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ANALYSIS OF THE PHYSICAL PROPERTIES OF ALTERNATIVE CEMENT MADE FROM RECYCLED WASTE MATERIAL

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ABSTRACT

This research aims to the environmental saving process and the discovery of the latest alternative building materials. In the research, the researchers have produced an organic cement that is the latest alternative cement aside from portland cement which is made through organic waste recycling system, fly ash, bottom ash, and substitution of mediteran soil and clay. The method used in this research is laboratory testing. The testing is used to determine the element of chemical compound on each organic cement's main ingredients. From the analysis result of chemical compound of organic cement through laboratory testing method, it has been found indication that similar to chemical compound of portland cement in the form of: CaO; 65.36%, SiO2 18.84%, Al2O3 6.33%, Fe2O3 2.29%, SO3 3.64%, MgO 1.35%, C3S 66 , 72%, C2S 3.98%, C3A 12.9%, and C4Af 6.97%. The bleeding of 1 m^3 organic cement concrete is 23,88 ml/cm^2,which is lower than the bleeding of portland cement concrete that reaches 31,83 ml /cm^2. The air content of 1 m^3 organic cement concrete is 2,2 %, which is lower than the air content of portland cement concrete that reaches 1,9 %. Result of another experimental research is the smoothness of the alternative cement granule that slips in the 200 mesh sieve is 56%, which is higher than the portland cement granule that reaches 52%. The obtained alternative cement solid weight is 1200 kg/m^3 more light from portland cement which reaches 1250 kg/m^3.

Key words: Bleeding, mediteran soil, organic cement, organic waste, portland cement

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1. INTRODUCTION

The emphasis of research results is oriented to the utilization of waste recycle on materials that do not contribute much in the community life so far. An organic cement is the latest alternative cement beside from portland cement which is made through organic waste recycling system and by substitution with mediteran soil [1]. This study aims as the development of previous experimental research that researchers have done titled Chacarteristic Of Compressive and Tensile Strength Using The Organic Cement Compare With Portland Cement [2].

The necessity of building materials need to be addressed by conducting research through the utilization of recycling waste to obtain building materials that can be an alternative material [3]. Currently, waste problem is a problem faced all over the world. Gradually, the high volume of waste has a negative impact on the environment. Handling of waste management is necessary because of there is a big negative impact that can be produced. The problem of garbage seems not a simple thing, because as long as there is human life then the problem will always arise. The management of municipal solid waste in Indonesia becomes an actual problem along with the increasing population growth which has an impact on the increasing number of garbage and the occurrence of aesthetic degradation problem around the landfill which has the potential to cause social conflict with the surrounding community [4]. Waste is goods or objects that have been depleted the value of the benefits and create a negative impression that makes the waste viewed as objects that must be removed from the home page any way [5].

The high growth of waste volume is often coincides with the high rate of population growth. Therefore, the current waste problem can be said to be a world problem at hand. Besides that, with good handling and good management of waste, environmental saving has been done. Handling of organic waste through the combustion process with furnace at a temperature of 700^{o}C until become ashes will contain elements of 69.7% $CaCO_3$, 12.1% KCl; 3% SiO_2, 8.1% Fe and 3% Al_2, while shellfish ash contains 100% $CaCO_3$ [6]. Along with economic growth, per-capita garbage production will continue to rise so prediction in 2030 will reach 1.2 kg / capita / day for urban areas and 0.55 kg / person / day for rural areas. In Indonesia organic waste is a major component in waste. The proportion of organic waste is between 34-70%, 20-30% higher than most countries in Europe [7].

Mediteran soil is a soil formed from weathering of sedimentary rock and limestone rock. This type of soil contains a considerable amount of carbonate and other compounds of iron, water, aluminum, and some other organic matter [8].

Clay undergoes a change consisting of several stages when the clay is burned, both primary and secondary clays. The first change that occurs in primary and secondary clays when burned, is the loss of free water, especially for secondary clays will be followed by the burning of other organic materials, such as humus, leaves, and twigs contained in the clay. On subsequent changes the chemical water content will be lost. Primary and secondary clays contain free silica in the form of sand, quartz, flint and crystals. Silica is the subject for changing the shape and volume of clay at a certain temperature. Some changes are fixed

(conversion) and others are reversible. Clay that through the combustion process with temperatures exceeding 600ºC will change into a solid, hard and permanent mineral [9].

Increased demand for housing and infrastructure automatically demands the need for ever-increasing building materials. Increased need of building materials must be addressed with the use and discovery of building materials that can provide an alternative. The increase of cement growth to date is still influenced by the high development done by the private sector and the high housing demand for the community [10].

A cement that contains mineral elements as a substitute for portland cement is known as composite cement, mixed cement or alternative cement. The added mineral component is called an additional mineral that is reactive and contributes to the hydration process. Fly ash is the most widely mineral used. Another mineral additions are natural pozzolans and microsilica/silica fume. Cement containing mineral elements as a substitute for Portland cement is known as composite cement, mixed cement or alternative cement. The added mineral component is called an additional mineral that is reactive and contributes to the process hydration process. The use of saturated fly ash is one way to reduce high exposure in the process of hydration to the density of cement in concrete [11].

Coal waste in the form of fly ash generated from burning waste disposal at power plants is generally still not utilized in most countries [12].

The greater the percentage of fly ash hydration. then the initial binding time and the end are slower. C3S, C2S, C3A and C4AF compounds will react with water, starting with C3A compounds. The reaction product reacts with the main elements present in the fly ash of silica and alumina thus the chain of hydration reactions will be so long that it will eventually increase the binding time of the concrete. The greater the fly ash content as a substitute for the amount of cement in the concrete mix, the C3S, C2S, C3A and C4AF compounds will decrease as this will result in reduced hydration heat. Reduced hydration heat will slow the reaction so that it will slow down the binding time [13]. Coal fly ash (fly ash coal) granules with very fine dimension equivalent pass sieve # 200. This type contains SiO2, Al2O3, P2O5, and Fe2O3 but the SiO2 content is high enough to reach ± 70 percent. With a high enough silica content allows coal ash meets the criteria as material that has the properties of cement / pozzolan [14]. The use of fly ash creates a reduction in air pollution emissions that have a negative impact on the economy, it has been observed that 0.9 tons of CO2 is produced per tonne of cement production. In addition, the cement composition is 10% of the weight in the cubic yard of the concrete. Thus the use of fly ash makes it possible to reduce atmospheric CO2 emissions as a form of environmentally friendly engineering [15]. The effect of adding a certain amount of fly ash will increase the strength of the concrete [16].

The development of the use of arletrantive sources for the manufacture of cement as well as those developed by Japan which have produced eco-cement made from municipal waste ash through incinerated as a substitute for some of the main raw materials containing 50% of cement raw materials such as mud waste [17].

To create an Eco-Semen CSA Clinker then the appropriate starting raw material needs to be burned at a maximum temperature of 1200-1300 ° C. Reuse of waste materials in the form of phosphogypsum will reduce the temperature and time of the combustion process. Large-scale eco-cement making can be done in conventional rotary kilns used for Portland Cement and producing chemical cement mineralization C = CaO, A = Al2O3, S = SiO2, s = SO3, F = Fe2O3, M = MgO. Ye'elimite 4CaO • 3Al2O3 • SO3 i.e. C4A3s [18].

2. RESEARCH METHODOLOGY

In this experimental research, the tests are conducted on the organic cement concentrate and conducted on the main raw material concentrate of organic cement forming through chemical

laboratory testing. The testing is used to determine the chemical element as well as the laboratory structure and materials to know its physical properties. In chemical laboratory, the chemical element analysis testing is to study the compound of CaO, SiO2, Al_2O_3, Fe_2O_3, SO_3, MgO, Loi, Na2O, K2O, C_3S, C_2S, C3A and C4Af. Chemical element testing method refers to ASTM C-114-07 [19]. The reference is a normative reference that is deemed highly relevant in the process of cement chemical compounds testing.

Physical properties testing methods are conducted in laboratory of structures and materials which include bleeding, air content, and unit weight testings on organic cement concrete and portland cement concrete. To see the feasibility of organic cement, the test sample also includes chemical compound testing to mediteran soil, organic wastes that are household waste, fly ash, bottom ash and clay. The benchmark used in this experimental testing is portland cement.

3. RESULTS AND DISCUSSION

Organic cement formed by utilizing natural materials substitution in the form of mediteran soil with the joint management or organic waste recycling in the form of household waste, fly ash, bottom ash and clay. After all the raw materials are processed, it is conducted the testing of chemical elements that are owned on each of these raw materials. Then, after the mixing of raw materials to form clinkernization, the material management is conducted until it forms organic cement concentrate. Furthermore, this organic cement concentrate is also processed by chemical element testing. To see the feasibility of organic cement concentrate as an alternative cement, the research development that is conducted by the researcher is to study organic cement concentrate on examination of physical properties in the form of bleeding, air content, and unit weight testing.

3.1. Chemical and Characteristic of Organic Cement

Chemical element testing is intended to determine the chemical compound content by comparing the chemical compounds that are contained in the portland cement. Organic cement concentrate is formed by utilizing natural materials substitution in the form of mediteran soil and recycling of organic waste that are household waste, fly ash, bottom ash and clay. Table 1 it shows testing result chemical element of organic cement concentrate. and table 2 it shows testing result chemical element main ingredient organic cement.

Fig 1 shows the burning process of the main ingredients of organic cement. The combustion of raw materials is conducted in a box fire machine that can withstand heat up to 1800^{o} C. Combustion temperature control by using TI-1500 infra red sanfix thermometer tool. To analyze the time setting, the vicat tool was used and to analyze the fineness, the blane tool was used. Examination of chemical compounds was conducted at the chemistry laboratory of the Faculty of Mathematics and Natural Sciences of Hasanuddin University and to know its physical properties, it was conducted in the laboratory of materials, structures and construction of the Faculty of Architectural Engineering Hasanuddin University.

Figure 1. The burning process of the organic cement main ingredients.

To form an organic cement concentrate, all the main ingredients are burned to a temperature of 1400^0 C. After all ingredients are burned for 4 hours, cooling and refinement are performed. The concentrate-shaped material is then subjected to chemical compound testing to see the chemical element feasibility approach to the portland cement chemical element and physical properties test to see the physical feasibility of organic cement in the form of fineness, density, initial and final Setting time, and the normal consistency and application against use in the building in the form of concrete testing to see the feasibility of fresh concrete and hard concrete.

Table 1 Chemical elements of organic cement concentrate compare with portland cement based on ASTM C114-07

Parameter	Unit	Results	
		Organic cement	Portland cement (ASTM –C 114)
C_3S	%	69,90	50-70
C_2S	%	7,30	15-30
C_3A	%	10,3	5-10
C_4AF	%	3,1	5-15
SiO_2	%	21,29	20,6
Al_2O_3	%	7,86	5,07
Fe_2O_3	%	4,40	2,9
CaO	%	68,43	63,9
SO_3	%	3,20	2,53
Na_2O+K_2O	%	1,58	0,88
MgO	%	4,80	1,53

Table 2 The chemical element is the main ingredient of organic cement concentrate

Parameter	Unit	Results				
		Organic waste	Mediteran soil	Clay	Fly ash	Bottom ash
SiO_2	%	46,65	23,68	30,63	22,14	15,20
Al_2O_3	%	2,28	0,44	3,41	3,84	2,99
Fe_2O_3	%	0,18	0,15	0,20	0,20	0,20
CaO	%	11,09	19,35	0,51	6,87	1,41
SO_3	%	1,01	1,66	0,01	0,89	0,15
Na_2O	%	2,24	0,01	0,23	0,37	1,03
K_2O	%	11,98	0,09	0,02	0,58	0,17
MgO	%	0,,02	0,018	0,36	0,03	0,02

Figure 2 below shows the organic cement raw material before the management process becomes organic cement concentrate.

A B C D E

Figure 2 Mediteran soil (A) , Household waste (B), Clay (C), Fly ash (D), Bottom Ash (E)

The percentage of the main ingredients used in the organic cement forming is shown in table 3 below.

Table 3. Percentage of organic cement forming

No	Main composition (Major)				Additional chemical elements (minor)
	Material Source	Major chemical elements	Material Source	Major chemical elements	
1.	Mediteran Soil /S	CaO	60,93	54	SiO2, Al2o3, Fe2o3, Mgo, So3, a2o,K2O
2.	Clay / I	SiO2	30,63	10	SiO_2, Al2O3, Fe2O3, CaO, Na2O, K2O, MgO, SO3
3.	Fly Ash / N	SiO2	22,14	4	Al2O3,CaO, Fe2O3, SO3, Na2O, K2O, MnO, MgO, TiO3,P2O5, HP
4.	Bottom Ash / A	SiO2	15,20	4	CaO, Al2O3, Fe2O3, MgO, K2O, Na2O, HP
5.	Organic waste /R	SiO2	46,65	28	CaO, Al2O3, Fe2O3, MgO, K2O,TiO2, Na2O, P2O5

The empirical formula of the organic cement-forming concentrate can be derived as follows:

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

Legend:

$\sum R_I f$ = Organic Cement Concentrate (kg)
$\sum S$ = Mediteran Soil Concentrate (%)
$\sum I$ = Clay Concentrate (%)
$\sum N$ = Fly Ash Concentrate (%)
$\sum A$ = Bottom Ash Concentrate (%)
$\sum R$ = OrganicWaste Concentrate (%)

3.2. Bleeding and Air Content

The amount of water bleeding as shown in table 4, where for the concrete of organic cement with the cylindrical concrete weight of 3,33 kg has a water bleeding value of 0.04 ml/cm² so that the prediction of water bleeding for 1 m^3 concrete with organic cement is 23,88 ml/cm^2.

Meanwhile, for the concrete that uses portland cement with cylindrical concrete weight of 3,36 kg has a water bleeding value of 0,05 ml/cm^2 and prediction of water bleeding for 1 m^3 concrete with portland cement is 31,83 ml/cm^2. Water volume testing of concrete cylinder bleeding is calculated by reference based on ASTM C 232-99 [20].

Bleeding = V / A ……(ml/cm^2) (2)

Legend:

V = volume of water bleeding from test specimens in ml

A = surface area of the test specimen in cm²

Table 4 Bleeding testing results of concrete with organic and portland cements

	Organic Cement	**Portland Cement**
Specimen Weight	3,33 kg	3,36 kg
Cylinder Volume	0,0016 m³	0,0016 m³
Surface Area of Test Specimen	78,53 cm²	78,53 cm²
Bleeding Value of Test Specimen (V)	3 ml	4 ml
Bleeding Against Test Specimen Area (A)	3/78,53= 4 ml/cm²	4/78,53= 0,05 ml/cm²
Bleeding Prediction on 1m³ concrete	23,88 ml/cm^2	31,83 ml/cm^2

For the air content measurement, it is obtained the results according to table 5 where in this research, the researchers also calculated the air content value of fresh concrete with organic cement test sample compared with the air content value of fresh concrete with portland cement. In Figure 3 A it shows the process of taking and measuring water bleeding between a concrete cylinder with organic cement and a concrete cylinder with portland cement and In figure 3 B it shows the measuring process of air content percentage of fresh air concrete in both organic cement concrete and portland cement concrete. The reference in this air content testing is ASTM C 231-03 [21].

A B

Figure 3 Bleeding measurement process (A), Air content measurement process (A)

Table 5 Air content of concrete cylinders

	Organic cement concrete	**Portland cement concrete**
Concrete Volume	0,0016 m³	0,0016 m³
Correction Factor	1 %	%
Reading Result	3,2 %	2,9 %
Reading Result of Air Content	2,2 %	1,9 %

3.3. Unit Weight

The unit weight of fresh concrete with organic cement is 2081 kg/m³ and its dry concrete weight is 2032 kg /m³, while the fresh concrete weight with portland cement is 2525 kg/m³

and its dry concrete weight is 2405 kg/m³. The composition in analyzing the fresh concrete and dry concrete unit weights between portland cement and organic cement is shown in table 6 below. Figure 4 is a concrete cylinder that is made from organic cement and portland cement concentrates. In the figure also, it shows the measuring process of temperature, specimen weight, and the condition of the cylinder concrete that has been tested tensile.

A B C D

Figure 4 Temperature measurement of cylinder concrete with organic cement (A), Weight measurement of cylinder concrete with organic cement (B), Concrete cylinder with organic cement of tensile test result (C), Concrete cylinder with portland cement of tensile test result (D)

Table 6 Fresh concrete unit weight with organic and portland cements

	Organic cement	**Portland cement**
Cylinder Mold Weight	6,20 kg	6,20 kg
Test specimen Weight	9.53-6,20=3,33 kg	10,24-6,20=4,04 kg
Cylinder Volume	0,0016 cm³	0,0016 cm³
Fresh Concrete	3.33/0,0016=2081	4,04/0,0016=2525
Weight Dry Concrete Weight (28 Days)	kg/m³	kg/m³
	3,33/0,0016=2032	4,04/0,0016 =2405
	kg/m³	kg/m³

4. CONCLUSIONS

From the examination results of chemical and physical properties of organic cement concentrate, it has obtained an indication that similar to the properties of portland cement chemical compounds which in this case used as a comparison sample. In improving the organic cement quality, it is deemed necessary to conduct an advanced experimental research. In the same concrete mix design although the concrete compression test with organic cement is still lower than the concrete with portland cement, but this organic cement can be used for light construction.

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