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RESEARCH ARTICLE

# Analysis of the Effect of Bagasse Addition on Compressive Strength, Porosity, and Permeability of Pervious Concrete as Material for Green Building Program

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**Abstract**

Pervious concrete is still not widely used in construction work because it has shortcomings in terms of compressive strength, The researcher tried to increase the percentage of aggregate from wasted materials in the form of bagasse and if the compressive strength of pervious concrete with additional bagasse material has a standard compressive strength of 12 MPa can be applied as parking areas, light-traffic roadways, and sidewalks while maintaining its permeability properties to reduce surface water runoff in construction. Because of these advantages, pervious concrete is often used as a supporting material for Green Building programs in the world.

This research method was carried out based on the standardization of SNI 7656-2012 and ACI 522R-10 for testing compressive strength, porosity, and permeability to pervious concrete in the form of cylinders measuring 15 x 30 cm, with variations in the addition of dry bagasse of 0%, 2%, 4%, and 6% by weight of cement.

The results of the average compressive strength of pervious concrete at the age of 28 days with a total of 3 samples for variations of 0%, 2%, 4%, and 6% are 12.4 MPa, 14.1 MPa, 16.5 MPa, and 18.9 MPa respectively and are in accordance with the ACI 522R-10 standard. The average porosity results of pervious concrete with a total of 3 samples for variations of 0%, 2%, 4%, and 6% are 23.5%, 20.6%, 19.5%, and 17.4%, respectively. The average permeability results of pervious concrete with a total of 3 samples for 0%, 2%, 4%, and 6% variations are 0.46 cm/sec, 0.33 cm/sec, 0.27 cm/sec, and 0.20 cm/sec, respectively. Therefore, the pervious concrete in this study uses environmentally friendly materials that comply with the first category of water conversion and the second category of material sources and cycles in the Greenship New Building assessment by GBCI.

**Keywords:** Pervious Concrete, Compressive Strength, Porosity, Permeability

## 1. Introduction

consisting of portland cement, coarse aggregate, little or no fine aggregate, additives, and water. The drainage rate of pervious concrete pavement varies with aggregate size and mix density (ACI 522R-10). Pervious concrete has been widely used in several countries. It is commonly applied as parking lots, light traffic roads, sidewalks and environmentally friendly residential areas due to its permeable nature (Trisnoyuwono, 2014).

Pervious concrete has a structure that has voids. With enough cement paste to coat and bind the aggregate, it creates highly permeable voids, have high porosity, provide a large drainage capacity so have the ability to reduce the flow of rainwater on the surface and are interconnected allowing water to drain quickly (Teraiya et al., 2015).

However, pervious concrete also has shortcomings in terms of compressive strength so that it cannot be used in construction work that has a heavy load. The compressive strength of sandless concrete is lower than the compressive strength of conventional normal concrete due to increased porosity (Ginting, 2019).

This research seeks to focus on the utilization of silica dioxide contained in bagasse in the manufacture of pervious concrete which comes from nature is classified as a non-renewable material and if exploitation continues, it will result in the depletion of its availability in nature (Hermanto, 2019). The silicate content in cement contains tricalcium silicate compounds as much as 55% and 18% dicalcium silicate, while the silicate content of bagasse ash is 68.5% so that it has pozzolanic properties (Putra et al., 2020).

If with the addition of bagasse, pervious concrete has a compressive strength that can be applied as parking areas, light traffic roads, and sidewalks but still maintains its permeability properties to reduce surface water runoff in construction. Another form of sugarcane wastes is the bagasse ash as there were a lot of researches carried out to investigate the use of its ash as a replacement of cement in concrete and mortar. The results obtained were promising as the result showed a significant increase in compressive strength of concrete when using sugarcane bagasse ash as a partial replacement of cement within certain limits of replacement (Hussien, 2022).

Pervious concrete can be a supporting material for the Green Building program in construction according to the Greenship New Building standard by the Green Building Council Indonesia in 2013 in 2 categories, namely water conservation because pervious concrete has the characteristics of passing water and sources and material cycles because the manufacture of pervious concrete utilizes waste in the form of bagasse.

## 2. Methodology

Pervious concrete is a uniformly graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, additives, and water. In general, research methodology includes several elements: Research Approach, Research Design, Data Collection, Data Analysis, Interpretation, and Reporting.

### 2.1 Pervious Concrete

Pervious concrete is a uniformly graded material consisting of Portland cement, coarse aggregate, little or no fine aggregate, additives, and water. The drainage rate of pervious concrete pavement varies with aggregate size and mix density (ACI 522R-10). Pervious concrete has a structure that has voids. With enough cement paste to coat and bind the aggregate, it creates highly permeable, high porosity voids, provide a large drainage capacity so as to have the ability to reduce the flow of rainwater on the surface and are interconnected allowing water to drain quickly (Teraiya et al., 2015).

Generally, the use of pervious concrete in construction work is only for light construction in the form of parking lots, sidewalks, drainage, noise dampers, permeable structures, canstones, low traffic roads, building structures with light loads. This is because pervious concrete has its own advantages and disadvantages that make its use specialized in certain conditions only (Putra et al., 2020).

Other advantages of this material include the ability to limit contaminants entering groundwater and reduce tire-pavement noise. Additionally, pervious concrete provides economic benefits, such as lower installation costs by eliminating expensive storm drains, reduced lifecycle costs due to fewer repairs, and recyclability at the end of its lifespan. The key properties of pervious concrete, including porosity, permeability, and compressive strength, significantly impact pavement performance. Consequently, extensive research has been conducted in this area, focusing primarily on mixture design, testing, characterization, and related aspects (Zhang et al., 2023).

### 2.2 Research Methods

The research conducted was experimental in nature guided by ACI 522R-10 and SNI 7656-2012, the research was carried out on test specimens in the form of cylindrical pervious concrete with a diameter of 15 cm and a height of 30 cm, where the test specimens had additional material in the form of bagasse with a percentage variation of 0%, 2%, 4%, 6% by weight of cement. The research location was at Civil Engineering structure, material and computer laboratory, Faculty of Engineering, Islamic University of Riau. The flow of testing methods carried out include material inspection, making pervious concrete, slump testing, compressive strength testing, porosity and permeability testing of concrete and Greenship New Building assessment by the Green Building Council Indonesia (GBCI) in 2013.

### 2.3 Pervious Concrete Material

(1) Portland Cement
The cement used in this research sample is Type 1 portland cement from PT. Semen Padang 50 kg packages, with a maximum cement weight range of 270 kg - 415 kg based on the provisions set by ACI 522R-10.

(2) Aggregates
The aggregate used in the design of pervious concrete is coarse aggregate without the use of fine aggregate, the coarse aggregate used in this study is crushed stone from the Pangkalan region of Kampar District. The maximum size is 9.5-19 mm with the weight range of aggregate used based on ACI 522R-10 provisions of 1190 kg to 1480 kg.

(3) Water
The water used for the design of pervious concrete mixtures is water from the borehole of Laboratorium Teknik Sipil Fakultas Teknik Universitas Islam Riau. The water content used in the design of pervious concrete uses cement water factor values based on ACI 522R-10 provisions with a range of values of 0.27 to 0.34.

(4) Additive
The additive used in the manufacture of pervious concrete is sugarcane bagasse which is dehydrated and cut into small flakes passing sieve no. 4 (4.75 mm) and retained sieve no.100 (0.15 mm), with a percentage variation of 0%, 2%, 4%, 6% by weight of cement.

### 2.4 Material Assessment

(1) Analysis of Aggregate Gradation
Analysis of Aggregate Gradation is one of the material tests that has the aim of determining the division or gradation of soil grain size from a soil sample using a tool in the form of a sieve. ACI 522R-10 states that the ideal aggregate size specification that can be used in planning pervious concrete mixes is a single aggregate grain with a gradation range between ¾" and ⅜" (19 mm and 9.5 mm). Sugarcane bagasse, which is an additional ingredient in the planning of pervious concrete mixtures, must also be checked for aggregate gradation, bagasse that can be used in the manufacture of pervious concrete is bagasse that has been dried by drying and mashed to mempeloreh size passes sieve no. 4 (4.75 mm) and retained sieve no.100 (0.15 mm).

Table 1. Results of Coarse Aggregate Gradation Assessment.

| Sieve Number | Sieve Size (mm) | Pass (%) |
|---|---|---|
| 1” | 25,4 | 100 |
| ¾ “ | 19,1 | 95,62 |
| ½ “ | 12,7 | 51,02 |
| 3/8 “ | 9,8 | 31,01 |
| #4 | 4,8 | 1,39 |
| #8 | 2,4 | 1,02 |
| #16 | 1,2 | 0,90 |
| #30 | 0,6 | 0,86 |
| #50 | 0,3 | 0,84 |
| #100 | 0,15 | 0,57 |
| #200 | 0,075 | 0,24 |

(2) Content Weight

Content weight is the ratio between the weight of the aggregate and the content or volume. Aggregate content weight is reviewed in two states, namely loose content weight and solid content weight. According to SNI 7656-2012, the volume weight of coarse aggregate for both loose and dense concrete has a value of 1.4 - 1.9 gr/cm$^3$.

Table 2. Results of Coarse Aggregate Loose and Solid Content Weight Assessment.

| Aggregate Condition | Aggregate Weight (gr) | Container Volume (cm$^3$) | Content Weight (gr/cm$^3$) |
|---|---|---|---|
| Loose | 4480 | 3069,568 | 1,459 |
| Solid | 5170 | 3069,568 | 1,684 |

(3) Specific Gravity

This is a test that aims to find the bulk specific gravity, saturated surface dry specific gravity and apparent specific gravity as well as the absorption rate with the standard specification of coarse aggregate specific gravity based on SNI 7656-2012 is 2.58 - 2.84 gr/cm³, while the water absorption rate is 2% - 7%.

Table 3. Results of Specific Weight and Water Absorption of Coarse Aggregate Assessment.

| Inspection | Description | |
|---|---|---|
| | Value | Units |
| Bulk specific gravity | 2,537 | $gr/cm^3$ |
| Saturated surface dry spesific gravity | 2,597 | $gr/cm^3$ |
| Apparent specific gravity | 2,699 | $gr/cm^3$ |
| Absorption | 2,366 | % |

(4) Water Content

The water content of the aggregate is a way to determine how much water absorption occurs in the aggregate. The water content allowed to be contained in coarse aggregate for concrete mixtures based on SNI 7656-2012 is 0 - 5%. The results of checking the moisture content of coarse aggregate obtained a value of 0.584%, which is in accordance with the moisture content specification for coarse aggregate for pervious concrete mix planning.

(5) Mud Content

The mud content of coarse aggregate is an experiment to determine the amount of coarse aggregate gradation that passes the No.200 sieve (0.075 mm) in the planning of the mixture, In order to maintain the quality of the pervious concrete plan. The mud content of the coarse aggregate for pervious concrete mix planning is 0.479%.

(6) Pervious Concrete Mix Design

The result of concrete mix planning is the proportion of material that will be mixed in the manufacture of pervious concrete, The materials are cement, coarse aggregate, water, and bagasse peeling additives with variations in proportions that have been planned per $m^3$ concrete mix. Data for the cement/aggregate ratio, cement weight, coarse aggregate (split) weight, and water weight at each percentage of bagasse have the same value, which is 1:4, 370 kg, 1480 kg, 111 L. The only difference is in the weight of the bagasse, which follows the percentage amount.

Table 4. percentage and weight of bagasse.

| Bagasse Percentage (%) | Bagasse Weight (kg) |
|---|---|
| 0 | 0 |
| 2 | 7.4 |
| 4 | 14.8 |
| 6 | 22.2 |

### 2.5 Methodology Flow Chart

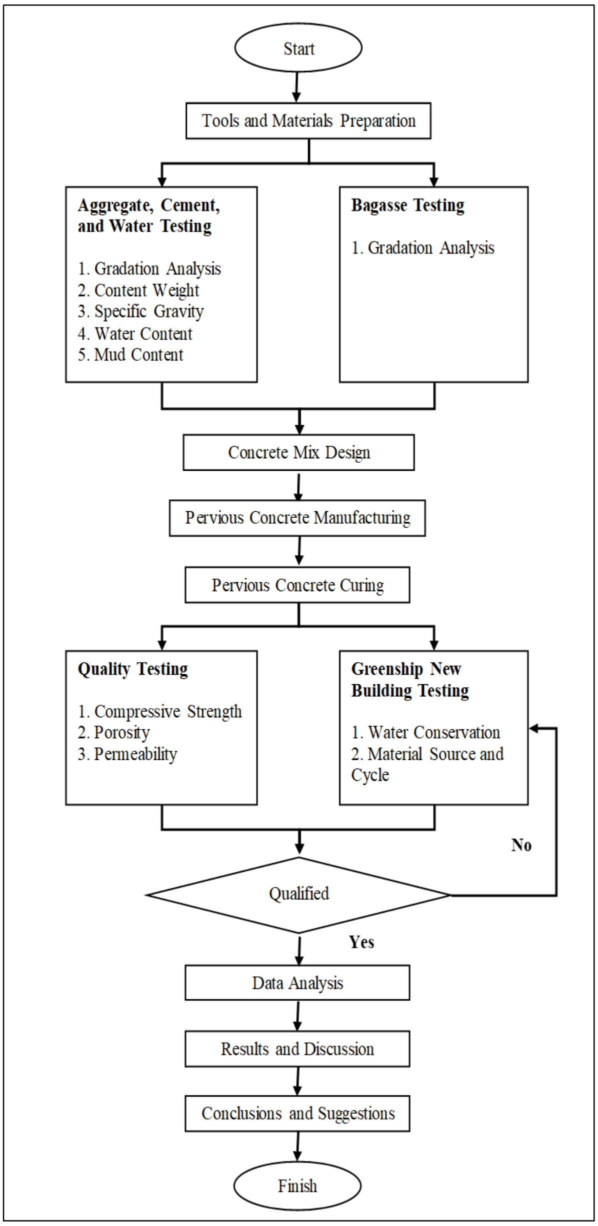


Fig 1. Research Methodology Flow Chart.

## 3. Result and Discussion

The data described in the results and discussion section consists of variations in quality testing data and the assessment of Greenship New Building, which refers to variations in the percentage and quantity of bagasse waste used. This waste can be processed back into construction material, specifically pervious concrete, while maintaining the quality of the pervious concrete.

### 3.1 Pervious Concrete Slump Test

Concrete batching plant is a kind of equipment used to mix cement, sand, water, aggregates and others together to produce concrete. While concrete slump testing is a way to find out, as well as determine the consistency or level of rigidity of fresh concrete mixes. The lower the slump value indicates the thicker the condition of the fresh concrete in the field, on the contrary, the greater the slump reading means the thinner the condition of the fresh concrete in the field. The minimum slump value is taken based on ACI 522R-10 which is zero, and the maximum value is taken based on SNI 7656-2012 the maximum slump value of pervious concrete is 50 mm.

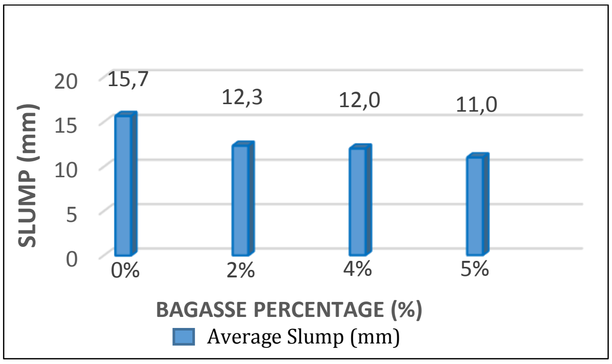


Fig 2. Comparison of Bagasse Addition Percentage with Slump Value.

### 3.2 Compressive Strength

Checking the compressive strength of concrete is done when the age of concrete has reached 28 days, on 3 samples of pervious concrete in the form of cylinders measuring 15 x 30 cm, for each variation of 0%, 2%, 4%, and 6% addition of dried bagasse, the planned compressive strength of pervious concrete is 12 MPa.

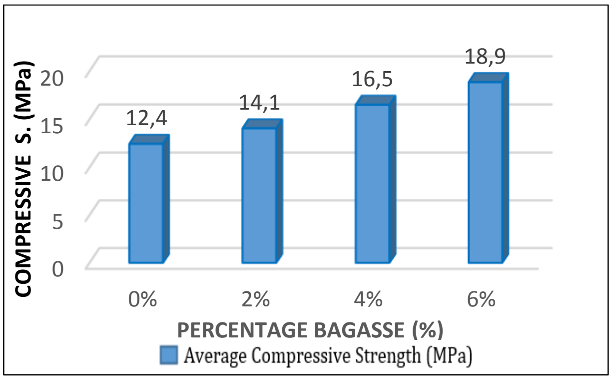


Fig 3. Comparison of Bagasse Addition Percentage with Compressive Strength.

### 3.3 Porosity

Porosity is a measure of the empty spaces or pores between materials, and is the fraction of the volume of empty space to the total volume, which is a percentage between 0-100%. Porosity depends on the material type, material size, pore distribution, cementation, and composition. Based on the provisions of ACI 522R-10 the range of porosity values allowed in the design of pervious concrete mixtures is 15% to 25%.

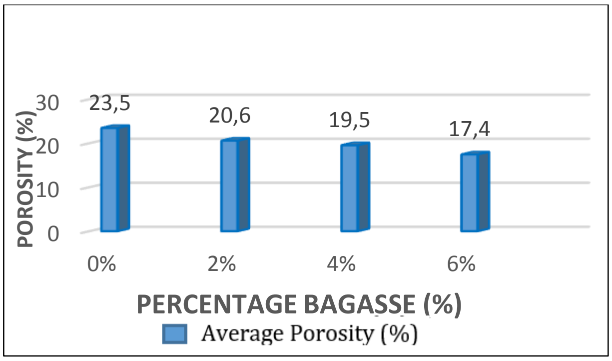


Fig 4. Comparison of Bagasse Addition Percentage with Porosity.

### 3.4 Permeability

Permeability is the ability of lightweight concrete pores to pass water. Hardened cement paste is composed of many particles, connected between surfaces that are relatively smaller than the total surface of the particles present. Permeability of concrete is measured based on the amount of fluid flow through a unit of pores in the concrete with a certain area that has been filled with water beforehand per unit time, based on the provisions of ACI 522R-10, the range of permeability values allowed in the design of pervious concrete mixtures is 0.14 to 1.22 cm/s.

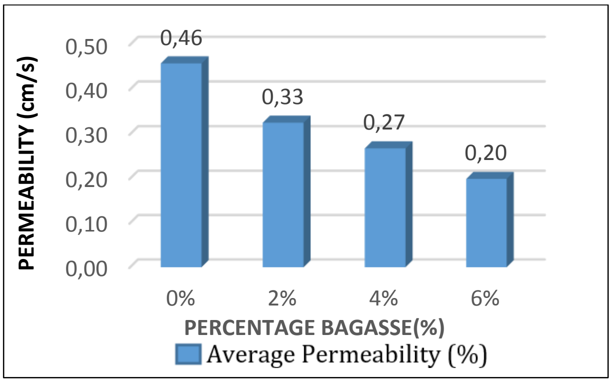


Fig 3. Comparison of Bagasse Addition Percentage with Permeability.

### 3.5 Greenship New Building Assessment by Green Building Council Indonesia

(1) Water Conservation

The Greenship New Building assessment in the water conversion category focuses on assessing the ability of a construction to collect and reuse water, In the water conservation category, researchers focused on 3 criteria, namely reducing water use (WAC 1) which has a maximum assessment point of 8 points, recycling water (WAC 3) which has a maximum assessment point of 3 points, and alternative water sources (WAC 4) which has a maximum assessment point of 2 points.

Table 5. Porosity and Permeability Values of Each Pervious Concrete Variation.

| Percentage Bagasse | Average Porosity (%) | Average Permeability (cm/s) |
|---|---|---|
| 0% | 23,5 | 0,46 |
| 2% | 20,6 | 0,33 |
| 4% | 19,5 | 0,27 |
| 6% | 17,4 | 0,20 |

(2) Material Source and Cycle

The material source and cycle category in the Greenship New Building assessment focuses on the ability of a construction to use materials that are environmentally friendly, not harmful to human health, can reduce construction waste, and reuse of waste that can be used as building construction material. In the material source and cycle category, researchers focus on environmentally friendly material criteria (MRC 2) which has a maximum assessment point of 3 points.

Table 6. Weight of Bagasse Used in Pervious Concrete/m3.

| Percentage Bagasse | Weight of Bagasse (kg) | Average Compressive Strength (MPa) |
|---|---|---|
| 0% | 0 | 12,4 |
| 2% | 7,4 | 14,1 |
| 4% | 14,8 | 16,5 |
| 6% | 22,2 | 18,9 |

## 4. Conclusions

Based on the research data on the water permeability of pervious concrete, the highest permeability value is 0.33 cm/s which is equal to 58.31 mL/s in pervious concrete with the addition of 2% bagasse to the weight of cement. If the water that escapes from the pores of this pervious concrete can be processed again by developing the use of this pervious concrete material in building construction such as canstines, paving blocks, and precast concrete that has the potential to cause puddles such as in building architecture, parks, sidewalks, and parking areas. Where the water permeability results from pervious concrete can be recycled water to become an alternative water source which is expected to reduce the use of water in a construction, so pervious concrete can be a supporting material in the green building program in the water conservation category, with maximum points that can be obtained by 13 points on the Greenship New Building Assessment.

The data above shows that with the addition of dry bagasse with a maximum percentage of 6% of the weight of cement or equivalent to 22.2 kg per $m^3$, the average compressive strength value of 18.9 MPa exceeds the initial planning standard limit of 12 MPa, so the addition of a maximum of 4% bagasse from the weight of pervious concrete quality cement is still in accordance with the planning standards, and is also able to utilize the reuse of bagasse waste that is often unused, so that the pervious concrete in this study uses environmentally friendly materials (MRC 2) which are in accordance with the material source and cycle category in the Greenship New Building assessment by GBCI, with the maximum points that can be obtained by 3 points.

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