Mechanical Properties of Concrete Production with Powdery Fowl Egg Shell (PFES) as Substitute for Ordinary Portland Cement

Adeniran Adeala & Olugbenga Soyemi
Department of Civil Engineering
Federal Polytechnic, Ilaro
Ogun state, Nigeria.
adeniran.adeala@federalpolyilaro.edu.ng; jidesoyemi@fedrealpolyilaro.edu.ng

ABSTRACT

An eggshell is a waste generated from fowl poultry, which causes nuisance to the environment and serious threat to human health. Fowls eggshell was washed, dried, crushed, ground by mechanical grinding machine and passing through sieve size of 75µm which falls within range of particle size of cement (50µm-90µm). Particle size distribution was carried out on both fine and coarse aggregate in accordance to (BS 1377-2:1990), Workability and density test were also carried out on concrete. Specific gravity was carried out on cement, fine aggregate and cement. Concrete cubes were cast for each replacement (15% & 20%) with varying water cement ratio (W/C) of 0.4, 0.5 and 0.6. and they were cured for 7, 14, 28 and 56days respectively. Water absorption and consistency test were carried out on conventional and modified concrete (Fresh fowl eggshell). The result showed that Particle size distributions of the aggregates are well graded. The result indicated that at 0.4w/c and 0.5w/c have true slumps. The densities of modified concrete varied from 2300-2500Kg/m^3. The result showed that 15% at 0.4w/c of replacement has higher water absorption rate 1.18% and 20% at 0.4w/c of replacement has lower water absorption rate 0.41%. The result further showed that control (0%) at 0.4w/c has compressive strength of 29.50N/mm^2 while replacement of 15% and 20% has compressive strength of 29.30N/mm^2 and 24.88N/mm^2 respectively at 28days. The research concluded that the modified concrete at 28days, having water-cement ratio of 0.4 at 15% fowl eggshell powder replacement have properties as a normal weight concrete.

KEYWORDS: Concrete, Fresh Fowl eggshell, Particle Size Distribution, Water Absorption, Workability,

1. INTRODUCTION

Concrete as a composite material contains cement, aggregate (gravel, sand or rock) and water. Concrete is a widely used material for the construction of civil engineering projects like bridges, roads, buildings, hydraulic structures etc. and it is being used mostly in all parts of the world and virtually in Africa and Nigeria. Limestone is a natural mineral resource, quarrying and consequent prolonged use of limestone may again lead to problems associated with environment and renewable development. Furthermore, lime production involves an energy-intensive process and consumes water. The principal binder used in concrete is Portland cement, the production of which is a significant contributor to greenhouse gas emissions that are implicated in global warming and climate change. In addition to, many concrete structures suffer from lack of durability which may reduce the natural resources such as limestone. Cement is one of the producers of carbon dioxide CO_2 emitted for every ton of concrete. In Basic Concrete Training as of 2001, the production of Portland cement contributed 7% to global CO_2 emission.

In order to lessen the adverse effect of production of Carbon (IV) Oxide in the production of cement waste such as eggshell can be recycled and pulverised at range of temperature which can be used as substitute for cement in concrete. Over 60 million tons of eggs were produced throughout the world per year, but according to Nigerian Poultry Association (2017) about 10.3billion eggs were produced per annul in Nigeria. It is evident that eggshell waste is available in abundant quantity. Okonkwo, et al., (2012) and Sanni, et al., (2018) described the use of fowl eggshell ash as partial replacement of cement in concrete production. In this study, the application of pulverised eggshell ash as partial replacement, up to 20% for cement in concrete production at 28 days compressive strength was recommended. In a similar study, Teara1, et al., (2019) posited that eggshells powder (ESP) and fly ash are effective supplementary elements for the improvement of the properties of concrete. However, either the combination of ESP and fly ash or ESP alone gave weak concrete and unsatisfying compressive strength test. The use of fly ash alone also yielded broken concrete even before testing. It was therefore recommended that the aforementioned materials should be used in combination with cement as supplementary elements for improving the concrete properties.

This agrees with previous research works that excessive replacement of fly ash in concrete is capable of compromising concrete performance. Even though fly ash has been proven to be more viable than eggshells powder in concrete production, its application beyond 30% could be counterproductive when used with the eggshells powder as partial substitute. Khalid et al., (2018) studied the overall pattern of the compressive strength of modified concrete with eggshell which showed that increment of strength development with the increment of curing age. However, GPOFA-ESP (Ground Palm Oil Fuel Ash) concrete had higher compressive strength as compared to UPOFA-ESP (Ultrafine Palm Oil Fuel Ash) and NC at age 28 and 56 days. Maximum compressive strength for GPOFA-ESP concrete with notation of G3 (10% GPOFA with 10% ESP) was reached approximately about 40MPa. While, compressive strength for UPOFA-ESP concrete with notation U4 (15% UPOFA with 5% ESP), for UPOFA-ESP concrete category, there was insignificant strength development. Bandhavya, et al., (2017) observed that compressive strength of conventional concrete was 33.18MPa and 5% ESP replaced concrete is 35.70MPa at the age of 28days. Francis, et al., (2016) worked on the experimental study to determine the strength development of specimens with varying eggshells at both primary and secondary curing ages (28- and 56-days curing ages). The compressive strengths of brick specimens generally increased as the eggshells contents increased. It was also observed that an increase as the curing ages increased from 28 days to 56days a phenomenon common with materials used as binders such as cement, lime, fly ash and so on. Dhanalakshmi, et al., (2015) studied the properties of the concrete with partial replacements of cement with eggshell and fly ash. In the study, two wastes namely eggshell powder and fly ash were adopted 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, and the compressive strength in MPa were 51.6, 44.27, 46.04, 48.42, 39.05 and 38.55 respectively. Gowsika et al., in 2014 observed that, the replacement of cement by eggshell powder 5%, 10%, 15% and fine aggregate by Crumb Rubber (CR) 2.5%, 5%, 7.5% and 10%. The compressive strength of concrete decreased with increase in varying dosage percentage of Crumb Rubber resulted in replacing cement by 5% ESP in 10% crumb rubber replaced concrete shows increase in both flexural and split strength. Raji & Samuel, (2015) carried out study on compressive strength of eggshell concrete, it was found that with up to 7.5% of eggshell replacement at 7 and 28 days of curing, strength reached 38MPa and 40.9MPa, respectively. While control concrete mixed under similar conditions reached strengths of 42MPa and 49.5MPa, respectively. This research work aimed to investigate the effect of partial replacement of cement with eggshell powder in production of concrete. The workability, water absorption and compressive strength of modified concrete were determined and compared to control concrete. The use of eggshell powder in concrete will reduce environmental pollution and reducing quantity of cement used in the production of concrete thereby reducing cost of construction.

2. MATERIALS AND METHODS

Fowl shell eggs used in this study were collected from food sheds scattered around a settlement in Abeokuta, Ogun State, Nigeria. The shells were washed, cleaned with warm water to remove micro-organism and impurities of organic origin .It was then sun – dried and shredded to enabling the eggshells to be uniformly dried and later ground into powder through milling machine and then sieved through 75micron which fall within the range of cement particle size (50-90 microns). Ordinary Portland Cement obtained directly from a Dangote Cement Depot to guarantee the integrity of the material. Coarse aggregate and fine aggregate applied in this study were obtained from a construction site within the Federal Polytechnic campus, Ilaro, Ogun State. All the aggregates were properly graded using sieve analysis in compliance with the British Standards Institution BS 1377-2. (1990). Specific was carried out on both powdery Egg shell and cement in accordance to BS 812-2:1995. The control specimens (concrete) and those of the PFES-blended species were prepared in sets of three each for 7 days 14days , 21 days and 28 days respectively, using plain cement , PFES modified cement (5%; 10%; 15%; 20%; 25% and 30%); sand and crushed granite in proportion 1:2:4. This design mix was prepared and batched by weight using water: cement ratio of 0.4, 0.5 & 0.6. Workability for the various fresh concrete mixes were determined using Slump test, as stipulated by the British Standards BS 1881-102 (1983). The resulting concrete specimens were cast into 150mm× 150mm × 150mm steel moulds, allowed to set under the ambient temperature, demoulded and then transferred into water bath to cure for 7days; 14days; 21days and 28days, respectively. Compressive Strength, density and water absorption property were determined in accordance with the British Standards Institute guides and regulations.

Plate 1: Sun-dried and shredded fowl eggshell

Plate 2: Powdery fowl eggshell.

Pictures of the sun dried, shredded fowl eggshell and powdery fowl eggshell are shown in plates 1 and 2 respectively. The one full head-pan of shredded fowl eggshell became about a third of head-pan when grounded into powder. The materials were combined in the matrices using the batching methods by weight of each materials at water-cement ratio of 0.4, 0.5 and 0.6 as shown in Table 1.

Table 1: Batch weight of materials with water cement ratio measured in (Kg).

		0.4		0.5		0.6	
MATERIALS	CONTROL	15%	20%	15%	20%	15%	20%
CEMENT	14	11.9	11.2	11.9	11.2	11.9	11.2
FA	28	28.0	28.0	28.0	28.0	28.0	28.0
CA	56	56.0	56.0	56.0	56.0	56.0	56.0
ESP	0	4.76	4.48	5.95	5.6	5.95	5.6
WATER	5.6	5.6	5.6	7.0	7.0	7.0	7.0

Note: FA- Fine Aggregate, CA- Coarse Aggregate

3. RESULTS AND DISCUSSIONS

3.1 Particle size distribution analysis

The result of sieve analysis showing the particle size distribution of fine and coarse aggregates utilized in this study are as depicted in Figures 1 and 2. All the fine aggregates passed through sieve of size 5mm, whereas, all coarse aggregates passed through sieve size 19mm as recommended for normal concrete. The coefficients of gradation curvature, Cc for the two aggregates further revealed that both are well graded BS 1377.

3.2 Standard consistency test

The standard consistency of a cement paste is defined as that consistency which will permit the vicat plunger to penetrate to a point 5 to 7mm from the bottom of the vicat mould. From Table 2, cement and its modification with powdery fowl eggshell (PFES) fall between 5 and 7mm which means the amount of water added are adequate for the cement paste.

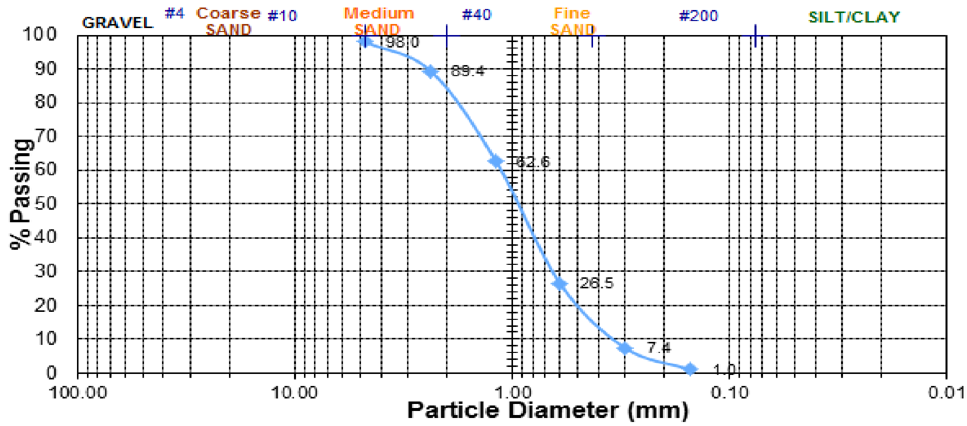


Fig. 1: Particle Size Distribution Curve of Fine Aggregates

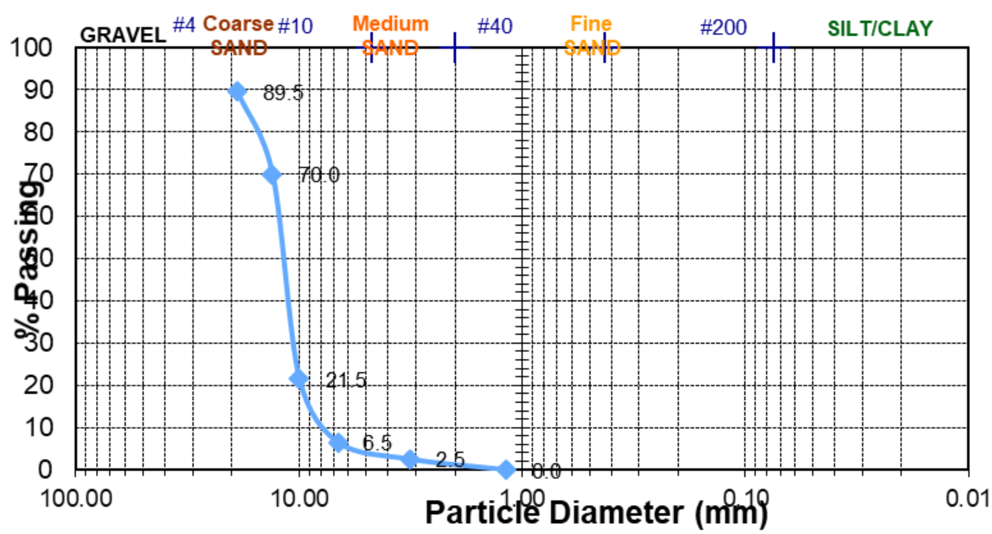


Fig. 2: Particle Size Distribution Curve of Coarse Aggregates

3.3 Setting time

This phenomenon by virtue of which the cement paste changes from plastic state to solid is known as setting of cement while setting time is the time taken for cement paste to change from plastic state to solid state. Table 3 shows the setting time of cement and modified cement paste.

Table 2: Result of Standard Consistency test for Cement and its Modification with Powdery Fowl Egg Shell.

Vicat apparatus	Cement	15% replacement	20% replacement
Needle penetration	5	5	6
Needle with collar	6	7	7
Needle without collar	5	5	6

Table 3: Setting time of cement and modified cement paste (Initial and Final setting time).

Sample	Initial setting time	Final setting time
Cement	1hour 30mins	2hours 45mins
Replacement of 15%	2hours 10mins	3hours 45mins

Replacement of 20%	2hours 45mins	4hours 15mins

The setting time results are satisfactory and in accordance with BS 12, 1987 since the setting times fall between 45mins and 10 hours.

3.4 Workability

Workability is the property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished' (BS EN12350-2. (2009).

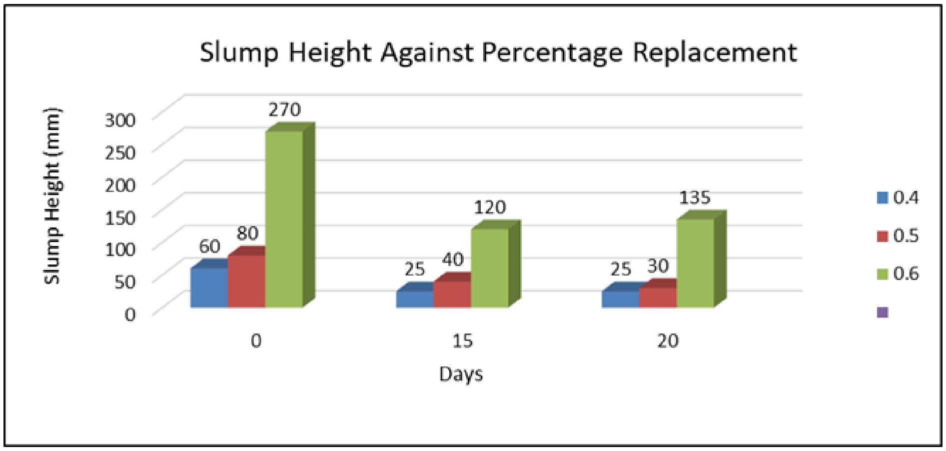


Fig. 3: Slump height against percentage replacement of powdery fresh eggshell.

From Figure 3, the control concrete with 0% replacement of cement for water-cement ratio of 0.4, the slump height was 60mm then at 15% and 20% replacements with PFES, the slump declined to 25mm. For 0.5 w/c, at 0% replacement, the slump height was 80mm later dropped to 40mm and 30mm at 15% and 20% replacement. For 0.6 w/c the height was 270mm for control specimen moved down to 120mm at 15% and finally dropped to 135mm at 20% replacement. The higher the water-cement ratio the lower the slump height, also the higher the PFES in concrete the lower the slump, that is the less workable the modified concrete.

3.5 Compressive Strength

This is defined as ratio of crushing force to cross sectional area of specimen. The cubes were cured in water for 7days, 14 days, 21 days, 28 days and 56 days. The compressive strength was carried on 150mm cubes after days of curing in accordance with (BS 1881- 116, 1983).

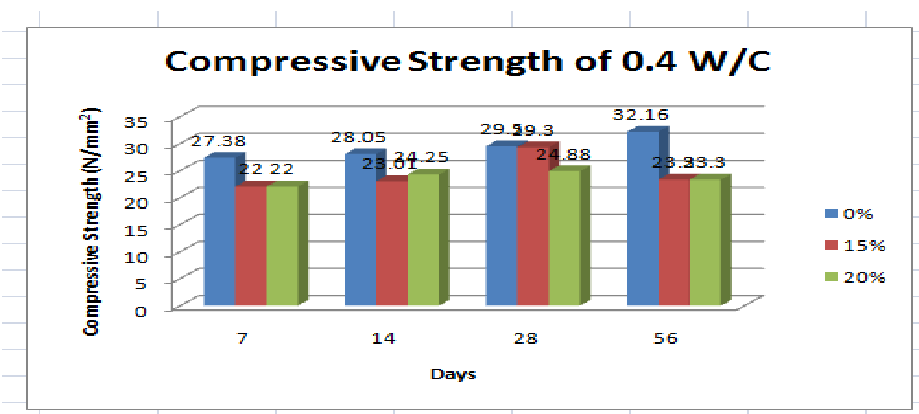


Fig. 4: Graph of compressive strength of concrete of w/c of 0.4 with curing days.

The compressive strength of control at 0.4w/c increases steadily from 7 days to 56days with 27.38N/mm^2 at 7 days and 32.16N/mm^2. For 15% and 20% replacement, produced the same compressive strength of 23.30N/mm^2 at 56days. At 15% replacement, the strength of the concrete matrix is good for structural members

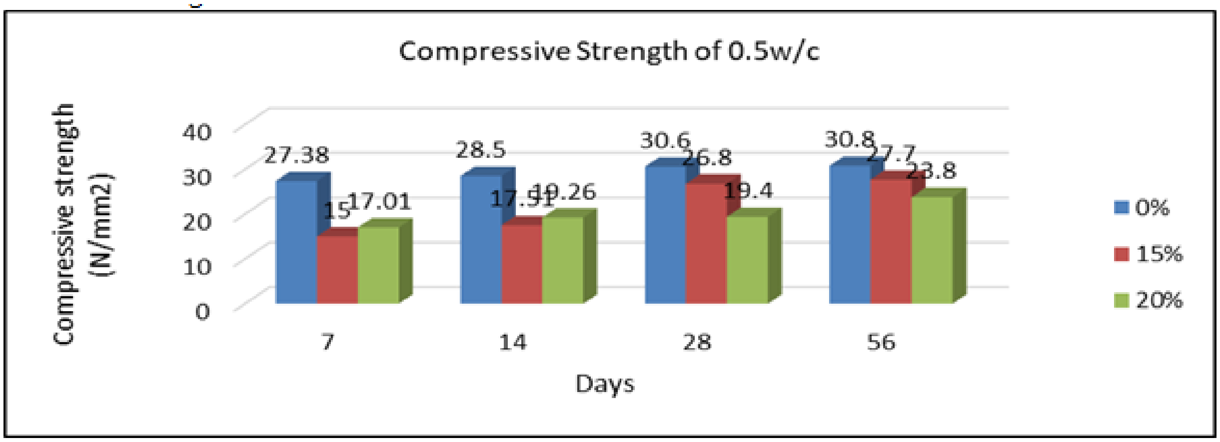
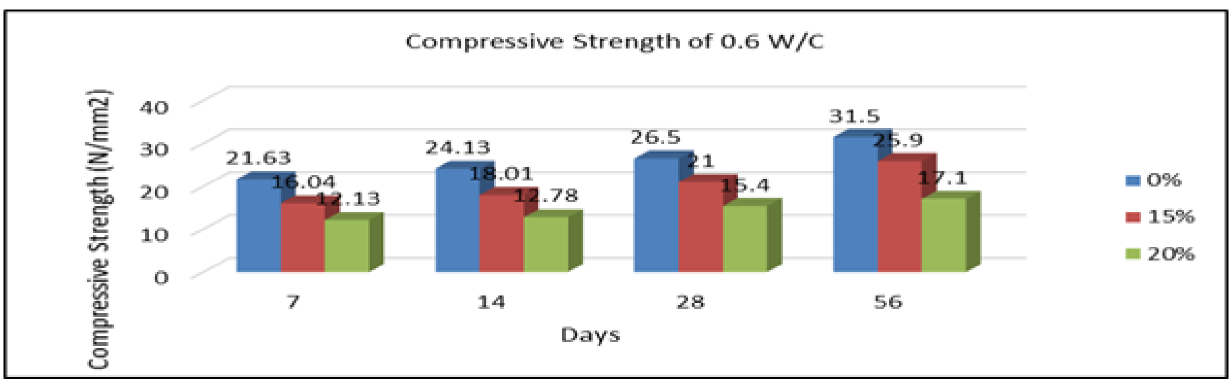


Fig. 5: Graph of compressive strength of concrete of w/c of 0.5 with curing days

The compressive strength of the control specimen at 0.5w/c also increases as the day for testing increases. The strength at 7 days and 56day were 27.38N/mm^2 and 30.80 N/mm^2 respectively. The 15% and 20% replacement concrete matrices have a strength of 26.8 N/mm^2 and 19.4N/mm^2 respectively. A steady increase in the strength was also achieved as the concrete matrixes matures. The 15% replacement concrete matrix is suitable for use as structural concrete.

Fig. 6: Graph of compressive strength of concrete of w/c of 0.6 with curing days.



The compressive strength of control concrete specimen at 0.6 w/c was 21.63 N/mm2 and 31.50 N/mm2 for 7 and 56 days respectively. The modified concrete at 15% and 20% replacement of cement with PFES have a strength of 21.0 N/mm2 and 15.4 N/mm2 at 28 days. At 28 days with 0.6 w/c, the 15% also give a class C20 strength, which is suitable for low strength concrete demand and also for general concreting works. Comparing the three water-cement ratios, it could be seen that the optimal strength was at 0.5% w/c for all concrete matrix samples.

3.6 Density

It was observed that for 0.4 w/c the density for control specimen was 2449Kg/m^3 which later dropped to 2344Kg/m^3 at 15% replacement then fall to 2335Kg/m^3 at 20%. It was also deduced at 0.5w/c for conventional concrete produced density of 2327Kg/m^3 which risen up at 15% replacement to 2413Kg/m^3 and reduced to 2369Kg/m^3 at 20%. It was found that 0.6 w/c at 0% replacement developed mass density of 2431Kg/m^3 which at 15% dosage produced 2335Kg/m^3 and later increased at 20% to 2381Kg/m^3. As the replacement percentage increases, the density decreases which can be attributed to reduction in the cohesive force within the concrete matrixes.

3.7 Water Absorption

The concrete cubes at 56 days curing were weighed after demoulding. It was observed that for 0.4 w/c, 0% eggshell powder has water absorption of 1.17% and 15% snail shell ash concrete has the highest water absorption rate of 1.18% while 20% has 0.41%. For 0.5 w/c, 0% and 15% has the highest and lowest absorption rate of 1.11 and 0.89% respectively, likewise 20% has 0.43. For 0.6 w/c, 0% and 20% has highest and lowest water absorption of 1.17 and 0.45% respectively, while 15% has 0.79%. The water absorption for all specimen with egg shell powder are good according to concrete Society, United Kingdom, concrete quality is classified as good if the saturated water absorption is between 0.89% and 3%, though 0.4 w/c 20% ,0.5w/c 15% and 0.6w/c 20% were below 0.89% but can classified as good.

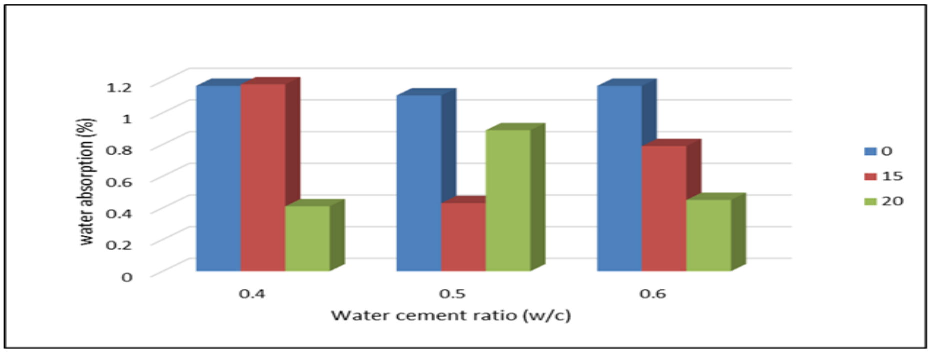


Fig. 8: Chart showing water absorption at 56 days with water-cement ratio of 0.4, 0.5 & 0.6

4. CONCLUSIONS

The mechanical characteristics of Fresh Fowl Eggshell Ash has been investigated using graded levels of powdery eggshell, ranging between 0%-20% as partial replacement for cement in the concrete. The performance indicators examined include Workability, water Absorption and comprehensive strength and density. The results showed that at w/c ratio of 0.5 and eggshell powder-cement replacement of 15%-20%; the modified concrete has compressive strength lying 23.80N/mm2 and 26.8N/mm2 at 28days; (other findings, including the one on density). The optimum values for all the indicators compared favourably with those of conventional concrete. Hence, the application of eggshell powder in concrete production would be advantageous, provided that the recommended limit (15%-20% eggshell powder-cement replacement) is not exceeded.

REFERENCES

Amarnath, Y. (2014). Properties of Concrete with Eggshell Powder as Cement Replacement. The Indian Concrete Journal, 94-102

Bandhavya, G. B., Sandeep, K., & Bindhushree, G. B. (2017). An experimental study on partial replacement of cement with egg shell powder in concrete. International Research Journal of Engineering and Technology (IRJET) 4(6). 2318-2323

BS 812:2. (1995). Testing aggregate- method for determination of density. London.

BS 1377-2. (1990). Test for geometrical properties of aggregates-Determination of particle size distribution-sieving method. London.

BS 1881-116. (1983). Testing concrete -method for determination of compressive strength of concrete cubes. London.

BS EN12350-2. (2009). Testing fresh concrete slump test. London

Dhanalakshmi M, Sowmya N.J and Chandrashekar A. (2015). A Comparative Study on Eggshell Concrete with Partial Replacement of Cement by Fly Ash. International Journal of Engineering Research & Technology, 4(05), 1532-1538.

Francis A., Peter P. and Moses A. (2016). Improving Compressed Laterite Bricks Using Powdered Eggshell. The International Journal of Engineering and Science, 5(4), 65-70.

Gowsika D, Sarankokila S and Sargunan K. (2014). Experimental Investigation of Eggshell Powder as Partial Replacement with Cement in Concrete. International Journal of Engineering Trends and Technology, 14(2), 65-68

Khalid N.H.A, Rasid N.N.A, Mohd.Sam A.R, Ismail M, Zardasti L, Mohamed A, Majid Z.A and Ariffin N.F. (2018). Characteristics of Palm Oil Fuel Ash and Eggshell Powder as Partial Cement Replacement in Concrete. International Journal on Concrete Engineering and Technology, 1-9.

Okonkwo, U.N, Odiong, I.C and Akpabio, E.E. (2012). The Effect Of Eggshell Ash On Strength Properties Of Cement-Stabilized Lateritic. International Journal of sustainable Construction Engineering & Technology, 3(1), 18-25

Raji S.A and Samuel A.T. (2015). Eggshell as a Fine Aggregate in Concrete for Sustainable Construction. International Journal of Scientific & Technology Research, 4(09), 8-13.

Sanni, H.A, Adeala, A.J and Adeoye J.A (2018). Investigation of Fresh Eggshell Ash as Partial Replacement of O.P.C in Concrete. International Conference and exhibition on Technology Innovation and Global Competitiveness.

Teara A, Doh S.I, Chin S.C, Ding Y.J, Wong J and Jiang X.X. (2019). Investigation on The Durability of Use Fly Ash and Eggshells Powder to Replace the Cement in Concrete Production. Conference Series: Earth and Environmental Science, 1-8.