Journal on Technical and Vocational Education (JTVE), Vol 4 No 3:Special Edition NASCO (2019)
eISSN: 0128-0821
http://upikpolimas.edu.my/ojs/

Compressive strength and workability of concrete using pozzolanic material as partial replacement of Ordinary Portland Cement (OPC)

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Abstract: Typical site projects in Malaysia use large amount of cement in the construction for concreting work and mortar production. Excessive usage of cement increases dust concentration around the construction project which contributes to severe surrounding air pollution and adverse health effects. Therefore, this study was conducted to investigate the potential of pozzolanic material as admixture to partially replace cement in concrete as a mean of producing more environmental friendly cement products. The content of fly ash as partial replacement of ordinary portland cement is investigated by weight. The workability of the fresh concrete mixtures was evaluated using slump test while compressive strength of cubes concrete were evaluated at 7, 14 and 28 days. The optimum compressive strength at all ages of testing was obtained at 10% replacement. Workability decreased with an increased in replacement percentage of fly ash. The results therefore shows that fly ash as pozzolanic materials can be used to partially replace ordinary portland cement.

KEY WORDS: *pozzolanic material, fly ash, compressive strength and workability*

1.0 Introduction

Fly ash is a pozzolanic material which is an industrial waste that is produced from the burning of coal in thermal power plant. It is typically in the form of a fine powder resulting from the burning of powdered coal and transported along with the flue gases of the boiler to be collector in the Electrostatic Precipitators (ESP). Englehard et al. (1995) mentioned pozzolana is a siliceous and aluminous material that in itself possesses little to no cementitious value. However, in finely divided form and in the presence of moisture, it is able to chemically react with calcium hydroxide (lime) at ordinary temperatures to form compound having cementitious properties. Malhotra and co-workers (2000) stated fly ash as one of the potential material in reducing the use of cement in construction as it possesses similar binding ability as of cement while containing little to no hazardous chemical substances, making it a more viable and environmentally friendly alternative. Osei, et al, (2012) further give credit to pozzolana by mentioning the replacement of cement with pozzolana significantly increased the strength of concrete, while at the same time, decrease the workability of concrete, which leads to better vibration resistance, giving it an alternative usage in construction industry such as road making. Therefore, from the collection of studies, fly ash as pozzolana presents itself as an attractive partial replacement to Portland cement due to leaving lesser environmental footprint while potentially enhances structural quality of concrete.

Currently in Malaysia, large amount of cement has been used for concreting work and producing mortar on construction projects. Using large amount of cement will increase dust around the construction site and contribute to environmental pollution and affect health. According to Chindraprasirt et al (2004), fly ash is more environmental friendly than typical cement because it does not release any dangerous chemical substance and thus, opening the door to partially replace cement in construction projects**.** However, the study on chemical composition and compressive strength of concrete containing fly ash is still considerably scarce in Malaysia, therefore limiting the extensive usage of fly ash-containing cement in construction industry. Therefore, this study aims at searching alternative pozzolanic material to partially replace cement. The pozzolanic material used in this work was provided by Jimah Energy Ventures Power Plant.

2.0 Material and Method

a. Material

The cement used was ordinary portland cement in compliance to BS12:1996, while the pozzolanic material used was fly ash with conformance with ASTM C618. Table 1 shows the chemical compositions of cement and pozzolanic material used in this study. The chemical composition of fly ash was conducted using X-ray Fluorescence(XRF) at Universiti Teknologi Malaysia. Coarse aggregates of nominal size 20mm was used in producing concrete and complied to BS 882:1996. River sand(fine aggregate) was used in this study and complied to BS 882:1992. Clean water was also added in the mixing of concrete. Grade 25 concrete was produced using a water binder ratio of 0.55. Four different mixes were used for this study according British Standard(Department of Environment) mix design method of concrete. These four mixes includes a control mix using OPC without admixture of fly ash and other three mixes with fly ash replacement 10%, 20% and 30% by mass of OPC as in the control mix. The details of mix proportions are shown in Table 2.

Table 1: Chemical composition of OPC and pozzolanic material

Component	Ordinary Portland Cement (%)	Pozzolanic Material (Fly Ash Type F)(%)
SiO_2	17–25	60
CaO	60–67	3.36
Al_2O_3	3.0–8.0	21
Fe_2O_3	0.5–6.0	7
MgO	0.1–4.0	1.24
SO_3	1.3–3.0	0.664
Na_2O	0.4–1.3	1.5

K_2O	0.4–1.3	1.88

b. Method

The slump test was used to evaluate the workability of the mix of concrete. Workability depends on water content, aggregate (shape and size distribution) and cementitious content. Casting of concrete was done in cube moulds measuring 100mm × 100mm × 100mm. A total of 36 cubes were made. The specimens were made in accordance to BS 1881-116:1983. Demoulding was done after 24 hours and the specimens were placed in a curing tank. The compressive strengths were determined by compressing the concrete cubes at 7, 14 and 28 days of curing using a 2,000kN Matest compression testing machine in accordance to BS 1881-116:1983. The concrete cubes were removed from the curing tank and placed in open air about 2 hours before compress.

3.0 Result and Discussion

Table 2 shows the details of coarse aggregate sieve analysis while Figure 1 shows the semi log graph of coarse aggregate sieve analysis. From the results, sample of coarse aggregate in all sizes within the limitation and can be considered as well graded.

Table 2: Sieve Analysis of Coarse Aggregate

Aggregate size	Weight Retained(g)	Individual Percent Retained(%)	Cummulative Weight Retained(g)	Cummulative Percent Retained(%)	Calculated Percent Passing(%)
28	0	0	0	0	100
20	2158	78.79	2158.00	78.79	21.21
14	508	18.55	2666.00	97.33	2.67
10	69	2.52	2735.00	99.85	0.15
5	4	0.15	2739.00	100.00	0.00
2.36	0	0	2739.00	100.00	0.00
Pan	0	0	2739.00	100.00	0.00
Total	2739				

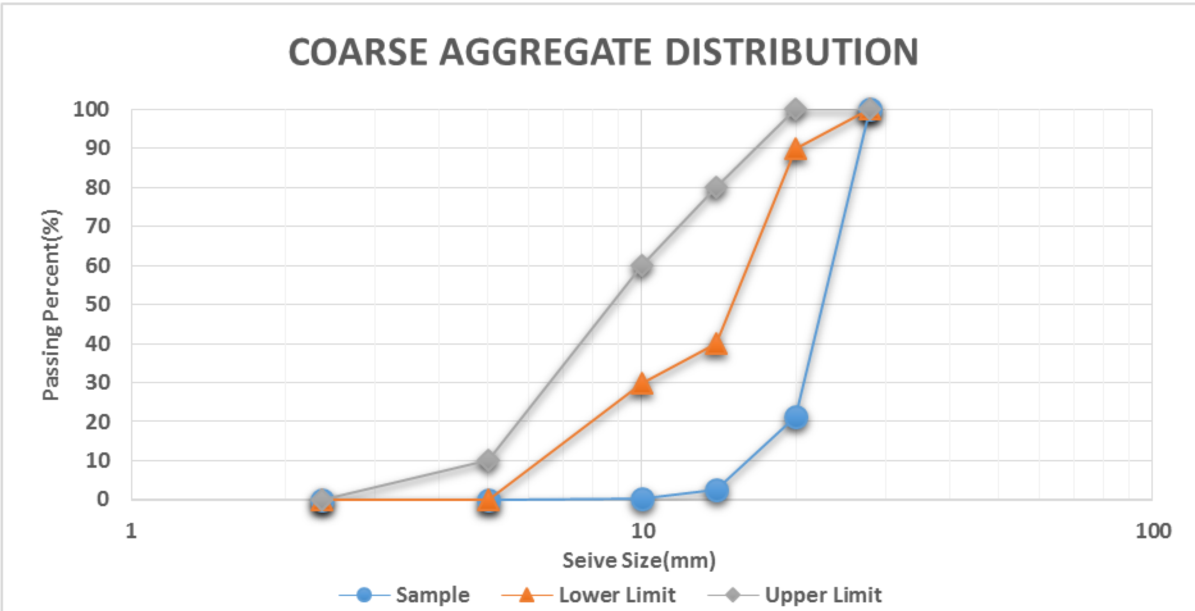

Figure 1: Sieve Analysis of Coarse Aggregate (BS 882:1992)

Table 3 shows the details of fine aggregate sieve analysis while Figure 2 shows the semi log graph of river sand analysis. From the results, sample of river sand in all sizes is within the limitation and can be considered as well graded.

Table 3: Sieve Analysis of River Sand

Aggregate size	Weight Retained(g)	Individual Percent Retained(%)	Cummulative Weight Retained(g)	Cummulative Percent Retained(%)	Calculated Percent Passing(%)
10	0	0	0	0	100
5	81	7.83	81.00	7.83	92.17
2.36	272	26.31	353.00	34.13	65.86
1.18	324	31.33	677.00	65.47	34.53
0.6	192	18.57	869.00	84.04	15.96
0.3	94	9.09	963.00	93.13	6.87
0.15	60	5.80	1023.00	98.94	1.07
Pan	11	1.06	1034.00	100	
Total	1034				

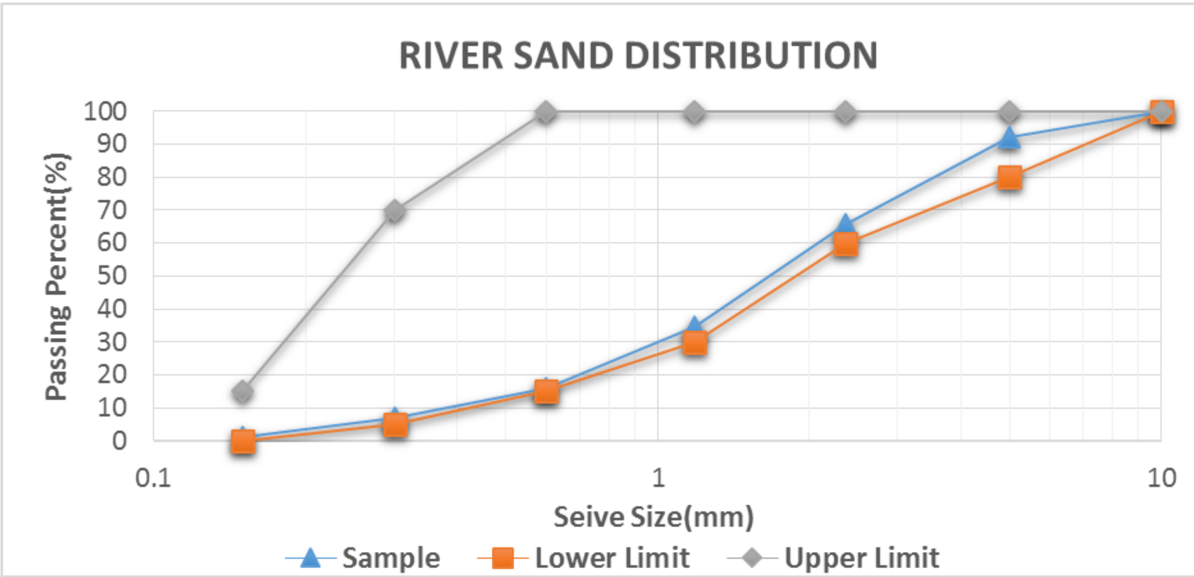

Figure 2: Sieve Analysis of River Sand(BS 882:1992)

From the results of sieve analysis of river sand and coarse aggregate, procedure of mix design according Department of Environment (DOE) method was applied. The details of mix proportions are shown in Table 4.

Table 4: Details of mix proportions of concrete grade 25

Percentage replacement(%)	**Weight of Materials**					
	Cement (kg)	***Fly Ash (kg)***	***River Sand (kg)***	***Coarse Aggregate (kg)***	***Water (L)***	**Target Mean Strength(N/mm^2)**
0	6.9	0	18.63	18.76	3.8	38.12
10	6.22	0.69	18.63	18.76	3.8	38.12
20	5.53	1.38	18.63	18.76	3.8	38.12
30	4.84	2.18	18.63	18.76	3.8	38.12

3.1 Slump Test

Table 5 shows the results of workability tests while Figure 3 shows graph of workability of fresh concrete containing a partial of fly ash. From the results, when the percentage of fly ash in mix of concrete increased, the workability of concrete decreased. Therefore, increasing replacement of cement with fly ash will be increased water demand in fresh concrete mix.

Table 5: Workability Test

Workability	**Cement Replacement (%)**			
	0	***10***	***20***	***30***
Slump (mm)	63	61	60	57

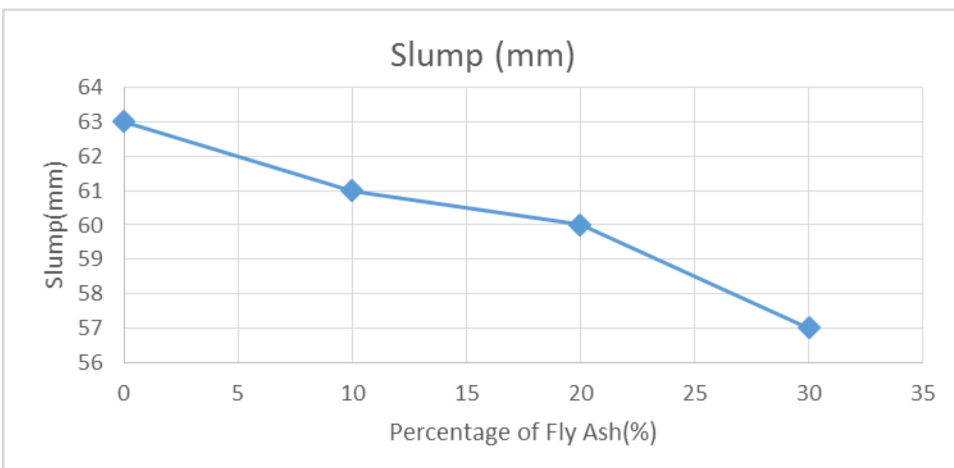

Figure 3: Graph of Slump Test

3.2 Compressive Strength

Table 6 shows the results of compressive strength. The compressive test was conducted to determine the compressive strength of concrete at the age of 7, 14 and 28 days. Generally, it is observed that the compressive strength experienced a decreasing trend from the control concrete (0% replacement) when percentage of replacement fly ash increased. This trend is similar at all ages of concrete. The compressive strength of concrete also increases with age. The maximum compressive strength(37.74 N/mm^2) was seen at 10% replacement of OPC with fly ash but still not achieved target mean strength(38.12N/mm^2) and lower than control concrete(39.18N/mm^2). The decreased in compressive strength may be due to slow hydration process when increased of fly ash in concrete which is slow reactive pozzolans causes delay the hydration process. Curing of cubes concrete are recommended to exceed 28 day for further investigate in compressive strength.

Table 6: Compressive Strength(N/mm^2)

Concrete Age (days)	Fly ash replacement percentage(%)			
	0	***10***	***20***	***30***
7	24.15	24.50	27.27	23.20
14	35.33	35.61	30.93	25.03
28	39.89	37.74	34.26	33.54

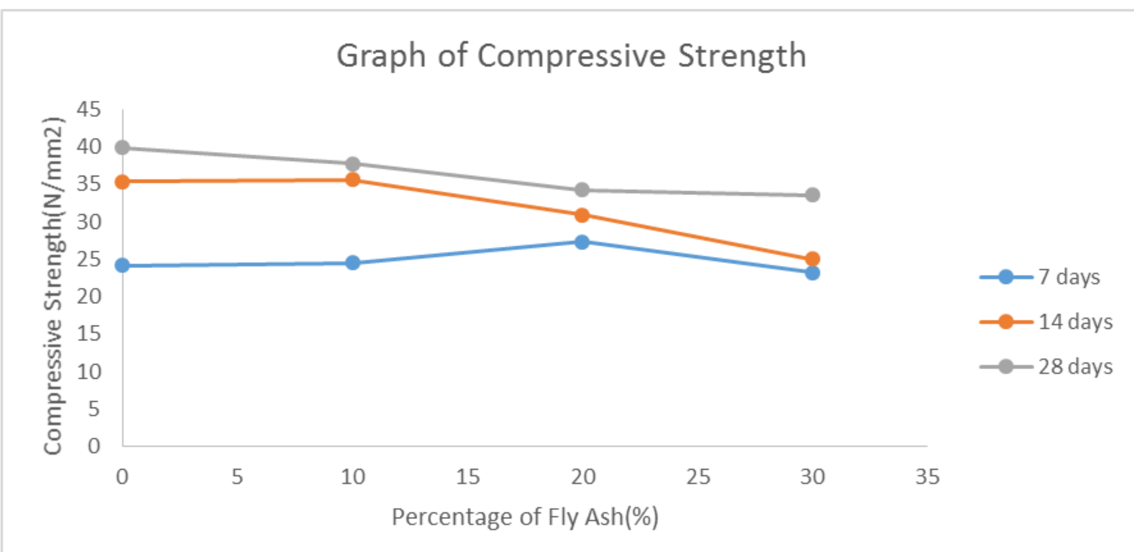

Figure 4: Relationship between compressive strength and difference percentage of fly ash at age 7 day, 14 days and 28 days

4.0 Conclusion

In this study fly ash was used as partial replacement of OPC in difference percentage of 0%,10%, 20% and 30%. Based on this study, the replacement of cement with fly ash significantly decrease the strength of concrete. From table 6, it is deduced that fly ash replacement of 10% of the weight of cement achieved the optimum value of compressive strength and considered the best ratio of cement replacement in a concrete mix at 28 days. From the slump test, the increase in fly ash content in concrete decreases the slump height, thus indicating that there is a decrease in the workability of concrete. Therefore, from this study, the partial replacement of cement by fly ash definitely opens up a viable option of reducing environmental impact to surrounding while providing more economical alternative in construction.

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