Journal of Engineering and Applied Sciences 12 (Special Issue 1): 5638-5643, 2017
ISSN: 1816-949X

Using Plywood Ash as Partial Substitution of Cement in Concrete

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Abstract: Plywood ash is one of waste material from plywood factory. Its bigger and cause contamination problem to the environment. The aim of this research to establish the potential of using plywood ash as substitution partial of cement in concrete. By reducing using of cement in concrete can reduce the effect of CO_2 emission which produced from the cement factory. The sample material was formed of the cylinder of 15 cm in diameter size and 30 cm in height for testing of compressive strength after curing in 28 days. From the result of research known that plywood ash can be used as substitution partial of cement. Using of cement can be reduced by 10% to get compressive strength almost equal to normal concrete without plywood ash. Using of plywood ash up to 10% cause decrease of compressive strength and cause increase water absorption of concrete. The research to using waste material to reduce using of cement must continue to prevents environment contamination and reduce CO_2 emission to the atmosphere.

Key words: Plywood ash, slump, compressive strength, water absorption, atmosphere, environment

INTRODUCTION

Concrete is a material structure made from mixture sand, gravel/coarse aggregate, cement and water as the adhesive. Sometimes, one or more admixtures are added. Portland cement is one of basic material for the concrete structure. The demand for portland cement is increasing in Indonesia and generally in developing country. Unfortunately, from some research knew that production of cement is not friendly to the environment.

The production process of portland cement uses fossil fuel to generate electricity during cement manufacturing process. Its process also causes CO_2 emissions into the atmosphere. The use of pozzolanas as the concrete material can be considered to reduce the cement consumption and can improve the strength of the concrete (Aiswarya *et al*., 2013). Manufacturing of cement included an energy intensive process. So that, it is necessary to have research as the effort to reduce cement usage in concrete material. Reduction of the use of portland cement has an ecological advantage and reduce the cost of construction.

Waste material from an industrial process can reuse to reduce the using of cement in the concrete mixture. From some research known that some of the waste material can be used as cementitious material and can improve mechanical properties of concrete. That material such as metakaolin (Aiswarya *et al*., 2013), bagasse ash (Srivastava *et al*., 2015), rice husk ash (Obilade, 2012, 2014), silica fume (Amudhavalli and Mathew, 2012), coal fly ash (Shah *et al*., 2013; Rohman *et al*., 2013), sea shells ash (Etuk *et al*., 2012), ceramic powder, glass powder (Baskar1 *et al*., 2015), natural pozzolan (Osei and Jackson, 2012), sawdust ash (Obilade, 2014), waste marble powder (Patel and Shah, 2014; Singh and Bansal, 2015), tile powder (Manogna and Lakshmi, 2015), Industrial Waste (Hypo Sludge) (Balamurugan and Karthickraja, 2014; Solanki, 2013), wood waste ash (Subbaramaiah *et al*., 2015), egg shell powder (Gowsika *et al*., 2014), blast furnace slag powder (Dubey *et al*., 2012), etc.

Subbaramaiah *et al*. (2015) studied about an effect of addition and partial replacement of cement by using wood waste ash on the strength properties of structural grade concrete. Their investigation is done at various levels 0, 10, 20, 30 and 40% of cement by weight. The mechanical properties of concrete were determined at different curing periods. From their research concluded at 10% of replacement of cement can improve the mechanical properties of concrete such as compressive strength, splitting tensile and flexural strength.

Using of High Calcium Wood Ash (HCWA) as partial cement replacement material in the production of mortar was investigated by Chee Ban Cheah and Mahyuddin Ramli. Their research used 6 mortar mixtures. Control specimen used mortar without HCWA (only containing neat cement as the binder). HCWA mortar mixture was used at partial cement replacement level of 5, 10, 15, 20 and 25% by weight of cement. For all mixtures water to

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binder ratio was used 0.35. From their research knew that the using of HCWA influence slump of fresh concrete decrease and constant at the use up to 10% of HCWA. At the age 28 days, the use of HCWA decreases compressive strength. Highest compressive strength achieved at the age of 90 days at 15% replacement cement with HCWA.

Plywood ash included one of wood ash. In this research use plywood ash as partial substitution of cement in concrete. The plywood ash gets from PT Prima Parquet Indonesia (PPI) that located at Sukoharjo regency, Central Java, Indonesia. The plywood ash is the result of combustion process of plywood factory. Plywood ash contains CaO (38%), SiO_2 (21.94 %) and so on. Two chemical constituents more than others in composition and dominantly in the chemical composition of Portland cement (Destiapni, 2014).

The purpose of research was to investigate the effect of the plywood ash usage as partial substitution of cement in concrete. Compressive strength and water absorption test will be held to identify the characteristic of concrete using plywood ash as the cementitious material. The result this research were expected to give the recommendations for the possibility of plywood ash usage as the cementitious material to reduce cement usage in the concrete mixture.

MATERIALS AND METHODS

In this research, the method used was the experimental laboratory to investigate the effect of using plywood ash as the cementitious material in concrete. This research was conducted in Concrete Laboratory of Civil Engineering Department of Engineering, Faculty of Merdeka University, Madiun, Indonesia.

Plywood ash: Plywood ash gets from PT Prima Parquet Indonesia that located in Sukoharjo, Central Java, Indonesia. The raw material of plywood used from local timber species dominantly pines, acacia and mahogany. Plywood ash was sieved through laboratory sieve No. 100 in order to remove any impurity and larger size particles. The chemical composition of plywood ash shown in Table 1.

Portland cement: Portland Cement (PC) was used from PT. Semen Indonesia Tbk. In this research, PC was used as a binding material. The value of specific gravity of portland cement was about 3.15.

Fine agregate: Fine aggregate used the river sand used passing through 4.75 mm. It was sourced from a quarry in Ngrao, Bojonegoro, East Java. The impurities were removed and it conformed to the requirements. The specific gravity of sand was about 2.56. The fine modulus of sand was about 2.84.

Coarse agregate: Coarse aggregate used local aggregate from Madiun available 20 mm size. The specific gravity of coarse aggregate 2.67. The fine modulus of coarse aggregate 6.87.

Water: The water used for the research was obtained from a free flowing stream in concrete laboratory. The water was clean and free from any visible impurities.

Concrete mix design: Concrete mix proportion was designed to achieve compressive strength 25 MPa at the age of 28 days. In this research, mix design refer to SNI 2834 1993. Water cement ratio was set as 0.45 for all concrete mixtures. The total binder content 400 kg/m^3, fine aggregate is taken 619.5 kg/m^3, coarse aggregate is taken 1150.5 kg/m^3. The concrete mix proportion was obtained 1:1.55:2,87 in weight.

Hence, cement was replaced by plywood ash at various percentage of cement replacement. The 5 mixtures were prepared by using plywood ash to substitute partial of cement. The plywood ash substitution rate was varied in increment of 10%. Variation of plywood ash substitution used 0, 10, 20, 30 and 40% from weight of cement. The sample of material makes some variation follow on the proportion of plywood ash that substitute of cement in the concrete mixture. Percentage of plywood ash 0% (without plywood ash) used as the control specimen. The result of mix design for the sample test of cylinder concrete in this research was given in Table 2.

Specimen preparation for testing: The concrete mixture was prepared with the variation of plywood ash substitution. For all mixtures, all material were weighed in dry condition. Cement, fine aggregates, coarse aggregates, water and plywood ash were mixed in a batch mixer of the laboratory.

After mixing the properties of fresh concrete were measured by slump test. The apparatus used for doing slump test are slump cone. The dimensions of slump cone are top diameter 10 cm, bottom diameter 20 cm and height 30 cm. The value of slump test determines workability of the concrete mixture. The slump is measured by using the difference level between the height of the slump cone and height of the subsided concrete. This difference in height in cm is the slump of the concrete.

Testing of sample material uses compressive strength test and water absorption test. A sample of use

compressive strength is cylinder 15 cm in diameter and 30 cm in height. A sample of water absorption uses cube 5×5×5 cm^3 in size. All sample material for testing were prepared according to mix design proportion.

In the casting process, all of the specimens were filled and compacted in 3 layers. Then were covered by the plastic sheet to avoid moisture loss. All specimens were kept at room temperature for 24 h and after that were moulded. Then, the specimens test conducted with a curing in water until the age of specimens reach 28 days.

Compressive strength of concrete is determined by testing failure of sample by depress hydraulic concrete mechanically. Sample of material is cylinder of concrete, diameter of sample is 15 cm and height is 30 cm. Calculation of compressive strength is done and packed into the following equation:

$$fc' = \frac{P}{A} \quad (1)$$

Where:

fc' = Compressive Strength Test (MPa)
P = Maximum force (N)
A = The width of pressed surface of tested material (mm^2)

Water absorbtion is one of parameter to know durability of concrete. It is definitely stated in terms of percentage of water absorbtion in concrete. The strength of concrete are also influenced by its water absorbtion characteristic. Many researchers have same opinion that water absorbtion of concrete can be reduced using pozzolan or supplementary cementitious material.

The cube 5×5×5 cm^3 in size after casting were immersed in water for 28 days curing. These specimens were then oven dried for 24 h at the temperature 110°C until the mass became constant and again weighed. This weight was noted as the dry weight (W_1) of the cylinder. After that the specimen was kept in hot water at 85°C for 3.5 h. Then, this weight was noted as the wet weight (W_2) of the specimen. The water absorbtion of concrete can be calculated by using the following equation:

$$p = \frac{W_2 - W_1}{W_1} 100\%$$

Where:

P = Water absorbtion of concrete (%)
W_1 = Weight of oven-dried samples measured in air (g)
W_2 = Weight of surface-dry samples in air after immersion (g)

RESULTS AND DISCUSSION

Slump test was done to fresh concrete after mixing. The result of the slump tests graphically shown in Fig. 1. The result indicated that the substitution of plywood ash reduce the value of slump, furthermore concluded the using plywood ash decrease workability of concrete. An increase in the substitution of cement cause decreases workability. The slump of fresh concrete using plywood ash was lower when compared with control (without used plywood ash) that indicated water absorption of plywood ash higher than portland cement.

Compression testing of the sample was done on the compression testing machine having the capacity of 2000 KN. This cylinder was loaded on their sides during compression testing such that the load was exerted perpendicularly to the direction of casting. The average value of the three cylinders was taken as the compressive strength. The sample was weighed before being put in the compressive test machine. The machine automatically stops when failure occurs and then displays the failure load. The compression test was shown in Fig. 2. The result of compressive strength test gives at Table 3 and are graphically shown in Fig. 3.

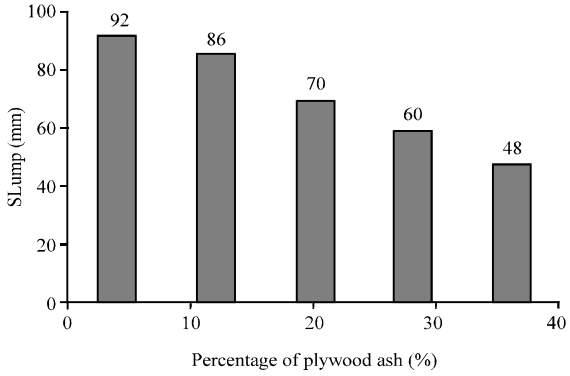

Fig. 1: Slump test result

Fig. 2: Compressive strength test

The results of the compressive strength of concrete cubes show that the compressive strengths reduced as the percentage plywood ash increased. Using of plywood ash makes the compressive strength of concrete decrease. Using of plywood ash 10% of cement found compressive strength 24.82 MPa (95.29% compared with control). Using of plywood ash 20% of cement found compressive strength 20.48 MPa (78.62% compared with control).

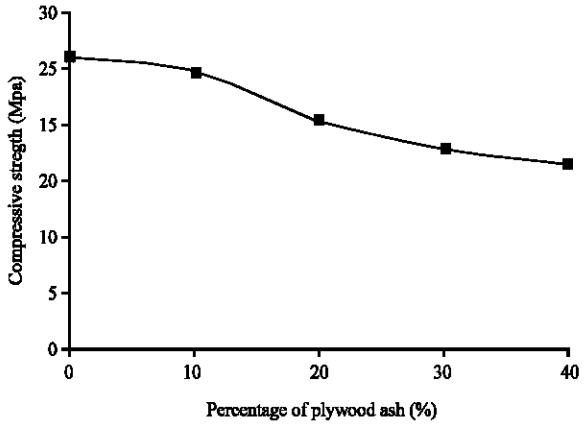

Fig. 3: Graph of result of compressive strength vs. percentage of plywood ash

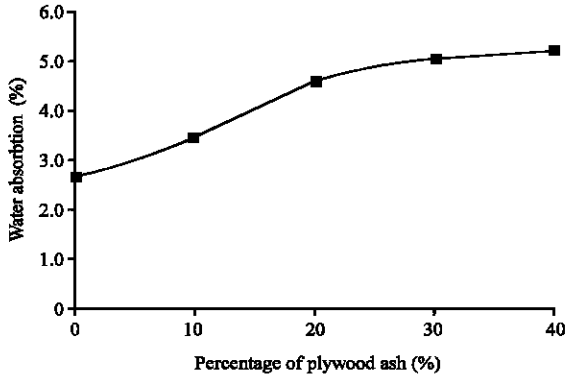

Fig. 4: Graph of result of water absorption test

The results also revealed that increase in the percentage of partial replacement of plywood ash decreased the compressive strength of concrete. Maximum replacement of cement must be limited to get maximum compressive strength. From the compression test result, plywood ash can be used as the partial substitution of cement in concrete.

From Table 3, we can show that the weight/unit volume of concrete reduced as the percentage plywood ash increased. The weight/unit volume of concrete using plywood ash was lower when compared with control (without plywood ash). Weight/unit volume of control concrete 2386.4 kg/m^3. Using of plywood ash makes the weight/unit volume of concrete decrease.

Water absorption is one of the parameters to know the durability of concrete. It is stated regarding the percentage of water absorption in concrete. The strength of concrete is also influenced by its water absorption characteristic. Water absorption is done by using sample cube 5×5×5 cm^3 in size. The average dry weight of cube specimens after removing from moulds was measured. Then the average weight of cube specimens after submerging in water for curing was measured at 28 days of age. The percentage of water absorption was measured for each concrete specimen and it gave an indirect measure of the durability of concrete.

The result obtained from water absorption test of the concrete shown in Table 4 and Fig. 4. Its shows that using

Table 1: Chemical composition of plywood ash

Chemical composition	Mass (%)
CaO	38.000
LOI	16.200
SiO_2	21.940
Al_2O_3	8.330
SO_3	2.520
fe_2O_3	2.490
MgO	2.160
K_2O	1.088
Na_2O	0.540
TiO_2	0.500
P_2O_5	0.210
Mn	0.140
Cu	0.100
Pb	0.004

Table 2: Mix design for the sample test

Sample code (%)	Weight (kg)	Cement (kg)	Water (kg)	Sand (kg)	Coarse agg (kg)	Plywood ash (kg)
0	41.09	6.99	3.15	10.83	20.12	0.00
10	41.09	6.29	3.15	10.83	20.12	0.70
20	41.09	5.60	3.15	10.83	20.12	1.40
30	41.09	4.90	3.15	10.83	20.12	2.10
40	41.09	4.20	3.15	10.83	20.12	2.80

Table 3: Compressive strength test

Sample code (%)	Weight (g)	Weight/unit volume (kg/m^3)	Average force (KN)	Compressive strength (MPa)
0	12645	2386.4	460.0	26.04
10	12476	2354.5	438.3	24.82
20	12284	2318.3	361.7	20.48
30	12220	2306.2	315.0	17.83
40	12156	2294.1	291.7	16.51

Table 4: Water absorbption test

Sample code (%)	Water absorption (%)	Percentage of increasing water absorbption
0	2.624	0.000
10	3.418	30.257
20	4.587	74.824
30	5.030	91.693
40	5.183	97.503

plywood ash in concrete cause the water absorption increased. The water absorption shows lower at 10% replacement of cement. Percentage of plywood ash >10% of the concrete mixture absorbed water in the large amount and will cause the mixture to be dry. There after the water absorption shows an increasing trend.

CONCLUSION

Based on the result of experimental investigation in this research, the following conclusions were made:

- Using plywood ash as partial substitution of cement decrease workability of concrete
- Using of the plywood ash influences the compressive strength of concrete decrease. Using plywood ash more than 10% makes the compressive strength of concrete decrease. So that, the maximum plywood ash which can be used is 10% to get the maximum strength of concrete
- Using of plywood ash up to 10% also makes water absorption of concrete increase
- The plywood ash can be use as innovative supplementary cementitious material in building construction. The use of plywood ash can reduce using of Portland Cement and overcome the environment pollution problem.

ACKNOWLEDGEMENTS

Researchers thankfully acknowledge to all lecturer and staff in Civil Engineering Department of Engineering Faculty of the Merdeka University of Madiun, Indonesia for the motivational and infrastructural support to carry out this research. Thanks to Merdeka University of Madiun, East Java, Indonesia that sponsored this research.

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