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THE POROUS CONCRETE FOR RIGID PAVEMENT

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Abstract

Roads play an important role as a connection between locations and can facilitate the efficient mobility of people's economic activities. Five tests are involved in evaluating of the porous concrete, such as the slump test, compressive strength test, permeability test, flexure test, and load capacity test (loading test). Meanwhile, there are three types of soil: peat, clay, and hard. The compressive strength test measured an average compressive strength between 24.17-27.36 MPa. According to the permeability test, the average speed of water infiltration on the porous concrete rigid pavement was 20 seconds on clay soil and 55.344 seconds on peat soil, with large areas drained on porous concrete rigid pavement of 346.185 cm^2 with 5 litres of water used, whereas it was 6.554 seconds with a flow area of 288.75 cm^2 and 2 litres of water used on hard soil. The Loading Test was conducted with a 10-ton. The maximum difference in deflection was 1-2 cm. In addition, there were no cracks in the porous concrete rigid pavement with a porous concrete rigid pavement thickness of 15 cm in three different soil conditions. A track with porous concrete rigid pavement on clay, hard soil, or peat soil can accommodate a maximum payload of 10 tons.

Keywords:

Porous concrete;
Physical and mechanical properties;
Puddles and floods;
Precast;
Porous pavement.

1 Introduction

In recent years, West Kalimantan developed significantly, resulting in a loss of green open space as a location for water to collect on its way to the ground. So, creating a speedier alternative route for water to reach the sea. Flexible and Rigid pavements are often used to develop road infrastructure and amenities. However, both flexible and rigid pavements have the drawback of being impermeable to water. This might result in a delay in the soil's absorption of water. Insufficient water absorption may lead to increased surface run-off, which can cause floods during the rainy season.

Porous concrete or pervious rigid pavement is the outcome of technologies that have yielded relatively good results in addressing the issues mentioned above. In addition, porous concrete has great permeability, allowing water to drain straight into the earth. This porous rigid pavement may subsequently open fields, walkways, low-traffic residential streets, parking lots, and home terraces. Fig. 1 depicts the stiff porous concrete pavement.

Concerning the load-bearing capacity of the structure is the most important aspect of planning previous rigid pavement, so the most important factor in designing road rigid pavements is the strength of the concrete itself and the presence of various layers of the sub-grade soil surface, such as hard soil surface, clay soil surface, and peat soil surface. Thus, these processes can impact the road's pavement.

Fig. 1: Porous concrete for rigid pavement.

2 Methodology

A literature review and an experimental assessment of porous concrete are both included in this work. Faculty of Engineering, Tanjungpura Pontianak University, Materials, and Construction Laboratory, Soil Mechanics Laboratory Surfaces with peat, clay, and hard soil.

2.1 Material and equipment

In the production of porous concrete, the following materials are employed: The kind of cement utilized is Portland Composit Cement (PCC).

1) Maximum particle size for coarse aggregate is between 0.5 / 0.5 and 1.0 / 1.0 cm.
2) Superplasticizer, specifically LN Sikamen, with a maximum dose of 0.1 - 1.2 % cement.
3) Dosage Silica Fume 3 % cement.
4) The pH of the used water is 6 - 7, and it is from Local Water Company (PDAM) water.

These material characteristics oare important related to the increase in traffic intensity, the level of dynamic loads, and the axle loads of heavy vehicles [2].

A compressive testing machine, a Los Angeles machine, a shieve shaker machine, a bearing block, a slump tool, a permeability equipment, cylinder molds, material ovens, mixing machines (mixer), scales, organic plates, loading test equipment, and other auxiliary equipment were used in this test.

2.2 Research methods

This study combines the following research methodologies:

1) Preparation of research materials and analysis:

a) A compilation of theoretical underpinnings and previous research articles that support this investigation, b) Material preparation and testing.

2) A study of the soil conditions of the field:

On three kinds of soil, the soil's condition was evaluated. Testing Soil Density (Sand Cone) and Testing Soil Carrying Capacity are two soil tests (CBR).

3) Planning a mix:

Calculation of a concrete mixture with a design compressive strength of 30 MPa using ACI 522R-10.

4) Casting of test objects:

The test item was a cylinder with a diameter of 15 cm and a height of 30 cm. This specimen is cast with the assistance of a concrete mixing machine.

5) Treatment of test objects:

Treatment Techniques the test subject is immersed in a bath of room-temperature water. Treatment was delivered from one day after casting to one day before testing.

6) 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.

7) Compressive strength test:

For measuring the compressive strength of concrete in accordance with SNI 03-1974-2011, this study used MTB compressive testing equipment with a capacity of 2,000 kN and an accuracy of 5 kN at 28 days of age.

8) Permeability testing:

The objective of permeability testing aims to assess and quantify the ease with which water may pass through concrete. A device measuring permeability was used to perform the test.

9) Loading test:

Through testing, the load capacity of porous concrete was established for each thickness and road condition. Measuring deflection is essential for the loading test, as the deflection that occurs may serve as an indication of the existing structure's strength and its behavior under load.

2.3 Analysis method

The soil density formula is as follows:

$$\delta_k = \frac{\delta_0}{W_{10}} \times \frac{W_{11}}{(1+W)}, \tag{1}$$

where:
δ_0 - sand density,
δ_k - soil density,
W - moisture content,
W_{10} - sand filled in the hole,
W_{11} - soil weight.

CBR measurement. There are two types of CBR measurement:

1) The CBR value for 0.254 cm penetration pressure on the normal penetration is 0.7037 kg/mm^2.

2) CBR value for penetration pressure at 0.508 cm vs the standard penetration pressure of 1.0556 kg/mm^2. Laboratory CBR is the larger of the two calculations and is utilized.

3) The formula for compressive strength is [2]:

$$F = \frac{4P}{\pi D^2}, \qquad (2)$$

where:
F - compressive stress [MPa],
P - maximum applied load on specimens by a device [kN],
D - diameter of the specimen [mm].

Fig. 2 depicts the compressive stress technique on a cylindrical test item with a diameter of 15 cm and a height of 30 cm.

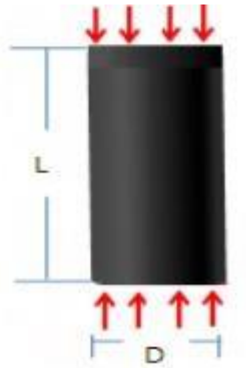

Fig. 2: Loading of specimens in the direct compression test.

4) The formula for the coefficient of permeability:

$$\frac{1}{A}\frac{\mathrm{d}q}{\mathrm{d}t} = k\frac{dh}{L}, \qquad (3)$$

$$K = \left(\frac{1}{A}\right).\left(\frac{\mathrm{d}q}{\mathrm{d}t}\right).\left(\frac{L}{dh}\right), \qquad (4)$$

where:
K - permeability coefficient [cm/s],
dq/dt - water flow rate [cm^3/s],
dh - falling water level [cm],
L - concrete sample's thickness [cm],
A - sample cross-sectional area [cm^2].

5) The volume weight formula is:

$$W_c = \frac{W}{V}, \qquad (5)$$

where:
W_c - volume weight [kg/m^3],
W - weight of the test object [kg],
V - volume of the test object [m^3].

3 Results and discussion

3.1 Material testing results

3.1.1 Cement

The chemical composition and physical properties of using cement are listed [26]. In this analysis determined the following components were determined to be present in Conch brand cement. It is shown in Table 1, and the cement used by the conch brand is shown in Fig. 3.

Table 1: Composition of Conch cement manufacturer.

Elements	[%]
Silicon Dioxide SiO_2	23.64
Aluminum Oxide Al_2O_3	8.40
Ferric Oxide Fe_2O_3	4.36
Calcium Oxide CaO	58.38
Magnesium Oxide MgO	1.91
Sulphur Trioxide SO_3	2.0
Loss On Ignition LOi	3.28
Chalk	0.56
Part not dissolved	8.96

Fig. 3: Conch Cement.

3.1.2 Water

In this research, the water was pure Local Water Company (PDAM) water with a pH of 6 - 7. Because water is often used as a beverage. This water information was acquired from earlier studies on porous concrete. Fig. 4 presents the water utilized in this investigation.


Fig. 4: Water from the local water company (PDAM).

3.1.3 Chemical admixtures

Chemical admixtures are often used in minute amounts in porous concrete formulations. It aims to speed up the curing of porous concrete and improve the mixture's properties.

This experiment employed the chemical additions of Sikamen LN and Silica Fume. The fibrous high-strength concrete analyzed comprised of coarse aggregate, fine aggregate, cement, silica fume, mixing water, high-performance admixture, and steel fibers [27]. For the precast concrete element business, a chemical additive was used to reduce the water content of concrete in order to increase the initial strength of concrete, allowing for the rapid release of formwork molds and the reduction of building time. According to these results, Sikamen LN is a type F chemical admixture with high initial strength and water reduction.

PT Sika Indonesia's Sikamen LN is a brownish-dark liquid. In 28 days, using Sikaman LN might reduce water content by up to 20 % and increase compressive strength and water resistance by 40 % at 2 + 20 °C, and its specific gravity is 1.22 ± 0.01 kg/l.

Depending on the workability and strength requirements, the maximum % of aged Sikamen LN that may be used based on the total weight of the cement material is between 0.30 and 2.0 %. The purpose of this trial combination is to determine the ideal dosage. Generally, the dose range for silica fume in a cement mixture is 0.30 - 1.20 % by weight for LN sikamen materials may be observed in Fig. 6.

Utilizing up to 25 % by weight of silica fume in cement manufacturing. The ideal amount of silica fume for concrete production [4]. Ultra-High Performance Concrete with Compressive Strength Exceeding 150 MPa: A Simpler Way. Silica fume is a great additive to concrete and enable the creation of high-performance concrete [5]. Fig. 5 depicts the used silica fume material.

Fig. 5: Silica fume.

Fig. 6: Sikament LN.

3.1.4 Coarse aggregate (Cracked stone)

In this experiment, the coarse material used was crushed stone. Crushed stone is required for the creation of porous concrete. This investigation used 1 / 1 cm and 0.5 / 0.5 cm crushed stones. West Kalimantan provides the used crushed stone.

3.1.5 Physical and mechanical characteristics of 1 x 1 cm stone

Throughout this investigation, the absorption value, which is the ratio between the weight of water was absorbed by the aggregate under surface-saturated conditions and the weight of the aggregate under oven-dry conditions was calculated. SSD (saturated surface dry) and absolute dry were used to distinguish between aggregate kinds (oven dry).

The dry weight was estimated to calculate the specific gravity and % age of water weight that coarse aggregate (stone) may absorb. The results are shown in the Table 2.

Table 2: Results of inspection of coarse aggregate size 1 / 1 cm.

No	Type of inspection	Inspection result	Unit
1	Absorption	0.025	%
2	Volume weight	1.40	kg/m^3
3	Moisture content	0.912	%
4	Fineness modulus	5.488	-
5	Aggregate abration	9.1	%
6	Mud content	0.944	%
7	Specific gravity	2.57	kg/m^3

The fineness modulus grade of this coarse aggregate lies between 2 and 8, fulfilling the requirements for 25 MPa concrete. The fineness modulus for coarse aggregate (split) with a size of 1 cm / 1 cm, according to common knowledge, is 5.488. Composition, properties, and mechanical characteristics of stone 0.5 cm / 0.5 cm.

3.1.6 Physical and mechanical characteristics of the 0.5 cm / 0.5 cm stone

The two forms of aggregate were oven-dried and surface dry-saturated (SSD). This investigation will also determine the absorption value. This is the ratio of the water absorbed weight by the aggregate under conditions of surface saturation to the aggregate weight in its oven-dried state.

The specific gravity test compares the dry weight to the specific gravity to estimate the quantity of water that coarse aggregate (stone) can absorb. It aims to quantify the weight % of the water that can be absorbed. The results are shown in Table 3 below:

Table 3: Results of inspection of coarse aggregate size 0.5 / 0.5 cm.

No	Type of inspection	Inspection result	Unit
1	Absorption	0.0128	%
2	Volume weight	2,506	kg/m^3
3	Moisture content	0.272	%
4	Fineness modulus	3.983	-
5	Aggregate abration	12.21	%
6	Mud content	0.872	%
7	Specific gravity	2,470	kg/m^3

The Fineness modulus is 3,983 for coarse aggregate (split) with a size of 0.5 cm / 0.5 cm. Due to its Fineness modulus value, which ranges from 2 to 8, this coarse aggregate is considered of good quality. As a result, it satisfies the standards for usage in 25 MPa concrete. Fig. 7 depicts the sort of stone used to produce porous concrete with a 1 / 1 cm grain size. Meanwhile, Fig. 8 depicts the process for producing porous concrete with a pore size of 0.5 / 0.5 cm.

Fig. 7: Stone size 1 / 1.

Fig. 8: Stone size 0.5 / 0.5.

3.2 Composition of porous concrete mixture with ACI 552R modification

Due to the lack of SNI for previous concrete in Indonesia, a mix design for previous concrete was built using the collected material data and instructions from the ACI 522R-10 Report on Pervious Concrete. Investigate the attachments [5].

The composition of the materials used to produce porous concrete for road paving in three kinds of soil is shown in Table 4.

Table 4: Material composition.

Materials	Composition / m^2
Cement	382.61 kg
Stone 1 / 1 cm	740.365 kg
Stone 0.5 / 0.5 cm	740.365 kg
Superplasticizer 0.6 %	2.296 kg
Water	114.4 kg
w/c	0.3
Silica fume 3 %	11.478 kg

3.3 Soil density test (sand cone)

It is essential to determine the soil density for estimating the dry unit weight of the original soil or the compaction operations result done on non-cohesive or cohesive soil. When comparing the density of three unique types of soil, as per the information was obtained from the conducted study.

The results of the Soil density test (sand cone) for each site are shown in Table 5, and the procedure for conducting sample tests in the field is shown in Fig. 9.

Table 5: Sand cone test.

No	Location	Depth [m]	Classification unified soil	Sand cone [g/cm^3]
1	Kab.Sekadau (Hard soil)	1.00 - 1.50	Clay low plasticity (CL)	1.455
2	Pontianak (Peat)	2.00	Organic high plasticity (OH)	0.130
3	Pontianak (Clay)	2.00 - 2.40	Silt high plasticity (MH)	0.715

Fig. 9: Sand cone.

3.4 Soil bearing capacity test (CBR)

Through this test, the strength value of the sub-grade or other materials used to create pavement may be measured by penetrating the specimen or pushing it with a tool. Where three kinds of soil were subjected to soil density testing. According to the study's findings, the results of the soil carrying capacity test for each site are shown in Table 6 and the sample testing method in the laboratory is depicted in Fig. 10.

Table 6: Soil bearing capacity test.

No	Location	Depth [m]	Classification unified soil	CBR [%]
1	Kab. sekadau (Hard soil)	1.00 - 1.50	Clay low plasticity (CL)	3.0
2	Pontianak (Peat)	2.00	Organic high plasticity (OH)	0.0
3	Pontianak (Clay)	2.00 - 2.40	Silt high plasticity (MH)	0.0

Fig. 10: CBR test.

3.5 Volume weight testing

The average volume/concrete weight of 28-day-old concrete ranges between 1,819.30 - 2,321.26 kg/m^3 based on the results of the porous concrete volume weight test at each of the 5 sample collection sites. This indicates that porous concrete has a lower density than ordinary concrete, which is limited to a density between 2,400 - 2,500 kg/m^3. The average density of porous concrete across the three construction sites is 2,105 kg/m^3. The results of evaluating the volume weight of porous concrete at each site are shown in Table 7, and Fig. 11 depicts the volume weight of the test item.

Table 7: Weight volume/fill average age of 28 days.

Location	Average volume weight [kg/m^3]
Kab.Sekadau (Hard soil)	1,819.30
Pontianak (Peat)	2,174.75
Pontianak (Clay)	2,321.26

Fig. 11: Volume of weight test.

3.6 Slump test

Slump testing is very important to determine the level of workmanship and the material produced [3]. The findings acquired from the conducted study are shown in Table 8, while the technique for slump testing is depicted in Fig. 12.

Table 8: Slump test results.

No	Mixture	Location	Slump test [cm]
1	A0	Kab.Sekadau (Hard)	2.5
2	A1	Pontianak (Peat)	1.0
3	A2	Pontianak (Clay)	12.0

Fig. 12: Slump test.

3.7 Concrete compressive strength test

The compressive strength test results for porous concrete that have been tested for cylinder samples with a size of Ø 15 x 30 cm. The results of compressive strength tests on samples of concrete from each site are shown in Table 9. Fig. 13 depicts the procedure for analyzing the specimens.

Table 9: Concrete compressive strength test results.

Location	Average compressive strength [MPa]
Kab.Sekadau (Hard soil)	25.02
Pontianak (Peat)	24.17
Pontianak (Clay)	27.36

Fig. 13: Compression test.

3.8 Permeability test

The three types of soil were subjected to permeability testing. Based on the findings, Pontianak 2 (peat, clay) and the Sekadau area (hard soil) fulfilled the ASTM C-1701 minimum permeability requirement of 0.00564 cm/s for pervious concrete. Minimum permeability requirement volumetric flow rate per unit of time for pervious concrete is 0.4 cm^3/s [27]. The results of permeability tests conducted on porous pavement on various soil types are shown in Table 10, while Fig. 14 depicts the testing procedure.

Table 10: Permeability test results.

Location	Diameter [cm]	High [cm]	Area [cm^2]	Water volume [l]	Absorption speed [s]	Volumetric flow [cm^3/s]	Permeability coefficient [cm/s]
Kab.Sekadau (Hard soil)	19.17	15.00	288.75	2.00	6.55	305.157	2.419
Pontianak (Peat)	21.00	15.00	346.185	5.00	55.34	36.138	0.028
Pontianak (Clay)	21.00	15.00	346.185	5.00	20.00	100.000	0.216

Fig.14: Permeability test.

3.9 Loading test

Loading tests were carried out on three types of soil, the deflection on the porous concrete pavement from the front and rear tires of the dump truck with a total load of 10 tons showed that the largest deflection difference was 2 cm and there were no cracks on the porous concrete surface.

These results indicate that the track with porous concrete pavement for the three types of soil can be passed with a payload of 10 tons. The results of the loading test are shown in Table 11 and the test's execution is shown in Fig. 15.

Table 11: Loading test results.

Location	Deflection difference [cm]
Kab.Sekadau (Hard soil)	0
Pontianak (Peat)	2
Pontianak (Silt/Clay)	1

Fig. 15: Loading test.

4 Conclusion

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

a) The Soil Carrying Capacity Test (CBR) was performed on three different kinds of soil. The area of Sekadau (soil hard) has the greatest soil-bearing capacity at 3.0%, according to the findings of the soil-bearing capacity test. Nevertheless, the three samples were included in the "bad" category for Subgrade [6].

b) Three kinds of soil were subjected to permeability testing, with Pontianak (land of clay), Pontianak (peat), and the Sekadau area (hard soil) fulfilling the ASTM C1701 minimum permeability requirement of 0.00564 cm/s for previous concrete. The volumetric flow rate per unit of time is 0.4 cm^3/s.

c) Using a cylinder sample of 15 x 30 cm evaluated the compressive strength of potted concrete. Based on the results of these tests, it is clear that the average compressive strength of 28-day-old porous concrete produced by three kinds of soil extracted from each of the ten samples produced ranges from 24.17 - 27.36 MPa.

d) The deflection of the porous concrete pavement from the front and rear tires of the dump truck with a total weight of 10 tons indicated the highest deflection difference, which was 2 cm, and the porous concrete surface lacked cracks. These findings demonstrate that a 10-ton load may be traversed on a route with porous concrete pavement.

e) According to the findings of the study, a porous concrete pavement with a thickness of 15 centimetres and a sub-base layer on road pavement on peat, clay, and hard soil may be utilized since it satisfies the aforementioned parameters.

f) This porous concrete roadway may transfer rainwater straight to the earth, reducing floods, and inundation on the highway.

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