# Experimental study

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# Experimental Study on Porous Concrete Regarding to Its Aggregates Variations of Compositions, Shapes, and Types for Sidewalk Application

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***Abstract***— Infrastructure growth is accompanied by decreasing water catchment and open space areas. It has caused surface water runoff which causing urban flooding. Research on pavement materials needs to develop a porous material that can drain water properly, and met the specifications of pavement materials, for sidewalk application or parking area.This research was conducted to develop a porous concrete mix design for sidewalk application with variations on types and shapes of aggregates. The results of this research is expected to provide a porous concrete mix design which met the technical specifications related to the compressive strength of the material.The method used on this experimental research is to develop specimens material that refers to ACI 522R-10 Standard and ASTM C33 Standard. Aggregate variations used are flat, sharp and crushed stone. There are 9 variations of compositions, shapes, and types of aggregates by adding admixture substance on these specimens. Results of this research has shown that 50% no. 8 sized (ASTM C33) crushed stone and 50% sharp aggregates sized <1cm, provided 12.816 MPa for compressive strength value, 20.3% for porosity value and 0.46 cm/s for permeability value. This mix design can be applied for sidewalk application, because the compressive strength values meet the specifications.

***Keywords***— **Porous concrete; Mix Design; Aggregates; Compressive Strength; Permeability; Sidewalk Application**

## I. Introduction

Surface runoff has become one of main problems caused by massive construction effort done on recent years. Construction site has taken major area used to serve as water infiltration area also known as green belt area. This phenomenon is often occured at mega cities around the world, one of it is Jakarta, with its major annual land subsidence rate (appr. 5 cm/ year). While some effort like biopore, infiltration wells, paving blocks has been used extensively, many has not proved effective to infiltrate water to earth.

One of the sound solution is to make a porous concrete [1],[2],[3]. Porous conrete itself has been used in some countries outside Indonesia. Porous concrete is a concrete that contains high amount of pores. In order to be effective at draining water, minimum 15% of pores is required. [4]

In Indonesia, many studies about porous concrete are focused mainly on porousity properties porous concrete posses which able to infiltrate water to earth, while there are not many study regarding its material, design and construction implementation. This study aims to continue previous studies on determining mix design job for sidewalk pavement, with minimum strength required by SNI (Indonesian National Standard) at 12,5 MPa [5]. Result on previous study has shown that rounded natural aggregates tends to have better strength capacity over other types of aggreates used [6] and additive is substantially needed to srengthen compressive strength [7],[8],[9].

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## II. EXPERIMENTAL PROCEDURES

The objective of this research is to determine which aggregate gradation types fit best to reach minimum strength required for sidewalk pavement application at 12,5 MPa, as stated by SNI (Indonesian National Standard). There were 3 types of aggregates used on this study, ASTM-C33-#8 gradation crushed aggregates [10], uniform graded artificial green aggregate, and uniform graded flat rounded natural ggregate. Gradation itself affect the compressive strength results [11],[12],[13]. All of three aggregates used are less than 1 cm in size. Mix design job was calculated based on ACI522R-10 mixture proportioning guidance. On mix design job, all variables were kept constant, except for aggregates proportions and weight.

## III. EXPERIMENTAL PROCEDURES

### A. *Materials*

Portland Composite Cement was used in this particular study, water used were from local water supply, tested for pH value, and three types of aggregates were used on this study. The properties of the aggregates used on this study were measured according to ASTM and listed in Table 1. Sika PV-100 was used as an additive to mixture [14]. Sika PV-100 were used because it has proven that it helps strengthen the compressive strength.

TABLE I
PROPERTIES OF AGGREGATES

| **Types** | **Properties** | | |
|---|---|---|---|
| | **Bulk Specific Gravity** | **Apparent Specific Gravity** | **Absorption (%)** |
| Green | 1,99 | 2,08 | 4,27 |
| Flat | 2,45 | 2,48 | 1,02 |
| Crushed | 2,55 | 2,60 | 2,08 |

Fig. 1 Crushed Stone

Fig. 2 Flat Natural Stone

Fig. 3 Artificial Green Stone

The photograph of the aggregate used in this study is shown in Fig.1, and each aggregate grain-size distribution are shown in Fig.2. Results shown that three of the aggregates used were uniform graded, with maximum size was 9,6 mm and absorption and specific gravity as shown on Table 1 [15],[16],[17] The distribution was determined according to ASTM C-33. Each aggregate were originally comes from local stones.

### B. *Mix Design*

Mix Design were calculated according to ACI522R-10 mixing proportion guidance. A preliminary mix design were calculated, and tested to find the best option of mix design that further will be used on all the sample making [1],[18],[19],[20],[21]. All variables were kept constant, except for weight of aggregates used. The primary mix design for 1 $m^3$ of sample is presented in Table II.

Some of the problems that occurs on the preliminary mix design were density and w/c rate. Porous concrete were normally uncompacted [19], or using a very light compacting method, that would results in uneven density of the sample. It was then decided to take standard compaction method, using rod for 25 times for each layer. Another problems that occurs during preliminary mix design was w/c ratio. As w/c ratio is crucial to the process of making porous concrete, water content that makes mixture sticky enough has to be calculated, to achieved maximum compressive strength.

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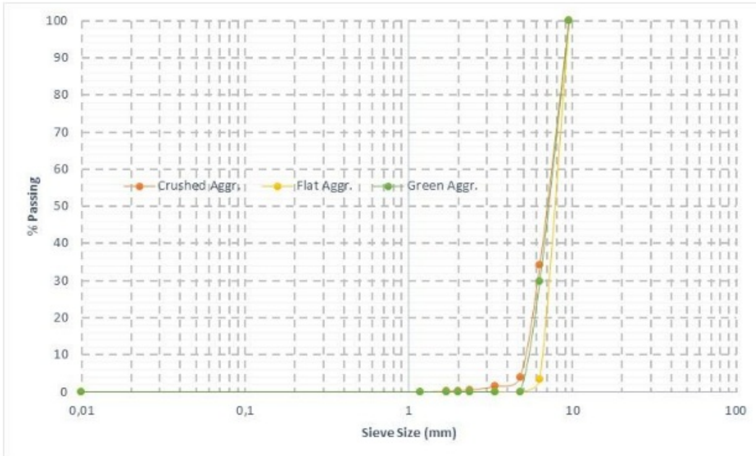


Fig. 3 Gradation

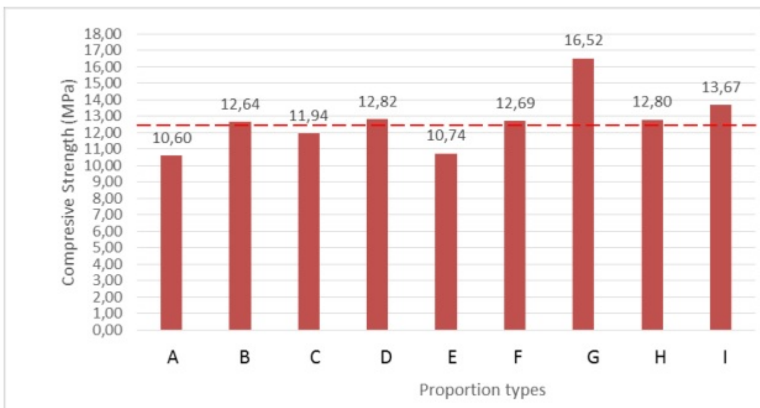


Fig. 4 Compressive Strength Result

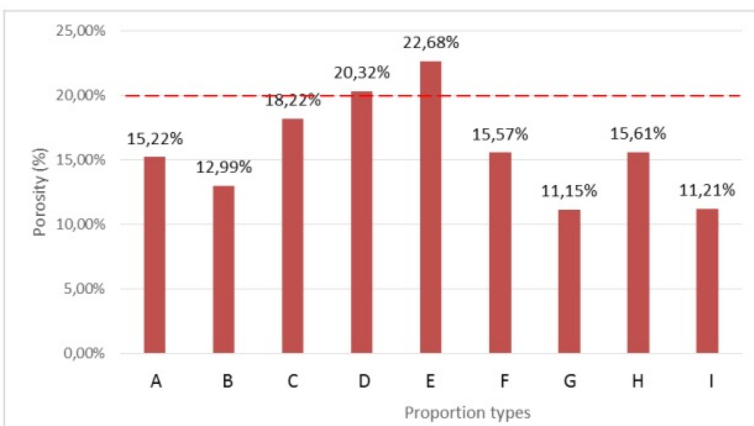


Fig. 5 Porosity test results

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TABLE II
MIX DESIGN

| Materials | Volume ($m^3$) | Weight (kg) |
|---|---|---|
| Aggregates | 0.484 | 1325 |
| Cement | 0.096 | 301.25 |
| Water | 0.103 | 0.103 |
| Additive | 17.5 | 19.5 |
| Pores | 0.300 | - |
| w/c | 0.4 | - |

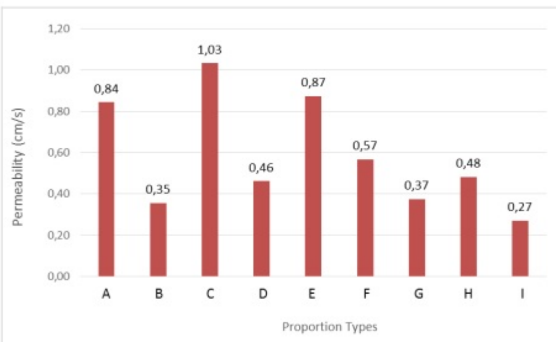


Fig. 5 Permeability test

The primary mix design were then modified by changing aggregates weight. The proportions of the aggregate are presented in Table III. There are 9 proportions of aggregate used in this study.

TABLE III
PROPORTIONS (% OF WEIGTH)

| Aggregate Type | *Proportions* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| Green | 100 | - | - | 50 | 25 | 75 | - | - | - |
| Flat | - | 100 | - | - | - | - | 50 | 25 | 75 |
| Crushed | - | - | 100 | 50 | 75 | 25 | 50 | 75 | 25 |

Fig. 6. One of the sample prepared in the Laboratory.

### *C. Sample Preparation*

The sample were mixed using electric hand mixer, and were molded into a cylindrical mold 10 cm in diametre and 20 cm in heigth. The samples were divided into 3 layers and were compacted on each layer each using standard rod for 25 times each. The samples were then cured in a standard curing chamber for 28 days.

### *D. Air voids test*

Some research has done more advanced technology to determine porosity such as using electrical measurements [17] ,but particularly on this research air voids test was done by using a simple method to determine its voids proportions. As reffered by ACI 522R-10, volumetric procedure were conducted. Samples were sealed, and the mass of water filled the samples were then calculated, and converted into an equivalent volume of pores.

$$\{\{(Wb-Wk) / Vb\} \times (1/\rho air)\} \times 100\% \qquad (1)$$

### *E. Permeability Test*

Permeability tests can be done on several Permeability test was done by using falling head permeameter based on Neithalath model reported in ACI 522R-10. The permeability rate are expected to be between 0,14-1,22 cm/s.

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Fig. 7. Simple Falling Head Permeameter

## IV. RESULTS AND DISCUSSION

### *A. Compressive Strength*

Compressive results has shown that concrete consist of artificial green aggregate showed relatively low compressive strength, while concrete that consist of flat natural aggregate showed greater strength. On 100% aggregate ratio, flat natural aggregate showed greater strength from other two aggregates. On mixed aggregate, flat natural aggregate and crushed aggregate mixed together showed greater strength than green and crushed aggregate combination.

While on overall, the compressive strength results didn't fluctuate that much between each proportions. It ranges between 10.62 – 16.52 MPa. With the lowest compressive strength was attained by mix A which consist of 100% artificial green aggregate. As artificial green aggregate tends to be angular at shapes, but rounded at its corner, interlocking between aggregate is not as good as crushed stone, and its suface is quite smooth, then creates bond that is not as strong as the other aggregates.

Fig. 8. One of the sample crushed in the laboratory

On figure 8, flat natural aggregate were used to make the sample. The sample incorporated the flat natural aggregate tends to be heavier, and denser than any other sample, thus created low porousity and permeability, but with decent compressive strength.

### *B. Porosity test*

On 100% aggregates ratio, crushed aggregate showed greater porosity than other two aggregates. Since crushed aggregates tend to angular, thus caused connection between aggregates happens in small dispersed area, cause interconnection is greater that other two types of aggregates. Results showed flat aggregate tend to have worse porosity. Overall porosity were between 11% - 23%, while required minimum porosity is 15% as stated by ACI522R-10. Highest porosity 22,7% reached on mix E, and by far the lowest porosity was 11.15%

### *C. Permeability Test*

Permeability result shown that best permeability reached on mix C, consist of 100% of crushed aggregate. While lowest permeability reached on mix I, consist of crushed aggregate and flat natural aggregate. Results showed that flat natural aggregate tends to have lower permeability rate than green aggregate. While on 100% aggregate ratio, there is no consistent result.

### *D. Results Summary*

From results summary, highest compressive strength reached by mix G, with very small porosity percentage and permeability rate. The best results, which fulfill minimum required standard value were showed by mix D, consisted of 50% natural aggregate and 50% crushed aggregate, with compressive strength as high as 12.816 Mpa, 20.3% porosity rate and 0.46 cm/s permeability rate.

TABLE IV
RESULTS SUMMARY

| Type | Compressive Strength (Mpa) | Porosity (%) | Permeability (cm/s) |
|---|---|---|---|
| A | 10.600 | 15.2% | 0.84 |
| B | 12.640 | 13.0% | 0.35 |
| B | 11.942 | 18.2% | 1.03 |
| D | 12.816 | 20.3% | 0.46 |
| E | 10.735 | 22.7% | 0.87 |
| F | 12.691 | 15.6% | 0.57 |
| G | 16.521 | 11.1% | 0.37 |
| H | 12.796 | 15.6% | 0.48 |
| I | 13.851 | 11.3% | 0.23 |

## V. SUMMARY AND CONCLUSIONS

An experiment to conclude which aggregate showed the best result was conducted to determined which aggregate characteristic best suited for porous concrete making. Based on this study, the following conclusions can be drawn:

1. Crushed Aggregate showed balanced value of compressive strength, porosity, and permeability value.
2. Rounded natural aggregate tends to have better compressive strength, but much lower permeability and porosity.
3. Green aggregate, which is sharp tends to have poor results, but better permeability and porosity value.
4. A mix between crushed and artificial green aggregate has shown best compressive strength, with adequate porosity and permeability rate.

## FUTURE RESEARCH

The results showed here were preliminary study. Further study is needed to be done to confirm the best results shown on this study. Several improvement on regularity on compressive strength result is also needed to be done.

## ACKNOWLEDGMENT

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