**Imperial Journal of Interdisciplinary Research (IJIR)**
**Vol-3, Issue-4, 2017**
**ISSN: 2454-1362,** http://www.onlinejournal.in

# Influence of Egg Shell Ash on the Properties of Cement

Balamurugan M[1] & Santhosh R[2]
[1] M.E Student, Structural Engineering, Dhirajlal Gandhi College of Technology, Salem, India.
[2] M.E Student, Structural Engineering, Dhirajlal Gandhi College of Technology, Salem, India.

***Abstract:*** *Cement is known to be an expensive construction material. Therefore, its quantity can be reduced by the addition of some waste materials which possess cementitious properties and are inexpensive as well. In this study, an attempt has been made to use Egg Shell Ash (ESA) as an admixture of cement to determine its influence on the properties of cement. A sample of Fowl's egg shell has been taken and incinerated to ash. The ash has been sieved through 75µm sieve. The ash passing through 75 µm sieve has been used for the investigation. Consistency test has been carried out to establish the quantity of water required to make a standard cement paste. Cement - Egg Shell Ash (CESA) paste has been constituted by adding 1%, 2%, 3%, 4% and 5% of ESA by weight of cement. Laboratory test has been conducted to determine the setting time of the CESA paste. Results have shown that the addition of ESA to the Ordinary Portland cement (OPC) has decreased the setting time of cement. Further, compressive and flexural strength tests have been carried out for CESA mortar cubes and beams respectively. An addition of up to 3% of ESA to the test samples has shown an increase in the strengths compared to the conventional cement.*

## 1. Introduction

Daily generation and dumping of solid wastes on authorized dumpsites, such as landfills and on unauthorized places such as roadsides, side drains and undeveloped plots of land in residential areas lead to accumulation of solid waste in the environment. Disposal and treatment of solid wastes in order to free the environment and the society of the menace, constituted by accumulated solid wastes, have been issues of serious concern to individual countries and the entire world. Attempts have been made by various researchers to convert solid wastes to beneficial applications, with a high level of success, as a way of reducing solid waste accumulation.

### 1.1 Composition of Egg Shell

The composition of the eggshells lends the effects of its ash on the cement to be articulated. It is scientifically known that the eggshell is mainly composed of compounds of calcium.

Eggshell is composed of:

| | |
|---|---|
| Calcium carbonate | 93.70% |
| Organic matter | 4.20% |
| Magnesium carbonate | 1.30% |
| Calcium phosphate | 0.8% |

### 1.2 Preparation of Egg Shell

- The broken pieces of eggshells have been placed in hot air drier oven for 24hrs at 200°C and dried in order to remove the moisture content present in the eggshell.
- After this process the eggshell has been allowed to undergo the process of Incineration. The eggshells have been placed in the Muffle furnace at 550°C and have been incinerated to ash.
- When the eggshells have reached the required temperature of 550°C, it has been removed from the furnace and allowed for cooling.
- After cooling of the eggshells, it has been crushed finely and sieved through a 75 µm sieve. The eggshells ash passing through 75 µm sieve have been used for this investigation.

### 1.3 Properties of Cement and Egg Shell

Cement is a naturally and abundantly available mineral. Calcium Tri-carbonate occurs abundantly in earth's crust as lime stone, marble, and chalk and in natural ores such as calcite, dolomite, and Iceland spar. It is found in caves in many parts of the world as stalactites and stalagmites. It is also an important constituent of bones and the external skeleton of organisms. This investigation, therefore is unveiling another area of interest in the continuous quest for safe and

economically viable ways of getting rid of solid waste in the environment and finding local substitutes for construction materials. On the basis of the common compositional characteristics of cement and eggshells, it was reasoned in this study that the incineration of the eggshells could produce elements and/or compounds in the resulting ESA that could induce changes in the properties of cement. Consequently, the admixture properties of ESA, with a focus on the setting time of OPC, were investigated. If ESA is found suitable as an admixture, a means of safely and economically disposing the eggshells would have been found.

The main objective of the project is to check the influence of egg shell's ash in the properties of cement by determining the compressive strength, flexural strength & setting time

## 2. Experimental Procedure

In this project, mainly the setting time of CESA has been checked. The study has discussed about the strength characteristics of cement due to the addition of ESA in partial replacement to cement. Indian Standard codes conforming to IS 1905:1987 have been followed determine the setting time and to make elements like mortar cube and beams.

### 2.1 Setting Time

Setting time means becoming firmer and harder, changing from semi liquid state to plastic state and from plastic state to solid state. Mortar of concrete when mixed is in semi liquid state. When the chemical reaction between cement and water begins the mixture goes into plastic state. As per IS 4031(1968) the standard consistency is obtained when the Vicat plunger penetrates to a point of 5 to 7mm from bottom of Vicat mould. For the given sample of cement, the standard consistency is archived with water percentage equal to 37.

**2.1.1 Initial Setting Time:** It is time interval between the time when water is added to cement and the time of partial loss of plasticity, as determined by a standard test in which the needle penetrates the block to a depth of 5mm from bottom.

**2.1.2 Final Setting Time:** It is time interval between the time when water added to cement and the time it acquires a certain firmness to resist certain definite pressure, as determined by a standard test in which the needle makes an impression on the test block while an attachment fails to do so. The steps has been carried out for conducting the tests,

- Take a sample of cement 400-gm. Weight it correctly.
- Add water 37% by weight, i.e. to the cement and mix it thoroughly, to make a cement paste.
- Place the Vicat mould on a non-porous plate; fill the mould with cement, paste and smooth off the surface of the paste making it level with the top of the mould. To expel air shake the mould slightly. While filling the mould use of operator's hand and blade of trowel only should be use.
- Place the test block in the mould together with the non-porous plate, under the rod
- Bearing the plunger gently to touch the surface of the test block and quickly release, allowing it to sink into the cement paste. Carry this operation after filling the mould with cement paste. Note the penetration of the needle from the bottom of mould indicated on the scale. The initial setting time will be noted.
- Further adding of the ESA to the cement in the percentage of 1%, 2%, 3%, 4% & 5%
- The Initial and final setting time are calculated and noted for the above percentage of adding ESA.

**Table 1. Setting Time Values**

| Test No | Ash Content (%) | Water Content (%) | Vol. Of water (ml) | Initial setting time (mins) | Final setting time (mins) |
|---|---|---|---|---|---|
| 1 | 0 | 37 | 148 | 33 | 611 |
| 2 | 1 | 37 | 148 | 30 | 603 |
| 3 | 2 | 37 | 148 | 26 | 511 |
| 4 | 3 | 37 | 148 | 21 | 467 |
| 5 | 4 | 37 | 148 | 17 | 397 |
| 6 | 5 | 37 | 148 | 13 | 313 |

Initial and final setting time has been calculated for the Conventional cement and cement when mixed with a percentage of ESA such as 1%, 2%, 3%, 4% & 5%. From the results in "Figure 1. Graphical Representation of Initial and Final Setting Time", it has been found that partial addition of ESA in cement decreases the both initial and final setting time when compared with unmixed cement.

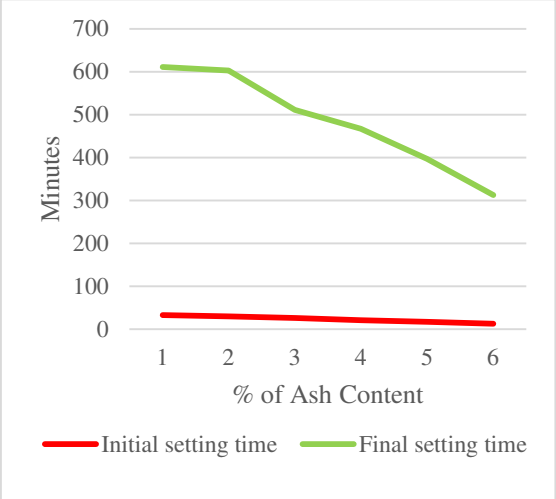


**Figure 1. Graphical Representation of Initial and Final Setting Time**

## 2.2 Mortar Cube Test

This test has been used to determine the compressive strength of the Mortar cube. The test has been employed in the 53 grade OPC (Ordinary Portland Cement). The Standard size of the mould is 70.6mm×70.6mm×70.6mm. Materials are selected based on the IS 1905-1987 codal provisions. The grade of the mortar selected to make the mortar cubes for the purpose of this study has been H1 grade mortar.

**2.2.1 Preparation of Mortar***:* Initially, the mortar cube has been prepared with the unmixed cement. The required amount of material to make a single mortar cube has been listed below:

- 135 g of cement
- 410 g of fine aggregates
- Water is added based on (2.5+p/4).

The materials have been mixed thoroughly in order to make a cement mortar paste. The mortar paste has been placed in a mould and filled properly. After the mould has been filled with the cement paste, it is introduced into the Vibrator in order to remove the air voids. The moulds have been placed in the vibrator for a period of 2 minutes. Since the mortar cement paste has very tiny particles the air gap is more. Therefore, it has to be allowed to vibrate for 2 minutes. Then, another set of samples of cube has been prepared by the addition of ESA to a percentage of 1%, 2%, 3%, 4% & 5% by weight of the cement.

The moulds have been prepared in 3 sets for each percentage. After 24 hrs the moulds have been removed and the cubes have been taken to the next step of curing. The curing has been done to find the 7 days and 14 days strength. The water should be changed every 7th day. After 7 days and 14 days the Compressive Strengths have been calculated using the UTM (Universal Testing Machine).

**2.2.2 Testing:** Before testing the cube, the moulds are taken out in the curing and dried in an atmosphere at room temperature. The moulds are placed one by one in a UTM. Using the movable plates they are fixing correctly on a machine. And the compressive load is applied gradually on the mortar cube. The values are noted and discussed below.

**Table 2 Compressive Strength Test Result**

| | $7^{th}$ Day | $14^{th}$ Day |
|---|---|---|
| Conventional ( $N/mm^2$) | 7.452 | 9.658 |
| 1% addition of ESA ($N/mm^2$) | 8.459 | 11.265 |
| 2% addition of ESA ($N/mm^2$) | 8.325 | 10.853 |
| 3% addition of ESA ($N/mm^2$) | 7.752 | 9.765 |
| 4% addition of ESA ($N/mm^2$) | 7.125 | 9.156 |
| 5% addition of ESA ($N/mm^2$) | 6.952 | 8.841 |

According to IS (1905-1987) codal provisions, the minimum compressive obtained at 7 and 14 days are 3.5 N/mm2 and 5 N/mm2 respectively. From "Figure 2. Graphical Representation of Mortar Cube Compressive strength Test", it has been found that the compressive strength at both 7 days and 14 days for cement mortar cubes mixed with eggshell powder to a percentage of 1% has shown an abrupt increase in the compressive strength, which gradually decreases with the increase of eggshell ash content. The compressive strength of cement mortar cubes, upto an addition of a percentage of 3% of eggshell ash has shown to be more than the compressive strength of conventional cement, after which it has found to decline. Therefore, it has been found that upto 3% addition of ESA to ordinary cement can be recommended.

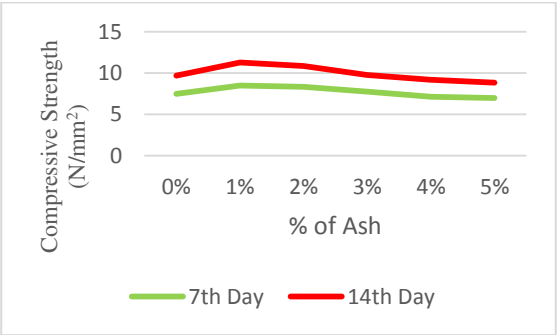


**Figure 2. Graphical Representation of Mortar Cube Compressive strength Test**

## 2.3 Flexural Strength Test

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given the symbol σ.

**2.3.1 Preparation of Materials:** A mix proportion of M25 grade of concrete has been used for this project. The materials for making the single beam the proportion is 1:1:2. The specimen size are 500mm × 100mm × 100mm. The mix proportions for M25 grade of concrete is discussed and details are shown below in Table 3.

**Table 3 Quantity of Amount Adding For Making Concrete**

| | Cement (g) | Fine Aggregate (g) | Coarse Aggregate (g) | Water (ml) | ESA (g) |
|---|---|---|---|---|---|
| Conventional | 2340 | 3100 | 6690 | 1000 | 0 |
| 1% adding of ESA | 2315 | 3100 | 6690 | 1000 | 23 |
| 2% adding of ESA | 2290 | 3100 | 6690 | 1000 | 47 |
| 3% adding of ESA | 2270 | 3100 | 6690 | 1000 | 70 |
| 4% adding of ESA | 2245 | 3100 | 6690 | 1000 | 94 |
| 5% adding of ESA | 2220 | 3100 | 6690 | 1000 | 117 |

**2.3.2 Testing:** Take a sample of cement, Coarse aggregate, Fine Aggregate and Water. Weight it correctly. Add water 0.44 by water cement ratio and mixing the materials properly. Apply the lubricant oil in the mould; fill the mould with Concrete. Smooth off the surface of the concrete making it level with the top of the mould. To expel air, place the mould in Vibrator for 2 minutes. After 24 hrs, the moulds are removed in the specimen and it will be allowed to Curing for 28 days. The water has been changed for every 7th day. The 7 days and 14 days strength are measured.

**Table 4 Flexural strength test result**

| | $7^{th}$ Day | $14^{th}$ Day |
|---|---|---|
| Conventional ( $kN/mm^2$) | 13 | 14 |
| 1% addition of ESA ($kN/mm^2$) | 13 | 14 |
| 2% addition of ESA ($kN/mm^2$) | 13 | 14 |
| 3% addition of ESA ($kN/mm^2$) | 13 | 14 |
| 4% addition of ESA ($kN/mm^2$) | 12 | 12.5 |
| 5% addition of ESA ($kN/mm^2$) | 10 | 11 |

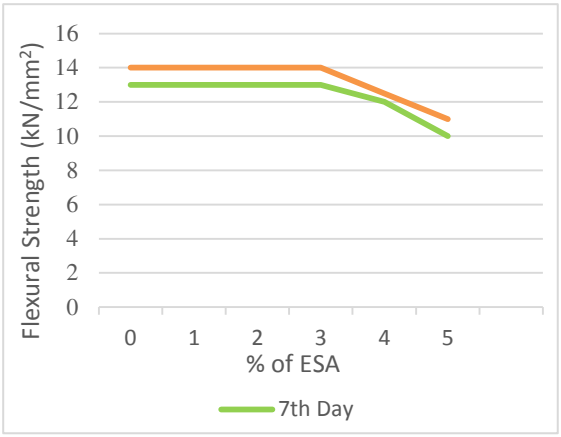


**Figure 3. Graphical Representation of Flexural strength Test**

From the IS codal provisions, the minimum flexural strength obtained at 7 and 14 days are 4.5 kN/mm2 and 6 kN/mm2 respectively. From "Figure 3. Graphical Representation of Flexural strength Test", it has been found that the flexural strength of concrete beams before mixing with eggshell ash at 7 days and 14 days have been 13 kN/m2 and 14 kN/m2 respectively. But even after the addition of eggshell ash, it has been noted that the strength remains the same upto 3% addition of eggshell ash content. At 4% addition of eggshell ash, the flexural strength of the beam specimens has been found to decrease considerably. Therefore, it has been concluded that it is possible to add a small percentage of up to 3% of ESA to the cement in concrete beams.

## 3. Results and Discussion

### 3.1 Setting Time

Initial and final setting time calculated for the conventional cement and cement mixed with different proportions of ESA as 1%, 2%, 3%, 4% & 5% has shown that, partial addition of ESA in cement decreases both initial and final setting time when compared with unmixed cement.

### 3.2 Compressive Strength

The compressive strength at both 7 days and 14 days for cement mortar cubes mixed with eggshell powder to a percentage of 1% has shown an abrupt increase in the compressive strength, which gradually decreases with the increase of eggshell ash content. The compressive strength of

cement mortar cubes, upto an addition of a percentage of 3% of eggshell ash has shown to be more than the compressive strength of conventional cement, after which it has found to decline.

### 3.3 Flexural Strength Test

Flexural strength of concrete beams before mixing with eggshell ash at 7 days and 14 days has been 13 kN/m2 and 14 kN/m2 respectively. But even after the addition of eggshell ash, it has been noted that the strength remains the same upto 3% addition of eggshell ash content. At 4% addition of eggshell ash, the flexural strength of the beam specimens has been found to decrease considerably.

## 4. Conclusion

The investigation into the effect of eggshell ash on the strength properties of Cement, has concluded that

- Eggshell ash (ESA) is an accelerator.
- The addition of different mix proportions of ESA contents used in this study, has satisfied the requirements of IS 4031(1968) for both initial and final setting time of the OPC.
- For Compressive and Flexural strengths, it has been concluded that upto an addition of 3% ESA, the strengths have not been reduced.
- In mass construction works, the amount of using cement could be reduced due to the addition of ESA.

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