Effect the silica sand percentage as substitution of fine aggregate on the concrete compressive strength

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Abstract. This study uses silica sand, which has a high SiO₂ content and micron size as a substitute for normal sand with control specimens with compressive strength of \( f'_c \) 45 MPa. Two types of silica sand gradations were used, namely 80-100 mesh (0.177 mm – 0.149 mm) in size and 325 mesh (0.044 mm) in size from Bangka as the fine aggregate. There were 45 cylindrical specimens sized 15 cm in diameter, 30 cm in height, and age of 7, 14, and 28 days. The tests carried out were absorption test and compressive strength test based on SNI 1974: 2011, which explained the testing method of the compressive strength of concrete with cylindrical specimens. Based on the test results, the optimum compressive strength was 53.07 MPa in the specimen with a composition of 50% sized 80-100 mesh (0.177 mm – 0.149 mm) (+) 50% sized 325 mesh (0.044 mm) silica sand, which can increase 4.12% of the compressive strength from normal concrete. On the other hand, the lowest compressive strength was obtained in a specimen with a composition of 25% sized 80-100 mesh (0.177 mm – 0.149 mm) (+) 25% sized 325 mesh (0.044 mm) silica sand, which was 48.43 MPa at 28 days.

1. Introduction
In facing the globalization era, the world competes to create many creative things to develop the construction field. Indonesia, as one of the developing countries, must be more creative and innovative in developing its construction sector, especially in the development of concrete technology. Concrete has a composition of a mixture of coarse aggregate, fine aggregate, water, and cement as the binding material. The use of alternative materials is currently widely used, especially using waste materials, one such material is silica sand. Silica sand is obtained from the raw material. After washing the raw material the silica sand is separated by sieve size 1.18 of raw material. Raw material is washed for taking out the clay material which is useful in making the tiles. In the raw material about 10% is clay which is supplied to the ceramic factories [1].

Sand is included as a standard concrete material which also functions as a filler. While Silica (SiO₂) is an adhesive material bind lime freely in concrete, if the material is mixed in concrete[2]. Silica sand is generally used as a filter to remove mud and sediment in the water in the water treatment industry. In Indonesia, there are several areas producing silica sand or quartz sand, including Bandar Lampung known as Lampung silica sand and Bangka known as Bangka silica sand. Silica sand is used in two types of size, namely 80-100 mesh (0.177 mm – 0.149 mm) in size and 325 mesh (0.044 mm), which are in the micron size. Micron-scale is used so that the cavity produced in the concrete can be minimized to increase the strength and quality of concrete[3].

Previously, Kasiati, Wibowo, and Sukaptini [4] have conducted research by mixing silica sand and waste sand as a substitute for normal sand in concrete mixtures. The silica sand used in the study was from Tuban. In the study, there was one variation by using 100% silica sand as a substitute for normal sand. By using fine aggregates, the study produced silica sand with a compressive strength of 409.21 kg/cm² or 40.1 MPa with w/c ratio of 0.4 at 28 days of concrete age. The study becomes a reference for
researchers to use different size of silica sand gradation to have higher concrete strength, even to obtain concrete in the high-quality category.

2. Method
The making of specimens consisted of various mixture variations for the experiment, namely a mixture of high-quality concrete in various substitutions of Bangka Silica Sand sized 80-100 mesh and 325 mesh with Normal Sand with a ratio (0:0)%, (25:25)%%, (50:50)%%, (25:75)%%, and (75:25)% Silica Sand against normal sand, and the use of 3.3% visocrete 8032s from the total weight of the fresh concrete mixture. The test specimens were cylinders with a diameter of 15 cm and a height of 30 cm, and the tests carried out were absorption test and compressive strength test when the specimens were 7, 14, and 28 days.

| Variation | Percentage of Fine Aggregate Composition (%) | Age of Specimen (Day) | Number of Specimen |
|-----------|-----------------------------------------------|-----------------------|--------------------|
| Normal Sand | Silica Sand 80-100 Mesh | Silica Sand 325 Mesh | 7, 14, 28 | 9 |
| I | 100 | 0 | 0 | 7, 14, 28 | 9 |
| II | 50 | 25 | 25 | 7, 14, 28 | 9 |
| III | 0 | 50 | 50 | 7, 14, 28 | 9 |
| IV | 0 | 25 | 75 | 7, 14, 28 | 9 |
| V | 0 | 75 | 25 | 7, 14, 28 | 9 |
| Total | | | | 45 |

From the mix design calculation, the mixture ratio, namely:

| Cement | Coarse aggregate | Sand | Silica 80-100 mesh | Silica 325 mesh | Water | HRWR |
|--------|------------------|------|-------------------|----------------|-------|------|
| 1 | 1.58 | 1.13 | 0 | 0 | 0.29 | 0.012 |

| Cement | Coarse aggregate | Sand | Silica 80-100 mesh | Silica 325 mesh | Water | HRWR |
|--------|------------------|------|-------------------|----------------|-------|------|
| 1 | 1.58 | 0.56 | 0.26 | 0.26 | 0.38 | 0.012 |

| Cement | Coarse aggregate | Sand | Silica 80-100 mesh | Silica 325 mesh | Water | HRWR |
|--------|------------------|------|-------------------|----------------|-------|------|
| 1 | 1.58 | 0 | 0.53 | 0.53 | 0.32 | 0.012 |
Table 5. Comparison of normal or mixed concrete mix (25:75\%).

| Cement | Coarse aggregate | Sand | Silica 80-100 mesh | Silica 325 mesh | Water | HRWR |
|--------|------------------|------|-------------------|----------------|-------|------|
| 1      | 1.58             | 0    | 0.26              | 0.79           | 0.312 | 0.012 |

Table 6. Comparison of normal or mixed concrete mix (75:25\%).

| Cement | Coarse aggregate | Sand | Silica 80-100 mesh | Silica 325 mesh | Water | HRWR |
|--------|------------------|------|-------------------|----------------|-------|------|
| 1      | 1.58             | 0    | 0.79              | 0.26           | 0.31  | 0.012 |

2.1. Absorption and compressive strength

Absorption is one of the benchmarks, which can be used as a guideline whether the durability of concrete will be reliable or not\[5\]. The measurement of water absorption of the concrete refers to the SNI 03-6433-2000\[6\] standard that can be calculated by the following equation:

\[
\text{Absorption} = \frac{B-A}{A} \times 100\%
\]  \hspace{1cm} (1)

Where:
- \(A\) = Mass of dry object (kg)
- \(B\) = Mass of saturated object (kg)

![Figure 1. Test specimen on the crib.](image)

The measurement of compressive strength of the cylinder concrete refers to the SNI 1974:2011 standard [7], and it can be calculated by the following equation:

\[
\sigma' = \frac{P}{A}
\]  \hspace{1cm} (2)

Where:
- \(\sigma'\) = Compressive strength (kg/cm\(^2\))
- \(P\) = Pressure load (kg)
- \(A\) = Surface area of the specimen (cm\(^2\))
2.2. Making test items
The making of the test object consists of various variations of the mixture for experiments, namely the variation of the substitution of silica sand size 80-100 mesh: 325 mesh is (0: 0)%, (25:25)%, (50:50)%, (25:75)%, and (75:25)% silica sand to fine aggregates. After all the ingredients are finished, turn on the molen machine and put water into it which serves to wet the machine so that the actual concrete mixture is not reduced. After ± 30 seconds, the water in the molen is removed. The first step is to insert sand, cement, silica sand and split stone, leave it for ± 7 minutes so that the sand, cement, silica sand and split stones are evenly mixed.

Then 80% of the amount of water is mixed with HRWR (according to the dosage) then stirred, and put in enough into the molen in a spread, with the aim that the mixture of sand, cement, silica sand and split stone does not cause ash to billow out of molen. After that enter the water gradually (remaining 20% water) so that the mixture starts to appear clumping. After that, wait for the concrete mixture to reach the flowing condition of fresh concrete. The mixture has been evenly mixed, poured into a large pan that does not absorb water, and then the thickness is measured by using the slump Flow test method from the Abrams-Harder cone. After measuring the slump flow value, the concrete mixture is inserted into a cylindrical mold measuring 15 cm in diameter and 30 in height by dividing it into two stages, where each step is filled with 1/2 part of the cylinder mold and then compacted using a vibrator. After the age of 24 hours of concrete, cylindrical molds are opened and curing is carried out by immersing it in a soaking tub until the planned period of testing.

2.3. Slump flow test
The slump flow testing stages based on BS EN 12350-5 are as follows:
- The cone is placed on a flat base that does not absorb water
- The concrete mixture is inserted into the cone until the 1/2 part of the cone height is cornered 10 times
- The concrete mixture is put back into the cone until it is fully cornered 10 times
- The cone surface is flattened
- Clean the area around the slump flow test pad
- Wait 30 seconds from when the cone surface is leveled
- The cone is lifted slowly vertically upward in a period of 3-6 seconds
- Allow the concrete to flow above the bottom of the slump flow test surface
- Measure the widest diameter of the spread of the flowing concrete and the result is called diameter 1, then measure from a different axis and the result is called diameter 2.

Figure 2. Slump test.
3. Results and discussion

3.1. Slump flow test
From Figure 4, it can be seen that the slump flow value of the five concrete variations shows a significant difference. The high value of slump flow is caused by the use of Superplasticizer which serves to improve the workability of fresh concrete. The variation test II experienced bleeding, because when mixing the water added too much so that the water content causes the concrete slump to become high.
3.2. Absorption values of concrete cylinders

Table 7. The test results of absorption values.

| No | Variation | Age of Concrete (Day) | Wet Weight (kg) | Dry Weight (kg) | Absorption (%) |
|----|-----------|-----------------------|-----------------|-----------------|----------------|
| 1  | I         | 13.238                | 13.184          | 0.41            |
| 2  | I         | 13.110                | 13.062          | 0.37            |
| 3  | I         | 12.869                | 12.828          | 0.32            |
| 4  | II        | 12.684                | 12.643          | 0.32            |
| 5  | II        | 12.642                | 12.601          | 0.33            |
| 6  | II        | 13.154                | 13.112          | 0.32            |
| 7  | III       | 13.367                | 13.339          | 0.21            |
| 8  | III       | 13.055                | 13.026          | 0.22            |
| 9  | III       | 13.445                | 13.410          | 0.26            |
| 10 | IV        | 12.903                | 12.879          | 0.19            |
| 11 | IV        | 12.620                | 12.585          | 0.28            |
| 12 | IV        | 12.908                | 12.881          | 0.21            |
| 13 | V         | 13.300                | 13.258          | 0.32            |
| 14 | V         | 13.378                | 13.345          | 0.25            |
| 15 | V         | 13.290                | 13.268          | 0.17            |

According to Table 2, it can be seen that the absorption value of the five concrete variations shows a significant difference. The low absorption value is due to the heterogeneous concrete constituent material so that the maximum concrete density while the high absorption value indicates more pores contained in the concrete. For absorbs in specimen IV variation is low, because fine aggregate with micron size is used more that is 325 mesh silica sand as much as 75% compared to the use of silica sand 80-100 mesh which is only 25% so that the pores produced are more on concrete specimens less.
3.3. Compressive strength of concrete cylinders

In the compressive strength test, the specimen was given pressure until the maximum load which can be held by the concrete cylinder was obtained at the age of 7, 14, and 28 days, the size was 15 in diameter and 20 cm in height. The test was conducted based on SNI 1974: 2011 [7] about the testing method of concrete compressive strength with cylindrical specimens.

The highest compressive strength of the concrete at 7 days was found in variation III with 42.03 MPa in a mixture of 50% silica sand sized 80-100 mesh and 50% silica sand sized 325 mesh, whereas the lowest compressive strength was obtained by variation V with 27.03 MPa in a mixture of 25% silica sand sized 80-100 mesh and 25% silica sand sized 325 mesh. For the concrete at 14 days, the highest compressive strength was obtained in variation III with a value of 46.17 MPa, while the lowest compressive strength was found in variation II with a value of 37.20 MPa. Finally, for the concrete at 28 days, the highest compressive strength was found in variation III with 53.07 MPa, whereas the lowest compressive strength was obtained by variation II with 48.87 MPa.
4. Conclusions
1. Absorption values of concrete with a mixture of silica sand tend to be lower than normal concrete because of the fine aggregate used in micron size so that fewer pores are produced from the concrete specimen. The lowest absorption is in the variation IV test that is equal to 0.22%.
2. The maximum compressive strength values of normal concrete found at 28 days was 50.97 Mpa. Variation III also has the maximum compressive strength values was 53.07 Mpa.
3. The optimum compressive strength was found in variation III with an increase of 4.12% in the compressive strength from normal concrete at 28 days. Variation III also has a low absorption of 0.23% which means that the pores produced in the specimens are less than normal concrete so that the quality of the concrete is higher than normal concrete.
4. The size of the material on a micron scale causes fewer pores to be produced in the concrete and can increase the compressive strength of the concrete. More variations in the size of the material used can also cause fewer pores produced in the concrete and the higher the compressive strength of the concrete.

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