

Effect of Eggshell Powder Solution on Some Properties of Cement Mortar

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Abstract— In this paper, eggshell waste from a pullulating chick hatched eggs farm was used to study the effect of substituted mortar mixing water by eggshell powder solution (ESPS). ESPS were made by dissolving 5%, 10%, 15%, 20%, 30% and 40% by weight of eggshell Concentrations in water by boiling. The microstructure and chemical composition were displayed. The physical and mechanical properties of ESPS cement mortar were experimentally studied at 2, 7 and 28 days of curing. X-Ray Diffraction patterns for eggshell powder displayed that the major component in eggshell powder is calcium carbonate (CaCO_3) in calcite form. The study showed that both workability and density were decreased with the increasing of ESPS concentration. The results indicated an improvement in both compressive and flexural strengths at 10% inclusion ESPS concentration.

Keywords— Eggshell powder, cement mortar, workability, compressive strength, Flexural strength.

I. 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].

One of the famous solid waste accumulations is eggshell waste. Eggshell waste is evolved from poultry farms, restaurants and hotels which thrown unused in many countries. The chemical composition of eggshell powder and cement were found to be similar [2].

Eggshell consists of several mutually growing layers of CaCO_3 , the innermost layer-maxillary 3 layer grows on the outermost egg membrane and creates the base on which palisade layer constitutes the thickest part of the eggshell. The top layer is a vertical layer covered by organic cuticle. The eggshell primarily contains calcium, magnesium carbonate (lime) and protein.

In many countries, it is the accepted practice for eggshell to be dried and used as a source of calcium in animal feeds. The quality of lime in eggshell waste is influenced greatly by the extent of exposure to sunlight, raw water and harsh weather conditions. It is the fine grained powder with a suitable proportion which is sieved to the required size before use with mortar [3].

The main objective of this study is to investigate the effect of using ESPS instead of mortar mixing water on the behavior of the cement mortar.

II. Experimental Work

A. Materials

Ordinary Portland cement (OPC type I 42.5N), coming from Northern Cement Company (NCCO) and complying with Jordanian standard specifications (JSS. 30/1979), was used in this work.

Locally available natural sand coming from a quarry located at the province Jerash with particles smaller than 2mm, fineness modulus of 2.25 and specific gravity of 2.60g/cm^3 and complying with Jordanian standard specifications (JSS. 96/1987) was used for mortars.

White eggshells coming from a pullulating chick hatched eggs farm were cleaned completely to remove any dirt. These shells were crushed and grinded with PULVERISETTE 7 Fritsch micro mill for one hour at 1100rpm speed for one cycle. The resulted powder was sieved through $75\mu\text{m}$ sieve. The passed powder was dissolved in water by one hour boiling with a ratio of 5%, 10%, 15%, 20%, 30% and 40% by weight. Properties of the eggshell solution are shown in Table I.

TABLE I. CHEMICAL COMPOSITION OF EGGSHELL POWDER

Composition	Chemical name	Percentage (%)
CaCO_3	Calcium carbonate	95
Cl	Chloride ion	0.63
SO_3	sulfur trioxide	0.60
Na_2O	Disodium monoxide	0.15
SiO_2	Silicon dioxide	0.08
Al_2O_3	Aluminum oxide	0.04
Fe_2O_3	Ferric Oxide	0.02
MgO	Magnesium oxide	0.01

B. Preparation of Mortar Specimens

Fresh mortars were prepared with cement to sand ratio (C/S) of 0.33 by weight. Eggshell powder solution (ESPS) with a ratio of 5%, 10%, 15% and 20% by weight was used instead of mixing water with (ESPS/C) ratio of 0.50 by weight to prepare different mortar specimens as given in Table II. For all mortars, a rotary mixer with inclined beater was used for mixing.

Concerning the mortar specimens, the cement and sand were first mixed dry for 2minutes; ESPS was added to the mix and mixed for another 3minutes. Flow table measurements [4] were carried out immediately after mixing.

After the flow testing, the mortars were cast in cubes of size 7.07 x 7.07 x 7.07cm for testing in density and compressive strength [5,6] and in prisms of size 4 x 4 x 16cm for the flexural testing (modulus of rupture) [7]. Vibrator table was used for compaction. The specimens were demolded after 24hrs then cured in fresh water at 23±2°C until the testing age.

Nine cubic specimens were made from each mixture. All tests were carried out in triplicate specimens. In addition, nine prism specimens for each mixture were cast for the flexural strength testing at the same ages of compression test. The microstructure of mortar was scanned by means of a scanning electronic microscope (SEM) JEOL-JSM5500LV and X-Ray diffraction (XRD) tests [8].

III. Results and Discussion

A. Microstructure Study

Fig. 1 displays the SEM micrograph for eggshell powder. The powder particles appeared to have structure nano-pores with irregular morphology and a varying particle size distribution due to the process of grinding.

Fig. 2 indicates X-Ray Diffraction patterns for eggshell powder. It can be noticed, from XRD peaks, that the major component in eggshell powder is calcium carbonate (CaCO₃) in calcite form which is, under ambient conditions, known as the most thermodynamically stable component. XRD peaks appeared, for the calcite, at approximately 2θ angles on 23°, 31.3°, 35.9°, 39.4°, 43.1°, 47.5°, 48.4°, 56.5° and 57.3° with a major peak at 29.3°. The intensities of the calcite peaks were comparatively indistinguishable with no other crystalline data card phase found.

Table 2. MIX PROPORTION OF MORTAR SPECIMENS

Mortar Designation	Mix proportion			
	Cement (gm)	Sand (gm)	ESPS/C	ESPS (gm)
ES ₀	555	1665	0.50	277.5
ES ₅	555	1665	0.50	277.5
ES ₁₀	555	1665	0.50	277.5
ES ₁₅	555	1665	0.50	277.5
ES ₂₀	555	1665	0.50	277.5
ES ₃₀	555	1665	0.50	277.5
ES ₄₀	555	1665	0.50	277.5

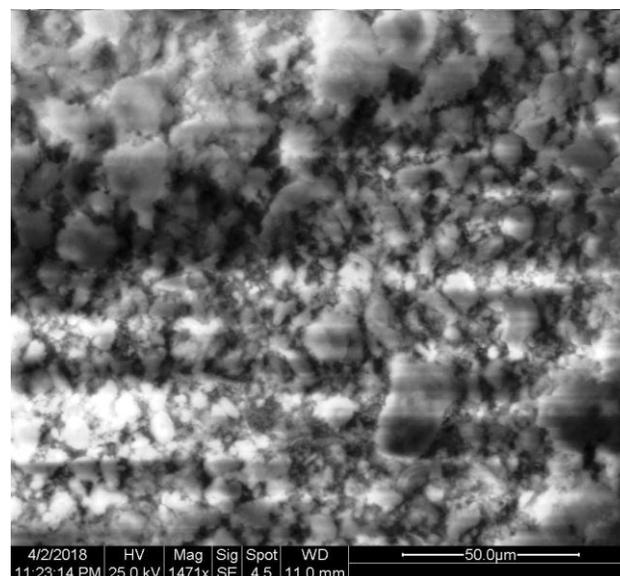


Figure. 1 SEM micrograph for eggshell powder

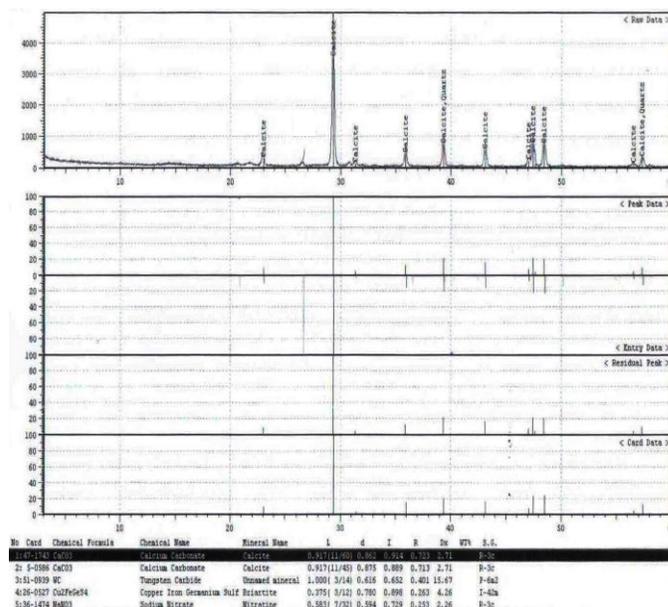


Figure. 2 X-Ray Diffraction patterns for eggshell powder

B. Workability

Workability of all mortar specimens was measured by Flow table measurements [4]. Table 3 shows the variation of the measured diameters of the flow table test for mortars which contains ESPS. It can be seen that the inclusion of ESPS reduced the workability of mortar specimens. Reduction in workability was observed from 5% ESPS substitution to 40% ESPS which confirmed the minimum workability among all mixtures. Due to the suspended smaller particles of CaCO₃ and its surface effect, more water was needed to be adsorbed on its surface. With the increasing of ESPS concentration, more water decreased which reflect great impact on mortar workability.

Table 3. FLOW TABLE DIAMETERS FOR MORTAR SPECIMENS

Average diameter (mm)	Specimen						
D	ES ₀	ES ₅	ES ₁₀	ES ₁₅	ES ₂₀	ES ₃₀	ES ₄₀
	110	100	89	75	58	38	15

C. Density

Fig. 3 shows the average dry, bulk and fully saturated densities for different concentrations of ESPS mortar cubes ranged from 0% to 40% after 28 days of curing age. It can be seen that the average densities decreased with the increasing of ESPS concentrations. Substitution of water by ESPS decreased the dry, bulk and fully saturated densities by 4% at the age of 28 days. With the increasing of ESPS concentrations, more adsorbed water were consumed which lead to more pores at mortar.

D. Compressive and Flexural Strengths

Fig. 4 designates the compressive strength test results for different concentrations of ESPS mortar cubes ranged from 0% to 40% as a function of curing time. It can be indicated that the compressive strength was improved at the inclusion of 10% ESPS concentration by 8%, 17% and 13% at ages of 2, 7 and 28 days respectively. Both concentrations of 5% and 15% ESPS enhanced the compressive strength by 4% at all ages of curing. The concentration of 20% ESPS enhanced the compressive strength by 3%, 1% and 1% at ages of 2, 7 and 28 days respectively. The concentration of 30% ESPS enhanced the compressive strength by 1%, 0.2% and 0.2% at ages of 2, 7 and 28 days respectively. The concentration of 40% ESPS enhanced the compressive strength by 0.4%, 0.1% and 0.02% at ages of 2, 7 and 28 days respectively.

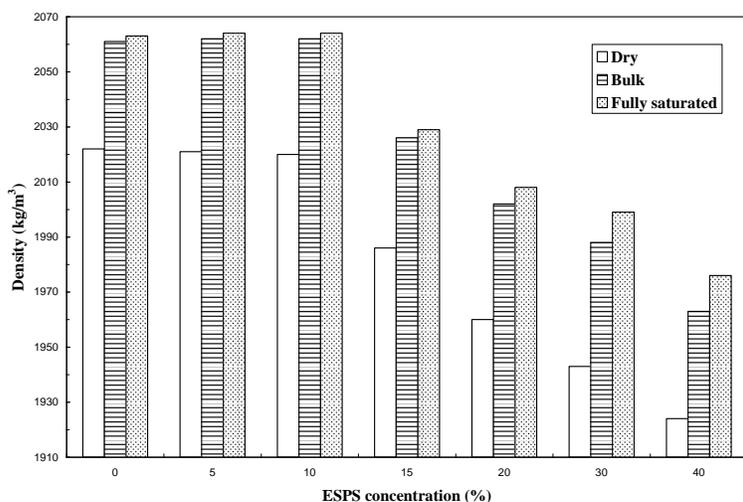


Figure. 3 Densities of mortar cubes with different ESPS concentrations at 28 days of curing age

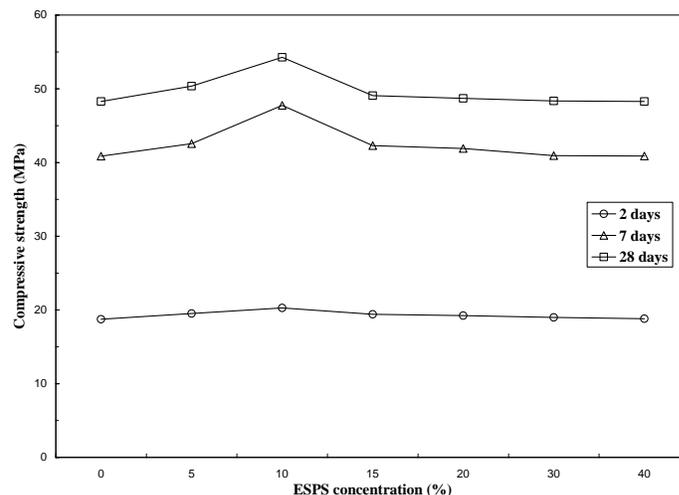


Figure. 4 Compressive strength of mortar cubes with different ESPS concentrations

Fig. 5 explains the flexural strength test results for different concentrations of ESPS mortar prisms ranged from 0% to 40% as a function of curing time. It can be noticed that the flexural strength was improved at the inclusion of 10% ESPS concentration by 56%, 41% and 13% at ages of 2, 7 and 28 days respectively. The concentration of 5% ESPS enhanced the flexural strength by 49%, 26% and 4% at ages of 2, 7 and 28 days respectively. The concentration of 15% ESPS enhanced the flexural strength by 35%, 25% and 2% at ages of 2, 7 and 28 days respectively. The concentration of 20% ESPS enhanced the flexural strength by 17%, 24% and 1% at ages of 2, 7 and 28 days respectively. The concentration of 30% ESPS enhanced the flexural strength by 11%, 22% and 0.5% at ages of 2, 7 and 28 days respectively. The concentration of 40% ESPS enhanced the flexural strength by 7%, 21% and 0.2% at ages of 2, 7 and 28 days respectively.

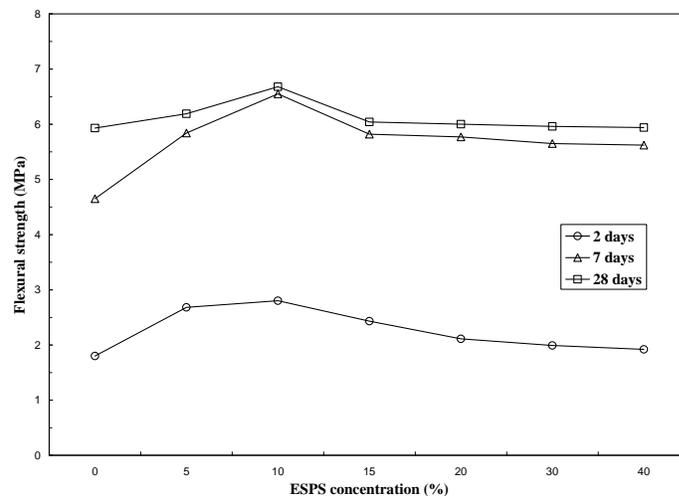


Figure. 5 Flexural strength of mortar prisms with different ESPS concentrations

Both compressive and flexure strengths were enhanced due to the producing of $\text{Ca}(\text{OH})_2$ refinement grain during the cement hydration process at early ages especially. Due to hydration process, many products formed like C-S-H gel which caused increasing in strengths till 10% concentration. After 10% concentration, strengths decreased due to the effect of ettringite (AFt) which transformed into monosulfate (AFm) and led to loss of strength caused by the internal stress due to the abundant (AFt) with the increasing of ESPS concentration [9].

IV. Conclusions

In this study, mortar mixing water was substituted by 0%, 5%, 10%, 15%, 20%, 30% and 40% concentrations of ESPS which produced by eggshell farm waste. The results showed that both workability and density were decreased with the increasing of ESPS concentration. The results indicated an improvement in both compressive and flexural strengths at 10% inclusion ESPS concentration.

Acknowledgment

The author would like to express gratitude to Northern Cement Company (NCCO) for providing the Raw Materials.

References

- [1] M. Balamurugan, R. Santhosh. "Influence of Egg Shell Ash on the Properties of Cement". Imperial Journal of Interdisciplinary Research (IJIR), Vol. 3, Issue. 4, 2017; 160-164.
- [2] B. Harinath, P. D. Varaprasad, U. L. Kanth, Y. H. Reddy. "Experimental Study on Compressive Strength of Cement Concrete Cubes by Partial Replacement of Cement with Egg Shell Powder". International Journal of Engineering Research & Technology (IJERT), Vol. 7, Issue. 3, 2018; 153-155.
- [3] D. Gowsika, S. Sarankokila, K. Sargunan. "Experimental Investigation of Egg Shell Powder as Partial Replacement with Cement in Concrete". International Journal of Engineering Trends and Technology (IJETT), Vol. 14, No. 2, 2014; 65-68.
- [4] ASTM C1437-99. "Standard Test Method for Flow of Hydraulic Cement Mortar". Philadelphia: American Society for Testing and Materials; 1999.
- [5] EN 1015-11. Methods of Test for Mortar for Masonry – Part 11: "Determination of Flexural and Compressive Strength of Hardened Mortar", 1999.
- [6] EN 16-1. Methods of Testing Cement: "Determination of Strength ", 2005.
- [7] ASTM C348-97. "Standard Test Method for Flexural Strength of Hydraulic Cement Mortars". Philadelphia: American Society for Testing and Materials; 1997.
- [8] L. E. Copeland, R. H. Bragg. "Quantitative X-ray diffraction analysis". Anal Chem 1958; 30: 196-201.
- [9] X. Liu, L. Chen, A. Liu, X. Wang. "Effect of Nano- CaCO_3 on Properties of Cement Paste". International Conference on Future Energy, Environment and materials, 16, 2012; 991-996.