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OPTIMIZATION OF RED SAND PARTICLE SIZE AND COMPOSITION IN MIXTURE WITH ORDINARY SAND TO ENHANCE CONCRETE QUALITY

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Abstract

In this study we determined the effect of variations in composition and particle size of Red Sand (RS) grains on the quality of concrete. Concrete was prepared as cubes of 15 cm^3 with a composition of cement, sand and gravel in a ratio 1:2:3 and water to cement ratio of 0.5. Variations of RS (fine aggregate) composition are 0 %, 5 %, 10 %, 15 %, 20 % of the weight and red sand grain particle size were prepared as 80 mesh, 100 mesh, 120 mesh. Mechanical properties of the maximum concrete pressure strength test at a composition of 5 % along with a decrease in the size of the red sand grain size of 100 mesh and 120 mesh RS 100-5 and RS 120-5 with pressure forces of 35.4 MPa, and 35.5 MPa, respectively. On the other hand, the red sand with 80 mesh grain size have maximum pressure force in a composition 10 % RS 80-10 is 34.6 MPa. It is considered the addition of red sand fine aggregate has an impact on improving the quality of concrete.

Keywords:

Red sand;
Ordinary sand;
Particle size;
Cement;
Concrete.

1 Introduction

Indonesia is a densely populated country, the rate of population growth in Indonesia which is impact in high demand for housing or housing construction, building, roads and bridges. Concrete is a very important and most dominant construction material used in building structures. Concrete is generally composed of three main constituent materials, such as cement, aggregate, and water. In some case, additives (admixture) can be added to change their properties of concrete to increase their function and more economically. Concrete is widely used because of its advantages which easily formed in accordance with construction needs, able to carry heavy loads, withstand high temperatures, and small maintenance costs [1-5]. Concrete can be obtained from mixing fine and coarse aggregate materials, namely sand, stone, broken stone, or other similar materials, by adding enough cement adhesives, and water as an auxiliary material for chemical reactions during the hardening and concrete treatment processing [5-8]. Fine and coarse aggregates are called mixed materials, which are the main components of concrete. The strength and durability value of concrete is a function of many factors, including the comparative value of the mixture and the quality of the stacking material, the method of casting and the hardening treatment conditions [9-13].

The Isparta Region's amorphous silica formations are characterized in a technical manner, and its application as a natural pozzolan in concrete manufacturing is assessed [14].The use of amorphous silica in the production of high-strength concrete is investigated experimentally, and the results are described. With similar properties, red sand is also widely used as an ingredient for making concrete. Red Sand (RS) is excavated sand from Padang Bulan village, Kota Pinang Subdistrict, Labuhan Batu Selatan District, North Sumatera, Indonesia which has very fine grains and lighter weight than ordinary sand. This RS is often used by the community as a road agency. In 1972, Air Bah

Company was uses this red sand as a road body by dumping this red sand and compact it with cylindrical trucks. Until now the road is still strong and only eroded little by little every year. South Labuhan Batu Red Sand also used as an ingredient in making concrete because it has ingredients such as SiO_2 (Silicon Oxide), TaO_2 (Tantalum Oxide), FeNi (Iron Nickel), Fe_2C (Iron Carbide) and high red sand silicon intensity contents [15, 16]. SiO_2 is one of the chemical elements contained in Portland cement, so this element makes it possible to obtain a stronger concrete mixture [10, 18].

Preliminary studies about the effect of adding RS volume to density, water absorption, and concrete compressive strength were determined with variations used of 50 % RS and 50 % ordinary sand and produced a compressive strength of 32 MPa. Based on the preliminary studies above, we observed that the aggregate bonds are not strong and to improve aggregate bonds there are several methods can generate, including the method of the Indonesian National Standard (SNI), the American Society for Testing and Materials (ASTM), and the American Association of State Highway and Transportation Official (AASHTO). The most appropriate method used in this study is SNI 03-2834-2000 which refers to the making of K-175 concrete. Variations that affect the strength of the concrete pressure in terms of aspects of the particle size of RS grain size and composition of RS, while other factors such as the way of compaction and maintenance during the hardening process are used as refer to the Indonesian National Standard (SNI). The SNI used in this study are SNI 15-2049-2004 (Portland cement), SNI 03-2834-2000 (Procedures for making and maintaining concrete) and SNI 03-1974-1990 (compressive strength testing).

In this study we prepared the red sand which used 0 %, 5 %, 10 %, 15 % and 20 % of RS and ordinary sand 100 %, 95 %, 90 %, 85 % and 80 % then the red sand is also varied the size of the granules with a variation of 80 mesh, 100 mesh, 120 mesh which is expected to be smaller the size of the sand grains, the sand will be stronger with cement and water so as to improve the quality and strength of concrete. Concrete was prepared as cubes of 15 cm^3 with a composition of cement, sand and gravel are 1 : 2 : 3 respectively.

2 Materials and methods

The cement was used in this study are Portland type I from PT. Mulia Sakti Perkasa, fine aggregates (red sand and ordinary sand), coarse aggregates, and water. The Red Sand was obtained from Padang Bulan Village in Kota Pinang sub-district, South Labuhan district, North Sumatera, Indonesia. The equipment used includes an analytical balance sheet, bucket, measuring cup, cement spoon, compactor stick, screen sieve (80, 100, 120 mesh), and concrete mold. Compressive strength analysis was carried out with the Compress Testing Machine with a capacity of 2000 KN. Phase analysis and structure were determined with XRD with CuKa and the speed (Scan speed) of 2.00 deg/min.

The form of the test sample in this study is cube shaped 15 cm x 15 cm x 15 cm. The results of concrete compressive strength testing with variations in the composition of RS are 0 %, 5 %, 10 %, 15 %, 20 % and variations in particle size are 80 mesh red sand grains, 100 mesh and 120 mesh. The well-printed concrete and the concrete top surface were prepared with a shovel which the flat top surface and after 24 hours was opened from the mold and put into the water for the wiring process (water absorption). This specimen is tested by a compression test machine after 28 days of treatment and drying based on the strength level to be determined. The load must be applied gradually and in the right interval until the specimen has cracked. The strength of the concrete is obtained from the load by cracking the specimen divided by the surface area of the specimen [8]. Concrete pressure testing is carried out after 28 days from casting and soaking. The amount of concrete pressure is influenced by the composition of the constituent material and the attachment of the cement paste to the aggregate.

3 Results and discussion

3.1 XRD characterization

XRD pattern as Fig. 1 shows the formation of SiO_2, $Ca(OH)_2$ and CaO. The optimum SiO_2 phase is at $2\theta = 26.65°$ with an intensity of 935.8 count second (cts) (which is given an asterisk) while the $Ca(OH)_2$ phase is at three angles, namely $2\theta = 17.98°$, $2\theta = 34.03°$, $2\theta = 50.84°$ $Ca(OH)_2$ phase is an element that can have a negative impact on concrete [9].

At an angle of $2\theta = 32.40°$ the CaO phase is formed. In the diffraction pattern of images 4.10 the phases formed are SiO_2, $Ca(OH)_2$, CaO, Ta_2O_5. The SiO_2 phase experienced a peak shift of 0.21

to the left and the optimum at an angle of 2θ = 26.44° with an intensity of 994.1 the similar case also was observed a peak shift in concrete RS 100-5 and RS 120-5 respectively 2θ = 26.68° and 2θ = 26.65° and the intensity increases and the detected phase is SiO_2 phase.

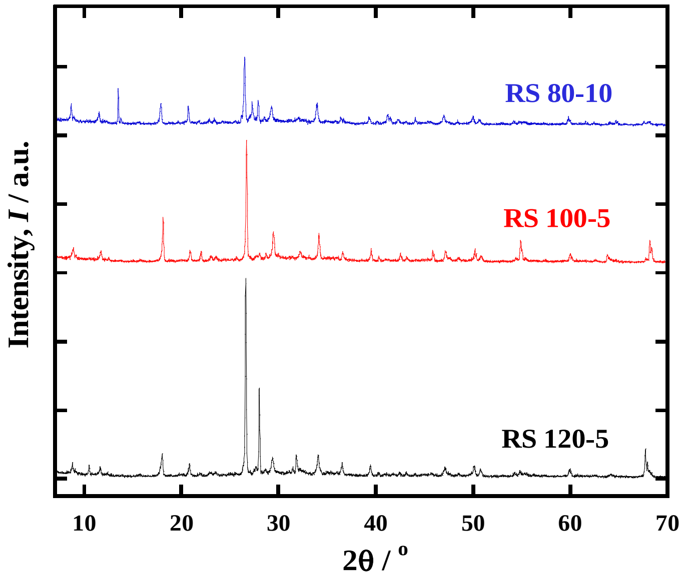


Fig. 1: XRD patterns of samples RS 80-10, RS 100-5 and RS 120-5.

The optimum $Ca(OH)_2$ phase at an angle of 2θ = 17.85° and experiencing a shift in concrete B23, B33 respectively 2θ = 18.00° and 2θ = 17.98°, while the optimum CaO phase is at an angle of 2θ = 32.04° and also experiences a peak shift on concrete 100-5 and RS 120-5 are 2θ = 32.19° and 2θ = 29.35° respectively. At an angle of 2θ = 29.28° the Ta_2O_5 phase is formed and in concrete 100-5 and RS 120-5 also occurs the buds of the shoots become 2.5 = 36.58° and 2θ = 47.08°. It indicated SiO_2 has the greatest intensity compared to other elements contained in concrete. The effect of damage on concrete can be improved by adding 35 - 40 % of SiO_2-rich material. It was confirmed that without the addition of SiO_2 at the first high temperature the value of the strength of the concrete pressure become decreases. And at the second critical temperature after the sample was evaluated with 35 - 40 % SiO_2 achieved the best pressure strength results.

The crystal structure formed in the samples RS 80-10, RS 100-5 and 120-5 were observed by using EXPO 2014 analysis which indicated a different crystal structure of RS 120-5 as monoclinic instead RS 100-5 and RS 80-10 formed as triclinic crystal. SiO_2 phase the crystal structure formed is hexagonal, in the phase of $Ca(OH)_2$ the structure of the crystal formed is hexagonal, and in the CaO phase the crystal structure formed is cubic, as for the Ta_2O_5 phase the crystal structure formed is orthorhombic.

Table 1: Crystal structure parameter of red sand in various composition and red sand grains by using EXPO 2014 analysis.

Concrete sample size – comp	A [Å]	B [Å]	C [Å]	α[°]	β[°]	γ[°]	Crystal system
RS 120-5	16.14	15.91	10.34	90	105.1	90	Monoclinic
RS 100-5	11.39	21.09	7.21	93.13	99.06	87.75	Triclinic
RS 80-10	10.92	14.75	8.02	93.56	105.34	102.48	Triclinic

To determine the volume fraction of SiO_2, Ca $(OH)_2$, CaO, Ta_2O_5, refer to this below equation:

$$SiO_2(\%) = \frac{\sum SiO_2}{\sum SiO_2 + \sum Ca(OH)_2 + \sum CaO + \sum Ta_2O_5}, \quad (1)$$

$$Ca(OH)_2(\%) = \frac{\sum Ca(OH)_2}{\sum SiO_2 + \sum Ca(OH)_2 + \sum CaO + \sum Ta_2O_5}, \quad (2)$$

$$CaO(\%) = \frac{\sum CaO}{\sum SiO_2 + \sum Ca(OH)_2 + \sum CaO + \sum Ta_2O_5}, \quad (3)$$

$$Ta_2O_5(\%) = \frac{\sum Ta_2O_5}{\sum SiO_2 + \sum Ca(OH)_2 + \sum CaO + \sum Ta_2O_5}, \quad (4)$$

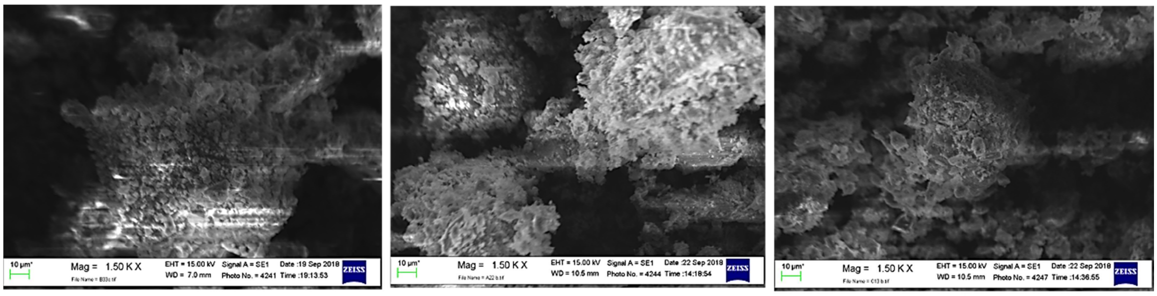
Table 2 shows the volume fraction of SiO_2 increases with the addition of red sand and decreases the size of sand grains on red sand. SiO_2 is one of the largest chemical elements contained in cement and red sand, so that this element can make a stronger concrete mixture.

Table 2: Volume fractions of concrete contain of RS 80-10, RS 100-5 and RS 120-5.

No.	Concrete sample size – comp	Volume fraction [%]			
		SiO_2	$Ca(OH)_2$	CaO	Ta_2O_5
1	RS 120-5	83.38	11.38	3.37	1.96
2	RS 100-5	69.12	24.96	2.54	3.36
3	RS 80-10	67.42	23.56	1.94	7.08

3.2 SEM characterization

Observation of SEM data shows that red sand with a larger size, 120 mesh forms a larger aggregate compared to other concrete samples. The larger size of the red sand particles creates a stronger interaction with ordinary sand, resulting in aggregate forming. With a decrease in the particle size of the red sand, it shows that fewer lumps are formed, which means the size of 80 mesh of red sand, although with a higher amount 10 % it produces a more homogeneous.



a) b) c)

Fig. 2: SEM Images of a) RS 120-5, b) RS 100-5 and c) RS 80-10.

3.3 EDX characterization

EDX analysis also shows the highest content of Silicon (Si) for concrete of RS 120-5 if compare than RS 100-5 and RS 80-10, Fig. 3.The similar content of concretes, the main content of which is silicon and the reduction of the silicon content caused by the reduction of the red sand particle size are also explained. These results were supported by XRD pattern (Fig. 2) which the highest peak reduced by reducing of red sand particle size, indicated the reducing of silicon content. The particle size of red sand will be stronger with cement and water in bigger particle size (120 mesh and 5 % content of RS) which possible have enough space to make their chemical and physical bonding of sand and cement.

Table 3: Comparison of weight fractions in samples RS 80-10, RS 100-5 and RS 120-5 by EDX analysis.

No.	Concrete sample size – comp	Weight fraction [%]				
		Si	O	Ca	C	Al
1	RS 120-5	30.56	51.18	11.28	5.76	1.22
2	RS 100-5	7.99	50.28	30.56	5.88	2.85
3	RS 80-10	5.46	53.37	34.53	4.94	1.21

3.4 Compressive strength analysis

Variation in composition and grain size of red sand affect to the strength of the concrete pressure. 80 mesh red sand granules have maximum average compressive strength at 10 % red sand composition RS 80-10 which is 34.6 MPa while 100 mesh red sand granules have maximum average compressive strength at 5 % red sand composition RS 100-5 which is equal to 35.4 MPa and the concrete with a size of red sand granules 120 mesh has the maximum average pressure strength in the composition of 5 % red sand RS 120-5 which is 35.5 MPa.

A composition of 5 % red sand is a concrete mixture that is more optimal than the composition of 10 % red sand, which observed from the results of testing the strength of concrete pressure. It shows that the composition of 5 % red sand has a linear increase in pressure strength along with the decrease in grain size. Red (80 mesh, 100 mesh, 120 mesh) respectively: 31.9 MPa, 35.4 MPa and 35.5 MPa. It suggesting the composition of 5 % red sand can cover the cavities in the concrete induce the water trapped in the concrete in small amount which means it can shrink the porosity of the concrete and increase the strength value of the concrete [9, 14]. While the addition of 10 % red sand composition not always increase in the strength of the concrete pressure due to un-mixing then the mixture is not mutually binding. Based on PBI 1971 it was found that K175 - K250 quality concrete had an average compressive strength of 15 - 20 MPa, while the concrete quality of K250 - K400 had an average compressive strength of 20 - 35 MPa. The data obtained in the study has pressure strength of 18 < 40 MPa using the concrete composition K-175 produced with medium quality concrete. It is higher than the force of pressure specification by the Indonesian National Standard Agency.

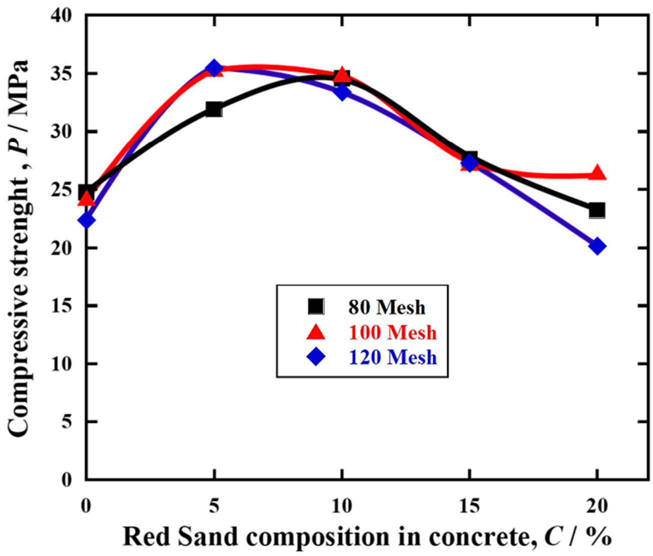


Fig. 3: Compressive strength on variations in composition and red sand grains.

Based on PBI 1971 it was found that K175 - K250 quality concrete had an average compressive strength of 15 - 20 MPa, while the concrete quality of K250 - K400 had an average compressive strength of 20 - 35 MPa. The data obtained in the study has a compressive strength of 18 < 40 MPa using the concrete composition K-175 produced with medium quality concrete. It is higher than the force of pressure specification by the Indonesian National Standard Agency.

4 Conclusions

The compressive strength of the concrete with variations in composition and variations in the size of the red sand grains increase the compressive strength of the concrete. Optimal compressive strength and increase linearly in the composition of 5 % along with a decrease in the size of the red sand grain size (100 mesh and 120 mesh) with the strength of pressure in a row that are 35.4 MPa and 35.5 MPa and 31.9 MPa for 80 mesh particle size and 10 % composition in concrete. XRD analysis indicate the elements of SiO_2 (Silicon Oxide), $Ca(OH)_2$ (Calcium Hydroxide), CaO (Calcium Oxide), Ta_2O_5 (Tantalum Pentoxide) suggest that silicon has the greatest intensity compared to other elements contained in concrete. SiO_2 is one of the largest chemical elements contained in cement and red sand, so that this element can make a stronger concrete mixture.

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