Pavement Design using Environmentally Friendly Porous Concrete

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Abstract. This study aims to analyze sidewalks in big cities and small towns, which is an important thing in designing urban road order. This research used descriptive qualitative method, which is done by collecting data from literature studies that support the theory of porous concrete. Based on the data obtained, the results showed that porous concrete has a compressive strength that is dependent on the size of the aggregate, cement water factor, and levels of additive substances used, with the highest compressive strength obtained in the study is 153 kg/cm² and is able to drain water between 69 – 113 litres/minute per m². It was concluded that porous concrete can be used as an environmentally friendly material, a construction that can withstand light loads and does not meet the pavement specifications for the road body because it has a flexural tensile strength and low compressive strength value, so that porous concrete can only be used as an open parking area, shoulder or pedestrian.

1. Introduction

Porous concrete is popular and continue to get a lot of attention in the construction industry. Porous concrete is usually formed with a high vacancy content (15-25%) there is no fine aggregate in porous concrete [1]. Prabowo explained that porous concrete is an element of building material made from a mixture of coarse aggregate, cement, water, and a little fine aggregate without other added ingredients which does not reduce the quality of the concrete, this mixture creates the material can be porous or structurally exposed like cells, as well as when it rains rain can penetrate the underlying land [2]. The concrete can flow through rainwater, this porous concrete can be used as a material pedestrian in parking areas, areas with lonely traffic, residential roads, sidewalks, and environmentally friendly homes. Permeable pavement systems can contribute to solving drainage problems and reducing the risk of flash floods, resulting from sustainable urban development. Portland Concrete Pervious Concrete (PCPC) or porous concrete is a special type of concrete characterized by interconnected pore structures and high void content/porosity, usually in the range of 15 to 35% by volume. The use of PCPC can reduce the risk of flooding, replenishing groundwater, reducing stormwater [3,5].

Concrete pore using broken stone aggregate can produce the greatest value for compressive strength, namely 5.631 MPa, porosity 5.03% and permeability 0.80 cm/sec. Whereas in the unbroken stone aggregate the largest value for compressive strength is 10.718 MPa, porosity 3.14% and permeability 0.50 cm/sec. So that the use of broken stone aggregate produces greater porosity and permeability values but with a smaller compressive strength compared to unbroken stone aggregate. Porous concrete mix with
broken stone and non-broken stone cannot be applied for pedestrian paths, because the compressive strength results achieved are still below the compressive strength requirements for pedestrian path applications according to SNI 03-06911996 which is 15 MPa. In the broken stone aggregate mixture, the greatest compressive strength is found in the composition with the addition of added material of 15 ltr / m3, while the greatest porosity and permeability is found in the addition of material add 10 litres/m3. In the unbroken stone aggregate mixture, the greatest compressive strength was found in the composition with the addition of added material of 15 ltr / m3, while the greatest porosity and permeability was found in the addition of 25 ltr / m3 admixture content [6-8]. The compressive strength, porosity, and permeability obtained, it can be seen that the compressive strength obtained will affect the porosity and permeability values in porous concrete. The greater the compressive strength of porous concrete, the porosity and permeability which [9,10].

This study aims to analyze sidewalks in big cities and small towns, which is an important thing in designing urban road order. This research used descriptive qualitative method, which is done by collecting data from literature studies that support the theory of porous concrete.

2. Method
This research used descriptive qualitative method, which is done by collecting data from literature studies that support the theory of porous concrete. Therefore, the influence of porous concrete has on the environmentally friendly pedestrian design can be analyzed.

3. Results and Discussion
To find out if porous concrete can affect the environmentally friendly sidewalk design, several studies have been carried out to determine the compressive strength, flexural strength, and absorption strength of porous concrete if it is used as material for the environmentally friendly pedestrian. From the method used that is collecting data in a study of research that has been done, the results of the study is explained in detail as follows: The composition of the test specimens in this study is based on the volume results obtained from normal concrete calculations, then the results of the composition obtained is rematched to the composition of the use of the material contained in ACI 522R-10 (see Table 1).

Table 1. The Composition of Porous Concrete Specimens and Rough Aggregate Test Results
From the Table 1 above, it was found that all coarse aggregate tests have met the requirements, so coarse aggregates are suitable for use in porous concrete mixes. Furthermore, Porous Concrete Average Pressure Test Results can be seen in Table 2.

**Table 2. Porous Concrete Average Pressure Test Results**

| Age of Testing (days) | I-A   | I-B   | I-C   | I-D   | II-A  | II-B  | II-C  | II-D  |
|-----------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| 14                    | 3.041 | 7.591 | 8.784 | 8.121 | 4.735 | 8.480 | 7.227 | 10.399|
| 28                    | 4.018 | 5.631 | 4.156 | 5.72  | 10.526| **10,718** | 7.175 | 10.272|

Based on Table 2, it can be seen that the porous concrete average pressure test results in II B for 28 days of testing ranks highest. The combined compressive strength of all porous concrete compositions can be seen in the following Figure 1.

**Figure 1. Comparison of Porous Concrete Pressure Strength**

Based on Figure 1 above, it can be seen that The combined compressive strength of all porous concrete compositions consists of two types. each type consists of 3 different types according to the age of concrete in a matter of days. Porous concrete priority testing results can be seen in Table 3.
Table 3. Porous Concrete Priority Testing Results

| Composition | Weight /Wk (gr) | Weight SSD/ Wb (gr) | Porosity | Average Porosity |
|-------------|----------------|---------------------|----------|-----------------|
| I-A         | 7800           | 8200                | 7.55     | 5.03            |
|             | 7600           | 7800                | 3.77     |                 |
|             | 7900           | 8100                | 3.77     |                 |
| I-B         | 8600           | 8700                | 1.89     | 2.52            |
|             | 9000           | 9100                | 1.89     |                 |
|             | 9000           | 9200                | 3.77     |                 |
| I-C         | 10100          | 10200               | 1.89     | 1.89            |
|             | 9800           | 9900                | 1.89     |                 |
|             | 9400           | 9500                | 1.89     |                 |
| I-D         | 9100           | 9250                | 1.89     | 1.89            |
|             | 9100           | 9250                | 1.89     |                 |
|             | 8700           | 8800                | 1.89     |                 |
| II-A        | 10800          | 11000               | 3.77     | 2.52            |
|             | 10000          | 10100               | 1.89     |                 |
|             | 10100          | 10200               | 1.89     |                 |
| II-B        | 10200          | 10300               | 1.89     | 1.89            |
|             | 11200          | 11300               | 1.89     |                 |
|             | 12200          | 12300               | 1.89     |                 |
| II-C        | 10700          | 10900               | 3.77     | 2.53            |
|             | 10100          | 10200               | 1.89     |                 |
|             | 10500          | 10600               | 1.89     |                 |
| II-D        | 11100          | 11300               | 3.77     | 3.14            |
|             | 10900          | 11000               | 1.89     |                 |
|             | 11400          | 11600               | 3.77     |                 |

From Table 3, it can be seen that the highest compressive strength value is found in the composition of a mixture of unbroken stone aggregate and added material content of 15 ltr / m³ with a value of 10.718 MPa. However, the compressive strength obtained has not yet reached the desired compressive strength target, which is 15 MPa for the sidewalk. With the compressive strength values obtained, the porous concrete mixture in this study can only be applied to parks in accordance with the classification of concrete bricks contained in SNI 03-0691/1996 for D quality with compressive strength values between 8.5 - 10 MPa. Porous concrete priority testing results can be seen in Table 4.
Table 4. Porous Concrete Priority Testing Results

| Composition | Weight (gr) | Content Weight (gr) | \( A \) (m) | Time (sec) | Average Time (sec) | \( k \) (m/sec) | Average \( k \) (m/sec) |
|-------------|-------------|---------------------|----------|------------|-------------------|----------------|--------------------------|
| I-A         | 7800        | 1,471               | 0,1008   | 11,07      |                   | 0,0091         | 0,0080                   |
|             | 7600        | 1,434               | 0,1008   | 11,70      | 12,89             | 0,0086         | 0,0080                   |
|             | 7900        | 1,490               | 0,1008   | 15,91      |                   | 0,0063         | 0,0066                   |
|             | 8600        | 1,622               | 0,1008   | 15,30      |                   | 0,0066         | 0,0066                   |
| I-B         | 9000        | 1,698               | 0,1008   | 16,05      | 17,40             | 0,0063         | 0,0059                   |
|             | 9000        | 1,698               | 0,1008   | 20,86      |                   | 0,0048         |                         |
|             | 10100       | 1,905               | 0,1008   | 24,16      |                   | 0,0042         |                         |
| I-C         | 9800        | 1,849               | 0,1008   | 37,57      | 30,58             | 0,0027         | 0,0034                   |
|             | 9400        | 1,773               | 0,1008   | 30,01      |                   | 0,0034         |                         |
|             | 9100        | 1,717               | 0,1008   | 22,15      |                   | 0,0046         |                         |
| I-D         | 9100        | 1,717               | 0,1008   | 26,66      | 23,45             | 0,0038         | 0,0043                   |
|             | 8700        | 1,641               | 0,1008   | 21,55      |                   | 0,0047         |                         |
|             | 10800       | 2,037               | 0,1008   | 34,51      |                   | 0,0029         |                         |
| II-A        | 10000       | 1,886               | 0,1008   | 30,10      | 32,11             | 0,0033         | 0,0031                   |
|             | 10100       | 1,905               | 0,1008   | 31,72      |                   | 0,0032         |                         |
|             | 10200       | 1,924               | 0,1008   | 31,91      |                   | 0,0032         |                         |
| II-B        | 11200       | 2,113               | 0,1008   | 34,19      | 38,12             | 0,0029         | 0,0027                   |
|             | 12200       | 2,301               | 0,1008   | 48,26      |                   | 0,0021         |                         |
|             | 10700       | 2,018               | 0,1008   | 35,24      |                   | 0,0029         |                         |
| II-C        | 10100       | 1,905               | 0,1008   | 23,01      | 28,77             | 0,0044         | 0,0036                   |
|             | 10500       | 1,981               | 0,1008   | 28,05      |                   | 0,0036         |                         |
|             | 11100       | 2,094               | 0,1008   | 18,59      |                   | 0,0054         |                         |
| II-D        | 10900       | 2,056               | 0,1008   | 20,15      | 30,11             | 0,0050         | 0,0050                   |
|             | 11400       | 2,150               | 0,1008   | 21,47      |                   | 0,0047         |                         |

Based on Table 4, the greatest porosity and permeability for broken stone aggregates are found in mixtures with 10 ltr / m3 added ingredients of 5.03% and 0.0080 m / sec, whereas for stone aggregates the highest porosity and permeability for broken stones do not break. found in the mixture with added ingredients 25 ltr / m3 of 3.14% and 0.0050 m / sec. From the permeability test results, it is also known that the faster the time required for water to absorb, the greater the permeability value. The relationship between time and permeability of porous concrete can be seen in the graph in Figure 2.
Figure 2. Time Comparison with Porous Concrete Permeability

Figure 2 showed that the relationship between time and permeability of porous concrete. Type I-A takes 10 seconds, type I-B takes 15 seconds, type I-C takes 30 seconds, and type I-D takes 35 seconds. Relationship of Compressive Strength with Porosity and Permeability Comparison of compressive strength with porosity and permeability can be seen in Figure 3.

Figure 3 shows that the compressive strength produced by porous concrete is inversely proportional to the value of porosity and permeability. The higher the compressive strength achieved, the lower the porosity and permeability of porous concrete.
4. Conclusion

The development of increasingly sophisticated technology created new innovations that can overcome problems, especially on the environment. Porous concrete is one of the new innovations that want to realize the ideals of the world to be more environmentally friendly. The greatest value for compressive strength produced is 5.631 MPa, porosity 5.03% and permeability 0.80 cm/sec. From studies of existing research results show that the level of porosity and permeability in porous concrete shows high results while the compressive strength of porous concrete shows low results. This shows that porous concrete is able to flow through rainwater through porous concrete to the ground foundation. However, the compressive strength of low porous concrete causes this material cannot be used as a material in the pedestrian because the compressive strength value is still below the compressive strength requirements for pedestrian path applications according to SNI 03-0691-1996 which is 15 MPa. The properties that occur in porous concrete are the greater the compressive strength of porous concrete, the porosity and permeability values produced is lower.

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