Effect of marble waste aggregate percentage with fly ash admixture toward compressive strength of pervious concrete

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Abstract. Pervious concrete with marble and gravel substitution shows low compressive strength. In another attempt the experiments carried out by adding fly ash as much as 20% of the weight of cement showed an optimal strength. This research aims to increase the compressive strength of pervious concrete by modify coarse aggregate proportions and adding fly ash admixture. Method that used is experimental with 4 variations aggregate size mixture. Type 1 are aggregate variation size of 2 cm, 1.5 cm, and 1 cm, type 2 are aggregate variation size of 2 cm and 1.5 cm, type 3 are aggregate variations size of 2 cm and 1 cm, and type 4 aggregate size 2 cm. Tests are on permeability test and concrete compressive strength test on age 3 days, 7 days, 14 days, 28 days. Permeability test results based on type of variations aggregate size respectively are 0.750 cm/sec, 0.737 cm/sec, 0.647 cm/sec, and 0.840 cm/sec. The results of the compressive strength test on all type at 28 days respectively are 8.008 MPa, 9.879 MPa, 11.542 MPa, and 8.357 MPa. Results of research on variations in the mixture, the maximum compressive strength is variations of coarse aggregate size 2 cm and 1 cm.

1. Introduction

There are universal water damages in the pavements serviced for one year irrespective of the structure type of the pavements only different by damage level [1]. From this problem, innovation arises namely pervious concrete. Pervious concrete is a special type of concrete with high porosity that has been applied as concrete slab that allows rain drops and water from another sources to through it, thereby reducing surface runoff and increase ground water level. High porosity achieved because interconnected cavity [2]. However, high drain ability characteristics do not generally correspond to high strength and good surface condition when submitted to vehicular traffic, hence, to date, the applications of pervious concrete are limited to particular urban areas [3]. Usually pervious concrete use a little or nothing fine aggregate and has enough cement paste to cover coarse aggregate dan to preverse pore interconnected [4,5]. According to ACI 522R-10 report of pervious concrete, pervious concrete is described as concrete that has zero slump test, formed from cement portland,coarse aggregate, little or nothing fine aggregate, admixture, and water. Pervious concrete have permeability value between 0.14 cm/s - 1.22 cm/s and have compresive strength value between 2,8 Mpa – 28 Mpa [6]. With that permeability value and compressive strength value, pervious concrete can be used for road construction, parking area, trotoar, and park area that can pass water from the surface that can seep into the ground [7].

Leaving the waste materials to the environment directly can cause environmental problem. Hence, many countries have been working on how to reuse the waste material so that they reduced hazards to
the environment [8]. In pervious concrete, waste material can be used as one of mixtures. The material is designed with a cementitious material content just enough to coat the coarse aggregate particles so that a configuration that allows the passage of water at a much higher rate than conventional concrete is produced [9]. Pervious concrete research previously done by Rahayu Jati Permana in 2017 with title “Effect of Addition Fly Ash to Compressive Strength of pervious concrete with Marble Waste Substitution” [10]. From this research coarse aggregate that has used is marble waste with size 0.5 inch and using water cement ratio 0.33 with coarse aggregate with cement ratio 0.36, admixture fly ash with percentage 0%, 5%, 10%, 15%, 20%, 25% with the result of compressive strength at 28 days consecutively 8.276 Mpa, 8.435 Mpa, 9.242 Mpa, 11.035 Mpa, 12.287 Mpa, and 11.968 Mpa. With permeability 0.82 cm/s, 0.758 cm/s, 0.717 cm/s, 0.709 cm/s, 0.471 cm/s, 0.496 cm/s. From this research writer want to continue this research with presenting marble waste coarse aggregate variations in pervious concrete with using admixture fly ash with optimum value at 20% with 4 variations aggregate sizes.

2. Research method
Research methods is doing experiment in laboratory. Materials that will be used is as follows:
- Portland cement used is PCC Tiga Roda Cement
- Coarse aggregate used is marble waste from Padalarang
- Admixture using fly ash type F from PT. Pionirbeton
- Water is using from Laboratory Structure Civil Engineering, Indonesia University of Education

Total sample that will be used is 48 sample. This based on size aggregate variations and day of test.

| Name Variation | Aggregate Size (%) | Ages (days) | Total |
|----------------|--------------------|-------------|-------|
|                | 1 cm               | 1.5 cm      | 2 cm  | 3   | 7   | 14  | 28  |       |
| MARBLE WASTE PERVIOUS CONCRETE WITH 20% FLY ASH | type 1 | 33,3 | 33,3 | 33,3 | 3 | 3 | 3 | 3 | 12 |
|                | type 2 | 50 | 50 | 3 | 3 | 3 | 3 | 3 | 12 |
|                | type 3 | 50 | 50 | 3 | 3 | 3 | 3 | 3 | 12 |
|                | type 4 | 100 | 3 | 3 | 3 | 3 | 12 |
|                | Total | 12 | 12 | 12 | 12 | 12 | 48 |

1 m³ pervious concrete, need 1478.558 kg coarse aggregate (marble waste), 422.764 kg cement, 126.829 kg water, and 84.553 kg admixture fly ash. On coarse aggregate material test, there are examination water content, volume weight test, and specific gravity and absorption. The results of the material testing will be presented in Table 2 until table 4.

| Test | 1   | 2   | 3   |
|------|-----|-----|-----|
| Vessel weight (W1) | 140 | 135 | 135 |
| Vessel weight + Sample (W2) | 4140 | 4135 | 4135 |
| Sample weight (W3) = (W2 - W1) | 4000 | 4000 | 4000 |
| Sample weight + Vessel after dried (W4) | 4135 | 4130 | 4130 |
| Sample after dried (W5) = W4 - W1 | 3995 | 3995 | 3995 |
| Water content [(W3-W5)/W3]x100% | 0.125 | 0.125 | 0.125 |
| Water content average (%) | 0.125 |
Table 3. Result of coarse aggregate material (volume weight).

| Test                              | Unit   | Loose   | Stabbing | Shaking |
|-----------------------------------|--------|---------|----------|---------|
| Vessel volume (A)                 | Litre  | 9.944   | 9.944    | 9.944   |
| Vessel weight (B)                 | Kg     | 8.980   | 8.980    | 8.980   |
| Vessel weight + Sample (C)        | Kg     | 22.470  | 23.580   | 22.070  |
| Sample weight (D) = (C-B)         | Kg     | 13.490  | 14.600   | 14.090  |
| Volume weight (D/A)               | Kg/Litre | 1.356 | 1.468    | 1.417   |
| Volume weight (D/A)               | Kg/m³  | 1356.597 | 1468.222 | 1416.934 |

Table 4. Result of coarse aggregate material (specific gravity and absorption).

| Test                              | 1     | 2     | 3     | Average |
|-----------------------------------|-------|-------|-------|---------|
| Sample weight SSD (A)             | 3000  | 3000  | 3000  | 3000    |
| Sample weight in water (B)        | 1745  | 1692  | 1765  | 1734    |
| Air dry sample weight (C)         | 2995  | 2995  | 2990  | 2993    |
| Apparent SG [(C/(C-B)]            | 2.396 | 2.298 | 2.489 | 2.394   |
| Bulk SG dried condition [(C/(A-B)]| 2.386 | 2.281 | 2.388 | 2.351   |
| Bulk SG SSD condition [(A/(A-B))] | 2.390 | 2.888 | 2.429 | 2.569   |
| Water Absorption percentage [(A-C)/A] (%) | 0.166 | 0.332 | 1.666 | 0.704 |

In making test sample, this research refers to SNI 2493 of 2011. Mold cylindrical test sample with a diameter of 10 cm and a height of 20 cm. The mold is filled with a concrete mixture in 3 layers, each layer is compacted by using a proctor 25 times evenly, after the surface of the sample is flattened and covered with waterproof material. After 24 hours, the mold is opened and the test object is removed from the mold. For maintenance (curing) the test object is covered using a wet burlap sack to make concrete stay hydrated.

In permeability test, the procedure is to prepare the samples which has been dried before, then prepare falling head permeability set-up with the faucet closed. Insert the sample of pervious concrete to the

Figure 1. Pervious concrete curing.
instrument (falling head permeability set-up) on the left tube. Put water into the left tube until the water level comes out on the right tube, lock the faucet and fill water on the right tube as much as 3 litres. Prepare stopwatch to count the time that water required to go through on pervious concrete sample. Open the faucet and run stopwatch at the same time and count until the water on the left tube has stop flowing, write down the time on the stopwatch and count the permeability with existing regulations.

![Figure 2. Falling head permeability tool.](image1)

![Figure 3. Permeability test.](image2)

### 3. Result and analysis

From the coarse aggregate test obtained a weight volume of 1468.222, the value of air content of 0.125%, and the value of absorption of the coarse aggregate of 0.704%. In permeability test, this test is carried out by the Simple Falling Head Permeameter method with the obtained parameter is time (second). The time obtained from water volume in a tube with a diameter of 10 cm with a height of 30 cm until it runs out (position 0 cm). In this test, the permeability requirements that must be approved for previous concrete are between 0.14 cm/s - 1.22 cm/s. The results of the permeability testing are shown in table 5.

| Aggregate Variation       | Average Permeability (cm/s) |
|---------------------------|----------------------------|
| Type 1 (2 cm: 1,5 cm: 1 cm)| 0.750                      |
| Type 2 (2 cm: 1,5 cm)     | 0.737                      |
| Type 3 (2 cm :1 cm)       | 0.647                      |
| Type 4 (2 cm)             | 0.840                      |

Average results of pervious concrete permeability test, the permeability value is 0.647 cm/s - 0.840 cm/s.
Figure 4. Average results permeability of pervious concrete.

On figure 4 average results of pervious concrete permeability testing can be seen that type 3 pervious concrete produces smaller permeability values compared to other types. This value can take conclusion that type 3 have the highest compressive strength value.

Pervious concrete compressive strength test is carried out at day 3, 7, 14, and 28. The test is done by recording the compressive load first which is then calculated to obtain the compressive strength (MPa) value. Following are the results of compressive strength tests of pervious concrete with various variations of the concrete aggregate mixing ratio presented in table 6 and figure 5.

| Variation | Compressive strength (MPa) |
|-----------|----------------------------|
|           | Ages 3 | Ages 7 | Ages 14 | Ages 28 |
| type 1    | 4.628  | 6.428  | 6.473   | 8.008   |
| type 2    | 6.645  | 7.629  | 8.701   | 9.879   |
| type 3    | 9.764  | 10.192 | 11.304  | 11.542  |
| type 4    | 6.358  | 6.453  | 6.614   | 8.357   |
| type 4    | 0.750  | 0.737  | 0.647   | 0.840   |
Greatest compressive strength value is achieved by type 3, namely aggregate variation the 2 cm and 1 cm with 11,542 MPa compressive strength. Then the second biggest compressive strength is obtained by type 2, which is the aggregate variation of 2 cm and 1.5 cm with a compressive strength of 9,879 MPa. Third is obtained by type 4, namely 2 cm aggregate with compressive strength of 8,357 MPa. Of the four compressive strength values, the smallest compressive strength value obtained by type 1 is the aggregate variation of 2 cm, 1.5 cm, and 1 cm with a compressive strength of 8.008 MPa.

On figure 6 it can be seen that the compressive strength is inversely proportional to the permeability value of pervious concrete. This is because the smaller the permeability value, the more solid the concrete is, thereby increasing the load and specific gravity of the pervious concrete which results in increased compressive strength.

Results on this research can be explained bellow:

- Permeability of pervious concrete have values that between the permeability range, which is 0.14 cm/sec - 1.22 cm/sec. From the type of concrete aggregate size variation it can be concluded that the lowest permeability is achieved by type 3 which is 0.647 cm/sec and the greatest permeability is achieved by type 4 which is 0.849 cm/sec. From this permeability value, it can be concluded that the smaller the permeability value, the higher the compressive strength achieved. This is because the smaller the permeability value, the less void content in pervious...
concrete, from less void content, it will produce more density in the concrete. So that the compressive strength of concrete can be estimated to increase from concrete which has a greater void content.

- The highest compressive strength value on the 28th day of test was achieved by type 3, namely the variation of coarse aggregate size of 2 cm and 1 cm with compressive strength value of 11.542 MPa. Then in type 2, the variation of coarse aggregate size of 2 cm and 1.5 cm with a compressive strength value of 9.879 MPa. Then in type 4, the size of coarse aggregate of 2 cm with a compressive strength value of 8.357 MPa. And the lowest compressive strength is type 4, namely the variation of coarse aggregate size of 2 cm, 1.5 cm, and 1 cm with a compressive strength value of 8.008 MPa. From the results of this compressive strength estimates of the permeability value proved to be true with type 3 which has the greatest compressive strength and has the smallest permeability.

4. Conclusion

- Pervious concrete with a substitution of 100% marble stone waste with a variation of 4 types of aggregate mixing ratio meets the requirements of pervious concrete permeability of 0.14 cm/sec - 1.22 cm/sec, type 1 variation (aggregate 2 cm, 1.5 cm and 1 cm) has a permeability of 0.75 cm/sec, variations of type 2 (aggregate 2 cm and 1.5 cm) have permeability of 0.737 cm/sec, variations of type 3 (aggregate of 2 cm and 1 cm) have permeability of 0.647 cm/sec, and type 4 variations (aggregate 2 cm) have permeability 0.840 cm/sec. This all types meet the specified permeability requirements.

- Pervious concrete with a substitution of 100% marble stone waste with a variation of 4 types of aggregate mixing ratio produces compressive strength as follows, namely type 1 with an aggregate mixture of 2 cm, 1.5 cm and 1 cm produces compressive strength of 8.008 MPa, type 2 with a mixture of 2 cm and 1.5 cm aggregate produces a compressive strength of 9.879 MPa, type 3 with an aggregate of 2 cm and 1 cm produces a compressive strength of 11.542 MPa, and a type 4 with an aggregate of 2 cm produces a compressive strength of 8.357 MPa.

- The maximum compressive strength of pervious concrete is achieved in type 3 (aggregate 2 cm and 1 cm) by showing a compressive strength of 11.542 MPa.

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