Application of porous concrete to resolve flood on the roads

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Abstract. In the rainy season, many cases of roads being submerged in water because of a lack of drainage capacity and low water absorption by the subgrade. This study utilizes porous pavement as an interlocking pavement to increase water absorption to the drainage layer and subgrade. Porous concrete is made from cement mixture: coarse aggregate = 1:6 with w/c ratio 0.4. The results showed the value of specific gravity, water absorption, compressive strength, and Na₂SO₄ resistance respectively 1.703 gr/cm³, 2.57%, 10.8 MPa, and 0.79%. To see the level of serviceability, no fine interlocking pavement is arranged above the drainage layer and the levelling layer, and then a trajectory and inundation test is performed. The result of inundation and track tests shows that the construction can pass water to subgrade without inundation and can withstand the wheel loader that is equivalent to 13000 kg so that it can be used for sidewalks, park lanes, and pavement with a maximum axle load of 8 tons.

1. Introduction
Many residential roads, sidewalks, and city parks are covered with concrete blocks that are placed on a layer of sand as an interlocking pavement. The disadvantages of interlocking pavement are the need to be minimized include, it is easily damaged through heavy traffic and easily flooded because the rainwater cannot flow under the drainage layer Figure 1.

![Image of interlocking pavement]

Figure 1. Disaster on the interlocking pavement; a. damage because of high traffic; b. lack of drainage capacity; c. flood because of low water absorption
To support the green pavement and consider the lack of use of interlocking pavement, it is necessary to use no fine aggregate concrete as a concrete block material. It is expected that this research can produce a type of pavement that can withstand the traffic load and easily escape the water so that is no flood and provide applicable insight for the community.

2. Literature review
Non-sand concrete or often also called no fines aggregate concrete is a simple form of this type of lightweight concrete, which in its manufacture does not use fine aggregate (sand). To get non-sand concrete that has good specifications, the first basic ingredients must be known. Good composition and determination of the right composition affect the quality of non-sand concrete. Non-sand concrete forming materials are water, cement, and coarse aggregate.

No fines aggregate concrete has compressive strength and small tensile strength so Basith (2017) added roving fiber to no fines aggregate concrete with PC: Gravel = 1: 5 ratio. On the addition of 5%, the fiber will increase the compressive strength of 31.92% the tensile strength 93.22%. [1] in a study on porous concrete showed the value of porosity has increased along with the increase in the aggregate/cement ratio. The porosity of porous concrete with cement water factor (fas) 0.25 is higher than fas 0.30. [2] conducted a study of compressive strength and infiltration in non-sand concrete. The results showed that the compressive strength of non-sand concrete with a variation ratio of 1: 2 gravel cement mixture was 33.19 MPa while for 1: 8 mixture was 5.23 MPa. The non-sand concrete infiltration rate has increased along with the greater variation in the mixture ratio. The largest infiltration rate occurred in a 1: 8 mixture of 9.44 mm/sec. A large infiltration rate in non-sand concrete can be used to accelerate the absorption of water into the soil and can serve to reduce standing water on the yard surface.

Previous research conducted by [3] showed concrete blocks with a mixture of PC: sand = 1:6 and w/c ratio 0.25 and calcite material 10% by weight cement had compressive strength 111.46 kg/cm² and airtight. The use on no fine aggregate concrete using PC:gravel = 1:6 at w/c ratio 0.4 give compressive strength and flexural strength value of 3.71 MPa and 0.96 MPa, [4]. [5] conducted a study on no fine aggregate concrete with aggregate from ape stone (North Sulawesi), with w/c ratio 0.4 and ratio PC: gravel = 1:6 producing a compressive strength of 7.67 MPa with a specific gravity 1.96 ton/m³ but cannot be used as a road amplifier because part of the structure that accept shock loads are easily destroyed but are easy to escape the water. Sebayang in 2011 study that the use on no fine aggregate concrete as interlocking pavement will produce compressive strength +/- 10 MPa which is likely to be used for pavement in class C or residential roads. The residences roads can be passed by fire trucks with a maximum axle load of 8 tons and are resistant to hot weather and rain. If used as a hardness, the concrete block arrangement must be supported by good drainage and levelling conditions.

Based on Sk [6], the interlocking pavement construction consists of a foundation layer, sand, locked concrete blocks, boundary concrete, and fill sand with a thickness of 6-10 cm (Figure 2). A common pattern used include brick stacking (stretcher), basketweave, fishbone (herringbone) as in Figure 1. For road pavement, the use of a fishbone pattern is preferred because it has better locking power.

**Figure 2.** Concrete block pattern; a. Brick stacking (very low locking); b. basket weave (medium locking); c. fishbone 90° (good locking); d. fishbone 450 (excellent locking)
Based on [7] and [8], the physical and mechanical properties of concrete blocks can be seen in Table 1. The combination of pattern, shape, quality of concrete blocks, and their use can be seen in Table 2.

**Table 1. Physical and mechanical properties of concrete blocks**

| Class | Function          | Compressive strength (Kg/cm²) | Wearing value (mm/menit) | Water absorption average (%) |
|-------|-------------------|-------------------------------|--------------------------|-----------------------------|
|       |                   | Average | Minimum | Average | Minimum |                      |
| A     | Roads pavement    | 400     | 350     | 0,09    | 0,103   | 3                     |
| B     | Parking area      | 200     | 170     | 0,13    | 1,149   | 6                     |
| C     | Sidewalks         | 150     | 125     | 0,16    | 1,184   | 8                     |
| D     | City garden       | 100     | 85      | 0,219   | 0,251   | 10                    |

**Table 2. Combinations of shape and function for concrete blocks**

| Function                      | Class        | Shape          | Combination Thickness | Pattern      |
|-------------------------------|--------------|----------------|-----------------------|--------------|
| Sidewalks and city garden     | C / D        | A, B, C, X     | 60 mm                 | SB², AT³, TF² |
| Parking area and garage       | B            | A, B, C        | 60 mm                 | SB², AT³, TF² |
| Residence roads               | A / B        | A or C         | 60 / 80 mm            | TF³          |
| Bus terminal                  | A            | A or C         | 80 mm                 | TF³          |
| Container yard, taxi way      | A            | A              | 100 mm                | TF³          |

a SB = brick stacking (stretcher)
b AT = basketweave
c TI = fishbone (herringbone)

3. The purpose of the study
The research of this study will make a sample of concrete blocks with no fine aggregate concrete material and prototype for pavement. Concrete block samples will be tested in a laboratory that includes specific gravity, compressive strength, and material durability. Samples will also be an arrangement in the field for further watering and vehicle crossing test. With this research, it is expected that alternative concrete block materials as environmentally friendly interlocking pavement will be obtained.

4. Research method
To produce no fine aggregate concrete as an interlocking pavement that is resistant to traffic loads and easily passes water, it is necessary to trajectory test and inundation test after the prototype of the material is finished. Stages of the implementation of the material study begin with the data collection and
literature review, and successively until the analysis and report. The complete stages of research are as follows in Figure 4.

![Research Method Diagram](image)

Figure 4. Research method

The procedure to make a concrete block from no fine aggregate concrete are:

a. Prepare material consists of cement (PC type 1), gravel 1/1, water
b. Weight the material according to mix design, PC:gravel = 1:6 and w/c ratio is 0.4
c. Fill the mixer with gravel
d. Put cement into the mixer
e. Wet the gravel surface with water (Saturated Surface Dry condition)
f. Put cement into the mixer
g. Add the remaining water slowly
h. Check the value of the slump test using Abraham’s cone until it has zero slumps
i. Check the workability of the mixture by taking the dough with your fist and kneading it. If the palm of the hand is made visible the dough is not separated/collapsed/fixed in the shape then the mixture is ready to be moulded Figure 5.

![Concrete Blocks Moulding](image)

Figure 5. Procedure to moulding concrete blocks

![Concrete Blocks Final Product](image)

Figure 6. The final product of no fine aggregate concrete blocks

The procedure of testing in laboratory and prototype test consists of:
a. Testing of dimensions and visual appearance
According to [8], the testing is done by measuring 10 samples using calipers with an accuracy of 0.1 mm. The result is “good” when showing a minimum thickness of 60 mm with a tolerance of +8%.

b. Testing of specific gravity [8] of 7 samples
According to [8], the testing is done by measuring the volume using a caliper with an accuracy of 0.1 mm and weight 7 samples. Specific gravity is calculated by the formula

\[ \text{Specific gravity} = \frac{\text{weight}}{\text{volume}} \text{(gr/cm}^3\text{)} \]

This test is to classified as lightweight concrete if specific gravity < 1.850 gr/cm\(^3\).

c. Testing of compressive strength
According to [8], the testing is done by pressing 7 samples of paving blocks using a Universal Testing Machine. Compressive strength is calculated using a formula

\[ \text{Compressive strength} = \frac{\text{compressive force}}{\text{area}} \text{(N/mm}^2\text{)} \]

This test is to classified the quality of paving block (Table 1)

d. Testing of water absorption
According to [8], the testing is done by submerged in water for 24 hours, weighing 5 samples in wet conditions. Then dried in the oven for 24 hours at a temperature of 105\(^\circ\)C until the weight is stabil. Water absorption is calculated by the formula

\[ \text{Water absorption} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100\% \]

This test is to classified the quality of paving block (Table 1)

e. Testing of resistance from sodium sulphate
According to [8], the testing was carried out by immersing in a saturated of sodium sulphate with specific gravity 1.152-1.174 for 24 hours, weighed in a wet condition for 3 samples. Then dried in an oven for 24 hours at a temperature of 105\(^\circ\)C until the weight is stable. Repeat this step 5 times in which the last step is washed and dried to determine the residual weight and any defect. If the difference between weighing before and after immersion <1% and no defect, then state that the samples are “good”. If the difference in weighing of 2 among 3 samples >1% while no defect, state that the whole sample is “defective”. Value of resistance from sodium sulphate is calculated by the formula

\[ \text{resistance from sodium sulfate} = \frac{\text{initial weight} - \text{residual weight}}{\text{residual weight}} \times 100\% \]

This test is to classified the quality of paving block (Table 1)

f. Testing of water infiltration or permissivity in 2 m\(^2\) area
Testing the interlocking pavement prototype by laying out an area of 2 m\(^2\), then watering it continuously to simulate the presence of rainwater for 1 hour. The result is said good if there is no puddle on the surface of the pavement.

g. Testing of vehicle trajectory in area 2m\(^2\) area
Testing the interlocking pavement prototype by laying out an area of 2 m\(^2\), then carrying out a heavy vehicle track with a load of 2-13 tons. The result is said good if there are no defects or fractures due to heavy vehicle trajectories.

5. Results and analysis

5.1 Dimension and visual appearance
Measurement of dimensions and visual appearance was carried out using a caliper and an average measurement of 20 x 10.2 x 6.01 cm was obtained. There are many pores between the gravel cavity with a flat surface, sharp edges, and elbows. No visible defects such as clumps, cracks, breakages, and the removal of gravel. The corners and the ribs are not easily crushed by the strength of your fingers.
Referring to [8] about Concrete Blocks for Floors, the visual appearance of paving blocks made of no fine aggregate concrete in accordance with SNI standards.

5.2 Specific gravity
Spesific gravity test result on 7 samples concrete blocks (Figure 7.a) have a range of value 1.58 – 1.8 gr/cm³ with an average of 1,703 gr / cm³. Referring to [9] where concrete blocks having a specific gravity of less than 1850 kg/m³ can be categorized as lightweight concrete.

5.3 Compressive strength
Compressive strength test on 7 samples concrete block (Figure 7.c) have a range of value 9.26 – 12.3 MPa with average of 10.8 MPa. Referring to [9] where concrete blocks having a compressive strength average 10 MPa and minimum 85 MPa can be categorized as quality D (Table 1) or suitable for a city garden, sidewalk, and park pavement.

5.4 Water absorption
Water absorption test on 5 samples concrete blok (Figure 7.b) have range of value 2.36% - 2.78% with average of 2.57%. Referring to [9] where concrete blocks having a water absorption average of 3% can be categorized as quality A or suitable for roads pavement.

5.5 Water permissivity test
Impression from the results of the field test carried out by splashing water on the interlocking pavement surface. From the observations, it can be seen that all water can seep into the interlocking pavement and enter the drainage layer for further drainage into the drainage channel. The application of no fine aggregates concrete as a concrete block shows the results of not occurring puddles on the surface of the interlocking pavement Figure 8 compare to conventional concrete block Figure 9.
5.6 Vehicle trajectory test
The test is carried out by crossing the surface of the concrete blocks with passenger vehicles according to real conditions. Vehicles that are used to trajectory tests include flatbed truck crane, wheel excavators, backhoe loader, large dump trucks, and tandem roller. The test result shows that the interlocking pavement can withstand a 13 tons wheel excavator Figure 10 and 5 tons of steel wheel roller Figure 11 without defects, fractures, cracks, or gravel discharges.

![Figure 10](image1.png)  vehicle trajectory test on the interlocking pavement with 13 tons wheel excavator-rubber wheel  

![Figure 11](image2.png)  vehicle trajectory test on the interlocking pavement with 5 tons tandem roller-stell wheel (right)

Seeing the result of the laboratory test and prototype test, the concrete blocks with no fine aggregates concrete material can be used as interlocking pavement for roads. The pavement performance is able to escape rainwater so that is no puddle on the road surface. The pavement is also able to withstand the weight of the fire truck that passes over it (13 tons). If used for residence roads, it can also withstand the weight of the fire truck. The durability of that pavement for Indonesia’s weather and climate conditions is also good.

6. Conclusion
The conclusions that can be drawn from the study of no fine aggregates concrete as an interlocking pavement is the visual appearance has a flat surface, sharp edges and elbows, and no visible defects and cracks. The specific gravity of concrete blocks made of no fine aggregates concrete has an average value of 1.703 gr/cm³ so that it is classified as lightweight concrete. The compressive strength and the level of water absorption of concrete blocks have an average value of 10.8 MPa and 2.57% so it is classified as quality A or suitable for use as road pavement. The no fine aggregates concrete block can pass water to the drainage and subgrade layer below and can withstand the wheel excavator that is equivalent to a fire engine (13000 kg) so that it can be used for roads with 8 ton axle loads.

7. Suggestions
To further develop the use of no fine aggregates concrete block (porous concrete) as the interlocking pavement is that pavement must be supported by a good drainage layer, good foundations layer, and levelling layer. With that arrangement, the pavement can withstand a maximum axle load of 8 tons and resistant to hot weather and rainwater.

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