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Effect of variations in the composition and size of red sand grains on the quality of K-225 concrete

Mukti Hamjah HARAHAP*, and Aulia E. PUTRI

Department of Physics, Faculty of Mathematics and Natural Sciences, State University of Medan, Indonesia

***Corresponding author e-mail:** muhtihamzah@unimed.ac.id, Mhfis08@gmail.com

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Abstract

The effect of variations in the composition and size of red sand grains on the solid quality made in the form of a 15×15×15 cm cubes were investigated. By implementing the standard of SNI K-225 which is a mixture of 1:1.9:2.8 with FAS 0.6 and the composition of red sand consisting of 0, 2, 4, 5, and 6.5% of the weight of fine aggregate and variations in the size of red sand grains of 80, 100, and 120 mesh, the concrete was being treated in a water bath for 28 days. It was tested by the method of water absorption, compressive strength test, Scanning Electron Microscope (SEM) and X-Ray Diffraction (XRD). The test result of SEM indicated that variations of both the composition and size of red sand grains affect the porosity of the concrete. XRD test obtained $Ca(OH)_2$, $CaCO_3$ and SiO_2, as the highest intensity element, and the similar crystal structure formed is hexagonal. The maximum compressive strength of the concrete on the composition of 4% with a grain size of 80 mesh red sand that is 32.3 MPa with is linear with the results of testing the water absorption of concrete along with the decreasing variations in the size of red sand grain.

1. Introduction

Indonesia is a densely populated country; the high rate of population growth in Indonesia has increased the need for housing, settlement construction, building construction, roads, and bridges. The world is now trying to answer the challenges of fantastic infrastructure and concrete is called one of the pillars of an advanced society that causes its increasing production than any other synthetic materials on earth. Double manufacture happened due to the fact that concrete and mortar are used in the construction of around 35 billion tons as a total of all industrial building materials, including wood, steel, plastic, and aluminum [1].

Red sand, in South Labuhan Batu, was used as a mixture in concrete because it contains SiO_2 (silicon oxide), TaO_2 (tantalum oxide), FeNi (iron nickel), FeC (iron carbide), TaO (tantalum oxide), Fe_2C (iron carbide). At the same time, the intensity of the red sand containing high silicon SiO_2 is one of the most significant chemical elements in the Portland cement so that these elements will further enable the acquisition of concrete mix is stronger [2].

The most appropriate method to improve the quality of the concrete aggregate is the Indonesian National Standard (SNI) method. The existing SNI method is SNI [3-5]. Concrete compressive strength is the magnitude of the burden of broad unity, which causes the real specimen to destroy if loaded with a specific compressive force. A press machine produces it, and for testing purposes, the object must be followed by several stages of fresh concrete representing the concrete mixture [6].

According to the study [7] on the effect of variations in composition and size of the red sand grain to the quality of the concrete, the test results demonstrated that differences in composition and size variations could increase the compressive strength of the concrete. The test results indicated that the power of optimal pressure rises directly on the composition of 5% along with a decrease in variation of grain size of the red 80, 100, and 120 mesh with the compressive strength, respectively, are equal to 31.9, 35.4 and 35.5 MPa which exceeded the strength of the pressure set by the Indonesian National Standard Agency.

Based on the above description, by using a mixture of quality K-225, with the smaller size of sand grains, more robust sand is produced and if it is mixed with cement and water, it can improve the quality and strength of concrete.

2. Experimental

2.1 Research methods

The method utilized in this study is an experimental study that refers to the manufacture of K-225 concrete quality. To determine the effect of variations in composition and size of the red sand grain, the method of water absorption, compression quality, SEM, and XRD were applied. The stages in this research were the preparation phase, materials testing phase, the testing phase of the test specimen, and data processing.

2.2 Materials

The materials used in this study are Portland cement type 1, fine aggregate (sand red with a grain size of 80, 100, 120 mesh, and regular sand), coarse aggregate, and water. While the types of equipment were used are analytical balance, measuring cup, stick compactors, spoon, sieve, mold, compression testing machine, pail, XRD, and SEM.

2.3 Sample Preparation

Sample preparation began by providing a mixture of Portland cement type I, red sand, ordinary sand, and water. Initially, the red sand was dried in the sun because it contains water, grind, and the red sand was sifted with a sieve of 80, 100, 120 mesh. The subsequent activity was cleaning the tools, followed by measuring the composition of raw material. After all supplied materials were ready, mold machine is turned on. Pouring cement, fine aggregate, and gravel on to the machine followed by the addition of a little water. When the mixture in the machine has been stirred evenly, then poured it into a large bucket after providing a mold that has been smeared by dirty oil. Fill the mold with the fresh concrete into three layers. Each layer is compacted with 25 stabs evenly, and insert the fresh concrete into the mold for 1/3 mold height [5], then poke several parts to ensure the density arrangement of the mixture using a stick compactor.

Furthermore, the printing surface was leveled with scrap and left for 24 h. Concrete that was only 24 h [5] opened from mold and treated in a soaking tub until the time of testing was given a code number as desired. Concrete cubes had been treated for 28 days at a temperature of 25°C [5]. The soaking tub was removed from the water, and the wet mass is calculated after 24 h of drying, and the dry mass is calculated to obtain the test results of water absorption. A concrete sample is placed on the testing machine. At the end of the process, the load is recorded. This load is then divided by the cross-section area of concrete samples and registered as a compressive stress value [9]. Finally XRD and SEM tests were conducted on the specimen.

2.4 Characterization of Concrete

This research, the water absorption, tensile strength, SEM and XRD tests were conducted to determine the properties and the ability of a material

2.4.1 Water Absorption

To determine the ability of concrete to absorb water when immersed in a water bath, a systematic amount of water absorption of a material formulated as follow:

$$Waterabsorption(\%) = (mb - mk)/mk \times 100 \quad (1)$$

Whereas, mb is the wet mass and mk is the dry mass.

2.4.2 Compressive strength

A compression strength test was necessary to determine the magnitude of the pressure of the concrete [5]. The tools which were used to test the amount of pressure is Compression Testing Machine (CTM).

2.4.3 SEM (Scanning Electron Microscope)

SEM test that was used for the examination and analysis of the surface can obtain data on the composition of particle pore size of the concrete mix.

2.4.4 XRD (X-Ray Diffraction)

XRD test was performed to identify the phase, phase composition, and crystal structure contained in the concrete sample.

3. Results and discussion

3.1 SEM (Scanning Electron Microscope)

To see the morphology and pore size of the mixed composition particles in concrete samples using red sand mixture, SEM tests were carried out. From the SEM magnification of 5000 times, the following is a picture of SEM test results on concrete samples. The following are the photo images of SEM analysis and pore analysis of the mixed particle composition of the concrete using the ImageJ software application.

The SEM photos in Figure 1 show the morphology of the concrete surface. It can be seen that in concrete there are cavities (pores) which are marked with black (dark) color. The cavities in Figures 1(a), 1(b), and 1(d) appear to be evenly distributed, but in Figure 1(c) it looks uneven, which indicates that the mixture in the concrete is less homogeneous.

The pore analysis of the concrete samples shown in Figure 2 above shows that the pores of Figure 2(a-d) appear to have different pore arrangements. In this morphology, the average pore sizes in Figures 2(a-d) are 67.01, 98.83, 207.11, and 181.67 nm, respectively. It can be concluded that in Figure 2(c) it is found that the largest average pore size is due to the less homogeneous mixture in the concrete resulting in a large porosity area.

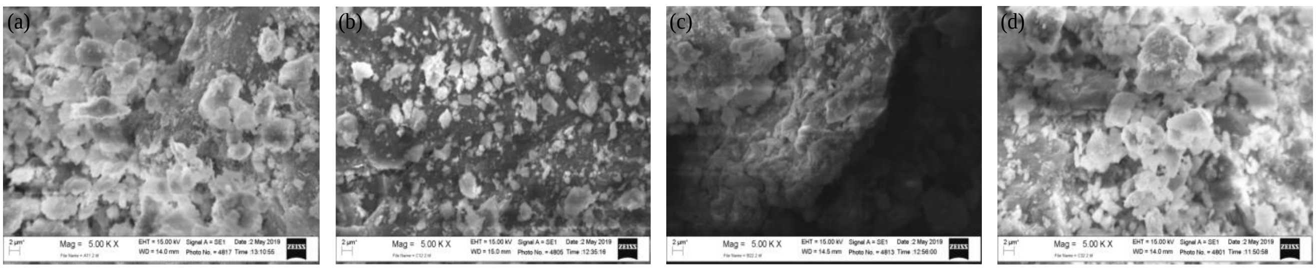

Figure 1. SEM photos on concrete samples (a) A_{11}, (b) C_{12}, (c) B_{22}, and (d) C_{32} with a magnification of 5000 times.

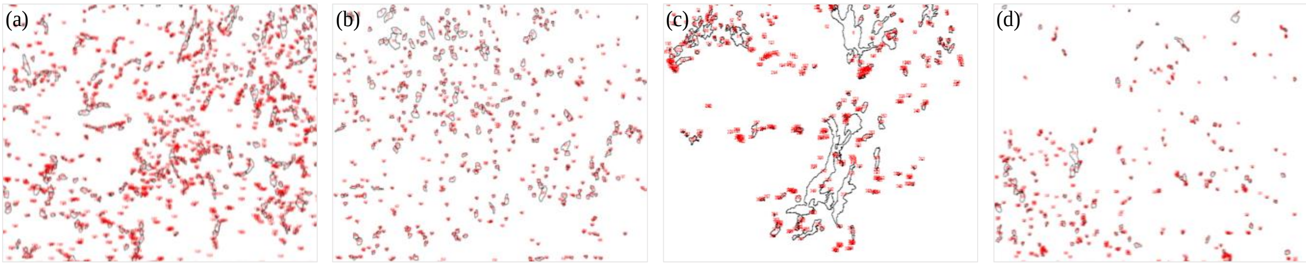

Figure 2. Pore analysis in concrete samples (a) A_{11}, (b) C_{12}, (c) B_{22}, and (d) C_{32}.

From the comparison of the morphology of Figures 2(a-d) that the variation in the size of the red sand grains and the addition of the composition of red sand affect the porosity of the concrete. Not all concrete is optimized to obtain the least possible porosity with a given set of aggregate, sand, cement, and fillers [1]. Basically, even coarse aggregate that has a good grade cannot support obtaining a greater strength of concrete. Smaller aggregates are used as an alternative. The addition of strength to concrete forms high-performance concrete. High-performance concrete is the manufacture of extra-solid concrete using fillers in the form of micro-sized particles. Aggregate grading also plays an important role in determining the quality of high-performance concrete. If the aggregate has finer grain sizes and varies in size, the pore volume of the concrete will be small. This is because the smaller grains will fill the pores between the larger grains, so that the pores are less and the concrete has a high density [9].

3.2 Water Absorption

The absorption of water in a concrete is affected by the presence of pores or cavities. The more pores contained in the concrete, the greater the absorption so that the resistance will be reduced. Figure 3 below shows that water absorption decreases with the addition of red sand and the particle size used. This shows that the particle size and the addition of red sand affect the density of the concrete. This result shows that variations in the size of red sand grains and the addition of red sand composition more effective for reducing the water absorption of concrete.

Concrete with 80 mesh sieve with a composition of 0 and 2%, has a water absorption capacity of 0.70% and 0.66%, at a composition of 4% has an increase of 0.67%, and the composition of 5 and 6.5% has decreased respectively by 0.56 and 0.50%. Concrete with 100 mesh sieve with a composition of 0, 2, 4, 5 and 6.5% decreased water absorption by 0.72, 0.66, 0.69, 0.55, and 0.52%, respectively. Concrete with 120 mesh sieve with a composition of 0, 2, 4, and 5% decreased water absorption by 0.71, 0.63, 0.34 and 0.31%, respectively, the composition of 6.5% increased by 0.34%. These results indicate that variations in the size of red sand grains and the addition of certain red sand compositions are more effective in reducing water absorption in concrete.

3.3 Compressive Strength

Based on Figure 4 above, concrete with a grain size of 80 mesh of red sand has a maximum average pressure strength at the composition of 4% red sand, which is 32.3 MPa, while concrete with a grain size of 100 mesh of red sand has an average pressure strength. The maximum composition of 2% red sand is 28.3 MPa and in concrete with a grain size of 120 mesh of red sand it has a maximum average pressure strength of 4% red sand composition, which is 25.26 MPa. These results indicate that the composition of 4% red sand is a more optimal concrete mixture compared to the composition of 2% red sand, this can be seen from the results of the concrete stress strength test which shows that the composition of 4% red sand has a good pressure strength value along with the decrease in size. red sand grains 80, 100, 120 mesh, namely: 32.3, 26.44 and 25.26 MPa. This is because the composition of 4% red sand is a suitable concrete mixture that can cover the cavities in the concrete so that only a little water is trapped in the concrete which means it can reduce the porosity of the concrete so that it will increase the value of the strength of the concrete. However, in the results obtained, the aggregate that passed the sieve with a smaller grain size actually experienced a decrease in compressive strength. This could be due to the small size of the aggregate has a large friction and absorbs more water so that the dough becomes stiff and not evenly mixed.

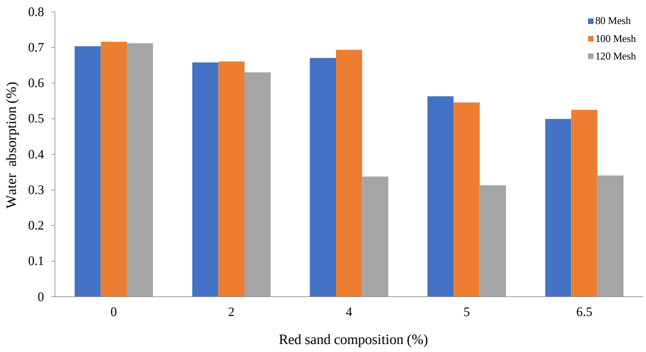

Figure 3. The overall graph of the water absorption capacity of concrete against variations in the composition and variations of red sand grains.

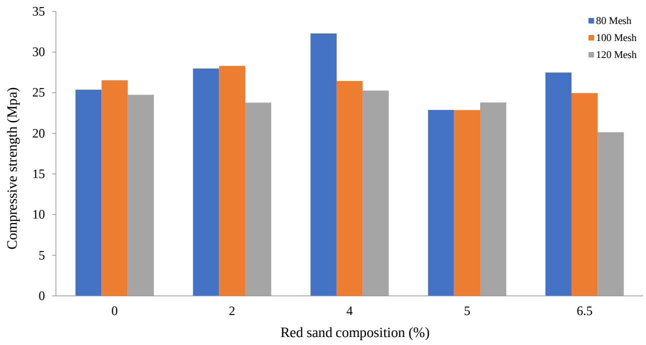

Figure 4. The overall graph of the stress strength of concrete against variations in the composition and variations of red sand grains.

Based on PBI [10], it is known that K-175 K <250 quality concrete has an average stress strength of 15 <20 MPa, while K-250 K<400 quality concrete has an average stress strength of 20 <35 MPa. The data obtained in this study have a pressure strength of 19 <35 MPa using the K-225 concrete composition, resulting in medium quality concrete. This result exceeds the pressure strength set by the Indonesian National Standard Agency, this is due to the size of the red sand and the silicon content more.

3.4 XRD (X-Ray Diffraction)

X-ray diffraction (XRD) is one of the most prominent analytical techniques in the characterization of crystalline, fine-grained materials, such as cement. The strength of XRD is the fast and precise, reliable delivery of quantitative data on the structural properties of the crystals and the number of individual phases contained in the cement. This technique is widely used for phase identification [11]. The data obtained were analyzed using *Match v1.10 software*. Below is the result of the diffraction pattern of concrete samples without red sand mixture (A_{11}), concrete with a grain size of 80 mesh of red sand (C_{12}), concrete with a grain size of 100 mesh of red sand (B_{22}), and concrete with a grain size of red sand. 120 mesh (C_{32}).

Based on Figure 5 and Table 1, it can be concluded that SiO_2 has the greatest intensity compared to other elements contained in concrete.

The crystal structure formed in samples A_{11}, C_{12}, B_{22}, and C_{32} is the same, namely in the SiO_2 phases, $Ca(OH)_2$, and $CaCO_3$ hexagonal crystal structure is formed.

To find out the value of the volume fraction of SiO_2, $Ca(OH)_2$, and $CaCO_3$, the following equations can be used in the sample.

Figure 5 is the diffraction pattern of samples A_{11}, C_{12}, B_{22}, and C_{32}. The diffraction pattern shows the formation of phases SiO_2, $Ca(OH)_2$, and $CaCO_3$. The optimum phase shift angle can be seen in the table below.

$$SiO_2(\%) = \frac{\sum ISiO_2}{\sum ISiO_2 + \sum ICa(OH)_2 + \sum ICaCO_3} \times 100\% \quad (2)$$

$$Ca(OH)_2(\%) = \frac{\sum ICa(OH)_2}{\sum ISiO_2 + \sum ICa(OH)_2 + \sum ICaCO_{35}} \times 100\% \quad (3)$$

$$CaCO_3(\%) = \frac{\sum ICaCO_3}{\sum ISiO_2 + \sum ICa(OH)_2 + \sum ICaCO_3} \times 100\% \quad (4)$$

Below is a comparison of the volume fractions of samples A_{11}, C_{12}, B_{22}, and C_{32}.

In Table 2 above, it can be seen that the volume fraction of SiO_2 increases with the addition of red sand and decreases in the size of the sand grains on the red sand. SiO_2 is one of the largest chemical elements contained in cement and red sand, so this element can make a stronger concrete mixture. Based on the reference, the more SiO_2 added is to the concrete, the strength also increases. But at a certain point, the compressive strength drops. This decrease arises because the SiO_2 content in the concrete is saturated so that the crystallinity is reduced and it is caused when the concrete mixes the molen is not maximal so it is not homogeneous. [12]. In a study confirmed that without the addition of SiO_2 at the first high temperature the value of the stress strength of the concrete decreased. And at the second critical temperature after evaluating the sample with 35-40% SiO_2 achieved the best pressure strength results [13].

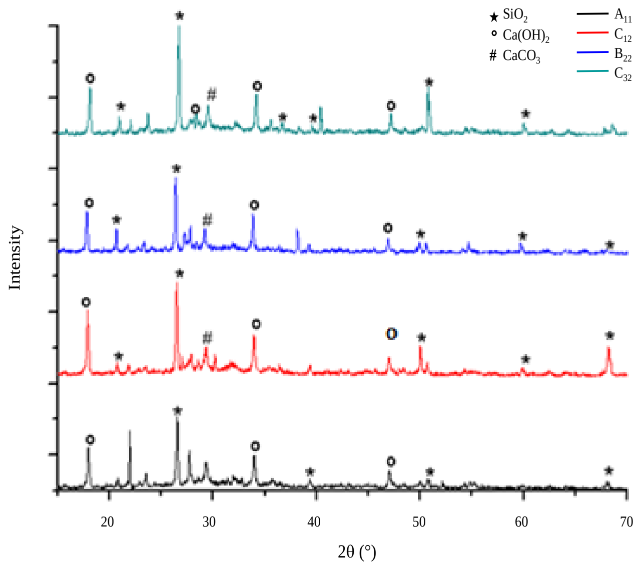

Figure 5. Diffraction pattern of samples A_{11}, C_{12}, B_{22}, and C_{32}.

Table 1. Shift phase angle.

Sample code	Phase generated (°)		
	SiO_2	$Ca(OH)_2$	$CaCO_3$
Sample A_{11}	26.63	34.07	-
Sample C_{12}	26.45	33.92	29.27
Sample B_{22}	26.64	34.10	29.44
Sample C_{32}	26.65	34.10	29.45

Table 2. Comparison of volume fractions in samples A_{11}, C_{12}, B_{22}, and C_{32}.

Sample code	Volume fraction (%)		
	SiO_2	$Ca(OH)_2$	$CaCO_3$
Sample A_{11}	57.8	42.2	-
Sample C_{12}	48.8	28.4	22.8
Sample B_{22}	52.6	32.7	14.7
Sample C_{32}	59.8	31.4	8.8

4. Conclusion

Based on SEM test results, variations in the size of red sand grains and the addition of red sand composition affect the porosity of the concrete. For the XRD test results, elements of SiO_2 obtained (silicon oxide), $Ca(OH)_2$ (calcium hydroxide), $CaCO_3$ (calcium carbonate) were, with the highest intensity being SiO_2 compared to other elements contained in concrete. The crystal structure formed is all the same, namely in the SiO_2 phase, $Ca(OH)_2$ phase and $CaCO_3$ phase the crystal structure formed is hexagonal. Based on the results of the water absorption test, the concrete has a linearity along with a decrease in the size variation of the red sand grains, but it does not have the linearity of the results with the concrete stress strength test. From the results of the stress strength test with variations in the composition and variations in the size of the red sand grains, it increases the stress strength in the concrete, but the results have not found linearity in the compressive strength. The optimum pressure strength is found in the composition of 4% red sand with a grain size of 80 mesh of red sand, namely 32.3 MPa. The compressive strength data obtained has reached the K-400 from the K-225. This goes beyond the strength of the pressure set by the Indonesian National Standard Agency.

Acknowledgments

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