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Case study

Characteristic of compressive and tensile strength using the organic cement compare with portland cement

Muhammad Syarif[a,*], Victor Sampebulu'[b], M. Wihardi Tjaronge[c], Nasruddin[b]

[a] Student of Doctoral Degree, Hasanuddin University Of Indonesia, Indonesia
[b] Dep of Architecture, Hasanuddin University Of Inonesia, Indonesia
[c] Dep of Civil Engineering. Hasanuddin University Of Indonesia, Indonesia

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ABSTRACT

The waste problem is a problem faced throughout the world. This research aims to save the environment with on the utilization of recycling waste materials that do not contribute much in people's lives over the years. Organic cement is an alternative cement besides portland cement made from organic waste recyled and substitution of mediteran soil. The research is oriented to chemical compounds, compressive strength, and tensile strength testings of concrete by using organic and portland cements. Age of concrete in the research are 3, 4, 14, 21, and 28 days old. Result for compressive test of cylinder concrete with organic cement, it obtained 6.10 MPa while the cylincer concrete with portland cement, it obtained 20.22 MPa. For tensile strength test of cylinder concrete with organic cement on 28-days-old concrete reached 1.09 MPa and those with portland cement reached 2.01 MPa. From the physical test result, it obtained the density of organic cement is 3.01 g/ml, while for the density of portland cement is 3.16 g/ml. From the analysis of organic cement chemical compounds through laboratory testing methods result, it found indications that resemble portland cement chemical compounds that are CaO;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%, and C4Af; 6,97%.

1. Introduction

Currently, the waste problem is a problem faced throughout the world. Gradually, the high volume of waste has a negative impact on the environment. Handling of waste management is necessary because of the huge negative impact that can be generated. The waste problem seems not a simple matter, as long as there is human life then the problem will always arise. Urban waste management in Indonesia is a real problem as population growth has an impact on increasing the amount of waste and the occurrence of aesthetic degradation problems around landfills that have potential to cause social conflict with surrounding communities [1].

Along with economic growth, per capita garbage production will continue to increase so it can be predicted in 2030 will reach 1,2 kg / capita / day for urban areas and 055 kg / person / day for rural areas. In Indonesia, organic waste is a major component of waste. The proportion of organic waste is between 34–70% which is 20–30% higher than most countries in Europe [2].

* Corresponding author.
E-mail address: muhsyarif00@gmail.com (M. Syarif).

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The high growth of waste volume coincides with high population growth rate. Therefore, the current waste problem can be said to be a world problem. In addition, with good handling and good waste management, environmental savings have been made.Handling of organic waste through the combustion process with the furnace at 700 °C to ashes will contain elements of 69.7% CaCo3, 12.1% KCl; 3% SiO2, 8.1% Fe and 3% Al2, while shellfish ash contains 100% CaCo3 [3].

Therefore, in dealing with it, it is deemed necessary to find the best solution to resolve current waste problems. This research aims to save the environment with emphasis on the utilization-oriented form of recycling waste materials that do not contribute much in people's lives over the years.This research is a renewable research to obtain alternative building materials, especially alternative cement in addition to portland cement which has been used in public life.

The increase in cement growth is still influenced by the high level of private sector development and the high demand for housing for the community [4]. The increasing demand for housing and infrastructure automatically demands the need for building materials that are also increasing.The need for building materials must be overcome with the use and discovery of building materials that can provide an alternative [5]. Organic cement is the newest alternative cement in addition to portland cement made through organic waste recycling systems and by substitution of mediteran soil [6].

The development of the use of alternative sources for the manufacture of cement has also been developed by Japan which has been producing eco-cement made from city ash waste through combustion in lieu of some of the main raw materials containing 50% of cement raw materials such as sewage sludge [7]. To create Eco-Cement CSA Clinker,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 furnace used for portland cement and produce chemical cement mineralization of C = CaO, A = Al2O3, S = SiO2, s = SO3, F = Fe2O3, M = MgO, Ye'elimite 4CaO, 3Al2O3, SO3 and C4A3s [8].

Mediteran soil is a soil formed from weathering of sedimentary rock and limestone. This type of soil contains a considerable amount of carbonate and other compounds of iron, water, aluminum, and some other organic materials [9].

Cement containing elements fly ash as a substitute for Portland cement is known as composite cement, cement mix, or alternative cement. Additional mineral components are called reactive supplemental minerals and contribute to the hydration process. Other elements additions include natural pozzolans and microsilica / silica fume [10].

The compressive and tensile strengths of concrete created in hot weather conditions will be reduced due to the loss of mixing water caused by high evaporation. One method to overcome the problem is the use of saturated fly ash aggregates. The water content in the fly ash aggregate can flow out into the cement solids to continue the hydration process [11].

The compressive strength result of concrete with the rice husk ash addition showed the optimal percentage to increase the compressive strength of concrete so that the compressive strength increases, the age of the concrete also increased [12].

The highest tensile strength in 14-day-old concrete with the addition of 5% bagasse ash would have a tensile strength of 6221 MPa or an increase of 2.45% of the concrete without using the addition of bagasse ash [13].

2. Research methodology

Organic cement is made from recycling organic waste (household waste, bagasse waste, rice husk waste) and combined with mediteran soil that is limestone type. All materials are burned to a temperature of 1450 °C. The cement clinker is produced by feeding the crushed, ground and screened raw mix into a rotary klin and heating to temperature of about 1300 °C–1450 °C, partial fusion of the mix occurs with the formation of C3S, C2S, and clinker [14]. After combustion and cooling, the resulting clinker is then refined as does portland cement. The composition of each forming material includes; 30% organic waste, 7% rice husk waste, 7% bagasse waste, and 56% mediteran soil. The use of the composition of the ingredients is taken because of the results of conducted chemical compound tests, the chemical content of the compound value is closer to the chemical content of portland cement which in the percentage variation of the material other than the above has also been tested chemical compounds but the results obtained did not indicate the approach chemical elements of portland cement.The combustion is done inside the furnace by combust the rice husk waster at 600 °C, then the bagasse waste at 700 °C, the organic waste at 700 °C, and the mediteran soil at 1000 °C. After that, all the fuel is put together and combusted again at 1400 °C. Testing the feasibility of organic cement carried out in this case is the examination of physical and chemical properties.

In this experimental study, the testing of organic cement concentrate and the main raw material concentrate of organic cement formation. For testing chemical compounds, it carried out in a chemical laboratory. The studied chemical elements refers to the chemical elements present in the portland cement which are CaO, SiO2, Al2O3, Fe2O3, SO3, MgO, Loi, Na2O, K2O, C3S, C2S, C3A and C4Af. The chemical element testing method refers to ASTM C-114-07 [15] which is a normative reference and considered to be highly relevant in the process of testing chemical compounds of cement.On examination of physical properties, measurements of compressive strength and tensile strength of concrete cylinders were measured. The used sample is cylindrical concrete with a height of 30 cm and a diameter of 15 cm. The concrete compressive examination was performed after the test specimen was 3, 7, 14, 21,and 28 days-old, while for tensile strength test was done on specimen of 28-days-old. Testing is done by using Universal Testing Machine (UTM). The compressive strength test is based on ASTM C 39 / C39M-05 [16]. The value of tensile strength is calculated using the formula based on the normative reference ASTM C-496 / C966M-17 [17].Testing of concrete slump test using ASTM C-143 reference [18]. For normal consistency test value, it is calculated by reference standard according to ASTM C 187-04 [19]. As for the portland cement and organic cementfineness test, it is calculated by reference standard according to ASTM C 430-08 [20]. Fig. 1 shows an example of a cylindrical concrete

Fig. 1. Compressive strenght test process.

with an organic cement after a compressive strength test. The compressive strength of concrete is the value of the load per unit area that causes the concrete test object to be destroyed when receiving a certain compressive force produced by the press machine using the formula:

$$fcr = fc + 1{,}64 \times s \quad (1)$$

With:

fcr σ = Average compressive strength (Kg/cm^2)

S = Standard deviation

In order to obtain good fresh concrete conditions, the specimens were placed at room temperature of about 20 °C, 30 °C and 35 °C. The temperature of the cement was conditioned to about 20 °C, 40 °C, and 60 °C [21]. In obtaining the correct proportions of mixtures according to plan, the mix design is made as shown in Table 1 below.

3. Results and discussions

3.1. Chemical of organic cement

Chemical element testing is intended to determine the chemical content of compounds by comparing the chemical compounds contained in portland cement. Organic cement concentrate is formed by utilizing the substitution of natural ingredients in the form of mediteran soil and recycling organic waste that are household waste, rice husk waste, and bagasse waste. The main ingredient of organic cement is shown by the testing result of chemical element of main material concentrate in Tables 2, 3, 4 and 5. Where the concentration analysis result of mediteran soil chemical concentrate as shown in Table 2. In Table 3, it showed the concentrate test result of organic waste chemical compound. Table 4 showed the chemical compounds of rice husk waste. Then in Table 5 showed the concentration testing result of bagasse waste. From the analysis results of organic cement chemical compounds, it has found similar indications to portland cement chemical compounds that are: CaO; 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%, dan C4AF; 6,97%.

Table 1
Proportion of mix design.

Sampel	WC (%)	Tempe rature (°C)	Curing	Water (kgm^3)	Cement (kgm^3)	Maximum size (mm) Aggregates (mm)		Materials (kg/m^3)	
						Fine	Coarse	Fine	Coarse
Organic Cement	52	30	30 °C–60 °C	195	375	2,5	20	538	1232
Portland Cement	52	30	30 °C–60 °C	195	375	2,5	20	538	1232

Table 2
Chemical elements of mediteran soil.

Parameters	Unit	Result
SiO_2	%	13,11
Al_2O_3	%	13,71
Fe_2O_3	%	1,18
CaO	%	40,93
SO_3	%	1,12
Na_2O+ K_2O	%	0,06
MgO	%	0,04

Table 3
Chemical elements of household waste.

Parameters	Unit	Result
SiO_2	%	32,56
Al_2O_3	%	4,37
Fe_2O_3	%	2,79
CaO	%	19,53
SO_3	%	0,05
Na_2O	%	0,15
K_2O	%	2,27
MgO	%	3,72
P_2O_5	%	0,80

Table 4
Chemical elements of rise husk waste.

Parameters	Unit	Result
SiO_2	%	71,27
Al_2O_3	%	0,91
Fe_2O_3	%	2,34
CaO	%	2,04
K_2O	%	0,60
MgO	%	1,11

Table 5
Chemical elements of baggase waste.

Parameters	Unit	Result
SiO_2	%	38,02
Al_2O_3	%	3,67
Fe_2O_3	%	4,04
CaO	%	12,88
SO_3	%	0,01
Na_2O	%	0,08
K_2O	%	0,49
MgO	%	1,47

Fig. 2. Mediteran soil (A), household waste (B), Rice husk waste (C), Bagasse wste (D).

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

Testing of chemical compounds on the organic cement concentrate has been carried out as shown in Table 6 below, where chemicals are formed such as ASTM C114-07 as opened in Table 7 below.

3.2. Compressive strength test

The result of cylinder concrete compressive strength with portland cement is 20.22 MPa and organic cement concrete is 6.10 MPa. The graph of the compressive strength test results can be seen in Fig. 3, which is a compressive strength test of concrete sample with comparison between compressive strength using portland cement and using organic cement. The standard reference uses the formula according to ASTM C-39 / 39M-05.

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

Table 6
Chemical elements of organic cement.

Parameters	Unit	Result
C_3S	%	66,72
C_2S	%	3,98
C_3A	%	12,9
C_4AF	%	6,9
LOI	%	24,5
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 7
Chemical elements of portland cement based on ASTM C114-07.

Parameters	Unit	Result
C_3S	%	50-70
C_2S	%	15-30
C_3A	%	5-10
C_4AF	%	5-15
LOI	%	1,58
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

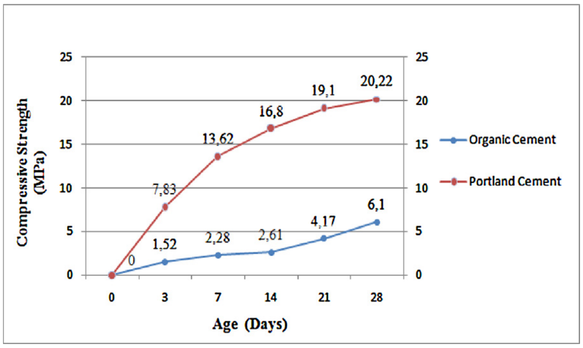

Fig. 3. Graph compressive strength of organic and portland cements.

With:
σ = Compressive stress of concrete characteristics (Kg/cm^2),
P = Compressive Force (Kg)
A = Cross-sectional area of cylinder concrete compressive area (cm^2)

3.3. Tensile strength test

The cylinder tensile test or splitting test is performed to determine the resistance of the specimen against the mechanical and thermal pressures calculated using the normative reference formula ASTM C-496 / C966M-17.

$$\text{Tensile strength test} \rightarrow fct = \frac{2 \times P}{LD} \quad (3)$$

With:
fct = Tensile Strength, in MPa,
P = Maximum test load (N),

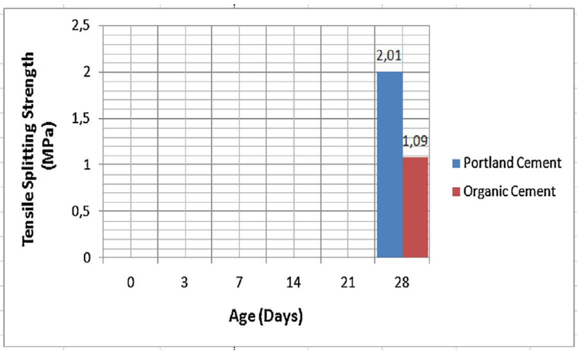

Fig. 4. Graph of tensile splitting strength with water curing method.

A B

Fig. 5. Cylinder concrete with organic cement from tensile splitting test (A).
Cylinder concrete with portland cement from tensile splitting test (B).

L = Specimen length (mm) and

D =Specimen diameter(mm)

From the result of physical test, organic cement density is 3.01 g/ml, while for portland cement is 3,16 g/ml. The resulting value of the specimen is calculated by reference to the normative standard using the formula in accordance with ASTM C-188-95 [22]. For tensile test results, portland cement reached 2.01 MPa and the organic cement reached 1.09 MPa organic cement. The graph of the tensile strength test results is shown in Fig. 4.

In Fig. 5A and B below, it shows the difference between the pore density concrete using organic cement and portland cements.

From the figure, it can be seen that bulk density and concrete porosity with organic cement tend to be smaller than concrete with portland cement. It is because the organic cement fineness level is lower than the portland cement fineness which is seen in the examination of previous physical properties. It is found that the fineness value of the material for organic cement passing through 200 mesh sieve is 1224 kg/m^3, while for portland cement is 1267 kg/m^3.The enormity of organic cement porosity showed that the specimen concrete has a large pore due to the water evaporation and the expansion of the concrete filler material. It is one of the fall causes of the quality of concrete in carrying the load, especially the ability of concrete in carrying press load. The high content of silica oxide (SiO2) to rice husk ash and ash of bagasse which reaches 71.27% gives good pozzolanic properties used as partial substitution material on cement so that it is used as substitution material in organic cement.However, the pozzolanic property of both materials also possesses high water-absorbing properties. As a result of substitution of both materials against mediteran soil and organic waste, it also affect the use of cement water factor (fas), as shown in the normal consistency test on organic cement is 37% and for portland cement is 25%. The standard reference uses the formula according to ASTM C 187-04.

3.4. Concrete workability

In obtaining good and homogeneous stirring of the material, a suitability between water use and the ratio of the coarse aggregate, fine aggregate and cement which are used. In this case, the slump value test is performed to find out the workability of fresh concrete before applied to the casting work of the concrete cylinder test object.Slump measurement is closely related to the application of the planned concrete mix design. In this test, 0.52% of the cement water factor (fas) is used and Fig. 6 indicates the process of testing the fresh concrete slump by organic and portland cements.

Fig. 6. Slump test of fresh concrete from organic cement and concrete portland cement.

The slump test plan is 12 cm and the slump test obtained is:

- For fresh concrete with portland cement, it is $\frac{10{,}7+14{,}4}{2} = 12{,}55\text{cm}$
- For fresh concrete with organic cement, it is $\frac{9{,}8+10{,}9}{2} = 10{,}35\text{cm}$

4. Conclusion

Through the results of the analysis on this research, the organic waste that has been the problem of the world now can be done the development of its utilization, especially to become alternative building materials in the form of alternative cement which is organic cement in addition to portland cement. From the examination of physical characteristic and chemical properties of organic cement concentrate, it has been obtained an indication that the organic cement chemical compound resembles the chemical compound of portland cement. While the physical characteristics are still under the physical characteristics of portland cement, especially on the ability of the compressive and tensile support. In an effort to improve the quality of organic cement, it is deemed necessary to conduct further experimental research.

Declarations of interest

None.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://doi.org/10.1016/j.cscm.2018.e00172.

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