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Enhancing Porous Concrete Strength through Superplasticiser Addition

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Abstract

Porous concrete is widely used as a sustainable construction material since it allows water to pass through its structure, reducing surface runoff and supporting groundwater recharge. However, its application is often limited by its low compressive strength. This study investigates the effect of adding superplasticiser at varying dosage levels: 0.3%, 0.6%, and 0.8% of cement weight, on the mechanical properties of porous concrete. The research was conducted through laboratory experiments, with material testing, slump testing, and compressive strength testing at 7 and 28 days of curing. The results showed that the addition of superplasticiser significantly improved the compressive strength of porous concrete without affecting its porosity. The highest compressive strength was achieved at a 0.8% dosage, reaching 23.01 MPa at 28 days, which represents a 21.4% increase compared to normal porous concrete. The slump test confirmed that all concrete mixtures maintained near-zero slump values, ensuring that permeability was not compromised. These findings suggest that superplasticiser is an effective additive for improving the strength of porous concrete while preserving its essential drainage function. The research supports the broader application of porous concrete in sustainable infrastructure, especially in areas where both strength and water management are critical.

Keywords: compressive strength, porous concrete, superplasticiser

1. Introduction

The rapid growth of urban infrastructure has brought many challenges, especially in managing rainwater. As cities expand, more land is covered with buildings, roads, and pavements. This process reduces the availability of natural land where water can infiltrate into the ground. The result is an increase in surface water runoff, which can cause flash floods, erosion, and the depletion of groundwater reserves [1]. Many flood events and landslides are linked to land degradation and poor water management [2]. Sustainable infrastructure solutions are urgently needed to address these problems.

Porous concrete, also known as pervious concrete, has emerged as a promising solution to reduce surface runoff and improve groundwater recharge [3]. Unlike conventional concrete, porous concrete is designed with interconnected voids that allow water to pass through the surface into the subsoil [4]. The American Concrete Institute describes porous concrete as a no-slump concrete made with cement, coarse aggregate, water, and sometimes a small amount of fine aggregate or admixtures [5]. Its primary function is not only as a structural component but also as a drainage medium, reducing surface water accumulation and supporting the natural water cycle.

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Porous concrete has gained popularity in constructing pavements, parking lots, pedestrian walkways, and low-traffic roads [6]. It also offers additional benefits such as noise reduction, thermal insulation, and environmental friendliness [7]. However, porous concrete has lower compressive strength compared to normal concrete due to its large void content [8]. This limitation restricts its application in areas where higher structural strength is required. The challenge is to develop porous concrete that maintains sufficient porosity for water infiltration while also achieving higher mechanical strength.

Previous research has explored several ways to improve the porous concrete performance. For example, studies by [9] and [10] showed that adjusting aggregate size and adding fine aggregates can improve compressive strength but may reduce permeability. Another approach is to use chemical admixtures, particularly superplasticisers, to improve workability and strength without compromising porosity [11].

Superplasticisers are high-range water-reducing admixtures allowing a lower water-to-cement ratio while maintaining workability [12]. Superplasticisers can reduce water content by up to 12% or more, which helps increase the density and strength of concrete [13]. In porous concrete, superplasticisers assist in achieving better compaction and bonding between aggregates while preserving the desired void structure [11]. This makes them an ideal additive for enhancing both mechanical and functional properties of porous concrete.

This research investigates the effect of varying superplasticiser dosages on the mechanical properties of porous concrete. The main objective is to investigate how different levels of superplasticiser, specifically 0.3%, 0.6%, and 0.8% of cement weight, affect the compressive strength of porous concrete at 7 and 28 days. By combining environmental benefits with improved strength, this study aims to support the broader application of porous concrete in sustainable infrastructure development.

2. Method

2.1. Research design

This research uses an experimental approach to study the mechanical properties of porous concrete with the superplasticiser addition. The experiments were carried out in the Civil Engineering Laboratory at President University. The main goal was to find out how different amounts of superplasticiser affect the compressive strength of porous concrete at different curing periods, specifically at 7 days and 28 days. The method follows standard procedures for concrete testing to ensure that the results are valid and reliable.

The scope of this research focuses on testing the compressive strength of porous concrete with varying levels of superplasticiser. The superplasticiser was added at three different concentrations: 0.3%, 0.6%, and 0.8% of the cement weight. The concrete samples were made using cylindrical moulds measuring 15 cm in diameter and 30 cm in height.

The mix design was based on the guidelines from the American Concrete Institute (ACI) standard 522R-10. The coarse aggregate used had a maximum size of 5 mm, and the water-to-cement ratio was set at 0.3 to produce a mix suitable for porous concrete. The compressive strength tests followed ASTM C-39 standards to ensure accuracy.

This research used both primary and secondary data. Primary data was collected directly through laboratory experiments. This included testing the specific gravity, absorption, mud content, moisture content, and gradation of aggregates. Data was also collected from the slump test, unit weight test, and compressive strength test.

Secondary data was obtained from literature reviews, journal articles, textbooks, and technical guidelines such as SNI (Indonesian National Standards), ACI 522R-10, and ASTM C-39. This information helped support the research framework and provided comparison data from previous studies.

2.2. *Tools and materials*

Several tools were prepared and used during the experiment. These included:

- Digital Scales: For accurate measurement of materials up to 30 kg.
- Sieve Shaker and ASTM Sieves: For grading the aggregates to determine their particle size distribution.
- Electric Oven: For drying aggregate samples to obtain consistent weight.
- Pycnometer (500 cc): For testing specific gravity and absorption of fine aggregates.
- Concrete Mixer: For mixing concrete uniformly.
- Slump Test Equipment: For checking workability, even though porous concrete typically has zero slump.
- Cylindrical Moulds (15 cm × 30 cm): For casting concrete specimens.
- Compressive Testing Machine: For testing the compressive strength of the hardened concrete.
- Curing Tub: For soaking the concrete specimens during the curing process.

The materials used in this research included:

- Cement: Portland Pozzolan Cement (PPC), Type I.
- Coarse Aggregate: Uniform size with a maximum size of 5 mm.
- Fine Aggregate: Zone II sand was used in small quantities to improve workability.
- Superplasticiser: Sika Viscocrete-3115N, used as a chemical admixture in varying doses.
- Water: Clean water sourced from the laboratory.

The design of the experiment involved creating four types of concrete samples based on superplasticiser content:

- Normal Porous Concrete: No superplasticiser (control group).
- Porous Concrete with 0.3% Superplasticiser
- Porous Concrete with 0.6% Superplasticiser
- Porous Concrete with 0.8% Superplasticiser

Each group consisted of six specimens, three for testing at 7 days and three for testing at 28 days, resulting in a total of 24 specimens. The cylindrical specimens were prepared following ACI 522R-10 recommendations to ensure consistent size and shape for accurate compressive testing.

2.3. *Material inspection*

Several tests were conducted on the coarse aggregates:

1. Specific Gravity and Absorption (SNI 1969-2008): This test measures the density and water absorption capacity of the aggregates, which is crucial for calculating mix proportions.
2. Mud Content (SNI 03-4142-1996): The mud content test ensures the cleanliness of the aggregates because excessive mud can weaken concrete.
3. Unit Weight (SNI 03-4804-1998): This measures the loose and compacted unit weight of the aggregates, which is

used in mix design calculations.

4. Moisture Content: Determined by drying aggregate samples in the oven and comparing weights before and after drying.

Similar tests were performed on fine aggregates:

1. Gradation Analysis (SNI 03-1968-1990): This test identifies the distribution of particle sizes in the sand, affecting concrete workability and strength.
2. Specific Gravity and Absorption (SNI 1970:2008): Used to measure the density and absorption of the fine aggregate.
3. Mud Content (SNI 03-4142-1996): Ensures that fine aggregates are clean and suitable for concrete production.
4. Unit Weight: Measures the volume weight of the fine aggregates in loose and compacted states.

Moisture Content: Measures the amount of water present in the fine aggregate, affecting the mix design.

2.4. Mix design and test

The mix design was prepared following the ACI 522R-10 standard. The porous concrete mix consisted of cement, coarse aggregate, fine aggregate, water, and superplasticiser. A fixed water-to-cement ratio (w/c) of 0.3 was used to maintain consistency in all mixes. The paste volume and void content were calculated to ensure sufficient porosity for water infiltration. The amount of paste was carefully controlled to coat the aggregate particles without filling the voids. Adjustments were made for the presence of superplasticiser to account for the reduction in water content while keeping the mixture workable.

Although porous concrete typically has zero slump, a slump test was still conducted to check for workability. The procedure followed SNI 03-1972-1990. The Abrams cone was filled with concrete in three layers; each tamped 25 times. After lifting the cone, the slump was measured. All mixes showed very low to zero slump, which is expected for porous concrete.

After casting, the specimens were kept in their moulds for 24 hours. After demoulding, they were submerged in water for curing (Fig. 1). The curing periods were 7 days and 28 days. Proper curing is necessary to ensure the hydration of cement and the development of strength.

Fig. 1 Immersion pond

Compressive strength tests were performed on the cylindrical specimens using a compression testing machine, following ASTM C-39 and SNI 03-1974-1990 standards. The samples were placed vertically in the machine, and the load was applied gradually until the specimen failed.

The compressive strength was calculated by dividing the maximum load by the cross-sectional area of the cylinder. The results were recorded for both the 7-day and 28-day curing periods.

3. Results and Discussion

3.1. *Aggregate testing results*

Aggregate testing is a crucial step in concrete production because it determines whether the materials meet the required standards. In this study, both coarse and fine aggregates were tested to ensure they were suitable for porous concrete. For coarse aggregate, the specific gravity (SSD) was measured at 2.54, which falls within the standard range of 2.5 to 2.7. This indicates that the aggregate has an appropriate density for use in concrete production. The absorption value of the coarse aggregate was 1.12%, which is also acceptable, as it indicates moderate water absorption that will not significantly alter the water content in the mix. The mud content was 0.4%, which is well below the maximum allowable limit of 1%, ensuring that the aggregates are clean and free from excessive fine particles that could weaken the concrete structure.

For fine aggregate, the specific gravity (SSD) was found to be 2.56, indicating that the sand used is of good quality and appropriate for concrete production. The absorption was 2.42%, which is slightly higher than the coarse aggregate but still within acceptable limits for fine aggregates. The mud content of the fine aggregate was 4.5%, which is under the maximum limit of 5% as defined in SK. SNI S-04-1989-F, ensuring that the sand is sufficiently clean for use. Overall, the aggregate test results confirm that the materials used in this study meet the standard requirements for concrete production. Proper aggregate quality is essential for achieving reliable compressive strength and consistent concrete behaviour

3.2. *Slump test results*

The slump test was conducted to assess the workability of the porous concrete mix (Fig. 2). As expected, all concrete mixes in this study showed a slump close to zero, which is typical for porous concrete (Table 1). Porous concrete is designed to have minimal or no slump to maintain its interconnected voids and permeability. A high slump value would indicate too much water or paste, which could close the voids and reduce water infiltration capacity.

Table 1 Slump test results

Variation	Slump (mm)		Average
	1	2	
Normal (Na)	1	1	1
0.3% superplasticizer (SP1)	1	2	1.5
0.6% superplasticizer (SP2)	2	1	1.5
0.8% superplasticizer (SP3)	2	2	2.0

The zero-slump result confirms that the mixture maintained the required consistency for porous concrete applications, regardless of the superplasticiser dosage. This finding suggests that the superplasticiser improved workability without causing segregation or excess flow, which is important for practical field applications.

Fig. 2 Slump test

3.3. Compressive strength test results

The compressive strength test was carried out at 7 days and 28 days to evaluate the mechanical performance of porous concrete with different superplasticiser dosages (Fig. 3). The results are shown in the following Table 2.

Table 2 Compressive strength results.

Superplasticiser (%)	7-Day strength (MPa)	28-Day strength (MPa)
0% (Normal)	15.43	18.96
0.3% (SP1)	16.69	20.50
0.6% (SP2)	17.64	21.60
0.8% (SP3)	18.11	23.01

The normal porous concrete (0% superplasticiser) achieved a 28-day compressive strength of 18.96 MPa. When 0.3% superplasticiser was added, the strength increased to 20.50 MPa, showing a modest improvement. At 0.6% dosage, the strength further increased to 21.60 MPa. The highest strength was achieved with 0.8% superplasticiser, reaching 23.01 MPa, representing a 21.4% improvement compared to the normal mix (Fig. 4).

Even at the lowest addition level (0.3%), the superplasticiser provided a noticeable enhancement in compressive strength. This demonstrates that the chemical admixture plays an important role in improving the strength of porous concrete without significantly altering its workability.

Fig. 3 Compressive strength test

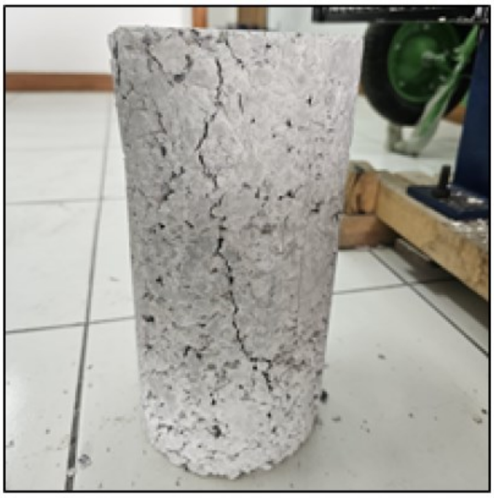

Fig. 4 Porous concrete after compression test

3.4. Discussion and implications

The findings from this research confirm that superplasticiser significantly enhances the compressive strength of porous concrete. The addition of superplasticiser helps to reduce the water content in the mixture while maintaining the required workability. This is particularly important in porous concrete because too much water can lead to excessive paste, closing the voids and reducing permeability. On the other hand, too little water can make the mixture difficult to handle, resulting in poor compaction and lower strength.

Superplasticisers solve this problem by allowing the concrete to flow and compact properly even with reduced water content. This leads to a better bond between the cement paste and the aggregate, filling small gaps and producing denser concrete with improved load-bearing capacity.

The improvement in strength observed in this study aligns with previous research findings. For example, [14] and [15] also reported that the use of superplasticisers can increase the strength of concrete mixtures while maintaining workability. This study further supports the idea that 0.8% superplasticiser is the optimal dosage for balancing strength, workability, and permeability in porous concrete [16] to mitigate damage to concrete [17].

The results of this research have practical and environmental implications for the construction industry. First, the study shows that porous concrete can be made stronger without losing its drainage function, allowing it to be used in more applications such as pavements, low-traffic roads, and parking lots where both strength and permeability are important.

Second, the use of superplasticiser contributes to green construction practices. By reducing the water-to-cement ratio, less cement may be needed in future developments, potentially lowering carbon emissions due to cement production. Additionally, porous concrete supports sustainable urban drainage systems.

Lastly, this research provides a foundation for future studies on the long-term durability of porous concrete with superplasticiser. Further investigation into aspects such as freeze-thaw resistance, permeability retention, and wear resistance could help expand the use of porous concrete in wider infrastructure projects, supporting sustainable development goals.

4. Conclusions

This study investigated the effect of adding superplasticiser to porous concrete, focusing on its impact on compressive strength. Porous concrete is widely used for eco-friendly infrastructure because of its ability to reduce surface water runoff and support groundwater recharge. However, its application has been limited due to its lower strength compared to conventional concrete. The findings of this research confirm that superplasticiser can significantly enhance the compressive strength of porous concrete without affecting its permeability. The best results were obtained with a 0.8% superplasticiser dosage, achieving a 28-day compressive strength of 23.01 MPa, which represents a 21.4% improvement compared to normal porous concrete.

The workability of the concrete mixes remained consistent across all superplasticiser levels, with slump values close to zero, as expected for porous concrete. This suggests that the superplasticiser improved the bonding between the cement paste and aggregates, allowing for better compaction and increased strength without closing the voids required for water infiltration. The research also confirmed that the quality of the materials used met the required standards, contributing to the reliability of the test results. The research supports the development of more sustainable and durable construction materials that align with green infrastructure goals. For future studies, it is suggested to explore other properties of porous concrete, such as permeability rates, durability, tensile strength, and resistance to weathering, to further optimise its use in a wider range of construction projects.

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