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Dekan Fakultas Teknik Universitas Muhammadiyah Surakarta menugaskan kepada saudara:

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Surakarta, 18 Oktober 2012
Dekan,

Ir. Agus Riyanto, MT

TANGGAL DATANG	
TANGGAL KEMBALI	

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Universitas Muhammadiyah Surakarta
54th Anniversary

INTERNATIONAL CONFERENCE

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Enhancement of Welfare Growth and Prevention of the Side Impact

CERTIFICATE

This is to certify that

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Presenter

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Universitas Muhammadiyah Surakarta
Surakarta, 20 October 2012

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DURABILITY OF 'TULAKAN' SOIL AS NATURAL POZZOLAN TO SUBSTITUTE PORTLAND CEMENT AS CONSTRUCTION MATERIAL

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Abstract

Tulakan soil containing compounds that needed in the formation of conventional cements, namely oxide compounds such as CaO, SiO_2, Al_2O_3, and Fe_2O_3. Tulakan soil contains siliceous and aluminous materials which react with calcium hydroxide in the presence of water. Based on the composition of Tulakan soil, Tulakan soil in this study classified in the class N pozzolan. The amount of $SiO_2 + Al_2O_3 + Fe_2O_3$ are more than 70% and SO_3 content is less than 4% by weight (based on ASTM C618-92). Concrete mix design using SK-SNI-T-15-1990-03. The ratio of Tulakan soil is vary at 10% ; 15% ; 20% ; 25% of Portland cement composition. The use of Tulakan soil as a partial replacement for cement can effectively maintain the compressive strength of concrete, it can even raise the value of compressive strength of concrete at a certain composition. A hundred concrete cylindric samples have been tested to study the concrete performance at two water cement ratio that are 0.4 and 0.5. Compressive strength of concrete with replacement of Tulakan soil + 10% of lime has a trend to increase and have a higher tendency to remain above the average of normal concrete. Overall, both for concrete with Tulakan soil or for concrete with Tulakan soil + lime are able to maintain even raise the value of compressive strength in concrete. As a result, the Tulakan soils effectively substitute the Portland cement, as it can increase the concrete compressive strength up to 3.24% on the percentage of Tulakan soil replacement of 10% – 20%. The split tensile strength test was able to raise up to 2.513% of normal concrete and the tension pullout bond test survive and rise up to 9.783% of the normal.

Keywords: compressive strength ; concrete performance ; pozzolan ; soil

Presenting Author's biography

Yenny Nurchasanah was born in Solo, central java, Indonesia, on March 31, 1977. She graduated from Muhammadiyah University of Surakarta, central java, Indonesia in 2000 and finished the master program at Brawijaya University, Malang, east java, Indonesia in 2006. Her employment experience are become a lecturer and researcher at Muhammadiyah University of Surakarta from 2001 until 2012.

1. INTRODUCTION

Ministry of Industry noted the national cement demand in 2010 reached 42 million tons, an increase compared with 2009 is 38.4 million tonnes. In fact, the national cement demand in the next year is projected to reach 46.2 million tons, up by 10% driven by infrastructure development, announced by the government and the national economy that is believed to continue to grow (bisnisindonesia/Rahmat). On the other hand, the operation of the cement industry produce some negative impacts such as emissions of combustion gases and dust emissions. Emissions of gases such as calcinations in the kiln gases SO_2, NO_2, and especially dust / particulates are severe for the environment (i.e. air pollution). Another aspect of this activity is the use of natural resources, in the form of coal and IDO (Industrial Diesel Oil), with the impact of the reduction of natural resources as coal and oil.

The existence of natural pozzolan in Indonesia are often found in areas near the active mountains such as Nagrek (West Java), Mount Moriah (Central Java), Mount Lawu (East Java) and other areas of Java, Sumatra, Sulawesi, Nusa Tenggara and Halmahera. Pozzolan material itself has long been known in Indonesia as a building material that is mixed lime outages. But the processing is still limited and has not been used optimally. It required more advanced technology in its process. Wherever and whoever cements produce, the same materials are still used, namely limestone and clay. Limestone mine is the result of a compound containing calcium oxide (CaO). The clay contains silica dioxide (SiO_2) and aluminum trioxide (Al_2O_3). Both materials are then subjected to melt the combustion process.

Tulakan soil is a kind of soil that comes from Tulakan, Pacitan, Central Java. This soil has a greyish color similar to the color of cement. Tulakan soil obtained by digging at the depth of approximately 8 meters. By people in that areas frequently used in making well, because if frequently exposed to water it will hardened. Based on the results of chemical analysis has been done by Balai Penyelidikan dan Pengembangan Kegunungapian (BPPK) of Yogyakarta, the soil element has a content of pozzolan. Pozzolan properties are the properties of materials in a delicate state can react with the lime (active) and water at room temperature (24°C - 27°C) to form a solid compound and is insoluble in water.

Tulakan soil is soil that contains elements of silicates and aluminates. Therefore, when mixed with lime, the character will behaves like cement because of the general content of cement is limestone, silicate, and aluminate. Thus, the Tulakan soil containing compounds that needed in the formation of conventional cements, namely oxide compounds such as CaO, SiO_2, Al_2O_3, and Fe_2O_3.

2. PROBLEM IDENTIFICATION

Further research needs to analyze the characteristics of Tulakan soil in its efforts to replace cement as a construction material. How the role of Tulakan soil in replacing cement as materials, and how its performance as a concrete structure, if some of the cement as one component of concrete materilas was replaced with Tulakan soil.

3. LITERATURE REVIEW

Pozzolan

Pozzolan is a compound material containing silica or silica-alumina and alumina, which has no binding properties such as cement. In the form of fine granules and the presence of water, these compounds will react with calcium hydroxide. At normal temperature will form calcium hydrate compounds that are hydraulic and have a relatively low solubility rate.

Pozolan quality standards according to ASTM C618-92a are classified into three classes, each class is determined chemical composition and physical properties. Pozzolan have a good quality if the number of levels of $SiO_2 + Al_2O_3 + Fe_2O_3$ is high and have a high reactivity with lime.

Pozzolan class are :

N : Natural pozzolan or the product of combustion, natural pozzolan that classified in this type such as diatomoic soil, opaline cherts and shales, tuff and volcanic ash or pumicite, which can be processed through a combustion or not. Various material properties of combustion products that have a good pozzolan characteristic.

C : fly ash that produced from lignite burning or subbituminous coal. This Fly ash has a pozzolan properties beside has the properties of cement with lime levels greater than 10%.

F : fly ash that produced from anthracite burning or coal. It has the properties of pozzolan fly ash.

The types of pozzolan in the process of formation in ASTM 593-82 is classified into two types namely natural Pozzolan and artificial Pozzolan. Natural Pozzolan is the natural material formed from sedimentation of volcanic ash or lava that containing active silica, when mixed with lime it will hold the cementation process. As for artificial pozzolan, there are many kinds, the combustion of furnace, and the utilization of waste that processed into ash that containing silica reactive with through the combustion process, such as fly ash, rice husk ash, silica fume and others.

Natural pozzolan has the quality, shape and color vary from one deposit to another. For example that the quality of pozzolan in Kalibagor, Situbondo has better quality than from Wlingi, Blitar. Because of different quality natural pozzolan in, it is necessary to standardize the quality of pozzolan used with ASTM to control their quality.

According to the Requirements of Chemistry, based on ASTM C618-92a, the content of pozzolan can be seen in the following table:

Table 1. Chemical Requirements Based on ASTM C618-92a

Composition	Class		
	N	**F**	**C**
$SiO_2 + Al_2O_3 + Fe_2O_3$ (min, %)	70.0	70.0	70.0
SO_3 (max, %)	4.0	5.0	5.0
Na_2O (max, %)	1.5	1.5	1.5
moisture content (max, %)	3.0	3.0	3.0
Lost of incandescent (max, %)	10.0	6[A]	12

[A] The use of class F pozzolan with Lost of incandescent up to 12% subject to approval and supported by the results of laboratory testing.

Natural pozzolan properties of concrete are essentially similar to other pozzolan, which slow down setting time so that the initial strength of the concrete low, reacts with $CaO(OH)_2$ forming calcium silicate hydrate (CSH), thereby reducing the content of $CA(OH)_2$ in concrete, making concrete resistant to sea water and sulfate.

In the cement hydration process, in addition to producing compounds of CSH, CAH and CAF that are as adhesives, also produces limestone which figures high solubility and alkaline. With the pozzolan, the lime will react to form CSH, CAH and CAF which has properties as an adhesive.

Cement with pozzolan-added material will have properties such as heat of hydration will drop due to the addition of pozzolan content of C_3A in the cement is reduced. Mixture of cement paste at normal consistency condition, the water cement factor will increase with the pozzolan.

Workability of concrete using pozzolan cement would be better, change the setting times, and change the strength of concrete.

Concrete Design

Concrete mix design using SK-SNI-T-15-1990-03. The design procedures covers determination of compressive strength of concrete (f'_c), setting the value of standard deviation (S), calculating the margin (M), design of compressive strength of concrete (f'_{cr}), design the type of Portland cement, design of aggregate type, design of water cement ratio, determination of slump value, design the maximum of aggregate size, design of the amount of water, design of the amount of cement, design of the ratio of weight between fine aggregate and coarse aggregate, design of aggregate specific gravity, design of concrete specific gravity, design of the needs of fine aggregate and coarse aggregate.

4. RESEARCH METHOD

Concrete Materials

Basic materials used are:

- Portland Cement Type I, used as a hydraulic binder of concrete
- Fine aggregate (sand), used as filler material of concrete
- Coarse aggregate (gravel), used as filler material of concrete. Coarse aggregate used is limited to a maximum diameter of 10 mm.
- Water, used as reagents Portland cement which also serves as a lubricant of concrete mixing.
- Soil of Tulakan-pacitan as partial cement replacement in concrete mixtures.
- Lime, the lack of CaO can be satisfied by the addition of lime.

Fig. 1. Soil and sampling sites

Stages of Research

Stage I : Materials Inspection

At this stage prepared all the materials used in the study, such as type I portland cement, Tulakan soil, lime, sand, gravel, and water. Quality inspection of materilas was carried out before all materilas are mixed.

Cement and Tulakan soil inspection covers grain fineness test and the visual tests. Fine aggregate (sand) covers organic content test, silt content, specific gravity, and gradation of grain.

Coarse aggregate (gravel) inspection covers grain hardness test, specific gravity, unit weight, and grain grading. These materials, the quality must meet the requirements set out in regulations.

Stage II : Mix Design

Mix concrete design in this study using the design method according to SNI (Standar Nasional Indonesia). Water cement ratio used is 0.5. Composition of Tulakan soil in the mixture is (0%, 10%, 15%, 20%, 25%) of the amount of cement used, with 5 test specimens for each variation of the mixture.

Table 2. Concrete mix design (with Tulakan soil)

Tulakan soil (%)	Water (liter)	Sand (Kg)	Gravel (Kg)	Cement (Kg)	Tulakan soil (kg)
0				6,473	0
5				5,502	0,6473
10	3,236	12,58	16,274	5,178	0,9709
15				4,855	1,2946
20				4,531	1.6182

Table 3. Concrete mix design (with Tulakan soil + lime)

Lime (%)	Tulakan Soil (%)	Cement (Kg)	Lime (kg)	Tulakan soil (kg)
0	0	6,473	0	0
10	5	5,502	0,6473	0,3237
	10	5,178	0,6473	0,6473
	15	4,855	0,6473	0,9709
	20	4,531	0,6473	1,2946

The content of CaO is still a small on the Tulakan soil. Lack of CaO can be satisfied by the addition of lime. Composition of Tulakan soil with the addition of lime to the mixture is (10% lime + Tulakan soil 0%, 5%, 10%, 15%, 20%) of the amount of cement, with five test specimens for each variation of the mixture.

Stage III : Preparation of Test Specimens

Preparation of the test object is executed after the calculation of the mixture design is completed, and preparation of equipment and materials must be in good condition.

Slump test. Tests for slump value is intended to determine the viscosity (consistency) of the concrete paste that has been created, using Abram's cone with a diameter of the top is 10 cm, the bottom diameter is 20 cm and 30 cm of high. Required slump value was 7.5 cm to 10 cm.

Curing. Concrete treatment carried out in order to keep the fresh concrete surface is always in humid conditions.

Specific gravity test. Specific gravity test of concrete intended to determine the density of the concrete.

Stage IV : Specimens Test

Mortar compressive strength test. Compressive strength test of mortar to obtain the compressive strength value at some certain age to determine the quality of cement-soil is used.

Concrete compressive strength test. The objects are test on the 28^{th} day. The day before testing, the test object is lifted from the tub soaking, dried with aerated. Then the cylinder is removed and placed sentries on a machine, in this case using Universal Testing Machine. Once ready, it

starts loading with the loading speed is set on 15 MPa/min. During the test, note the value of load and shortening the test object. Observations made until the test object crush.

Stage V : Analysis

Mortar test. Mortar compressive strength will be obtained at a certain age to determine the quality of the soil + cement.

Compressive strength test. The data of cylinder compressive strength test shows in the form of the P load and shortening the test object that can read from the dial gauge. The value is depicted in a graph of the stress-strain relationship. Concrete compressive strength (f'_c) is obtained by calculating the compressive strength of concrete formula. The average value takes from the five test objects. From comparing the average compressive strength values between the variation of test objects, it can be seen the influence of soil composition on the compressive strength of concrete.

5. ANALYSIS and DISCUSSION

Tulakan Soil

The results of chemical analysis conducted in Balai Penyelidikan dan Pengembangan Teknologi Kegunungapian (BPPTK) Yogyakarta, showed :

Table 4. Composition of Tulakan soil compounds

Compound	Composition (%)
SiO_2	53,36
Al_2O_3	14,68
Fe_2O_3	7,66
CaO	4,87
MgO	1,10
Na_2O	2,15
K_2O	2,69
MnO	0,07
TiO_2	1,08
P_2O_5	0,27
H_2O	4,20
HD	7.84

Based on the composition of Tulakan soil, Tulakan soil in this study classified in the class N pozzolan, can be seen from **Table 1**. The amount of $SiO_2 + Al_2O_3 + Fe_2O_3$ are more than 70% and SO_3 content is less than 4% by weight (based on ASTM C618-92).

Compressive strength test

Concrete with Tulakan soil

Comparison between normal concrete cylinders with a concrete cylinder that replaced some cement with Tulakan soil shows the compressive strength of each variation.

Replacement of cement with the soil by 10%, rose 0.755 MPa or 2.59% of compressive strength of normal concrete, from 29.048 MPa to 29.803 MPa.

The replacement of soil by 15%, rose 0.943 MPa or 3.24% of compressive strength of normal concrete to 29.991 MPa.

The replacement of soil by 20% increasing 0.97% or 0.283 MPa of compressive strength of normal concrete to 29.331 MPa.

While the replacement of soil by 25%, decreasing 0.849 MPa or 2.93% of normal concrete compressive strength of 29.048 MPa to 28.199 MPa.

It can be seen that replacement of cement with the soil by 15%, reaching a maximum compressive strength of concrete, which is 29.991 MPa and at the replacement of 25%, decreased to 28.199 MPa.

Thus, replacement of cement with the Tulakan soil, will be effective in the range between 10% - 20% which can still be used as a mixture of the concrete.

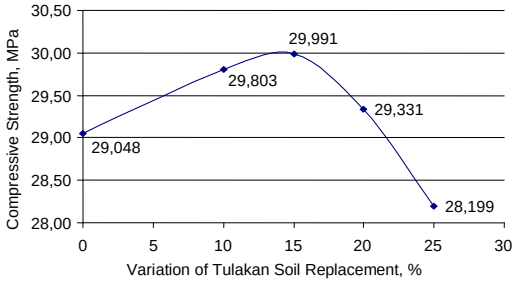

Fig. 2. Effects of replacement of cement with the Tulakan soil in the specimens

Concrete with Tulakan Soil + Lime

Normal concrete has a compressive strength of 29.048 MPa. After replacement with 5% Tulakan soil + 10% lime, the compressive strength increase 9.092% to 31.689 MPa.

The replacement of 10% Tulakan soil + 10% lime, becomes 32.632 MPa of compressive strength, up 12.338% of normal concrete.

The replacement of 15% Tulakan soil + 10% lime, compressive strength rose to 31.877 MPa or 9.739% of normal concrete.

The replacement of 20% tulakan soil + 10% lime increase 9.415% to 31.783 MPa.

So the optimum of compressive strength is 32.632 MPa, occurred on the replacement of concrete with 10% of Tulakan soil + 10% of lime.

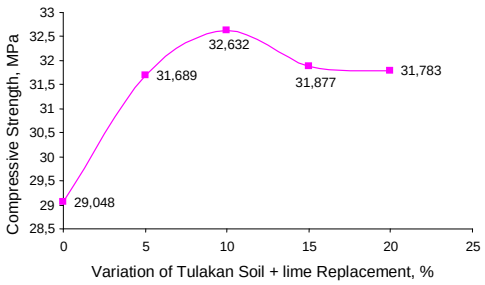

Figure 3. Effects of replacement of cement with the Tulakan soil + lime in the specimens

Table 4. Composition of Tulakan soil compounds

Concrete type	f'c (MPa)	Compare to Normal Concrete
Normal	29,048	0%
(10% lime + 5% Tulakan soil)	31,689	+ 9,092%
(10% lime + 10% Tulakan soil)	32,632	+ 12,338%
(10% lime + 15% Tulakan soil)	31,877	+ 9,739%
(10% lime + 20% Tulakan soil)	31,783	+ 9,415%

6. CONCLUSION

Based on the composition of Tulakan soil, Tulakan soil in this study classified in the class N pozzolan, on the amount of $SiO_2 + Al_2O_3 + Fe_2O_3$ are more than 70% and SO_3 content is less than 4% of total weight (based on ASTM C618-92).

The use of Tulakan soil as a partial replacement for cement can effectively maintain the compressive strength of concrete, it can even raise the value of compressive strength of concrete at a certain composition, which is on the percentage replacement of cement between 10% to 20% as an ingredient in concrete mixtures.

Compressive strength of concrete with replacement 5% to 20% of Tulakan soil + 10% of lime has a trend to increase and have a higher tendency to remain above the average of normal concrete.

The split tensile strength test was able to raise up to 2.513% of normal concrete and the tension pullout bond test survive and rise up to 9.783% of the normal

Overall, both for concrete with Tulakan soil or for concrete with Tulakan soil + lime are able to maintain even raise the value of compressive strength, the split tensile strength and the tension pullout bond in concrete.

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