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Influence of Addition Eggshells Ash as Partial Replacement Cement on the Durability of Concrete

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Abstract: A large amount of industrial waste is produced every year around the world in which it has a direct impact on the environment. The storage of such wastes that remains at the disposal area poses a problem in present day society which will pollute the air. These wastes thus require a suitable form of management to achieve sustainable development. This study presents an experimental investigation on the effect of the addition of eggshells ash partially replaced with cement in the concrete mix. In this study, the ordinary portland cement has been replaced by eggshells waste ash accordingly in the range of 0, 1 and 2.5%. The specimens were casted and cured under standard curing conditions for 28 days before inserted into carbonation chamber for 5 and 10 weeks. At the end of carbonation process period, the depth of carbonation penetrates values were determined. The result demonstrates that eggshells ash can be used as a partial replacement in the concrete mix. The concrete passed the workability test and gave positive results on the concrete durability. Reusing this kind of waste poses advantages to the economic and environmental. Indirectly, it will contribute to a better quality of life for the civilian and at the same time introduce the concept of sustainability in the construction industry.

Key words: Construction materials, eggshells ash, solid waste, durability, replacement, waste

INTRODUCTION

In the present scenario, concrete is one of the most widely used construction materials which usually associated with portland cement as the main component in making concrete. Ramesh and Kavitha (2014) reported that it is expected that the production of cement will increase from about 1.5 billion tons in 1995-4.2 billion tons in 2013. Today, the world is advancing too fast and the environment is changing progressively due to the industrial waste and debris accumulation and this has created serious problem to the world. In Malaysia, approximately 25,000 metric tonnes of domestic waste are produced per day. Hence, there is a need to recycle these wastes into something more useful to the environment by giving more attention to the use of waste from various industries.

In the recent decades, the efforts have been made to use industry by-products. Among such researchers are (Puri *et al*., 2013) which studied on the utilization of recycled wastes as ingredients in the concrete mix. Next, Raval *et al*. (2013) a study on eco-efficient concretes, use of ceramic powder as a partial replacement of cement. Lastly, a study has also been made by Dwivedi and Lal (2013) on the influence of addition of pond ash as a partial replacement with sand and cement on the properties of mortar.

Even though there are many previous researchers investigated the use of other wastes in the construction industry, however, the research on the eggshell ash in investigating the influence of addition eggshells ash as partial replacement cement on the durability of concrete has not been given much attention. In this study, eggshells wastes were used to augment the durability of concrete.

Experimental details

Material: The materials used for this experimental investigation consisted of eggshells ash, ordinary portland cement, coarse aggregate, fine aggregate and water. The fundamental characteristic of these materials was carried out in accordance with the British Standards (BS) and Malaysian Standard (MS).

Ordinary portland cement: Ordinary portland cement was used as the primary binder throughout the research for making the concrete in this experiment. Meanwhile, the eggshells ash was used as a supplementary binder up to

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Table 1: Chemical properties of eggshells ash

Chemical composition	Values (%)
SiO_2	0.08
Al_2O_3	0.04
Fe_2O_3	0.02
CaO	53.6
MgO	0.01
Na_2O	0.01
SO_3	0.61
Others	0.62

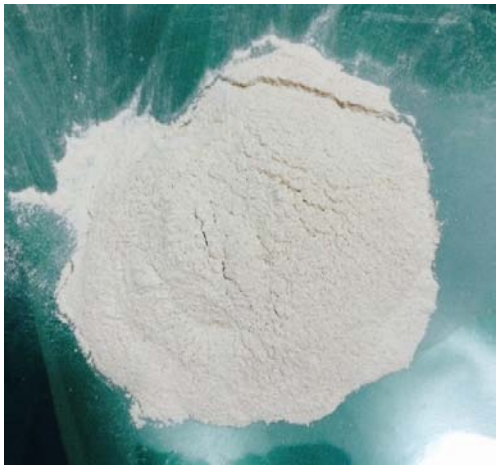

Fig. 1: Eggshells ash

a replacement level of 2.5%. The cement used in this study complies with the ordinary portland cement according to British Standard which is practice code. It was also marketed under the trade name of YTL throughout this study.

Eggshells ash: Eggshells waste is a waste product produced by the food industry such as from restaurants or from the agricultural industry which is the poultry farm. The raw waste material used in this investigation was chicken eggshells which were collected from a bakery shop in Klang Valley, Selangor. Firstly, the eggshell waste was dried before the incineration process started which was about 24 h with the temperature of 100°C and later sieved through a 90 μm sieve to remove bigger size ash particles and impurities. Figure 1 shows the eggshells ash that has been thoroughly sieved. The chemical properties of eggshells ash is shown in Table 1.

Aggregate: Aggregate gives body to the concrete, reduces shrinkage and affects the economy. One of the most important factors for producing workable concrete is good gradation. Aggregate used in this experiment is with maximum nominal sizes of 19-20 mm.

Sand: The fine aggregate was locally available river sand which was passed through 4.75 mm sieve. Sands that

Table 2: Concrete design mix

W/C ratio	Mix (%)	Cement (kg/m^3)	Water (kg/m^3)	Aggregate (kg/m^3)	Sand (kg/m^3)	Eggshells Ash (g)
0.47	0.0	435	205	890	860	-
	1.0	435	205	890	860	57.0
	2.5	435	205	890	860	143.0
0.55	0.0	375	205	860	960	-
	1.0	375	205	860	960	48.8
	2.5	375	205	860	960	122.0
0.70	0.0	295	205	780	1115	-
	1.0	295	205	780	1115	38.4
	2.5	295	205	780	1115	96.0

are complied with coarse, medium or fine grading requirements, free from natural resources or crushed stone sand and not contained any harmful impurities have been used. To ensure the water cement ratio is not affected, the sand must be dried out first.

Water: Water is an essential ingredient of concrete as it participates in the chemical reaction with cement. Since, it helps to form the strength giving cement gel, the quantity and quality of water are required to be looked into very carefully.

Design mix: The mixes in Table 2 were designed to comply with the standard requirement of public research Department of Malaysia and the same was used to prepare the test samples.

MATERIALS AND METHODS

The evaluation of eggshells ash waste for use as a replacement of cement material begins with the concrete durability testing. Concrete contains cement, fine aggregate, coarse aggregate, water and eggshells ash. With the control concrete, 1 and 2.5% of the cement is replaced with eggshells ash waste, the data from the eggshells ash waste is compared with data from standard concrete without eggshells ash. Three cube samples in accordance with were cast in the mould of nominal size 100×100×100 mm for each percentage with water cement ratio of 0.47, 0.55 and 0.70. After conducting the slump test, the concrete mix then needs to be poured in the concrete mould. After about 24 h the specimens were de-moulded and the specimens were cured in water for 28 days according to EN (2009).

Test procedure: Several tests were carried out in accordance with the British Standards (BS) and Malaysian Standard (MS) to determine the workability and compressive strength. The details about the test procedures are given as.

Slump test: Slump test was used to access the flowability and the flow rate of self-compacting concrete in the absence of obstructions. One of the methods used to determine the consistency of the concrete is slump test. The principles of this slump test are the fresh concrete is compacted into a mould in the shape of a frustum of a cone. Then, the cone is lifted upwards and the distance the concrete has slumped is measured. Figure 2 shows the true slumps types and Fig. 3 shows the measurement of highest point of slump.

Carbonation test: Concrete carbonation is one of the indicators of concrete durability. Concrete carbonation is the reaction process between CO_2 in the air and alkaline substances in concrete (Yang *et al*., 2012). In this study, all mixes were performed in accordance with EN (2009).

The accelerated carbonation chamber machines were used to determine the carbonation depth of the concrete specimen. Three samples for each water cement ratio and percentage were placed in the accelerated carbonation chamber for 5 and 10 weeks after being cured in curing tank for 28 days. The comparative studies were conducted on the carbonation depth for all mix ratios with a partial replacement of 0, 1 and 2.5%. Figure 4 shows the concrete specimen and Fig. 5 shows the specimens were place in the carbonation chamber.

Fig. 2: True slumps

Fig. 3: Measurement of highest point of slump

Fig. 4: Concrete cube specimen

Fig. 5: Concrete cube placed in the carbonation chamber

RESULTS AND DISCUSSION

Slump test: Table 2 shows the results of slump test for all mixes. Table 3 shows the slump test result of target material, eggshells ash as partial cement replacement in the concrete mix. The purpose of carried out the slump test in this experiment is to point out the workability of different type of fresh concrete mixture. According to MS, the test is only valid if it yields a true slump. The result in Table 3 shows that, the slump for all water cement ratio of concrete mixes is in the range of 15-100 mm which is acceptable.

Carbonation test: The carbonation test is important to determine the durability of the concrete before failure is sustained. Figure 6 shows the carbonation test results of eggshells ash as a partial replacement in concrete mix. Based on the results obtained, it was discovered that there is a relationship between water content of concrete with its carbonation depth. It is shown that the concrete with 0.47 water cement ratio have a lower depth, followed by 0.50 water cement ratio as compared to the 0.70 water cement ratio. Thus, it can be described that the water cement ratio affects the durability of the concrete. The higher the water cement ratio, the higher the carbonation depth that can be achieved. Moreover, the carbonation depth also increased significantly with the addition of eggshells ash in concrete mix. It can be said that the chemical properties of eggshells ash which is calcium carbonate greatly influenced the carbonation depth which indirectly create a difference of depth between the standard concrete without eggshells ash and concrete that has been added with 1 and 2.5% of eggshells ash.

Table 3: Slump test result

	Slump (mm) (%)		
Water ratio	0	1	2.5
0.47	20	25	25
0.55	15	16	16
0.70	15	16	17

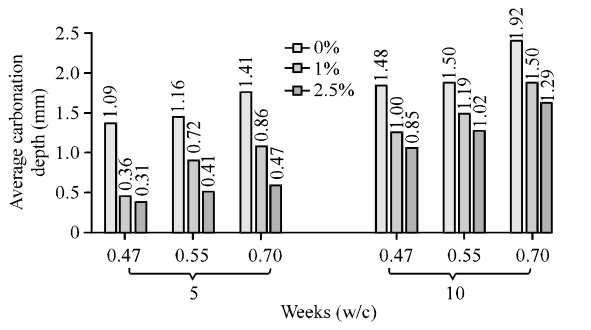

Fig. 6: Carbonation depth at week 5 and 10 with 0.47, 0.55 and 0.70 water cement ratio

CONCLUSION

The conclusion that can be drawn from the results and discussion above indicated that when eggshells ash is added to the cement it resulted in a favorable effect on carbonation rate of concrete. Rate of carbonation depth is related with the water-cement ratio of a concrete. Carbonation rate affects normal concrete faster. Thus, carbonation depth can be minimized by reducing the water-cement ratio in the concrete structure. The eggshell ash is a good waste material to be incorporated in the concrete mixture. Their chemical property that contains a variety of calcium can enhance the durability of the concrete and reduce the carbonation depth on the concrete. Moreover, the amount of eggshell ash affects the rate of carbonation. Higher proportion of eggshell will increase its performance in terms of strength and durability on the concrete.

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