

Analysis of the Effect of Aggregate Gradation Size (0.2 – 2cm) on the Compressive Strength of Porous Concrete for Parking Applications

Dilla Natasya Amelia¹, Dedy Rutama^{1*}, Lintang Dian Artanti¹

¹Department of Civil Engineering, Faculty of Engineering and Computer Science, Jakarta Global University, 16412, Indonesia

Article Info

Article history:

Received March 06, 2025

Revised April 27, 2025

Accepted May 29, 2025

Keywords:

Porous Concrete

Parking

Aggregate

Compressive Strength

Porosity

ABSTRACT

Many parking lots are not well designed, so they often experience waterlogging due to rain, which disrupts user comfort and causes damage to infrastructure. Porous concrete is one of the new innovations being developed. This study uses various aggregate gradations to evaluate the mechanical characteristics and physical properties of porous concrete with a design compressive strength of K-150 kg/cm². This study aims to analyze the effect of aggregate gradation with a size of 0.2 cm to 1.2 cm on the compressive strength and porosity of porous concrete used in parking lot applications. The research method applies an experimental approach in the laboratory, with compressive strength testing referring to ASTM C39 and concrete porosity referring to ASTM C192-2012. The results show that aggregate gradation of 0.2 cm - 0.7 cm has a greater average compressive strength at the age of 28 days, namely 90.19 kg/cm² but the porosity value is smaller, namely 24.29%. Aggregates with an aggregate gradation of 0.7 cm - 1.2 cm showed an average compressive strength value of 85.06 kg/cm² and a porosity value of 28.7% while aggregate gradations with a size of 1 cm - 2 cm showed a small average compressive strength value at the age of 28 days of 80.01 kg/cm² but the porosity value obtained was higher at 30.5%. In this test, the compressive strength at the age of 28 days with an aggregate gradation of porous concrete of 0.2 cm - 0.7 cm still meets the SNI 03-0691-2022 standard for Class B qualification (parking lot)

*Corresponding Author:

Dedy Rutama

Department of Civil Engineering, Faculty of Engineering & Computer Science, Jakarta Global University, 16412, Indonesia.

Email: dedyrutama@jgu.ac.id

1. INTRODUCTION

Parking problems in urban areas are increasing with the growing number of vehicles and rapid urbanization. Many parking lots are poorly designed, resulting in frequent flooding due to rain, which disrupts user comfort and causes damage to infrastructure [1], [2]. Furthermore, poor rainwater management can exacerbate flooding in urban areas. Porous concrete is one of the new innovations currently being developed. Many researchers have conducted various experiments to develop superior and more effective porous concrete for use in infrastructure such as parking lots. Due to its widespread use by the public, porous concrete is crucial for construction. Porous concrete is often used in parking lot applications because it allows water to permeate through the surface, reducing puddles and improving drainage [3].

This type of concrete uses no sand in the mix, creating cavities between the coarse aggregates that allow water to penetrate quickly. This effectively reduces pooling and improves water absorption into the soil, which

also reduces the risk of flooding and optimizes groundwater supply. This research focused on testing the compressive strength and porosity of porous concrete [4], [5]. Porous concrete is often used on low-intensity sidewalks, parking lots, road user areas, and park facilities, where water is immediately absorbed into the ground without pooling for long periods. Referring to ACI 522R-10, the compressive strength of porous concrete is in the range of 2.8 to 28 MPa. Where the target of the concrete quality is K-225. Currently, SNI has not set a quality standard for porous concrete. The mix design of porous concrete generally includes cement as much as 270 to 415 kg, aggregate as much as 1190 to 1480 kg, water cement proportion between 0.27 to 0.34, and sand and gravel weight ratio that varies from 0 to 1:1 [6].

In recent years, numerous studies have examined the influence of aggregate size on the compressive strength and permeability of porous concrete. Porous concrete is generally produced using single-sized aggregates to form its structural framework [7]. Aggregate size plays a crucial role in determining pore characteristics and cement paste thickness, which in turn significantly affect both compressive strength and permeability. Zhi et al. (2024) investigated the relationship between porosity and aggregate size with respect to the hydraulic and mechanical properties of porous concrete through laboratory testing and reported that aggregate size is a dominant factor governing porosity distribution [8]. Previous studies on pervious concrete have also demonstrated that variations in aggregate gradation markedly influence mechanical performance; an increased proportion of larger aggregate particles tends to decrease compressive strength while increasing porosity. Experimental results using combined aggregate sizes of 12–18 mm and 18–25 mm in varying proportions indicated that compressive strength decreased as aggregate size increased, although this effect was also influenced by the aggregate-to-cement ratio and the level of compaction applied during casting [9]. Aggregate gradation, defined as the distribution of particle sizes within an aggregate mix, strongly affects pore structure [10]. Uniformly sized aggregates produce higher pore volumes, whereas graded aggregates with a range of particle sizes reduce pore volume as smaller particles fill the voids between larger ones, resulting in a denser structure. In planting concrete, smaller aggregate particle sizes are associated with lower porosity and a more compact microstructure, leading to improved compressive strength [11]. Similarly, in porous asphalt concrete, pore characteristics and connectivity are governed by nominal maximum aggregate size and gradation, which ultimately influence permeability and durability [12]. Although previous studies have shown that aggregate size and gradation significantly influence pore structure and compressive strength of porous concrete, limited research has focused on fine-to-medium aggregate gradation sizes (0.2–2.0 cm) for parking applications. Therefore, this study aims to analyze the effect of aggregate gradation size on pore characteristics and compressive strength to identify an optimal balance between porosity and mechanical performance for porous concrete used in parking pavements.

2. METHOD

The research was conducted systematically, beginning with a literature study to understand the concept of porous concrete and relevant testing standards. Following this, material and tool preparation was carried out, including cement, coarse and fine aggregates, water, mixers, moulds, and measuring instruments. Material testing was conducted to ensure the quality of each component, with coarse aggregates evaluated through sieve analysis in accordance with ASTM C136, unit weight testing following ASTM C29, and specific gravity and water absorption tests conducted based on ASTM C127. These preliminary tests ensured that the materials met the requirements for concrete production.

The porous concrete mix design was developed based on findings from previous journal studies, with reference to ACI 522R-10 as the primary guideline for pervious concrete and SNI 03-2834-2000 adapted to determine basic mix proportion parameters. Coarse aggregates with particle sizes of 0.2–0.7 cm, 0.7–1.2 cm, and 1.0–2.0 cm were proportioned with cement and water to achieve the desired specifications. Test specimens were cast in cylindrical moulds measuring 15 cm in diameter and 30 cm in height at the Burangkeng Civil Engineering Laboratory. After demoulding, specimens were cured by immersion in water for 28 days. Compressive strength testing was conducted using a 2000 kN compression machine, applying axial loads uniformly along the specimen's length. Prior to testing, specimens were weighed to determine density, and porosity testing was performed at 28 days. The results were analyzed and discussed to draw conclusions and provide recommendations.

3. RESULTS AND DISCUSSION

3.1. Material test results

3.1.1 Coarse Aggregate Gradation Testing

- a. Results of coarse aggregate gradation testing 0.2 cm-0.7 cm.

Based on Table 1 Result of Coarse Aggregate Gradation Testing (0.2–0.7 cm), the gradation analysis indicates that the coarse aggregate is predominantly retained on the #4 (4.75 mm) and #8 (2.36 mm) sieves. The highest retained weight occurs on the #8 sieve, with 1163.4 g (77.17% cumulative escape), followed by 339.1 g retained on the #4 sieve, resulting in a cumulative retained percentage of 22.83% at that size. This distribution shows that the aggregate particles are concentrated within the target size range, with minimal material passing through the finer sieves (16 to 200), each showing negligible or zero retained weight. The cumulative retained percentage reaches 99.77% at the #8 sieve and becomes 100% after the pan, indicating very limited fines content. The calculated Fineness Modulus (FM) of 5.22 reflects a relatively coarse aggregate, which is consistent with the intended size range of 0.2–0.7 cm. Overall, the gradation results demonstrate a well-defined and uniform coarse aggregate distribution, suitable for use in concrete mixtures where adequate strength and good particle interlocking are required, while minimizing the risk of excessive fines that could adversely affect workability and water demand.

Table 1. Result of coarse aggregate gradation testing 0.2 cm-0.7 cm

Size		Held back			Escape Accumulation
Inch	mm	Weight gr	Cumulative gr	%	
2''	50.0				
1/12''	37.5				
1''	25.0				
3/4''	19.0	0.0	0.0	0.0	100.00
1/2''	12.5	0.0	0.0	0.0	100.00
3/8''	9.5	0.0	0.0	0.0	100.00
1/4''	6.3	6.2	6.2	0.41	99.59
#4	4.75	339.1	345.3	22.83	77.17
#8	2.36	1163.4	1508.7	99.77	0.23
#16	1.18	0.0	1508.7	99.77	0.23
#30	0.60	0.0	1508.7	99.77	0.23
#50	0.30	0.0	1508.7	99.77	0.23
#100	0.15	0.0	1508.7	99.77	0.23
#200	0.075	0.0	1508.7	99.77	0.23
Pan	-	3.5	1512.2	100.00	0.00
FM	Cumulative Retained Amount (100%) total retained weight (100%)				5.22

b. Results of coarse aggregate gradation testing 0.7 cm-1.2 cm

Table 2. Results of coarse aggregate gradation testing 0.7 cm-1.2 cm

Size		Held back			Escape Accumulation
Inch	mm	Weight gr	Cumulative gr	%	
2''	50.0				
1/12''	37.5				
1''	25.0	0.0	0.0	0.0	100.00
3/4''	19.0	0.0	0.0	0.0	100.00
1/2''	12.5	345.2	345.2	19.50	80.50
3/8''	9.5	681.1	1,026.3	57.96	42.04
1/4''	6.3	720.5	1,746.8	98.65	1.35
#4	4.75	0.0	1,746.8	98.65	1.35
#8	2.36	0.0	1,746.8	98.65	1.35
#16	1.18	0.0	1,746.8	98.65	1.35
#30	0.60	0.0	1,746.8	98.65	1.35
#50	0.30	0.0	1,746.8	98.65	1.35
#100	0.15	0.0	1,746.8	98.65	1.35
#200	0.075	0.0	1,746.8	98.65	1.35
Pan	-	23.9	1,770.7	100.00	0.00
FM	Cumulative Retained Amount (100%) total retained weight (100%)				5.92

The gradation characteristics of the coarse aggregate with a particle size range of 0.7–1.2 cm in table 2, were evaluated through sieve analysis to assess its suitability for use in porous concrete mixtures. The results indicate that the aggregate distribution is dominated by particles retained on the 1/2-inch (12.5 mm) and 3/8-inch (9.5 mm) sieves, with cumulative retained percentages increasing significantly at these sieve sizes. This distribution reflects a relatively uniform coarse aggregate structure with limited fine material content. The cumulative retained percentage reached approximately 98.65% at the 1/4-inch (6.3 mm) sieve, while the percentage passing was approximately 1.35%, indicating minimal fine aggregate presence. Such a gradation is desirable for porous concrete applications, as it promotes interconnected voids that enhance permeability while maintaining sufficient structural integrity. The fineness modulus (FM) obtained from the test was 5.92, which confirms that the aggregate falls within the coarse aggregate classification. A high fineness modulus value is indicative of a coarser particle distribution, which is consistent with the intended aggregate size range of 0.7–1.2 cm. This gradation supports the formation of a stable skeletal structure in porous concrete, allowing effective load transfer while preserving void spaces essential for drainage performance. Overall, the gradation results demonstrate that the coarse aggregate meets the requirements for porous concrete and is suitable for use in subsequent mixture proportioning and mechanical performance testing.

c. Results of coarse aggregate gradation testing 1 cm – 2 cm

Table 3. Results of coarse aggregate gradation testing 1-2 cm

Size		Held back			Escape Accumulation
		Weight	Cumulative		
Inch	mm	gr	gr	%	
2"	50.0				
1/12"	37.5				
1"	25.0	0.0	0.0	0.0	100.00
3/4"	19.0	1,425.7	1,425.7	40.73	59.27
1/2"	12.5	1,701.6	3,127.3	89.35	10.65
3/8"	9.5	246.9	3,374.2	96.41	3.59
1/4"	6.3	25.6	3,399.8	97.14	2.86
#4	4.75	4.8	3,404.6	97.27	2.73
#8	2.36	3.9	3,408.5	97.39	2.61
#16	1.18	2.7	3,411.2	97.46	2.54
#30	0.60	1.8	3,413.0	97.51	2.49
#50	0.30	0.0	3,413.0	97.51	2.49
#100	0.15	0.0	3,413.0	97.51	2.49
#200	0.075	0.0	3,413.0	97.51	2.49
Pan	-	87.0	3,500.0	100.00	0.00
FM	Cumulative Retained Amount (100%) total retained weight (100%)				5.85

The gradation of coarse aggregate with particle sizes ranging from 1.0 cm to 2.0 cm was evaluated through sieve analysis in table 3 to determine its suitability for porous concrete applications. The test results show that a significant proportion of the aggregate was retained on the 3/4-inch (19.0 mm) and 1/2-inch (12.5 mm) sieves, indicating a predominantly coarse particle distribution consistent with the intended size range. The cumulative retained percentage reached 89.35% at the 1/2-inch sieve and increased to 97.14% at the 1/4-inch (6.3 mm) sieve. Only approximately 2.49% of the aggregates passed the #30 sieve and finer, indicating a very low fine content. This limited presence of fine particles is advantageous for porous concrete, as it contributes to the formation of interconnected voids and enhances permeability. The fineness modulus (FM) obtained from the gradation test was 5.85, confirming that the aggregate is classified as coarse aggregate. This relatively high FM value reflects a coarse gradation, which supports the development of a stable aggregate skeleton within the porous concrete matrix. Such a structure is essential for maintaining mechanical strength while preserving adequate pore connectivity. Overall, the results of the gradation test demonstrate that the coarse aggregate with a size range of 1.0–2.0 cm exhibits an appropriate particle size distribution for use in porous concrete mixtures and meets the requirements for subsequent mix design and performance evaluation.

3.1.2 Unit Weight Test

- a. The unit weight test in the 0.2 cm – 0.7 cm

Table 4. Results of coarse aggregate unit weight testing 0.2 cm – 0.7 cm

	Remarks	Unit	Test 1
Tube weight	A	gr	1,659.0
Tube weight + sample	B	gr	5,860.0
Sampel weight	C = B – A	gr	4,641.0
Tube volume	D	cc	3,017.5
Weight of contents	E	Gr/cc	1,538.0

The results of the coarse aggregate unit weight test for the 0.2–0.7 cm size range, as presented in Table 4, show that the aggregate has a unit weight of 1.538 g/cm³. This value was determined from the ratio of the aggregate mass to the volume of the measuring container. The obtained unit weight reflects the physical characteristics of the aggregate and indicates that the material is appropriate for use in porous concrete mixtures, as it supports the development of a stable aggregate structure while maintaining adequate void content.

- b. Results of coarse aggregate density testing 0.7 cm – 1.2 cm

Table 5. Results of coarse aggregate density testing 0.7 cm – 1.2 cm

	Remarks	Unit	Test 1
Tube weight	A	gr	6,144.4
Tube weight + sample	B	gr	13,780.0
Sampel weight	C = B – A	gr	7,635.6
Tube volume	D	cc	4,941.0
Weight of contents	E = C/D	gr/cc	1,545

The results presented in Table 5 indicate that the coarse aggregate in the 0.7–1.2 cm size range has a density of 1.545 g/cm³. This value was obtained from the ratio of the sample mass to the measured volume, following standard density testing procedures. The observed density reflects the physical characteristics of the coarse aggregate and suggests that the material is suitable for use in porous concrete mixtures, as it provides sufficient mass while still allowing the formation of interconnected voids essential for permeability.

- c. Results of testing the unit weight of coarse aggregate 1 cm – 2 cm

Table 6. Results of testing the unit weight of coarse aggregate 1 cm – 2 cm

	Remarks	Unit	Test 1	Test 2	Average
Tube weight	A	gr	6,144.4	6,144.4	6,144.4
Tube weight + sample	B	gr	13,480.0	14,080.0	13,780.0
Sampel weight	C = B – A	gr	7,335.6	7,935.6	7,635.6
Tube volume	D	cc	4,941.0	4,941.0	4,941.0
Weight of contents	E = C/D	gr/cc	1,485	1,606	1,545

The results indicate that the coarse aggregate exhibits a relatively high and consistent unit weight, with only a moderate difference between Test 1 and Test 2. The variation in unit weight values (1.485 g/cc and 1.606 g/cc) can be attributed to differences in particle packing during sample placement, which is a common phenomenon in bulk density testing of coarse aggregates. Slight variations in compaction level, particle orientation, and void distribution may influence the measured weight of contents. The average unit weight of 1.545 g/cc suggests that the coarse aggregate has a dense structure with relatively low void content, which is favorable for concrete production. Aggregates with higher unit weight generally contribute to improved mechanical interlocking and can enhance the strength and stability of concrete mixtures. A lower void content also allows for more efficient paste distribution, potentially reducing cement demand while maintaining adequate workability. Additionally, the consistent tube volume and stable tube weight confirm that the testing procedure was performed under controlled and repeatable conditions, thereby increasing the reliability of the obtained results. The observed consistency between tests indicates that the aggregate exhibits uniform physical characteristics and minimal segregation during handling.

Overall, the obtained unit weight falls within the typical range for crushed coarse aggregates used in structural concrete applications. This indicates that the tested aggregate is suitable for use as a coarse aggregate component, particularly in mixes requiring good strength characteristics, dimensional stability, and reliable material performance. Furthermore, the favorable unit weight characteristics suggest that aggregate can support

the development of dense and durable concrete, especially when combined with appropriate design and quality control practices.

3.1.3 Specific Gravity and Water Absorption Testing

a. The specific gravity and water absorption of coarse aggregates 0.2-0.7 cm

Table 7. Results of specific gravity and water absorption tests of coarse aggregate 0.2 cm – 0.7 cm

Description	Unit	Test 1	Test 2	Average	
Weight of airborne dry sample	A	gr	1461.2	1441.9	1451.5
Weight of the base SSD	B	gr	1500.9	1501.0	1500.9
Saturated runoff weight in water	C	gr	889.7	882.7	886.2
Dry specific gravity	$\frac{A}{B + S + C}$	gr/cc	2.391	2.332	2.346
Specific gravity of SSD	$\frac{S}{B + S + C}$	gr/cc	2.456	2.428	2.435
Pseudo-specific gravity	$\frac{A}{B + A + C}$	gr/cc	2.557	2.579	2.576
Absorbs (%)	$\frac{S - A}{A} \times 100$	%	2.717	4.099	3.811

The results presented in Table 7 indicate that the coarse aggregates with a particle size range of 0.2–0.7 cm exhibit relatively consistent physical properties, as reflected by the measured specific gravity and water absorption values obtained from two test repetitions. The dry specific gravity values of 2.391 (Test 1) and 2.332 (Test 2), with an average of 2.346, suggest that the aggregates possess a typical density characteristic of natural or crushed stone aggregates commonly used in construction materials. The specific gravity under saturated surface-dry (SSD) conditions shows slightly higher values, with an average of 2.435, which is expected due to the presence of water filling the permeable pores of the aggregate particles. Similarly, the pseudo-specific gravity demonstrates the highest average value (2.576), indicating the density of the solid portion of the aggregate excluding permeable pores. The progressive increase from dry specific gravity to SSD and pseudo-specific gravity confirms the presence of internal porosity while still maintaining acceptable aggregate quality. Water absorption values ranged from 2.717% to 4.099%, resulting in an average absorption of 3.811%. The relatively higher absorption in Test 2 suggests variability in pore structure or surface texture, which may be influenced by the partial substitution of finer aggregate fractions with rock dust. Higher absorption values are typically associated with increased porosity, which can affect water demand and workability in mixture design. However, the average absorption value remains within acceptable limits for many structural and pavement applications, provided that appropriate moisture corrections are applied during mix proportioning. Overall, the specific gravity and water absorption characteristics indicate that the 0.2–0.7 cm coarse aggregate is suitable for use in construction mixtures. The observed variations between tests are considered reasonable and reflect normal material heterogeneity rather than deficiencies in aggregate quality. These properties should be considered in mixture design to ensure consistent performance, particularly in controlling effective water content and achieving the desired mechanical properties.

b. Specific Gravity and Water Absorption Characteristics of Coarse Aggregate (0.7–1.2 cm)

Table 8. specific gravity and water absorption tests 0.7 cm – 1.2 cm

Description	Unit	Test 1	
Weight of airborne dry sample	S	gr	500
Oven dry weight	A	gr	483.3
Picometer weight + water	B	gr	665.6
Picometer weight + water + sample	C	gr	972.8
Dry specific gravity	$\frac{A}{B + S + C}$	gr/cc	2.507
Specific gravity of SSD	$\frac{S}{B + S + C}$	gr/cc	2.593
Pseudo-specific gravity	$\frac{A}{B + A + C}$	gr/cc	2.744
Absorbs (%)	$\frac{S - A}{A} \times 100$	%	3.455

The results presented in Table 8 show that the coarse aggregate with a particle size range of 0.7–1.2 cm exhibits favorable physical characteristics in terms of specific gravity and water absorption. The measured dry specific gravity value of 2.507 indicates that the aggregate has a relatively dense structure, which is characteristic of good-quality coarse aggregates commonly used in concrete and pavement applications. The specific gravity under saturated surface-dry (SSD) conditions was slightly higher, at 2.593, reflecting the presence of water occupying the permeable pores within the aggregate particles. This increase is consistent with expected aggregate behavior and confirms the existence of internal porosity without compromising material integrity. Furthermore, the pseudo-specific gravity reached 2.744, representing the density of the solid mineral content excluding permeable voids. This value suggests a strong and compact aggregate matrix. The water absorption value obtained was 3.455%, indicating a moderate level of porosity. While higher absorption values generally imply increased water demand in mixture design, the observed absorption remains within acceptable ranges for many construction applications when appropriate moisture adjustments are applied. Aggregates with moderate absorption can still perform satisfactorily if water content is carefully controlled to maintain workability and strength.

Overall, the specific gravity and water absorption results demonstrate that the 0.7–1.2 cm coarse aggregate is suitable for use as a construction material. The combination of relatively high specific gravity and moderate absorption suggests that the aggregate can contribute positively to the mechanical performance and durability of mixtures. These properties should be considered during mix proportioning to ensure consistent quality and optimal performance of the final product.

c. Specific Gravity and Water Absorption Characteristics of Coarse Aggregate (1–2 cm)

Table 9. specific gravity and water absorption tests 1 cm – 2 cm

Description		Unit	Test 1
Weight of airborne dry sample	A	gr	1461.2
Weight of the base SSD	B	gr	1500.9
Saturated runoff weight in water	C	gr	889.7
Dry specific gravity	$\frac{A}{B + S + C}$	gr/cc	2.391
Specific gravity of SSD	$\frac{S}{B + S + C}$	gr/cc	2.456
Pseudo-specific gravity	$\frac{A}{B + A + C}$	gr/cc	2.557
absorbs (%)	$\frac{S - A}{A} \times 100$	%	2.717

The results presented in Table 9 describe the physical properties of coarse aggregate with a particle size range of 1–2 cm, as evaluated through specific gravity and water absorption tests. The dry specific gravity value of 2.391 indicates that the aggregate possesses a relatively dense mineral composition, which is characteristic of quality coarse aggregates used in concrete production. This density suggests good load-bearing capability and contributes positively to the mechanical performance of concrete mixtures. The specific gravity under saturated surface-dry (SSD) conditions was recorded at 2.456, which is higher than the dry specific gravity due to the presence of water filling the permeable pores of the aggregate. This behavior is expected and confirms the existence of internal porosity within the aggregate particles. Furthermore, the pseudo-specific gravity value of 2.557, representing the density of the solid portion excluding permeable voids, reflects a compact aggregate structure with limited internal defects. The water absorption value obtained for the 1–2 cm coarse aggregate was 2.717%, indicating a moderate level of porosity. This absorption level suggests that the aggregate can absorb a limited amount of water, which should be considered during mixture proportioning to ensure accurate control of effective water content. Compared to finer aggregate fractions, the absorption value for this size range is relatively lower, which can be attributed to a reduced surface area and fewer interconnected pores.

Overall, the combination of relatively high specific gravity values and moderate water absorption demonstrates that the 1–2 cm coarse aggregate is suitable for structural concrete applications. These characteristics support the production of dense, strong, and durable concrete when proper moisture corrections and mix design adjustments are applied. Consequently, the tested aggregate can be considered appropriate for use as a coarse aggregate component in concrete mixtures requiring reliable performance and structural integrity.

3.2 Results of concrete Mix design

The porous concrete mix design was developed at the Burangkeng Civil Laboratory by following the guidelines of ACI 522R-10 and SNI 03-2934-2000, which provide standards for proportioning materials in pervious concrete. The purpose of this design approach is to establish the appropriate composition of cement, aggregate, and water to achieve the desired balance between strength and permeability.

Table 10. Concrete Mix Composition

	Porous Concrete 0,2 cm – 0,7 cm	Porous Concrete 0,7 cm – 1,2 cm	Porous Concrete 1 cm – 2 cm
Cement (Kg)	15.68	15.68	15.68
Crude Aggregate (Kg)	69.86	73.39	67.28
water (Liters)	3.32	4.65	4.69

Table 10 presents a comparison of porous concrete mixes using different aggregate size ranges namely 0.2–0.7 cm, 0.7–1.2 cm, and 1–2 cm, while maintaining a constant cement quantity of 15.68 kg. Notably, the mix with 0.7–1.2 cm aggregates use the highest amount of crude aggregate (73.39 kg), suggesting optimal packing efficiency, whereas the 1–2 cm mix uses the least (67.28 kg), possibly due to increased void space and reduced particle interlock. Water content also rises with aggregate size, from 3.32 liters in the smallest aggregate mix to 4.69 liters in the largest, likely to maintain workability as particle size increases and surface area decreases. These variations imply a trade-off between strength and permeability: smaller aggregates may enhance strength through tighter packing, more contact points, and better cement bonding, while larger aggregates improve drainage and porosity, making them suitable for applications like pavements, parking lots, or stormwater management systems. The consistent cement content across all mixes highlights a standardized binder approach, with aggregate and water adjustments tailored to balance mechanical strength, durability, and hydraulic performance. In practice, engineers must select the appropriate aggregate size depending on whether the priority is structural integrity or water infiltration capacity, demonstrating how mix design directly influences the functional role of porous concrete in construction.

3.3 Result of concrete compressive strength testing

The test results in table 11 indicate that variation in coarse aggregate size influences the compressive strength of K-150 concrete. Three aggregate gradations were tested, namely 0.2–0.7 cm, 0.7–1.2 cm, and 1–2 cm. The average compressive strengths obtained were 90.19 kg/cm², 85.06 kg/cm² and 80.01 kg/cm² respectively. These results show a general trend that compressive strength decreases as the aggregate size increases. For the aggregate size of 0.2–0.7 cm, the compressive strength values ranged from approximately 83.63 to 102.25 kg/cm², producing the highest average compressive strength among all mixtures. This indicates that smaller aggregate sizes provide better bonding with the cement paste, resulting in higher density and improved mechanical interlocking. Concrete using aggregates sized 0.7 –1.2 cm produced a slightly lower average compressive strength of 85.06 kg/cm². The results show more uniform distribution, but slightly lower strength compared to the smallest aggregate group. This may be associated with reduced surface area, which limits the bond interface between aggregate and paste even though workability generally improves. The lowest compressive strength was 80.01 kg/cm², was obtained from aggregate sizes of 1–2 cm. The compressive strength values recorded ranged from 78.6 to 81.46 kg/cm². Larger aggregates tend to lead to higher void content and weaker transition zones between aggregate particles and the cement matrix, which may contribute to reduced compressive strength.

Table 11. Concrete compressive strength test

Test Specimen Code	Concrete Weight (Kg)	Load (KN)	Compressive Strength (kg/cm ²)	Average Compressive Strength (kg/cm ²)
K-150 Aggregate 0,2 cm – 0,7 cm	1	8,55	147,13	102,25
	2	8,82	120,24	83,63
	3	8,6	121,77	84,7
K-150 Aggregate 0,7 cm – 1,2 cm	1	9,6	110,16	76,62
	2	9,86	150,2	104,48
	3	9,56	106,54	74,1
K-150 Aggregate 1 cm – 2 cm	1	9,76	113,01	78,6
	2	9,06	117,11	81,46
	3	9,4	114,96	79,96

Overall, the data indicates that concrete using smaller aggregate sizes tends to achieve higher compressive strength compared to mixes with larger aggregates. This supports the theory that smaller aggregates enhance bond strength and compactness. However, other influencing factors such as water–cement ratio, curing quality, and compaction method should also be considered, as they may contribute to the observed variability among samples.

3.4 Porosity test result

Table 12. Porosity test

Test Specimen Code	Porosity Value
porous concrete 0,2 cm - 0,7 cm	24,29%
porous concrete 0,7 cm - 1,2 cm	28,70%
porous concrete 1,2 cm - 2 cm	30,50%

The porosity test results presented indicate that the porosity of porous concrete increases along with the increase in aggregate size. Specimens with aggregate sizes of 0.2–0.7 cm, 0.7–1.2 cm, and 1.2–2.0 cm produced porosity values of 24.29%, 28.70%, and 30.50%, respectively. This trend shows a clear relationship between aggregate gradation and void content within the concrete matrix. The lowest porosity value (24.29%) was obtained in the specimen with the smallest aggregate size range of 0.2–0.7 cm. Aggregates with smaller particle size tend to pack more densely, filling void spaces more effectively and reducing interconnected pores. As a result, less void volume is available for water or air, leading to lower porosity. Conversely, the highest porosity value (30.50%) occurred in the specimen with the largest aggregate size range of 1.2–2.0 cm. Aggregates with larger particle size generally produce larger and more interconnected voids because the paste cannot completely fill the spaces between coarse particles, thus increasing total porosity. The gradual increase in porosity across the three specimens suggests that aggregate size distribution plays a dominant role in governing pore structure in porous concrete. Higher porosity is typically associated with improved permeability and drainage capacity, which is desirable for applications such as pervious pavements and stormwater management systems. However, increasing porosity may also result in a reduction in mechanical strength due to decreased solid volume and weaker paste–aggregate contact. Therefore, an optimal balance between porosity and strength is necessary depending on functional requirements. Overall, the results confirm the expected behaviour of porous concrete, where coarser aggregate gradations generate greater void content and, consequently, higher porosity values.

4. CONCLUSION

This study demonstrates that coarse aggregate size is a critical determinant of the performance of porous concrete, establishing an inverse relationship between compressive strength and porosity. The highest average compressive strength of 90.19 kg/cm² was achieved using the smallest aggregate gradation (0.2 cm – 0.7 cm), a value that satisfies the Class B qualification for parking areas under SNI 03-0691-2022. However, as aggregate dimensions increased to the 1 cm – 2 cm range, compressive strength declined by 12.72% to a minimum of 80.01 kg/cm², while porosity reached a peak value of 30.5%. This indicates that while larger aggregates optimize void volume and permeability within the concrete matrix, they compromise structural integrity. Ultimately, although the compressive strength of the finer aggregate mix adheres to national standards for parking lots, the lack of a specific porosity threshold in current regulations suggests a need for further standardization to balance durability with hydrological performance.

ACKNOWLEDGEMENTS

The authors would like to express their gratitude to Jakarta Global University and CV Laboratorium Sipil Burangkeng for providing the laboratory facilities and technical support that served as the primary foundation for the completion of this research.

REFERENCES

- [1] J. Parmar, P. Das, and S. M. Dave, "Study on demand and characteristics of parking system in urban areas: A review," *J. Traffic Transp. Eng. (English Ed.)*, vol. 7, no. 1, pp. 111–124, Feb. 2020, doi: 10.1016/j.jtte.2019.09.003.
- [2] T. Campisi, B. Caselli, S. Rossetti, and V. Torrisi, "The Evolution of Sustainable Mobility and Urban Space Planning: Exploring the factors contributing to the Regeneration of Car Parking in Living Spaces," *Transp. Res. Procedia*, vol. 60, pp. 76–83, 2022, doi: 10.1016/j.trpro.2021.12.011.
- [3] T. Kishii, "Parking areas that support comfort and safety in urban pedestrian environments," *IATSS Res.*, vol. 48, no. 2, pp. 121–128, Jul. 2024, doi: 10.1016/j.iatssr.2024.02.005.
- [4] E. Khakimova and E. Tokhirov, "CAR PARKING PROBLEMS IN CITIES, CAUSES AND SOLUTIONS," *UniversumTechnical Sci.*, vol. 110, no. 5, May 2023, doi: 10.32743/UniTech.2023.110.5.15513.
- [5] C. Sánchez-Mendieta, J. J. Galán-Díaz, and I. Martínez-Lage, "Relationships between density, porosity, compressive strength and permeability in porous concretes: Optimization of properties through control of the water-cement ratio and aggregate type,"

-
- J. Build. Eng.*, vol. 97, p. 110858, Nov. 2024, doi: 10.1016/j.job.2024.110858.
- [6] P. Smarzewski and A. Stolarski, "Properties and Performance of Concrete Materials and Structures," *Crystals*, vol. 12, no. 9, p. 1193, Aug. 2022, doi: 10.3390/cryst12091193.
- [7] J. Kong *et al.*, "The screening effect of coarse aggregate on the air void structure and durability of air-entrained concrete," *Constr. Build. Mater.*, vol. 451, p. 138786, Nov. 2024, doi: 10.1016/j.conbuildmat.2024.138786.
- [8] D. Zhi *et al.*, "RBSM-based mesoscale study of mechanical properties and frost damage behaviors for recycled fine aggregate concrete," *Constr. Build. Mater.*, vol. 416, p. 135136, Feb. 2024, doi: 10.1016/j.conbuildmat.2024.135136.
- [9] A. Anburuvel and D. N. Subramaniam, "Influence of aggregate gradation and compaction on compressive strength and porosity characteristics of pervious concrete," *Int. J. Pavement Eng.*, vol. 24, no. 2, Jan. 2023, doi: 10.1080/10298436.2022.2055022.
- [10] H. Yang, E. Zhu, and L. Liu, "Analysis of the Effect of Pore Structure on the Mechanical Properties of Concrete Based on the Meso Numerical Model," *Appl. Sci.*, vol. 12, no. 11, p. 5428, May 2022, doi: 10.3390/app12115428.
- [11] J. Chen, W. Du, G. Zhao, M. Shi, and B. Xue, "Effect of Aggregate Size and Water/Cement on Compressive Strength and Physiological Performance of Planting Concrete," *Materials (Basel)*, vol. 15, no. 19, p. 6685, Sep. 2022, doi: 10.3390/ma15196685.
- [12] W. Huang, X. Cai, X. Li, W. Cui, and K. Wu, "Influence of Nominal Maximum Aggregate Size and Aggregate Gradation on Pore Characteristics of Porous Asphalt Concrete," *Materials (Basel)*, vol. 13, no. 6, p. 1355, Mar. 2020, doi: 10.3390/ma13061355.