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# Viability of Eggshells Ash Affecting the Setting Time of Cement

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***Abstract*—**This research paper reports on the feasibility and viability of eggshells ash and its effects on the water content and setting time of cement. An experiment was carried out to determine the quantity of water required in order to follow standard cement paste of normal consistency in accordance with MS EN 196-3:2007. The eggshells ash passing the 90µm sieve was used in the investigation. Eggshells ash with percentage of 0%, 0.1%, 0.5%, 1.0%, 1.5% and 2.0% were constituted to replace the cement. Chemical properties of both eggshells ash and cement are compared. From the results obtained, both eggshells ash and cement have the same chemical composition and primary composition which is the calcium compounds. Results from the setting time show that by adding the eggshells ash to the cement, the setting time of the cement decreases. In short, the higher amount of eggshells ash, the faster the rate of setting and apply to all percentage of eggshells ash that were used in this investigation. Both initial and final setting times fulfill the setting time requirements by Malaysian Standard. Hence, it is suggested that eggshells ash can be used as an admixture in concrete mix.

***Keywords*—**Construction Materials, Eggshells Ash, Solid Waste, Setting Time.

## I. Introduction

DAILY life in industrialized nations can generate several pounds of solid waste per consumer, not only directly in the home, but indirectly in factories that manufacture goods purchased by consumers. Following a normal growth in population, the amount and type of waste materials have incremented accordingly. A large number of the non-decaying waste materials will effect to the environment for a decade. Rapid urbanization in most developed countries which uncontrolled and unplanned, has brought a serious solid waste dumping issues which these non-decaying waste materials can cause a waste disposal crisis, thus contributing to the environmental problems. Improper solid waste disposal and management cause all types of pollution, for example, uncontrolled burning of solid waste and improper incineration contributes to urban air pollution. Proper treatment of solid waste in order to free the environment from any hazard that created by this solid waste have been taken into serious to the entire world. Malaysia huge problems are a food waste which is around 33,000 tonnes of solid waste generated every day [1]. Table I shows that the percentage of solid waste keeps increasing from 2001 until 2010. Food waste and organics are the main component of the solid waste in Malaysia which is around 32% in the year 2001 and increased to 43.5% in 2010. The other components such as paper, plastics and glass around 16% to 25.2%, 6.3% to 22.7% and 1.4% to 2.6% respectively. This is translated that food, paper and plastic wastes comprised around 70% of the total wastes produced in Malaysia [2]. Food waste is one of the biggest contributors of greenhouse gases. If food waste can be properly tackled, then half of the problem will be solved.

TABLE I
THE MATERIAL COMPOSITION OF MUNICIPAL SOLID WASTE FROM VARIOUS STUDIES AND SITES

| Components | 2001 | 2002 | 2003 | 2004 | 2005 | 2007 | 2010 |
|---|---|---|---|---|---|---|---|
| Food waste& Organics | 32 | 56.3 | 37.4 | 49.3 | 47.5 | 42 | 43.5 |
| Mix Plastics | 16 | 13.1 | 18.9 | 9.7 | NA | 24.7 | 25.2 |
| Mix Paper | 6.3 | 8.2 | 16.4 | 17.1 | 18.5 | 12.9 | 22.7 |
| Textiles | 3.4 | 1.3 | 3.4 | NA | NA | 2.5 | 0.9 |
| Rubber & Leather | 2 | 0.4 | 1.3 | NA | NA | 2.5 | NA |
| Wood | 7 | 1.8 | 3.7 | NA | 4.41 | 5.7 | NA |
| Yard Wastes | NA | 6.9 | 3.2 | NA | 2.72 | NA | NA |
| Ferrous | 3.7 | 2.1 | 2.7 | 2 | NA | 5.3 | 2.1 |
| Glass | 5.5 | 1.5 | 2.6 | 3.7 | NA | 1.8 | 2.6 |
| Pampers | NA | NA | 5.1 | NA | NA | 3.81 | NA |
| Other | 1.9 | 8.4 | 5.3 | 18.2 | 21.93 | 2.6 | 1.8 |
| Total | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

*Note:* NA – Not Available

Different researchers have proven that the solid waste can be changed to something useful applications for example, as components in building structure and at the same time reducing the solid waste accumulation [3]-[6].

Attempts have been made by researchers to analyze the viability of agriculture waste used as by-products. Efforts have been made on the effects of eggshells ash use in cement. In concrete, cement being the most expensive material while the aggregate constitutes the bulk volume of concrete [7]. To decrease the expense of concrete and the deficiency of its constituent materials, there is a need to create different materials which can substitute concrete constituent materials. These new materials are generally waste products and by-products which, if utilized as a part of concrete will diminish both environment pollution. Eggshells are agricultural waste materials generated from poultries and the food industry that can litter the environment and consequently constituting an environmental problem and require proper handling to manage it [8].

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Using Eggshells Ash as a cement replacement in concrete mix can save the cement that may be insufficient later on. In addition, the issue of waste disposal and the protection of the environment will be overcome. Ordinary salt utilized on eggshells stabilized lateritic soil with a perspective, acquiring a decent compliment. In order to stabilize lateritic soil for the subgrade of a roadwork, this eggshells powder likewise has been used and it was found that eggshell powder has low binding characteristics which, however, enhance the strength of the subgrade soil altogether.

The effort of converting eggshell to something advantageous becomes an idea which worth investigating. Table II shows the chemical composition analysis that was conducted in the laboratory for both eggshells ash and cement. The calcium oxides are the most significant oxide present in the cement and eggshells ash. As expected calcium oxide is the major composition of the cement and eggshells ash, which are 62.5% and 53.6% respectively. The composition of both eggshells ash and cement other than calcium oxides comprise of silicon oxide, aluminum oxide, iron oxide, magnesium oxide, sodium oxide, potassium oxide and sulfur trioxide. It is scientifically proven that both eggshells ash and cement have the same primary composition which is calcium carbonate ($CaCO_3$) [9]. The eggshells ash can be added to the cement due to the similarity characteristics eggshells ash compound that has in cement.

TABLE II
CHEMICAL COMPOSITION ANALYSIS OF CEMENT AND EGGSHELL

| | Cement | Eggshell |
|---|---|---|
| $SiO_2$ | 22.8 | 0.08 |
| $AI_2O_3$ | 6.6 | 0.04 |
| $Fe_2O_3$ | 4.1 | 0.02 |
| CaO | 62.5 | 53.6 |
| MgO | 2.7 | 0.01 |
| $Na_2O$ | 0.4 | 0.13 |
| $K_2O$ | 0.4 | - |
| $SO_3$ | 2.5 | 0.61 |
| Others | - | 0.62 |

Even though there have been many previous researchers investigated the use of other waste in the construction industry, research on the eggshells ash in investigating the effects of eggshells ash as to improve the setting time of cement has not been given as much attention. Thus, this research was designed to address the following objective which is to investigate the viability of the eggshells ash affecting the setting time of the cement.

## II. Materials

The materials used for experimental research consisted of Ordinary Portland Cement as the target material and eggshells ash and water as a binder. The basic materials characterization was carried out in accordance with the British Standards (BS) and the Malaysian Standard (MS) and other accepted engineering standards.

### *A. Cement*

Ordinary Portland Cement was used for making the concrete in this experiment as the main binder, whereas eggshells ash was used as a supplementary binder up to a replacement level of 2%. This complies with Specification of British Standard which is BS EN 196-6:2010 [10] and BS 4550-6:1978 [11] practice code. Ordinary Portland Cement produces high compressive strength in mortar and concrete. In addition, it is also very durable and hardens when interacting with water and thus, forming a water resisting compound.

### *B. Eggshells*

Eggshells waste is a waste product produced by the food industry such as the restaurants or from the agricultural industry such as the poultry farm. The raw waste material used in this investigation was chicken eggshells, which were collected from bakery shop in Klang Valley, Selangor.

Eggshell comprises of a few commonly layers of $CaCO_3$. The top layer is a vertical layer secured by the organic cuticle. The second layer is the eggshell shell which principally contains calcium, magnesium carbonate (lime) and protein. The inner layer is the egg membranes, which consist of the air cell, inner shell membrane and outer shell membrane.

Fig. 1 Eggshells Ash

### *C. Water*

Water plays an important role in order to produce great quality of concrete. Usually, water can result in hydration when to combine it with cement. Water used for mixing and curing should be clean and free from harmful amounts of oils, dust, mud, acids and alkalis having pH value less than 6, free from iron which can cause affect when dealing with reinforcement and organic materials.

## III. Mix Proportion and Procedure

To investigate the viability of using eggshells ash affecting the setting time of cement, six different percentage of eggshells ash were used in this investigation. The variable percentages investigated in this study was 0%, 0.1%, 0.5%, 1%, 1.5% and 2.0% of the weight of cement, added to the cement and mixed comprehensively.

The collected eggshell waste was dried before the incineration process start which is about 24 hours with temperature 100°C. The ash was sieved through a 90μm sieve as shown in Fig. 2. In order to prepare a standard cement paste

of normal consistency, the consistency test accordance to MS EN 196-3:2007 [12] need to be conducted to get the required quantity of water for setting time test. Vicat apparatus used in this experiment is a standard Vicat with the dimension of 160 L x 200 W x 350 H as shown in Fig. 2.

For the consistency test, the cement paste was filled in the Vicat mould and smoothing the top of the paste making it level at the top of the mould. The mould containing the paste was then placed centrally under the rod bearing plunger. The plunger was then gently lowered until the end of the plunger contact with the surface of the paste and quickly released the plunger allowing it to sink into the paste. This must not exceed 30 s after completion of mixing. The paste of normal consistency is achieved when the rod settles to a point such that it is 5-7 mm above the bottom surface as shown in Fig. 3. The trial paste was conducted with different percentages of water until the normal consistency is obtained. After the required amount of water has been determined from the consistency test, the water was added to the mixture of cement and eggshells ash, making into a cement paste and then tested for setting time.

In setting time test consisted of two tests which are initial and final setting time. To conduct the initial setting time, the needle will lower gently in order to make contact with the surface of the cement paste and release quickly, in order it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5 mm which measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5 mm measured from the bottom of the mould, is the initial setting time. As for the final setting time, the needle at the vicat was replaced with an annular attachment needle. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time as shown in Fig. 4. Results obtained were compared with the Malaysia Standard (MS) specifications for the production standard cement paste.

## IV. Results and Discussion

The result and discussion on this paper represent two different tests which are consistency test and setting time test in accordance with the MS for methods of testing cement.

### *A. Consistency Test*

The consistency test is important to determine the amount water required before conducting the setting time tests. Table III illustrates the consistency tests result of cement. There were six different tests conducted in order to achieve the amount water required. Based on the result, test number 5 has the amount of water required to make a standard cement paste of normal consistency which is equal to 148ml and equivalent to 37% by weight of Ordinary Portland Cement used. Thus, this shows that 0.37 water cement ratio was used in order to constitute the cement paste in the setting time test.

Fig. 2 Vicat Apparatus

Fig. 3 Consistency Test for Cement

Fig. 4 Setting Time Test on Cement

TABLE III
Consistency Tests Results

| Test No | Weight of cement (g) | Water content | Equivalent volume of water (ml) | Penetration of plunger from bottom (mm) | Comment |
|---|---|---|---|---|---|
| 1 | 500 | 20 | 120 | 19 | Inconsistent |
| 2 | 500 | 45 | 160 | 1 | Inconsistent |
| 3 | 500 | 35 | 140 | 9 | Inconsistent |
| 4 | 500 | 38 | 152 | 4 | Inconsistent |
| 5 | 500 | 37.5 | 148 | 6 | Consistent |
| 6 | 500 | 38.5 | 154 | 2 | Inconsistent |

*A. Setting Time Test*

The setting time test was carried out to determine whether cement sets at a rate suitable for a particular work. Slow setting cement may harden more rapidly than a quick setting one and vice versa. The hardening of cement is a continuation of the chemical action which began with the setting. The significance of this setting time test is as a loss of plasticity starts at the end of initial setting time, it is necessary that concrete must be mixed, transported and placed in position before initial setting time. As the final setting time approaches cement becomes harder and harder and concrete cannot be placed or deposited. The setting time test result in Table IV and as illustrated in Fig. 5, the cement which mixed with eggshells ash sets more rapid than the ordinary cement paste. This determined that the addition of the eggshell ash in the cement shortened the setting time of cement. From the Table IV and illustrated in Fig. 6, it can be clearly seen that the percentage decreases for both initial and final setting times with an increased amount of eggshells ash added into the cement paste, the setting time of the cement become faster. Referring back to the requirement of MS EN 196-3:2007 [11], the percentages of the eggshells ash used in the cement paste are within the range of the initial and final setting time for Ordinary Portland Cement which should not be less than 45 minutes and not greater than 10 hours respectively. The addition of eggshells ash in the cement paste indicated that eggshells ash is a good waste material and can be used as an admixture in concrete mix

TABLE IV
SETTING TIME TESTS RESULTS

| Test No | Ash Content (%) | Water content | Vol. of water (ml) | Initial setting time (mins) | Decrease in initial setting time (%) | Final setting time (mins) | Decrease in final setting time (%) |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 37 | 148 | 152 | - | 257 | - |
| 2 | 0.1 | 37 | 148 | 148 | 2.63 | 252 | 1.95 |
| 3 | 0.5 | 37 | 148 | 139 | 8.55 | 238 | 7.39 |
| 4 | 1 | 37 | 148 | 128 | 15.79 | 217 | 15.56 |
| 5 | 1.5 | 37 | 148 | 117 | 23.03 | 199 | 22.57 |
| 6 | 2 | 37 | 148 | 110 | 27.63 | 187 | 27.24 |

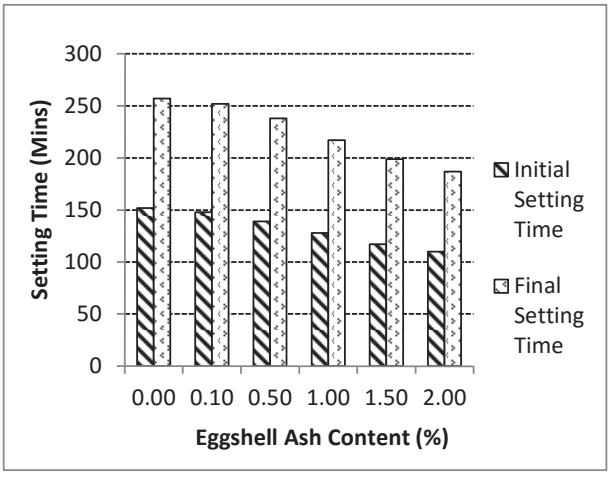


Fig. 5 Setting time vs Eggshells Ash

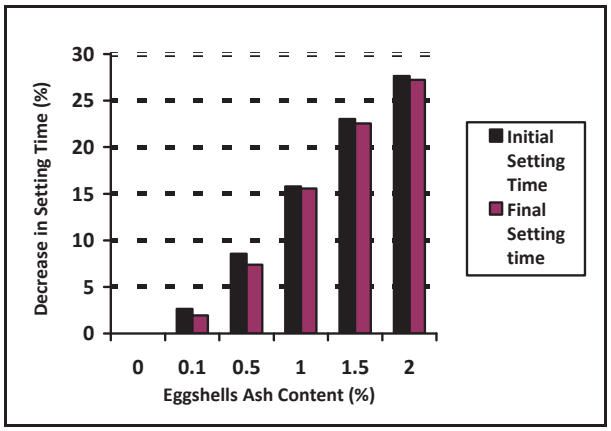


Fig. 6 Effect of the Change of Setting Time on Eggshells Ash

## V. 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 the initial and final setting time. There is a potential for using eggshells ash as an addition material in the cement and by using eggshell waste in cement can solve several environmental problems. The setting time of the cement paste decreased by the presence of the eggshells ash in the mix. The results obtained show that the higher the amount of the eggshells ash, the better the acceleration effect. Hence, waste materials are recommended, especially when the materials give an advantage to experimental works and to the environment and thus, reducing cement consumption in construction work. The authors will be investigating into the following variables which are the mechanical and durability properties of concrete mix with eggshells in cement.

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