ECO FRIENDLY HIGH EARLY STRENGTH SELF COMPACTING CONCRETE USING KAOLIN AND WASTE MARBLE DUST

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Abstract

The growth and development of infrastructure in Indonesia is currently growing very rapidly, and the cement production process produces the second largest amount of carbon dioxide after waste, which plays an important role in the current global warming. Self compacting concrete is one of the biggest innovations in the field of construction, Self compacting concrete is one of the biggest innovations in the construction field, where this concrete has high workability but does not ignore compressive strength. Therefore, new, sustainable materials are needed to replace cement production, but they are also required for the workability required to make self-compacting concrete. Green concrete concept, the use of kaolin, and marble dust waste, can be a solution to replace some cement. This innovation research uses XRF or X-ray fluorescence methods to identify and analyze the constituent elements of self-compacting concrete innovations. In this study, self-compacting concrete was obtained using (marble dust waste) which replaced 15% cement, and kaolin which replaced 10% concrete waste. with the main element calcium oxide (CaO) and containing (SiO) can be used as an additive or partial replacement of cement in the manufacture of concrete and kaolin can be obtained from kaolin mines spread across Indonesia, and waste marble dust can be obtained from marble processing, for information 25% of the mass of marble will be lost in the cutting process obtained from marble companies in Solo Raya, the slump flow test measurement is carried out with reference to according to the rules of SNI 1972-2008 and the workability of self-compacting concrete also meets the required requirements. So it can be concluded that it can be a reference source by utilizing waste in Indonesia, easy to obtain, and effective.

Keywords: Self-compacting concrete, waste marble dust, kaolin

1. PRELIMINARY

Nowadays, concrete is one of the most widely used construction materials in the world so it becomes an opportunity to make innovative applications, Self Compacting Concrete is one of the innovative application compared to the normal concrete. By using SCC, the concrete has high deformability and flowabilty to compact by itself. It does not require vibrator to remove air from the concrete because the air content can make lower compressive strength. SCC with low cement do not only represent cheaper and more competitive mixes, but also reduce the environmental impact. With low cements, it will reduce CO_2 emission during cement production. On the other hand, Substituting cement by using the similar content material and waste material are neccesary, Kaolin is increasingly seen as a pozzolan cementitious material that is available to apply to the construction industry. Kaolin is a rock mass composed of clay material with low iron content and at generally white with a chemical composition AL_2O_3. $_2SiO_2.{}_2H_2O$, Total kaolin reserves in the village of Toraget are estimated at 1,000,000 tons, and according to the results of chemical tests there are 43.88% Silica (SiO_2), 38.79 % Alumina (AL_2O_3) and 0.42% iron oxide (Fe_2O_3) (Departement of industry North Sulawesi Province, 1984). If you add the third percentage these compounds exceed 70% according to the standards of the American Society for testing and materials (ASTM) C 618-04, ("Standard Specification for Fly Ash and Raw or Calcinated Natural Pozzolan for use a mineral admixturein portland cement concrete"), if the composition of these there compounds exceeds 70%, then can be used as a partial substitude for cement, Waste marble dust is the result of waste from cutting marble. According to Bahar Demirel, in the process of cutting marble, 25% of the initial mass will be lost through the cutting process (Demirel B, 2010). With a sustainable concept, the use of marble dust waste will reduce environmental pollution, can save the use of material costs and at the same time the use of marble dust waste will add to the people's insight to use waste. Thus, the sustainable concept can be applied by using two materials,Kaolin and waste marble dust. Two aspects of sustainable concept are environmental, economy.The process to get addition materials.

Marble is obtained from nature through mining activities. Mining results in the form of chunks of rock. These chunks will process the process to furniture and other needs, so that in the process of processing, the marble will be cut and crushed. In the process of cutting and refining is the residual production in large quantities in the form of pieces, fine powder and liquid waste.

Kaolin is a rock mass formed from the hydrothermal process, composed of clay minerals with a low iron content with a hardness level between (2-2.5), the color varies from yellow to brown gray, and loss at temperatures between 390 degrees and 450 degrees. kaolin will turn into metakaolin $AL_2SI_2O_7$ at a temperature of 550-600 degrees celsius. (Hartomo, 1994)

I. DATA OF MATERIAL

A. *Self Compacting Concrete*

Self Compacting Concrete is a concrete that can compact with itself without any segregation in the concrete. Based on Okumara & Ouichi (2003) there is 3 methods to make self compacting concrete, the methods id :

1. Minimum of w/binder
2. Limiting quantity of aggregate
3. Additive application

Limiting quantity of aggregate is done on coarse aggregate, and adding the quantity of binder is the method to make this concrete can easily compact. From figure 1, we can the composition of self compacting concrete that issued by Okumara & Ouichi (2003)

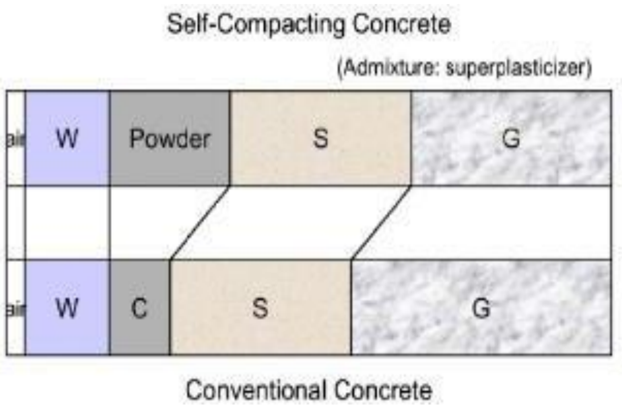


Figure 1. Material composition of self compacting concrete

B. Kaolin

Kaolin is a mass of soil consisting of clay material with low iron and white content or more promising (Ministry of Industry and Trade Republic of Indonesia, 1999). Sediment kaolin that occurs as a result of the hydrothermal process found on cracks or factions in other permeable areas (Ministry of Industry and Trade of the Republic of Indonesia, 1999). Physical Characteristics of Kaolin, namely (Department of Sulawesi Province North, 1984):

1. Fine and homogeneous grain size
2. A little plastic
3. Specific gravity 2,778 gr / cm3
4. Fireproof with melting point 17000 up to 17850^{o}C
5. Because of its purity, kaolin shows burning dense levels and gradual shrinkage.

Picture presented of kaolin from rumuskimia.net

Figure 2. Kaolin

C. *Waste Marble Dust*

Marble dust is crushed or ground marble particles that can still be formed to make a solid object. Waste marble powder is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled. The amount of waste marble powder generated at the study site every year is very substantial being in the range of 250-400 tones. The dust is used in many more instances than marble itself because of its lower cost and versatility. Marble dust is typically mixed with cement or resins to make cultured marble, which looks similar to true marble.

Kalsium Oksida (CaO) is the biggest chemical element in the marble content, which is 55,07% , same as the basic ingredients compiler of portland cement. So that marble can function for increase binding distribution just like cement. Waste marble dust solution to reduce, refurbish, reuse, and recycle with cement.

Picture presented of waste marble dust

Figure 4. waste marble dust

Waste marble dust is the result of waste from cutting marble. According to Bahar Demirel, during the marble cutting process, 25% of the initial mass will be lost through the cutting process (Demirel b, 2010). With a sustainable concept, waste marble dust will reduce environmental pollution, can apply material costs and at the same time the waste will increase people's insight to utilize Obtained from PT Solo Marmer Surakarta.

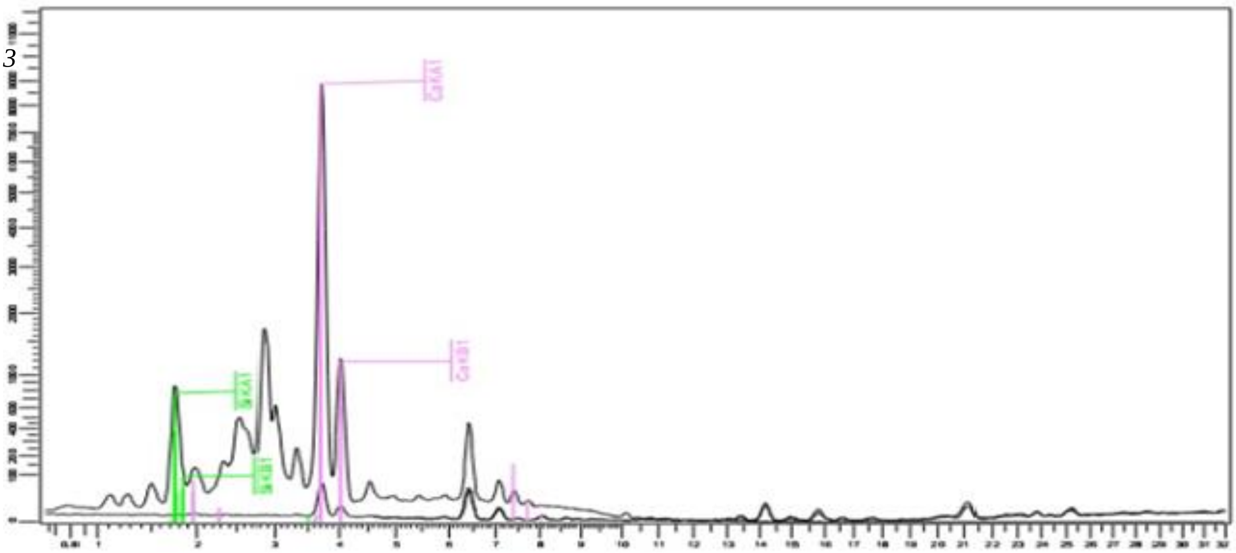


Figure 5 Analisis of qualitative of waste marble dust

Source : Research from examiner

Table 1 Reaction chemical of *waste marble dust*

Chemical elements	Content (%)
Silikon dioksida (SiO_2)	0,13
Aluminium dioksida (AlO_3)	0,31
Feri oksida (FeO_3)	0,04
Kalsium oksida (CaO)	55,07
Magnesium oksida (MgO)	0.36
Kalium oksida (K_2O)	0,01
Sulfur trioksida (SO_3)	0,08
(lol)	44

II. RESEARCH METHODS

A. Place of Research

Testing and implementation, testing in the Laboratory of the Faculty of Engineering, Tunas Pembangunan Surakarta University.

B. Method of collecting data

In this chapter, the use of materials for cement substitution and fine aggregate replacement will be analyzed. The cement content in self-compacting concrete is reduced and replaced by using marble dust and kaolin waste by 15% and 10% to create environmentally friendly self-compacting concrete. Data collection techniques in this study

C. Data On Materials And Material Used

a. Cement

Cement is a binder, a substance used in construction that hardens and can bind other materials together. The most important elements in cement are:

1. *Tricalcium Silikat* (C_3S)
2. *Dicalcium Silikat* (C_2S)
3. *Tricalcium Aluminate* (C_3A)
4. *Tetracalcium Aluminoferrite* (C_4AF)

The cement used in this study was from PCC Cement Tiga Roda with a specific gravity of 3.15

b. Water

Water is needed in the manufacture of concrete to trigger the chemical process of cement, wet the aggregate and provide convenience in concrete work. It is advisable to use fresh water that can be drunk. Water used in the manufacture of concrete must not contain harmful amounts of chloride ions (ACI318-89:2-2)

c. Consol P102HE

The Console P102 HE is a uniquely versatile superplasticizer that is particularly suitable for optimizing curing cycles by shortening curing times or reducing curing times for precast concrete production. In addition, it provides very high water reduction, high initial strength and excellent flow characteristics.

P102 HE is used for:

1. Wide range of applications requiring initial strength development.
2. Concrete with ultra high water reduction (up to 30%).
3. High performance concrete

d. Fine Aggregate

Fine aggregate is often referred to as sand. Fine aggregate serves as a filler derived from natural sand. Based on the fine aggregate material test, the fine aggregate requirements for concrete mixes are:

1. Fine aggregate should not contain more than 5% clay.

2. Sand storage area must be separated from other materials.
3. The sand used is Muntilan from Merapi
4. Specific Gravity: 2.6

e. Coarse Aggregate

Coarse aggregates that are often used in concrete mixtures are gravel and crushed stone. Coarse aggregates are particles that are retained on a 4.75 mm sieve. The quality of the coarse aggregate can be measured by the Los Angeles abrasion test which results in no more than 50% of its initial weight

Table 4. Result sieve analysis sand aggregate

No. Sieve	Sieve Weight (Gram)	Sieve Weight + Aggregate (Gram)	Aggregate Weight (grams)	Retained (%)	Cumulative Retained (%)	Get away (%)
2.36 mm	570	725	155	8.28877	8.2887701	91.7112
1.18 mm	495	670	175	9.35829	17.647059	82.3529
0.6 mm	535	1065	530	28.3423	45.989305	54.0107
0.3 mm	455	1050	595	31.8182	77.807487	22.1925
0.15 mm	485	775	290	15.508	93.315508	6.68449
0.075mm	465	520	55	2.94118	96.256684	3.74332
Basic	350	405	55	2.94118	99.197861	0.80214

Table 5. Result sieve analysis coarse aggregate

No. Sieve	Sieve Weight (Gram)	Sieve Weight + Aggregate (Gram)	Aggregate Weight (grams)	Retained (%)	Cumulative Retained (%)	Get away (%)
20.0 mm	1250	1275	25	0.60827	0.6082725	99.3917
14.0 mm	1070	2775	1705	41.4842	42.092457	57.9075
10.0 mm	1055	3030	1975	48.0535	90.145985	9.85402
5.0 mm	1145	1535	390	9.48905	99.635036	0.36496
2.36 mm	1070	1075	5	0.12166	99.756691	0.24331
Basic	1000	1000	0	0	0	0

(ENI 12620). Locally available sand from Klaten is used with a specific gravity of 2.65. The coarse aggregate requirements for the concrete mix are:

1. Coarse aggregates come from sharp and hard particles, are impermeable to water, and are cube-shaped.
2. Split used is Sentolo, Yogyakarta
3. Coarse aggregate should not contain more than 1% clay by dry weight

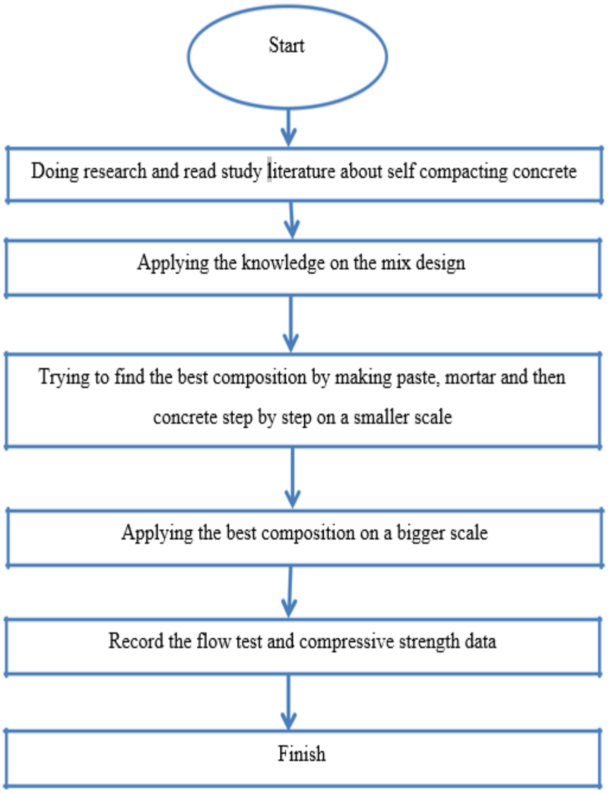
D. Mix Design

Table 3 Calculation of the Mix design of the innovative Self Compacting Concrete using the ACI 211.4r-93 1998 method.

Quality	Specific Gravity	Unit
Cement pcc	3150	Kg/m³
Kaolin (10%)	2778	Kg/m³
Waste marble dust (15%)	2300	Kg/m³
Water Binder w/b (Fas)	0,28%	
Material	**Volume**	**Volume**
	1 m³ (Kg)	**Cylinder (0,0052) Kg**
Air content	1%	1%
Water	180	1,216
Semen pcc	450	3,042
Fine Agreggate	822,016	5,556
Kaolin	60	0,405
Waste marble dust	90	0,608
Superplasticizer	7,2	0,048
Coarse Agreggate	773,376	5,228

Specific gravity testing is carried out based on laboratory tests referring to SNI 13-6717-2002

E. Research flow



Picture 7 Research flow

III. RESULTS AND DISCUSSION

A. Budget Plan

Table 4.1 Budget Plan for Making Self Compacting Concrete resource: HSPK Kota Surakarta

Material	Team	Concrete of TRI GANESHA 18		Conventional Concrete	
	Unit Price (Kg)	m³	Price	m³	Price
Cement	Rp.1.250	450	Rp. 562.500	591	Rp. 738.750
Fine aggregate	Rp.200	822,016	Rp. 164,403	678,8	Rp. 137,760
Coarse Aggregate	Rp.100	773,376	Rp. 77,337	1018,2	Rp. 101,820
Water	Rp.0.0	187	Rp. 0.0	142,5	Rp. 0.0
Superplasticizer	Rp.80.000	7,2	Rp. 576.000	14.775	Rp. 1.182.000
Waste Marble Dust	Rp.14,45	90	Rp. 1,300	-	-
Kaolin	Rp. 22	60	Rp.1,320	-	-
		Total	**Rp.1.354.860**	**Total**	**Rp 2.158.330**
				Save	**Rp.803.470**

B. Impact analysis of *Self compacting concrete*

a. Aspect of Economy

By using kaolin slime and marble dust waste can save costs compared to using conventional concrete can reduce excessive use costs in the manufacture of concrete by Rp. 803.470.00/m3. This shows quite a lot, in addition to utilizing materials that become waste that are easily obtained.

b. Aspect of Environmentally friendly

Kaolin powder is widely disposed of in the trash, as well as marble flake dust waste which is often dumped into rivers and pollutes. environment, so this is one solution to the problem of impact analysis. In Indonesia, which will be developed, cement production contributes 5-7% of carbon dioxide emissions (Sakai 2008). They can produce concrete at a lower cost. Utilization of this waste material can reduce global warming, reduce the amount of existing waste, because rice husk ash increases every year and because as we know that cement production is the largest contributor of carbon dioxide gas in the world, it will harm the environment. by reducing, renewing, reusing, and recycling based on the 4R concept (Reduce, Refurbish, Reuse, Recycle)

c. *Aspects of Application in society*

Based on research with the use of typical regional waste, namely waste marble cutting dust, and kaolin which can reduce environmental pollution and have a positive impact on society, because the community can cooperate with the marble industry in the territory of Indonesia and cooperate with building construction parties if they have waste.

C. Table of results of waste testing on concrete.

based on the results of field trials, the following results are obtained:

a. Kaolin testing

No.	Presentase Kaolin	Compressive Strength 1 Day (MPa)
1	0%	4
2	5%	5,2
3	10%	7,3
4	15%	4,7
5	20%	6,41

Results obtained from direct experiments

b. Testing of Waste Marble Dust

No.	Presentase WMD	Compressive Strength 1 Day (MPa)
1	0%	3,4
2	5%	4,32
3	10%	6,32
4	15%	8,2
5	20%	7,52

IV. CONCLUTIONS

1. Based on the research that has been done, waste marble dust and kaolin can be used as a substitute for cement.
2. The effect of marble cutting waste is that there is no decrease in strength and can increase workability when compared to concrete without marble cutting waste.
3. The use of large quantities reduces cement production, thereby reducing the greenhouse gases produced from cement production.
4. Using waste marble dust and kaolin will save time, be economical and environmentally friendly.
5. Utilization of marble and kaolin cutting waste for innovative concrete will save concrete production of Rp. 803.470.00/m3

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