Effect of Mixing Ingredient on Compressive Strength of ISSA Concrete Containing Eggshell Powder

Tan Yeong Yu
Faculty of Civil Engineering, University Malaysia Pahang
Kuantan, Malaysia
Alvin9636@gmail.com

Doh Shu Ing
Faculty of Civil Engineering, University Malaysia Pahang
Kuantan, Malaysia
dohsi@ump.edu.my*

Chin Siew Choo
Faculty of Civil Engineering, University Malaysia Pahang
Kuantan, Malaysia
scchin@ump.edu.my

Abstract— Waste management is one of the alarming issues in developing country like Malaysia. It is reported that sewage sludge and eggshell waste are generated annually. The amount of waste is expected to increase from year to year. Thus it is viable to investigate the possibility to turn waste into suitable construction materials in concrete production. In this paper, sewage sludge and eggshell waste are treated and used as blended cement to reduce the use of cement consumption in concrete production. At early stage of research, mortar cubes of mm of cubes were cast to identify the optimum percentage of ISSA. At the second stage, only optimum percentage of ISSA concrete were added with difference percentages of eggshell powder and tested by slump test and compressive strength. All the specimens were subjected to water curing before undergo compressive strength test. The optimum of ISSA and eggshell powder were 10% and 15% which capable to use as partial cement replacement. The total cement replacement is 25%. The compressive strength result was 37% higher than normal plain concrete. On the right formulation, ISSA and eggshell can be used partial cement replacement that exhibit optimum strength.

Keywords— incinerated sewage sludge ash, eggshell powder, compressive strength, partial cement replacement

1. INTRODUCTION

Concrete is the most used materials construction materials in the industrialized countries. However, the concrete production required natural resources such as water, cement and aggregates whose production is costly due to its energy required. As the result, the use of sewage sludge ash in the concrete production has attracted an international interested since there is a significant growth of sewage sludge. Moreover, Malaysia is one of the largest egg consumers in the world that consumed 36.5 million eggs daily [1]. Most of the sewage sludge and eggshell are disposed as landfill [2]. The sewage sludge is not recommended for buried in soil or treated as fertilizer due to its heavy metals content [3]. Copper (Cu), Zinc (Zn), lead (Pb) and cadmium (Cd) are the elements that often reported to cause contamination of soil and food chain which can cause health problems [4]. The number of landfill increase significantly from 49 in 1988 and 161 in 2002, yet is increasing annually [5]. In addition, the increasing of demand of using cement in construction had made the potential of seeking potential cement replacement in order to use natural resource to produce it. Sewage sludge and eggshell are rich in SiO2 and CaCO3 respectively which responsible in pozzolanic activity and concrete strength development. In this research is to determine the optimum of sewage sludge and eggshell that capable to use as partial cement replacement.

2. EXPERIMENTAL METHODS

A. Materials

Materials used in this research work consists of eggshell powder, incinerated sewage sludge ash, ordinary Portland cement, coarse aggregate, fine aggregate and water. The Ordinary Portland cement used is conforming to MS 522: Part 1 for Portland cement specification from single source was used as binder [6]. Air dried river sand was selected as fine aggregate. Eggshell and sewage sludge were collected form Eggtech Manufacturing Sdn Bhd and IWK Kuantan respectively. Eggshells were oven-dried for 24 hours and sewage sludge was incinerated at 800ºC. Then, both of these materials undergo grinding process to produce finer particle till 60µm that fulfill the requirement of ASTM C618-12 [7]. According to the chemical composition that shown in the Table 1, the incinerated sewage sludge ash and eggshell powder were classified as class C pozzolans according to the ASTM C618-12 [7]. Tap water were used during concrete preparation and curing purpose.

B. Specimens preparation and testing

The experimental work was divided into two stages. During the first stage, the experimental work focuses on optimum percentage of ISSA as partial cement replacement. The sewage sludge incinerated at 800ºC were used as replacement cement at different percentages namely 10% and 15%. Cement mortar with no cement replacement is considered as control specimen. The percentages of the ISSA replaced to the mix was by unit weight of the ordinary Portland cement. All cast mortar cubes are water cured for 1, 7, 28 and 90 days. Table 2 show the mix proportion of the specimens. All the specimens were cast into mortar cube (50x50x50) mm. The compressive strength analysis was conducted by following BS 12390-3 [8]. The specimens undergo field emission scanning electronic microscope (FESEM) to provide higher resolution of the internal structure of the specimens.

In the second stage, the eggshell powders were added to the concrete and used as partial cement replacement. Five types of mixes that containing eggshell powder as partial cement replacement ranging from 0% to 20%. The workability of the specimens was tested by through slump test which following BS 12390:2[9]. Table 3 show the mix proportions of the specimens after adding eggshell powder. All the specimens were cast into cube size (100x100x100) mm and placed in the water for curing purpose. Then, the compressive strength of the specimens was determined according BS12390-3 [8]. Figure 1 and 2 were the incinerated sewage sludge ash and eggshell powder respectively.

3. RESULTS AND DISCUSSION

A. Effect of sewage sludge in mortar properties

The specimens were water cured and tested at the age of 1, 7, 28 and 90 days for the compressive strength. The early strength of the specimens contain ISSA were lower than ordinary plain mortar because of ISSA reduced the early hydration process of the cement [10]. The formation of calcium silicate hydrate gel (C-S-H) at early stage become retarded as the replacement of the ISSA increase where the C-S-H gel is responsible for the early strength development. The design grade for the control mix was 30 MPa. Figure 3 clearly shows the compressive strength of the mortar with different day of curing. At the age of 90 days of curing, specimen ISSA 10% was higher than the control plain specimens. However, additions of 15% of ISSA do not show any improvement of in term of compressive strength and reduce more than 50% of the strength. In term of strength, a suitable combination of ISSA content produced concrete with enhanced strength as illustrated in Figure 4. Replacement of 10% of ISSA resulted in strength higher than the control specimens. As the result, the quantity of using ISSA as the partial cement replacement cannot exceed more than 10%. Figure 5 (a) show the control specimens undergo FESEM test, from the figure it can clearly showed that the existing of the pores is larger compare to the Figure (b) and (c). The Figure 5(b) shows large structure that formed by cross-linked of network of silica. The porous structure is produced by process of sintering densification. At higher temperature, the particles are compacted and form a structure with higher density [10]. Figure 5(c) shows the smooth surface of the structures were formed during the reaction of pozzolanic material from SSA with the $Ca(OH)_2$ [11]. The smooth texture of the particles the product of pozzolanic activity of SSA and cement which able to fill up the existing void and pores. As the result, the addition of the bonding can increase the compressive strength of the specimens.

Table 1: Chemical Composition of Materials

Material	Silicon Dioxide (SiO_2)	Aluminum Oxide (Al_2O_3)	Iron Oxide (Fe_2O_3)	Calcium Oxide (CaO)
OPC	21.8	6.6	4.1	60.1
Sewage sludge ash	53.90	9.13	8.05	6.80
Eggshell	0.08	0.03	0.02	52.1

Table 2: mix proportion of mortars specimens

Mixture	Cement (kg)	SSA(kg)	Fine aggregate (kg)	Water (kg)
SSA 0%	1	0	2.75	0.6
SSA 10%	0.9	0.1	2.75	0.6
SSA 15%	0.85	0.15	2.75	0.6

Table 3: mix proportion of the specimens included eggshell powder

Materials	Amount (kg/m^3)				
Cement	400	380	360	340	320
Coarse aggregate	1120				
Fine aggregate	650				
ISSA (%)	0	10	10	10	10
Eggshell powder (%)	0	5	10	15	20
W/C ratio	0.45				

Figure 1: Incinerated sewage sludge ash

Figure 2: Eggshell powder

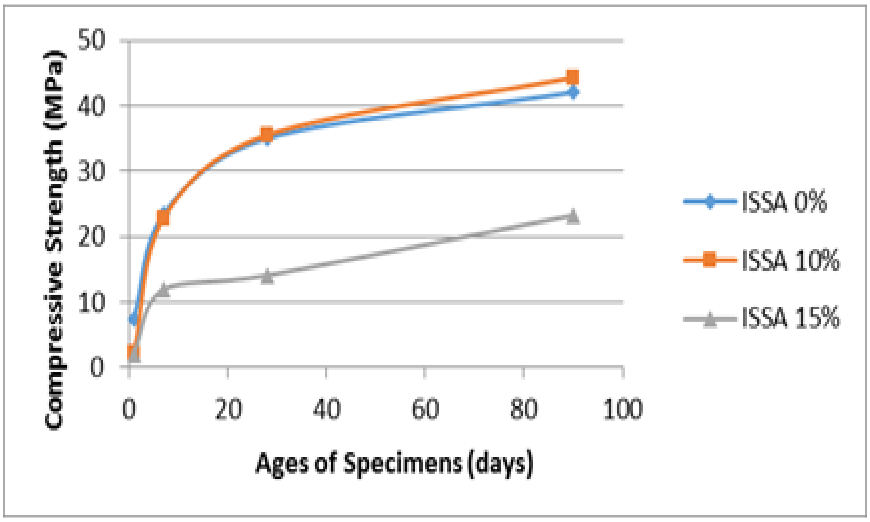


Figure 3: Compressive strength against curing time

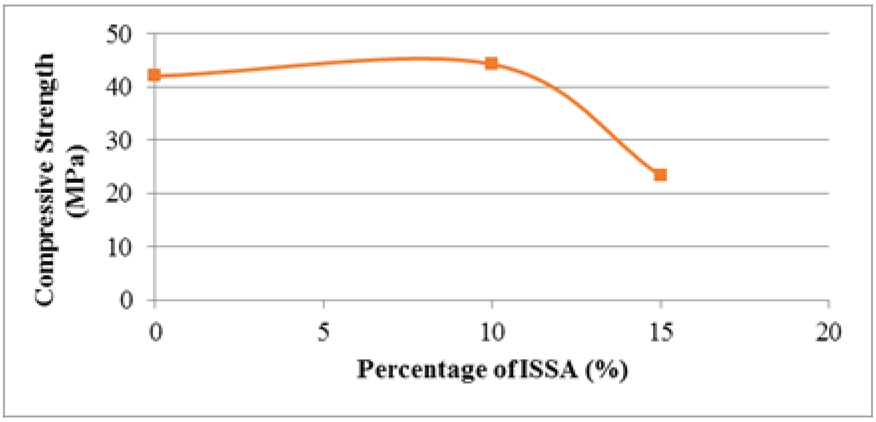
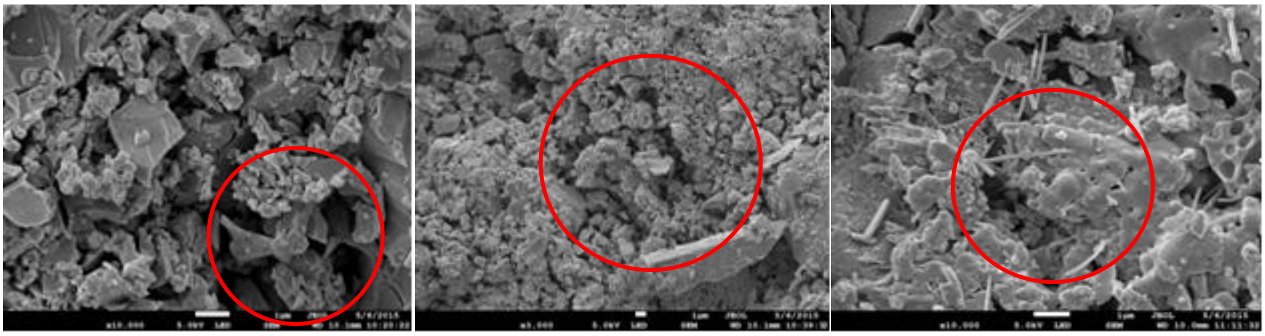


Figure 4: Compressive strength of specimens with varied percentage of ISSA at 28 days of curing



(a): FESEM of ISSA 0% (b): FESEM of ISSA of 10% (c): FESEM of ISSA of 15%

Figure 5 (a)(b)(c): FESEM result of ISSA with varied percentage

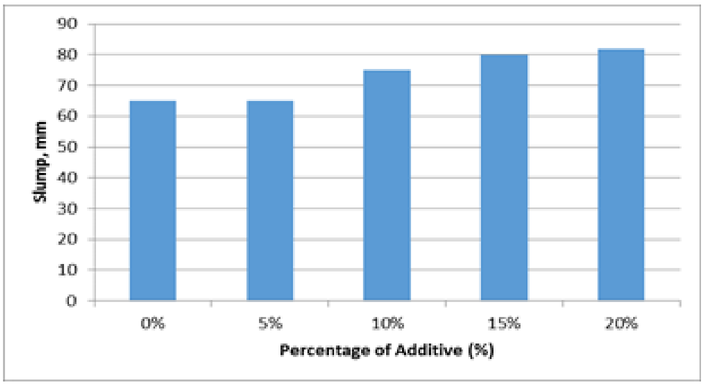


Figure 7: Slump test result of the concrete cube specimens

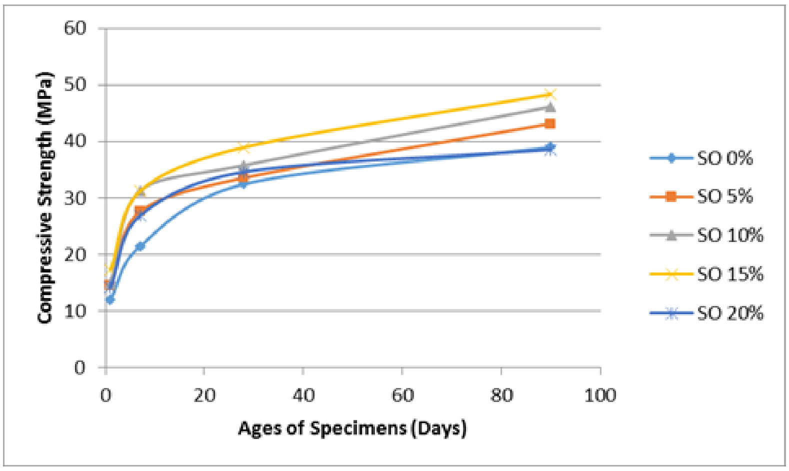


Figure 8: Compressive strength of the concrete cube specimens

B. Effect of eggshell powder in ISSA concrete

Amount of the eggshell powder do not influence the workability of the concrete that show in the Figure 7. The slump values of ISSA concrete with varied percentage of eggshell powder were measure between 62 and 81 mm. All of the results were fall under true slump which is suitable for normal concreting work. Addition of 20% of the eggshell powder produced a direst mix but provide the highest slump result. The dry mixture is lead to low cohesion which able to cause the slump to collapse. The most suitable for eggshell to use as partial cement replacement was not more than 15% which based on slump test result.

In term of compressive strength, a suitable combination of the eggshell ISSA concrete had illustrated in Figure 8. The compressive strength of the concrete cubes specimens increases with the increment of the percentage of eggshell powder. Addition of eggshell powder provides extra calcium oxide (CaO) to the concrete which allow the compressive strength of the concrete specimen is higher than the normal plain concrete. Inclusion of adequate of CaO assists towards occurrence of better hydration process resulting in formation of secondary C-S-H gel making the concrete structure stronger [12]. The most optimum percentage of using eggshell powder as partial cement replacement to the ISSA concrete was 15% with the compressive achieved 48.36 MPa at day 90. Although the compressive strength of concrete with 20% of eggshell decreases, the strength was compatible with normal plain concrete.

4. CONCLUSION

The use of sewage sludge and eggshell in the concrete industry able to reduce the amount waste disposed to the environment. It is possible to utilize sewage sludge and eggshell as the partial cement replacement with optimum 25%. Addition of eggshell allowed the concrete to achieve higher compressive strength with 37% higher than normal plain concrete.

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