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STRUCTURE AND MATERIALS

A Study of Cement Made From Recyled-Garbage Materials Compared With Portland Cement

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Abstract. Garbage waste is a worldwide environmental problem. Various ways have been implemented for these recycled-garbage materials to be useful in order to save the environment. One of the ways to recycle the garbage into cementitious materials is by combining organic garbage (household garbage, bagasse and rice husks) with mediteran soil. Hereinafter the recycled garbage material is called organic cement. The results of this research is aimed as a movement to save the environment. The test result of chemical compounds, through laboratory test method showed the indication of organic cement resembling the portland cement chemical compounds in the form of: CaO of 65,36%, SiO_2 18,84\\%, Al_2O_3 6,33%, Fe_2O_3 2,29%, SO_3 3,64%, MgO 1,35%, C_3S 66,72%, C_2S 3,98%, C_3A 12,9%, C4Af 6,97%. The density of organic cement was discovered trough physical examination with the amount of 3,01 g/cm^3, lower than the density of portland cement which was 3,16 g/cm^3. The fine cement grain which passes the 200 mesh sieving was as much as 59 %, more than the portland cement which was 33 %. The solidity of organic cement was 1224 kg/m^3, 3,52% lighter than the solidity of portland cement which was 1267 kg/m^3. The testing of initial and final setting time using normal consistency water content with 37 % for organic cement, more than the normal consistency of portland cement of 25 %. The initial setting time of organic cement was 105 minutes, longer than the initial setting time of portland cement which reached the 90 minutes mark. The final setting time of organic cement was on 330 minutes mark, longer than the final setting of portland cement which reached 180 minutes mark. Organic cement concrete possesses cohesive and adhesive properties as such in portland cement concrete. In the same design and age mix, the strengths of organic cement concrete were lower than portland cement concrete, caused by the slow setting time. The evaluation of recycled-garbage materials composition is needed for the faster setting time. Although the results of organic cement concrete strengths test are below than that of the portland cement concrete, organic cement concrete can still be utilized for lightweight construction and hot regions.

Key words: *organic cement, portland cement, organic garbage, bagasse garbage, rice husk garbage, setting time.*

1 Introduction

Due to the high trash volume, it is considered essential to manage it seriously (Suarna, 2008). Trash production by day increases (Umar, 2009). To decompose organic and inorganic waste, community's role is extremely important (Wompere, 2012). The high burden of trash gradually causes negative impact on the environment and population (Waryono, 2009). Makassar as part of Indonesia has produces trash as much as 4000 m^3 per day (Oktavianus, 2015). Through incineration process the organic waste will turn to ash containing SiO2 23% to 46%, AI2O3 13% to 29%, and CaO12% to 31% (Priyatna 2009). The trash in the study were collected from the final trash dump site in Antang of Makassar City. The research result orientation is the utilization of waste recycle of the materials of a little use in the community so far. Experimental study already performed in connection with such thing is a recycle a combination of organic waste (household garbage, bagasse garbage, rice husk garbage) and mediteran soil substitute to become an organic cement instead of Portland cement.

Rice husk ash, although unable to be categorized as cement matrix for not containing C3S and C2S, it can be used as partial replacement of cement to produce secondary CSH in constructing cement composite (Bakri, 2009). Bagasse ash obtained through perfect regulation of itsincineration will contain very high amorphous silicate about 88.9% to 96.7% (Wibowo. et.al. 2006). From hydration, the mixture of bagasse ash with Portland cement results in an addition setting time (Haryono et al, 2005).

The use of saturated fly ash is one of the ways to reduce high evaporation in the hydration process against the density of cement in the concrete (Victor Sampebulu, 2012). Mediteran soil is an infertile soil formed by limestone weathering and containing calcium and magnesium. This type of soil does not give a lot of benefits to agriculture but very good for building materials (Maria Sanico, 2012).

Japan has produced eco-cement made from ash of the city waste through incineration as replacement for some primary raw materials consisting of 50% ofcement made of sewage sludge (Shunsuke Hanehara, Iwata University, 2011). Hydration properties of eco-cement of sludge ash to become klinkers have obtained three kinds of hydraulic cement by developing sludge ash from primary plant waste and water distillation plant, as well as slag from steel factory (ferrate), as a replacement for some of the clay, silica alumina, and iron oxide to become raw material for cement (Kae-Long Lin, at al. 2004).

In the picture of 1A, organic cement concentrate made of organic waste (household garbage, bagasse and rice husk garbage) with mediteran soil

substitute. While in the picture of B is Portland cement used as comparison in the examination of physical nature of this study.

A B

Figure 1 (A) Organic cement made from organic gerbage. (B) Portland cement

2 Outline Of Experiment

2.1 Methods Of Experiment

In examining and evaluating the chemical properties of the organic cement concentrate, a comparative study of the physical properties of the similarities and differences between portland cement and organic cement. The examination of chemical properties is first conducted to each raw material which has been processed and become the concentrate for the organic cement. Later, tests on the concentrate of the organic cement are performed. To obtain the optimal result of the tests and evaluation of the chemical and physical properties of organic cement concentrate, laboratory test based on the American Standard Testing and Material (ASTM) and Standar Nasional Indonesia (SNI).

2.2 Material and Mix Proportion

Organic cement concentrate is formed utilizing natural ingredient like mediteran soil and recycled organic garbage i.e. household garbage, bagasse garbage, and rice husk garbage. When all the raw materials are managed, it is necessary to identify the level of chemical content produced by each concentrate. Table 1 below shows the proportion of the use of the main ingredients and the chemical content produced by each concentrate.

Table 2 The presentaion of the primary materials for organic cement

No	Material Sources	The (Large) The Primary Chemical Component	Primary Composition Content/ Composition Level (%)	Composition taken (%)	Additional chemical elements. (Small)
1.	Mediteran Soil / I	CaO	60,93	61	SiO2, Al2o3, Fe2o3, Mgo,So3,Na2o,K2O
2.	Organic Garbage :				
	Household Garbage/ N	SiO2	32,56	35	Al2O3,CaO, Fe2O3, SO3, Na2O, K2O, MnO, MgO, TiO3, P2O5, HP
	Rice Husk Garbage/ A	SiO2	71,27	2	CaO, Al2o3, Fe2O3, MgO,K2O,Na2O,HP
	Bagasse/ R	SiO2	38,06	2	CaO, Al2O3, Fe2O3, MgO, K2O, TiO2, Na2O, P2O5

The empirical formula of the concentrate forming organic cement can be presented as follow:

$$\sum R_I f = \frac{\sum I + \sum N + \sum A + \sum R}{100} \quad (1)$$

In which :

$\sum R_I f$ = Organic cement concentrate (kg)
$\sum I$ = Mediteran soil concentrate (%)
$\sum N$ = Household garbage concentrate (%)
$\sum A$ = Rice husk garbage concentrate (%)
$\sum R$ = Bagasse concentrate(%)

3 Results and Discussion

Organic waste that comes from household waste is combusted to a temperature of 700°C. Meanwhile, the rice husk and bagasse wastes are combusted to a temperature of 600°C. For mediteran soil, it is combusted to a temperature of 1000°C. After all the materials become a concentrate, then the material combination is conducted in accordance with the percentages shown in Table 1. The combined material is then combusted in the combustion engine until it

reaches the temperature of 1400ºC to remove the C2S, C3S, C3A, and C4Af compounds. The combustion results in this phase will produce clinker granules which then requeires a smoothing process so that the grinding process is possible to be conducted. The results of concentrate grinding are then examined or tested its chemical compounds where the testing that has been conducted is the testing of organic cement forming elements and several tests of physical characteristics such as its granular fineness, specific gravity, density, the initial setting time and the final setting time of the organic cement. The organic cement in this instance is the organic cement made from a combination of several recycled organic garbage (household garbage, bagasse, and rice husk garbage) with mediteran soil substitution.Table 2 indicates analysis results of chemical elements of organic cement and table 3 shows the chemical properties of portland cement based on ASTM C114.

Table 3 Chemical components of organic cement

Parameter	Percentage	Result
C_3S	%	66,72
C_2S	%	3,98
C_3A	%	12,9
C_4AF	%	6,9
LOI	%	24,5
Ash Analysis		
SiO_2	%	18,84
Al_2O_3	%	6,33
Fe_2O_3	%	2,29
CaO	%	65,36
SO_3	%	3,64
Na_2O+K_2O	%	1,01
MgO	%	1,35

Table 4 Chemical components of portland cement according to ASTM C114-07

Parameter	Percentage	Result
C_3S	%	50-70
C_2S	%	15-30
C_3A	%	5-10
C_4AF	%	5-15
LoI	%	1,58
Ash Analysis		
SiO_2	%	20,6
Al_2O_3	%	5,07

Fe_2O_3	%	2,9
CaO	%	63,9
SO_3	%	2,53
Na_2O+K_2O	%	0,88
MgO	%	1,53

3.1 Caracteristic Of Organic Cement

3.1.1 The Fineness of Cement

The fineness value of the materials for organic cement passing through strainer of 200 mesh is 59% with a solid weight of 1224 kg/m^3 while portand cement is 33% with a solid weight of 1267 kg/m^3. The picture of 2 A is the process of the examination of the fineness of the organic cement and portland cement. Meanwhile, the picture of 2 B explains the examination of the specific gravity of the organic cement. According to Kimberly Kurtis (2010), the specific gravity of portland cement is 3.15 g/cm^3 and the specific gravity of organic cement is 3.01 g/cm$^{3.}$ The specific gravity examination refers to ASTM C 188-95. The fineness of cement, the wider the surface of the granule causing its compounding with water much quicker and needing also a lot of water.

A B

Figure 2 (A) Organic cement examination process. (B) Organic cement specific gravity examination.

3.1.2 Setting Time

Setting time is the time needed for cement to harden starting from mixing with water until the cement turns into paste later become hard enough to resist a strenht as seen in Picture 3. In the study, the setting time of cement being studied is the initial setting time and final setting time.

Initial setting time of portland cement was tested with vicat needle with a diameter of 1 mm piercing through cement paste as long as 24 mm at 90 minutes after the needle has been released. The water content used for the test of setting time is water with normal consistency (25%).

The initial setting time of organic cement is also tested with similar method piercing the cement 25 mm long at 105 minutes after the needle is released. The water content used for the initial setting time is water with normal consistency (37%). According to ASTM C-191-8, the initial setting time should not be less than 45 minutes.

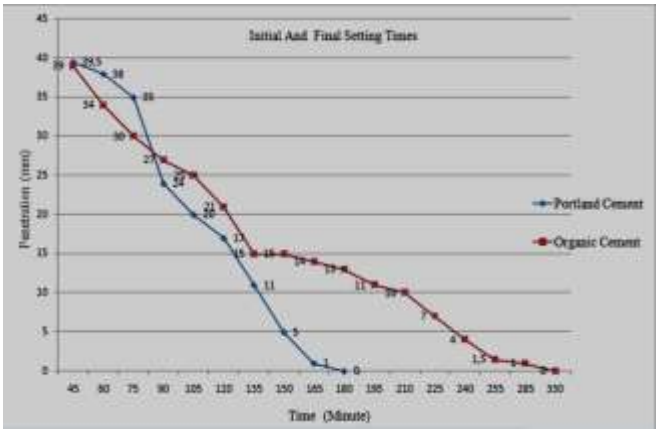

Figure 3 Initial and final setting time Graph

The final setting time of portland cement is on the 180 minutes while of the organic cement is on the 330 miutes. According to SNI standard 03-6827-2002 the final setting time should not be more than 375 minutes.

3.2 Concrete Using Organic Cement

3.2.1 Workability

Water has an influence on the workability of concrete paste, its strength, shrinkage, and durability. Normal consistence formed in organic cement is 37% and in portland cement is 25%. The following table 4 shows the result of normal consistency test. The test of normal consistency is referred to ASTM C 187-04 and SNI 03-6827-2002. To obtain good and fresh concrete, it is to be in a room temperature of about 20^0C, 30^0C, and 35^0C. The cement temperature is conditioned to 20^0C, 40^0C, and 60^0C (Sampebulu', 2012).

Table 5 Normal consistency of organic cement

Experiment	Portland Cement			Organic Cement		
	I	II	III	I	II	III
Cement (gr)	500			500		
Water (ml)	128	121	122	175	180	200
Consistency (%)	25,6	25	24,4	35	36	40

To obtain mix proportion as required by the plan, a mix design should be made as shown in Table 5.

Table 6 Mix design

Sampel	WC (%)	Temperature (^{0}C)	Curing Condition and Method	Water (kgm^3)	Cement (kgm^3)	Maximum size (mm) Aggregates		Materials (kg/m^3)	
						Fine	Coarse	Fine	Coarse
Organic Cement	52	30	Water	195	375	2,5	20	538	1232
			Dry,30^{0}C-60^{0}C						
Portland Cement	52	30	Water	195	375	2,5	20	538	1232
			Dry,30^{0}C-60^{0}C						

3.2.2 Slump Test

To obtain good and homogenous material mix (workability), suitability is needed between water and the coarse, smooth aggregate, as well as the cement used. Slump value test is to prove the workability of fresh concrete before being applied to cast a test material of cylindrical concrete. Picture 4 shows slump test process of fresh concrete. The slump measurement in this case is closely related to planed concrete mix design. This test uses cement water (fas) 0,52%. Concrete cylinder slump test refers to ASTM C-1611 and SNI 1972-2008. The slump planned height is 12 cm and the reached height is:

- Fresh concrete using portland cement $\frac{10.7 + 14.4}{2}$ = 12.55 cm

- Fresh concrete using organic cement is $\frac{9.8 + 10.9}{2}$ = 10.35 cm

High ratio of water against cement in a concrete mix is one of the factors degrading the strength of the concrete. In the concrete mixture, the ratio of water against the cement is defined as water weight and cement weight shortened w/c. the ratio of w/c has a strong influence on the strength of a concrete. For certain mixture to increase the ratio of the w/c will decrease the strength of all ages and to decrease the w/c ratio will increase the strength of the concrete strength (Nicholas, 2014).

Figure 4 Slump test of fresh concrete

3.2.3 Strength Test

3.2.3.1 Compressive Strength Test

The compressive strength test of the cylindrical concrete made from portland cement using water curing method results in 21.08 Mpa. and using dry curing method 20.22 Mpa.The compressive strength test for the cylindrical concrete made from organic cement using maintaining method of water curing, results in 5.00 Mpa. and using dry curing method 6.10 Mpa. The Picture 5, seen test process of compressive strength cylindrical concrete. And the graphs of the test results of compressive strength of cylindrical concretes of organic cement and of portland cement using dry curing and water curing methods can be seen in Picture 6. The compressive strength values produced was calculated with normative standard reference using formula according to ASTM C-39/39M-05 and SNI-03-1974-1990.

Figure 5 Test Process of Compressive Strength Cylindrical Concrete

The compressive strength test of cylindrical concrete was calculated with the following formula:

$$\sigma = \frac{P}{A} \ (kg/cm^2) \qquad (2)$$

In which:

σ = Concrete Compressive Strength Characteristics(kg/cm^2)
P = Compressive Force (kg)
A = Cylindrical Concretesectional stress field (cm^2).

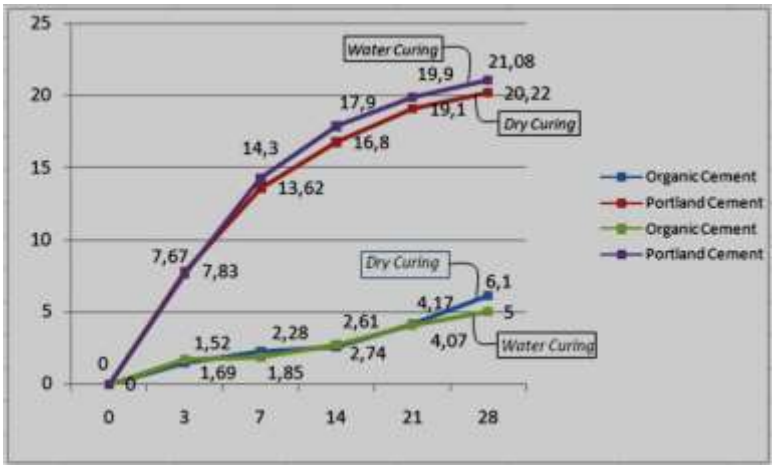

Figure 6 The Comparison graphs of compressive srength of cylindrical concretes between organic cement and portland cement

3.2.3.2 The Splitting Test

Results of spliting test indicate the measurement of the material endurance against mechanical strenght, and thermal strenght. The tensile strength of cylinder test shows tensile strength of concrete (ft) normally is around 0.05 to 0.1 compare with compressive strength value (Dicky Rezady Munaf, 2011). The tensile strength value of the tested materials can be calculated using the formula:

$$fct = \frac{2 \times P}{LD}$$

In which fct = Tensile Splitting Strength
P = Maximum Test Load (N)
L = Length of Test Item (mm)
D = Test Item Diameter

Tensile Splitting Strength of Concrete with portland cement at water curing treatment method has more strength than the concrete treated with dry curing method. Water curing method result 2,16 Mpa, while dry curing result in 2,01 Mpa. Tensile splitting strength of concrete with organic cement at water curing treatment has an ability lower than the one using dry curing method. The water curing method result 0,66 Mpa and while dry curing method result in 1,09 Mpa.

The graph of the Splitting test results is revealed in Picture 7 which is the results of tensile splitting strength test of cylindrical concrete based on the concrete age plan i.e. 28 days.

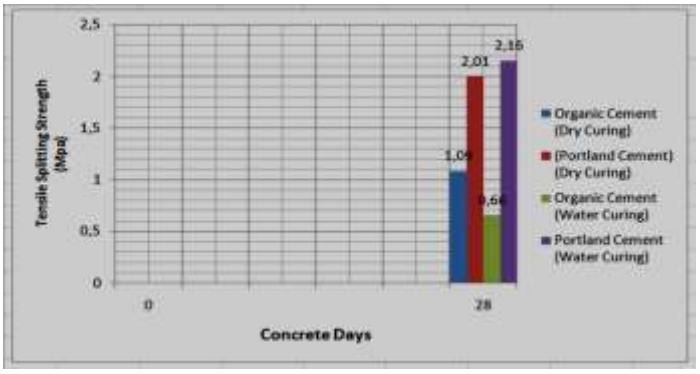

Figure 7 Comparative Graphs of Tensile Splitting Strength of Cylindrical Organic Cement Concrete and Cylindrical portland Cement Concrete.

In 8A picture, is a form of concrete cylinder using organic cement concentrate, while in 8B picture is a form of concrete cylinder using portland cement. Both pictures were taken after tensile strength test was perform.

A B

Figure 8 Cylindrical concrete of organic cement (A). Cylindrical concrete of portland cement (B)

4 Conclusion

The chemical and physical tests of organic cement concentrate have an indication of similar compound properties of portland cement which is used as sample comparator. In the mix design of similar concrete, although the results of concrete strenghts test indicated that organic cement is still under the portland cement, the organic cement can be used for lightweight construction and in the hot regions. To increase the quality of organic cement, it is important to conduct continued advanced experimental study.

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