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The Effect of Different Curing Methods on the Compressive Strength of Eggshell Concrete

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Abstract

The work assesses the effect of different curing conditions on the compressive strength of the eggshell concrete. Two different qualities of the eggshell powder were used to make concrete with 0.45 water/cement ratio. The eggshell powders were treated as partial cement replacement of 5%, 10%, 15% and 20%. The concrete cube specimens (100 x 100 x 100) mm were exposed to two different environments (full water curing and open-air curing) for 1, 7 and 28 days. The results exhibit that the initial strength growth for the compressive strength with increases with the percentage of the replacement up to 15%, being this behaviour more evident for the full water curing environment up to 67.53%. The 28-days compressive strength of the eggshell concrete for full water curing and open air curing were found at 49.23 MPa and 46.34 MPa respectively. However, the concrete specimens lost 24.7% and 34.83% when the eggshell powder replace up to 20% of the partial cement replacement for full water curing and open air curing. Thus, water curing is found to be more suitable compared to to open air curing.

Keywords: Compressive Strength, Curing, Eggshell Powder, Partial Cement Replacement

1. Introduction

Concrete is one the most important materials that used up lots of natural resources[1]. In the modern era, the use of concrete had been the backbone of the construction industry of the nation. The development of the local construction industry demands for higher concrete volume higher which indirectly increase the need for larger natural resources supply to produce concrete. Continuous demand for natural resources would pose negative impact in terms water pollution and air pollution[2]. As the result, reuse of waste materials can be considered as the best alternative solution to overcome the environmental and natural resources issue.

Eggshell is known as waste materials or byproduct from hatcheries and food industries[3]. Most of the eggshell was disposed in the landfill without undergoing any pre-treatment since it is traditionally known as useless[4]. Thus waste disposal and land-filling are considered one of the severe issues in Malaysia. The number of the landfill had increased significantly from 49 in 1998 to 161 in 2002[5].

Eggshell consists of several mutually growing layers of $CaCO_3$, the most innermost layer mutually 3 layer grows on the outermost egg membrane and creates the base on which palisade layer constitutes the thickness part of the eggshell. The quality of the eggshell waste is greatly influenced by the extent exposure to the sunlight, raw water and harsh condition[6].

There is a limited source of studies had been conducted on the re-use of the eggshell waste as the alternative materials in the construction field. Eggshell has been used to stabilize the soil since the source of chemical composition is quite similar to lime[7]. The investigation on soil bricks that containing a partial eggshell replacement of 0-30%[8]. The result of compression strength of the brick that containing 10% of eggshell powder increase by 12%, however, when the replacement up to 30% the compression strength result decreased only 2%. From the result, the eggshell powder may be the potential reuse material in the cement production which able to reduce the using the ordinary Portland cement as well as minimizing the impact of the environment.

The aim of this investigation to identify the effect of different curing environments affects the compressive

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strength of the eggshell concrete. The curing regime that used in this investigation is continuous full water curing and air curing under room temperature.

2. Materials and Methods

2.1 Materials

Among the mixing ingredient used in the production of the eggshell concrete is Ordinary Portland Cement (OPC), river sand, coarse aggregate, potable water and eggshell. Eggshell used in the investigation was obtained from Egg-tech Manufacturing Sdn Bhd in the state of Selangor, West Malaysia. Eggshells were cleaned with potable water and oven-dried at 105°C for 24 hours. Then the eggshell undergoes the grinding process which passes through 45 µm. In Table 1 showed the chemical composition of the eggshell powder that obtained through X-ray fluorescence spectrometer.

Table 1. Chemical composition of eggshell powder

Chemical composition	Eggshell (%)
Calcium oxide (CaO)	61.71
Silicon dioxide (SiO_2)	0.61
Aluminium oxide (Al_2O_3)	0.07
Iron oxide (Fe_2O_3)	0.63
Magnesium oxide (MgO)	0.36
Potassium oxide (K_2O)	0.22
Sulphur trioxide (SO_3)	1.32

2.2 Mixing Proportion and Testing

Specimens were prepared in two sets, a control specimen with 100% of OPC known as plain concrete and another mix consist of eggshell powder as partial cement replacement at 5%, 10%, 15% and 20%. Specimens were produced by adding the constant quantity of coarse aggregate, river sand and adequate water dry mix ratio. The mix proportion to produce eggshell concrete was tabulated in Table 2.

Table 2. Mix proportion of concrete specimens

Materials	Quantity (kg/m^3)
Cement	400
Coarse aggregate	1120
River sand	690
W/C ratio	0.45

The specimens were prepared by pouring the slurry concrete mix into the mould cubes (100 mm x 10 mm x 100 mm). After that, the specimens were left under shaded for 24 hours before demoulded. Then, the specimens were placed in different curing environment namely Water curing (WO) and Air curing (AO) until the testing date. The compressive strength test was carried out in accordance to BS EN 12390[9] at 1, 7 and 28 days.

3. Results and Discussion

The effect of the curing method on the compressive strength of the concrete cube specimens were illustrated in Figure 1 and 2. Eggshell powder as partial cement replacement enhances the compressive strength of the eggshell concrete. This is because eggshell filling affect which increase the concrete packing density and pozzolanic reaction that contribute towards densification of the concrete microstructure[10]. Specimens subjected to the water curing exhibit the highest compressive strength than air curing and control specimens as illustrated in Figure 1. The WO15 specimens had the compressive strength of 49.23 MPa, while AO15 reached 46.34 MPa at the concrete age of 28 days. Overall, the specimens that exhibit continuous strength development throughout the curing age which indicate the increment of the total amount of the Calcium-Silicate-Hydrate gel (C-S-H).

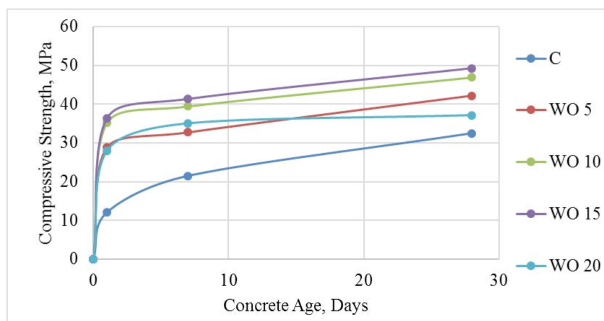

Figure 1. Compressive strength of concrete specimens with water-cured condition.

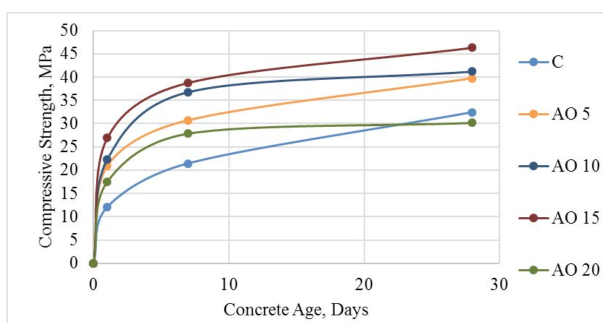

Figure 2. Compressive strength of concrete specimens with air-cured condition.

Cement replacement with eggshell powder provide extra calcium hydroxide for the formation of the secondary C-S-H gel during the hydration process in the presence of moisture. As increase the compressive strength of 34% higher than the control specimen. Furthermore, the fine eggshell powder also functions as filler by filling up the existing voids which able to make the internal structure more packed and leads strength development.

Looking at the effect of the curing regime on the concrete compressive strength, it is evident that the strength developments of the concrete cube become varied when placed in the different condition of the curing environment. Continuous of moisture allows undisturbed pozzolanic reaction as well as hydration process to take place thus generate larger amount of C-S-H gel to fill up the concrete pores. Through water curing, concrete specimens possess the densest of the internal structure and being able to have the highest compressive strength compared to other concrete cube specimens.

Air-cured concrete cubes compressive strength exhibit lower strength than water-cured specimens as illustrated in Figure 2. Evidently, concrete that cured under air curing environment only depends on the concrete moisture itself for hydration process. Insufficient of the moisture that may retard the hydration reaction and pozzolanic reaction and cause retard formation of the C-S-H gel. Thus, the compressive strength of air cured specimens are relatively low[11].

Eggshell concrete exhibit higher compressive strength during the early strength development at the concrete age of 1 day. This is because eggshell provides sufficient of calcium hydroxide which allows the formation of the C-S-H gel is larger than the normal plain concrete. The eggshell concrete undergoes water curing and air curing reach 28 MPa and 19 MPa at the concrete age of 1 day respectively.

From the result illustrated in Figure 3, the compressive strength of the eggshell concrete specimens is greatly influenced by the amount of replacement of eggshell powder. The optimum partial cement replacement is 15%, as the compressive strength is the highest among all. The compressive strength for the eggshell concrete decrease significantly when the eggshell powder replaces up to 20% as illustrated in Figure 3. During the water-cured condition, the specimens undergo sufficient moisture for the hydration process, but the amount of the silicon dioxide is insufficient to complete the process. As the result, the compressive strength for WO20 showed the significant drop in strength. Since the development on the strength of concrete is very much dependent of the availability of moisture for hydration process or pozzolanic reaction as well as the sufficient amount of silicon dioxide and calcium hydroxide. Therefore, AO20 possessed the lowest compressive strength due to the incomplete formation of C-S-H gel during the hydration process. As the result, the hydration process as well as pozzolanic reaction are interrupted due to two factors that are the availability of silicon dioxide and absence of moisture.

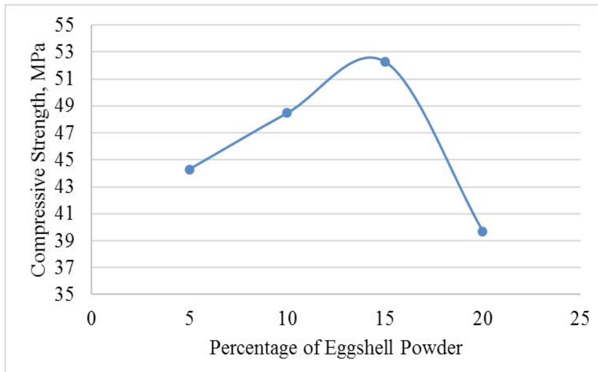

Figure 3. Effect of compressive strength of concrete specimens with different percentage of eggshell powder replacement.

4. Conclusion

Water curing is the most suitable method to ensure the excellent strength development of the eggshell concrete. On the other hand, air curing can be considered since the compressive strength is still higher than the control specimens. Success in incorporating eggshell as partial cement replacement up to 15% is expected to produce more affordable concrete and reduces environmental problems. The International Conference on Fluids and Chemical Engineering (FluidsChE 2017) is the second in series with complete information on the official website[12] and organized by The Center of Excellence for Advanced Research in Fluid Flow (CARIFF)[13]. The publications on chemical engineering allied fields have been published as a special note in volume 3[14]. Host being University Malaysia Pahang[15] is the parent governing body for this conference.

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