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An Experimental Study on Concrete Strength Using Egg Shell Powder (ESP) as Partial Replacement of Cement

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Abstract: The emission of Carbon Dioxide (CO_2) into the atmosphere becomes one of the most common issues that is discussed within the construction industry. Concrete as the most common materials used in construction had contributed the most CO_2 emission compared with other building materials. As the solution to reduce the negative impacts of CO_2 on the environment, cement is been replaced partially by eggshell powder (ESP). The objective of this study are study the workability of concrete with ESP and determine the effect of ESP toward density and compressive strength development in concrete. In this study, cement was replaced partially by ESP by 5%, 10%, and 15% to investigate the compressive strength of the concrete with ESP as an addictive concrete mix. The samples were divided into 4 types according to the percentage of the ESP replacement with cement which are no replacement, 5%,10%, and 15%. The concrete was tested by compressive strength test according to BS EN 12390-2: 2009 / BS EN 12390-3: 2009. The result compressive strength of the OPC-ESP concrete was decrease in this study.

Keywords: Eggshell Powder, Cement Replacement, Sustainable, Concrete Manufacturing, Compressive Strength

1. Introduction.

1.1 Research Background

Concrete is the main component in building construction because of its availability, strong adaption to extreme weather and lower cost compare to other construction components with great compressive strength [11]. In concrete manufacturing, cement, aggregate, and water are the three main materials while cement plays an important role as a binder in concrete mixes [2]. As one of the significant building materials in construction, concrete had contributed 70% emission of carbon dioxide compare to the

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other building materials such as reinforcing rod and section steel [3]. The main ingredient in concrete that causes massive carbon dioxide emission is the Ordinary Portland Cement (OPC). However, there have no alternatives that can replace cement fully in construction manufacturing [5]. Besides construction, cement is being used widely by human and is the second-largest material used by humans after water [4]. The production of 1 ton of cement is expected to release about 0.9 tons of Carbon Dioxide (CO_2) into the environment [10]. Carbon Dioxide is a greenhouse gasses that are the main cause of the Greenhouse Effect and global warming [3].

Therefore, an effective solution must be found to reduce the use of cement in concrete production. Currently, many researchers had begun to find other alternative materials that can replace cement without altering the function of cement in concrete mixes. The materials currently used as the partial replacement are rice husk ash, silica fumes, fly ash, etc [5]. Agriculture waste has become the main materials to substitute cement as it is a sustainable and convenient material, ubiquitous and inexpensive [6]. One of the agricultural wastes that can substitute cement partially in concrete mixes is an eggshell powder (ESP) which able to shorten the hydration time of concrete mixes [7]. There are about 250 thousand tons of eggshell produced every year while most of them are being cumulated on-site with no proper treatment [8]. From the total of 1 billion eggs, the high-grade lime powder that could be produced is about 6600 t [9]. Thus, various tests and research have been made currently to maximize the use of eggshell. Replace cement partially with eggshell powder helps to minimize the production of Carbon Dioxide and decrease environmental emissions in terms of solid waste [1].

This study was focusing on the compressive strength of ESP-OPC concrete by conducting a compressive strength test by concrete cube. The compressive strength of the concrete was decease in this study. The objectives of this study is to define the role of eggshell powder (ESP) as the partial replacement material to ordinary Portland cement (OPC) in concrete. The objectives needed to achieve in this research are to study the workability of concrete with ESP and determine the effect of ESP toward density and compressive strength development in concrete.

2. Materials and Methods

The preparation of materials in implementing this study is very necessary because these materials are important to make this study succeed. The material consists of cement, fine aggregate, coarse aggregates, and eggshell powder. Cement is an important component used in the production of concrete. This material can be found in civil engineering laboratories located at UTHM Pagoh campus. This cement is easy to find because it is already available in UTHM. The type of cement used is just ordinary Portland cement (OPC) which has a moderate hardening rate suitable for various types of work in the construction. This is one of the most-commonly used types of cement for structural purpose. Eggshell powder that will be used in this study will be collected in the cafeteria UTHM Pagoh. Eggshell is a waste that can be easily collect and available in abundance and free of charge. The eggshell will be washed and dried under the uncontrol temperature to discard the water content. The eggshell will be then crushed to form a powder with 90 µm using grinder machine.

Fresh concrete is tested to ensure the workability of the concrete mixes. Slump test is carrying out according to BS EN 12350-2:2000. A Slump Testing mould should made by metal materials which not damaged by cement paste with a hollow frustum of a cone structure. Density of the concrete cube sample calculated by dividing the weight of concrete after curing with its volume. The mass of the concrete cube sample was weighting by the electronic balance to the nearest 0.001kg. Compressive strength test is a method used to determine compressive strength of a concrete using a concrete cube that undergoes a load or applied force at the vertical diameter. In the direct compressive strength test there will definitely be specialization so it is impossible to apply the actual axial load [14]. Compressive strength test is performed to find out the compressive strength of concrete. Compressive strength test specimens were prepared and tested in accorded with BS EN 12390-2: 2009 / BS EN 12390-3: 2009 Method Specimens in concrete containing cement with eggshell powder (5 to 15%). In this study, 24 units of concrete cubes were produced with dimensions of 100mm x100mm x 100mm and underwent a curing process in a water tank. The compressive strength test was performed after the specimen was removed from the water tank. All specimens were tested at 7 days and 28 days, make sure the surface of the specimen is dry and the bearing surface of the equipment is cleaned before being put into the test machine [15]. Then, place the specimen on the test machine centrally and carefully place the loading pieces at the top and bottom of the specimen loading plane. Further, ensure that the position of the specimen is still centred when subjected to load. The load increase will continue at a predetermined 10% constant until failure. Check the loading rate from time to time to ensure that every constant rate occurs. Finally, the maximum load that causes the concrete to achieve failure is recorded.

3. Results and Discussion

This chapter will cover the data analysis, which includes the concrete workability test analysis, concrete compressive strength, and density analysis. The research objectives will be answered and interpreted by analysing the data obtained for each test. The workability of the ESP-OPC concrete was determined by conducting a slump test and the slump value was obtained. The slump value in this study was being measured as the height of the slump from the top to the bottom of the concrete slump after removing the cone. The compressive strength of the concrete cube was determined by the compression machine in the laboratory, and the mass of the concrete cube was obtained by weighting it mass after curing by electric balance to the nearest o.o1 kg to calculate the density of each concrete cube sample.

3.1 Workability

Slump tests are used to evaluate the qualities and capabilities of a new concrete. In this study, slump test was conducted on concrete mixes before being moulded into concrete cube sample. Figure 4.1 shows the slump test conducted during the sample production.

Table 1: Slump test result

Sample	Slump value (mm)	Percentage different with control sample (%)
A (Control)	78	-
B (5%-ESP)	70	10.26
C (10%-ESP)	64	17.95
D (15%-ESP)	60	23.08

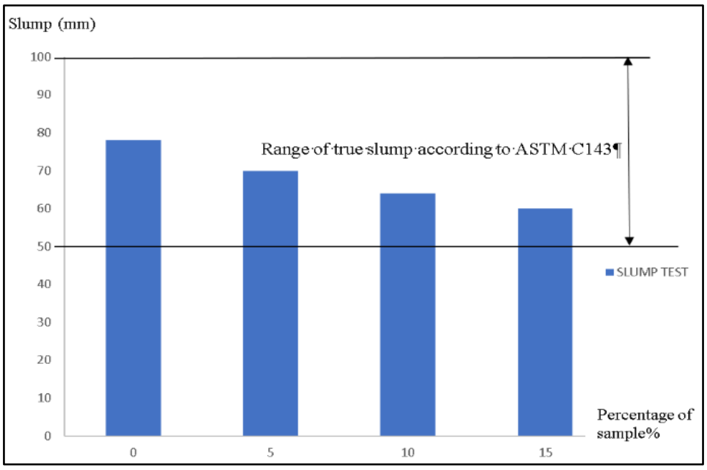

Figure 1: Slump test result

Table 1 shows that the slump value of the sample decrease with the increase of ESP replacement with cement. The higher the ratio of ESP used, the slump value decreases from 78 mm in the control sample to 60 mm in Sample D which contains 15% ESP. This indicates that the workability of the concrete increases as the collapse on the slump increases. Percentage of different between control samples and ESP-OPC concrete cube sample was being found to be increased by 10.26% at a ratio of 5% of ESP replacement, 17.95% at a ratio of 10% and 23.08% at a ratio of 15%. This percentage can also prove that the more the replacement of ESP with cement in concrete mixes the higher the workability of the concrete until it reaches an optimum level.

Figure 1 shows that all samples within the range of true slump which is 50mm to 100mm. For the concrete mix with slump value less than 50 mm, its degree of workability is low and vice versa. Therefore, the slump height in the range of 50-100 mm has a degree of workability at the medium level which consistency is plastic. The compacting factor that has a slump range like this is 85 mm to 95 mm. Slump value in this range is suitable for slab manufacturing and if it is too low it is suitable for road construction [12].

3.2 Density

Mass concrete cube used in this study was obtained by weighting the concrete cube after the curing process to ensure the density calculated is the density at which the concrete sample had achieved its maximum strength.

Table 2: Density of each sample concrete cube for 7 days and 28 days.

Sample	Density (kg/m^3)		Percentage Different 7 days with 28 days (%)
	7 Days	28 Days	
A (Control)	23.80	24.10	1.24
B (5%-ESP)	23.50	23.75	1.05
C (10%-ESP)	22.50	22.60	0.44
D (15%-ESP)	22.00	22.30	1.35

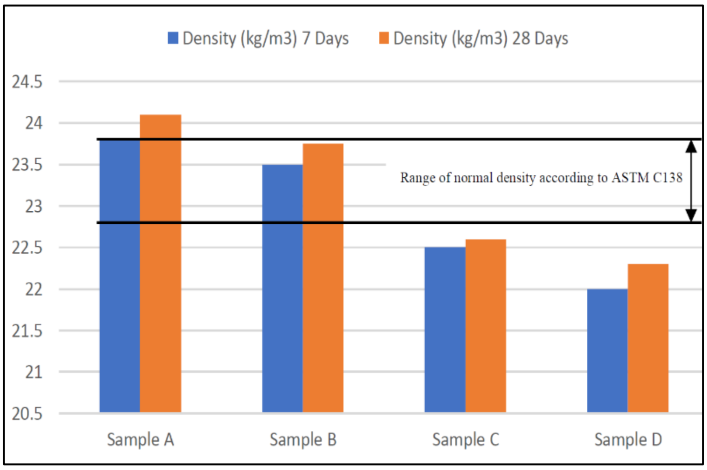

Figure 2: Density of concrete sample for 7 days and 28 days

According to **Table 2**, the density of concrete cube sample for 7 days and 28 days is elaborated and the percentage difference between the sample of 7 days with 28 days was calculated to observe the effect of ESP replacement to the concrete cube density.

From **Figure 2**, the density for 7 days concrete cube sample is lower than the density of 28 days concrete cube sample due to the more water absorption in 28 days concrete cube sample. The density of the 7 days concrete cube Sample A, Sample B, Sample C, Sample D are 23.80 kg/m^3, 23.50 kg/m^3, 22.50 kg/m^3, and 22.00 kg/m^3 while the density of the 28 days concrete cube Sample A, Sample B, Sample C, and Sample D are 24.10 kg/m^3, 23.75 kg/m^3, 22.60 kg/m^3, and 22.30 kg/m^3. Both density of concrete cube sample for 7 days and 28 days is decrease with the increase of ESP replacement with cement. This is because of the replacement of high density materials, cement with the low density materials, ESP [13]. The concrete cube Sample C and Sample D are considered as light weight concrete due to its density which lower than the normal fresh concrete density.

3.3 Compressive Strength

Compressive strength is to obtain the maximum level of strength of the concrete. In this study, compressive strength was tested after the curing process for 7 days and 28 days

Table 3: Result of compression strength test

Sample	7 Days (Mpa)	28 Days (Mpa)	Percentage different with control sample (%)	
			7 Days	28 Days
A (Control)	34.81	44.29	-	-
B (5%-ESP)	31.22	40.26	10.31	9.10
C (10%-ESP)	30.09	39.29	13.56	11.29
D (15%-ESP)	28.91	39.10	16.95	11.72

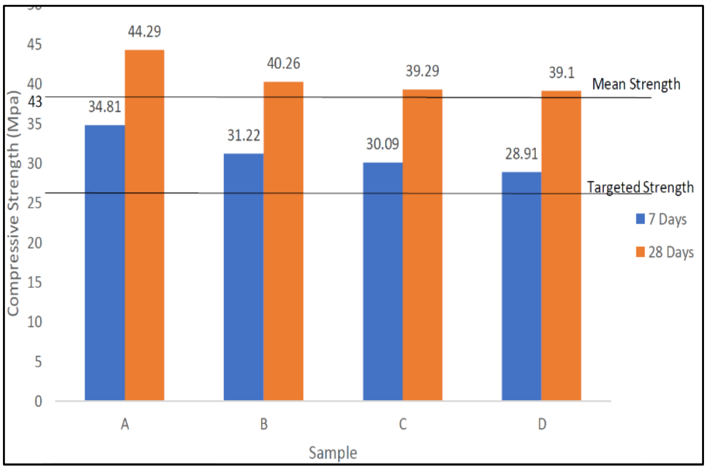

Figure 3: Compressive strength of sample at 7 days and 28 days

Based on **Figure 3**, the compressive strength value of the sample reached the targeted strength range of 30Mpa except for sample D at 7 days which did not reach targeted strength with the value of 28.91 Mpa, while sample A 28 days exceeded the 43Mpa mean strength value with 44.29 Mpa. The sample D at 7 days is less than the targeted strength because cement is the main material of concrete manufacturing that cannot be replaced with ESP. However, only sample A for 28 days exceeded the mean strength because sample A was a control sample that was not mixed with ESP which made the concrete stronger than the one containing ESP. By the other hand, Sample A, Sample B, Sample C, and Sample D at 28 days meet the targeted strength shows that the ESP can be replace for small construction which has limited cost resources to achieve targeted strength [13].

4. Conclusion

The workability of ESP concrete increase when the percentage of ESP replacement in concrete increases before it reaches the optimum level. From the slump test conducted, the percentage different between ESP concrete sample with control sample is increasing with the increase of ESP replacement in the concrete mix which is 10.26% (5%-ESP), 17.95% (10%-ESP) and 23.58% (15%-ESP). The slump value decreased from 78mm on the control sample, 70mm (5%-ESP), 64mm (10%-ESP), and 60mm (15%-ESP). The decrease in value indicates that the workability of concrete mix increases in line with the increasing of ESP replacement in concrete.

The ESP concrete achieved lower density compare with OPC concrete. With 5% of ESP replacement, the density of the concrete is within the average density for normal concrete according to ASTM C138 which is 23.75 kg/m^3 after 28 days. A light-weight concrete is produced with 10% and 15% of ESP replacement which can be shown as the density for Sample C and Sample D is lower than the average density for a normal concrete which is 22.60 kg/m^3 and 22.30 kg/m^3.

The compressive strength of the ESP concrete achieved the design strength and exceed the mean strength for normal concrete. The compressive strength of the concrete decreases with the increases of the ESP replacement. This shows that ESP cannot replace OPC fully as the different chemical properties between OPC and ESP. ESP can be one of the alternatives for small construction which need to cut off some cost in the project.

Future work of this study:-

1) In this study only ESP replacement of 5%, 10%, and 15% being used. The sample will be increased by doing every 2% ESP content up to 20% so that the results of the study and ESP reaction in cement replacement can be analysed in a more detail way.

2) Curing process can be done with a period of 7 days, 14 days, 28 days and 56 days because to study the compressive strength of the ESP concrete which ESP is a biodegradable material. Longer curing process allow researcher to study for the effect of using biodegradable materials to the compressive strength development of the concrete.

3) Different sizes or finesses for ESP need to be added in this study. The effect of different finesses of ESP to compressive strength of the concrete can be discussed.

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References

[1] N.Parthasarathi, M.Prakash, and K.s. Satyanarayanam (2017). India. Experimental Study on Partia Replacement of Cement with Egg Shell Powder and Silica Fume.

[2] Aj Patel, Dr.Vikram M Patel and Mittal Patel (2015). India. Review on Partial Replacement of Cement In Concrete.

[3] Taehyoung Kim, Sungho Tae, Changu Chae (2016). Korea. Analysis of Environmental Impact for Concrete Using LCA by Varying the Recycling Components, the Compressive Strength and the Admixture Material Mixing.

[4] Anand G, Tharunkumar N (2019). India. Review on Partial Replacement of Cement in Concrete by Using Waste Materials.1(6);526-531.

[5] B.Tipraj, M.Guru Prased, E.Laxmi Prasanna, A.Priyanka, Prashnant.K.Hugar (2019). International Journal of Recent Technology and Engineering (IJRTE). Strength Characteristics of Concrete with Partial Replacement of Cement by Fly Ash and Activated Fly Ash. ISSN: 2277-3878, Volume-8 Issue-4.

[6] Jing He, Satoru Kawasaki, Varenyam Achal (2020). The Utilization of Agriculture Waste as Agro-Cement in Concrete: A Review. 12(17), 6971.

[7] Natnael Shiferaw Legesse, Ji-Whan Ahn, Lulit Habte, and Thriveni Thenepalli (2016). Korea. Effect of Eggshell Powder on The Hydration of Cement Paste.

[8] Hamideh Faridi and Akbar Arabhosseini (2018). Department of Agrotechnology, College of Abouraihan, University of Tehran, Iran. Application of Eggshell Wastes as Valuable and Utilizable Products: A Review. Vol. 64, 2018 (2): 104-114.

[9] Stephen Owuamanam and Duncan Cree (2020). Department of Mechanical Engineering, University of Saskatchewan, 57 Campus Drive, Saskatoon, Canada. Progress of Bio-Calcium Carbonate Waste Eggshell and Seashell Fillers in Polymer Composites: A Review. Sci. 2020, 4, 70.

[10] Atishay Lahri & Dr. Savita Dixit (2015). International Journal of Scientific & Engineering Research. Alternatives to Cement in Concrete – A Review. Volume 6, Issue 10. ISSN 2229 – 5518.

[11] Hasan M.Y. Tantawi (2015). Department of Civil Engineering, Fahad Bin Sultan University. Introduction to Concrete Technology.

[12] Rahul Chaudhary, Ahahbaz Ahamad, Nabiullah Khan and Varshney Kumar (2017). Rahul Chaudhary. et.al. Int. Journal of Engineering Research and Application. Analysis of Concrete Containing Different Admixtures as Partial Replacement of Cement. ISSN: 2248 – 9622, VOL. 7, Issue 7, (Part - 4), pp 31 – 38.

[13] Ashfaque Ahmed Jhatial, Samiullah Sohu, Nadeem-ul-Karim Bhatti, Muhammad Tahir Lakhiar, and Raja Oad. Effect of Steel Fibres On The Compressive And Flexural Strength Of Concrete. International Journal of Advanced and Applied Sciences. 5 (10) 2018, Pages: 16-21.

[14] Selva Prakash (2017). Split Tensile Test in Concrete. Retrieved 2021 from:

https://www.slideshare.net/selvaprakash549/split-tensile-strength-in-concrete

[15] A Teara, Doh Shu Ing, S.C. Chin, and Y J Ding (2019). IOP Conference Series: Earth and Environmental Science. Investigation on The Durability of Use Fly Ash and Eggshells Powder to Replace The Cement in Concrete Productions.doi: 10.1088/1755-1315/244/1/012025.