

Partial replacement of cement by egg shell powder and M-sand in concrete

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ABSTRACT

Concrete made with concrete is widely used in construction because of its many benefits. However, this heavy use of natural resources is causing them to run out very quickly. So, there is an urgent need to find other materials that can replace the natural ones in concrete. This paper tries to find suitable materials to partly replace cement and fine aggregate in concrete. The study uses M40 grade concrete, and cement is replaced with egg shell powder in amounts of 5%, 10%, and 15%. The best amount of egg shell powder is found to be 10%. At this best amount, fine aggregate is replaced with quarry dust in amounts of 25%, 50%, and 75%. The strongest and most durable concrete is achieved when egg shell powder is used at 10% and quarry dust at 50%. This concrete also has a water-cement ratio of 0.38.

Key Words :- Egg Shell Powder (ESP), Quarry dust (QD), Cement, Fine aggregate, Coarse aggregate, Specific gravity (SG).

I. INTRODUCTION

Cement composites were one of the first materials used in civil and engineering. In 3000 BC, pyramid facing stones were attached using a non hydraulic mortar made from gypsum and lime. This type of mortar spread quickly, especially when used to encase rammed earth buildings in Mesopotamia. The builders of the Great Wall used a cement-like mixture made from rice gluten. Within a few centuries, engineers started mixing cement with different types of particles and other materials to create early forms of modern concrete.

The use of concrete wasn't new in ancient Egypt.

Around 800 BC, the Nabataeans used hydraulic cement materials to build cisterns. In the Mediterranean, various Greek cultures used concrete in building palaces and small infrastructure projects. However, using concrete as a major building material on a large scale required a specific mix of ingredients.

1.1 Evolution of the concrete:-

The theory becomes interesting for our purpose is in the mineral inputs available to Roman engineers. While concrete and cement technology were established by the time Roman civil engineers came on to the scene, the unique blend of minerals present in regional deposits of volcanic ash enabled the development of a concrete measurable superior to modern varieties.

The higher alumina and silica contents in available cash deposits produced a concrete with comparable structural strength to our modern cements and a much greater inherent resistance to seawater.

Cements (both hydraulic and non-hydraulic) were relatively quickly and were entirely inappropriate as breakwater or harbor material, the Roman breakwaters in the harbor at Pozzuoli Bay remain intact and serviceable after thousands of years. Modern Portland cement, by contrast, is rated for a fifty year service life under comparable conditions.

Roman Pozzolona-lime concrete cured slowly, but was incredibly strong and resilient once fully hardened. Tinkering further experimentation with aggregate and admixtures led to Roman engineers developing concrete with greater frost resistance and differing strength.

1.2 Modern and future concrete:-

Concrete is everywhere, used in buildings, roads, and other structures that make up our modern world. Looking back at its history, it's clear that concrete shows how simple and affordable technologies can change things a lot. Today, this is even more true than it was in ancient times, when concrete was already widely used. Even a small change in how it's made, what it's made of, or how it's used can lead to big improvements.

1.3 M-Sand concrete:-

Manufactured sand is a newer type of sand used in concrete these days. Instead of using natural river sand, this type of concrete uses man-made sand. The construction industry is growing fast, and there's a high demand for natural materials, so manufactured sand has become a popular and widely used substitute.

Because good quality river sand is running out, more people are using manufactured sand.

Another reason is that manufactured sand is easier to get and cheaper to transport. Since it can be made by crushing hard granite rocks, it is often available nearby, which reduces the cost of transporting sand from far away river beds.

II. OBJECTIVES

- To find out the compressive strength, split tensile strength, and flexural strength.
- Compare conventional concrete with M sand concrete.
- To examine the crack patterns in concrete.
- To understand how egg shell powder and M-sand affect the properties of hardened concrete.
- To study the characteristics of the egg shell powder and M-Sand.

III. LITERATURE REVIEW

- Partial replacement of m-sand for natural aggregate – Prof. B.V. Venkatarama reddy, CSIC project 2011
- Studies were done on using m-sand in place of natural fine aggregate in sustainable concrete.
- The results showed that the compressive strength of m20 and m30 concrete was +6% and -9% compared to normal concrete (which uses river sand). The flexural strength was 12% and -15% compared to normal concrete.
- Use of egg shell powder and micro silica to study the effect on concrete strength – D.Gowsika, S. Sarankokila, International journal of Engineering Research and Technology (IJERT) 2014.
- It was found that replacing 5% of egg shell powder and 20% micro silica in conventional concrete did not reduce its compressive strength.
- The strength was similar to normal concrete. Using this mix also resulted in higher split tensile strength.
- Experiment on using egg shell powder in conventional concrete – Amaranth, yerramala, International Concrete Journal (ICJ) 2014
- The study by Amaranath, Yerramala found that the best usage of egg shell powder was at 5%.

They showed that using 5% egg shell powder gives higher strength than normal concrete. They also tested using 10% egg shell powder and saw different results compared to 5% and normal concrete. The study also found that using fly ash helps in keeping the strength consistent.

- Use of egg shell powder (ESP) and m-sand for sustainable construction – Anita J, H. Ravi Kumar, Pradeepa. S, Pranav – International Research Journal of Engineering Research and Technology (IJERT) 2016
 - The study showed that using egg shell powder and m-sand can increase the compressive and flexural strength of concrete. Three different mixes were made with egg shell powder at 5%, 10%, and 15%, and m-sand at 20%, 40%, and 60%. The different mix proportions showed varying results in terms of strength. The highest strength was achieved at 5% egg shell powder and 20% m-sand.

IV. MATERIAL STUDY

The concrete mix is made using regular materials such as cement, fine aggregate, and coarse aggregate. From an experimental perspective, natural ingredients for cement and fine aggregate are replaced with other materials like Egg Shell Powder (ESP). Additionally, M-sand, which is a standard for concrete, is also used.

4.1 Cement :-

Portland cement is the most commonly used type of cement globally and is used as the main material in concrete, mortar, and stucco.

It was first developed from a type of hydraulic lime in England during the mid-19th century and is usually made from limestone. It is a fine powder created by heating materials in a kiln to form clinker, then grinding the clinker and adding a small amount of other materials, resulting in the final product known as cement.

The low cost and wide availability of materials like limestone and shale, which are used in Portland cement, make it one of the most affordable materials widely used around the world in the last century.

Ordinary Portland cement of 43 grades with the brand name Ultra Tech, meeting the IS 8112-1989 standards, has been used in preparing the concrete mix for casting different specimens.

Aggregate:-

Aggregates are inert, granular, and inorganic materials that typically consist of stone or stone-like solids.

They can be used alone in road bases and various types of fill or combined with cementing materials like Portland cement or asphalt cement to form a composite material such as concrete. Approximately three-quarters of the volume of Portland cement concrete is made up of aggregates

Classification of aggregates:-

Aggregates can be grouped into several categories based on different criteria.

4.2 Fine aggregate (sand)

Fine aggregates are those that pass through a 4.75mm sieve and are retained on a 75mm sieve. The use of fine aggregates that are free from any organic particles and have a low amount of silt has been employed. The material used must conform to the IS code 383-1970, table 4.

4.3 Coarse aggregate:-

Aggregates that are mostly kept on the IS sieve with a size of 4.75mm are usually called coarse aggregate. The largest size of the coarse aggregate should not

be more than 20mm. The material used is confirmed to meet the IS code 383-1970. A crushed natural stone from local crushers has been used. predominately retained on the IS sieve 4.75mm size are usually termed as the coarse aggregate, the maximum size of the coarse aggregate shall not exceed 20mm. The used material shall confirm the IS code 383-1970 crushed natural stone from local crushers has been used.

The tests for natural aggregate are done according to IS 383-1970

V. EXPERIMENTAL INVESTIGATION

The materials used in this study included Portland cement, m sand, natural sand, coarse aggregate, and egg shell powder. The cement used was Ultra tech cement. The aggregate used was of nominal size 20mm, and smaller sizes were also used.

The sand used was sourced from sand suppliers, while the M sand was obtained from a nearby stone crusher in Kalaburagi. Ordinary portable water available on campus was used for mixing the materials. The concrete mix ratio was designed according to IS 10262-2009, with a mix ratio of 1:1.56:2.32 by volume and a water-cement ratio of 0.45, which was used as the control mix. In this study, natural aggregate was completely replaced by M sand, and egg shell powder was used as a replacement at percentages of 0%, 5%, 10%, and 15% by weight of cement. Different mixes were prepared, and 27 specimens were made for each mix. The concrete was cast in specified molds. After 24 hours, the molded specimens were remolded and placed in a curing tank to allow for strength gain.

The curing process helps in the hydration of cement and improves the physical and mechanical properties of concrete. On each testing day, the samples were taken out of the curing tank and kept in open air for about two hours. Once the specimens were properly dried, they were tested at regular intervals of 7 days, 14 days, and 28 days. For each test, a set of three specimens was tested to understand the variation in mean strength parameters.

The tests conducted on the cast specimens were compressive strength test, split tensile strength test, and flexural strength test. Cubes were tested for compressive strength, while cylinder specimens were tested for split tensile strength using a CTM machine as per IS standards. Prisms were tested for flexural strength using a flexural testing machine. The failure loads were recorded, and strength gain graphs for different mixes were plotted.

VI. PRELIMINARY INVESTIGATION

6.1 The Tests On Materials Conducted Are As Follows:-

6.1.1 Test on cement.

6.1.2 Test on fine aggregate.

6.1.3 Test on coarse aggregate.

6.1.4 Test on egg shell powder.

6.1.5 Tests on M-Sand.

Table 6.1.1:-Test Results Of Ordinary Portland cement

SL NO	PROPERTIES	RESULT S
01	Specific gravity	3.16

02	Standard consistency	33%
03	Initial setting time	32min
04	Final setting time.	500min

Table 6.1.2 Test Result of Natural Sand

SL NO	PROPERTIES	RESULT S
01	Specific gravity	2.7
02	Fineness modulus	3.07
03	Water absorption	1.5%
04	Zone grade	2

Table 6.1.3 Test Results of Coarse Aggregate

SL NO	PROPERTIES	RESULTS
01	Specific gravity	2.65
02	Water absorption	1.03%

Table 6.1.4 Test Results of Egg Shell Powder

SL NO	PROPERTIES	RESULTS
01	Specific gravity	2.4
02	Fineness modulus	21%
03	Water absorption	NIL

Table 6.1.5 Test Result of M-Sand

SL NO	PROPERTIES	RESULTS
01	<i>Specific gravity</i>	2.71
02	<i>Fineness modulus</i>	2.58
03	<i>Water absorption</i>	1.35 %

VII. TEST ON FRESH AND HARDENED CONCRETE

7.1 Test on Fresh Concrete:-

Slump cone test (workability test):-

- ❖ To find the best amount of water, several tests like the Vee-Bee consistometer, compaction factor, and flow table are used. Among these, the slump cone test is the most common.
- ❖ The equipment needed for this test includes a non-porous metal tray, a slump cone (which is 300 mm tall, 200 mm wide at the bottom, and 100 mm wide at the top), a tamping rod, a trowel, and a measuring scale.
- ❖ Before starting the test, the inside of the slump cone is cleaned to make sure there is no moisture or old hardened concrete on it.

➤ PROCEDURE

- The test is done using a slump cone, also called Abram's cone.
- The cone is put on a hard, non-absorbent surface like a metal tray.
- The cone is filled with the concrete mix of different water amounts in three layers. Each layer is compacted 25 times using a tamping rod to remove any trapped air.
- After the third layer, the top surface is smoothed, levelled, and any extra concrete outside the cone is removed

Then the cone is slowly lifted without disturbing the concrete inside, using a twisting motion. The concrete settles down.

This settling is called slump. If the slump is less than 100mm, it is measured to the nearest 5mm. If it is more than 100mm, it is measured to the nearest 10mm.

Table 7.1.1 Slump Cone Test Values

% of M-Sand	% Egg Shell Powder	Slump value (mm)
100%	0%	112
	5%	107
	10%	105
	15%	94

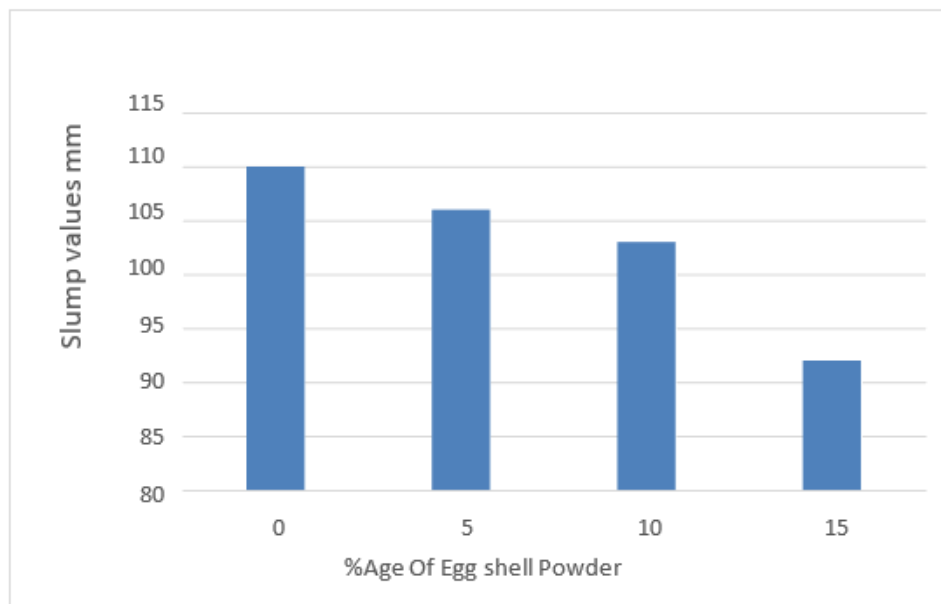


FIG 7.1.1

Table 7.1.2 Compaction Factor Values

% of M-Sand	% Egg Shell Powder	Compaction factor
	0%	0.97
	5%	0.99
	10%	1.0
	15%	0.96

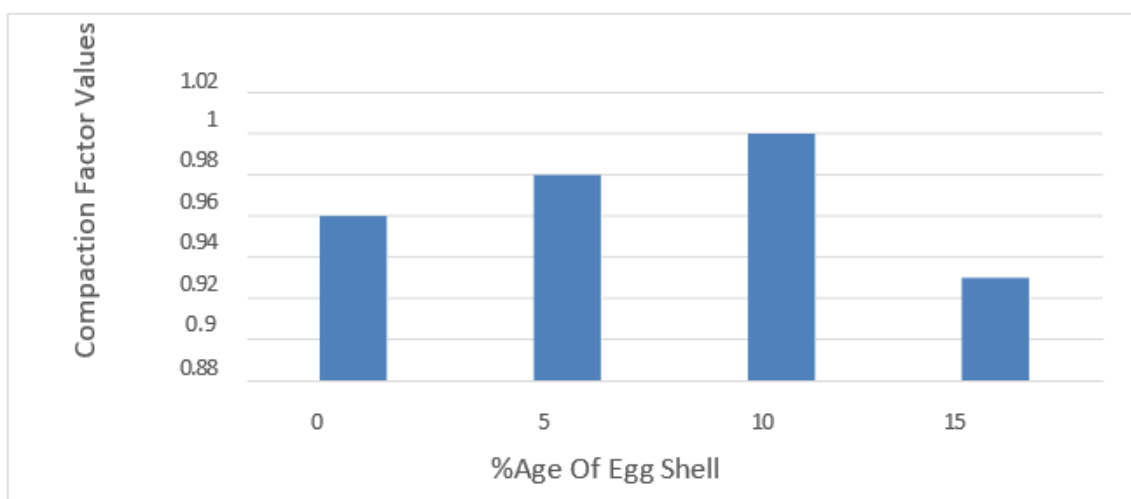


FIG 7.1.2

Table 7.1.3 Compaction Factor Values

% of M-Sand	% Egg Shell Powder	Compaction factor
	0%	0.97
	5%	0.99
	10%	1.0
	15%	0.96

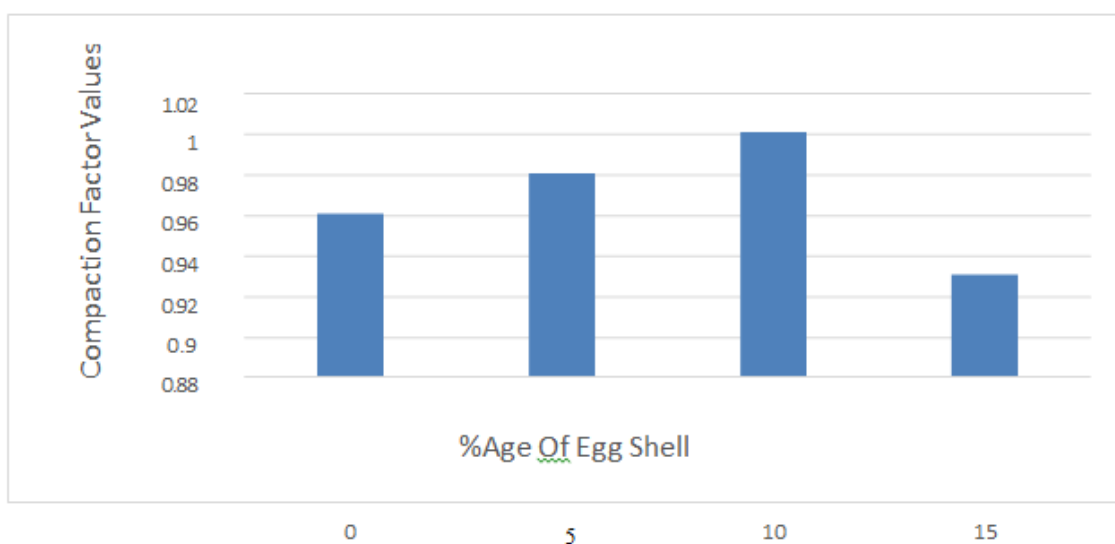


FIG 7.1.3

7.2 Test On Harden Concrete

The following tests were done on the concrete specimens made by replacing natural sand with 100% M-Sand and using egg shell powder to replace cement at 0%, 5%, 10%, and 15%. Different types of specimens like cubes, cylinders, and prisms were made for each mix percentage and cured for 7 days, 14 days, and 28 days, then tested accordingly. The following tests were conducted on different specimen at different curing periods:-

7.2.1 Compressive strength test.

7.2.2 Split tensile strength test.

7.2.3 Flexural strength test.

7.2.1 Compressive Strength Test:-

To calculate the compressive strength of concrete cubes that are 150MM x 150MM x 150MM, a compression testing machine with a loading capacity of 2000KN was used, as shown in fig 6.1. Compressive strength of concrete is the process of a mechanical test that measures the maximum amount of compressive load a material can take before it breaks. The test specimen is usually in the shape of a cube or cylinder and is placed between the plates of the loading frame. A gradual load is applied to it. It is a well known fact that brittle materials such as rock and concrete can have high compressive strength, but they eventually fail, and the failure is in the form of a fracture. The compressive strength of brittle materials can vary from 3 tonnes per square inch for a cube to 10 tonnes per square inch for granite stone. Some ductile materials, like mild steel, also have compressive strength, but measuring the actual values is difficult because of their elastic failure nature. When a load is applied to a ductile material, it deforms elastically up to a certain point, and after that, if the load is increased further, it starts to deform plastically. The plates may flatten without a clear fracture taking place. It is a standard test to determine the compressive strength of concrete indirectly. This test is conducted following the IS 5816-1970 standard. A standard test cube of concrete specimen, which is 150MM x 150MM x 150MM, is placed horizontally between the loading surfaces of the compression testing machine.



Fig 7.2.1

The compressive strength of a cube is calculated using the formula $\text{Compressive strength} = P \text{ divided by } A$, which gives the result in N per mm squared. Here, P represents the ultimate compressive strength measured in kilonewtons, and A is the cross-sectional area of the cube.

7.2.2 Split Tensile Strength:-

It is the standard test used to find out the tensile strength of concrete. This test is done as per IS 5816-1970. A standard concrete cylinder specimen, which is 300 mm long and has a diameter of 150 mm, is placed

horizontally between the two surfaces of a compression testing machine. A compressive load is applied from both sides, along the length of the cylinder, until the cylinder breaks along its vertical axis.

Because of the compression applied along the vertical diameter of the cylinder, it experiences both vertical compressive stress and horizontal stress.

The loading condition creates a high compressive stress right below the points where the load is applied. However, the rest of the cylinder, especially the part deeper inside, experiences uniform tensile stress that acts horizontally. It is estimated that the compressive stress acts over a depth of about one-sixth of the cylinder, while the remaining five-sixths of the depth is under tension.

The split tensile strength of the specimen is calculated using the following formula:

$$\text{Split tensile strength} = 2P / (D^2)$$

Where:

P = compressive load (in kilonewtons)

D = diameter of the cylinder (in millimeters)



Fig 7.2.2

7.2.3 Flexural Strength Test:-

The test is done according to BS 1881: part 118:1983. A simple concrete beam is placed and loaded at points that are one-third of the span from each end. The standard size of the beam specimen is 500mm in length and 100mm in width and height. Equal weights are added at these positions, which are one-third away from both ends of the beam. This setup creates equal reactions at both ends, matching the applied load. The load is increased slowly so that the stress increase in the bottom part of the beam stays between 0.02MPa and 0.01MPa. From this setup, it is clear that in the middle one-third part of the beam, between the two loads, the beam experiences bending. There is no shear force in this area. This middle section is where the highest bending moment of $Pd/2$ occurs, and there is no shear. If the beam breaks in this middle one-third section, it is called the "modulus of rupture."

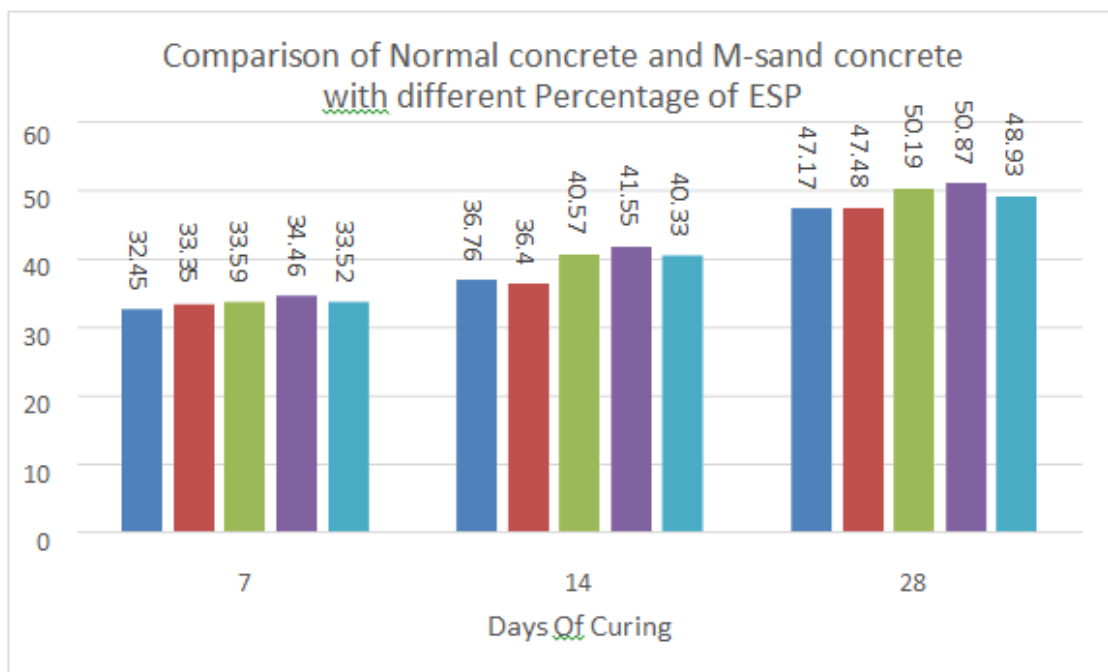


Fig 7.2.3

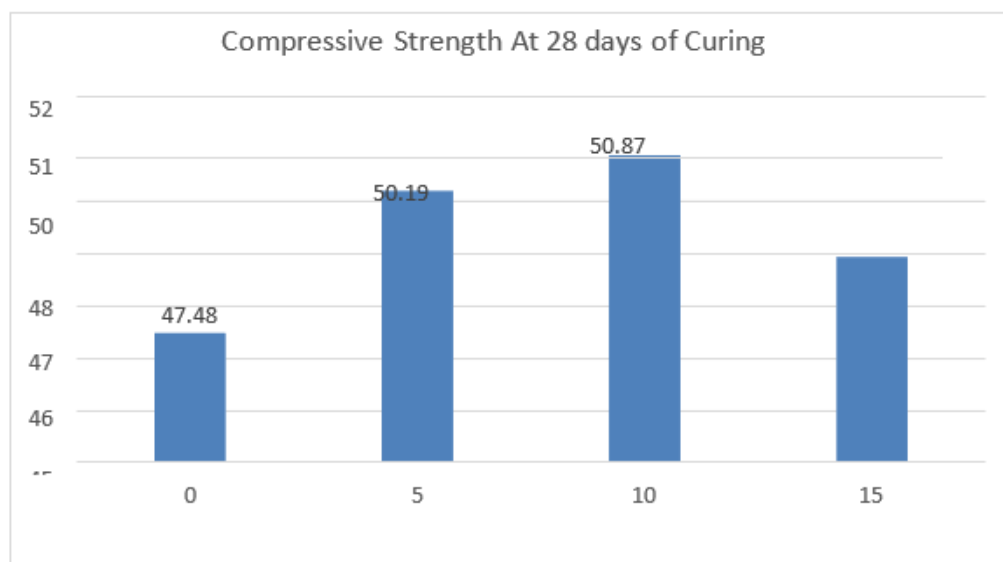


Fig 7.2.4

From the above numbers, we can see that the average compressive strength of normal concrete is 32.45 N/mm², 36.76 N/mm², and 47.17 N/mm².

For M-sand concrete with egg shell powder added in different amounts, the compressive strengths are 33.35 N/mm², 36.4 N/mm², and 47.48 N/mm² when there is 0% replacement of cement with egg shell powder at 7 days, 14 days, and 28 days of curing, respectively.

As the amount of egg shell powder increases, the compressive strengths are 33.59 N/mm², 40.57 N/mm², and 50.19 N/mm² for 5% replacement at 7 days, 14 days, and 28 days, respectively.

At 28 days of curing, the compressive strengths for 10% and 15% egg shell powder by weight of cement are 48.93 N/mm² and 50.87 N/mm², respectively.

So, it can be said that as the percentage of egg shell powder increases, the compressive strength tends to decrease.

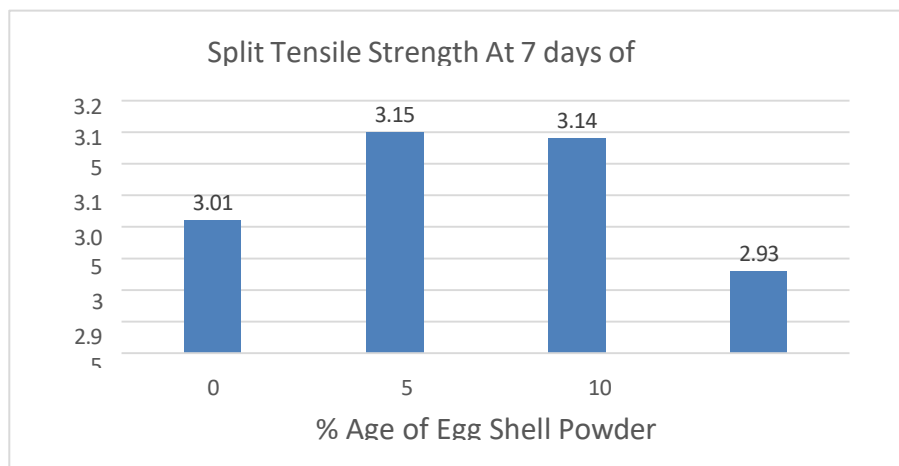


Fig 7.3.1

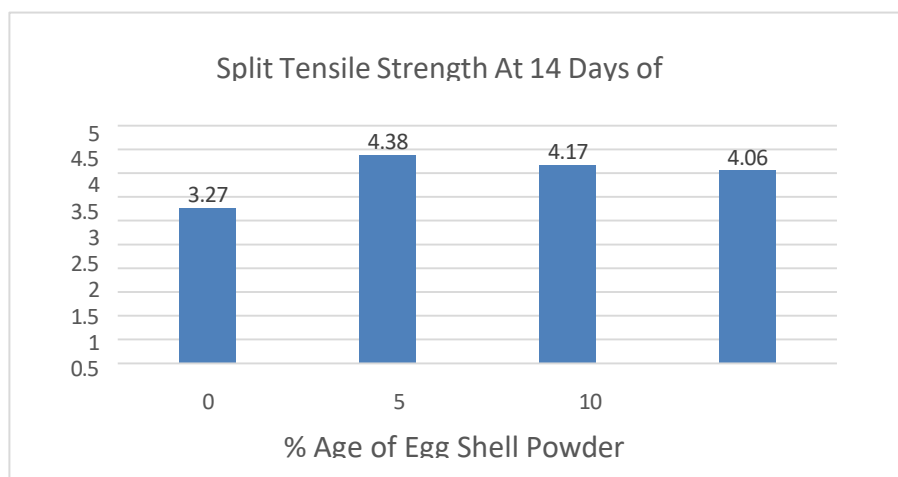


Fig 7.3.2

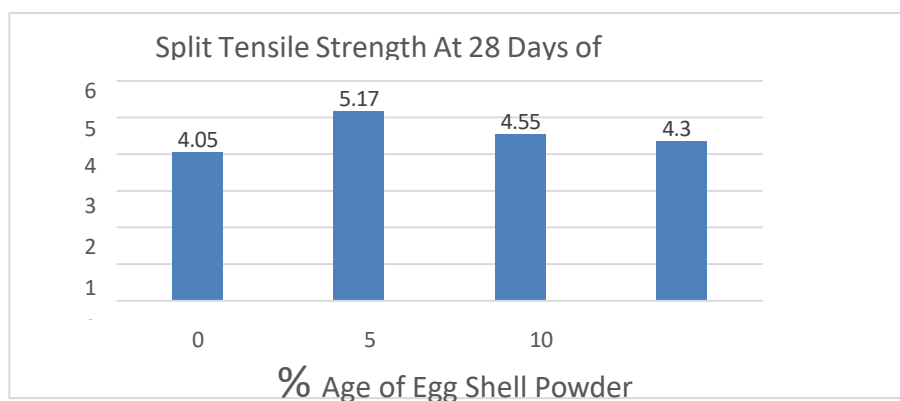


Fig 7.3.3

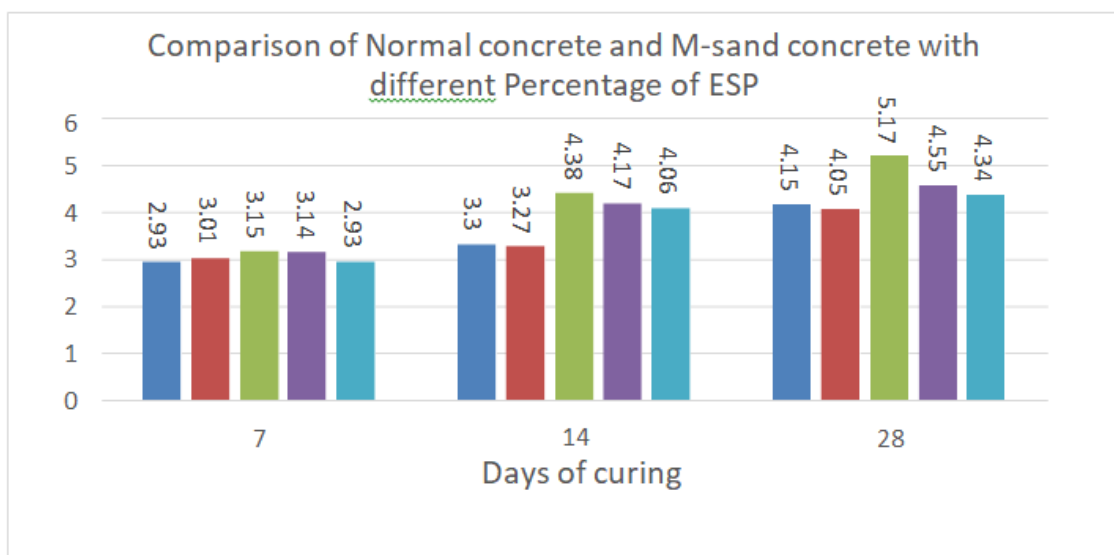


Fig 7.3.4

From the above figures, it is clear that the average split tensile strength of normal concrete mix is 2.93 N/mm², 3.3 N/mm², and 4.15 N/mm² for curing periods of 7 days, 14 days, and 28 days respectively. Similarly, the strength of concrete with 0%, 5%, 10%, and 15% egg shell powder after 7 days of curing is 3.10 N/mm², 3.15 N/mm², 3.14 N/mm², and 2.93 N/mm² respectively. For 14 days of curing, the strengths are 3.27 N/mm², 4.38 N/mm², 4.17 N/mm², and 4.06 N/mm² respectively. For 28 days of curing, the strengths are 4.05 N/mm², 5.17 N/mm², 4.55 N/mm², and 4.34 N/mm² respectively. Hence, from the obtained results, it can be seen that every increase in the content of egg shell powder or decrease in cement content leads to a decrease in the split tensile strength.

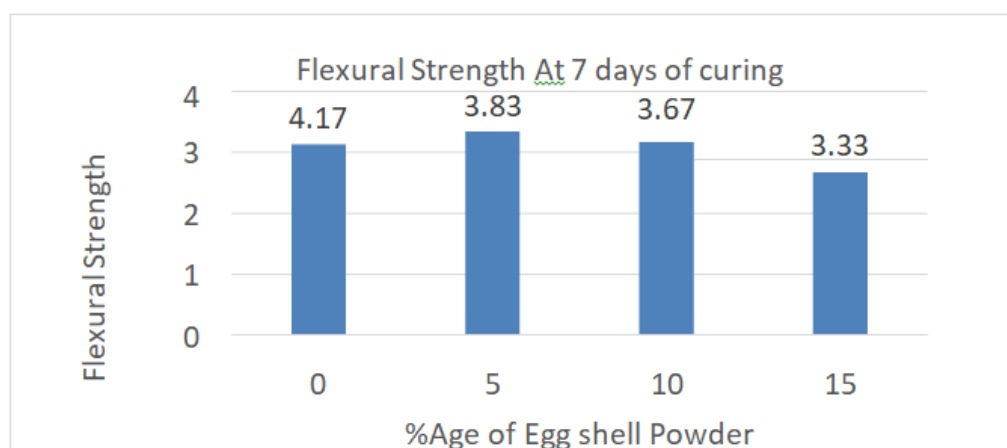


Fig: 7.4.1

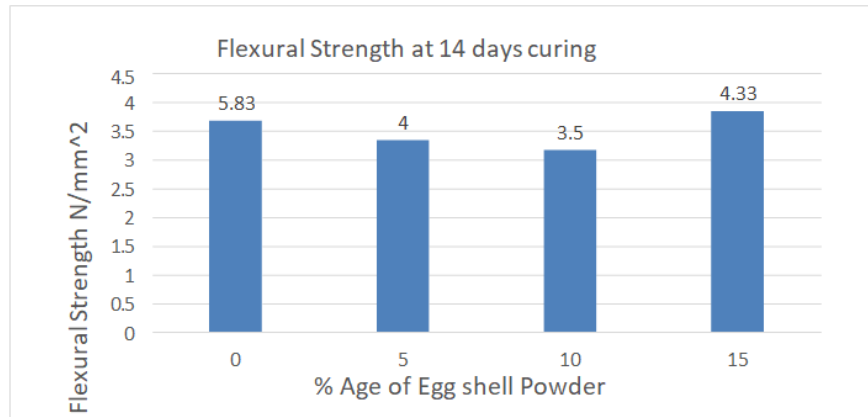


Fig: 7.4.2

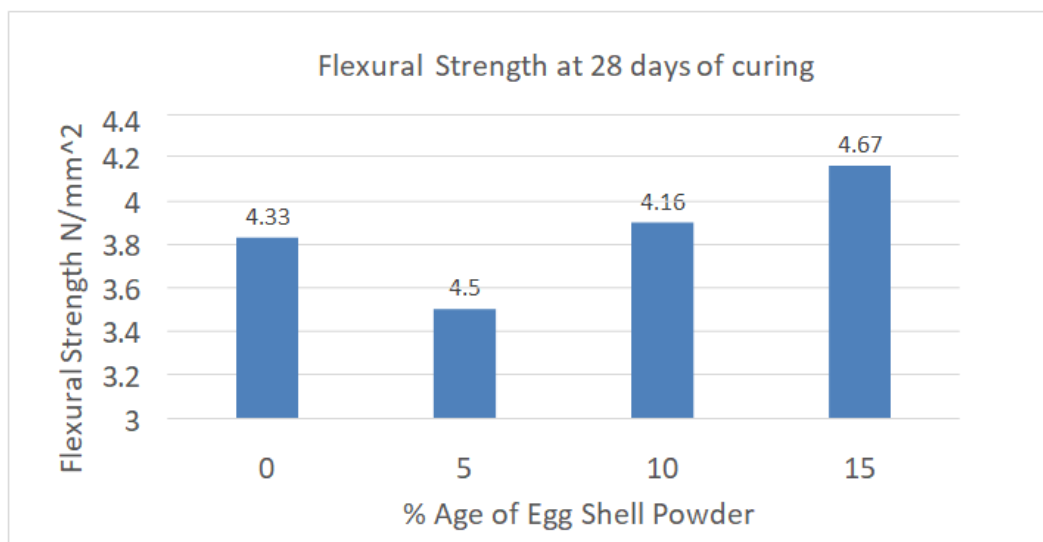


Fig: 7.4.3

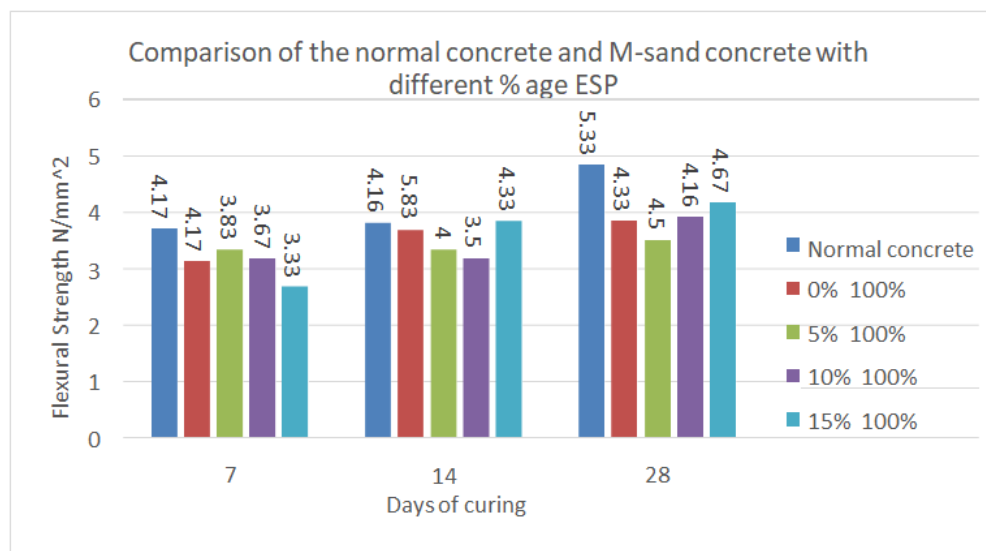


Fig: 7.4.4

From the figures, it is clear that the average split tensile strength of normal concrete at 7 days, 14 days, and 28 days is 4.17 N/mm², 4.16 N/mm², and 5.33 N/mm² respectively. For concrete with 0%, 5%, 10%, and 15% eggshell powder by weight of cement, the average split tensile strength at 7 days of curing is 4.17 N/mm², 3.83 N/mm², 3.67 N/mm² respectively. At 14 days of curing, the values are 4.16 N/mm², 5.83 N/mm², 4.00 N/mm², and 3.50 N/mm² respectively. At 28 days of curing, the values are 4.33 N/mm², 4.50 N/mm², 4.16 N/mm², and 4.67 N/mm² respectively. It can be said that the results are satisfactory when 5% eggshell powder is used by weight of cement, and a decrease in cement content leads to a decrease in the average strength of the concrete.

VIII. CONCLUSION

From the studies done, the following results were observed and concluded:-

- The compressive strength of normal M-sand concrete was 25.37 N/MM² at 7 days, 14 days, and 28 days respectively.
- The maximum compressive strength was achieved at 5% egg shell powder, which is considered satisfactory and can be used as the best proportion of egg shell powder to cement.
- The results from the flexural testing showed that the higher the cement content, the higher the flexural strength.
- Since concrete is a brittle material and compressive strength is the main concern, using egg shell powder up to 5% is considered optimal for structural use.
- Split tensile strength tests were carried out on cylinder prisms.
- The test results showed a decrease as the amount of egg shell powder increased.
- At 28 days of curing, the test results were 1.97 N/mm², 1.57 N/mm², and 1.56 N/mm², showing a decrease with higher egg shell powder content. Workability tests were also performed.
- The results showed that higher percentages of egg shell powder led to higher workability values.
- The density of the concrete decreased as the amount of egg shell powder increased.

References

- Amaranath, Y., & Ramachandrudu, C. (2016). Properties of concrete with eggshell powder as cement replacement. *Indian Concrete Journal*, 90(4), 94-102.
- Freyne, S. F., & Scrivener, K. L. (2017). Sustainable concrete: The role of supplementary cementitious materials in reducing carbon emissions. *Cement and Concrete Research*, 91, 1-12.
- Gowsika, D., Sarankokila, S., & Sargunan, K. (2014). Experimental investigation of egg shell powder as partial replacement with cement in concrete. *International Journal of Engineering Research and Technology*, 3(11), 856-860.
- Jayasankar, R., Mahindran, N., & Ilangovan, R. (2019). Studies on concrete using M-sand as a partial replacement of fine aggregate. *International Journal of Civil Engineering*, 6(1), 1-8.
- Reddy, B. V. V., & Gupta, A. (2011). Characteristics of cement-soil blocks using highly sandy soils. *Materials and Structures*, 44(3), 755-764.

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- Sathiparan, N., Rupasinghe, M. N., & Pavithra, B. H. M. (2017). Performance of eggshell powder as a partial replacement of cement in concrete. *Journal of Engineering Research and Application*, 7(9), 12-19.
 - Siddique, R., & Klaus, J. (2009). Influence of metakaolin on the properties of mortar and concrete: A review. *Applied Clay Science*, 43(3-4), 392-400.
 - Vijayalakshmi, R., Ramanagopal, S., & Christina, A. L. (2013). Effect of partial replacement of cement with eggshell powder on compressive strength of concrete. *International Journal of Emerging Technology and Advanced Engineering*, 3(4), 536-540.