INVESTIGATION ON THE PROPERTIES OF CEMENT MORTAR CONTAINING EGGSHELL POWDER AS A PARTIAL REPLACEMENT OF CEMENT

A Dissertation Submitted
in Partial Fulfilment of the Requirements
for the degree of

MASTERS OF ENGINEERING

IN

STRUCTURAL ENGINEERING

Submitted by:

AMAN SAINI
Registration No.: 801422002

Under the Supervision of

Dr. SHRUTI SHARMA
Associate Professor
Civil Engineering
Thapar University, Patiala

DEPARTMENT OF CIVIL ENGINEERING
THAPAR UNIVERSITY,
PATIALA-147004
JULY 2016

DECLARATION

I, AMAN SAINI, hereby declare that this thesis entitled **"INVESTIGATION ON THE PROPERTIES OF CEMENT MORTAR CONTAINING EGGSHELL POWDER AS A PARTIAL REPLACEMENT OF CEMENT"** in fulfilment of the requirement for the award of the Degree of **Master of Engineering** in **Structural Engineering** and submitted in the Civil Engineering Department, Thapar University, Patiala is an authentic record of my work carried out during a period from July 2015 to July 2016 under the supervision of **Dr. Shruti Sharma, Associate Professor,** Department of Civil Engineering, Thapar University, Patiala.

This matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other University.

Date: 15/07/2016

AMAN SAINI

Roll No. :801422002

CERTIFICATE

This is to certify that above statement made by the student concerned is correct and true to the best of my knowledge and belief.

25/7/2016

Dr. SHRUTI SHARMA
Associate Professor
Department of Civil Engineering
Thapar University, Patiala

Countersigned by:

Dr. Naveen Kwatra
Professor & Head
Department of Civil Engineering
Thapar University, Patiala- 147004

Dr. S.S.BHATIA
Dean of Academic Affairs
Thapar University, Patiala-147004

ACKNOWLEDGMENT

I am thankful to the Almighty for bringing this day in my life. Time has provided me the wonderful opportunity to express my heartfelt gratitude to my guide Dr. Shruti Sharma, Associate Professor, Civil Engineering Department, Thapar University, Patiala, who permitted me to carry out research work under her valuable guidance with patience. I shall ever remain indebted to her for meticulous guidance, constructive approach, clear thinking, keen interest, constant encouragement and forbearance right from the beginning of this research to its completion.

I wish to express my sincere thanks to Dr. Naveen Kwatra, Dr. Rafat Siddique, Dr. Prempal Bansal, Dr. Shweta Goyal, Dr. Heaven Singh and Sh. Rajesh Pathak whose lessons have invariably created great interest in the subject matters of Structural Engineering.

The cheerful support of my friends and colleagues is sincerely appreciated. Special words of appreciation goes to Sh. Ram Simran and Sh. Virender Sharma.

I am indeed indebted to my parents, Mr. Balbir Singh Saini and Mrs. Renu Saini and my younger brother Mr. Manu Saini for their encouraging words and constant support throughout the research work.

July, 2016

AMAN SAINI

(801422002)

ABSTRACT

Mortar and concrete are the main ingredients of the construction industry. To produce mortar or concrete, cement is the building block. Cement is produced by using natural limestone. When limestone is burned for the production of the cement, carbon dioxide gas was liberated as a by-product which is recognised as a greenhouse gas and have harmful effects on the environment. To minimize the harmful effects and to reduce the consumption of natural materials, waste materials are incorporated in the production of mortar and concrete.

In research eggshells in the powdered form which passed through the 90µm IS sieve has used as a partial replacement of cement for the production of cement mortar. Eggshells are rich in CaO and have chemical composition equivalent to that of natural limestone.

Mix proportion of 1:3 is used for the production of the cement mortar. ESP is added in the proportions of 0%, 2.5%, 5%, 7.5% and 10% by weight of cement. The effect of ESP on the compressive strength, flexural strength, split tensile strength, weight, bulk density, water absorption and sorptivity are find out. SEM/EDS analysis is done to understand the micro-structural analysis to correlate the mechanical properties.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Mortar and concrete materials are used at a large extent in the construction industries. As per World Business Council for Sustainable Development (WBCSD) concrete is extensively used man made material, and after water it is on second position as the most consumed material on the earth, around three tonnes used annually for each men, women and child. Concrete and mortar are tremendously used by developing countries to develop their infrastructure and India is one of such country in which government is utilizing most of its resources to develop the infrastructure of the Country, hence we can say that concrete and mortar are the building blocks of the development of any country and they are known as backbone of the infrastructural development of a nation.

Presently, for a number of reasons, the construction industry is not sustainable. Firstly, cement is the major component for the production of concrete and mortar, for the manufacturing of cement lot of energy is required. Secondly, it consumes huge amount of natural resources due to which no virgin material will be left for the future generation hence we have to utilize some waste material which can be easily used in the production of the cement mortar without altering the properties of the mortar. Lastly at the present time we need structures which are durable and can carry large amount of load without undergo successive deflection and cracking. To achieve this we need concrete of high mechanical properties like compressive strength, flexural strength and split tensile strength. To enhance the mechanical and durability properties we have to use other supplementary cementing materials. Let us discuss all these factors together which make the concrete industry unsustainable.

1.2 CEMENT

Cement is the main element for the formulation of cement mortar and concrete. Cement mortar is a mixture of cement, sand and water. Cement acts as a binder and filler which fills the void between the fine and coarse sand particles and give a denser configuration.

It sets and hardens severally also binds alternative materials along with it. Cement employed in construction is divided as hydraulic or non-hydraulic.

Hydraulic cement hardens because of hydration. Hydration is a chemical reaction between cement and water and as a result C-S-H gel is formed. This gel is important for the strength and binding action of the cement mortar. Hydraulic cement can harden even underwater or when control exposed to wet weather. Portland cement is the example of the hydraulic cement. Non-hydraulic cement should be conserved to get its strength. Gypsum plaster is the example of non-hydraulic cement. Hydraulic cement was used throughout the research work.

1.3 CEMENT PRODUCTION

According to the CDP`s cement report 2016 (www.google.com) after China, India is on the second position for the production of the cement in the world. In China 2482.42 Million Tonnes of cement was produced every year and in India 285.83 Million Tonnes of cement is produced followed by USA 80.36 Million Tonnes. China yields thirty-seven percent of the world`s cement, followed by Republic of India with six percent and USA with five percent.

Two different strategies of raw mix preparation were used: the minerals were either dry-ground to make powder, or were wet-ground with added water to provide a fine suspension.

The wet method suffered the apparent disadvantage that, once the suspension was introduced into the oven, an oversized quantity of additional fuel was employed in evaporating the water. Moreover, a bigger oven was required for a given clinker output, as a result of this lot of the kiln's length was exhausted for the drying method.

On the opposite hand, the wet method had variety of benefits. Wet grinding of minerals is typically way more economical than dry grinding. Once suspension is dried within the oven, it forms a granular crumble that's ideal for resulting heating within the oven. Within the dry method, it's terribly tough to stay the fine powder raw combine within the oven, as a result of the fast-flowing combustion gases tend to blow it back out. Currently dry method is employed.

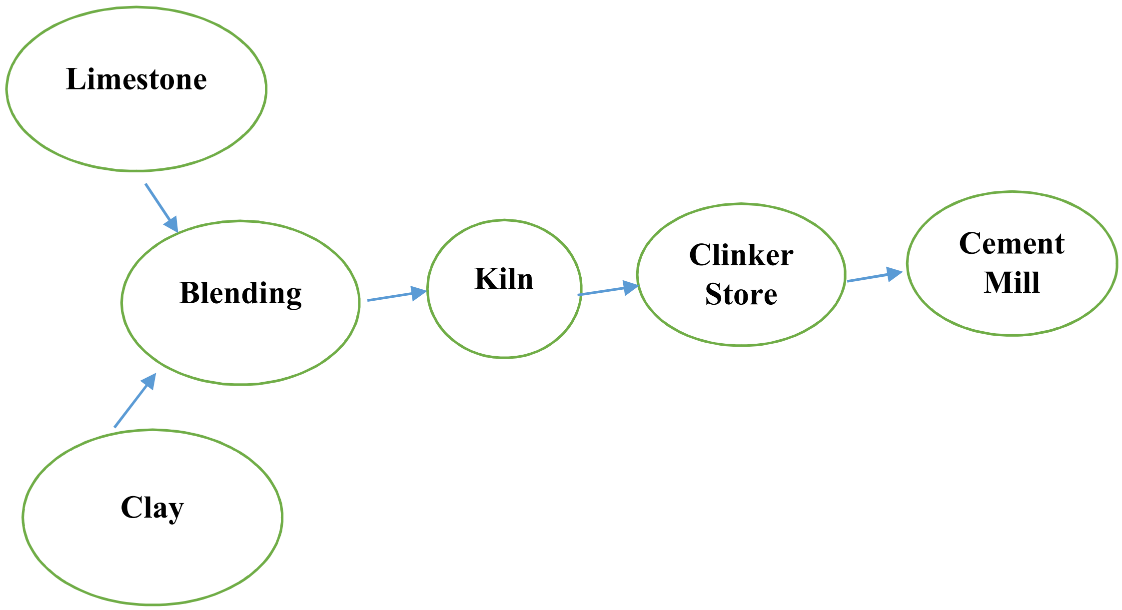


Figure 1.1: General layout of the cement production.

Limestone and clay is used for the production of the Portland cement. Lime, silica, alumina and iron oxide are the crucial ingredients for the production. The process of producing cement consists of changing raw materials into fine powder, compounding them and burning at a temperature of 1400º C. The resultant product is named clinker. Clinker is then cooled, ground to fine powder with the addition of a mineral called gypsum. The product obtained is called cement.

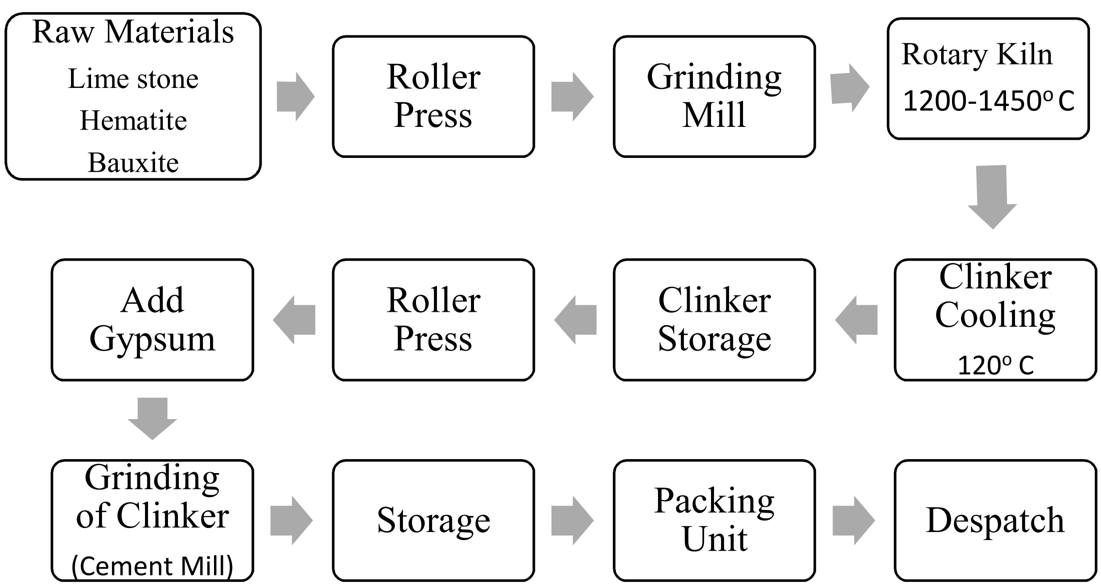


Figure 1.2: Flow diagram of manufacture of Portland cement by dry process. (Wikipedia)

As stated earlier lot of energy is consumed for the production of cement. In the cement industry, the cost of energy varies between 25% to 35% of total direct cost. Hence, industry is searching for the more energy-efficient technique. Some of the plants have refused to use less fuel-efficient wet process and started work with more energy-efficient dry process.

Table 1.1: Average fuel consumed in the cement production (www.google.com)

KILN TYPE	AVERAGE FUEL CONSUMPTION (GJ/t)
Wet kilns	6
Dry kiln (single stage preheaters)	4.5
Dry kiln (multi stage preheaters)	3.6

One of the main ingredient of cement mortar, Portland cement is costlier and emits carbon dioxide (CO_2) during its manufacturing. CO_2 which is released from the cement plants are divided into two classes named as combustion and calcination.

From a cement plant Combustion take place roughly 40% and calcination about 60% of the total CO_2 ejaculation. The combustion is accompanying with fuel use. Calcination take place when CO_2 is released by burning the limestone and clay above 2500ºF. Calcination take place with the manufacturing of cement. Hence, for the reductions in CO_2 we have to reduce the manufacturing of the cement.

Cement is manufactured near to the limestone quarries or near to other raw carbonate minerals as these minerals are the principal raw materials which are used in the production of the cement. Production of cement is very expensive, generally any nation has less number of cement plants less than 100. CO_2 is liberated as a by-product of clinker production, which is an intermediate product in cement production, in which calcium carbonate is calcinated and converted into lime, which is the main component of the cement.

Fossil fuel combustion also generates carbon dioxide. Carbon dioxide is emitted during the manufacturing of clinker, when calcium carbonate ($CaCO_3$) is heated in a rotary kiln chemical reactions take place carbon dioxide as a side product of CaO also generates.

Mathematically:

$$CaCO_3 + heat = CaO + Carbon\ dioxide \qquad \text{---------------------- (1.1)}$$

At higher temperatures in the lower end of the furnace, lime (CaO) responds with silica, aluminum and iron consisting materials to create clinker, which is a transitional result of bond production. Clinker is then expelled from the oven to cool, ground to a fine powder, and blended with a little part (around five percent) of gypsum to make the most well-known type of bond known as Portland cement. The second most type of cement is masonry cement. More lime is used in the masonry cement as compared to Portland cement hence more CO_2 emission takes place.

The cement produces about 5% of CO_2 emissions of the world. 900kg of CO_2 for every 1000kg of cement produced (Pliya and Cree, 2015)

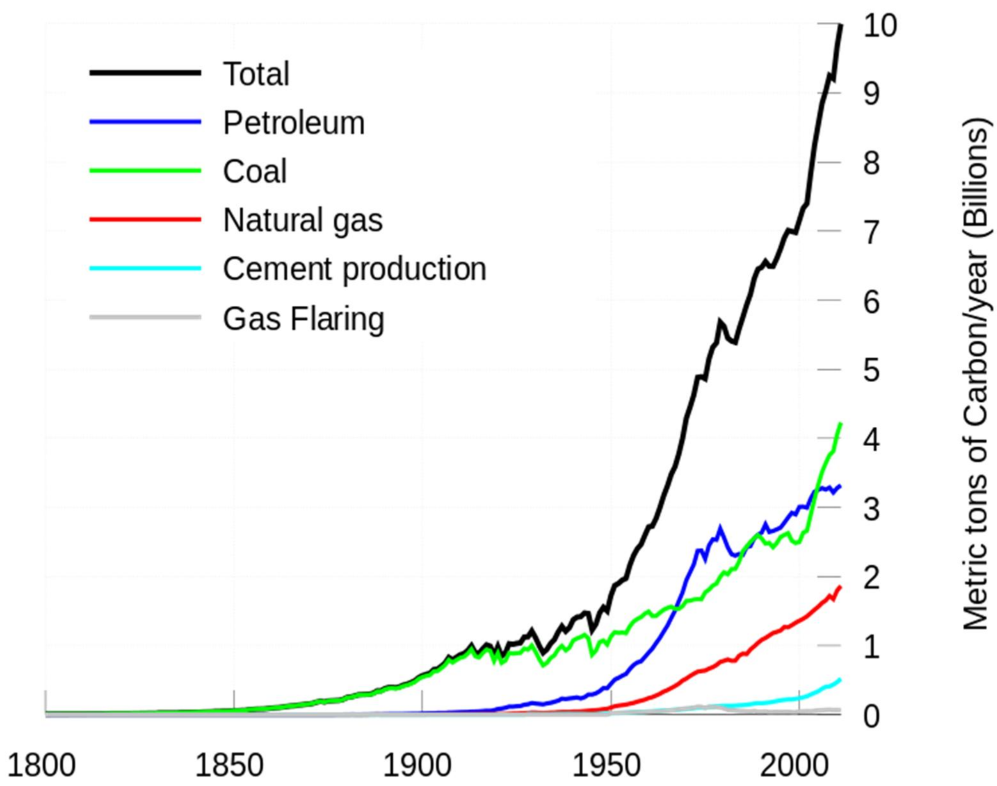


Figure 1.3: Carbon dioxide liberated from the various industries (Wikipedia)

As CO_2 contributes to the green-house gases so the reduction of the CO_2 is a challenging problem in front of the cement industry. World leaders of 20 significant nations including India came together during COP-21 (conference of parties) agreement held in Paris in February 2016 decided to reduce the CO_2 emission. Hence, to minimize the use of cement the whole construction industry is looking for some waste material that can be incorporated in the concrete without altering its properties.

By minimizing the use of cement, energy which is used to produce the cement is reduced and ultimately reduction of the CO_2 emission and construction cost and on the other hand at the same time utilization of the waste product take place.

1.4 VARIOUS WASTE PRODUCTS

As stated above to minimize the CO_2 emission, manufacturing of cement should have to be reduced. Energy is very important for the advancement of developing nations like India. With regards to low accessibility of non-renewable vitality assets combined with the necessities of extensive amounts of vitality for building materials like concrete, the significance of utilizing modern waste can't under evaluated.

Hence instead of cement identifying analogous material from waste and using the same as partial replacement or fully replacement of cement is a wise idea. Various waste byproducts from agriculture and industry like rice husk ash, fly ash, copper slag, quarry dust, silica fume, egg shells, saw dust ash, micro silica, granulated blast furnace slag, metakaolin, scrap-tire, waste glass, municipal solid waste, volcanic ash, waste-foundry sand etc. shall be used. Therefore, in the present study Egg shell powder is used as a partial replacer of cement for the production of cement mortar.

1.5 EGG SHELLS

Eggshell is basically a waste material which is produced from the egg breaking plants, bakeries, and restaurant and also from other sources which effect the environment and creates environmental problems like pollution. Hence proper disposal of such a waste is very important. Lot of efforts are required to convert the waste material into the useful materials.

The chemical composition of eggshell shows that it can be used in the concrete by converting it in the powdered form. The composition of the eggshell is such that it contains CaO in a large extent which resembles with the composition of the cement as cement is also very rich in the calcium oxide.

Literature has shown that the ESP mainly composed of lime and calcium. ESP can be used as a substitute material for the production of wall tile material, cement concrete, cement paste and others. Eggshell also contribute to construction industry by reducing the construction cost. Thus, eggshells can be produced a new substitute for the development of the cement industry as a supplement for the production of conventional cement concrete and mortar.

Egg shell is basically a poultry waste which is very rich in calcium and having composition nearly same as that of limestone. Type of hen, strain on hen, its breed, age, diet and many others factors are responsible for the quality of the eggshell. Generally it was observed that white eggs are smaller, lighter and have thinner shells than Brown eggs; however, the shell color is not a true indicator of the inner quality of an egg. In a study it was observed that, the $CaCO_3$ and organic matter present in brown eggs was recorded as 95% to 96% by weight and 3% to 4% by weight respectively. In other investigation white eggs have 94% by weight calcium carbonate and 6% by weight organic matter and other minor compounds. Based on the facts it was concluded that, percentage of calcium carbonate in white and brown eggs is approximately same.

Limestone rocks, chalk and sea shells are the main source of obtaining limestone. It is basically treated as an inert material. Limestone does not possess any cementing properties as it is not capable of producing C-S-H gel. Addition of limestone does not alter the properties of the cement concrete at some specific replacements. On the other hand its use in the concrete industry is beneficial as it reduces the energy produced during the production of cement. Limestone can be used as a filler in conventional Portland cement, in Portland-limestone cement and as a filler in self-compacting concrete.

Use of eggshell waste instead of natural lime to replace cement in mortar can have benefits like minimizing use of cement, conserving natural lime and utilizing waste material.

Hen eggshell is made up from three different layers, first one is cuticle which is observed on the outer surface of the egg, second one is spongy (calcareous) layer and the last one is an inner lamellar layer also called as mammillary layer. The spongy and mammillary layers form a matrix of protein fibers is produced by lamellar and spongy layers. This protein fibers bond the calcite (calcium carbonate) crystals along with it.

Lot of pores are present between these two layers. These pores allows the gases to escape from the shell.

An egg is basically consists of calcium carbonate and eggshell membrane (ESM). The eggshell membrane is generally present between the albumen that is white portion of the egg and inner surface of the eggshell. Two shell membranes are present in an egg, first one is a thick outer membrane which is attached with the eggshell and second one is a thin inner membrane. The approximate thickness of the two membranes is about 100µm.

A semi-permeable membrane is formed from these two membranes as these membranes contains protein fiber along with them.

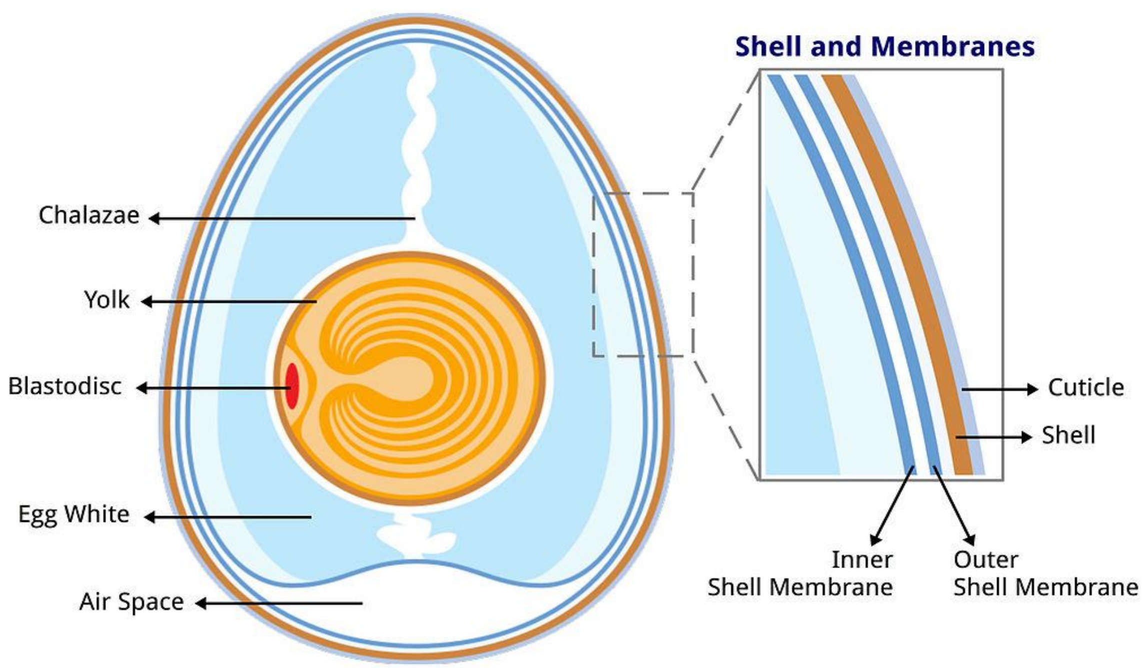


Figure 1.4: Inner structure of an egg (Wikipedia)

1.6 EGG PRODUCTION IN THE WORLD

The top five countries that produces most of the eggs in the world are:

Table 1.2: Egg production in 2015 throughout the world (FAOSTAT DATA 2015).

S. NO.	Country	Egg production 2015 (metric tonnes)	%age of total World
1	China	29,128,716 m/t	39.45 %
2	USA	5,636,231 m/t	7.61 %
3	India	3,835,206 m/t	5.11 %
4	Japan	2,521,975 m/t	3.40 %
5	Mexico	2,516,095 m/t	3.41 %

1.7 EGG PRODUCTION IN INDIA

As stated above India is on the third position for the production of the eggs in the world with an average egg production of 3,835,206 metric tonnes. Andhra Pradesh is the biggest egg producer state of the India. Andhra Pradesh stands first for the maximum egg production having daily production of 5.5 crore. Maximum poultry industry is found to be in Hyderabad With in the Andhra Pradesh.

Predominantly India send out eggs, egg powder, solidified egg yolk and egg whites powder to Europe, Japan and different nations. Fare of eggs from Andhra Pradesh goes to West Asia and African nations. Day by day fare of around 20 lakh eggs in holders are being sent to the United Arab Emirates, Kuwait, Muscat, Iran, Iraq and a few African nations. The egg holders are being transported to Dubai from where they were conveyed to different nations in the Gulf and Africa. Andhra Pradesh positions second in egg sends out, after Tamil Nadu.

Utilization of eggs in eateries and families are minor contrasted with the greater part of eggs used in egg breaking plants for large scale manufacturing of fluid eggs for use in nourishment and non-sustenance related items.

The yearly measure of eggs sent to softening up plants in France and Canada is roughly 1 billion and 2.3 billion, separately. The heaviness of a normal egg is around 60 g, while the void shell relates to 11 % by weight. Approximately, 6600 tonnes of limestone powder is produced by 1 billion of eggs (Pliya and Cree, 2015).

According to a study eggshell waste generation in India is 1,90,000 tonnes per annum. As India has a very high population density so the disposal of such a huge waste is always a challenging problem.

Majority of the eggshell waste is deposited as landfills. Eggshell waste in landfills attracts vermin due to attached membrane and causes problems associated with human health and environment. Hence we have to find out other the alternatives through which, we can easily dispose off eggshell waste without affecting the environment and human health.

1.8 USES OF EGGSHELL

The various uses of the egg shells are:

- Egg shell waste can be used as fertilizer
- It can be used as animal feed as it is very rich in calcium, so it becomes the source of calcium for the animals.
- Egg shell can be used as accelerator as it reduces the setting time of the rigid road pavements and hence we can use it in the rainy seasons also.
- Egg shell waste may be used in the powdered form as a partial replacer of the cement in concrete.
- It can be used as a fine aggregate in concrete production.

1.9 MOTIVATION

The motivation behind the usage of ESP is

- Reducing the landfill problem by using in the mortar or concrete production.
- Contribution to our environmental problems by reducing the CO_2 emission.
- Optimum utilization of the waste that is ESP without compromising the strength and durability of the mortar / concrete.

1.10 OBJECTIVE AND SCOPE OF THE PRESENT STUDY

Objective of the work is to investigate the mechanical and durability properties of the cement mortar by partially replacing cement with the egg shell powder. In the current scenario, structures with high compressive strength, flexural strength, split tensile strength and durability properties are the first and last choice of the engineers.

In order to achieve the objectives, various trial mixes of cement mortar were conducted by varying the percentage the egg shell powder as a partial replacement of cement in cement mortar. Also many other properties have been tested in order to achieve the aforesaid objectives, as fresh properties like consistency, setting time, unit weight variations and hardened properties such as weight loss, water absorption, water sorption and micro structural analysis using scanning electron microscope (SEM).

The result of these tests were compared with that of the normal mortar mixture. The use of egg shell material in cement mortar have many advantages which are directly proportional to the durability of the structure, along with it the quantity of the cement used in various mix proportions was also reduced.

- Scope of the present study is to limit the use of cement by replacing it partially with the different percentages of the egg shell powder in cement mortar.
- The properties of the cement mortar with ordinary Portland cement of grade 43 with inclusion of egg shell powder were experimentally studied.
- To find the effect of ESP on compressive strength, split tensile strength, flexural strength, water absorption, and water sorption of cement mortar.
- To study the micro structure using SEM analysis of phases concerning chemical composition.

1.11 RESEARCH SIGNIFICANCE

This research is very important as India is the second world producer of cement and it is on third position in the production of eggs. A huge amount of egg shells are available in India. As after China, India is the second world`s most populated country having very high population density.

So the disposal off such a huge waste as a landfill becomes a challenging problem for the India as it creates environment and health related issues. In order to reduce this burden, let us try to use egg shell waste as a partial replacement of cement in the manufacturing of cement mortar.

In spite of the fact that the waste measure of egg shells would not support the industry altogether, it could be utilized as halfway supplements.

With the use of ESP, the consumption of the cement will be reduced to a certain extent. CO_2 emission will also be reduced by the less use of cement which solve the environmental problems.

1.12 ORGANIZATION OF THE THESIS

Five chapters are compiled in the thesis and each chapter has its own importance.

Chapter 1: Represent the general introduction of the study background along with objectives, scope, significance, expected outcomes of the study.

Chapter 2: Covers a brief literature review variety of strength development of cement mortar containing different proportions of ESP. In this chapter work done by various researchers on the use of ESP in construction industry is demonstrated in detail.

Chapter 3: Details of experiment program, materials used and its sources, proportioning of ingredients, specimen preparation and testing procedures are presented. This also discusses in detail about the scanning electron microscope studies.

Chapter 4: Presents experiment results, analysis and relevant discussion.

Chapter 5: Summarizes the test results and conclusion drawn based on findings of work, limitations and recommendations for further research are also presented.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter consists of numerous application and procedures used for finding the use of eggshell powder in cement mortar. Very few researchers carry out their research on eggshell powder. Research performed by the numerous researchers in the zone of strength development of cement mortar containing eggshell powder at early age and the adverse effect on the various properties of over addition of the eggshell powder was studied. A very less information is present in literature of the effect of eggshell powder on the various properties of the cement mortar like compressive strength, split tensile strength, flexural strength, water absorption water sorption etc. so the effect of eggshell powder on cement concrete is also studied along with the cement mortar.

2.2 REVIEW OF LATEST WORK IN THE FIELD

In this section, the work done by the various researchers on the use of eggshell powder in the construction world is as follows:

Amu et al., 2005 carried out the practical experiment and reported that Egg Shell Powder (ESP) can be utilized as a supplement for modern lime on an expansive clay soil and also reported that the combination can be used where high subgrade performance is not necessary. Freire and Holanda, 2006 carried out the investigation on egg shell waste and found out its use in a ceramic wall tile paste. Based on the presence of $CaCO_3$ in egg shell wall tiles can also be prepared from the ESP. Researchers additionally found that egg shell can be utilized as an fabulous option for material reuse and waste reusing practices. Lau yih bling (2010) conducted the investigation in egg albumen and reported that foamed concrete were prepared by egg albumen which has reduce the cost and time of project. 1per cent and 5 percent egg albumen were used.

From the investigation it was concluded that 5 percent of EAFC consists of unstable compressive strength and higher flexural strength with increased density when compared with control foamed concrete which was 64% and 35%.

Amu and Salami (2010) carried out the experiment and stated that common salt with egg shell on lateritic soil was the best endorsement for egg shell as an effective stabilizer for the road works. Stabilization obtained by adding 2-10 percent of common salt with optimum egg shell powder. The compaction and CBR properties of the egg shell used soils was improved as marked by the results. Ngo slew kee, 2010 investigated on the topic of "Effect of coconut fiber and egg albumen in mortar for greener environment" and reported the effect of egg & coconut fiber on compressive and flexural strength of mortar. Three types of samples were prepared and tested to make a comparison between the strength developments of each sample.

The quality of mortar containing 0.1% for every coconut fiber with 1% egg whites was higher than the control mortar while the mortar containing 0.5% coconut fiber ± 5 % egg whites was lower quality than the control mortar. The quality of mortar containing 0.1% for every coconut fiber with 1% egg whites was higher than the control mortar though the mortar containing 0.5% for each coconut fiber ± 5% egg white was of lower quality than the control mortar.

Amarnath Yerramala, 2014 studied the properties of the concrete with eggshell powder as cement replacement. Author replaced the cement partially with the percentage 0%, 5%, 10% and 15 %. Researcher finds the performance of ESP concretes in terms of strength properties like compressive strength, split tensile strength also properties like water absorption and sorption at an age of 1 day, 7 days and 28 days. Results derived by the author indicates that ESP can effectively be utilized as incomplete substitution of cement in solid creation. As per author when cement was replaced by 5% of eggshell powder the strength of concrete was higher than the control concrete which indicates that 5% eggshell powder was an optimum content for maximum strength. The results derived by author further shows that expansion of fly ash alongside ESP was beneficial for enhanced execution of cements.

Materials used

Author used OPC of 53 grade. Which has conformation from the IS:12269 and also conforming the requirements of ASTM C 642-82 type I.

Researcher collects the eggshells from the local sources and the eggshell powder was passed through the 90 µm IS sieve was used for the replacement of the cement with eggshell powder.

Author used coarse aggregate of maximum size 20mm which were crushed blue granite and well graded river sand having fines less than 2.36 mm as fine aggregate. Coarse aggregates and fine aggregates had specific gravity of 2.65 and 2.63 respectively.

Mix proportion

Author replaced the ESP in proportions of 0%, 5%, 10% and 15%. And after that, for the combined effect of eggshell powder and fly ash he replaces both eggshell powder and fly ash 15% each. Water to cement ratio was taken 0.6 throughout the research.

Results

Author used 150 mm X 150 mm X 150 mm specimens at an age of 1 day, 7 days and 28 days for finding out compressive strength with the help of CTM (Compression Testing Machine) having capacity of 2000 kN. For this loading rate adopted was 2.5 kN/s.

It was observed that with the passage of time strength of all the concrete also increases. Control concrete gained 31 % at 1 day and 50 % after seven days of curing over its 28 days compressive strength. The ESP concretes gained 20-43% at one day and 56 to 61% after seven days of curing as compared with 28 days strength. M5 mix which contained both ESP and fly ash attained 23 % and 57 % strengths over 28 day strength at one and seven days respectively. This observation suggests that the strength enhancement of ESP concretes is lower than control concrete between 7 and 28 days.

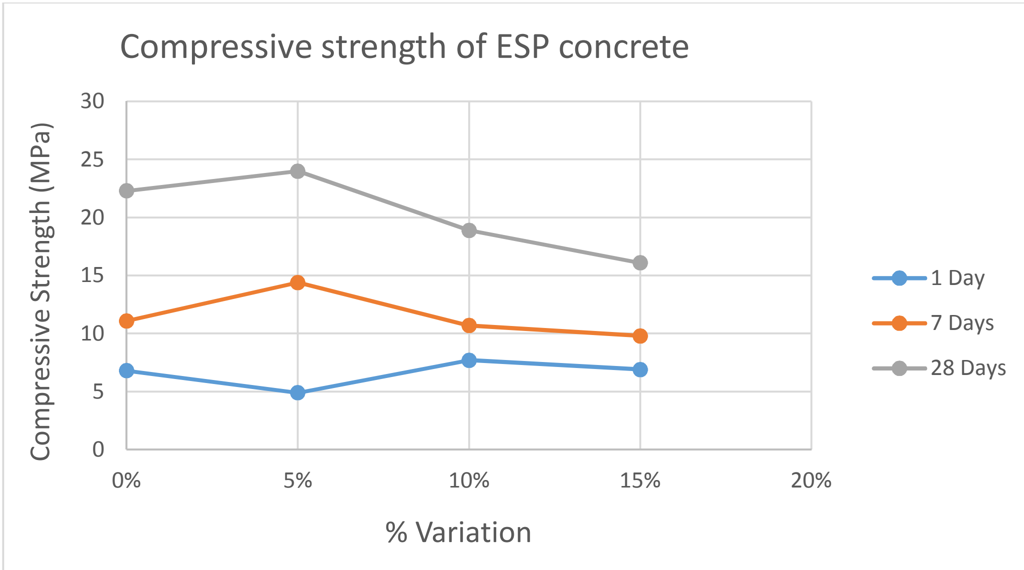


Figure 2.1: Compressive strength of concrete having ESP (Amarnath Yerramala, 2014)

At one day curing, the compressive strength of M2 concrete was less than M1 concrete. However, the compressive strength increased to 30 % and 7 % at 7 days and 28 days of curing over concrete M1. The strength increase of M2 concrete was higher between one and seven days over control concrete. One day strength of M3 and M4 was nearly same as that of control concrete M1. However, the compressive strength of these concrete mixes were less than control concrete at seven days and twenty-eight days of curing. The strengths were 4% and 12% lower at seven days for M3 and M4, whereas, the strengths were 15% and 28 % lower than control concrete at 28 days of curing.

M5 concrete had 35%, 1% and 13% lower strengths than control concrete for 1 day, 7 days and 28 days of curing. This observation suggests that ESP replacement of 5% can give higher strength than control concrete. However, further increase of ESP will decrease compressive strength at all curing ages. Furthermore, addition of fly ash increases compressive strength over its corresponding ESP replaced concrete. Split tensile strength test was performed as per the recommendations of ASTM C 496. Cylinders of size 100 mm X 200 mm were used. Obtained results for the split tensile strength were presented in the Figure 2.2

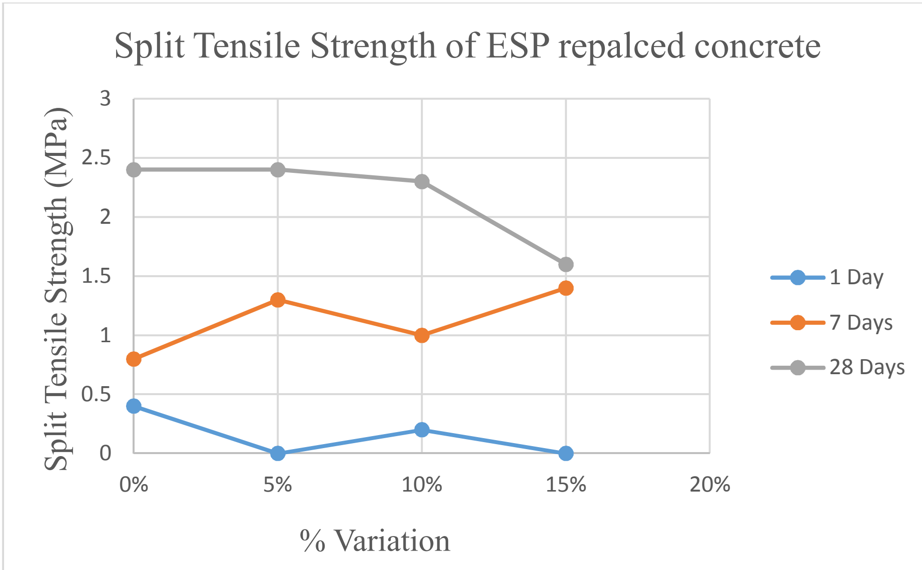


Figure 2.2: Split tensile strength of concrete having ESP (Amarnath Yerramala, 2014)

According to the author, all the concretes failed to show enough resistance against split tensile strength at 1 day. However, split tensile strength of the concretes attains the range of 0.8 MPa to 1.4 MPa for the curing of seven days. However 28 days strength of control concrete (M1) was 32%. The ESP concretes had high strength gain as compared to control concrete at the age of 7 days. Maximum strength enhancement was for M4 concrete with 88 % over its twenty-eight days split tensile strength. M5 also had higher strength gain at 7 days of curing than control concrete. This results implies that like compressive strength, addition of ESP, especially above 10% will retard strength gain between 7 and 28 days. Split tensile strength of the concretes at 28 days of curing was between 1.6-2.4 MPa. The lowest strength was for M4. Although there was good strength enhancement between one and seven days of curing, this mix failed to maintain same enhancement between 7 and 28 days of curing. The remaining concretes did not show any major difference in split tensile strengths with control concrete after 28 days of curing.

For the concrete to be durable, density, water absorption, water sorption and permeable voids are the main properties. Lower the water absorption and sorption more will be the durability of the concrete. Result of all these properties carried by the researcher were presented in the Table 2.1

Table 2.1: Density, Water absorption, Sorption and Permeable voids result. (Amarnath Yerramala, 2014)

Concrete	Density kg/m^3	Absorption % 72 hr	Sorption mm/s$^{0.5}$	Permeable voids
0 % ESP	2364	4.39	0.12	7.7
5 % ESP	2347	2.94	0.106	7.7
10 % ESP	2323	3.41	0.11	8.89
15 % ESP	2305	4.38	0.16	8.3
15 % ESP + 15 % FA	2317	5.13	0.17	9.48

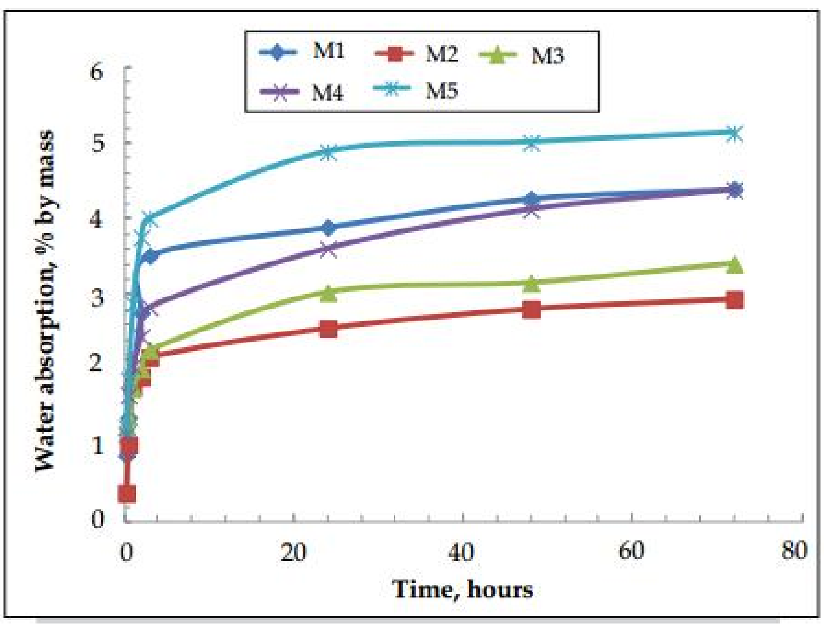


Figure 2.3: Water absorption of concrete having ESP (Amarnath Yerramala, 2014)

From the Table 2.1 it was noticed that water absorption for M2 and M3 was lower than control concrete, whereas, M4 show nearly same absorption as that of control concrete. M5 concrete show higher water absorption as compared to control concrete. With the increase in ESP content permeable voids also increases. As the permeable voids increases water absorption also increase. Variation of the water absorption with time for the concretes was shown in Figure 2.3. It showed that the water absorption of all the concretes was maximum for first 3 hours and it becomes nearly constant with time. From the figure it was also be observed that the water absorption for M2 and M3 was lower than control concrete, whereas, M4 show nearly same absorption as that of control concrete. M5 concrete show higher water absorption than control concrete. Sorptivity obtained for the concrete lies between 0.106-0.17 mm/s$^{0.5}$. The minimum sorptivity recorded was for M2 concrete while the maximum obtained for M5 concrete. Like the water absorption, sorptivity also decreases with increase in compressive strength.

The main conclusions drawn from the work are:

- Compressive strength was higher than control concrete for 5 % ESP replacement at an age of 7 days and 28 days. Strength starts decreasing with the increase of ESP content beyond 10%. Compressive strength of eggshell powdered concrete increases with the incorporation of the fly ash.
- Split tensile strength of ESP concretes were comparable with control concrete up to 10 % ESP replacement. However, concrete with 15% ESP had lower split tensile strength as compared to control concrete. As in compressive strength, addition of fly ash improved split tensile strength of 15 % ESP concrete. ESP performance was nearly same as that of lime stone filler in concrete.
- The maximum absorption observed was 1.87 % for 15 % ESP and 15 % fly ash concrete. Absorption decreases with the reduction of permeable voids.
- Sorptivity of the concretes was comparable with control concrete up to 10 % ESP replacement. However, sorptivity of 15 % ESP concrete and 15 % ESP and 15 % fly ash concrete was higher than control concrete.
- The maximum sorptivity was for ESP and fly ash replaced concrete with 0.17mm/s$^{0.5}$. Sorptivity decreased with strength and increased with water absorption.

Gowiska et al., 2014 carried out the research on the properties of the cement concrete by partially replacing OPC with the ESP, saw dust, fly ash and micro silica. Researchers used mix proportion of 1:1.7:3.08 in which cement was partially replaced with ESP as 5%, 10%, 15%, 20%, 25%, and 30% by weight of cement. Water to cement ratio was taken 0.5. Compressive strength, flexural strength and split tensile strength were found out to use the eggshell powder in cement mortar with proportions 0%, 5%, 10%, 15%, 20% and 25% along with some admixtures. Admixtures used were saw dust, fly ash and micro silica.

Materials used

In their research work researchers used Ordinary Portland Cement of 53grade confirming to IS 12269-1987. River sand confirming to grading zone III of Is 383-1970 was used as a fine aggregate. Well graded coarse aggregate passing through 20mm sieve according to IS 383-1970 was used. Egg shell procured from local industry. Saw dust was obtained from sawmill and saw dust ash was obtained by incineration process and sieved before used. Fly ash was collected from Salem steel Plant, Salem, Tamilnadu and sieved before used confirming to IS 3812 (part I). Portable water was used in the entire research work for different purposes. Properties of the various materials used in the research were presented in the Table 2.2:

Table 2.2: Properties of the materials used (Gowiska et al., 2014)

Description	Cement	Fine aggregate	Coarse aggregate	ESP	Sawdust ash	Fly ash	Micro silica
Consistency	33 %	NA	NA	NA	NA	NA	NA
Initial setting time	34 min	NA	NA	NA	NA	NA	NA
Final setting time	350 min	NA	NA	NA	NA	NA	NA
Fineness modulus	3.2 %	2.369	6	NA	NA	NA	NA
Water absorption	NA	0.51 %	0.3 %	NA	NA	NA	NA
Specific gravity	3.12	2.63	2.68	2.14	2.19	2.17	2.2

Results

Cubes of size 150 mm X 150 mm X 150 mm were used for the determination of the compressive strength. Beams of size 100 mm X 100 mm X 500 mm were used for the determination of the flexural strength. Testing was done at an age of 28 days.

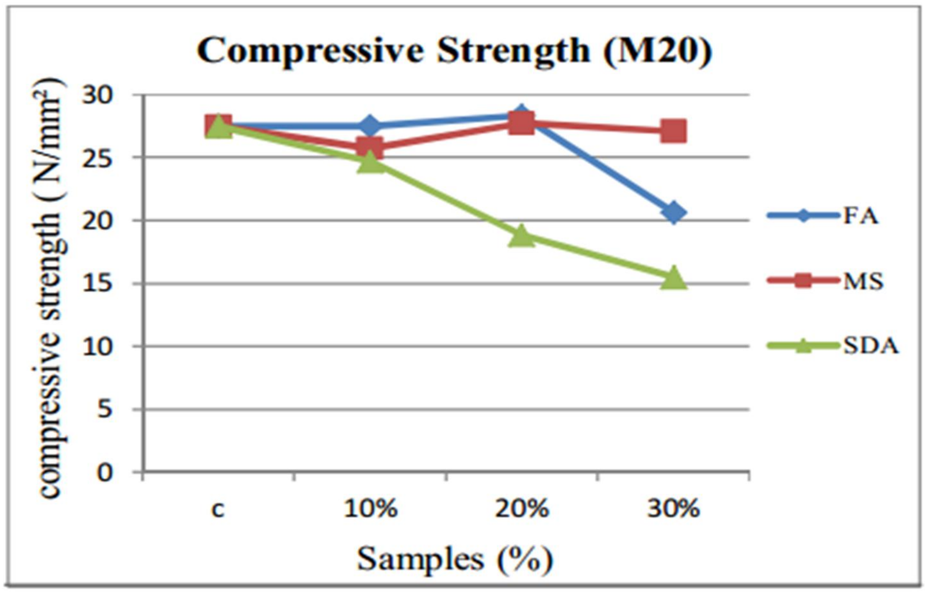


Figure 2.4: Compressive strength of eggshell powder concrete with admixtures at the age of 28 days (Gowiska et al., 2014)

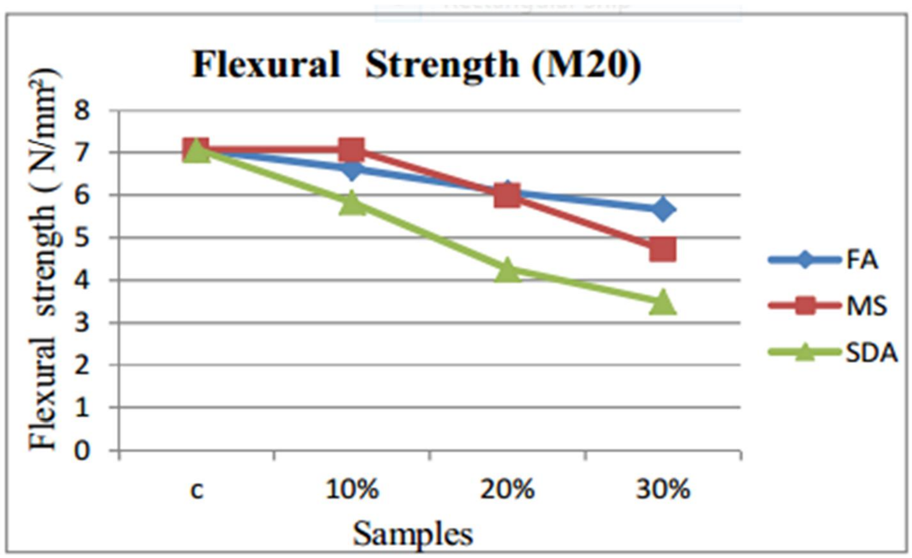


Figure 2.5: Flexural strength of eggshell powder concrete with admixtures at the age of 28 days (Gowiska et al., 2014)

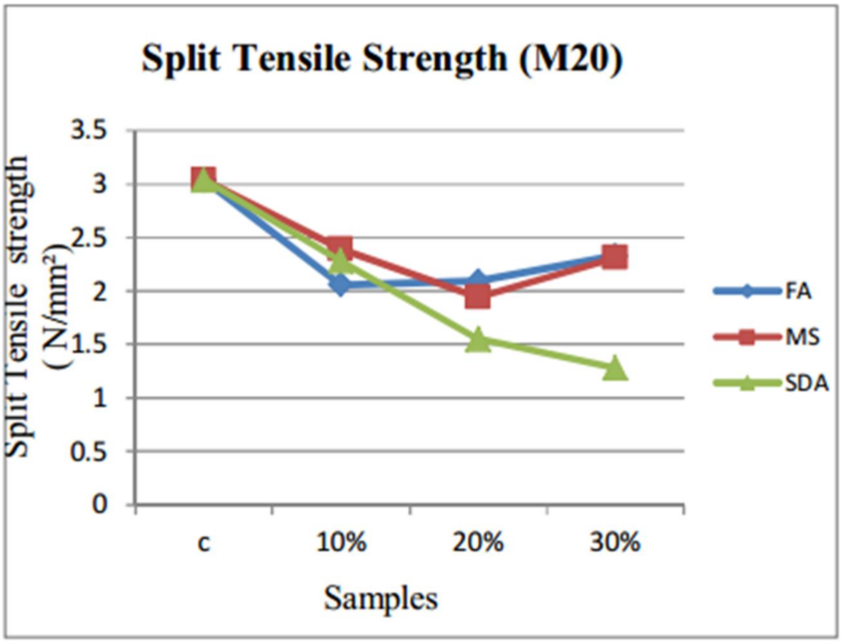


Figure 2.6: Split tensile strength of eggshell powder concrete with admixtures at the age of 28 days (Gowiska et al., 2014)

From the Figure 2.4 it was clear that compressive strength of the concrete increases up to addition of 5% eggshell powder. Beyond that compressive strength as well as split tensile and flexural strength decreases. Egg shell powder acquired from modern squanders is included various proportions for concrete substitution and it was found that substitution of 5% Egg shell powder + 20% Microsilica can be included with no decrease in compressive quality properties of cement. Also, substitution of 5% ESP + 10% Microsilica replacement in cement yields comparable flexural quality as in ordinary concrete. Furthermore, replacement of 5% ESP + 10% Microsilica substitution in cement yields higher Split Tensile strength when contrasted with different arrangements.

Okonkwo et al., 2014 concentrated on the impacts of eggshell powder on the quality properties of the cement balanced out lateritic soil. Lateritic soil was ordered to be A-6(2) in AASHTO rating system and reddish brown clayey sand (SC) in the Unified Classification System. Consistent cement substance of 6% and 8% were added to the lateritic soil with varieties in eggshell powder content of 0% to 10% at 2% interims. Cement and eggshell were measured by weight with respect to the dry soil.

The Compaction test, California Bearing Ratio test, Unconfined Compressive Strength test and Durability test were done on the soil-cement eggshell mix.

The expansion in eggshell powder content expanded the Optimum Moisture Content however diminished the Maximum Dry Density of the soil-cement eggshell ash. Additionally the expansion in eggshell powder content impressively expanded the quality properties of the soil concrete. Eggshell ash blends up to 35% in the normal yet missed the mark regarding the quality prerequisites except the durability necessity was fulfilled.

Lateritic soils are lingering soils and are essentially found in the tropical and sub-tropical locations. These are soils framed by the draining of lighter minerals like silica and the enrichment of heavier minerals like iron and aluminum oxides. The World Bank similarly has been spending considerable measures of cash on exploration went for outfitting mechanical waste products for further use. Eggshells are rural waste materials created from chick incubation facilities, pastry shops; fast food eateries among others which effect the earth and therefore constituting ecological issues/contamination which would require appropriate handling. In the regularly expanding endeavors to change over waste to riches, the viability of changing over eggshells to helpful use turns into a thought worth grasping. The arrangement of eggshells indicates that the impact of its ash on bond treated materials ought to be verbalized. It is scientifically realized that the eggshell is mostly made out of mixes of calcium which is very like that of concrete. Eggshell was introduced as being made out of 93.70% calcium carbonate, 4.20% natural matter, 1.30% magnesium carbonate, and 0.8% calcium phosphate

Materials used and Methodology

Ordinary Portland cement, eggshell powder, lateritic soil and potable water were used in the entire research by the researchers. The eggshells were later converted into ash by burning at a temperature of approximately 500º C thoroughly. After that ash was cooled and sieved through 75 µm. The soil was collected from a deposit of Oboro, Ikwuano Local Government Area of Abia state, Nigeria.

The settled blends were set up by most importantly blending altogether dry pounded lateritic soil with cement and eggshell powder until a uniform shading was accomplished after which water was added. Consistent cement of 6% and 8% with varieties of eggshell ash as 0%, 2%, 4%, 6%, 8% and 10% by weight of the dry soil in all extents of cement and ESP were received for all the blends.

Moisture-density relationship was used for the determination of the water which was to be added in the mix. Soil-cement eggshell ash mixtures was poured with the help of proctor mould in three different layers and each layer recives 25 blows.

Results

The soil was arranged to be A-6(2) soil as per AASHTO rating framework. It was genuinely useful for street construction works. This is on the grounds that it has a group index of 2. Furthermore from the perspective of Atterberg limits, it has liquid limit of 38% and it has plasticity index of 28% and shrinkage limit of 8%. All the limits were satisfactory. Lateritic soil contains illite mineral which gives less variations with the change of moisture but if the quantity of the illite mineral was increased it gives huge variation with the change of moisture so in such a case soil has to be stabilized with the help of cement.

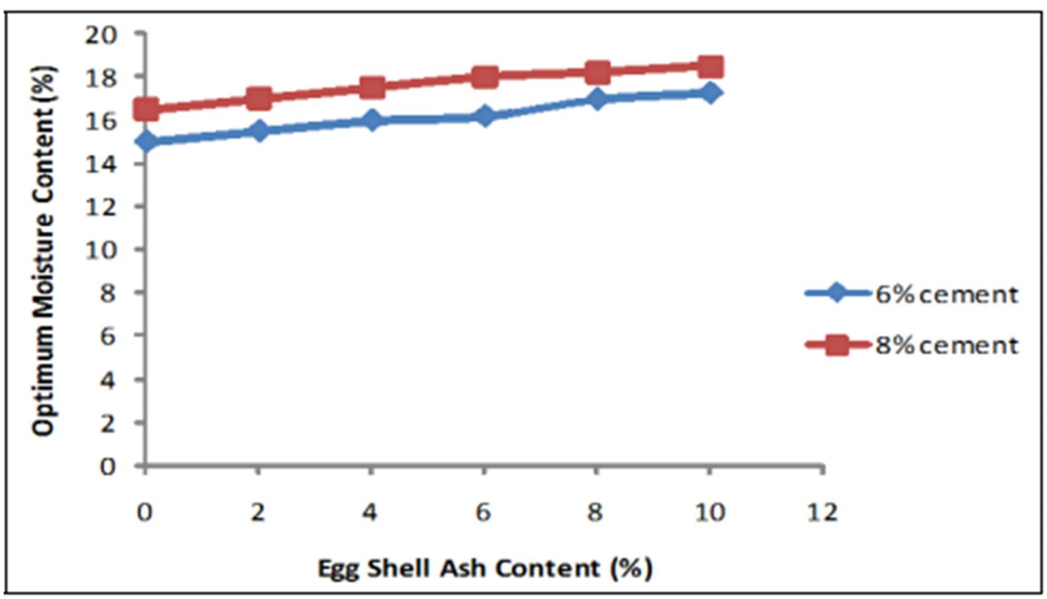


Figure 2.7: OMC of the soil having different proportions of ESP and cement (Okonkwo et al., 2014)

Figure 2.7 represents the relation between OMC and eggshell ash content. The Optimum Moisture Content expanded logically from 15% to 17.30% and 16.50% to 18.50% at 6% and 8% concrete substance separately with expansion of eggshell cinder of 0% to 10%.

These additions in OMC with expansion in eggshell ash could be ascribed to the expanded measure of calcium oxide in the mix, this increases the rate of hydration response which quickly kept on spending the water in the framework.

The amount of water was also increased which was required for the lubrication purpose of all the minerals of the soil-cemented eggshell ash with the increment of eggshell ash. Hence, OMC increases continuously with the increment of the eggshell ash content.

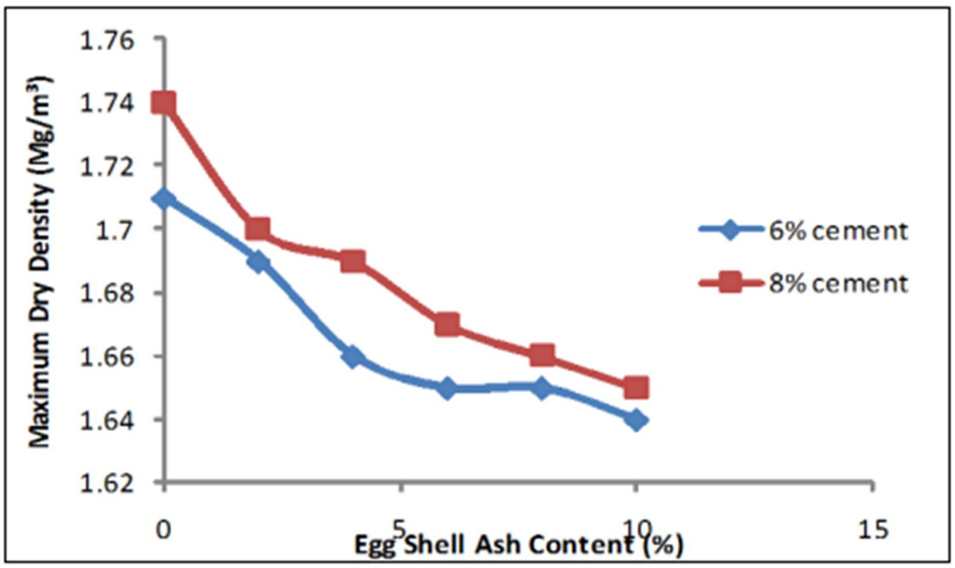


Figure 2.8: Maximum dry density of the soil having different proportions of ESP and cement (Okonkwo et al., 2014).

Figure 2.8 shows the variations of Maximum Dry Density with the increase in eggshell ash content. It was observed that with the increase in the eggshell ash content dry density starts decreasing while on the other hand OMC increases with the increases in the ESP content. Maximum Dry Density decreases from 1.71 Mg/m^3 to 1.64 Mg/m^3 at 6% cement content and from 1.74 Mg/m^3 to 1.65Mg/m^3 at 8% cement content. This could be as an after effect of the response between cement, eggshell powder and fine fractions of the soil as pozzolanic segment in which they take shape look like of coarse aggregates.

These clusters possessed bigger spaces in this way expanding their volume and consequently diminishing the Maximum Dry Density.

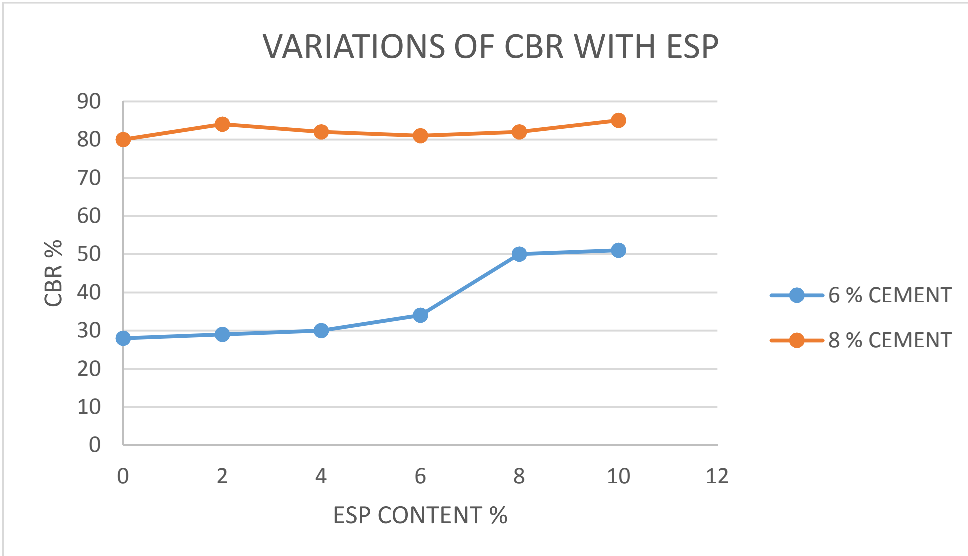


Figure 2.9: CBR of soil with different proportions of ESP and cement (Okonkwo et al., 2014).

Figures 2.9 represents the variations in CBR and Compressive Strength. The California Bearing Ratio (CBR) increased from 26.45% to 56.19% at 6% cement content and 82% to 93% at 8% cement content by the inclusion of ESP from 0% to 10%. Also, Unconfined Compressive Strength (UCS) increases from 370KN/m^2 to 471KN/m^2 at 6% cement content the age of 7 days and 614KN/m^2 and 687KN/m^2 at 8% cement content at an age of 7 days. The main conclusions drawn from the work were:

- The lateritic soil is genuinely useful for street development work.
- The increment in eggshell powder content expanded the Optimum Moisture Content however diminished the Maximum Dry Density of the dirt bond eggshell fiery remains balanced out lateritic soil.
- The increment in eggshell ash remains content expanded the quality properties of the concrete balanced out grid up to around 35% averagely.

Dhanlakshmi et al., 2015 studied the properties of the concrete with partial replacement of cement with eggshell and fly ash. In their study they use two wastes namely eggshell powder and fly ash for the various replacements of cement in the production of concrete and various properties like workability, compressive strength and density were determined. The replacement of the eggshell was 0%, 2.5%, 5%, 7.5%, 10% and 12.5%. Fly ash was added to the optimum eggshell powder content with varying percentage as 0%, 5%, 10%, 15%, 20%, 25% and 30%. The strengths were checked for the ages of 7, 28 and 56 days.

Materials used

In their research they use OPC 43 grade cement confirming to IS 8112-1989. Fine aggregates having size less than 4.75 mm having conformation of zone II of IS 383-1970. Coarse of size 20 mm was used. Class F fly ash was utilized in this study and it was taken from Udupi Power Corporation Limited. Eggshells was collected from KVG engineering hostel mess and was sun dried. Eggshell was powdered in flour mill. Conplast SP430 was used as a super plasticizer. Basic properties of all the materials were presented in the Table 2.3

Table 2.3: Properties of the materials used (Dhanlakshmi et al.,2015)

Properties	**Cement**	**Fine aggregate**	**Coarse aggregate**	**Fly ash**	**Eggshell powder**
Specific gravity	3.1	2.62	2.65	2.5	1.95
Standard consistency	31%	NA	NA	NA	NA
Initial setting time	38 min	NA	NA	NA	NA
Final setting time	480 min	NA	NA	NA	NA
Fineness	5.3%	NA	NA	2.28 %	5.9 %
Water absorption	NA	1.45 %	0.39 %	NA	NA

Concrete mix and specimen

Mix proportion used in their study was 1:1.61:2.65 (M40) conforming to IS 10262-2009 with water to cement ratio of 0.4 and super plasticizer of 0.75%. The mix proportion used and nomenclature assigned was presented in the Table 2.4

Table 2.4: Mix proportion used and nomenclature assigned (Dhanlakshmi et al., 2015)

ESP Replacement		Optimum ESP + FA Replacement		
Mix Name	**ESP (%)**	**Mix Name**	**ESP (%)**	**FA (%)**
0% E	0	7.5% E + 5% F	7.5	5
2.5% E	2.5	7.5% E + 10% F	7.5	10
5% E	5	7.5% E + 15% F	7.5	15
7.5% E	7.5	7.5% E + 20% F	7.5	20
10% E	10	7.5% E + 25% F	7.5	25
12.5% E	12.5	7.5% E + 30% F	7.5	30

For determination of compressive strength 100 mm X 100 mm X 100 mm cubes were used and for flexural strength 100 mm X 100 mm X 500 mm beams were used. Both the strengths were find out at the ages of 7 days, 28 days and 56 days.

Results

With increase in eggshell powder content workability of the concrete reduces. Figure 2.10 graphically represents the result of workability on cement concrete with ESP as a partial replacement of cement. From the graph it was noticed that, with the increase of ESP workability decrease.

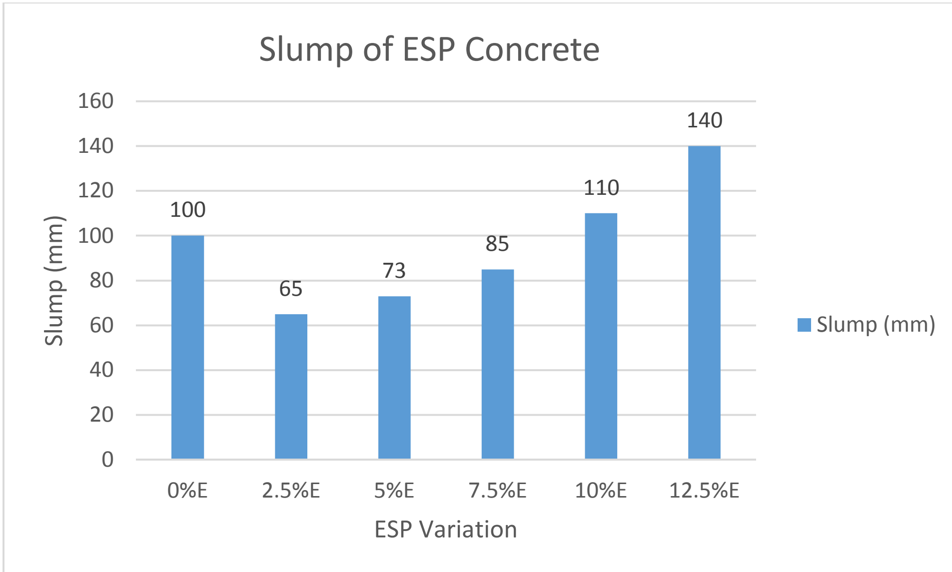


Figure 2.10: Slump result of ESP Concrete (Dhnalaksmi et al., 2015)

Figure 2.11 graphically represents the slump test on optimum ESP + FA variation concrete. It was observed that optimum ESP replacement concrete slump value is lower than control concrete. Addition of fly ash to optimum ESP content concrete has increased the workability compared to egg shell concrete slump results.

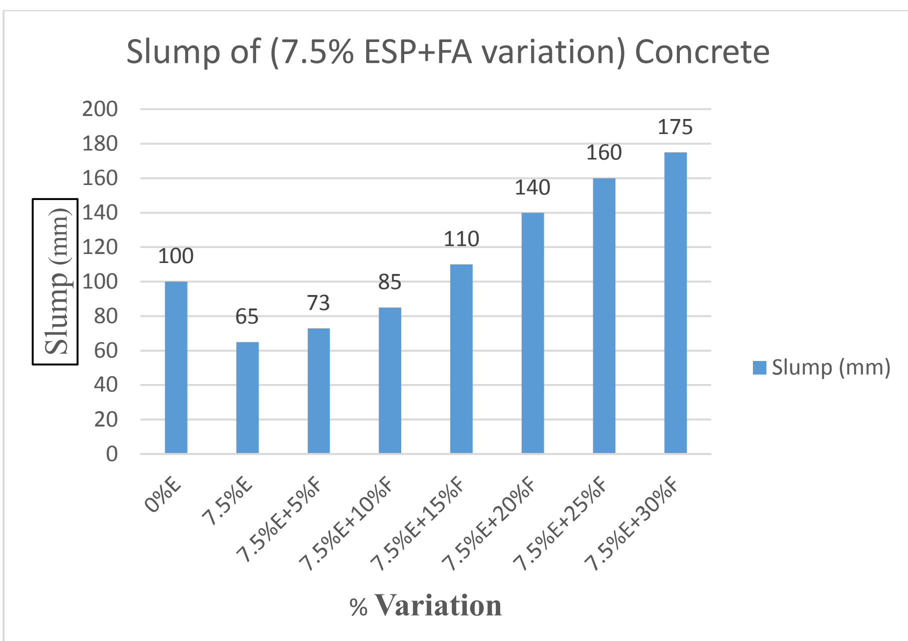


Figure 2.11: Slump result of concrete having Optimum ESP in addition with different proportions of fly ash (Dhnalaksmi et al., 2015)

Figure 2.12 graphically represents the density of egg shell concrete cubes. It was observed that increase in ESP content decreases the density of concrete cubes.

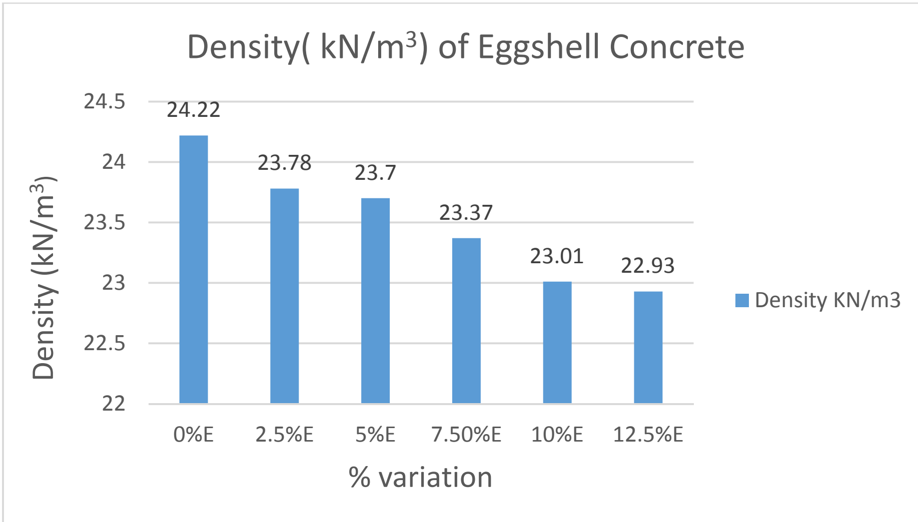


Figure 2.12: Density of concrete having ESP (Dhnalaksmi et al., 2015)

Figure 2.13 graphically represents the density of optimum egg shell concrete with fly ash variation. It is observed that density increases after addition of fly ash to optimum egg shell powder concrete in reverse order compared to egg shell powder concrete.

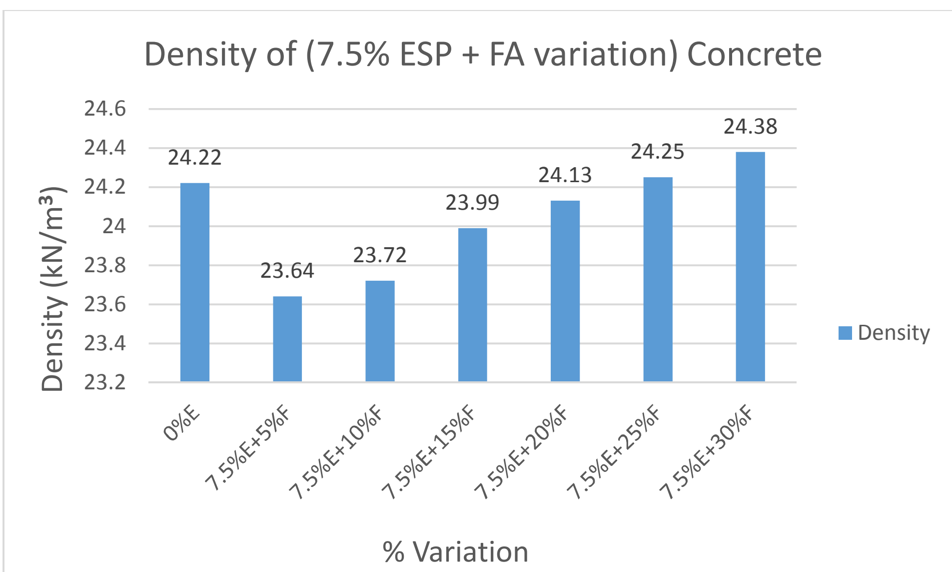


Figure 2.13: Density of concrete having Optimum ESP in addition with different proportions of fly ash (Dhnalaksmi et al., 2015)

Researchers found the compressive strength at an age of 7 days, 28 days, and 56 days with the varying percentages of eggshell powder and fly ash. But here am going to show the compressive strength results of 28 days only with eggshell and flyash. According to researchers compressive strength of egg shell powder concrete was lower to that of control concrete mix. Maximum compressive strength is obtained at 7.5% replacement of ESP for all ages.

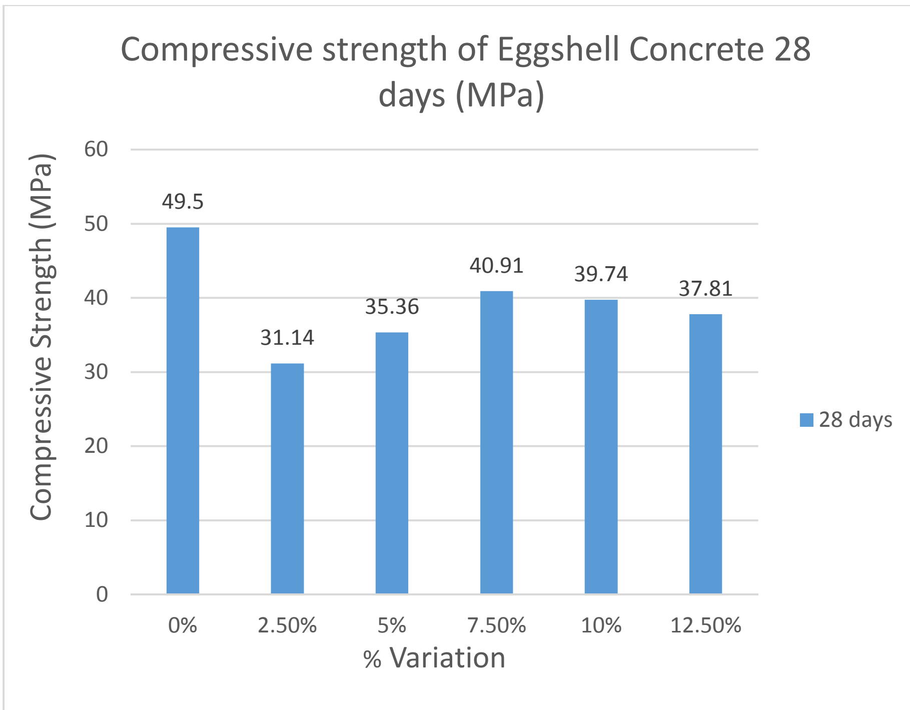


Figure 2.14: Compressive strength of concrete at the age of 28 days having ESP (Dhnalaksmi et al., 2015)

By considering 7.5% ESP as optimum dosage, FA was varied in concrete mix It was noticed that, the maximum compressive strength of optimum ESP + FA concrete is attained at 7.5%ESP + 5%FA. Addition of fly ash at 10%, 15%, 20% and 30% to optimum egg shell concrete has decreased the strength in all ages but addition of fly ash at 5% and 25% to optimum egg shell concrete has increased the strength. Optimum egg shell powder with addition of fly ash concrete result is less compared to optimum ESP concrete strength at 7, 28 and 56 days.

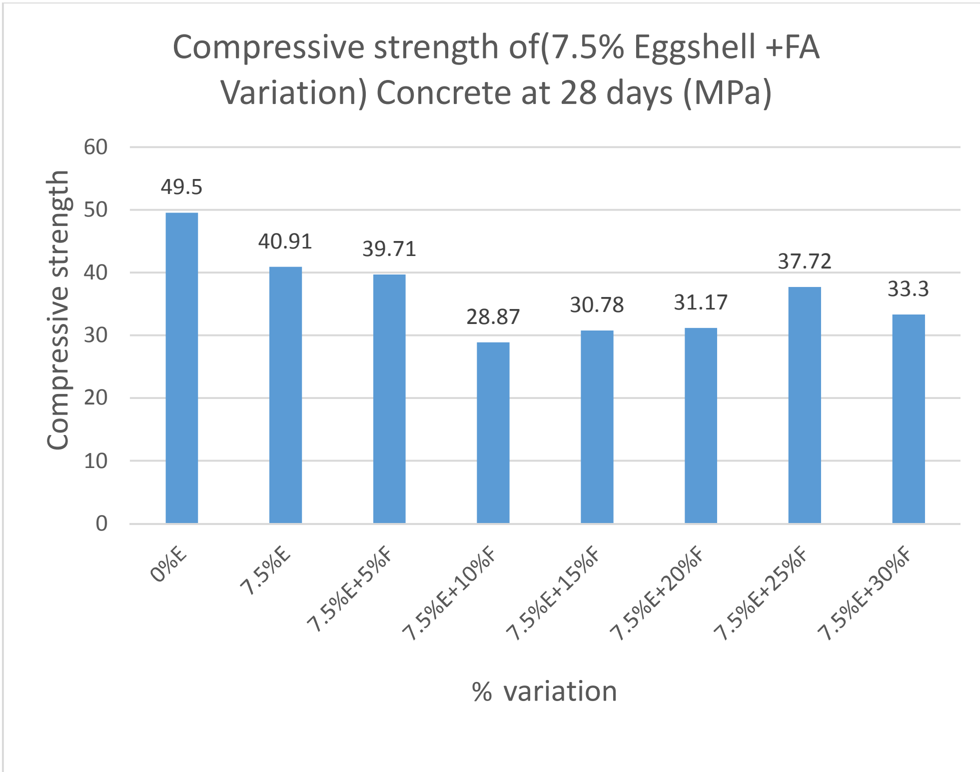


Figure 2.15: 28 days Compressive strength of concrete having Optimum ESP in addition with different proportions of fly ash (Dhnalaksmi et al., 2015)

Based on work they concluded that

- Addition of ESP to cement concrete leads to reduction in workability.
- Density decreased with addition of ESP to cement concrete.
- Workability increases with the incorporation of fly ash to the optimum egg shell powder concrete.
- Increase in density was observed with incorporation of fly ash to the optimum egg shell concrete.
- Compressive strength of egg shell concrete was less as compared to control concrete mix (M40).
- The combination of ESP + FA showed the reduction in compressive strength as compared with control concrete and egg shell powder concrete.

Pliya and Cree, 2015 contemplated the execution of brown and white ESP as potential substitutions of traditional quarried limestone in Portland cement mortar. Powder amounts of 0%, 5%, 10%, 15% and 20% by weight were included in the Portland cement. Compound arrangement, temperature, and eggshell molecule morphology were researched. Compression and flexural quality estimations were conveyed out on mortar samples. The outcomes indicated that eggshell contains calcite and little minerals. The powdered eggshell particles seemed to have an unpredictable morphology because of the grinding procedure used. The quality of the mortars were affected by the expansion of different limestone materials. Taking everything into account, white and brown eggshells have poor properties contrasted with regular conventional limestone even with 5 % Portland cement substitutions.

Materials used

White and brown eggshells were acquired from two areas. White eggshells from an egg breaking plant were gotten pre-compacted and semi-squashed as shown in Fig 2.13(a), while brown eggs from a neighborhood incubation facility was collected. Both eggshell wastes were converted into powders by an indistinguishable system. In isolated clumps, the eggshells were first dry-pulverized in a steel drum containing eleven steel balls with distances across of 47.62 mm for 60 minutes. In a brief moment step, the squashed eggshell were immediately disturbed in water using an electric drill with stirrer and ceaselessly washed with clean water until a reasonable fluid was noticeable.

Eggshells contain a slim inward layer which were expelled. In a modern procedure, wastewater produced from the flushing step could be separated and re-utilized. Case in point, recirculating the water in a constant circle could save some amount of water. The wastewater could additionally be utilized for farming watering system. Likewise, the separated medium comprises of the thin internal eggshell layers and could be recovered, prepared and cleaned for its high valued collagen content (10%). A third step comprised of drying the finely pulverized material at 105ºC for 24 hours. For better powder, a second crushing stage was required. The powders were then sieved to three distinct sizes and blended to a last fineness as indicated by the French standard prerequisites NF P 18-508. Siliceous sand was used as fine aggregate having conformation to CEN EN 196-1.

Specimens

Mortar specimens were prepared with and without the inclusion of limestone. Three specimens were prepared first one was control cement mortar (M), second one was with the inclusion of natural limestone (CN) and last one with the addition of white eggshell powder (CW) and brown eggshell powder (CB). Water to cement ratio used was 0.5. Authors replaces eggshell as 0%, 5%, 10%, 15%, and 20%. Small mortar prisms of size 40 mm X 40 mm X 160 mm were used. Testing was done at the ages of 7 days, 14 days and 28 days.

Results

Pliya and Cree uses Quantech™ R^3 test machine for finding the compressive strength and flexural strength. The maximum compressive load taken by the sample was 250 kN and flexural load was 8 kN. Tests were done as per the procedure laid by EN 196-1. The rate of loading was adopted as 2.4 kN/s for compressive strength and 0.5 kN/s for flexural strength. The specimens were tested at room temperature at an age of 7 days, 14 days and 28 days. Three specimens of each were prepared.

Table 2.5: Mix Proportion used (Pliya and Cree, 2015)

Components (kg/m^3)	Percent replacement (%)				
	0%	**5%**	**10%**	**15%**	**20%**
Cement	450	427.5	405	382.5	360
Limestone (CN, CW, or CB)	0	22.5	45	67.5	90
Sand	1350	1350	1350	1350	1350
Water	225	225	225	225	225

Chemical and physical properties of the natural limestone, white eggshell and brown eggshell which were used by the researchers were presented in Table 2.6.

Table 2.6: Physical and chemical properties of the commercial limestone, White eggshell and Brown eggshell (Pliya and Cree, 2015)

Properties	**Commercial limestone**	**Eggshells (white)**	**Eggshells (brown)**
Chemical characteristics			
$CaCO_3$ content (%)	96.3	98.3 (±1.9)	97.8 (±1.4)
Chloride (%)	0.002	0.058	0.033
Sulfate (%)	0.003	0.034	0.022
Sulfur (%)	0.090	0.067	0.063
Organic matter (%)	0.040	1.3	3.2
Lost on ignition (LOI) (g)	–	0.028	0.067
Particle size (%)			
Particles <2 mm	100	100	100
Particles <0.125 mm	94	80	80
Particles <0.063 mm	83	65	65
Physical characteristics			
Blaine (m^2/kg)	435	367	307
Specific gravity	2.7	2.5	2.5

Mechanical properties

Compressive strength obtained by authors from the studies was presented in the Table 2.7

Table 2.7: Compressive Strength results (Pliya and Cree, 2015)

Mortar type (% by weight)	Compressive strength		
	7 days	14 days	28 days
M 0	38.5 ± 2.1	44.3 ± 1.4	50.2 ± 2.7
M CN 5	47.6 ± 3.1	47.3 ± 0.4	54.0 ± 2.8
M CN 10	41.5 ± 0.1	40.9 ± 3.3	44.1 ± 2.5
M CN 15	39.9 ± 0.2	43.4 ± 3.0	45.2 ± 2.1
M CN 20	30.7 ± 2.9	39.2 ± 2.1	40.6 ± 1.3
M CW 5	32.4 ± 1.8	38.1 ± 3.1	43.1 ± 3.2
M CW 10	24.8 ± 1.4	25.4 ± 1.3	28.5 ± 1.4
M CW 15	21.1 ± 1.3	23.4 ± 0.1	25.9 ± 3.4
M CW 20	16.1 ± 1.5	21.1 ± 0.4	25.5 ± 0.9
M CB 5	37.1 ± 0.1	37.3 ± 2.7	43.1 ± 1.7
M CB 10	29.4 ± 2.5	30.5 ± 1.8	31.8 ± 0.9
M CB 15	22.8 ± 0.6	23.7 ± 2.3	29.1 ± 3.7
M CB 20	18.5 ± 0.9	20.9 ± 1.7	23.0 ± 0.5

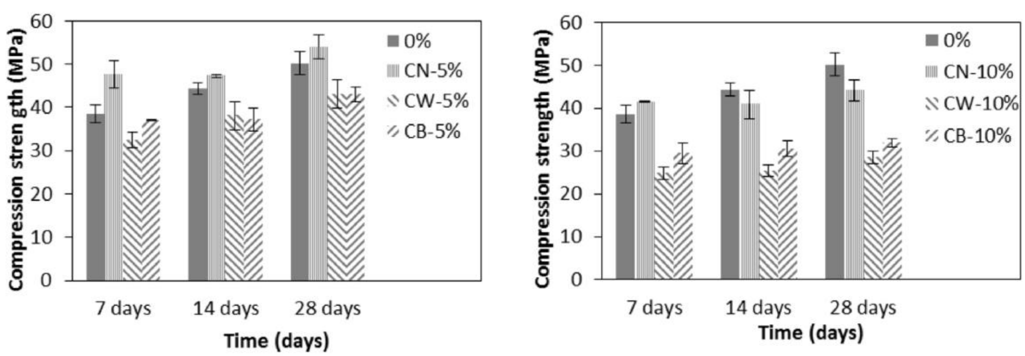


Figure 2.16: Compressive strength of concrete having different ESP content at the age of 7, 14 and 28 days (Pliya and Cree, 2015)

Flexural strength obtained by the authors from the research was presented in the Table 2.8

Table 2.8: Flexural Strength results (Pliya and Cree, 2015)

Mortar type (% by weight)	Flexural strength		
	7 days	14 days	28 days
M 0	7.5 ± 0.3	8.6 ± 0.6	9.1 ± 0.5
M CN 5	7.3 ± 0.7	8.1 ± 0.5	9.2 ± 0.6
M CN 10	7.0 ± 0.1	7.9 ± 0.6	8.2 ± 0.4
M CN 15	6.8 ± 0.5	7.1 ± 0.1	8.2 ± 0.7
M CN 20	6.6 ± 0.6	7.9 ± 0.1	8.3 ± 0.9
M CW 5	6.6 ± 0.2	7.3 ± 0.0	7.5 ± 0.1
M CW 10	5.8 ± 0.1	6.5 ± 0.2	7.3 ± 0.3
M CW 15	5.8 ± 0.8	5.7 ± 0.5	6.0 ± 0.4
M CW 20	5.0 ± 0.3	4.9 ± 0.2	4.9 ± 0.5
M CB 5	6.5 ± 0.7	6.9 ± 0.9	8.4 ± 0.3
M CB 10	5.8 ± 0.2	7.1 ± 0.5	8.6 ± 0.4
M CB 15	6.2 ± 0.6	6.1 ± 0.5	6.5 ± 0.2
M CB 20	5.1 ± 0.1	5.3 ± 0.2	5.8 ± 0.2

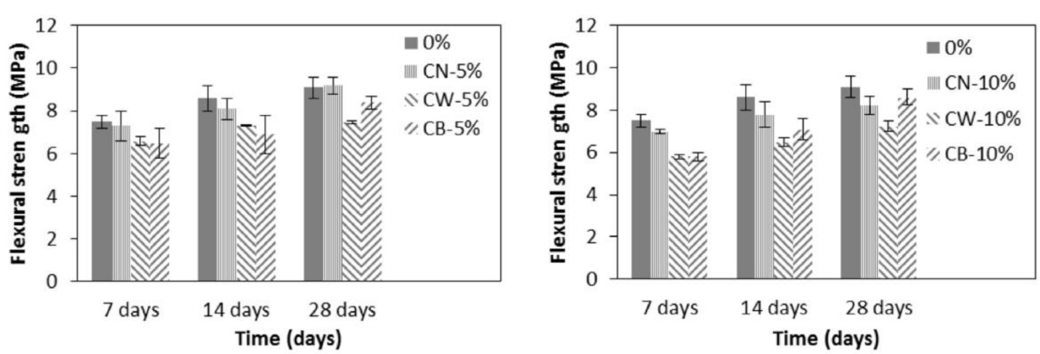


Figure 2.17: Flexural strength of concrete having different ESP content at the age of 7, 14 and 28 days (Pliya and Cree, 2015)

As indicated by the authors, compressive quality was seen to be higher than the control when 5 % limestone was added to the blend, and all other mixes have less compressive strength as compared to control.

Expansion of 5 % of common limestone (CN-5%) expanded the compression strength by 8% at the age of 28 days to 54.0 MPa, while the reduction was 40.6 MPa comparing to CN-20%. Notwithstanding, when 10 % limestone was added to the Portland cement the quality was lessened to 44.1 MPa and we can also say that 12% quality decreases when contrasted with the control. Therefore including more than 5 % of natural limestone to mortars can be seen as an impediment for compressive quality. In the writing, there is contention with regards to the impact of adding limestone to PC, both compressive quality increments and reductions have reported.

The ESP concrete had strength of 43.1 MPa or we can say that 14% strength declines as matched with the control when 5% eggshell powder was included. The least strengths were 25.4 MPa and 23.0 MPa equivalent to CW-20% and CB-20%, respectively. Likewise, for 10 % eggshell powder additions, the drop in strength for white and brown ESP were 43% and 37%, respectively.

When the incorporation of 5% limestone flexural strength was 9.2 MPa while for white and brown ESP were 7.5 MPa and 8.4 MPa, respectively, as equated with 9.1 MPa for the control mortar.

At the same age, limestone powder and white & brown ESP had strengths of 8.2 MPa, 7.3 MPa and 8.6 MPa, respectively, which interpreted the strength decrement of 10%, 20% and 6%, respectively. At an age of 28, addition of more than 10% limestone badly affect the flexural strengths of the mortar mixes. Parallel trends were obtained for compression tests

CHAPTER – 3

EXPERIMENTAL DETAILS

3.1 GENERAL

The experimental program of the research was designed to investigate the effect of EGG SHELL POWDER in different proportion as cement replacement in cement mortar. The effect on mechanical as well as on micro structural properties were studied by varying the proportion of ESP as 0%, 2.5%, 5%, 7.5%, and 10 % in cement mortar. The cement mortar was prepared by using a ratio of cement to sand as 1:3 while Water to cement ratio was kept 0.42 in the entire research work.

3.2 MATERIALS USED

3.2.1 Ordinary Portland Cement

Bangur OPC of 43 grade having conformation of IS: 8112- 1989 of BIS (reaffirmed 2005) was used in the research work. The cement was easily available in the local market of the Patiala city. The Bangur cement which is used for performing out the different tests throughout the research work is of the same batch. The chemical composition of the cement as provided by the supplier was presented in the table 3.1. Physical properties which were found out by performing various tests on the cement sample was presented in the table 3.2. The physical properties of the cement were also compared with the Indian standards.

Figure 3.1: Bangur OPC 43 grade cement

3.2.1.1 Chemical Composition of Bangur OPC

The chemical composition of the bangur cement as provided by the supplier was mentioned in the Table 3.1

Table 3.1: Chemical Composition of Bangur OPC 43 Grade

Mineral	Percentage
CaO	60.50
SiO_2	22.30
Al_2O_3	6.81
Fe_2O_3	4.30
MgO	2.11
Na_2O	0.41
SO_3	2.2
K_2O	0.40
LOI	2.40

3.2.1.2 Physical properties of OPC 43 grade

Tests performed to find out physical properties of the cement were presented in Table 3.2

Table 3.2: Physical properties of Bangur OPC 43 Grade

Physical property	Results obtained	IS 8112:1989
Consistency	30%	-
Initial setting time	42 min.	Greater than 30 minutes
Final setting time	480 min.	Less than 600 min
Fineness	5.1%	10% (maximum)
Specific Gravity	3.08	3.15 (maximum)
Compressive Strength		
3 days	25.20 N/mm^2	23 N/mm^2 (minimum)
7 days	36.12 N/mm^2	33 N/mm^2 (minimum)
28 days	44.31 N/mm^2	43 N/mm^2 (minimum)

3.2.2 Fine Aggregate

Ennore sand that is Indian standard sand of three different grades obtained from TamilNadu was used in the research work. The size specifications as well as technical details provided by supplier are shown in table and were found compatible with the requirements of IS: 650-1991.

3.2.2.1 Size of Indian standard sand

Indian standard sand is available in three grades having different size, details of which is provided in the Table 3.3

Table 3.3: Size specification of Indian standard sand

Sr. No.	Grade	Size specification
1.	Grade I	2mm to 1mm
2.	Grade II	1mm to 0.5 mm
3.	Grade III	0.5mm to 0.09mm

Figure 3.2: Indian standard sand of three grades

3.2.2.2 Properties of Indian standard sand

Various physical, chemical and petrographic properties of the Ennore sand was illustrated in the Table 3.4

Table 3.4: Various properties of the Indian standard sand

Sr. No.	Properties	Ennore sand used
1	**Physical Properties:**	
	Colour	Greyish white
	Specific gravity	2.64
	Water absorption (24 hours)	0.30%
	Grains shape	Sub angular
2	**Chemical properties:**	
	Chemical analysis	
	SiO_2	99.30%
	Al_2O_3	-
	Fe_2O_3	0.10%
	CaO	-
	Loss on extraction with HCI	0.11%
	Loss of Ignition	-
3	**Petrographic analysis:**	
	Quarts	97.40%
	Feldspar	2.50%
4	**Compressive strength:**	
	3 days curing	160 kg/cm^2
	7 days curing	220 kg/cm^2

3.2.3 Water

Tab water of structural lab having pH > 6, of Thapar University that is Ordinary potable water was used for both mixing and curing of cement mortar confirming to IS: 456-2000.

3.2.4 Egg Shell Powder

For making egg shell powder, white eggs was used and these were collected from the local market and mess of the Thapar University Patiala. After collection egg shells were washed in the flowing water and then dried in the air for five days at a temperature of about 25ºC to 30ºC. The shells then hand crushed, grained in a grinding machine for obtaining a very fine powder then sieved through 90 µm Indian standard sieve. The powder which passed through 90 µm IS sieve was used as cement replacement in the entire research work and the material which retained on the sieve was discarded as a waste.

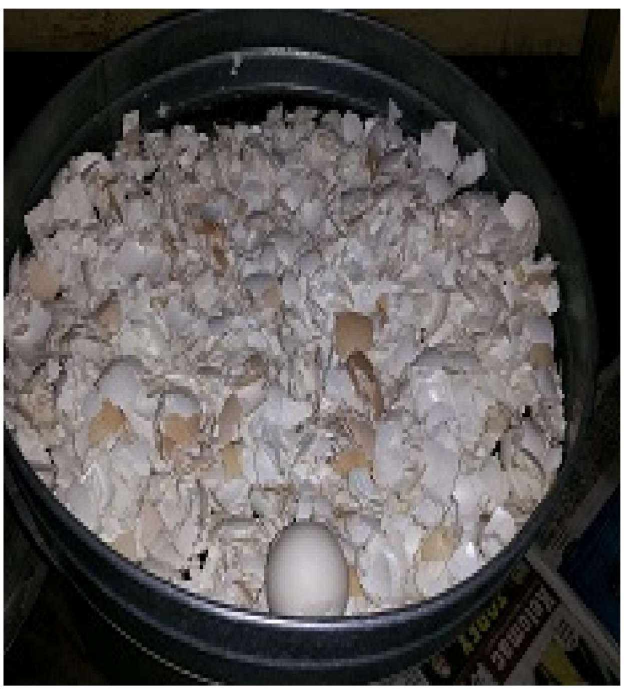


Figure 3.3(a): Raw Eggshell

Figure 3.3(b): Hand Crushed Eggshell

Figure 3.4: Grinding of eggshell by grinding machine

Figure 3.5: Sieving of ESP through 90 µm sieve obtained after grinding

3.2.4.1 Specific gravity and chemical composition of ESP

Specific gravity of the ESP was found out in the laboratory by using Le Chaterlier`s flask while chemical composition was analyzed in the SAI labs of Thapar University.

Table 3.5: Specific gravity and Chemical Composition of ESP used

Parameters	Test Method	Results (%)
specific gravity	Le Chaterlier`s flask	2.32
CaO	Digestion followed by APHA 22nd. Edn.3500Ca B	51.57
SiO_2	IS : 1727-1967, reaffirmed-2004	0.35
Al_2O_3	Digestion followed by AAS	0.40
Fe_2O_3	Digestion followed by AAS	0.03
Na_2O	Digestion followed by Flame Photometer	0.15
SO_3	IS : 1727-1967, reaffirmed-2004	2.21
LOI	IS : 1727-1967, reaffirmed-2004	45.1

A comparison is drawn between the chemical composition of cement, ESP and limestone which is presented in the table 3.6

Table 3.6: Comparison of Chemical composition of Cement, ESP and limestone

Parameters	Cement (%)	ESP (%)	Limestone (%)
CaO	60.5	51.57	55.85
SiO_2	22.3	0.35	0.58
Al_2O_3	6.8	0.40	0.06
Fe_2O_3	4.3	0.03	0.02
MgO	2.1	-	0.06
Na_2O	0.4	0.15	0.31
SO_3	2.2	2.21	0.07
K_2O	0.4	-	0.25
LOI	2.4	45.1	43.58

From the Table 3.6 it was observed that cement, ESP and limestone were rich in CaO and have comparable amount of CaO. LOI of ESP and limestone is very high as compared to cement. SiO_2 is very less in ESP and limestone as compared to cement.

3.3 SAMPLE PREPARATION AND PROPORTIONING OF INGREDIENTS

In order to investigate the properties of ESP mortar, cubes were prepared with proportion of cement and sand in the ratio 1:3.

3.3.1 Samples prepared and tests conducted

Specimens used for finding out the mechanical properties, micro structural analysis and durability properties of the cement mortar are presented in the Table 3.7, Table 3.8 and Table 3.9 respectively.

Table 3.7: Detail of samples used for finding mechanical properties

Test conducted	Specimen	Specifications (mm X mm X mm)
Compressive strength	Mortar cubes	70.6 X 70.6 X 70.6
Split tensile strength	Mortar cubes	70.6 X 70.6 X 70.6
Flexural strength	Mortar beams	40 X 40 X 160

Table 3.8: Details of sample used for the micro structural analysis

Specimen	Test conducted
Broken piece of sample at respective days of curing	SEM

Table 3.9: Detail of sample used for durability properties

Test conducted	Specimen	Specifications (mm X mm X mm)
Water absorption	Mortar cubes	70.6 X 70.6 X 70.6
Water sorption	Mortar cubes	70.6 X 70.6 X 70.6

3.4 EXPERIMENTAL PROCEDURE AND METHODOLOGY

3.4.1 Mechanical Properties

Three tests were generally performed to investigate the mechanical properties of the cement mortar by the incorporation of Egg Shell Powder as a partial replacement of cement in different proportions. The proportions used in the research are 0 %, 2.5 %, 5 %, 7.5 % and 10 %. The three tests which performed for finding out the mechanical properties of cement mortar were compressive strength test, split tensile strength test and flexural strength test at the age of 3 days, 7 days and 28 days. The rate of loading for compressive strength test and split tensile strength test was adopted 70 kN/min and for flexural strength test 2.65 kN/min.

3.4.2 Micro structural Properties

Scanning Electron Microscope (SEM) and Energy Dispersive X- ray Spectroscopy (EDS) tests were carried out by the Sophisticated Analytical Instruments Laboratories (SAI Lab) Thapar University Patiala. SEM and EDS tests were performed on the broken pieces of the specimens which were used earlier for the compressive strength test at the age of 7 and 28 days for the proportion of 0%, 2.5%, 5%, 7.5% and 10%.

3.4.3 Durability properties

Water absorption test and Sorption test were performed for finding out the durability properties of the cement mortar. Cement mortar cubes of proportions 0%, 2.5%, 5%, 7.5%, and 10% were prepared to carry out these tests. Water absorption and sorption was done for the samples at the age of 28 days.

3.4.4 Detail of Test Matrix and Nomenclature

The details of test matrix and nomenclature used for various additions of egg shell powder in cement mortar by weight of cement are presented in table 3.10

Table 3.10: Designed names for the various mixes

Details of addition of ESP by weight of cement	Designed name for reference
0% (Control)	M_0
2.5%	$M_{2.5}$
5%	M_5
7.5%	$M_{7.5}$
10%	M_{10}

3.4.5 Proportioning of Ingredients

The proportion of cement and sand is in the ratio of 1:3 for the entire research work. Three specimen of each were prepared and 10% extra was taken for the preparation of the mortar cubes and 5% extra was taken for the preparation of the beams to compensate the waste. The quantities of various constituents used in the study were presented in the Table 3.11 for compressive strength and split tensile strength and Table 3.12 for flexural strength.

Table 3.11: Mix proportion for Compressive Strength and Split Tensile Strength.

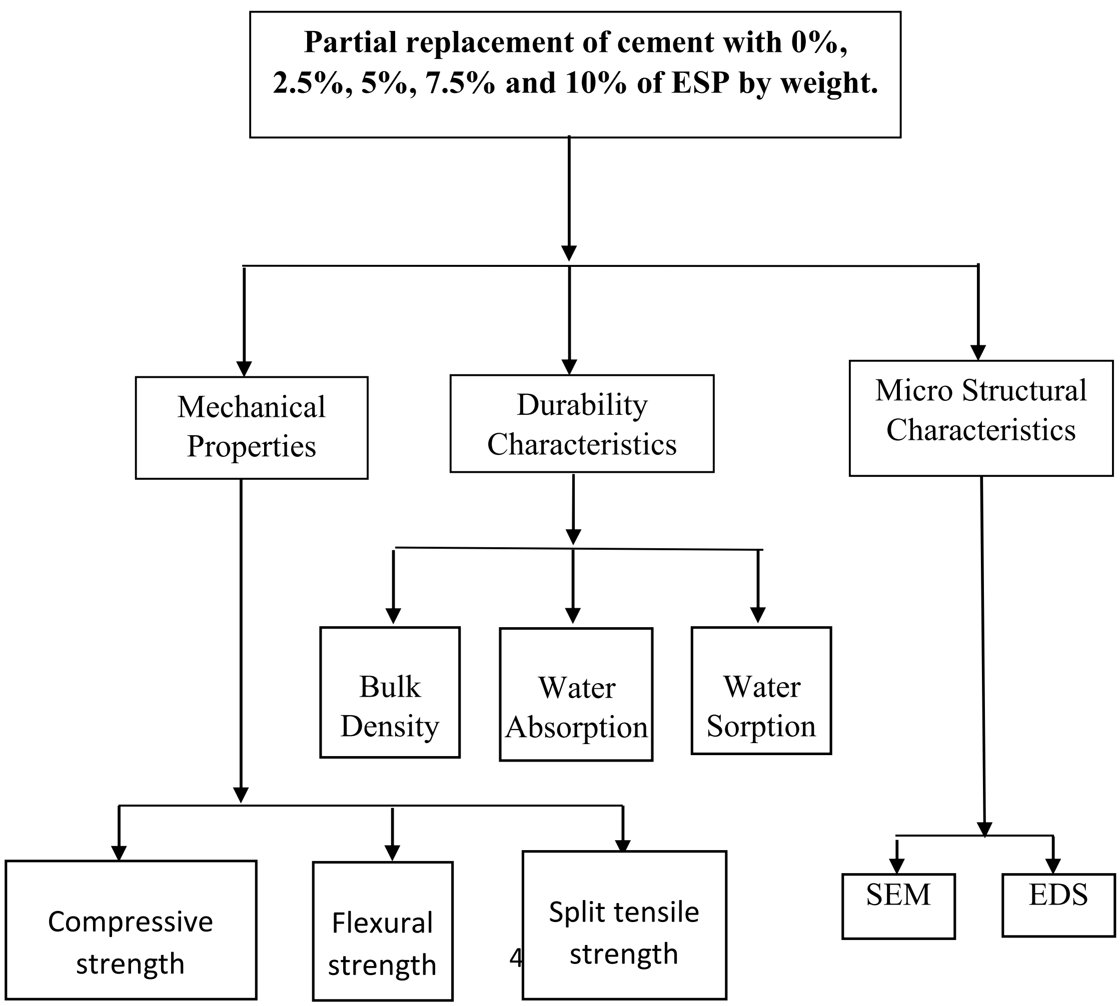
S. No.	Designated mix No.	Cement (gm)	Standard Sand			Water (ml)	ESP (gm)	remarks
			Grade I	Grade II	Grade III			
1	M_0	200	200	200	200	84	0	0% ESP
2	$M_{2.5}$	195	200	200	200	83.475	5	2.5% ESP
3	M_5	190	200	200	200	82.95	10	5% ESP
4	$M_{7.5}$	185	200	200	200	82.425	15	7.5% ESP
5	M_{10}	180	200	200	200	81.9	20	10% ESP

Table 3.12: Mix proportion for flexural strength.

S. No.	Designated mix No.	Cement (gm)	Standard Sand			Water (ml)	ESP (gm)	remarks
			Grade I	Grade II	Grade III			
1	M_0	160	160	160	160	67.2	0	0% ESP
2	$M_{2.5}$	156	160	160	160	66.78	4	2.5% ESP
3	M_5	154	160	160	160	66.57	8	5% ESP
4	$M_{7.5}$	150	160	160	160	66.15	12	7.5% ESP
5	M_{10}	146	160	160	160	65.73	16	10% ESP

Flow Chart

Flow chart of experimental program and test matrix of the research work is shown below.



3.4.6 Methodology of Casting of Specimens

All specimen were cast according to the mix proportions as discussed in the previous section. For each mix, required quantities of the material were weighed. Standard cubes of 70.6mm X 70.6mm X70.6mm were used for compressive strength and split tensile strength while for flexural strength beams of size 40mm X 40mm X 160mm were used as per provision of ASTM standards. The mixing procedure adopted is as follows:

- First of all the moulds should be properly cleaned. No lumps of mortar or any other material should stick to the moulds. The inside surface of the moulds should be felt smoothed when rubbed with hand. After cleaning operation, the inside surface of all the moulds should be oiled with the de shuttering oil properly and then screws should be tightened with a great care so that perfect dimensions of the mould can be achieved such that there should be no gap through which mortar comes out from the mould.
- In the next step, all the materials that is cement, three different grades of standard sand, ESP and water should be weighed accurately with a great precision for the different propositions. In a day 9 cubes and 9 beams were prepared from the same batch that is in the first run material for the 9 cubes was prepared and in the second, for the 9 beams.
- The material for each batch was mixed separately and the quantity of cement, standard sand and water used was cement (200gm), sand (600gm each) and water (p/4 +3) % of combined mass of cement and sand, where p is the percentage of water required to produce a paste of standard consistency determined as describe in IS:1403 (Part 4) 1988.
- After weighing all the materials should be poured into a clean and dry tray.

Figure 3.6: Weighted dry Cement, Sand and ESP in a dry tray

- After that, all the ingredients should be first mixed in the dry state at least for the 10 minutes so that a uniform mix of uniform color was obtained.

Figure 3.7: Dry mixing of Cement, Sand and ESP in a dry tray

- A clean and dry trowel should be used for the mixing of the ingredients in the dry state and all other equipment's which have to be used should be clean and free from the traces of the chemicals.
- Next to that, water is added in the dry mixture and then again mixture is mixed for at least 3 minutes and maximum for 5 minutes to obtain the uniform color. If the time taken to obtain the uniform color exceed 5 minutes then reject the mixture and entire operation was repeated with the fresh ingredients.

Figure 3.8: Mixing of Cement, Sand, ESP and Water in a tray.

- Immediately after mixing, casting of the moulds should be done. Excess of the mortar should be scrapped off from the mould and vibration of the mould should be done for 2 minutes. After vibration mould is dried for 24 hours at room temperature. After that specimens were removed from the mould and dipped in the water for the respective days of the testing.

Figure 3.9: Filling of moulds with cement mortar

Figure 3.10: Vibration of moulds filled by mortar in vibrating table

3.5 TESTS CONDUCTED

3.5.1 Compressive Strength Test [IS: 4031 (Part 6):1988]

The compressive strength test is performed on mortar cubes to determine the compressive strength at the various ages of different proportions.

Testing Machine: The testing equipment used was universal testing machine (Hung Ta Instrument Co. Ltd.) of 1000 kN capacity which is available in the structure laboratory of the Thapar University. The rate of loading for compressive strength test is 70 kN/min. The permissible blunder should not be more than ± 2 % of the most extreme load. The testing machine have two steel bearing platens. One of the platens generally which touches the upper surface of the sample should be fitted with a ball. The second platen was plain inflexible bearing square.

Figure 3.11: Compressive strength test in UTM

Placing of specimen in testing machine: Generally the side face of the specimen is kept upward or direct under the load from the UTM as this face is more smoother then the upper face of the specimen because the smoothness of the upper face of the specimen is prepared by us and the side faces which are in touch with the walls of the mould are more smoother hence any of the face which is in contact with the mould is kept upward and the top face of the specimen as a front face as described in the figure.

Age at test: Tests were performed at the age of 3 days, 7 days and 28 days. The age of the specimen shall be calculated from the time of addition of water in the dry ingredients of the cement mortar.

Number of specimens: Three specimens of each proportion were prepared for the ages of 3, 7 and 28 days respectively.

Formula used:

As we know,

Strength = Load / area

$$\text{Compresive Strength} = \frac{P \, X \, 1000}{70.6 \, X \, 70.6} \quad \text{MPa} ---------- (3.1)$$

Where

P = load at fracture in kN in compressive strength test.

3.5.2 Flexural Strength Test

The flexural strength test is performed on 40mm X 40mm X 160mm mortar beams under two point loading to determine the flexural strength at various ages of curing of samples prepared by varying the proportions if eggshell powder. Flexure strength is basically the measure of modulus of rupture and it is the maximum tensile stress that the concrete can take in bending without cracking. Flexural strength of concrete is the tensile strength of concrete in bending.

Testing Machine: The testing machine may be of any reliable type, of sufficient capacity for the tests and capable of applying the load at the rate specified which is 2.65 KN/min for 40×40×160 mm size of mould. The permissible blunder should not be more than ± 2 % of the most extreme load. The testing machine have two steel bearing platens. One of the platens generally which touches the upper surface of the sample should be fitted with a ball. The second platen was plain inflexible bearing square.

Figure 3.12: Flexural strength test on Beam in UTM

Age at test

Tests were performed at the age of 3 days, 7 days and 28 days. The age of the specimen shall be calculated from the time of addition of water in the dry ingredients of the cement mortar.

Number of specimens

Three specimens, preferably from different composition, were prepared made for testing at each selected ages of 3, 7, and 28 days.

Formula used

$$Flexural\ Strength\ \ (modulas\ of\ rupture) = \frac{\mathrm{M}}{\mathrm{Z}}$$

$$Flexural\ Strength = \frac{(\mathrm{P\ X\ x})\ \mathrm{X6\ X\ 1000}}{\mathrm{bd}^2}\ \ MPa ------------ \quad (3.2)$$

Where

P = Load at which beam fails (kN)

b = width of the beam

d = depth of the beam

3.5.3 Split tensile strength test

Apparatus

Testing Machine: The testing machine may be of any reliable type. The machine should have sufficient capacity to perform the tests and capable of applying the load at the rate of 5 kN/min on 70.6 mm × 70.6 mm × 70.6 mm cube size. It shall comply with the requirements given in IS 516 as far as applicable except that the bearing faces of both platens shall provide a minimum loading area of 12 mm x the length of the cube, as the case may be so that the load should be applied over the entire length of the specimen.

Various test methods are available to perform the split tensile strength but only two types are discussed here:

The split tests are well- known indirect tests which are used to determine the tensile strength of the concrete, also referred as the splitting tensile strength of the concrete.

Due to this tensile stress, the specimen fails finally by splitting along the loaded diameter and knowing the value of the P at failure, the tensile strength can be determined.

The same test can also be performed on the cubes by splitting either:

a) Along its middle parallel to the edges by applying two opposite compressive force through 15mm^2 bars of sufficient length
b) Along one of the diagonal planes by applying compressive forces along the opposite.

In the case of side-splitting of the cubes:

$$\text{Split Tensile Strength} = \frac{0.642\ P}{S^2}\ MPa \text{ --------------- } (3.3)$$

Where;

P= load at failure

S= side of the cube

In the case of diagonal splitting :

$$\text{Split Tensile Strength} = \frac{0.5187\ P}{S^2}\ MPa \text{ --------------- } (3.4)$$

Figure 3.13: Split tensile strength test in UTM

Age at test

Tests were performed at the age of 3 days, 7 days and 28 days. The age of the specimen shall be calculated from the time of addition of water in the dry ingredients of the cement mortar.

Number of specimens

Three specimens, preferably from different composition, shall be made for testing at each selected ages of 3, 7, and 28 days.

Formula used

$$\text{Split Tensile Strength} = \frac{0.5187\,P}{S^2}\,MPa \quad --------------- \quad (3.5)$$

Where

P = Load at fracture

S = Side of cube

3.5.4 Water absorption

The 70.6 mm X 70.6 mm X 70.6 mm cubes after casting were immersed in water for 28 days curing. Weight of these specimens were noted down as (W_1). These specimens were then oven dried for 24 hours at the temperature110°C until the mass became constant and again weighed. This weight was noted as the dry weight (W_2) of the cube.

$$Percentage\ Water\ Absorption = \frac{W_2 - W_1}{W_1}\ X\ 100 \quad ---------- \quad (3.6)$$

Where,

W_1 = wet weight of the specimen

W_2 = Oven dry weight of cylinder in grams

3.5.5 Water sorption

In 1957 John Philip introduced the term sorptivity and defined it as a measure of the capacity of the medium to absorb or desorb liquid by capillarity.

According to C Hall and W D Hoff, the sorptivity expresses the tendency of a material to absorb and transmit water and other liquids by capillarity.

The sorptivity is widely used in characterizing soils and porous construction materials such as brick, stone and concrete.

Calculation of the true sorptivity required numerical iterative procedures dependent on soil water content and diffusivity. John R. Philip (1969) showed that sorptivity can be determined from horizontal infiltration where water flow is mostly controlled by capillary absorption:

$$\mathbf{I = S.t^{1/2}} \qquad \text{--} \quad \mathbf{(3.7)}$$

The sorptivity can be determined by the measurement of the capillary rise absorption rate on reasonably homogeneous material. Water was used as the test fluid. The cubes after casting were immersed in water for 28 days curing. The specimen size 70.6 mm X 70.6 mm X 70.6 mm after drying in oven at temperature of 100 + 10 °C were drowned in water with water level not more than 5 mm above the base of specimen and the flow from the peripheral surface is prevented by sealing it properly with non-absorbent coating.

The quantity of water absorbed in time period of 30 minutes was measured by weighting the specimen on a top pan balance weighting upto 0.1 mg. surface water on the specimen was wiped off with a dampened tissue and each weighting operation was completed within 30 seconds. Sorptivity (S) is a material property which characterizes the tendency of a porous material to absorb and transmit water by capillarity. The cumulative water absorption increases as the square root of elapsed time (t).

$$S = I / t^{1/2} \quad \text{--------------------------------------} \quad (3.8)$$

Where;

S= sorptivity in mm,

t= elapsed time in mint.

$I = \Delta W / Ad$

ΔW= change in weight = W_2-W_1

W_1 = Oven dry weight of cube in grams

W_2 = Weight of cube after 30 minutes capillary suction of water in grams.

A= surface area of the specimen through which water penetrated.

d= density of water

3.5.6 Scanning Electron Microscopy (SEM)

SEM is conducted to study the micro-structural properties of the samples. The samples which are already casted and cured for 3 days, 7 days and 28 days are used for the compressive strength test. This test is used to identify the changes which had occurred inside the micro-structure and also the formation and deformation of the phases. By SEM we got the images of the sample at the Nano scale level. In which formation of C-S-H gel, pores and cracks are easily shown, by which we can easily judge the strength and durability parameters of the specimen.

Figure 3.14: SEM equipment (SAI Labs, Thapar University).

3.5.7 Energy-Dispersive X-ray Spectroscopy (EDS)

Energy-dispersive X-ray spectroscopy (EDS), also known as energy dispersive X-ray analysis (EDXA) or energy dispersive X-ray microanalysis (EDXMA), is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on an interaction of some source of X-ray excitation and a sample. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing unique set of peaks on its X-ray emission spectrum. To stimulate the emission of characteristic X-rays from a specimen, a high-energy beam of charged particles such as electrons, protons or a beam of X-rays, is focused into the sample being studied. At rest, an atom within the sample contains ground state (or unexcited) electrons in discrete energy levels or electron shells bound to the nucleus. The incident beam may excite an electron in an inner shell, ejecting it from the shell while creating an electron hole where the electron was.

An electron from an outer, higher-energy shell then fills the hole, and the difference in energy between the higher-energy shell and the lower energy shell may be released in the form of an X-ray. The number and energy of the X- rays emitted from a specimen can be measured by an energy-dispersive spectrometer. As the energies of the X-rays are characteristic of the difference in energy between the two shells and of the atomic structure of the emitting element, EDS allows the elemental composition of the specimen to be measured. Before doing EDS, gold plating of the material was performed and then that gold plated material was put inside the energy-dispersive spectrometer.

Figure 3.15

Figure 3.16

Figure 3.15: Gold plating of the material whose EDS was to be performed.

Figure 3.16: Energy-Dispersive Spectrometer (SAI Labs, Thapar University).

3.6 CLOSING REMARKS

In this chapter, the experimental details of various tests and the methodology for investigating the effect of Eggshell powder on the mechanical and microstructural properties had been studied. In the next chapter the experimental results obtained from the various tests will be presented and discussed.

CHAPTER 4

RESULTS, ANALYSIS AND DISCUSSIONS

4.1 GENERAL

This chapter represents the details of the results and analysis of the experimental work carried out in the study by replacement of cement partially with the eggshell powder in cement mortar for the various percentages of cement by weight as discussed earlier. In this chapter results which were obtained from the test results of various properties were discussed. The properties which were discussed under this chapter are compressive strength, flexural strength, split tensile strength, bulk density, water absorption, water sorption along with micro structural analysis using SEM. All these properties were discussed and analyzed for control mortar and cement replacements of 2.5%, 5%, 7.5% and 10% by weight with eggshell powder. Let us discuss the effects of eggshell powder on all these properties one by one.

4.2 COMPRESSIVE STRENGTH TEST RESULTS

After construction moulds were cured in the water and tested under the uniaxial compression testing machine at the age of 3 days, 7 days and 28 days. The rate of loading adopted for carrying out the compressive strength test was 70 kN/min. Three samples of each replacement for the different ages were prepared and tested under the UTM one by one. After that average of these three specimens was considered as average value of the load which a specimen can carry just before the collapse. Next to that compressive strength was found out by dividing the average load with the area of the specimen. The load which were taken up by the each sample at the respective age were presented in the Table 4.1

Table 4.1: Compressive load taken up by the specimens at different age of curing.

ESP Replacement	No. of specimens	3 days (kN)	7 days (kN)	28 days (kN)
M_0 (Control)	**1**	126.6	134.49	161.280
	2	114.065	126.815	166.96
	3	119.025	140.64	158.82
	Average	120.025	134.118	162.353
$M_{2.5}$	**1**	124.54	142.872	171.481
	2	128.23	139.428	168.625
	3	132.812	138.618	-
	Average	127.527	140.618	170.053
M_5	**1**	143.03	161.375	182.917
	2	132.624	154.475	188.245
	3	137.827	145.871	179.82
	Average	137.827	153.907	183.66
$M_{7.5}$	**1**	103.805	118.93	148.98
	2	111.495	125.12	154.240
	3	99.94	108.37	150.871
	Average	105.08	117.473	151.35
M_{10}	**1**	92.13	122.075	13.845
	2	102.08	108.518	129..372
	3	99.86	113.413	136.821
	Average	98.004	113.688	133.346

After load the compressive strength of the different mix was presented in the Table 4.2

Table 4.2: Compressive strength of different mortar mix at different age of curing.

S. No.	Mix	Compressive strength of the cement mortar (MPa)					
		3 days	% variation	7 days	% variation	28 days	% variation
1	**M_0**	24.08	Reference	26.911	Reference	32.572	Reference
2	**$M_{2.5}$**	25.585	+6.25	28.151	+4.61	34.12	+4.75
3	**M_5**	27.652	+14.83	30.91	+14.86	36.85	+13.14
4	**$M_{7.5}$**	21.082	-12.45	23.571	-12.41	30.365	-6.775
5	**M_{10}**	19.662	-18.35	22.818	-15.21	26.752	-24.79

Note: (+) sign indicates increase in compressive strength and (–) sign shows decrease in compressive strength.

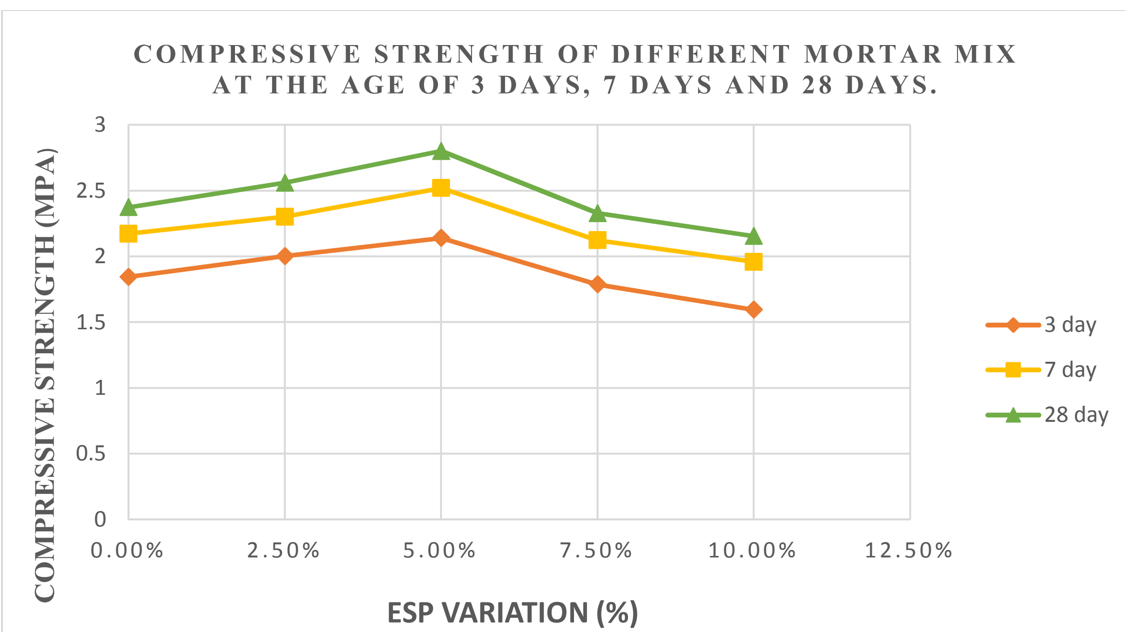


Figure 4.1: Compressive strength of ESP cement mortar

From Table 4.1 & 4.2 and Figure 4.1 following observations are made:

- It is clear that the compressive strength of the cement mortar increases with increase in eggshell powder content in the cement mortar upto 5% at all the ages.
- At 3 days of curing with 2.5% replacement of cement with ESP, compressive strength increases by 6.25% with respect to M_0. With 5% replacement 14.83% increase in compressive strength was observed with respect to M_0. If we further increase the ESP content beyond this limit then decrease in compressive strength was observed. With 7.5% replacement 12.45% strength was reduced and with 10% replacement 18.35% strength was reduced.
- At the age of 7 days, M_0 gives the compressive strength of 26.911 MPa with 2.5% replacement compressive strength of the mortar increases by 4.61% of the control mortar and with 5% replacement of cement with ESP strength increases by 14.86% and beyond this value compressive strength tremendously decreases 12.41% and 15.21% with 7.5% and 10% replacement of cement with ESP respectively.
- Similar trend was noticed at the age of 28 days also. With 2.5% replacement of cement the compressive strength of the mortar was increased by 4.75%, and with 5% replacement of cement with ESP maximum gain of strength was noticed having a value of 36.85 MPa which is 13.14% more than the M_0. If we further increase the ESP content in the cement mortar decrease in compressive strength was noticed and maximum reduction take place by replacing the cement with 10% of the eggshell powder which is 24.79% of M_0.
- The increase in compressive strength upto 5% replacement is probably due to the formation of more uniform C-S-H gel and less voids that is denser configuration as compared to M_0 and other mixes which is verified by the micro structural analysis.
- The decrease in compressive strength beyond 5% replacement is probably due to the presence of excess amount of ESP in the cement mortar due to which improper mixing and crystallization of the ESP take place and hence more voids and lack of formation of C-S-H gel take place in the cement mortar.
- Optimum replacement level for ESP in cement mortar for compressive strength is 5%.

4.3 FLEXURAL STRENGTH

Flexural strength of control sample and of ESP replaced samples of the cement mortar was carried out at the age of 3 days, 7 days and 28 days. The load taken up by the samples under two point loading was presented in the Table 4.3

Table 4.3: Flexural Load taken up by the specimens at different age of curing.

ESP Replacement	No. of specimens	3 days (kN)	7 days (kN)	28 days (kN)
M_0 (Control)	1	2.112	2.203	2.326
	2	1.91	2.276	2.380
	3	2.1	2.18	2.372
	Average	2.04	2.221	2.360
$M_{2.5}$	1	2.147	2.235	2.513
	2	2.226	2.405	2.495
	3	2.176	2.359	2.481
	Average	2.194	2.363	2.496
M_5	1	2.228	2.413	2.583
	2	2.231	2.398	2.561
	3	2.238	2.419	2.597
	Average	2.232	2.41	2.580
$M_{7.5}$	1	1.985	2.148	2.285
	2	1.947	2.217	2.301
	3	2.014	2.173	2.29
	Average	1.982	2.179	2.292
M_{10}	1	1.935	2.119	2.291
	2	1.931	2.096	2.28
	3	1.893	2.126	2.201
	Average	1.921	2.111	2.257

After loading flexural strength of the cement mortar was calculated by using the formula as illustrated in chapter 3. The flexural strength of the various cement mortar was presented in the Table 4.4

Table 4.4: Flexural strength of different mortar mix at different age of curing.

S. No.	Mix	Flexural strength of the cement mortar (MPa)					
		3 days	% variation	7 days	% variation	28 days	% variation
1	M_0	7.65	Reference	8.331	Reference	8.851	Reference
2	$M_{2.5}$	8.23	+7.58	8.861	+6.001	9.361	+5.765
3	M_5	8.37	+9.41	9.03	+8.39	9.676	+9.323
4	$M_{7.5}$	7.43	-2.87	8.171	-1.92	8.595	-2.89
5	M_{10}	7.23	-5.49	7.92	-4.94	8.463	-4.383

Note: (+) sign indicates increase in compressive strength and (–) sign shows decrease in compressive strength.

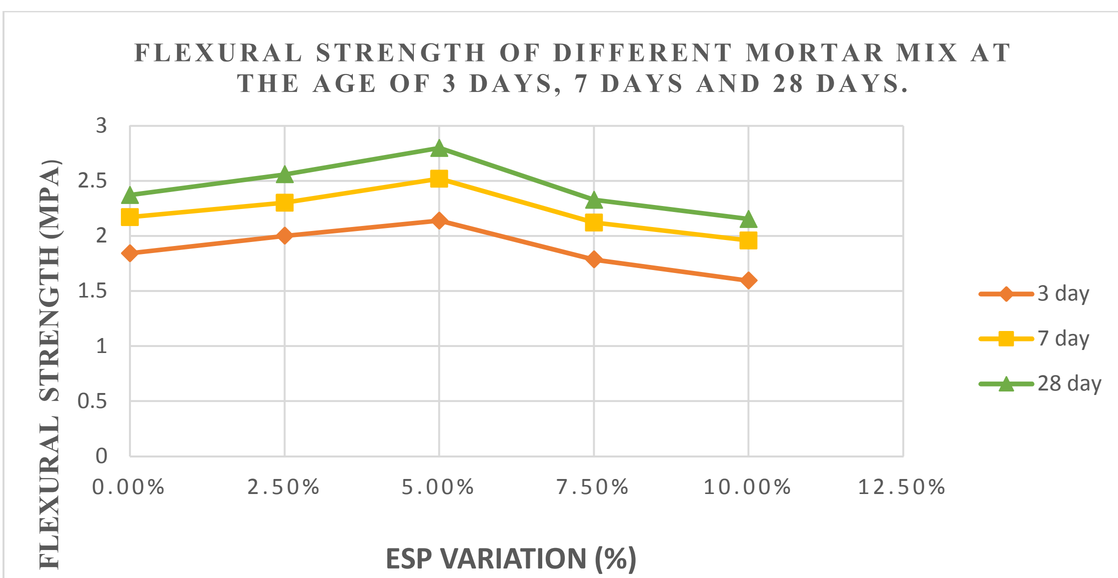


Figure 4.2: Flexural strength of ESP cement mortar

From Table 4.3 & 4.4 and Figure 4.2 following observations are made:

- The flexural strength of the cement mortar with inclusion of eggshell powder increases upto 5% and beyond that it starts decreases. Maximum reduction takes place at a replacement of 10% ESP at all the ages. While maximum increase was shown at a replacement of 5% at all the ages.
- At the age of 3 days, the flexural strength of $M_{2.5}$ and M_5 increases 7.58% and 9.41% respectively. Mix proportion $M_{7.5}$ and M_{10} shows reduction of 2.87% and 5.49% in the flexural strength.
- At the age of 7 days, again $M_{2.5}$ and M_5 shows increment of 6.001% and 8.39% while $M_{7.5}$ and M_{10} shows reduction of 1.92% and 4.94% respectively as compared to M_0.
- Similarly at the age of 28 day again $M_{2.5}$ and M_5 shows increment of 5.765% and 9.323%, while $M_{7.5}$ and M_{10} shows reduction of 2.89% and 4.383% respectively as compared to M_0.
- The increase in compressive strength upto 5% replacement is probably due to the formation of more uniform C-S-H gel and less voids that is denser configuration as compared to M_0 and other mixes which is verified by the micro structural analysis.
- The decrease in compressive strength beyond 5% replacement is probably due to the presence of excess amount of ESP in the cement mortar due to which improper mixing and crystallization of the ESP take place and hence more voids and lack of formation of C-S-H gel take place in the cement mortar.
- Optimum replacement level for ESP in cement mortar for flexural strength is 5%.

4.4 SPLIT TENSILE STRENGTH

Split tensile strength of the control as well as replaced cement mortar was found out on the standard cubes of size 70.6 mm X 70.6 mm X 70.6 mm at the age of 3 days, 7 days and 28 days by using the UTM. The rate of loading was kept 5 kN/min during the split tensile strength test. The split tensile strength of control cement mortar and the mortar which is prepared by replacing the cement partially with different proportions of eggshell powder were presented in the Table 4.5

Table 4.5: Split tensile strength of different mortar mix at different age of curing.

S. NO.	Mix	Split tensile strength of the cement mortar (MPa)					
		3 days	% variation	7 days	% variation	28 days	% variation
1	M_0	1.845	Reference	2.173	Reference	2.374	Reference
2	$M_{2.5}$	2.003	+8.56	2.303	+6	2.561	+7.83
3	M_5	2.141	+16.04	2.521	+16.01	2.801	+17.94
4	$M_{7.5}$	1.788	-3.09	2.124	-2.25	2.329	-1.895
5	M_{10}	1.596	-13.49	1.96	-9.80	2.155	-9.22

Note: (+) sign indicates increase in compressive strength and (–) sign shows decrease in compressive strength.

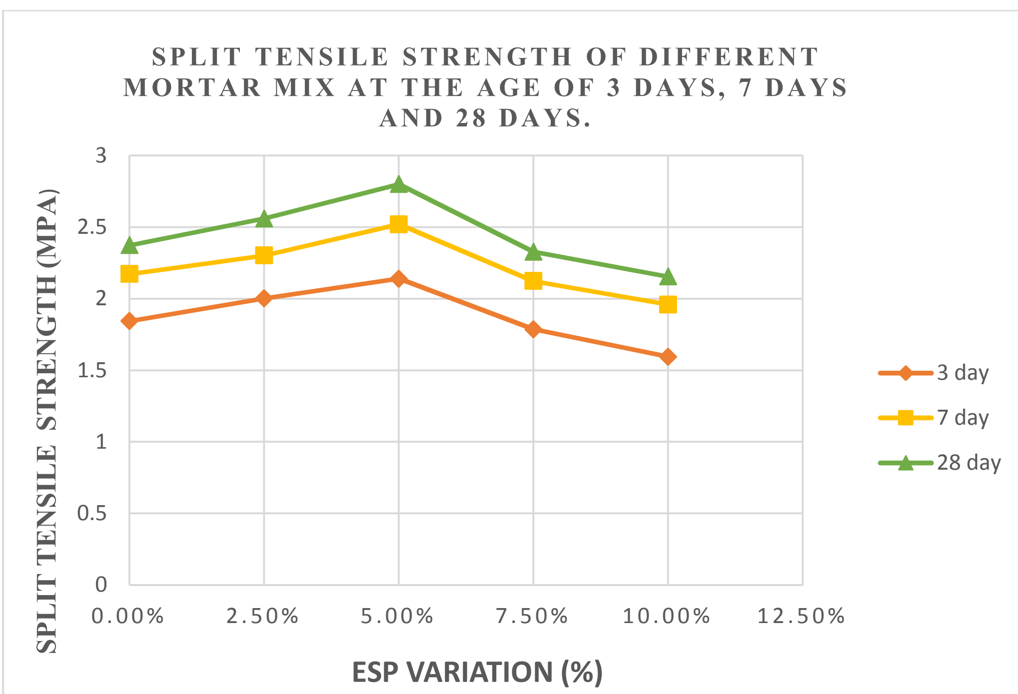


Figure 4.3: Split tensile strength of ESP cement mortar.

From Table 4.5 and Figure 4.3 following observations are made:

- It is clear that the split tensile strength of the cement mortar increases with increase in eggshell powder content in the cement mortar upto 5% at all the ages.

- The test results obtained by mix M_5 gives the maximum split tensile strength at all the ages as compared to control and other mixes. After addition of 5% of ESP in cement by weight the split tensile strength increased by 16.04%, 16.01% and 17.94% at the age of 3 days, 7 days and 28 days as compared to M_0.
- The increase in compressive strength upto 5% replacement is probably due to the formation of more uniform C-S-H gel and less voids that is denser configuration as compared to M_0 and other mixes which is verified by the micro structural analysis.
- Beyond 5% if we further increases the ESP content in the cement mortar then adverse effect on the strength took place.
- With 7.5% replacement of cement with eggshell powder the split tensile strength decreases by 3.09%, 2.25% and 1.895% at the age of 3, 7 and 28 days respectively. If we further increase the eggshell powder content then more decrement in the strength was noticed. The strength reduced by 13.49%, 9.80% and 9.22% at the age of 3, 7 and 28 days respectively.
- Maximum reduction take place with replacement of 10% ESP. Split tensile strength decreases by 13.49% , 9.80% and 9.22% at the age of 3 days, 7 days and 28 days respectively as compared to M_0.
- The decrease in compressive strength beyond 5% replacement is probably due to the presence of excess amount of ESP in the cement mortar due to which improper mixing and crystallization of the ESP take place and hence more voids and lack of formation of C-S-H gel take place in the cement mortar.
- Optimum replacement level for ESP in cement mortar for split tensile strength is 5%.

4.5 DURABILITY PROPERTIES

Water absorption test and water sorption test were performed to found out the durability requirements of the mortar. Bulk density was found for the control cement mortar and for the various replacements of the cement by eggshell powder. Water can penetrate into the capillary voids of the mortar. If the cement mortar has more number of voids then water penetration in these voids will be more and hence strength of the mortar reduces. If the voids are less, mortar have denser configuration thus less penetration of water take place hence strength of that mortar will be more.

4.5.1 BULK DENSITY AND WATER ABSORPTION

Bulk density and water absorption of the control and of the various mixes were presented in the Table 4.6

Table 4.6: Bulk Density and Water Absorption of various mixes.

S. No.	Mix	Bulk Density (gm/cc) and Water Absorption (%)					
		Wt. of Mortar (gm)	% variation	Bulk Density (gm/cc)	% variation	Water Absorption (%)	% variation
1	M_0	828	Reference	2.352	Reference	1.207	Reference
2	$M_{2.5}$	825	-0.362	2.344	-0.340	1.091	-9.610
3	M_5	822	-0.724	2.335	-0.722	1.095	-9.280
4	$M_{7.5}$	820	-0.966	2.330	-0.935	1.219	+0.994
5	M_{10}	818	-1.207	2.324	-1.190	1.223	+1.325

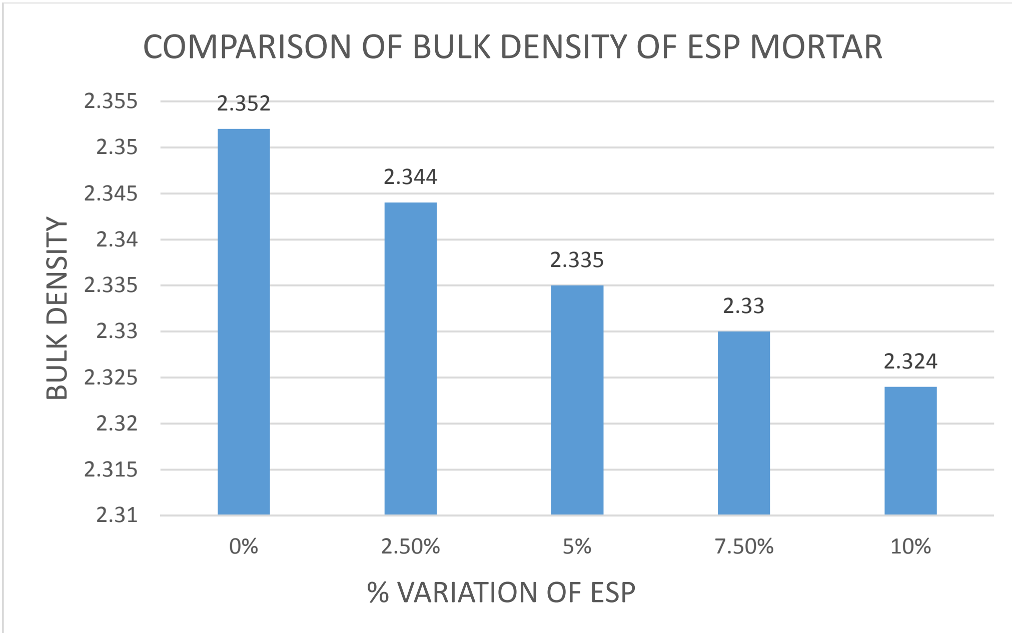


Figure 4.4: Bulk Density of ESP cement mortar

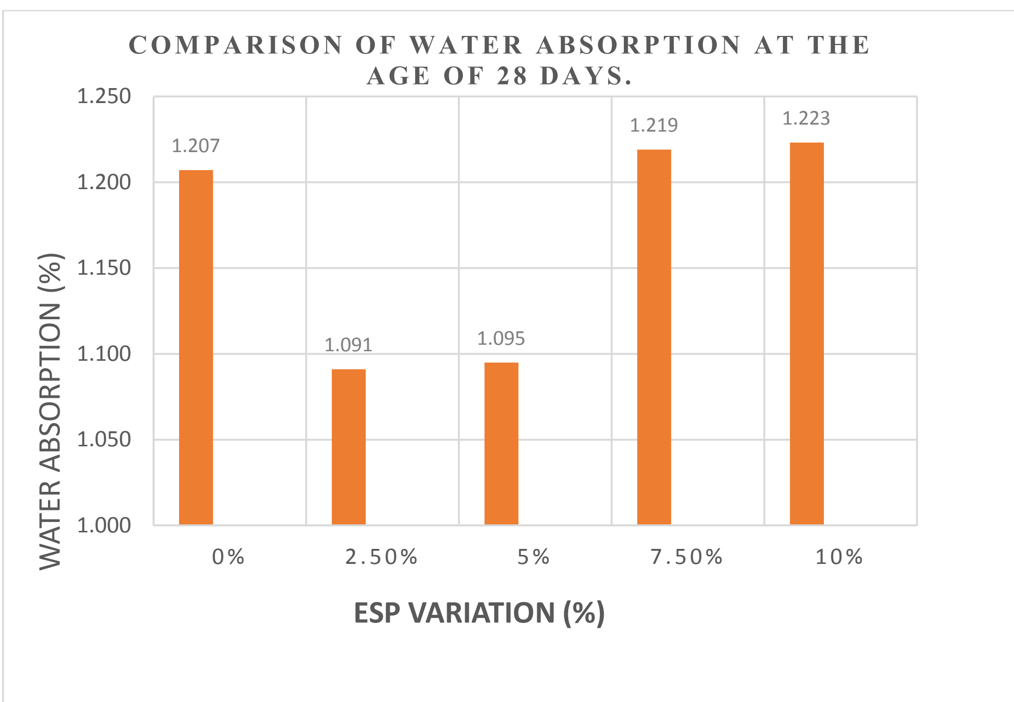


Figure 4.5: Water absorption of ESP cement mortar

From the Table 4.6 and Figure 4.4 & 4.5 following observations are made:

- The weight of the mortar cube decreases with increase in the eggshell powder content. Decrease in weight take place because eggshell powder has lower specific gravity as compared to cement. Specific gravity is indirectly related with the weight. More the specific gravity more will be the weight and vice versa.
- That is light weight mortar can be obtained by using ESP.
- Bulk density is related with the weight, less the weight lower will be the bulk density of the cement mortar. As the weight decreases bulk density of the mortar also decreases.
- Water absorption for the mix $M_{2.5}$ and M_5 decreases while for all other mixes it increases. Water absorption of the cement mortar was related to the voids present in the mortar. As with the incorporation of the ESP, voids present in the cement mortar decreases upto a replacement of 5% as shown by SEM images hence water absorption was less for mix $M_{2.5}$ and M_5 as compared to M_0 while for mix $M_{7.5}$ and M_{10} C-S-H gel formation was not smooth and voids present was also more as compared to other mixes hence water absorption for mix $M_{7.5}$ and M_{10} was more as compared to other mixes.

4.5.2 SORPTIVITY

Sorptivity of the cement mortar cube having size 70.6 mm X 70.6 mm X 70.6 mm was determined for the elapsed time of 30 minutes for each mix. Samples were cured for 28 days then they were oven dried at a temperature of 105±10º C after that cubes were immersed in water such that only 5 mm from the bottom of cube get immersed in the water.

Table 4.7: Sorptivity of various mixes at the age of 28 days.

S. No.	Mix Proportion	Dry Weight (gm) W_1	Wet Weight (gm) W_2	$\Delta W = W_2 - W_1$	$I = \Delta W / Ad$	$S = I / t^{1/2}$ mm/min$^{0.5}$
1	M_0	828	834	6	1.201	0.219
2	$M_{2.5}$	825	830	5	1.003	0.183
3	M_5	822	826	4	0.802	0.146
4	$M_{7.5}$	820	826	6	1.201	0.219
5	M_{10}	818	825	7	1.404	0.256

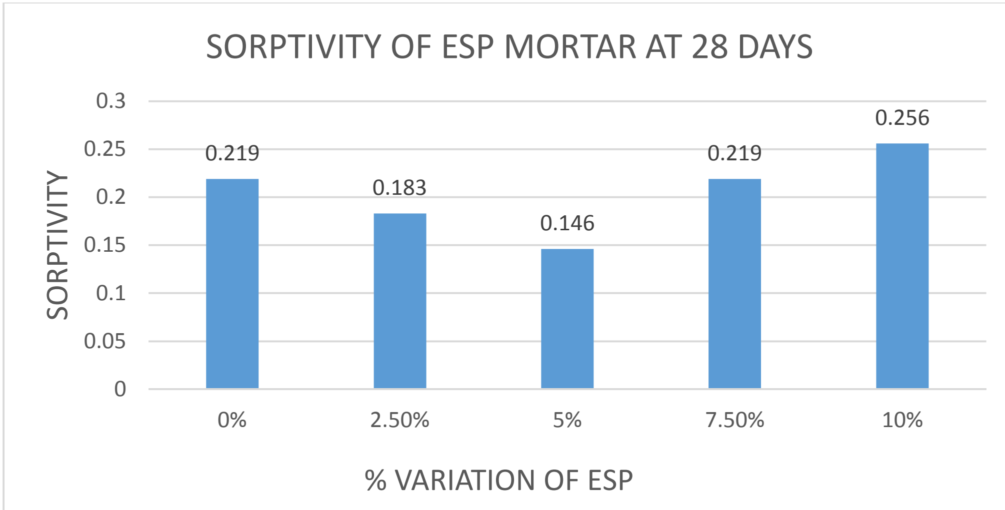
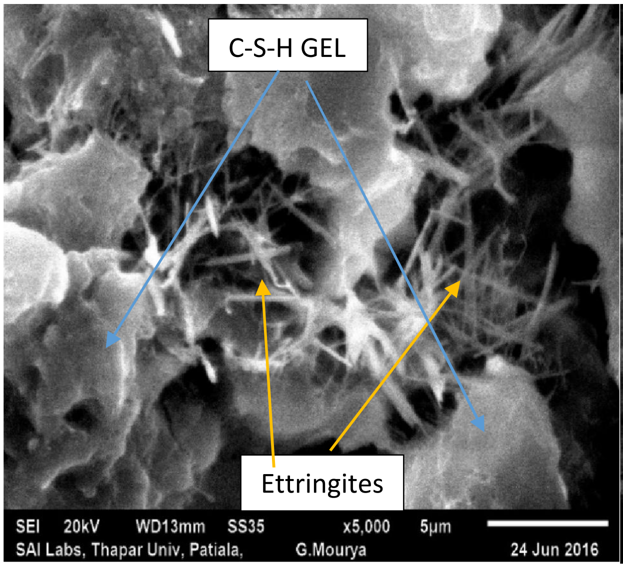


Figure 4.6: Sorptivity of ESP cement mortar

From Table 4.7 and Figure 4.6 it was concluded that as like absorption, sorptivity was also water will penetrate through one surface and hence more was the sorptivity. On the other hand if the gel was uniformly present, voids present was less hence sorptivity was also less. Sorptivity for mix $M_{2.5}$ and M_5 was less as compared to M_0 this is because C-S-H gel formed in these mixes has more uniform surface and hence voids were less as compared to other mixes as verified by the micro structural analysis. Mix $M_{7.5}$ has same value of sorptivity as of M_0 but mix M_{10} has more sorptivity as compared to all other mixes because as per micro structural analysis M_{10} has more voids and less uniform C-S-H gel that's why M_{10} has more sorptivity.

4.6 SCANNING ELECTRON MICROSCOPY (SEM)

SEM was carried out at the age of 7 days and 28 days for the control cement mortar and with various replacements like 2.5%, 5%, 7.5%, and 10% by weight of cement. The microstructure shows the formation and smoothness of the C-S-H gel and voids present in the mortar. The test samples were obtained from the central part of the specimen and then these samples were tested in the SAI labs, Thapar University Patiala. In SEM images, if the surface of the image is smooth then that smooth surface is C-S-H gel and the needles which are known as ettringites forms at that particular point where the structure is porous or we can say that ettringites represents the porous structure. The various images of the mortar with different mixes were shown below:



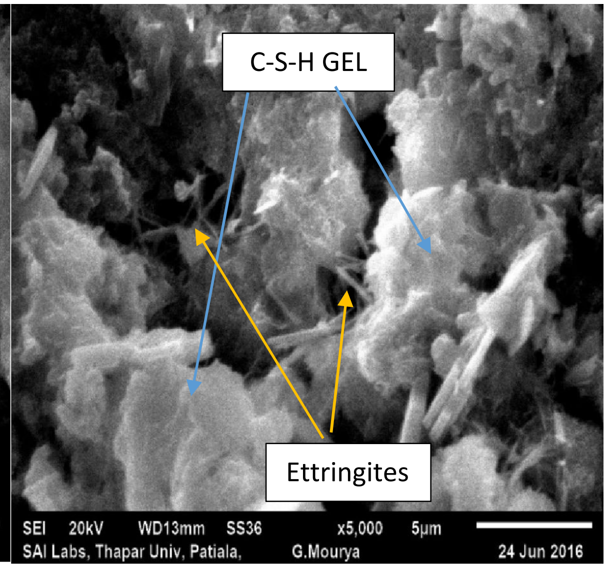


Figure 4.7 **Figure 4.8**

Figure 4.7: SEM image of M_0 at the age of 7 days.

Figure 4.8: SEM image of M_5 at the age of 7 days

From the Image 4.7 it was clear that plenty of ettringites (pores) were present in the mix M_0 and C-S-H gel formation was not uniform that's why M_0 has lesser strength as compared with other mixes.

From Figure 4.8 it was observed that ettringites formed are less and C-S-H gel formation was more uniform in mix M_5 as compared to M_0. This was the basic reason of increasing strength of mix M_5.

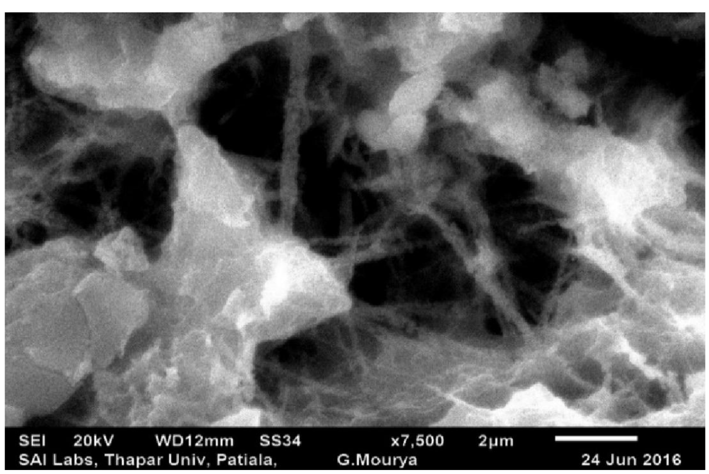


Figure 4.9

Figure 4.9: SEM image of M_{10} at the age of 7 days.

From the Figure 4.9 it was observed that the formation of the C-S-H gel reduces and pores increases due to which strength of the cement mortar decreases as compared with other mixes.

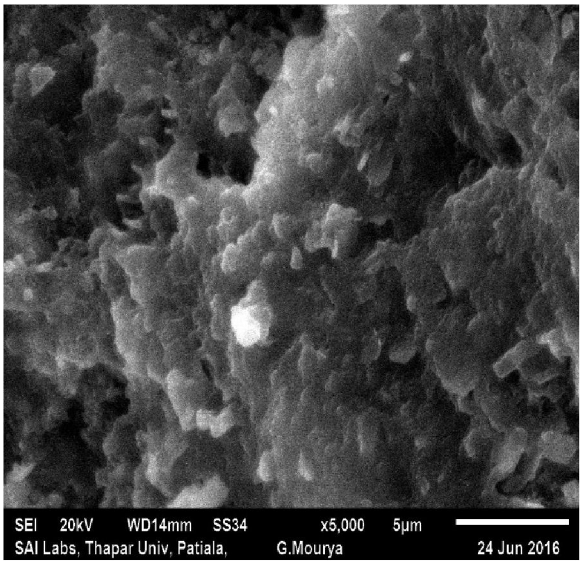


Figure 4.10

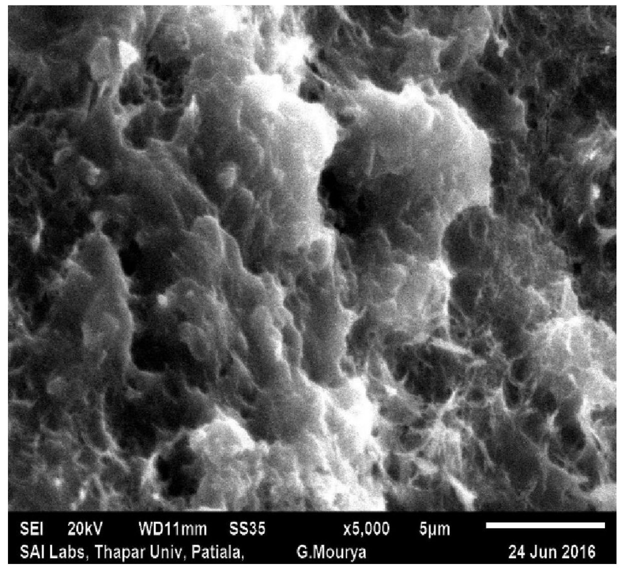


Figure 4.11

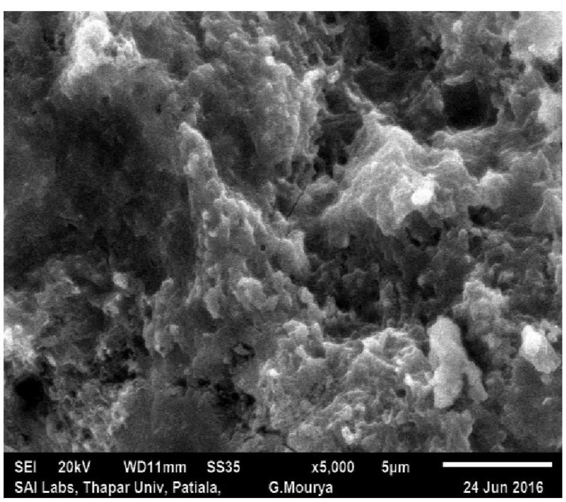


Figure 4.12

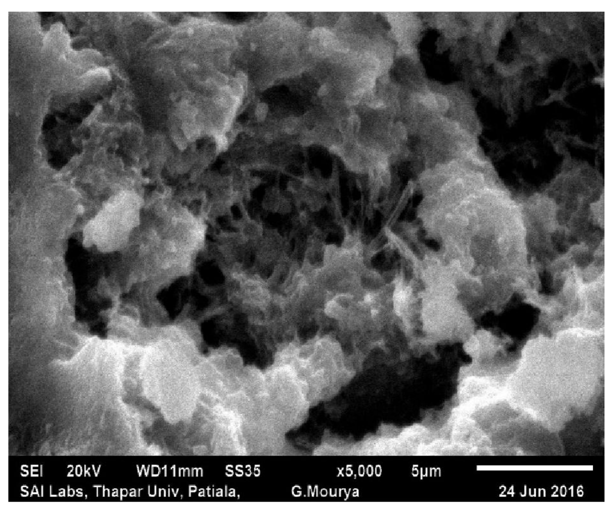


Figure 4.13

Figure 4.10: SEM image of M_0 at the age of 28 days.

Figure 4.11: SEM image of $M_{2.5}$ at the age of 28 days.

Figure 4.12: SEM image of M_5 at the age of 28 days.

Figure 4.13: SEM image of M_{10} at the age of 28 days.

From image 4.10 it was observed that M_0 at the age of 28 days contain some voids while on the other hand image 4.11 which represents mix $M_{2.5}$ contains less voids as compared to M_0 but more voids if we compare it with mix M_5. That's why mix $M_{2.5}$ gains more strength as compared to mix M_0 and lesser than mix M_5. Mix M_5 have uniform C-S-H gel that's why its strength was higher than other mixes but on the contrary crack was also seen in the SEM image due to which load carrying capacity of the mortar decreases means strength decreases to a certain extent. Mix M_{10} contain voids and gel formation was not uniform as shown in the image that's why its strength was less as compared to other mixes.

CHAPTER 5

CONCLUSIONS AND FUTURE SCOPE

5.1 GENERAL

High potential has been predicted for the use of eggshell powder in the various applications of the concrete industries as very less work had been done on this topic. Minor improvements in this material could bring large accumulated benefits to the construction industry as this material has similar properties as that of natural limestone. In the whole study, various tests had been performed on the various mix proportions like compressive strength, split tensile strength, flexural strength, water absorption, sorptivity etc. the various results which we get from all these studies had already been reported in the previous section. In this section we are going to summarize all the results which we obtained during the studies. The present study aims to improve the fresh and hardened state properties of the cement mortar by replacing the cement partially with the various proportions of the eggshell powder. The present experimental study was conceived to the general purpose of testing new sustainable building processes and modern production system aimed at saving natural raw materials and reducing energy consumption.

5.2 CONCLUSIONS AND MAJOR FINDINGS

Based on the scope, materials, techniques, procedure and other parameter associated with this work the following conclusions and recommendations can be stated as under:

5.2.1 Effect of Eggshell Powder on the compressive strength of the cement mortar

- With increase in the dosage of ESP the compressive strength of the cement mortar increases upto an optimized value and beyond that of we further increases the quantity of eggshell powder then strength starts reducing.
- In our studies the optimized value of ESP was 5%.

- With 5% replacement of ESP, 13.14% increase in compressive strength was noticed at the age of 28 days and below this age near about 14% increase in strength was noticed.
- By replacing cement with 7.5% and 10% of ESP 6.775% and 24.79% reduction in compressive strength was observed at the age of 28 days.
- The maximum compressive strength obtained was 36.85 MPa at the age of 28 days.

5.2.2 Effect of Eggshell Powder on the flexural strength of the cement mortar

- Flexural strength shows progressive increase in the strength with the addition of eggshell powder in the cement mortar for mix M_2 that is for the replacement of 5% at every age that is for the age of 3days, 7 days and 28 days.
- The optimum dosage for the flexural strength was 5%.
- The 3 day strength increased by 9.41%, 7 day increased by 8.39% and 28 days increased by 9.323% at optimum dose.
- The addition of more percentage that is 10% of ESP in cement mortar reduces the 3 day strength by 5.49%, 7 day by 4.94% and 28 day strength by 4.383%.

5.2.3 Effect of Eggshell Powder on the split tensile strength of the cement mortar

- Split tensile strength shows progressive increase in the strength with 5% addition of ESP in cement mortar at the age of 3, 7 and 28 days. At the age of 3 days the strength was increased by 16.04%, at 7 days strength increased by 16.01%, and at the age of 28 days the strength was increased by 17.94%.
- If we increases the dosage of the ESP by more than 5% then the strength of the mortar reduced.
- Hence the optimum dosage of ESP was 5%.
- At 10% replacement the split tensile strength was reduced by 13.49%, 9.80% and 9.22% at the ages of 3day, 7 day and 28 days respectively.

5.2.4 Effect of ESP on water absorption, sorption and bulk density of the cement mortar

- Water absorption for the mix M_1 and M_2 was lower than the control mix as these mixes have less voids and more uniform C-S-H gel as compared to the control and other mixes.
- With 2.5% replacement of cement with ESP water absorption was 1.091% which was 9.610% less than the control mix and for 5% replacement it was 1.095% which was 9.280% less than the control mix and with further increments water absorption was higher than the control cement mortar. It was 1.219% and 1.223% for replacements of 7.5% and 10% respectively.
- As like water absorption, sorptivity also follows the same criteria. Sorptivity for 2.5% and 5% replacement was 0.183 $mm/min^{0.5}$ and 0.146 $mm/min^{0.5}$ which was lower than the control mix. While for 7.5% and 10% replacement it was 0.219 $mm/min^{0.5}$ and 0.256 $mm/min^{0.5}$ respectively which was higher than M_0.
- Bulk density of the cement mortar was reduced as the ESP content was increased as ESP had lower specific gravity and lower weight as compared to cement hence by reducing the cement content and by increasing the ESP content, bulk density decreases.

5.2.5 Effect of ESP on the micro structural properties of the cement mortar

- SEM micrographic shows that the microstructure is appeared quite dense, compact which can be explained by great surface area.
- With the help of SEM images, correlation with the mechanical properties was observed at the age of 7 days and 28 days. The surface area of the C-S-H formed at the age of 28 days with mix proportion of 5% is more among all other mixes and number of pores were also reduced for the mix M_5 as compared with all other mixes at the age of 7 days.

5.3 WORK LIMITATIONS

There are certain limitations in the present study as the study of cement mortar with partial replacement of cement with ESP is a very broad topic and lot of research is required in this field to explore the properties of the cement mortar with ESP. Certain limitations are explained below:

- ESP is available in a very limited quantity.
- Lot of eggs are required to produce ESP.
- Grinding of egg to the required size is a difficult process.
- Instead of mortar, concrete have to be used as the concrete is more widely used than mortar.
- The replacements in the present study was done upto 10% only which can be increased in the future studies.
- The study is limited to the mixes without using super plasticizer. In future studies plasticizer can be used which decreases the water requirement of the cement and hence strength increases by using super plasticizer.
- Some of the test employed in this study such as SEM are not common in the construction industry. Which made it difficult to compare against reference data.
- Nondestructive tests can also be performed which provides more realistic approach.

5.4 SUGGESTIONS FOR FUTURE RESEARCH WORK

- After considering all aspects, it is suggested that optimum amount of eggshell powder can be used in the cement mortar to strengthen the mortar and to reduce the consumption of the cement.
- Along with ESP, Fly ash or some other waste material or we can say that combination of the waste material must be added in the cement mortar and concrete to check the performance in fresh as well as in hardened state.
- Instead of cement mortar, research should be carry forward in cement concrete as concrete is the most widely used construction material.

References

- Amu O. O. and B. A. Salami. (2010). "Effect of common salt on some engineering properties of eggshell stabilized lateritic soil." *ARPN journal of Engineering and applied sciences* 5.9: 64-73.
- Amu O. O., Fajobi A. B., and Oke B.O. (2005). "Effect of Eggshell Powder on the Stabilizing Potential of Lime on an Expansive Clay Soil", Research Journal of Agriculture and Biological Sciences 1(1): 80-84.
- ASTM, C. (2004). "Standard Test Method for Measurement of Rate of Absorption of Water by Hydraulic-Cement Concretes." 1585-04.
- Dhanalakshmi, M., N. J. Sowmya, and A. Chandrashekar. (2015). "A Comparative Study on Egg Shell Concrete with Partial Replacement of Cement by Fly Ash." *International Journal of Engineering Research and Technology*. Vol. 4. No. 05, May-2015.
- Gowsika, D., S. Sarankokila, and K. Sargunan. (2014). "Experimental Investigation of Egg Shell Powder as Partial Replacement with Cement in Concrete. "*International Journal of Engineering Trends and Technology* 14.2: 64-68.
- IS 1727:1967: "Methods of test for pozzolanic materials."
- IS 4031 (Part 4)-1988 "Methods of physical tests for hydraulic cement: Part 4 Determination of consistency of standard cement paste."
- IS 4031 (Part 6)-1988 "Methods of physical tests for hydraulic cement: Part 6 Determination of compressive strength of hydraulic cement (other than masonry cement)."
- *IS 8112* (*1989*) "Specification for 43 grade ordinary. Portland cement."
- IS 650-1991 "Specification for standard sand for testing of cement."
- IS 456-2000: "Code of practice for plain and reinforced concrete."
- Karthick, J.,jeyanthi, R., petchiyammal, M. (2014). "Experimental Study on Usage of Egg Shell as Partial Replacement for Sand in Concrete." *International Journal of Advanced Research in Education Technology (IJARET).*Vol. 1, Issue 1, ISSN: 2394-2975.
- King'Ori, A. M. (2011). "A review of the uses of poultry eggshells and shell membranes." *International Journal of Poultry Science.* 10.11: 908-912.
- Kumar, Praveen. "Experimental Study on Partial Replacement of Cement with Egg Shell Powder."

- Okonkwo, U. N., I. C. Odiong, and E. E. Akpabio. (2012). "The effects of eggshell ash on strength properties of cement-stabilized lateritic." *International Journal of Sustainable Construction Engineering Technology* 3.1: 18-25.
- Pitroda, Jayeshkumar, et al. (2013). "Evaluation of sorptivity and water absorption of concrete with partial replacement of cement by thermal industrial waste (Fly Ash)." *International Journal of Engineering and Innovative Technology (IJEIT) Volume* 2.
- Pliya, P., and D. Cree. (2015). "Limestone derived eggshell powder as a replacement in Portland cement mortar." *Construction and Building Materials* 95: 1-9.
- Raji, S. A., and A. T. Samuel. "Egg Shell as a Fine Aggregate in Concrete for Sustainable Construction."
- Tsai, W. T., et al., (2006) "Characterization and adsorption properties of eggshells and eggshell membrane." *Bioresource technology* 97.3: 488-493.
- Yerramala, Amarnath. (2014). "Properties of concrete with eggshell powder as cement replacement." *Indian Concrete Journal* : 94.