

ANALYSIS OF THE USE OF ZEOLITE AS A SUBSTITUTE FOR SOME OF THE COARSE AGGREGATE IN POROUS CONCRETE

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ABSTRACT

Rapid urban development increases water runoff due to impervious areas. Porous concrete is an environmentally friendly solution because it absorbs water and preserves groundwater. This study examines the use of porous zeolite as a partial substitute for coarse aggregate to improve the mechanical and environmental performance of porous concrete, particularly in areas with light traffic and sustainable water management requirements. The compressive strength of concrete with 0% zeolite stone composition reached 18.66 MPa (7 days), 22.60 MPa (14 days), and 25.60 MPa (28 days), exceeding all SNI 2847:2019 requirements. The compressive strength of concrete with 15% zeolite stone reached 16.06 MPa (7 days), 20.82 MPa (14 days), and 22.18 MPa (28 days), but none of them met the minimum limit of SNI 2847:2019. The compressive strength of concrete with 30% zeolite aggregate reached 16.07 MPa (7 days), 20.83 MPa (14 days), and 22.20 MPa (28 days), but none of them met the minimum standard of SNI 2847:2019.

Keywords: Porous Concrete, Zeolite Rock, Compressive Strength, Substitution

INTRODUCTION

Urban development using conventional concrete increases impervious areas, triggering surface runoff and flooding. The solution is porous concrete innovation that can absorb water and is environmentally friendly. Porous concrete is high-porosity concrete that allows water to seep into the ground, thereby reducing surface runoff and maintaining groundwater quality. Made from cement, coarse aggregate, water, and admixtures, this concrete has a compressive strength of 2.8–28 MPa and is suitable for light traffic areas such as sidewalks, sports fields, and limited parking. Various substitute materials, such as fibers, powders, and liquids, can be tested through mechanical, chemical, and thermal tests. However, some materials do not improve concrete performance, and excessive use can reduce its quality. Zeolite, which contains aluminum and silica, acts as a natural ion exchanger to absorb pollutants and is used in aquarium filtration. This study uses zeolite as a substitute for some of the coarse aggregate in porous concrete. Zeolite, which is abundant in the Indonesian mining industry, contains cement-forming elements such as Na₂O, MgO, CaO, Mn, and SiO₂, and has great potential as a pozzolanic material. This study aims to analyze the effect of zeolite on the mechanical properties of concrete.

METHODS

Before making concrete test specimens, tests were conducted on the characteristics of fine and coarse aggregates. The aggregate characteristic tests conducted in this study referred to ASTM and SNI standards, which included the following:

Table 1. Aggregate Test References

No.	Type of Examination	standard reference
1.	Pemeriksaan Analisa Saringan	ASTM/SNI C136-2012
2.	Specific Gravity and Absorption Examination	SNI 1969 : 2018
3.	Volumetric Weight Check	SNI-03-4804-1998
4.	Water Content Check	SNI-1971-2011
5.	Sludge Level Check	ASTM/SNI-C117-2012

Source: Research Data Processing, 2025.

The testing of concrete mix materials is intended to measure and test materials to obtain the physical properties required for concrete mixes. The information obtained from these material tests is very important in determining the optimal concrete mix proportions to meet technical requirements, structural strength, durability, and construction cost efficiency. One example of the main equipment used in this research is:



Figure 2 Concrete Compressive Strength Testing Machine



Figure 3. Research Flow Chart

Preparation of tools and materials consists of sieves, scales, measuring cups, ovens, cement spoons, concrete mixers, cylinder molds, concrete compressive strength testing machines, wheelbarrows, and slump test equipment. The stages of test specimen production consist of the mix design stage, the mixing stage, the slump test stage, the test specimen curing stage, and the concrete compressive strength test.

RESULTS AND DISCUSSION

The mix design used in this study was designed with the aim of achieving a slump value of 12 ± 2 cm, which indicates the workability of fresh concrete mix. This slump value was chosen so that the concrete would be easy to work with in the field without compromising structural quality. In addition, the specified planned compressive strength is $f'_c = 25$ MPa, which is known as K-300 in concrete quality units. This value indicates that the concrete is designed to withstand compressive loads of up to 25 MPa at 28 days after curing, which is the general standard for medium structural construction such as floors, columns, and building beams. The mix design planning includes the proportions of all the main components that make up porous concrete, namely cement, coarse aggregate (gravel or crushed stone), and water. The composition of these materials has been carefully calculated to achieve a balance between strength, durability, ease of workmanship, and material efficiency. The details of the concrete mix composition based on the mix design with the target slump and compressive strength can be seen in the table below:

Table 2 Total Number of Samples

No.	Material	Information	Volume	Unit
1.	Cement	Indocement	330	Kg
2.	Coarse aggregate, maximum 2.5 cm	Rumpin	1334	Kg
3.	Water		165	Liter

From the results of the mix design calculations that have been carried out previously, the theoretical mixture proportions are obtained for every 1 m³ of concrete. These proportions include the measurements of each concrete constituent material, namely cement, coarse aggregate, water which are calculated carefully to produce concrete with the planned quality, namely $f'_c = 25$ MPa or equivalent to K-300 quality. The results of this mix design are then used as a reference in determining the material requirements for the volume of concrete to be used in making test specimens. The volume of concrete mix required in this study is adjusted to the number and size of test specimens to be made. The number of planned test specimens includes 27 cylindrical test specimens with dimensions of 15 cm in diameter and 30 cm in height. All test specimen sizes have been converted into meters to facilitate the calculation of the total volume of concrete required. By referring to these dimensions, the volume of each cylindrical test specimen is calculated using the cylinder volume formula, namely $\pi \times r^2 \times t$, while the volume of the beam test specimen is calculated using the formula length $\times$ width $\times$ height. After the individual volume of each test object is obtained, the total volume of all test objects is added up, then compared with the proportion of the concrete mixture per cubic meter. This step aims to determine the exact amount of material that must be prepared on a laboratory scale, so that there is no shortage or waste of material during the mixing and molding process of the test object. The calculation of the volume of normal porous concrete, variation 1, and variation 2 for cylindrical test objects is as follows:

$$\begin{aligned}
 \text{Volume} &= 9 \text{ pieces} \times \text{cylinder volume} \\
 &= 9 \text{ pieces} \times (\text{circle area} \times \text{height}) \\
 &= 9 \text{ pieces} \times (1/4 \times \pi \times d^2 \times t) \\
 &= 9 \text{ pieces} \times (1/4 \times 3.14 \times 0.152 \times 0.3)
 \end{aligned}$$

$$= 0.0477 \text{ m}^3$$

Thus, the test mixture proportion is 0.0477 m³.

Table 3 Mix Design for Normal Porous Concrete Cylinder Test Specimens

Description	Water	Cement	Coarse aggregate
Every 1 m ³	165 liter	330 kg	1334 kg
Every 0,0477 m ³	0,0477 m ³ x 165 liter = 7,8686 liter	0,0477 m ³ x 330 kg = 15,7373 kg	0,0477 m ³ x 1334 kg = 63,6168 kg

Table 4 Mix Design for Variation 1 Porous Concrete Cylinder Test Specimens

Description	Water	Filler		Coarse aggregate
		(15%) zeolite rock	(95%) Cement	
Every 1 m ³	165 liter	49,50 kg	280,50 kg	1334 kg
Every 0,0477 m ³	0,0477 m ³ x 165 liter = 7,8686 liter	0,0477 m ³ x 49,50 kg = 2,3606 kg	0,0477 m ³ x 280,50 kg = 13,3767 kg	0,0477 m ³ x 1334 kg = 63,6168 kg

Table 5 Mix Design for Variation 2 Porous Concrete Cylinder Test Specimens

Description	Water	Filler		Coarse aggregate
		(30%) zeolite rock	(70%) Cement	
Every 1 m ³	165 liter	99 kg	231 kg	1334 kg
Every 0,0477 m ³	0,0477 m ³ x 165 liter = 7,8686 liter	0,0477 m ³ x 99 kg = 4,7212 kg	0,0477 m ³ x 231 kg = 11,0161 kg	0,0477 m ³ x 1334 kg = 63,6168 kg

Compressive strength testing of concrete is carried out when the concrete has reached 7 days, 14 days, and 28 days of age, which are important stages in evaluating the quality and performance of concrete under compressive loads.



Figure 4. Concrete Compressive Strength Testing Process

The results of the compressive strength testing of normal porous concrete in cylindrical form can be seen in Table 4 below.

Table 6 Normal Porous Concrete Compressive Strength

No.	Date		Age	Weight	Load	C. Strength	Remark	Rata-rata
	Casting	Test	(Days)	(Gram)	(kN)	(MPa)	%	(MPa)
1.	24 Jun 25	01 Juli 2025	7	10660	324,5	18,37	73,5	18,66
2.	24 Jun 25	01 Juli 2025	7	10340	329,6	18,66	74,6	
3.	24 Jun 25	01 Juli 2025	7	10460	335,2	18,97	75,9	
4.	24 Jun 25	08 Juli 2025	14	10660	397,0	22,47	89,9	22,60
5.	24 Jun 25	08 Juli 2025	14	10880	402,2	22,77	91,1	
6.	24 Jun 25	08 Juli 2025	14	10920	398,7	22,57	90,3	
7.	23 Jun 25	21 Juli 2025	28	10700	446,8	25,29	101,2	25,80
8.	23 Jun 25	21 Juli 2025	28	10720	461,4	26,12	104,5	
9.	23 Jun 25	21 Juli 2025	28	10760	459,3	26,00	104,0	

The results of the compressive strength test of porous concrete variation 1 in cylindrical form can be seen in Table 5 below

Table 7 Compressive Strength of Porous Concrete Variation 1

No.	Date		Age	Weight	Load	C. Strength	Remark	Rata-rata
	Casting	Test	(Days)	(Gram)	(kN)	(MPa)	%	(MPa)
1.	24 Jun 25	01 Juli 2025	7	10360	281,1	15,91	63,6	16,06
2.	24 Jun 25	01 Juli 2025	7	10400	276,8	15,67	62,7	
3.	24 Jun 25	01 Juli 2025	7	10420	293,1	16,59	66,4	
4.	24 Jun 25	08 Juli 2025	14	10780	370,4	20,97	83,9	20,82
5.	24 Jun 25	08 Juli 2025	14	10800	360,9	20,43	81,7	
6.	24 Jun 25	08 Juli 2025	14	10880	372,1	21,06	84,3	
7.	23 Jun 25	21 Juli 2025	28	10600	390,1	22,08	88,3	22,18
8.	23 Jun 25	21 Juli 2025	28	10700	386,7	21,89	87,6	
9.	23 Jun 25	21 Juli 2025	28	10740	398,7	22,57	90,3	

The results of the compressive strength test of porous concrete variation 2 in cylindrical form can be seen in Table 6 below

Table 8 Compressive Strength of Porous Concrete Variation 2

No.	Date		Age	Weight	Load	C. Strength	Remark	Rata-rata
	Casting	Test	(Days)	(Gram)	(kN)	(MPa)	%	(MPa)
1.	24 Jun 25	01 Juli 2025	7	10580	277,2	15,69	62,8	16,07
2.	24 Jun 25	01 Juli 2025	7	10660	283,2	16,03	64,1	
3.	24 Jun 25	01 Juli 2025	7	10780	291,4	16,50	66,0	
4.	24 Jun 25	08 Juli 2025	14	10700	360,1	20,38	81,5	20,83
5.	24 Jun 25	08 Juli 2025	14	10880	367,4	20,80	83,2	
6.	24 Jun 25	08 Juli 2025	14	10900	376,4	21,31	85,2	
7.	23 Jun 25	21 Juli 2025	28	10560	394,0	22,30	89,2	22,20
8.	23 Jun 25	21 Juli 2025	28	10620	397,4	22,50	90,0	
9.	23 Jun 25	21 Juli 2025	28	10720	385,0	21,79	87,2	

The results of testing the compressive strength of normal porous concrete with f'_c 25 MPa and the compressive strength of porous concrete with zeolite variation with a quality of f'_c 25 MPa can be seen in Figure 4 below.

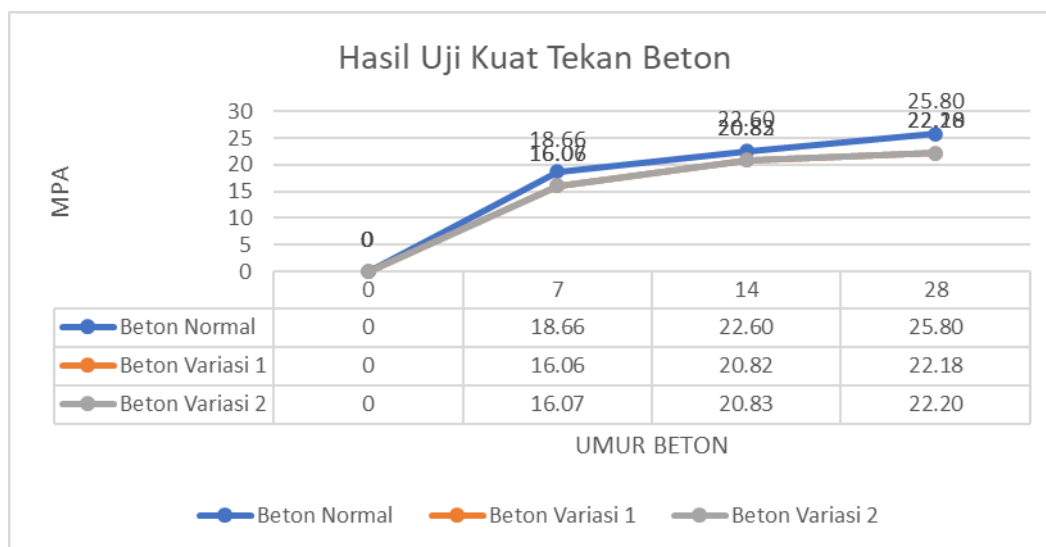


Figure 4. Porous Concrete Strength Test Results

When comparing the compressive strength of normal porous concrete with porous concrete that uses a zeolite mixture as a partial cement replacement at 28 days of age, there is a decrease of:

- 1) Porous concrete using 15% zeolite + 85% coarse aggregate
 28 days = $\frac{25-22.18}{25} \cdot 100\% = 11.28\%$ (Decrease)
- 2) Porous concrete using 30% zeolite + 70% coarse aggregate
 28 days = $\frac{25-22.20}{25} \cdot 100\% = 11.20\%$ (Decrease)

The average compressive strength of normal porous concrete at 28 days is 25.60 MPa, exceeding the planned compressive strength of 25 MPa, while the average compressive strength of porous concrete using 15% - 30% zeolite rock at 28 days is 22.18 MPa and 22.20 MPa, respectively. Therefore, it can be concluded that the addition of zeolite rock as a substitute for some of the coarse aggregate affects the decrease in the planned concrete quality.

CONCLUSIONS

Based on the research conducted, several conclusions were obtained, including the following:

- 1) Based on the compressive strength test table for normal porous concrete and zeolite stone as a partial replacement for coarse aggregate for a 0% composition, the average compressive strength of concrete at 7 days was 18.66 MPa, at 14 days it was 22.60 MPa, and at 28 days it was 25.60 MPa. From this data, the percentage increase in compressive strength of concrete using zeolite stone for a 0% composition was 74.66% on average, 90.43% on average at 14 days, and 103.23% on average at 28 days. These results exceed the concrete compressive strength requirements according to SNI 2847:2019, which are a minimum limit of 65% for 7 days, 88% for 14 days, and 100% for 28 days.
- 2) Based on the compressive strength test table of normal porous concrete and zeolite stone as a partial replacement for coarse aggregate for a composition of 15%, the average compressive strength of concrete for 7 days is 16.06 MPa, for 14 days is 20.82 MPa and for 28 days is 22.18 MPa. From the data obtained the results of the percentage increase in the compressive strength of concrete using zeolite stone for a composition of 15% from the age of 7 days obtained an average of 64.23%, the age of 14 days

obtained an average of 83.30% and the age of 28 days obtained an average of 88.73% where these data explain that at the age of 7 days the compressive strength of the concrete does not reach the requirements for the compressive strength of concrete according to SNI 2847: 2019 71 for the age of 7 days the minimum limit is 65% and at the age of 14 days the average result of the compressive strength of the concrete is 83.30% also this result does not reach the minimum limit required which is 88% and at the age of 28 days the average result of the compressive strength of the concrete is 88.73% also this result does not reach the minimum limit required which is 100%.

- 3) Based on the compressive strength test table of normal porous concrete and zeolite stone as a partial replacement for coarse aggregate for a composition of 30%, the average compressive strength of concrete for 7 days is 16.07 MPa, for 14 days is 20.83 MPa and for 28 days is 22.20 MPa. From the data obtained the results of the percentage increase in the compressive strength of concrete using zeolite stone for a composition of 30% from the age of 7 days obtained an average of 64.30%, the age of 14 days obtained an average of 83.30% and the age of 28 days obtained an average of 88.80%, where the results of these data explain that at the age of 7 days the compressive strength of the concrete does not reach the requirements for the compressive strength of concrete according to SNI 2847: 2019 for the age of 7 days the minimum limit is 65% and at the age of 14 days the average results of the compressive strength of the concrete do not reach the minimum limit required which is 88% and at the age of 28 days the average results of the compressive strength of the concrete are also obtained this result does not reach the minimum limit required which is 100%.

REFERENCES

- Sinabutar, D., & Rumbyarso, Y. P. A. (2025). THE USE OF BLACK BAMBOO AS A SUBSTITUTE FOR COARSE AGGREGATE TO INCREASE CONCRETE COMPRESSIVE STRENGTH. *INTERNATIONAL JOURNAL OF MULTI SCIENCE*, 5(02), 68-76.
- Hawari, F., Pribadi, G., & Rumbyarso, Y. P. A. (2025). ANALYSIS OF CONCRETE COMPRESSIVE STRENGTH AGAINST BAMBOO FIBER WASTE. *INTERNATIONAL JOURNAL OF MULTI SCIENCE*, 5(02), 17-21.
- Pribadi, G., & Rumbyarso, Y. P. A. (2024). ANALISIS UJI TEKAN BETON MENGGUNAKAN BAHAN LIMBAH KARET DILATASI KONDISI CURING DENGAN AIR LAUT. *Jurnal Konstruksi Teknik Sipil*, 1(3), 203-213.
- ASTM-C136. (2002), Standard test method for sieve analysis of fine and coarse aggregates. Annual Books of ASTM Standards. USA., 8.
- ASTM-C33. (2003): Standard specification for concrete aggregates, Annual Books of ASTM standards. USA., 11.
- SNI 03-1974-1990, (1990): Metode pengujian kuat tekan beton. Badan Standarisasi Nasional. Bandung., 1-5.
- SNI 03-2461-1991/2002, (1991): Spesifikasi agregat ringan untuk beton struktural. Badan Standarisasi Nasional. Jakarta., 8.