Kg/m^3, which is less than normal concrete.
4. By replacement of fine aggregate by pumice stone upto 10% gives best results when compared to coarse aggregate.
5. For replacement of 10% of pumice stone gives optimum value beyond that different strength value decreases.
6. By replacement of coarse aggregate about 10% we observe that the compressive strength, tensile strength and flexural strength values are decreased by 13.28%, 34.31% and 7% respectively.
7. By replacement of fine aggregate about 10% we observe that the compressive strength, tensile strength are decreased by 9.59%, 21.77% and flexural strength is increased by 6.31% respectively.

Ceramic tiles:-

1. Ceramic tile aggregate is an appreciated and appropriate concrete material for substitution into concrete based on its properties.
2. Mechanical properties of ceramic aggregate are similar to the natural aggregate and it's behavior is similar but not same.
3. It is possible in M20 grade concrete to substitute 10% of normal 20mm and fine material of 4.75mm aggregates with ceramic tile aggregates without compromising.
4. It is observed that by usage of ceramic tiles as replacement of fine aggregate in concrete upto 10% gives better results when compared to replacement of coarse aggregate.
5. Maximum compressive strength is obtained when 10% of tiles waste was replaced in coarse aggregate.

6. When crushed tiles replacing in place of coarse and fine aggregate, it gives optimum values upto 10% beyond that the strength values decreases.
7. By replacement of coarse aggregate about 10% we observe that the compressive strength, tensile strength and flexural strength values are increased by 26.30%, 4.42% and 26.24%

respectively.

8. By replacement of fine aggregate about 10% we observe that the compressive strength, tensile strength and flexural strength values are increased by 11.07%, 3.32% and 9.63% respectively.

CLC Lightweight bricks:-

1. Based on the experimental study, by replacement of 30% of coarse aggregate by CLC lightweight bricks gives unsatisfactory results.
2. It is observed that by replacement of fine aggregate gives best results when compared to coarse aggregate.
3. Maximum compressive strength is obtained when 10% of fine aggregate replaces as CLC lightweight bricks.
4. For replacement of 10% of CLC lightweight bricks gives optimum value beyond that different strength value decreases.
5. By replacement of coarse aggregate about 10% we observe that the compressive strength, tensile strength values are decreased by 63.83%, 54.98% and flexural strength is increased by 9.63% respectively.
6. By replacement of fine aggregate about 10% we observe that the compressive strength, tensile strength values are decreased by 9.59%, 22.50% and flexural strength is increased by 47.84% respectively.

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