Development of Single Sized Aggregate Porous Concrete for Sustainable Road in Low Traffic Area

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Abstract. Porous concrete design with selected gradation and the developed method is proven to be able to withstand light traffic loads and pass water so that rainwater can be used optimally and keep the ground surface remains a green open area. Porous Concrete is a special concrete material produced with aggregate, cement and water with high porosity, which is between 15 to 30 %, so that water can be easily to pass. The main function of porous concrete is as a concrete pavement covering the soil surface with the aim that water can easily flow under the concrete layer, and thus the excess surface water will be reabsorbed into the ground, rather than just being wasted into the sea, the method of producing porous concrete has been patented. The mixture creates an open cell structure, allowing rainwater to penetrate the underlying land. It can be used for low-traffic areas. Porous concrete that uses one size aggregate or uniform aggregate has low compressive strength but good permeability. Porous concrete at 28 days age has a compressive strength between 3 to 28 MPa with a porosity of 14 to 31 % and a permeability ranging from 0.25 to 6.1 mm / second.

1. Introduction
The US Environmental Protection Agency's porous sidewalk research program along with the economy, benefits, potential applications, and future research needs of porous walkways. Porous walkways are available rainwater management techniques that can be used on parking lots and low volume highways to reduce runoff and rainwater pollution. In addition, ground water refilling can be increased. And the reduction in costs due to the removal of restrictions, waterways, and gutters. Porous asphalt pavement consists of a relatively thin arrangement, an open graded asphalt mixture with relatively large broken stone sizes. Water can be stored in a rock arrangement until it can seep into the bottom foundation layer. Other types of porous concrete block and porous concrete [1]. Porous sidewalks allow rainfall to seep through the pavement into the ground, reducing the volume of rainwater runoff that occurs at a location. However, porous sidewalks are not widely used in fine-grained soils because they will affect water absorption. The aim of the study was to investigate the effectiveness of porous walkways in controlling runoff in clay. We compared the performance of an asphalt parking and porous concrete sidewalk parking in Athens, Georgia, United States, relatively small rain and low intensity. Porous concrete produces 93% less runoff than asphalt. Our results show
porous sidewalks are a viable option for reducing rainwater runoff and some pollutants from small storms or the first flush of large storms in clay [2].

Paved concrete pavement used for roads was introduced. Using common methods and materials, porous concrete itself has a low compressive strength. The use of smaller aggregates, silica fume (SF), and superplasticizer (SP) in porous concrete can increase compressive strength. Porous pavement consisting of surface and base layers. Compressive strength of composites can reach 50 MPa and 6 MPa flexural strength. Water penetration, abrasion resistance, freezing and thawing have excellent material durability. This can be applied to both footpaths and road vehicles. This is an environmentally friendly pavement material [3]

Porous concrete is an effective and environmentally friendly road material, because it drains rainwater and allows water to seep into the ground, porous concrete material can fill groundwater reserves, and reduce surface runoff. By being applied to the shoulder of the road, runoff from the road is expected to be absorbed into the ground and can reduce water discharge in the drainage channel [4]. The more environmentally friendly of porous concrete has been conducted using recycled aggregates [5] and provide excellent performance as using fresh aggregates. It could be a challenge to continue the research.

2. Experimental
In general, a research has the aim to develop and test the truth of a knowledge. In research so that the expected goals can be achieved, then carried out a method, the research method is the steps of research a particular problem, case, symptom, or phenomenon with a scientific path to produce a ratio answer. In this study the method used is an experimental method that is the method carried out by conducting an experiment directly in the laboratory or in the field. The experimental method can be done inside or outside the laboratory. The tests carried out include testing and compressive strength in the lab and in the field.

The production of test specimens uses the results of gradations from the results of previous research [6] and the results of gradations of crushed stone materials of 1-2 and 2-3 sizes. The design of the mixed design uses the SK SNI T-15-1990-03 method as a reference material in the porous concrete design mix, because porous concrete has no regulations that govern the standard for making porous concrete. The test were performed at Sebelas Maret University's Materials Laboratory. The steps of making test specimens in this study can be described as follows:

- Prepare materials (cement, aggregate, and water) and equipment that will be used for concrete mix.
- Preparing porous concrete casting areas and molds for samples.
- Weigh each material based on porous concrete mix design calculations.
- Making porous concrete mortars and making test specimens in the laboratory.
- Caring for porous concrete (curing) and soaking the sample in water until the time of testing.

3. Results and Discussions
Porous concrete is concrete with a porosity value of 15-30% made from a mixture of coarse aggregate, cement, water, and a little fine aggregate. The difference between porous concrete and normal concrete lies in:

- Aggregates used are coarse aggregates or with small amounts of fine aggregate.
- The cement water factor must be maintained so that after the concrete has hardened the pores formed are not covered by the hardened cement paste mixture. In addition, the control on the cement water factor also aims so that the aggregate grains can be tightly bound to one another.

Porous concrete forming materials can be described as follows:

- Cement, The cement used in porous concrete is the same as conventional concrete, namely Portland cement. The cement used in this study was PPC cement.
• Aggregate, The use of fine aggregate in porous concrete is very limited, even if necessary it is not used. Avoidance of the use of fine aggregate aims to prevent the formation of solid concrete so that the resulting concrete is no longer porous. Coarse aggregate size used is 1-2 aggregate with uniform gradation.

• Water, The composition of water and cement in porous concrete must be arranged in such a way so that the concrete that is formed has sufficient pores so that it can function as a drainage channel for water and is able to bind the existing aggregate grains firmly into a single unit. Errors in calculating the composition of water can result in porous concrete formed having a low compressive strength or producing porous concrete which has a weak bond between cement paste and aggregate.

3.1 Aggregate Gradation
The tests conducted on fine aggregate in this study include testing the content of sludge, organic matter content, specific gravity, and grading of sand. Specifications of coarse aggregate gradation for ordinary concrete using ASTM C33-1997. The ASTM C33-1997 specification is an example of gradation for ordinary concrete, whereas porous concrete does not yet have gradation specifications. So ASTM C33-1997 is only a comparison of coarse aggregate gradations between ordinary concrete and porous concrete.

| No | Sieve Size (mm) | Retain Weight | Passing weight (%) | ASTM C-33 |
|----|-----------------|---------------|--------------------|-----------|
|    | Gr. | % | Cumulative (%) |              |           |
| 1/4 | 38  | 0  | 0,00             | 0,00       | 100,00    | 100       |
| 3/4 | 25  | 0  | 0,00             | 0,00       | 100,00    | 100       |
| 1/2 | 19  | 80 | 2,68             | 2,68       | 97,32     | 95-100    |
| 1   | 12,50| 2020| 67,67            | 70,35      | 29,65     | 65-85     |
| 2   | 9,50| 685 | 22,95            | 93,30      | 6,70      | 22-55     |
| 4   | 4,75| 185 | 6,20             | 99,50      | 0,50      | 0-10      |
| 8   | 2,36| 15  | 0,50             | 100,00     | 0,00      | 0-0       |
| Pan | 0   | 0   | 0,00             | 100,00     | 0,00      |           |
|     | Total Weight | 2985,00 | 100,00           |           |           |

3.2 Mixture Design
The standard of porous concrete planning in Indonesia does not yet exist, therefore, as a reference for calculating a normal concrete mix plan using SNI T-15-1990-03 Concrete Mixing Plan that has been conducted by Rochim in 2014 with the use of 30 % of sand and cement needs 300 kg and a cement water factor of 0.45[5].

Here are the requirements for each m³ of porous concrete
- Sand = 173.33 kg
- Cement = 300 kg
- Crush Stone = 1666.67 kg

3.3 Laboratory Sample
Based on the mixture plan that has been discussed previously, then for research in the lab to make test specimens for compressive strength tests in the form of concrete cylinders with size D = 0.15 m, height 0.3 m, there are 3 specimens for each type of material.
## 3.4. Field sample

The application of porous concrete in the field by converting from the results of the calculation of the mixed design is made applicable in the field, namely by using a bucket size that has been determined and researched. For more details can be seen in the table below.

### Table 3 Material for Field Sample

| Sample Code | Materials |
|-------------|-----------|
|             | Sand      | Portland Cement | Coarse Aggregate | Water | Additive |
|             | (kg)      | (kg)            | (kg)             | (liter) | (milliliter) |
| A Type 1-2  | 1,75      | 1               | 7,3              | 18      | 0          |
| B Type 1-2 + Additive | 1,75 | 1 | 7,3 | 18 | 2 |
| C Type 2-3  | 1,8       | 1               | 7,5              | 18      | 0          |
| D Type 2-3 + Additive | 1,8 | 1 | 7,5 | 18 | 2 |

Based on the Decree of SNI S-36-1990-03 about the minimum requirement for waterproof concrete it is stipulated that the minimum content of fine grains in 1 m$^3$ of concrete is 450 kg / m$^3$ for a nominal maximum size of 20 mm aggregate grains, from the results of the mixed design it is known that the sand used for concrete is 575 kg / m$^3$, so it still meets the requirements as a fine aggregate for water-resistant concrete. For porous concrete, 30% of the normal concrete K is taken, so only use 173.33 kg of sand. Based on the Decree of SNI S-36-1990-03 about the minimum requirement of waterproof reinforced concrete it has been determined that the minimum cement content in 1 m$^3$ of concrete for a nominal maximum aggregate size of 20 mm and environmental conditions associated with fresh water is 300 kg. From the results of the mixed design it is known that the cement used for rigid pavement concrete in this study was 448.83 kg, so it still meets the requirements for waterproof concrete. For porous concrete studies, 300 kg of cement was used.

### 3.5. The Compressive Strength

Compressive strength testing is carried out when the specimen is 28 days old by using the Compression Testing Machine to get the maximum load that is the load when the concrete is destroyed when receiving the load (Pmax). The use of additives as added ingredients contributes to the compressive strength. Concrete mixture added with additives has a higher compressive strength compared to those not added with additives. It can be seen in Table 4 that the concrete mixture added with additives has an increase in compressive strength. Judging from the composition of the coarse aggregate, apart from the addition of additives, between stones 1-2 and stone 2-3, a mixture of porous concrete with aggregate 2-3 has a higher compressive strength compared to lab results. This can be seen from the results of compressive strength in the laboratory and in the field, 2-3 aggregates have the same compressive strength better than porous concrete mixtures with 1-2 aggregate compositions.

The highest compressive strength value is achieved by a concrete mixture with 1-2 aggregates plus additives in the lab that is equal to 10,584 MPa. But the results of the implementation in the field...
achieved by a concrete mixture with 2-3 aggregates with the addition of additives that is equal to 7.130 MPa.

Table 4 The Compressive strength results from laboratory and field Test

| Place of experiment | Compressive Strength (MPa) | Different in Compressive (MPa) | %  |
|---------------------|---------------------------|--------------------------------|----|
|                     | With Additive  | No Additive               |      |
| Laboratory          | 7,420         | 10,584                   | 3,164 | 29,89 |
| Type 1-2            | 7,940         | 8,937                    | 0,998 | 11,16 |
| Type 2-3            | 5,391         | 6,933                    | 1,541 | 22,23 |
| Filed               | 6,031         | 7,130                    | 1,099 | 15,41 |

Previous study concluded that there are many differences between laboratory and field test [7,8,9], the results from this research provide similar trend as shown at the results of the difference in compressive strength in Table 4, the production of porous concrete has increased after the addition of additives. For porous concrete with a 1-2 stone mixture in the laboratory, an increase of 3,164 MPa or as much as 29.89%. While the implementation in the field increased by 1.541 MPa or as much as 22.23%. Likewise, porous concrete mixes use 2-3 stones, although the increase is relatively less but still increases, ie 0.998 MPa or 11.16% for laboratory testing, and 1.099 MPa or 15.41% for field implementation.

4. Conclusion
Application of porous concrete on environmental roads as a reference using the Procedure for Making SNI Concrete Mixture Plan T-15-1990-03, by converting existing units in the lab with units used in the field. The need for each m³ of broken stone porous concrete is 1666.67 kg, the reduction of sand is 30% so that the sand demand becomes 173.33 kg, and the cement is 300 kg and the cement water ratio is 0.45. To be applied in the field using a bucket, so the size is the same as the size in the lab. Because compaction in the field is not as good as compaction in the lab, the compressive strength in the field is lower than the compressive strength in the laboratory. From the comparison of the compressive strength values of the equation \( y = 0.7258x \) or can be interpreted as a field = 0.7258 fc laboratory. With a correlation coefficient \( R^2 = 0.4672 \).

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