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Experimental Study of the Effect of Coarse Aggregate Fine Modulus (MHB) on the Physical and Mechanical Properties of Pervious Concrete

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ABSTRACT

In recent years developments in Indonesia have increased rapidly where more and more lands that were originally green areas were converted into land with water-resistant concrete pavements. This causes a reduction in green open land as a place for water absorption because it is covered by concrete that is impermeable to water. Therefore one solution that can be taken to reduce the impact of this development is the use of porous concrete which can allow water to pass directly to the ground surface to be absorbed by the soil, thus reducing Surface Run Off. This study aims to examine the physical and mechanical properties of porous concrete with differences in Fine Grain Modulus (MHB) of coarse aggregate as the main ingredient for forming porous concrete. In this study tests will be carried out for the physical and mechanical properties of porous concrete. From the test results, the highest compressive strength was found in the 0.5/0.5 stone sample, namely 20.403 MPa, the best permeability was obtained in 1/1 stone sample, which was 0.835 cm/s, the best splitting tensile strength was obtained in 0.5/0 stone sample. 5 which is 6.356 MPa and the best volume weight is obtained in rock samples 0.5/0.5 which is 2106 Kg/m^3.

Keywords: Porous concrete, Split Tensile Strength, Compressive Strength, Permeability, Surface Run Off

I. INTRODUCTION

In recent years, there has been a significant surge in development in Indonesia, resulting in the conversion of an expanding area of verdant land into impermeable concrete pavement land. The implementation of impermeable concrete covers results in a diminished capacity of verdant open land to serve as a water catchment area. Consequently, the implementation of porous concrete that allows water to percolate directly to the soil surface for absorption, thereby mitigating Surface Run Off, represents one potential approach to alleviate the consequences of this development. Infrastructure development in Indonesia has yet to fully incorporate porous concrete. The presence of voids in porous concrete, which result from the reduction of additives during the manufacturing process, significantly affects the concrete's compressive strength.The dimension of the coarse aggregate is critical to the achievement of success in the production of porous concrete. In situations where the compressive strength and permeability of porous concrete are influenced by the size of the coarse aggregate. 25 MPa is the upper limit of the greatest compressive strength of porous concrete.

As a constituent material for porous concrete, the objective of this research was to identify the coarse aggregate with the highest possible fine modulus of grains (MHB). Volume weight, compressive strength, split tensile strength, and permeability were the physical and mechanical properties of porous concrete that were evaluated. This study encompasses the subsequent scope:

1. In accordance with ACI 522R-10, develop a porous concrete mixture.
2. ACI 522R-10 regulates the concrete mixture formulation. Based on ACI 522R-10, the concrete mixture is designed. Based on ACI 522R-10, the concrete mixture is designed. Aspertained through the 4.75 mm sieve from the 9.52 mm sieve, cashara aggregate constitutes the second coarse aggregate.

3. The volume weight of the concrete itself was evaluated as a physical property.
4. Compressive strength, divided tensile strength, and permeability were the mechanical properties that were assessed.
5. Cylinders measuring 15 cm in diameter and 30 cm in height, as well as 10 cm in diameter and 20 cm in height, are employed as the test objects.
6. At 3, 7, 14, 21, and 28 days, volume weight and compressive strength assessments were performed.
7. Passibility and fracture tensile strength tests were not conducted until day 28.

II. METHODOLOGY

As part of this experimental investigation, samples will be fabricated with the mix design content determined in accordance with ACI 522R-10. The research consists of the subsequent stages:

1. Separation of coarse aggregate from fractured stone.
2. Evaluating porous concrete substances.
3. Designing a mixture for porous concrete in accordance with ACI 522R-10.
4. Prototypes of porous concrete.
5. Porous concrete testing in the laboratory.
6. Examination of the resultant porous concrete tests.
7. Suggestions and conclusion

2.1 Methods of Research

The subsequent tests will be conducted on manufactured samples of porous concrete:

1. Slump Testing 1.

In order to ascertain concrete workability conditions based on the capacity to descend to a depth of 30 cm, it is necessary to assess the "filling ability" in both laboratory and field settings. Succumbed to testing in accordance with SNI 1972:2008.

2. Testing for Permeability

Quantity denoting the rate at which fluid seepage occurs within a given substance.

3. Evaluation of Volume Weight

In order to determine the volume weight of the test specimen, volume weight testing is performed. Criterion-compliant: 2008 SNI 1973 The methodology for determining the weight of components, production volume, and air content of concrete.

4. Strength of Compression Testing

The determination of the test specimen's compressive strength value can be achieved by dividing the maximum loading by the burdened cross-sectional area.

5. Tensile Testing on Splits

The tensile strength of concrete test specimens is determined indirectly through the pressing table of the testing equipment using load tests with the specimens laid level and parallel to the surface.

2.2 Analysis Methods

1. Analysis of the Hydraulic Content of Coarse Aggregate

In order to ascertain the moisture content percentage of coarse aggregate (stone), the following formula is employed:

$$\text{Content of moisture} = \frac{(W_3 - W_5)}{W_5} \times 100\% \qquad (1)$$

Where:
W3 = Weight of the initial sample(grams).
W5 = Weight in grams of the oven-dried sample.

2. Evaluation of the Gradation of Porous Concrete Composing Stone

Maximal particle size (MHB) can be determined using the following formula:

$$\text{MHB} = \frac{\text{Percentage of the Cumulative Total Weight Retained}}{100} \qquad (2)$$

3. Behavior Evaluation of Coarse Aggregate Wear

Calculation formula for wear:

$$\text{Wear} = \frac{a-b}{a} \text{x}100 \quad (3)$$

Where :
a = Initial weight (grams) of the test object
b = Solidified weight in grams of test specimens through sieve No. 12

III. CONCLUSIONS AND RESULTS

3.1 Investigation into the Gradation of Coarse Aggregate

The subsequent findings were derived from the results of the coarse aggregate gradation test:

Porous concrete samples that have been manufactured will be subjected to the subsequent tests:

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1. The evaluation of the gradation of coarse aggregate 1/1

The sole objective of the 1/1 coarse aggregate gradation test is to verify that the suitable aggregate possesses uniformly sized grains. According to Table 1 and Figure 1, the subsequent information presents the findings of the coarse aggregate gradation investigation (Stone 1-0).

Table 1. Gradation Analysis of Coarse Aggregate (Stone 1-1)

No.	Container Weight	Container Weight + Test Item	Retained Weight		Cumulative (%)	
			(gram)	(%)	Restrained	Escaped
37.50	538.70	538.70	0.00	0.00%	0.00%	100.00
25.40	513.80	513.80	0.00	0.00%	0.00%	100.00
19.10	529.30	529.30	0.00	0.00%	0.00%	100.00
12.00	583.90	1740.20	1156.30	46.25%	46.25%	53.75
9.52	490.70	1790.90	1300.20	52.01%	98.26%	1.74
4.75	492.30	525.40	33.10	1.32%	99.58%	0.42
2.38	499.00	499.00	0.00	0.00%	99.58%	0.42
1.18	444.50	449.90	4.40	0.18%	99.76%	0.24
Pan	264.70	270.70	6.00	0.24%	100.00	0.00
Total			2500.00	100.00%	543,440	
Grain Fineness Modulus						5,434

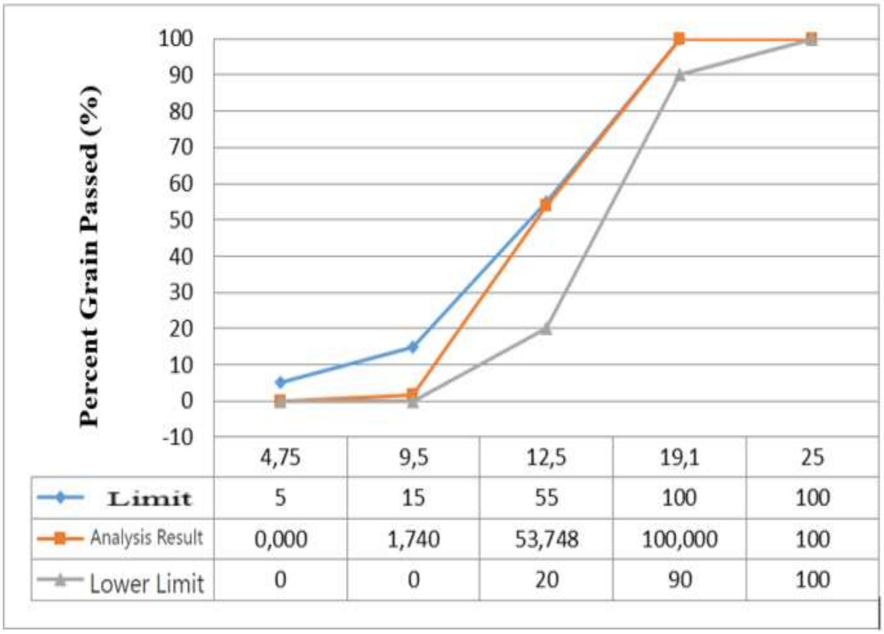

Fig 1. Stone Aggregate Gradation Analysis 1/1

According to the outcomes of the tests, the fine modulus of grains (MHB) of coarse aggregate composed of 1/1 stone is 5.434.

2. Evaluating the 0.2/0.5 gradation of coarse aggregate

As shown in Table 2 and Figure 2, the following are the outcomes of the investigation on coarse aggregate gradation (Stone 0.5):

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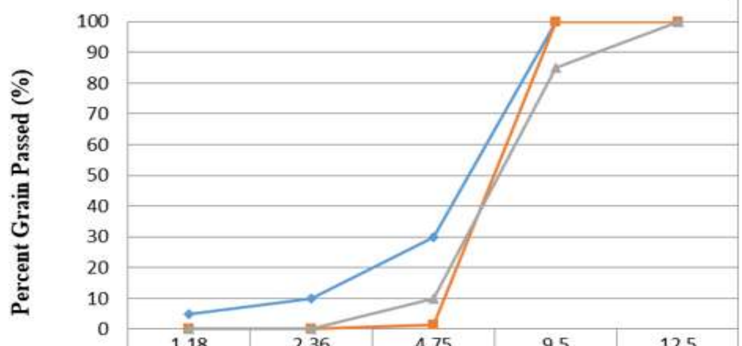
Table 2. Coarse Aggregate Gradation Analysis (Stone 0.5)

No.	Container Weight	Container Weight + Test Item	Retained Weight		Cumulative (%)	
			(gram)	(%)	Restrained	Escaped
37.50	538,60	538,60	0,00	0,00	0,00	100,00
25.40	514,10	514,10	0,00	0,00	0,00	100,00
19.10	529,90	529,90	0,00	0,00	0,00	100,00
12.00	583,40	583,40	0,00	0,00	0,00	100,00
9.52	532,50	532,50	0,00	0,00	0,00	100,00
4.75	492,20	2958,00	2465,90	98,66	98,66	1,34
2.38	500,00	528,3	28,30	1,13	99,79	0,21
1.18	444,90	447,00	2,00	0,08	99,87	0,13
Pan	264,90	268,6	3,20	0,13	100,00	0,00
Total			2500.00	100.00%	398.256	100
Grain Fineness Modulus						3,983



	1,18	2,36	4,75	9,5	12,5
Limit	5	10	30	100	100
Analysis Result	0,128	0,208	1,340	100,000	100
Lower Limit	0	0	10	85	100

Fig 2. Stone Aggregate Gradation Analysis 0,5/0,5

Fine grain modulus (MHB) of 0.5/0.5 coarse stone aggregate was determined to be 3.983 based on test results.

3.2 Testing Scrubs

It is critical to conduct slump tests in order to ascertain the resulting material's smoothness. The location where slump tests are conducted. The following information was obtained from the experiments that were conducted: Table 3.

Table 3. Slump Test

No	Mix	Slump Test (cm)
1	Stone 1/1	9,5
2	Stone 0,5/0,5	8
3	Mix Stone	8,2
4	Conventional Concrete	7

Table 3 presents the results of the droop test, which indicated an average deviation of 9.5 to 7 centimeters. No determination of the decline value was made in this study. Slump testing is performed solely to collect data. SNI regulations for concrete construction stipulate that the optimal sag for concrete is between 25 and 100 millimeters. Therefore, the four constructed variables have complied with the SNI regulations.

3.3 Testing Volume Weight

The volume weight and average content of the tested porous concrete for a 10cm x 20cm sample are shown in Table 4 and Figure 3, respectively:

Table 4. Weight of Average Volume at Ages 3, 7, 14, 21, and 28 Days

Aggregate Type	Volume Weight (Kg/m^3)				
	3 Days	7 Days	14 Days	21 Days	28 Days
Stone 1/1	1811,040	1800,425	1794,055	1791,932	1787,686
Stone 0,5/0,5	2135,881	2118,896	2118,896	2112,527	2106,157
Mix Stone	2074,310	2061,571	2057,325	2053,079	2046,709
Conventional Concrete	2430,998	2430,998	2428,875	2430,998	2426,752

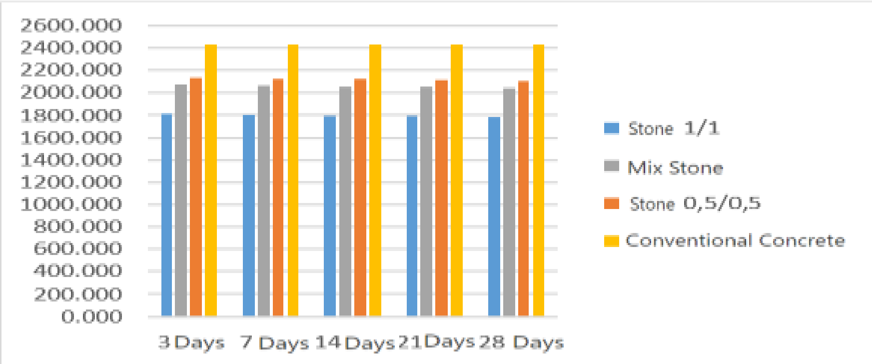


Fig 3. Average Volume Weight of Porous Concrete and Conventional Concrete

At the 28-day mark, the mean volume weight of porous concrete containing aggregate 1 is 1781.686 kg/m3, while that of aggregate 0.5 is 2106.157 kg/m3. The average volume weight of aggregate mixes is 2046.709 kg/m3, and that of conventional concrete is 2426.752 kg/m3.

3.4 Testing for Compressive Strength

The specimen employed for the compressive strength test measures 10 centimeters in diameter and 20 cm in height. Table 5 and Figure 2 present the outcomes of the compressive strength testing conducted on porous concrete.

Table 5. Results of Compressive Tests on Conventional and Porous Concrete

Aggregate Type	Compressive Strength (Mpa)					Average 28-Day Compressive Strength
	3 Days	7 Days	14 Days	21 Days	28 Days	
Stone 1/1	3,087	5,503	6,309	7,383	8,054	9,083
	4,430	4,698	6,040	6,980	8,859	
	6,846	4,832	5,772	7,517	10,336	
Stone 0,5/0,5	5,369	9,664	9,396	14,631	17,987	20,403
	12,752	6,174	8,591	8,591	20,134	
	3,758	7,651	14,362	13,691	23,087	
Mix Stone	5,638	12,886	12,752	15,839	15,705	17,136
	6,577	8,054	16,107	14,094	16,510	
	5,638	7,785	14,899	15,302	19,195	
Conventional Concrete	35,705	35,302	27,383	45,101	55,436	52,125
	37,047	38,792	39,597	36,510	52,886	
	32,752	29,799	39,597	43,356	48,054	

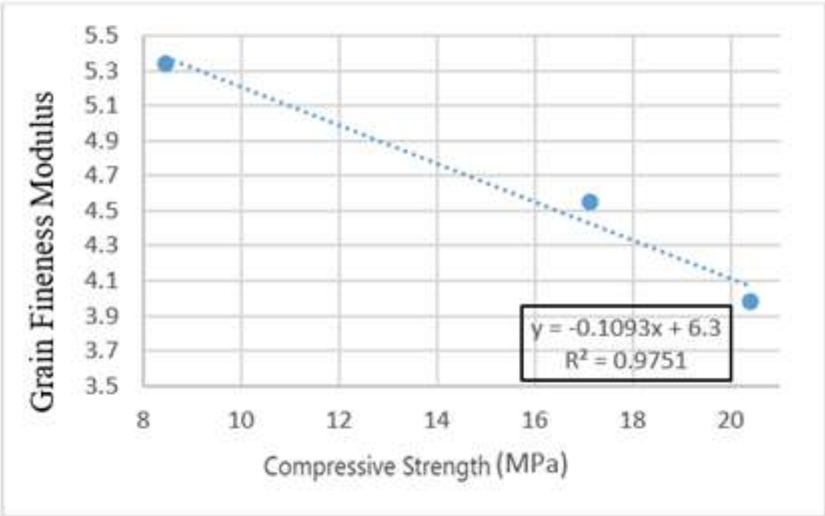


Fig 4. Graph of Compressive Strength VS MHB

The table and graph for each variation illustrate that the essential 28-day compressive strength for porous concrete, as specified in ACI 522.1R, is 2.8 MPa. However, the actual 28-day compressive strength of porous concrete did not meet the desired target of 25 MPa, as indicated by the obtained results. This phenomenon could potentially occur if the porous concrete sample material is comminuted to an extent beyond its effective limit within the concrete container. As a consequence, inter-aggregate samples may become deficient.

3.5 Testing for Permeability

The consequences of conducting a constant head permeability test on cylindrical specimens measuring 10 cm in diameter and 20 cm in height for porous concrete were evaluated.

Table 6. Average 28-Day Permeability Test Results

Aggregate Type	Volume (cm^3)	Time (second)	Cross Section Area (cm^2)	Pipe Length (cm)	Permeability Coefficient (cm/s)	Average
1	4.930	30	78,5	50	0,837	0,835
	4.980	30	78,5	50	0,846	
	4.840	30	78,5	50	0,822	
0,5	3.920	30	78,5	50	0,666	0,679
	4.060	30	78,5	50	0,690	
	4.010	30	78,5	50	0,681	
Mix	4.390	30	78,5	50	0,746	0.728
	4.220	30	78,5	50	0,717	
	4.240	30	78,5	50	0,720	

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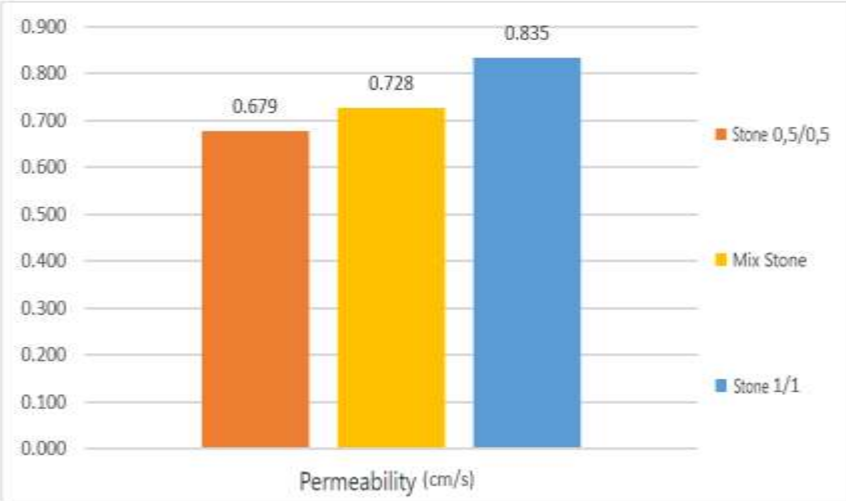

Fig 5. Average Permeability Results of Test Objects

The analysis of the data presented in the table above reveals that the permeability outcomes achieved for every iteration of porous concrete conform to the permeability criteria outlined in ACI 522R-10, specifically within the range of 0.14–1.22 cm/s. The average permeability is greatest at coarse stone aggregate size 1, measuring 0.835 cm/s, and lowest at coarse stone aggregate size 0.5, measuring 0.679 cm/s. In contrast, conventional concrete has a permeability of 0 cm/s.

3.6 Evaluation of Split Tensile Strength

The outcomes of the split tensile examination of porous concrete were assessed using cylindrical specimens measuring 15 cm in diameter and 30 cm in height.

Table 7. Results of Split Tensile Strength Tests

Coarse Aggregate Type	Compression Force (kN)	Split Tensile Force (kN)	Diameter (mm)	Length (mm)	Split Tensile Strength (Mpa)	Average
Stone 1/1	72	144000	150	300	3,20	3,41
	86	172000	150	300	3,82	
	72	144000	150	300	3,20	
Stone 0.5/0,5	122	244000	150	300	5,42	6,36
	141	282000	150	300	6,27	
	166	332000	150	300	7,38	
Mix Stone	129	258000	150	300	5,73	4,53
	130	260000	150	300	5,78	
	47	94000	150	300	2,09	
Conventional Concrete	233	466000	150	300	10,36	10,89
	241	482000	150	300	10,71	
	261	522000	150	300	11,60	

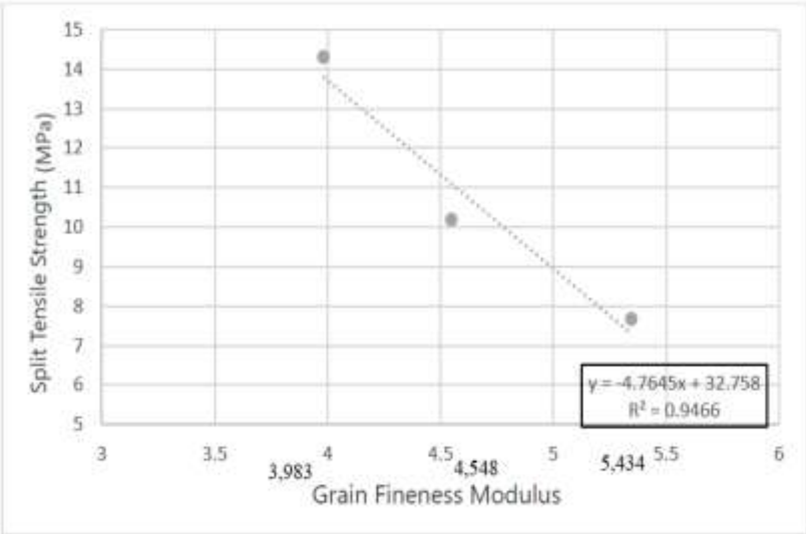

Fig 6. Graph of Modulus of Fine Grain (MHB) Vs Tensile Strength (MPa)

According to the data presented in the table above, the porous concrete variant containing coarse stone aggregate size 0.5 exhibits the highest split tensile strength at 14.30 MPa. In contrast, the variant containing coarse stone aggregate size 1 demonstrates the lowest split tensile strength at 7.67 MPa.

IV. CONCLUSION

Drawing from the findings of the conducted research and data analysis, the following conclusions can be drawn:

1. The average compressive strength at the 28-day mark for 1-1 stone porous concrete was determined to be 9.083 MPa, for 0.5-0.5 stone porous concrete it was 20.403 MPa, for stone porous concrete mix it was 17.136 MPa, and for conventional concrete as a comparative concrete it was 52.125 MPa, according to the study's findings.
2. According to the study's findings, the volume weight of 1-1 porous stone concrete at 28 days was 1787.686 kg/m3, that of 0.5-0.5 porous stone concrete was 2106.157 kg/m^3, that of porous stone concrete mix was 2046.709 kg/m3, and that of conventional concrete was 2426.752 kg/m^3.
3. The split tensile strength at the 28-day mark for 1-1 stone porous concrete was 3.41 MPa, for 0.5-0.5 stone porous concrete it was 6.36 MPa, for stone porous concrete mix it was 4.53 MPa, and for conventional concrete as a comparison it was 10.89 MPa, according to the research findings.
4. According to the findings of the study, the permeability of 1-1 stone concrete was 0.835 cm/s, 0.679 cm/s for 0.5-0.5 porous stone concrete, and 0.728 cm/s for 0.728 cm/s. The comparative speed of porous stone mix concrete and conventional concrete was 0 centimeters per second.
5. A compressive strength of 20.403 MPa, which satisfies the minimum compressive strength requirement for porous concrete as specified by ACI 522R-10 (at least 2.8 MPa), and a permeability of 0.679 cm/s, which still falls within the range of 0.14 cm/s to 1.22 cm/s, indicate that the aforementioned test results and conclusions support the conclusion that stone porous concrete with a size of 0.5-0.5 exhibits the most favorable physical and mechanical characteristics.
6. The research results support the initial hypothesis that the physical and mechanical properties of porous concrete are influenced by the size of the aggregate. Specifically, the volumes, tensile strengths, and compressive strengths of the concrete are all increased as the size of the coarse aggregate decreases, whereas the permeability decreases.
7. Serving the ready-mix concrete batching equipment and industry for the past quarter-century, our family-owned company has been in this business for the past 25 years.
8. Porous concrete with 0.5/0.5 aggregate can drain runoff from rainwater to reduce puddles and assist water in passing into the channel, thereby mitigating the effects of flooding caused by heavy rains, according to the study's findings regarding the minimum permeability of porous concrete as specified by ACI522R-10.

Recommended Courses of Action

Several recommendations for future research can be derived from the findings of the conducted research:

1. Plaster mortar should be applied to the surface of the compressive test sample once the construction process is finished, as this will serve to level the surface of the specimen undergoing pressure testing.
2. Enhancing the precision of the material during testing is crucial as it significantly impacts the outcomes of subsequent testing samples.

REFERENSI

[1]. American Concrete Institute Committee. 2010. ACI 522 R -10 Report On Pervious Concrete, New York.

[2]. Vista, Irene Simanjuntak., Tampubolon and Sudarno. "Pengaruh Variasi Agregat Kasar Penyusun Beton Porous Terhadap Kuat Tekan dan Porositas Beton."Universitas Kristen Indonesia, 2022.

[3]. Indrayadi, Erwin Sutandar.. "Pengunaan Perkerasan Berpori (Precast Pervious Pavement) sebagai Perkerasan Kaku (Rigid Pavement)." Universitas Tanjungpura, 2022.

[4]. Desmaliana,Erma., Herbudiman Bernadinus, and Lesmana Rossa."Kajian Eksperimental Sifat Mekanik Beton Porous Dengan Variasi Faktor Air Semen". Institut Teknologi Bandung2018.

[5]. Yi Zhang, "Comparative laboratory measurement of pervious concrete permeability using constant-head and falling-head permeameter methods." Sichuan University 2020.

[6]. Badan Standarisasi Nasional, "Cara Uji Slump Beton. SNI 1972." Badan Standarisasi Nasional.2008.

[7]. Badan Standarisasi Nasional, "Cara Uji Kuat Tekan Beton dengan Benda Silinder. SNI 1974 : 2011." Badan Standarisasi Nasional.2011.

[8]. Badan Standarisasi Nasional, "Metode Pengujian Kuat Tarik Belah Beton. SNI 03 – 2491 – 2002." Badan Standarisasi Nasional.2002.

[9]. Badan Standarisasi Nasional, "Cara Uji Kadar Air Agregat dengan Pengeringan. SNI 1971 : 2011." Badan Standarisasi Nasional.2011.

[10]. Badan Standarisasi Nasional, "Cara Uji Berat Jenis dan Penyerapan Agregat Kasar. SNI 1969 : 2008." Badan Standarisasi Nasional.2008.

[11]. Badan Standarisasi Nasional, "Cara Uji Keausan Agregat Kasar dengan Mesin Los Angels. SNI 03-2417-1991." Badan Standarisasi Nasional.1991.

[12]. ASTM, "Standard Specification for Concrete Aggregates. ASTM C-33." ASTM International.2002