

Eggshell Powder: Potential Filler in Concrete

DOH Shu Ing, CHIN Siew Choo

Faculty of Civil Engineering and Earth Resources, Universiti Malaysia Pahang
Lebuhraya Tun Razak, 26300 Gambang,
Kuantan Pahang
dohsi@ump.edu.my

Abstract—An investigation of eggshell powder as potential additive to concrete. In this investigation, five different percentages of eggshell powder with respect to cement were added into the concrete mix of Grade 25. The materials used were mainly Portland cement, crushed sandstone, river sand, plasticizing accelerator and eggshell powder. From the investigation, all the slump results of eggshell concrete were at medium degree of workability ranging from 65-75 mm. Eggshell concrete of 10% achieved the highest compressive strength at 42.82 N/mm² which is 57% higher than the control specimen. There is an increasing trend of flexural strength from 2.36 to 3.50 N/mm² with the increase of eggshell powder from 0 to 20%. Besides that, the eggshell concrete has shown significant reduction in water absorption and water penetration.

Keywords—eggshell; concrete; compressive strength; water absorption; additive.

I. INTRODUCTION

Malaysian is one of the largest eggs eater in the world consumed 20 millions egg daily [1]. Most of the eggshell waste is commonly disposed in the landfills without pretreatment because it was traditionally useless [2]. Although eggshell is known as natural solid waste which is non hazardous, it may attract rats and worms due to the organic protein matrix that may pose health problem to the public [3]. Waste disposal and landfilling has been one of the major issue in Malaysia. The number of landfilling in Malaysia has increased from 49 in 1988 to 161 in 2002, and the number is still increasing alarmingly [4]. The scarcity of land has increase the cost of landfill tremendously causing waste disposal to be expensive. High disposal of waste may pose treat environmentally as such as contamination to the surface water, soil and ground water. On top of that, it may affect the health of exposed populations and ecosystems. Not much research has been conducted for eggshell. Eggshell powder which is rich in CaCO₃. Amu et al. (2005) used eggshell powder as stabilizer of lime in clay expansive soil [5]. Besides that, eggshell is also used as stabilizing material to increase the liquid limit and plasticity index of lateritic soil [6]. Since there is not much research has been conducted on eggshell powder, further investigation can be conducted to identify the use of eggshell powder as construction material.

II. EXPERIMENTAL

A. Materials

The material used in this investigation are Portland Composite cement, granite, river sand, eggshell powder, water and plasticizing accelerator. Portland Composite cement manufactured by YTL, which can produce high early strength, complied by NS EN 197-1:2000 CEM II/B-M is used as the binder. Eggshell powder which have high calcium content up to 95% is used as filler in the concrete mix. The eggshells were obtained from Eggtech Manufacturing Sdn Bhd located at Puncak Alam, Selangor. The eggshells dried under the sun and grinded into powder. The eggshell powder then was sieve using 2.36 mm sieve. Particles passing through 2.36 mm sieve will be used as filler in concrete.

B. Slump Test

Slump test was conducted to determine the workability of concrete. The slump test was conducted according to BS 1881: Part 102 [7].

C. Compressive Strength Test

Concrete cubes (100 mm x 100 mm x 100 mm) were used for compressive strength test. All concrete cubes were cured in the water tank. The compressive strength test were conducted according to BS 1881: Part 116 [8]. The cubes were tested using Shimadzu Universal Testing Machine of capacity 1,000 KN at a loading rate of 0.25N/mm²/sec. A total of nine cubes were case for each mix design. The compressive strength test was carried out at concrete age of 3, 7 and 28 days.

D. Flexural Strength Test

Beam (100 mm x 100 mm x 500 mm) were used for flexural strength test. The flexural strength of beam were tested using T-Machine Universal Testing Machine according to BS 1881: Part 118 [9]. A constant loading rate of 0.03 N/ mm²/sec was maintained for this test.

E. Water Penetration Test

Water Penetration test is to define the rate movement of water through the porous material under capillary action. It

is a rapid and simple test and it does not require any special equipment. To ensure uniform moisture throughout the specimens, the specimens were dried at 50°C for three days in the oven. After that, the specimens were removed from the oven and allowed to cool in a desiccator for 2 hours. The sides were then sealed with vinyl electrician's tape to ensure a unidirectional flow of water. At this time, the initial mass of the specimen was measured. The test was conducted according to BS EN-12390-8 [10]. The bottom surface was then immersed in distilled water to a depth of about 2-4 mm. The concrete cubes were taken out from the water after 24 hours. The cubes were then cut using concrete cutter. The colored water mark on the cut cubes is measured as water penetration.

F. Water Absorption Test

Water absorption test is conducted to identify the ability of concrete to absorb water. The full size of concrete cubes (100 mm x 100 mm x 100 mm) were used in this investigation. To ensure uniform moisture throughout the specimens, the specimens were dried at 50°C for three days in the oven. After that, the specimens were removed from the oven and allowed to cool in a desiccator for 2 hours. The initial weight of concrete cubes were weighted. The test was conducted according to BS 1881: Part 122 [11]. The cubes were immersed in the water and is wipe with dry cloth to ensure that the cubes were surface dried. The cubes were repeatedly measured at 1, 5, 10, 20, 30, 60, 120, 180, 1440, 2880 and 4320 minutes.

III. RESULT AND DISCUSSION

A. Slump Test

Slump test is to determine the workability of concrete prior to casting. In this investigation, slump test are carried for concrete with different percentage of eggshell filler namely 0%, 5%, 10%, 15% and 20%. The results of slump tests of different percentages of eggshell powder as concrete filler is tabulated in Table 1. From Fig. 1, it is observed that the slump for all proportion can be categorized as true slump ranging between 70-75 mm. Concrete A5 (20%) shows the highest slump of 75 mm while A1 (0%) shows the lowest slump of 70 mm. The slump for all the proportion of eggshell powder fall into the acceptable range of slump which is 75 ± 25 mm. Thus eggshell powder is suitable to be used as filler in the concrete mix as it do not absorption water excessively.

TABLE I. RESULT OF SLUMP TEST

Sample Mark	Filler	Water/ Cement Ratio	Slump (mm)
A1	0%	0.4	70
A2	5%	0.4	71
A3	10%	0.4	72
A4	15%	0.4	75

Sample Mark	Filler	Water/ Cement Ratio	Slump (mm)
A5	20%	0.4	75

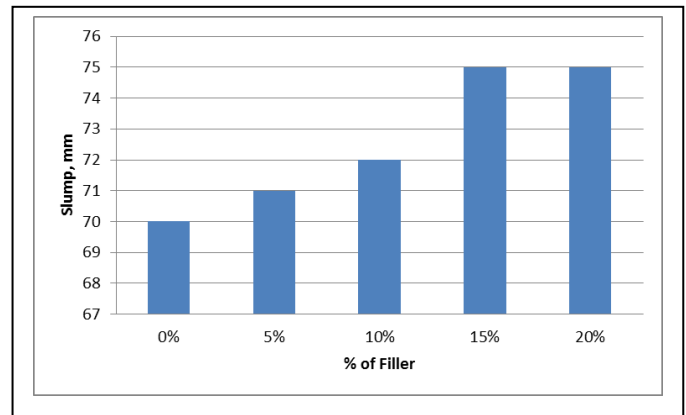


Fig. 1. The effect of eggshell powder as filler to concrete mix

B. Compressive Strength Test

Compressive strength test is one of the most important properties for hardened concrete. In this investigation, concrete of different proportion of eggshell powder of filler are tested at 3, 7, and 28 days. The result of the compressive strength test is tabulated in Table II. result of compressive strength test.

TABLE II. RESULT OF COMPRESSIVE STRENGTH

Sample Mark	Filler	Water/ Cement Ratio	Compressive Strength Test		
			3 days	7 days	28 days
A1	0%	0.4	16.15	21.22	27.20
A2	5%	0.4	10.14	17.48	29.63
A3	10%	0.4	14.89	18.38	42.82
A4	15%	0.4	14.48	15.14	38.67
A5	20%	0.4	16.86	17.20	37.60

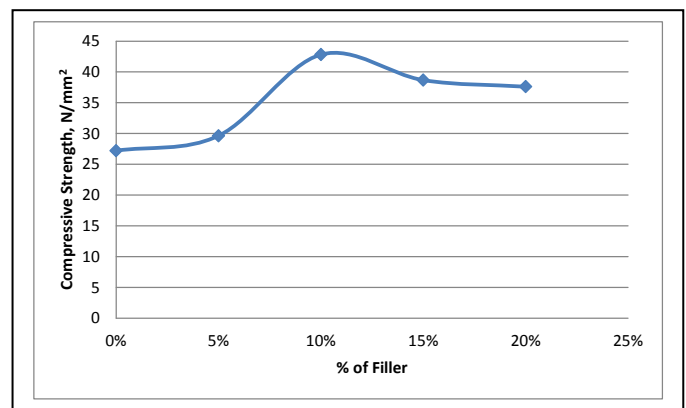


Fig. 2. The effect of filler to compressive strength

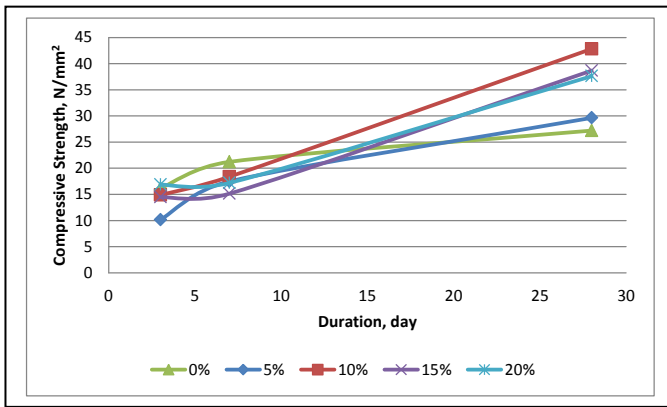


Fig. 3. The effect of concrete age to compressive strength of concrete

Fig. 2 and Fig. 3 shows the compressive strength of different proportion of eggshell filler and the effect of concrete age of different proportion of eggshell filler. From Fig. 2, it is observed that A2 (10%) shows the highest compressive strength of 42.82 N/mm² while A1 (0%) the lowest of 29.63 N/mm². It is observed that the addition of eggshell powder as filler up to 20% in concrete increase the compressive strength of concrete. From Fig. 3, it is observed that concrete with eggshell powder as filler has generally lower initial strength as compared to control concrete. However, it shows high compressive strength at 28 days.

C. Flexural Strength Test

Flexural strength test is to determinen the ability of unreinforced concrete to resist failure of beding moment. Flexural strength test is only conducted on concrete of 28 days. The result of flexural strength for concrete with different percentage of eggshell powder as filler is tabulated in Table III. Fig. 4 shows the effect of eggshell powder as filler to the flexural strength of concrete. From Fig. 4, it is shown that the flexural strength of concrete increases as the percentage of eggshell powder as filler increase in the concrete mix. All the concrete mix with eggshell powder shows higher flexural strength compared to the control concrete. It is suggested that eggshell powder is a suitable filler that could improve the flexural strength of concrete.

TABLE III. RESULT OF FLEXURAL STRENGTH TEST

Sample Mark	Filler	Water/ Cement Ratio	Flexural Strength, N/mm ²
A1	0%	0.4	2.75
A2	5%	0.4	2.76
A3	10%	0.4	3.18
A4	15%	0.4	3.27
A5	20%	0.4	3.38

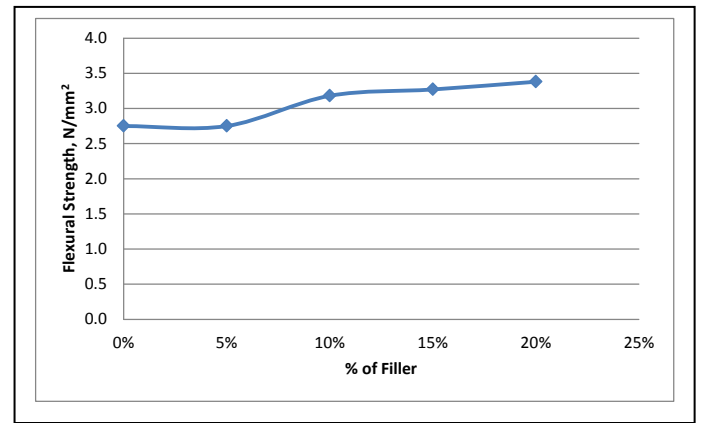


Fig. 4. The effect of filler to flexural strength of concrete

D. Water Penetration Test

Water penetration test is to determine the permeability and durability of concrete which is specified by BS EN-11390. The concrete specimen with age 28 days were used in this investigation. The depth of is indicated as the water penetration. The result of water penetration is tabulated in Table V while the effect of different percentages of eggshell powder as filler in shown in Fig. 6. Fig. 6 shows a reducing trend of water penetration with the increase of eggshell powder as filler in the concrete. All the concrete mix with different percentages of eggshell powder as filler shows improvement of water penetration compared to the control concrete. Thus, the used of eggshell is effective in reducing the water penetration into concrete thus reducing the risk of corrosion of steel in reinforced structure (Slag Cement Association, 2002).

TABLE IV. RESULT OF WATER PENETRATION

Sample Mark	Filler	Water/ Cement Ratio	Depth of Water Penetration (mm)
A1	0%	0.4	8.5
A2	5%	0.4	7.5
A3	10%	0.4	4.0
A4	15%	0.4	3.0
A5	20%	0.4	1.5

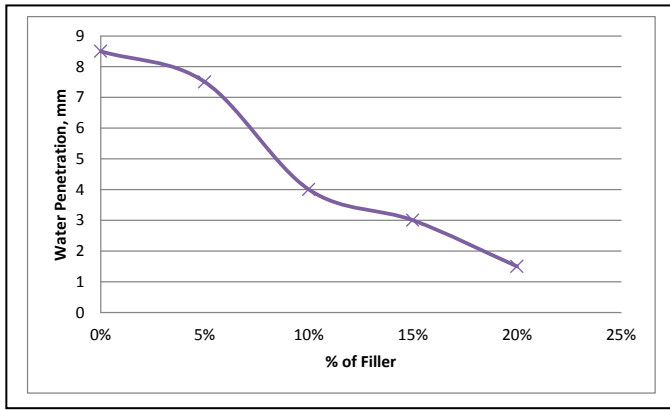


Fig. 6. The effect of filler to water penetration of concrete

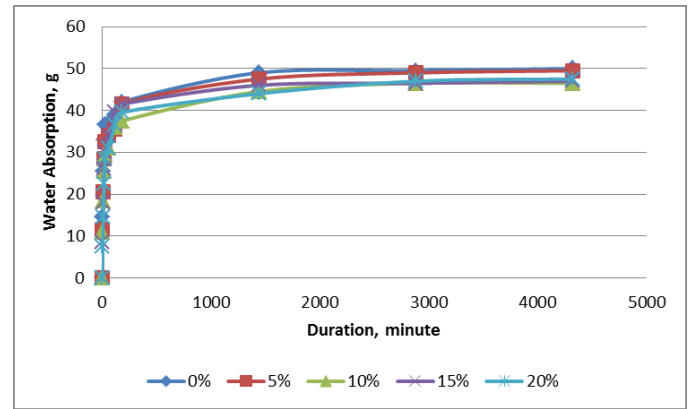


Fig. 5. The effect of time to water absorption of concrete

E. Water Absorption Test

Water absorption test is used to determine the absorption rate and the absorption capacity of concrete. This test is only conducted on concrete of 28 days. The result of concrete mix with different percentages of eggshell powder as filler is tabulated in Table IV. From Table IV, it is observed that higher percentage of eggshell powder as filler shows lower initial water absorption up to 60 minutes. Fig. 5 shows the effect of different percentage of filler to water absorption of concrete. In general, the addition of eggshell powder as filler reduces the ability of specimen to absorb water. The presence of eggshell sealed the existing void occurred in the control concrete.

TABLE V. RESULT OF WATER ABSORPTION

Time, minutes	Water Absorption (g)				
	A1	A2	A3	A4	A5
1	0	0	0	0	0
5	14.5	11.5	11	8.5	7.5
10	25.5	20.5	18.5	18	14.5
20	33	28.5	25.5	26	22.5
30	36.5	32.5	29.5	30	28.5
60	37	34	31	34	31
120	39	35.5	36	39.5	36.5
180	42	41.5	37.5	41.5	39.5
1440	49	47.5	44.5	46	44
2880	49.5	49	46.5	46.5	47
4320	50	50.5	46.5	49	47.5

IV. CONCLUSIONS

From the investigation, the following conclusions can be obtained.

- The water cement ratio of 0.4 produces medium degree of workability which is suitable for most of the concrete casting on site.
- The inclusion of eggshell powder as filler in concrete has improved the compressive strength of concrete. Concrete with addition of 10% eggshell powder as filler showed the highest compressive strength of 42.82 N/mm².
- The inclusion of eggshell powder as filler into concrete has also improve the flexural behavior of concrete up to 22.9% compared to the control concrete. The addition of eggshell powder as filler in concrete improves the resistance of failure in bending.
- The eggshell powder as filler shows significant reduction initial water absorption. Besides that, it also reduces the ability of specimen to absorb water compared to control concrete.
- The inclusion of eggshell powder as filler in concrete shows significant reduction of water penetration up to 82.3% as compared with the control concrete.

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