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# Experimental Study On Increasing The Characteristics Of Porous Concrete With The Addition Of Silica Fume

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## Abstract :

In the construction of road facilities and infrastructure, concrete or asphalt pavement is frequently used, which has the drawback of being impermeable. When the rainy season arrives, puddles or floods become more frequent as a result of the decline in water-absorbing areas. With the discovery of porous concrete, innovation is a solution to this problem; so in the following research, the authors will examine the addition of mineral admixture (Silica Fume) with proportions of 0%, 5%, 10%, and 15% in a porous concrete mixture that aims to improve the characteristics of porous concrete with the addition of mineral admixture (Silica Fume) so that a standard composition can be found and utilized in the construction industry. According to the study's findings, the variation containing 15% Silica Fume is the most effective at enhancing the characteristics of porous concrete. Where with a compressive strength of 21.327 MPa, which meets the minimum compressive strength requirements of porous concrete according to ACI 522R-10, which is at least 2.8 MPa, the permeability test result of 1.002 cm/s meets the requirements of ACI 522R-10, which is a minimum value of 0.14 cm/s, and the porosity test result of 15.605% meets the requirements of ACI 522R-10, which is 15-30%.

**Keywords**: Porous Concrete; Silica Fume; Compressive Strength; Permeability; Porosity.

## 1. Introduction

Concrete is a mixture of fine and coarse aggregate, Portland cement, and water, with or without additives [1]. Currently, the use of concrete as a building material is more prevalent than the use of other building materials. The use of concrete as a building material is due to the material's numerous advantages, including its ability to withstand high compressive forces, its adaptability to the needs of the structure, its malleability, its resistance to high temperatures, and its affordability as a result of the use of locally sourced materials.

Increasing urbanisation and shrinking ecological space, which cause flooding and inundation, pose the greatest problem in Indonesia today. Consequently, catastrophes are more likely to occur. Some nations have discovered that porous concrete is one of the Best Management Practises (BMPs) recognised by the Environmental Protection Agency (EPA) (Environmental Protection Agency, 2012) [2].

Due to the absence of fine aggregate, pervious concrete is classified as a form of lightweight concrete. In some investigations, silt is no longer employed, making the bulk of the concrete itself lighter than conventional concrete.High permeability of porous concrete allows water to percolate directly into the earth.

Mineral admixtures, such as Silica Fume, are added to the composition of porous concrete in an effort to increase its strength. Silica Fume is a very fine pozollan material with a very high concentration of SiO2 compounds (> 90%) and a particle size of about 1/100 the average size of cement particles. Silica Fume can strengthen concrete and improve the bond between cement paste and aggregate.

Based on prior research, porous concrete can be used to construct road pavements with a maximum load capacity of 10 tonnes [3] . However, it cannot be applied to dense and high-intensity pavements due to the insufficient compressive strength of concrete for high-intensity pavements. So in this study, the authors will examine the addition of mineral admixture (Silica Fume) in proportions of 0%, 5%, 10%, and 15% to a porous concrete mixture in an effort to improve the physical and mechanical properties of porous concrete with the addition of mineral admixture (Silica Fume) so that a standard composition can be identified and used in construction.

## 2. Methods

This research study is a literature study and experimental study of porous concrete. The research location is at the Materials and Construction Laboratory, Faculty of Engineering, Tanjungpura University, Pontianak.

### 2.1. Material and equipment

The materials used in porous concrete research are as follows:

1. The cement used was Portland Composite Cement (PCC) under the brand name Conch.
2. The size of the coarse aggregate used was 1.0/1.0 cm.
3. Superplasticizer, brand name LN Sikamen, at a dosage of 2% of cement.
4. Silica Fume dosage of 0%, 5%, 10%, 15% of cement.
5. With PH 6-7 water from the PDAM.

In this research, tests were carried out using a compressive testing machine, Los Angeles machine, shieve shaker machine, bearing block, slump tool, permeability tool, cylinder mold, material oven, mixing machine (mixer), scales, organic plates, loading test equipment, and other auxiliary equipment.

**Fig 1.** Sampel's of Porous concrete .

### 2.2. Research methods

This study combines the following research methodologies:

1. Preparation and analysis of research materials: Material preparation and testing.
2. Mix design:

Calculation of concrete mix with a design compressive strength of 25 MPa using ACI 522R-

10 [4].

3. Casting of test objects:

The specimens were cylinders of 15 cm diameter and 30 cm height & 10 cm diameter and 20 cm height. These specimens were cast with the help of a concrete mixing machine.

4. Test piece treatment:

Treatment technique when the evaluated object is immersed in a bath of room temperature water. Treatment is carried out one day after casting up to one day before testing.

5. Volume weight testing:

Treatment Techniques as the object being evaluated is immersed in a bath of room-temperature water.Treatment was delivered in one day after casting until the day before testing.

6. Compressive strength test:

To measure the compressive strength of concrete in accordance with SNI 03-1974-2011 [5], this study used an MTB press tester with a capacity of 2,000 kN and an accuracy of 7 kN at 28 days.

7. Split Tensile Strength Testing

Tensile strength testing using cylindrical specimens is carried out by applying a load to the side of the cylinder until it splits or breaks. Test objects that split or break due to tensile stress are called split tension strength based on ASTM C496-96 standard [6].

8. Permeability Testing

The purpose of permeability testing is to assess and measure the ease with which water passes through concrete. The method used is Falling Head permeability based on the ACI 522R-10 standard [4].

9. Porosity Testing

Concrete porosity testing is to obtain the results of the ratio between the volume of air cavities to the total volume of the entire porous concrete test specimen. Standard ACI 522R-10 [4] porous concrete has a porosity percentage requirement of 15-30%. This test is based on ASTM C 1754 standard.

## 2.2. Analysis method

1. The formula for calculating the compressive strength of concrete is :

$$f'c = \frac{P}{A}$$

where:

f'c= compressive strength value [MPa]

P = maximum test load [kN]

A= cross-sectional area [mm]

2. The formula for calculating the Concrete content

weight of concrete is:

Concrete content weight = $\frac{W}{V}$

where:

W= Weight of test specimen [kg]

V = Volume of test piece [$m^3$]

3. The formula for calculating Permeability is **:**

$$k = \frac{aL}{At} \log\left(\frac{h1}{h2}\right)$$

where:

*K* - permeability coefficient [cm/s],

h1- water fall start height [cm],

h2- water fall finish height [cm],

*L* - concrete sample's thickness [cm],

*a* - cross-sectional area of pipe [$cm^2$],

*A* - cross-sectional area of concrete sample [$cm^2$],

*t* - the time water falls from h1 to h2 [s]

4. The formula for calculating Porosity is:

$$\eta = \left[1 - \left(\frac{M_d - M_s}{\rho_w - V}\right)\right] x\ 100\ \%$$

Where:

$\eta$ - Porosity (%)

$M_d$ - Oven dry mass weight

$M_s$ - Weight of mass in water

$V$ - Sample Volume

$\rho_w$ - Specific gravity of water

## 3. Results

The Portland cement used is PCC Cement (Portland Composite Cement) with the brand name Conch. The condition of the cement visually should be in good condition, smooth and not lumpy or hardened [7]. This cement must be placed in a protected and dry place, in this case in the laboratory.

Before mixing the materials, first testing and checking the properties and feasibility of the materials to be used in accordance with ASTM C33 [8]. In this study the type of aggregate used is only coarse aggregate in the form of stones from watering with a size of 1/1 cm. The following are the results of the coarse aggregate test:

**Table 1.** Testing results of coarse aggregate

| No. | Type of inspection | Inspection Result | Unit |
|---|---|---|---|
| 1 | Absorption | 0,008 | % |
| 2 | Weight content | 1,371 | $kg/m^3$ |
| 3 | Water content | 0,222 | % |
| 4 | Modulus of fine grain (MHB) | 5,642 | - |
| 5 | Aggregate wear | 17,190 | % |
| 6 | Sludge Content | 0,306 | % |
| 7 | Specific gravity | 2,741 | $kg/m^3$ |

The type of water used according to the requirements is distilled water, but can be replaced with clean water that meets the physical requirements visually and chemically. Where water must be clean according to SNI 03 - 2874 - 2019. Where for water because it uses water from PDAM, the water already meets SNI 03 - 2874 - 2019.

High Range Water Reducing admixture is an ingredient that can reduce water demand to a maximum of 20 %. For example, cycament - LN produced by PT Sika is a type of chemical additive to reduce water content (waterreducer) and accelerate bonding time (accelerator). The data used is secondary data for the mineral composition contained in the LN cycament. Chemical Admixture usage standards based on [9].

This mineral additive is an additive intended to improve the performance of porous concrete, so mineral additives tend to be cementing in nature. Mineral additives consist of several kinds [10] . Mineral Admixture used is silica fume. Silica Fume is an excellent and highly useful admixture for concrete mixes, in order to produce high- performance concrete.

Concrete with Silica Fume can reduce pores in the cement paste, because this admixture is a mineral that is more cementitious and is widely used to improve the strength performance of concrete. The application of Silica Fume can also reduce the use of water in concrete materials and the presence of this material is able to fill the pores in the concrete and form a pozzolanic reaction that increases the strength of the concrete, thus making the concrete impermeable, durable, and high-strength.

Data and properties of silica fume refer to the ACI 234R-10 standard [11].

**Table 2**. Product Information of Silica Fume used.

| | |
|---|---|
| Chemical base | A blend of latently reactive ingredients. |
| Packaging | 20 kg bag 1,000 bulk |
| Appearance/Color | Powder/Grey |
| Shelf life | 36 months shelf life from date of production if stored properly in undamaged, unopened, original sealed packaging. |
| Storage conditions | Storage in a dry environment, not sensitive to frost. |
| Density | 0.65 kg/L |
| Total Chloride Ion Content | < 0.3 M-% |

From the material data obtained, a design is made mix design for pervious concrete refers to the ACI 522R- 10 Report on Pervious Concrete [4], because at this time Indonesia does not have SNI for pervious concrete.

A0 - Silica fume variation of 0%

A1 - Silica fume variation of 5%

A2 - Silica fume variation of 10%

A3 - Silica fume variation of 15%

**Table 3**. Composition porous concrete

| **Materials** | = | A0 | A1 | A2 | A3 | **Unit** |
|---|---|---|---|---|---|---|
| **Cement** | = | 313,04 | 313,04 | 313,04 | 313,04 | kg/m$^3$ |
| **Waters** | = | 65,11 | 68,36 | 71,62 | 74,88 | kg/m$^3$ |
| **Coarse Aggregate** | = | 1361,97 | 1361,97 | 1361,97 | 1361,97 | kg/m$^3$ |
| **Superplasticizer** | = | 6,261 | 6,261 | 6,261 | 6,261 | kg/m$^3$ |
| **Silica Fume** | = | 0 | 15,65 | 31,30 | 46,95 | kg/m$^3$ |
| **Total** | = | 1746,38 | 1765,29 | 1784,20 | 1803,11 | kg/m$^3$ |

The process of testing the casting sample gets the result of a good concrete mixture that is not too watery and does not lose water.

**Fig 2.** process of checking concrete mix.

### 3.1 Slump Test

Slump testing is very important to determine the level of smoothness and the resulting material. Where the slump test is carried out. The data from the experiments that have been carried out obtained the following data.

**Table 4.** Slump test results

| Type Variations | Slump Test (cm) |
|---|---|
| A0 | 1 |
| A1 | 0,5 |
| A2 | 0,8 |
| A3 | 0,5 |

**Fig 3**. Slump test

### 3.2 Volume Weight Testing

The results of the average volume/fill weight of porous concrete that has been tested for a sample size of 10cm x 20 cm are 5 samples for each variation

**Table 5**. Volume weight test results.

| Type Variations | Volume Weight Kg/m$^3$ | | |
|---|---|---|---|
| | 7 days | 14 days | 28 days |
| A0 | 1685.350 | 1751.592 | 1765.605 |
| A1 | 1745.223 | 1782.166 | 1798.726 |
| A2 | 1787.261 | 1848.408 | 1892.994 |
| A3 | 1871.338 | 1917.197 | 1955.414 |

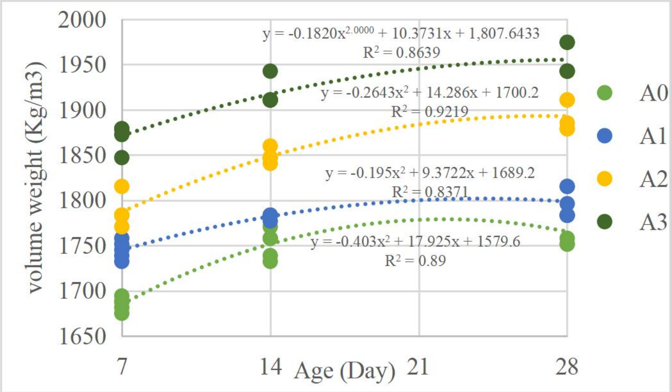


**Fig 4**. Graph of average volume weight of porous concrete.

### 3.3 Compressive Strength Testing

The results of the average compressive strength of porous concrete that has been tested for a sample size of 10cm x 20cm are 5 samples for each variation

**Table 6**. Compressive Strength test results.

| **Variations** | Average Compressive Strength **(MPa)** | | |
|---|---|---|---|
| | **7 days** | **14 days** | **28 days** |
| A0 | 6,154 | 8,785 | 10,873 |
| A1 | 8,191 | 10,186 | 13,114 |
| A2 | 11,459 | 14,260 | 18,207 |
| A3 | 12,414 | 16,679 | 21,327 |

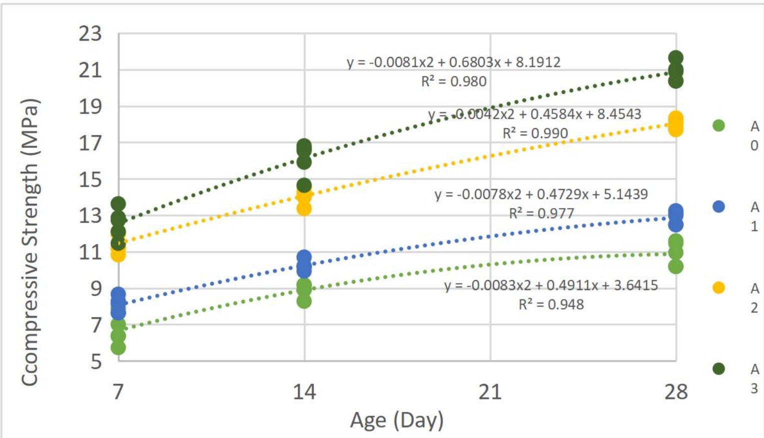


**Fig 5**. Average compressive strength of porous concrete

**Fig 6**. compressive strength testing

## 3.4 Split Tensile Testing

The results of the average Split Tensile Testing of porous concrete that has been tested for a sample size of 15 cm x 30cm are 5 samples for each variation.

**Table 7**. Test results for split tensile strength

| Variations | Average Split Tensile Strength (MPa) |
|---|---|
| A0 | 2,604 |
| A1 | 3,671 |
| A2 | 4,987 |
| A3 | 5,422 |

**Fig 7**. tensile strength testing

### 3.5 Permeability Testing

The average permeability results of porous concrete that has been tested for a sample size of 10cm x 20cm are 5 samples for each variation.

**Table 8**. Permeability test results

| Variation Type | Average Permeability Coefficient (cm/s) |
|---|---|
| A0 | 3,475 |
| A1 | 2,039 |
| A2 | 1,452 |
| A3 | 1,001 |

**Fig 8**. permeability test.

### 3.6 Porosity Testing

The average Porosity results of porous concrete that has been tested for a sample size of 10cm x 20cm are 5 samples for each variation.

**Table 9**. Porosity test results

| Variation Type | Average Percentage (%) |
|---|---|
| A0 | 24,204 |
| A1 | 16,408 |
| A2 | 18,641 |
| A3 | 15,605 |

**Fig 9.** Porosity testing process by oven

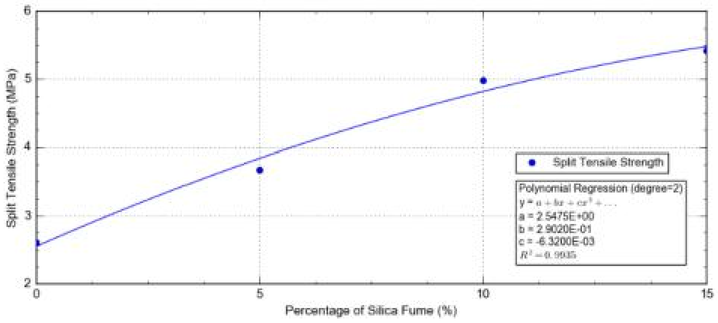


**Fig 10**. Graph of the results of the average tensile strength of objects

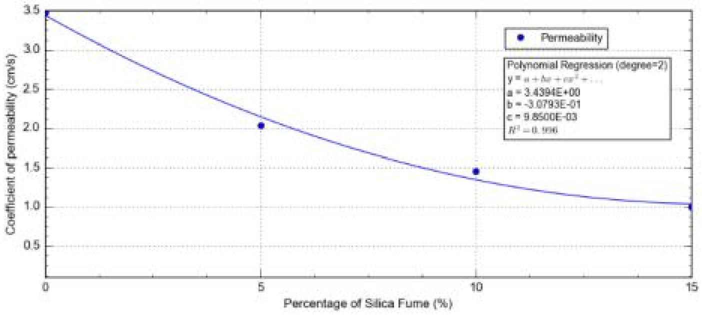


**Fig 11**. Graph of variation of silica fume vs permeability

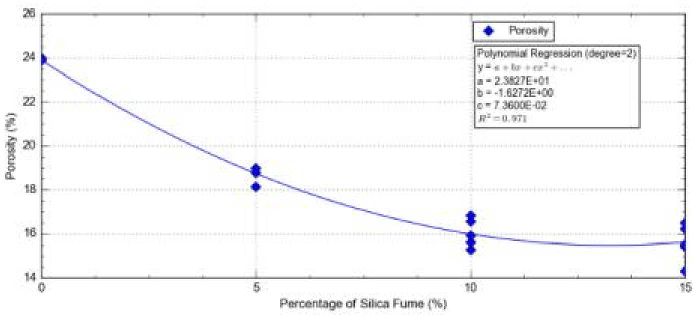


**Fig 12**. Graph of variation of silica fume vs Porosity

## 4. Discussion and Conclusion

According to the results that have been carried out in this research, so it can be concluded that:

a) Based on the results of all research tests, it is concluded that porous concrete with the addition of 15% Silica Fume (A3) is the best variation in influencing the improvement of porous concrete characteristics. Where with a compressive strength of 21.327 MPa which meets the minimum porous concrete compressive strength requirements according to ACI 522R-10 which is at least 2.8 MPa, in the permeability test of 1.001 cm/s meets the requirements of ACI 522R-10 which is with a minimum value of 0.14 cm/s and in the porosity test of 15.605% meets the requirements of ACI 522R-10 which is 15-30%.

b) From the graph of the relationship between the percentage increase in the compressive strength of porous concrete with Silica Fume variations, the equation = 0.080796 2 + 5.493 - 2.219 is obtained, with this equation the results will be obtained if using 20% Silica Fume variations can increase by 139.96% with a value of 26,093 MPa.

c) The initial hypothesis stating that the addition of Silica Fume affects the improvement of porous concrete characteristics has been answered by the results of the research obtained where the results of the initial hypothesis are that the higher the addition of Silica Fume variation increases the compressive strength, split tensile strength and volume weight while the permeability and porosity decrease. This is inversely proportional to porous concrete without Silica Fume, the compressive strength is low but the permeability and porosity are high.

## 5. Acknowledgements

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