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MANUFACTURING OF CEMENT FROM EGG SHELL

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Abstract: *Effective deployment of bio-waste has been given importance in our society for environmental and economic concerns. Reclamation of eggshell from hatcheries, home, bakeries and industries is an efficient and cost productive way to reduce waste disposal and prevent serious environmental pollution. Egg shells waste constitutes essential organic and inorganic materials that can be composted with other materials for enhancing the pre-existing property. The major concern in any civil sector is efficient construction with minimal cost investment. Cement is one of the pivotal components for construction. It is the backbone to the infrastructure development. Rapid infrastructure developments ensued in high demand for raw materials worldwide that resulted in huge imbalance between demand and supply. However, cement plants are the source of few harmful compounds like nitrogen oxide (NO_x), Sulphur dioxide (SO_2) and Carbon monoxide (CO) which can cause serious health defects and also affects our environment as well. The cement manufacturing sector is the third largest reason for total pollution in our environment. In spite of all these there is a huge demand for the cements for the development of a country. This increase in demand, led to search for alternative raw materials from enormous waste product which is both efficient and cost productive began. In this work, calcinations of chicken eggshells with different ingredients were carried out and the chemical composition of the resultant product was analyzed.*

1 INTRODUCTION

An eggshell on an average is composed with 2.2 g of calcium in the form of $CaCO_3$. An estimate of around 98.2% of dry shell constitutes $CaCO_3$, and 0.9% of each magnesium and phosphorous are the composition of eggshell[1]. The chemical composition of chicken eggshells has been well researched upon [2]. Elemental and ultra-structural analysis revealed heterogeneous distribution of minerals throughout the thickness of the shell. Concentration of calcium, magnesium, and sodium were higher in inner layer of the shell before hatching[3].

Eggshells offer wide range of applications in varied sectors such as in nutrition, art works, construction, fertilizers, and medicine It is speculated to be the better source of calcium than limestone[4].Eggshells have been reported has an alternative source for soil stabilizing agent[5].It is used as fertilizer supply for calcium. The acidity of soil can be reduced with the utilization of calcium from eggshell. The waste eggshells were reported to be a good adsorbent of humidity. CaO was produced when the eggshells were heated at 1300°C for four hours. The difference in hydration rate of CaO produced from heating of duck and chicken eggshells were investigated, where duck eggshells showed higher adsorption of humidity [6].

Eggshell waste produced from poultry is huge in number. Traditional methods of disposal are employed such as landfill, rendering, composting, and incineration[7]. Ground water and soil get equally polluted. The expenditure for disposal is huge setback for the industry.

Cement is considered as one of the oldest and irreplaceable building material [8]. It is a soft and fine constituent of various mixtures of elements including limestone, shale and clay. Cement when further mixed with water, sand and gravel forms into a hard solid mass called the concrete. Tremendous amount of thermal and electrical energy is consumed during the manufacturing process of the cement which alone accounts for 40% of the operational cost[9].

Energy is an important aspect in the growth and development of a country especially in India. In the current scenario of less availability of nonrenewable energy resources and the huge demand of the construction materials, it is very much necessary to implement and adapt other alternative methods to manufacture cements. To manufacture two tons of cements, about 1.1 tons of various elements of the mixtures of earth resources are used. While in the manufacture equal amount of CO₂ is released to the environment.

In portland cement, around 5 % mass fraction of limestone is mixed [10]. But due to over exploitation of limited resources of natural limestone and rising concerns in carbon dioxide emissions necessitates a substitute for limestone. Utilization of eggshell as a sustainable analogue for limestone tackles various issues. Conservation of natural resources and recycling of waste materials can occur simultaneously with the use of eggshell. Also, production of lime is an energy intensive and water consuming procedure. Use of eggshell can be cost effective and tremendously decrease the energy consumption.

This work focuses on calcinations of eggshells and analyse the chemical composition of the resultant product.

2. EXPERIMENT

2.1 MATERIALS

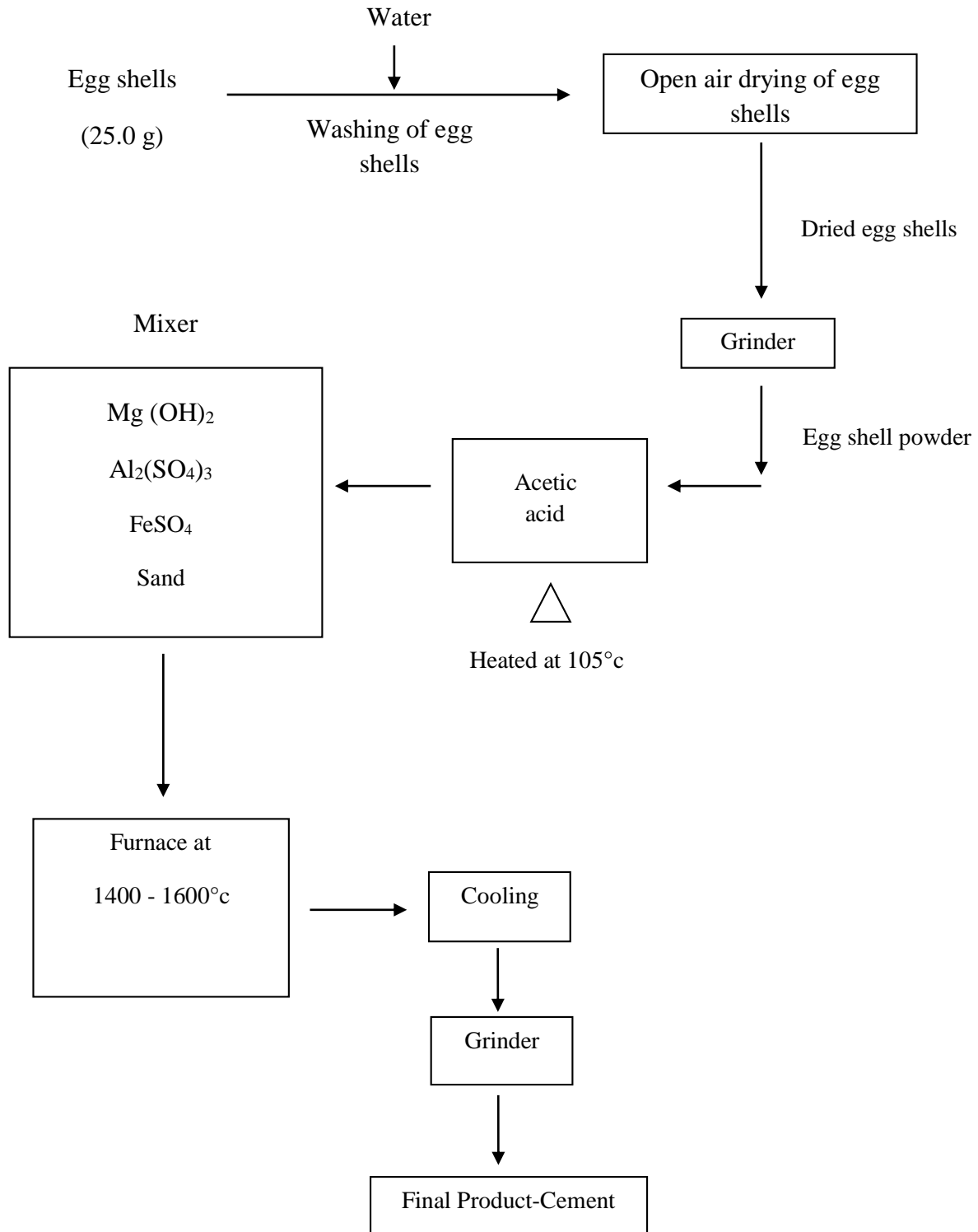
Egg shells (30 g), Calcium carbonate (2 g), Sand (21 g), Aluminium sulphate (10 g), ferrous sulphate (5 g), and Magnesium hydroxide (2.5 g).

2.2 METHODOLOGY

It is described below:

2.2.1 MANUFACTURING OF CEMENTS FROM EGG SHELLS

Waste eggshells were collected and sterilized by boiling in fresh water for 15-20 minutes. Shells were air dried and grinded in acetic acid which was further heated to 110°C for 20 minutes. Acetic acid is used to dissolve polar and hydrophilic components, with its relative static permittivity of 6.2 it dissolves not only the polar compounds such as inorganic salts and sugars but also the non-polar solvents like oils, sulfur and iodine. The whole experimental setup is shown in **Fig 1 (Manufacturing of cement from egg shell)** Shown on next page.



To the egg shell powder, Magnesium hydroxide ($Mg(OH)_2$), Aluminum sulfate ($Al_2(SO_4)_3$), Ferrous sulphate ($FeSO_4$), and sand were added and mixed thoroughly to form a raw mix. The raw mix thus formed is heated to about 1400-1600°C for about 4.5 hours. The calcium oxide thus formed reacts with alumina and ferric oxides (formed from the respective sulphates of oxidation at high temperatures) to form calcium silicate, tri calcium silicate, tri calcium silicate and tetra calcium aluminoferrite. The product thus formed is cooled and grinded to better fineness.

2.2.2 ANALYSIS OF THE CEMENT FORMED

The quantitative assessment of the cement formed, were analyzed using the methods below:

2.2.2.1 INSOLUBLE RESIDUE

1 gram of the cement sample is taken in 100ml of a beaker. To this 10 ml of the distilled water and 5 ml of the concentrated HCL were added and heated. The mixture is grinded with the flat end of a glass rod after making sure that the decomposition is complete. 50 ml of the water is added to make it dilute and it heated in a hot water bath for 15 minutes. The solution is filtered using distilled water. The filtered residue is burned along with the filter paper in a pre-weighed crucible till a constant weight was attained. Then it was cooled and calculated to find the weight of the insoluble residue.

2.2.2.2 SILICA

1 gram of the cement sample is weighed and transferred to a china dish and mixed with 10 ml of distilled water to avoid lumping. To this 10 ml of concentrated HCL is added. The whole set up is evaporated to dryness on a steam bath. The residue is heated about 150° C for about one hour. 20 ml of 1.1 HCl was added. The dish was covered for about 15 minutes. The solution is diluted with water and filtered using the gravimetric filter paper. The paper is dried and heated till a constant weight is attained.

2.2.2.3 IRON AND ALUMINIUM OXIDES

The filtrate obtained from the assessment of silica is diluted with 250 ml of water. The solution 5 ml of the concentrated HCl and few amount of bromine water were added. Pinch of ammonium chloride was added; the solution was made alkaline using ammonium hydroxide. The solution was boiled until the smell of ammonia is gone. The solution is cooled and filtered with gravimetric filter paper. The residue is washed with hot water and then with ammonium nitrate solution and with hot water and again with distilled water. The residue is dried and heated in a weighed crucible till a constant weight is attained, cooled and then weighed as iron and aluminum oxides.

2.2.2.4 LIME

To the filtrate obtained from the above, 1ml of liquor ammonia is added and heated till boiling point. To the boiled solution 25 ml of saturated ammonium oxalate solution is added and the boiling is continued for 5 minutes. The contents were cooled and filtered through the gravimetric paper. The precipitate is washed with the distilled water, dried in the oven and burned using the crucible and cooled and the weight was calculated. The chemical reactions at various temperatures during the process of manufacturing of cement from egg shells are listed in **Table 1**.

3. RESULTS AND DISCUSSION

The weight of the cement obtained from the experiment was found to be 50.8 grams. The different various constituents of the cements manufactured were analyzed and was compared with Ordinary Portland cement as mentioned in **Table 2**. The proportion of CaO in Portland cement and cement derived from eggshell was approximately in the ratio of 5:1. The percentage of SiO_2 was found to be 32 % in cement derived from eggshell, whereas, it constitutes 18.8 % of Portland cement. The silica composition can be altered by varying the sand added during the process. It is observed that the insoluble substances in cement derived from eggshells are more compared to the Portland cement. By varying the composition of compounds added, the resultant cement composition can be diversely varied. Thus, many such waste materials can be incorporated in cement manufacturing process.

4. CONCLUSION

In this experiment were able to manufacture cements from egg shells by adding the sand, aluminum sulphate, ferrous sulphate and magnesium hydroxide. In comparison of cement made from eggshells and Portland cement, similar compounds were found in both with varying proportion. Thus, any type of cements can be manufactured by suitably taking in the raw mixture. By altering the compositions of the ingredients in the raw mixture, the properties of the cement can be altered to improve the quality. The emissions from the manufacturing process can be controlled by converting them into useful products through appropriate process. This is an efficient way to utilize the waste materials. Similar to eggshells, many other waste materials can be recycled for a sustainable environment. This study requires further validation by analyzing other properties of cement derived from eggshells compared to Portland cement. The cement hardening and setting time and other key characteristics needs to be further researched upon.

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APPENDIX

Table: 1 Chemical reaction at different temperature during the process of manufacturing of cements

S.no	Temperature (°c)	Reactions
1	110	Evaporation of free water

2	400-600	Decomposition of clayey minerals to oxides, like silicone oxides (SiO_2), Aluminium oxide (Al_2O_3) and the decomposition of dolomite [$\text{CaMg}(\text{CO}_3)_2$] into Calcium Carbonate (CaCO_3), Magnesium oxide (MgO) and Carbon dioxide.
3	650-900	Calcium carbonate reacts with Silicone oxide to form belite (Ca_2SiO_4)
4	900-1050	Decomposition of remaining CaCO_3 to CaO and carbon dioxide.
5	Above 1300	Melting of partial of belite with Calcium oxide to form alite ($\text{Ca}_3\text{O.SiO}_4$).

Table: 2. Composition of Portland cement and cement obtained from eggshells

Compound	Mass percentage of constituents	
	Ordinary portland cement (%)	Cement obtained from egg shells (%)
CaO	63.4	38

SiO ₂	18.8	32
Al ₂ O ₃	5.0	16
Fe ₂ O ₃	5.9	
SO ₃	5.2	4.5
Na ₂ O	0.1	NA
K ₂ O	0.3	
Insoluble substances	0.5	9.5

CALCULATIONS:

Insoluble residue

Weight of the cement taken for analysis = 1g
 Weight of the empty silica crucible = 13.72 g
 Weight of the silica crucible + residue after incineration = 13.95 g
 Weight of the insoluble residue = 13.95 – 13.72 = 0.23 g
 Insoluble residue = 0.23 g / 1 g = 23 %

Silica

Weight of the cement taken for analysis = 0.5 g

Weight of the empty silica crucible = 13.72 g

Weight of the silica crucible + residue after incineration = 13.88 g

Weight of silica residue = $13.88 - 13.72$ = 0.16 g

Silica = $0.16 \text{ g} / 0.5 \text{ g} = 32 \%$

Iron and Aluminum oxides

Weight of the cement taken for analysis = 0.5 g

Weight of the empty silica crucible = 13.72 g

Weight of the silica crucible + residue after incineration = 13.80 g

Weight of residue = $13.80 - 13.72$ = 0.08 g

Iron and Aluminum oxides = $0.08 \text{ g} / 0.5 \text{ g} = 16 \%$

Lime

Weight of the cement taken for analysis = 0.5 g

Weight of the empty silica crucible = 13.72 g

Weight of the silica crucible + residue after incineration = 13.91 g

Weight of calcium oxide residue = $13.91 - 13.72$ = 0.19 g

Calcium oxide residue = $0.19 \text{ g} / 0.5 \text{ g} = 38 \%$