Comparison of compressive strength and porosity of porous concrete using the coarse aggregates graded uniform with continuous gradient

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Abstract. Porous concrete is a special type of concrete with high porosity. Porous concrete mix consisting of cement, water, and single sized coarse aggregate (graded uniformly). Uniformly graded coarse aggregate difficult to obtain in the market and are usually available are continuously graded coarse aggregate. Compressive strength and porosity are two very important things in porous concrete. Under these conditions, do research that aims to determine the ratio between the compressive strength and porosity of the concrete shaft using coarse aggregate graded uniformly with the use of coarse aggregate graded continuously. Gradation of coarse aggregate (gravel) used in the manufacture of porous concrete in this study there are two types of gradation uniform and continuous gradation. The weight ratio of aggregate / cement used was 4 and 5, and the water-cement factor (FAS) is 0.27. Chemical additives used are Sicacim Concrete Additive at a dose of 7.5 ml / kg cement. The test object in the form of concrete cylinders with a diameter of 15 cm and 30 cm high. Number of test specimens for each variation of a mixture of 3 pieces and the total test object as much as 27 pieces. Treatment is done by soaking the specimen in a tub filled with water. Testing porosity and compressive strength of concrete is done after only 28 days. The study concluded that the larger the maximum size graded gravel uniformly and consistently graded used resulted in the smaller compressive strength and greater porosity. Compressive strength of porous concrete that uses graded aggregate uniformly graded lower than continuous. Compressive strength of porous concrete that uses the highest uniformly graded aggregate amounted to 8.92 MPa and continuous grading is 14.04 MPa. Porosity of porous concrete that uses graded aggregate uniformly graded higher than continuous. Porosity of porous concrete that uses the highest uniformly graded aggregate amounted to 87.68 ltr / dt / m2 and continuous grading of 37.86 liters / sec / m2. Unit weight of porous concrete that uses graded aggregate uniformly graded lower than continuous.

1. Introduction

The Porous concrete is a mixture of cement, water, and single-sized rough aggregates, which are combined to produce porous structural materials. Porous concrete has a high pore volume, resulting in low strength and light weight. Non-sand concrete has many different names, including zero-fines concrete, pervious concrete, and porous concrete [1]. Porous concrete is a special type of high porosity concrete applied as a concrete plate that allows rainwater and water from other sources to pass through, thereby reducing surface runoff and improving groundwater levels [2].
Common applications for porous concrete are for parking lots, sidewalks, walkways, tennis courts, parks, slope stabilization, pool terraces, greenhouse floors, zoo area, road shoulders, drainage, noise absorbers, surface layers for road pavements, Permeable layer under concrete pavement, and road with low traffic volume. Translucent concrete is generally not used for pavement with heavy traffic and heavy wheel loads [3].

Porous concrete is obtained by removing the fine aggregate of the mixture so as to obtain a nominal aggregate particle agglomeration of one size, each covered with a layer of cement paste to about 1.3 mm (0.05 in) thick [4].

Based on [5] mix design for 1 m³ pervious concrete consisting of: cement (270 - 415 kg), aggregate (1190 - 1480 kg), cement water factor (0.27 - 0.34), and using chemical admixtures.

[6] conducted a non-sand concrete study with an aggregate weight ratio with cement from 6: 1 to 10: 1. The strength of non-sand concrete at 28 days varied from 1.1 to 8.3 MPa, depending on the aggregate ratio with cement, and the decrease occurs with increasing aggregate comparisons with cement. The mixture with aggregate ratio with 6: 1 cement is the strongest. The non-sand concrete compressive strength is lower than the conventional normal compressive strength of concrete caused by the increase in porosity.

Gradation is the grain size distribution of aggregates. If the aggregate item has the same size (uniform) then the pore volume is large. If the aggregate grain has varying sizes, the pore volume is small, since small grains fill the pores between the larger grains so that the pore is small and the pitch is high. Uniform gradations are gradations of equal or uniform size, whereas continuous gradations are gradations that have all grain sizes and are well distributed [7].

In porous concrete making it is usually advisable to use a uniformly aggregate graded aggregate. Uniformly graded aggregate aggregates are difficult to obtain on the market and usually available are coarse graded aggregates.

Based on the above description, we conducted a study on the compressive strength ratio and porosity of axle shafts using a uniform aggregate of uniform gradation with continuous gradation.

2. Method

The research method used is quantitative method that is by doing experiments in the laboratory. The main materials used in this study consisted of cement and coarse aggregates (gravel) originating from Merapi, Sleman, Yogyakarta. The graded coarse aggregates (gravel) used there are two types of uniform gradation and continuous gradation. The maximum size of gravel with uniform gradation is three types: 10 mm, 20 mm, and 40 mm. Maximum size of gravel with continuous gradation there are two types, namely 20 mm and 40 mm.

The weight ratio of aggregate / cement used there are two types namely 4 and 5, and the water cement ratio (wcr) used is 0.27. The additional chemical used is SicaCim Concrete Additive, with a dose of 7.5 ml / kg of cement. first The number of specimens of each variation is 3 pieces, and with the total number of specimens of 27 pieces. For more details can be seen in Table 1.

In this research, there are several types of testing, among others are: preliminary aggregate testing (gravel), compressive strength testing, porosity testing, and unit weight testing (porous concrete). Preliminary aggregate preliminary (gravel) test results can be seen in Table 2, Table 3, and Figure 1 to Figure 5.

| Gavel Max Size (mm) | Type of Gradation | Gavel/Cement Ratio | Numb of Cylinder Specimen |
|---------------------|-------------------|--------------------|---------------------------|
| 10                  | uniform           | 4                  | 3                         |
| 20                  | uniform           | 4                  | 3                         |
| 40                  | uniform           | 4                  | 3                         |
| 20                  | uniform           | 5                  | 3                         |
Table 2. Results of uniform gradation gravel testing.

| Types of testing | Max gravel size (mm) | Unit |
|------------------|----------------------|------|
|                  | 10       | 20    | 40    |          |
| Density (SSD)    | 2.274    | 2.341 | 2.338 |          |
| Absorption       | 3.407    | 2.596 | 2.556 | %       |
| Unit weight      | 1.498    | 1.523 | 1.536 | gr/cm³  |
| Water Content    | 0.523    | 0.624 | 0.543 | %       |
| Fineness Modulus | 6.018    | 6.986 | 7.979 | -       |

Table 3. Result of continuous gradation gravel testing.

| Types of testing | Max gravel size (mm) | Unit |
|------------------|----------------------|------|
|                  | 20       | 40    |       |
| Density (SSD)    | 2.365    | 2.409 | -     |
| Absorption       | 2.504    | 2.601 | %     |
| Unit weight      | 1.528    | 1.618 | gr/cm³|
| Water Content    | 0.482    | 0.563 | %     |
| Fineness Modulus | 6.958    | 7.358 | -     |

Figure 1. Gradation of gravel uniform maximum size 10 mm.

Figure 2. Gradation of gravel uniform maximum size 20 mm.
This study uses the following main tools: molon concrete is used for mixing and stirring concrete, compression machine is used to test compressive strength of concrete, and falling head tool for porosity testing.

The test specimen in the study refers to [8]. The specimen is a cylinder with a diameter of 152 mm and a height of 305 mm. The mold is filled with a concrete slab in 3 layers, each layer compacted with 25 punctures evenly, after which the concrete surface is flattened and covered with waterproof material. After 24 hours the mold is opened and the specimen is removed and then immersed in a water-immersion bath at 25 ° C. For more details, the specimens used in this study can be seen in Figure 6, Figure 7, and Figure 8.

Testing of concrete compressive strength refers to [8]. Test procedure through the following stages:

a. The test object is placed centric on the press machine.
b. The press machine is run by adding loads between 2 to 4 kg / cm² per second.
c. The loading is done until the test object is destroyed.
d. The maximum load occurring during the examination of the specimen is recorded.
e. The compressive strength of the concrete is calculated from the large unity load.
Concrete porosity testing through the following stages:

a. The test specimen is placed at the bottom of the porosity test instrument with a diameter of 15 cm.
b. The top end is inserted a pipe with a diameter of 15 cm with a length of 1 meter, on the connection given the plaster so as not to leak.
c. The pipe is filled with water as high as the specimen, the other pipe is 8 cm in diameter closed.
d. Pipe filled with water as high as 1 meter full, then cover pipe diameter of 8 cm removed, so that water flowing from the pipe through the concrete.
e. The time it takes water to penetrate the concrete until water is reduced by 50 cm which has been marked is recorded.
f. Debit is calculated from the amount of water that is divided by time.

For more details concrete porosity testing can be seen in Figure 9.
3. Results and Discussion

Compressive strength of porous concrete at various gravel/cement ratios, gradation types, and maximum gravel size are as Table 4, Figure 10, and Figure 11.

| Gavel Max Size (mm) | Type of Gradation | Gavel/Cement Ratio | Average Compressive strength (MPa) |
|---------------------|-------------------|--------------------|-----------------------------------|
| 10                  | uniform           | 4                  | 15.56                             |
| 20                  | uniform           | 4                  | 8.49                              |
| 40                  | uniform           | 4                  | 5.40                              |
| 20                  | uniform           | 5                  | 8.92                              |
| 40                  | uniform           | 5                  | 6.60                              |
| 20                  | continuous        | 4                  | 14.04                             |
| 40                  | continuous        | 4                  | 8.58                              |
| 20                  | continuous        | 5                  | 12.88                             |
| 40                  | continuous        | 5                  | 10.99                             |

From Table 4 and Figure 10 it can be seen that the compressive strength of porous concrete using a uniform aggregate gradation of maximum size 10 mm, 20 mm, and 40 mm, the ratio of gravel / cement 4, and with the water cement ratio (wcr) 0.27, respectively of 15.56 MPa, 8.49 MPa, and 5.40 MPa. From this result it can be seen that the larger the maximum size of the uniform gradation gradation used the smaller the compressive strength of the porous concrete produced.

From Table 4 and Figure 10 it can also be seen that the compressive strength of porous concrete using a continuous gradation aggregate of maximum size of 20 mm and 40 mm, the ratio of pebbles / cement 4, and with water cement ratio (wcr) 0.27, respectively of 14.04 MPa and 8.58 MPa. From this result it can be seen that the larger the maximum size of the continuous gradation gravel used the smaller the compressive strength of the resulting porous concrete.

From Table 4 and Figure 11 it can be seen that the compressive strength of porous concrete using a uniform aggregate gradation of maximum size of 20 mm and 40 mm, the ratio of gravel / cement 5, and with water cement ratio (wcr) 0.27, respectively of 8.92 MPa and 6.60 MPa. From this result it can be
seen that the larger the maximum size of the uniform gradation gradation used the smaller the compressive strength of the porous concrete produced.

From Table 4 and Figure 11 it can also be seen that the compressive strength of porous concrete using a continuous gradation aggregate of maximum size of 20 mm and 40 mm, the ratio of gravel / cement 5, and with water cement ratio (wcr) 0.27, respectively of 12, 88 MPa and 10.99 MPa. From this result it can be seen that the larger the maximum size of the continuous gradation gravel used the smaller the compressive strength of the resulting porous concrete.

Compressive strength of porous concrete using uniform gradations and continuous gradations decreases as the maximum size of gravel is used. This occurs because the larger the maximum size of gravel used causes the total surface area to be smaller, so that the aggregate surface attachment and paste are less strong and decrease the compressive strength of the concrete.

Compressive strength of porous concrete using a uniform gradation aggregate is lower than the continuous gradation at the same maximum size, the same aggregate ratio, and with the same water-cement factor. This occurs because the aggregate of the uniform gradation of the total surface area is smaller so that the aggregate interface between the surface and the paste is less strong and the interlocking is also less good, thus reducing the compressive strength of the concrete.

Porosity of porous concrete at various gravel/cement ratios, type of gradation, and maximum size of gravel are as Table 5, Figure 12, and Figure 13.

### Table 5. Porosity of porous concrete.

| Gravel Max Size (mm) | Type of Gradation | Gravel/Cement Ratio | Flow rate (ltr/dt/m²) |
|----------------------|-------------------|---------------------|-----------------------|
| 10                   | uniform           | 4                   | 17.94                 |
| 20                   | uniform           | 4                   | 52.99                 |
| 40                   | uniform           | 4                   | 87.68                 |
| 20                   | uniform           | 5                   | 86.74                 |
| 40                   | uniform           | 5                   | 61.49                 |
| 20                   | continuous        | 4                   | 20.56                 |
| 40                   | continuous        | 4                   | 31.50                 |
| 20                   | continuous        | 5                   | 28.11                 |
| 40                   | continuous        | 5                   | 37.86                 |

**Figure 12.** Porosity of porous concrete with gravel / cement ratio = 4.

**Figure 13.** Porosity of porous concrete with gravel / cement ratio = 5.
From Table 5 and Figure 12 it can be seen that porosity of porous concrete uses a uniform gradation aggregate of maximum size 10 mm, 20 mm, and 40 mm, gravel/cement ratio 4, and with water cement ratio (wcr) 0.27, respectively of 17.94 ltr / dt / m2, 52.99 ltr / dt / m2, and 87.68 ltr / dt / m2. From this result it can be seen that the larger the maximum size of the uniform gradation used the greater the porosity of porous concrete produced.

From Table 5 and Figure 12 it can also be seen that porosity of porous concrete uses a continuous gradation aggregate of a maximum size of 20 mm and 40 mm, gravel/cement ratio 4, and with water cement ratio (wcr) 0.27, respectively of 20.56 ltr / dt / m2 and 31.50 ltr / dt / m2. From this result it can be seen that the larger the maximum size of the continuous gradation used the greater the porosity of porous concrete produced.

From Table 5 and Figure 13 it can be seen that porosity of porous concrete uses a uniform aggregate gradation of maximum size of 20 mm and 40 mm, gravel/cement ratio 5, and with water cement ratio (wcr) 0.27, respectively of 86.74 ltr / dt / m2 and 61.49 ltr / dt / m2. From this result it can be seen that the larger the maximum size of the uniform gradation used the smaller porous porosity produced.

From Table 5 and Figure 13 it can also be seen that porosity of porous concrete uses a continuous gradation aggregate of a maximum size of 20 mm and 40 mm, gravel/cement ratio 5, and with water cement ratio (wcr) 0.27, respectively of 28.11 ltr / dt / m2 and 37.86 ltr / dt / m2. From this result it can be seen that the larger the maximum size of gravel used the greater porous porosity produced.

Porosity of porous concrete using uniform gradations and continuous gradations has increased as the maximum size of gravel is used. This happens because the larger the maximum size of the gravel used, the greater the void ratio, thereby increasing the porosity. Exceptions occur on uniform gradations and cement aggregate ratios 5 because the bottom of the cylinder is covered.

Porosity of porous concrete using a uniform gradation aggregate is higher than the continuous gradation at the same maximum size, same aggregate and cement ratio, and with the same water cement ratio. This happens because the aggregate of uniform gradation of the void ratio is larger because it has almost the same size while on the aggregate the continuous gradation is smaller because it has all grain sizes and is well distributed.

Unit weight of porous concrete at various aggregate ratios of gravel/cement, type of gradation, and the maximum size of gravel are as Table 6, Figure 14, and Figure 15.

| Gavel Max Size (mm) | Type of Gradation | Gavel/Cement Ratio | Average Unit Weight (kg/m³) |
|---------------------|-------------------|-------------------|-----------------------------|
| 10                  | uniform           | 4                 | 1903                        |
| 20                  | uniform           | 4                 | 1848                        |
| 40                  | uniform           | 5                 | 1775                        |
| 20                  | uniform           | 5                 | 1779                        |
| 40                  | continuous        | 4                 | 1912                        |
| 20                  | continuous        | 4                 | 1878                        |
| 40                  | continuous        | 5                 | 1871                        |

From Table 6, Figure 14, and Figure 15 it can be seen that unit weight of porous concrete using uniform gradation aggregate is lower than the continuous gradation at the same maximum size, the same aggregate/cement ratio, and same cement water cement ratio. This happens because the aggregate of the uniform gradation is smaller because it has almost the same size, whereas in the aggregate the continuous gradation density is greater because it has all grain sizes and is well distributed.
4. Conclusions

From the results of comparison of compressive strength and porosity of porous concrete using the coarse aggregates graded uniform with continuous gradient can be drawn conclusion as follows:

a. The greater the maximum size of the uniform graded and uniformly graded granules used, the smaller the compressive strength of the porous concrete produced.

b. The porous concrete compressive strength using a uniform gradation aggregate is lower than the continuous gradation.

c. The greater the maximum size of the uniform graded and uniformly graded granules used, resulting in greater porosity of the resulting porous concrete.

d. Porous porosity porosity using a uniform gradation aggregate is higher than continuous gradation.
e. The weight of the porous concrete volume using a uniform gradation aggregate is lower than the continuous gradation.

5. References

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