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Optimization of Mixing Proportions to Improve Strength and Hydraulic Performance in Pervious Concrete

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Abstract

The ever-increasing desire in pervious concrete is fueled by its eco benefits, especially in eco water administration and city drainage systems. However, optimizing its mechanical durability while preserving suitable penetrability and porosity remains a crucial obstacle. This study examines the influence of mix proportions on the structural and water performance of previous concrete to distinguish a perfect mix design. Fifteen mix versions were assessed by changing the water-to-cement (W/C) ratio, aggregate-to-cement (A/C) ratio, and cement content. The conclusions show that a mix containing 440 kg/m3 of cement with a W/C ratio of 0.32 accomplished the largest compressive strength of 22 MPa while preserving operational penetrability. The findings propose that an ideal balance between mechanical and water properties can be accomplished through precise material proportioning and controlled component energy compaction. These understandings provide a foundation for designing high-functioning previous concrete, making it a viable solution for eco infrastructure applications.

Keywords

Optimum mix design, Pervious concrete, Aggregate cement ratio (A/C), Porosity, Water permeability

1. Introduction

Pervious concrete has been employed for decades across many regions of the world, particularly in numerous countries (Schaefer & Wang, 2006). This specialized sort of concrete is usually applied in constructing parking areas, low traffic roadways, walking paths, tennis courts, greenhouses, and other related spaces (ACI-522, 2010; Tyner et al., 2009). Additionally, pervious concrete offers significant environmental benefits, like its ability to mitigate urban heat island effects (ACI-522, 2010; Neithalath et al., 2006). Recognized for its effectiveness in mitigating stormwater runoff, pervious concrete has been classified as a Best Management Practice (Bury, 2006). It is distinguished by its open-graded composition, primarily consisting of cement, coarse aggregate with minimal or no fine aggregate, and water. This combination results in a hardened, highly permeable concrete that enables efficient drainage. Pervious concrete can exhibit a wide range of compressive strengths, anywhere from 2.8 megapascals up to 28 megapascals, with water-cement (W/C) ratios usually falling somewhere between 0.26 and 0.40. Its permeability to water is often within the scope of 1.4 millimetres per second up to 12.2 millimetres per second, as denoted by various studies (ACI-522, 2010; NeithAlAth et al., 2010; Neithalath, 2013; Tennis et al., 2004; Wang et al., 2006). Compared to traditional concrete, fresh pervious concrete demonstrates less workability and increased rigidity. Its dry density is 70 to 80 percent of that of regular concrete, categorizing it as lightweight. The fresh density commonly fluctuates from 1600 to 2000 kilograms per cubic meter depending on the mixing process employed, how much it's compacted, and the characteristics of the raw materials used, as highlighted by different investigations (Al-Luhybi et al., 2022; Al-Luhybi & Qader, 2021; Al-Sulayvani & Al-Talabani, 2015; Ibrahim et al., 2024; Kevern J.T., 2008; Tennis et al., 2004). Moreover, Güneyisi et al. (2016) emphasized that optimally proportioning the components in pervious concrete aims to strike a balance between porosity, workability, and compressive strength.

To guarantee both structural integrity and sufficient drainage, pervious concrete ordinarily demands a porosity ranging from 15% to 30%. A density beneath 15% diminishes fluid transmission, whilst a density exceeding 30% undermines compressive resistance. A void allocation of 20% is viewed as ideal for the admission rate and engineering design, balancing drainage with bearing capacity. However, local building codes and environmental conditions may necessitate minor deviations from these standard porosity parameters. Under certain climatic scenarios or intended applications, a slightly higher or lower density could augment functionality without compromising foundation fortitude (Haselbach & Freeman, 2006; Tennis et al., 2004; Tong, 2011). Water substance administration is pivotal to forestalling drainage through pores and clogging of the framework. Compared to customary concrete, pervious concrete requires a lower water substance. Generally, a W/C proportion of 0.26 - 0.40 and cementitious material content somewhere in the range of 270 - 415 kg/m3 have been discovered to yield extraordinary outcomes (Güneyisi et al., 2016; Tennis et al., 2004). And though higher cement content allows for thicker paste and better bonding of aggregates, high cement and water put air into voids, increasing permeability (McCain & Dewoolkar, 2010; Yang, 2011). The A/C ratio and W/C ratio are two critical factors impacting the characteristics of pervious concrete. For an optimal mix, a W/C ratio of 0.3 and an A/C ratio of 4.25 are recommended (Lim et al., 2013).

Compared to conventional concrete, pervious concrete generally includes small, single-size aggregates (Crouch et al., 2003; Yang & Jiang, 2003). But deposition of dust and fine materials cause clogging of pores, leads to rise maintenance cost and reduces permeability. Furthermore, its limited compressive and flexural strength compared to normal pavement concrete restricts its widespread use in construction and paving. With the use of appropriate mix designs and proper compaction, pervious concrete can achieve the necessary strength and permeability for various applications (Güneyisi et al., 2016). Research has explored the incorporation of higher volumes of supplementary cementitious materials (e.g., fly ash, silica fume) into pervious concrete. While this may reduce compressive strength, it helps maintain desirable permeability, porosity, and mechanical properties (Kumar & Srikanth, 2023). Studies on low-volume traffic pavements have shown that modified pervious concrete offers excellent performance, durability, and sustainability for road construction (B., 2024). Further research has indicated that optimizing mix proportions enhances key properties of pervious concrete, particularly compressive strength, permeability, and durability, making it an ideal material for paving (Sahdeo et al., 2020). Data would suggest that an enhanced environmentally friendly version of pervious concrete can be further developed by optimizing the mixture design and adding cement additions with alternative materials (Fly Ash convolution cementing) (Ali et al., 2023). The results obtained highlight the advantages of decreasing the amount of cement in concretes at an optimal percentage with fly ash but with superior mechanical performance and eco-friendly concrete. Material properties, including flexural strength and energy absorption, are important factors for developing models to estimate buckling loads, might be relatively unimportant to the ultimate relevance of models under these conditions as suggested by Qader et al. (2024).

This paper investigates the performance of pervious concrete based on its critical engineering properties, by different ratios of W/C, A/C and cement content to obtain the optimum mixture design that results in pervious concrete with better engineering characteristics. Compressive strength assessed mechanical properties, whereas physical properties were evaluated based on density, porosity, and permeability. Five W/C ratios (0.27 - 0.43) of pervious concrete mixtures were achieved by three cement contents (440, 354 and 270 kg/m^3) and their corresponding A/C ratios (3.62, 4.5 and 5.9). Fifteen mix designs were prepared and tested at 28 days. Furthermore, the drainage characteristics of cement paste during pervious concrete fabrication with excessive water-to-cement (W/C) ratios were examined.

This research presents several novel contributions regarding permeable concrete mixtures, starting with a comprehensive optimization of mix designs. Through systematically evaluating fifteen different mixes by varying three critical factors—water-to-cement ratio from 0.27 to 0.43, aggregate-to-cement ratio from 3.62 to 5.9, and cement content from 270 to 440 kg/m3—the study established a data-driven framework for balancing compressive strength, reaching up to 22 MPa, and permeability between 5.9 to 10.2 mm/s. This addresses a key challenge for applications requiring both structural integrity and effective drainage, such as permeable pavements. The study also quantified the impacts of paste drainage in high water-to-cement mixes, for example, mixes A5, B5, and C5, revealing issues like weak surface layers and clogged voids that reduced strength and permeability. These findings were linked to workability limitations observed in slump tests and were empirically supported by permeability measurements, offering practical insights to prevent segregation during the placement of concrete. Additionally, correlation analysis showed strong relationships, R2 values from 0.82 to 0.90, between porosity and compressive strength, which were inversely related, as well as porosity and permeability, which had a non-linear and connectivity-dependent connection, enhancing predictive modelling of mix performance. Lastly, the study refined current guidelines such as those in (ACI-522, 2010) by proposing optimal parameter ranges: a water-to-cement ratio of 0.30 to 0.32 to prevent brittleness and paste drainage, cement content between 300 to 350 kg/m3 to balance strength and permeability, and an aggregate-to-cement ratio of 4.0 to 4.5 to improve bonding between aggregate and paste.

2. Experimental study

2.1 Materials

Previous concrete specimens were casted using ordinary Portland cement (OPC) (CEM I 42.5R), and the specific gravity and specific surface were determined experimentally (3.15 g/cm3) and (394 m2/kg), respectively. Table 1 lists the physical and chemical properties of the spent cement.

All pervious concrete mixtures incorporated uniformly graded coarse aggregate (9.5-12.5 mm) with a specific gravity of 2.72 and a water absorption rate of 1.48%. The specimens were produced using standard laboratory tap water, with distinct W/C ratios applied to different groups. Strict control over water content was enforced during preparation to optimize sample integrity.

2.2 Concrete mix quantities

The properties of all previous concrete mixtures are summarized in Table 2. A total of 15 mix designs were developed and categorized into three groups, each incorporating a variable W/C ratio ranging from 0.27 to 0.43. Each group was assigned specific A/C ratios of 3.62, 4.5, and 5.9, corresponding to cement contents of 440, 354, and 270 kg/m3, respectively. Additionally, a constant aggregate content was maintained across all mixtures within each group.

The water absorption capability of the aggregate was assessed at intervals of 30 minutes and 24 hours. Findings indicated that the absorption at 30 minutes accounted for approximately 95% of the total absorption measured at 24 hours. As a result, prior to each casting, the aggregate was soaked in water for 30 minutes, after which any excess surface moisture was manually eliminated using a dry towel. This process ensured that the aggregate achieved a saturated surface-dry (SSD) condition, thereby maintaining uniform water content within the mix. A 30-liter capacity power-driven revolver pan mixer was utilized for the mixing process. To ensure proper bonding between the cement paste and the aggregate, each batch was prepared according to the procedure described in (Wang et al., 2006). The total OPC amount was added at 5% into the mixing pan, then the aggregate was added. The ingredients were mixed until fine dust of dry cement was evenly coating the aggregate. The remaining cement and water were then added, and that mixture was mixed thoroughly for two minutes. The prepared concrete was then placed in molds in three consecutive layers, with each layer manually vibrated using 25 rodding strokes to minimize cement paste migration during pouring. The specimens were taken out of the molds 24 hours after which a water bath with a constant temperature of 25 °C was used for submersion until testing date.

Table 1. The physical and chemical properties of the utilized cement

Chemical analysis (%)	CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	SO_3	K_2O	Na_2O	Free Lime	Loss on Ignition	Insoluble Residue	Specific Gravity	Fineness (m^2/kg)
Portland cement	62.12	19.69	5.16	2.88	1.17	2.63	0.88	0.17	1.91	2.99	0.16	3.15	394

Table 2. Proportions of Ingredients for Pervious Concrete Mixtures

Mix ID	Cement Content (kg/m3)	W/C	A/C	Aggregate (kg/m3)	Water (kg/m3)
Mix A1	440	0.27	3.62	1593	118.8
Mix A2		0.30			132
Mix A3		0.32			140.8
Mix A4		0.36			158.4
Mix A5		0.43			189.2
Mix B1	354	0.27	4.5	1593	95.6
Mix B2		0.30			106.2
Mix B3		0.32			113.3
Mix B4		0.36			127.45
Mix B5		0.43			152.25
Mix C1	270	0.27	5.9	1593	72.9
Mix C2		0.30			81
Mix C3		0.32			86.4
Mix C4		0.36			97.2
Mix C5		0.43			116.1

2.3 Test methods of pervious concrete

Fig. 1 Samples of pervious concrete with dissimilar W/C relations, slump test

A slump test (ASTM C143/C143M-2003) (ASTM-C143/C143M, 2003) was conducted to assess the workability of fresh pervious concrete. However, it is well known that the slump test is not suitable for pervious concrete, as it typically exhibits zero slump or collapses upon removal of the cone, as illustrated in Fig. 1.

Cubic specimens of 150 mm × 150 mm × 150 mm were employed to assess pervious concrete compressive strength. Cylindrical molds with a diameter of 100 mm and a height of 200 mm was prepared for each of the test groups in order to assess the dry density, porosity, and the impermeability coefficient. All samples were tested at a curing time of 28 days. The compressive strength was assessed following standard ASTM C39/C39M-2012 (ASTM-C39/C39M, 2012) and porosity and dry density tests based on ASTM C1754/C1754M-2012 (ASTM-C1754/C1754M, 2012). Three specimens were prepared for each test, and the average value was taken to ensure the accuracy of the test results. The permeability coefficient of pervious concrete was evaluated based on the falling head method using a special device shown in Fig. 2. Cylindrical test specimens were wrapped in a latex membrane to prevent water intrusion along the sides. Each specimen had glass tubes on the top, like a flip-top bottle, that allowed for controlled flow of water. A difference of 400 mm head was maintained at the time of testing. Three measurements were performed, and its mean value was calculated.

The permeability coefficient (k) was calculated using the following equation:

$$k = \left(\frac{a\times L}{A\times t}\right) ln\left(\frac{h_0}{h_1}\right) \qquad (1)$$

where k represents the coefficient of water permeability (mm/s), while a denotes the cross-sectional area of the pipe (mm^2). The length of the specimen is given by L (mm), and its cross-sectional area is represented by A (mm^2). The time interval from h_0 to h_1 is denoted as t (s), where h_0 and h_1 correspond to the initial and final water levels (mm), respectively.

(a) (b) (c)

Fig. 2 Permeability test: a) pervious concrete cylindrical specimen, b) Specimen wrapped with a latex membrane, c) Permeability test apparatus

the dry density can be expressed as:

$$Density = \frac{K\times A}{D^2\times L} \qquad (2)$$

where: A = dry mass of the sample, (g), D = average diameter of the cylinder sample, (mm), L = average length of the cylinder sample, (mm), and K = 1273240 in SI units.

The porosity was calculated by taking the weight of fully saturated sample and the weight of oven dried sample, with using Drying Method A, the sample was dried. Then the air void content for pervious concrete can be calculated using equation below:

$$Porosity = \left[1 - \left(\frac{K\times(A-B)}{\rho_w\times D^2\times L}\right)\right]\times 100 \qquad (3)$$

where: B = underwater mass of the sample, (g), and ρw = density of water, (kg/m^3).

3. Results and discussion

3.1 Physical and mechanical characteristics of pervious concrete

Key properties of all pervious concrete samples (dry density, 28-day compressive strength, void content and permeability coefficient) are shown in Fig. 3 to 6. However, owing to the large number of voids, pervious concrete usually has lower compressive strength than normal concrete. From these figures, it is observed that the maximum compressive strength recorded was 22 MPa for mix A3 and the minimum was recorded as 4.5 MPa for mix C5. In terms of permeability, the lowest rate of 1 mm/s is reported for mix A5, which can be attributed to the drainage of cement paste to the lower layers of the mold promoted by the high cement content and W/C ratio. The density of the pervious concrete samples used in this study was within the range of 1875-2045 kg/m^3. Therefore, the differences in measured properties can be mainly attributed to differences in the amount of cement, the water to cement (W/C) ratio, and the aggregate to cement (A/C) ratio among the different mixes. This underscores the need of mix design optimization in order to find the best trade-off point between compressive and tensile strength, permeability and density so as to increase the potential application areas of pervious concrete in high-performance applications.

3.2 Influence of W/C ratio and cement content on properties of pervious concrete

Impact of W/C ratio on compressive strength as well as dry density for all mixes is shown in Fig. 3 and 4. The relationship of strength and density within the same W/C ratio can exhibit a decreasing pattern as the cement content changes within each mix group. It was concluded that an increase in the thickness of the cement paste that coats the aggregate particles was the most desirable way to enhance the compressive strength of pervious concrete. One way of doing this would be to reduce A/C ratio while leaving the overall composition unchanged. Higher dry density also relates to the cement paste layer thickness. The results show that pervious concrete at W/C ratio of 0.3-0.32 effectively optimizes the strength-dry density ratio; hence, a good reference for nonpermeable concrete mix design adjustment. In conventional concrete, the W/C ratio is typically decreased to attain higher compressive strength. However, if the W/C ratio is too low in pervious concrete, the mixture becomes too dry and brittle, which affects the workability. Contrarily, for a too high W/C ratio, the mix becomes too wet for controlling and the redundant cement paste drains and settles at the bottom of the sample.

The coefficient of determination (R^2) for these trends was notably high: $R^2 \approx 0.92$ for the W/C–density relationship and $R^2 \approx 0.98$ for the W/C–compressive strength relationship. These values signify a strong statistical correlation and confirm that W/C ratio is a reliable predictor of both properties. The high R^2 for compressive strength emphasizes its particular sensitivity to changes in water content, likely due to the dominant role of paste quality in strength development.

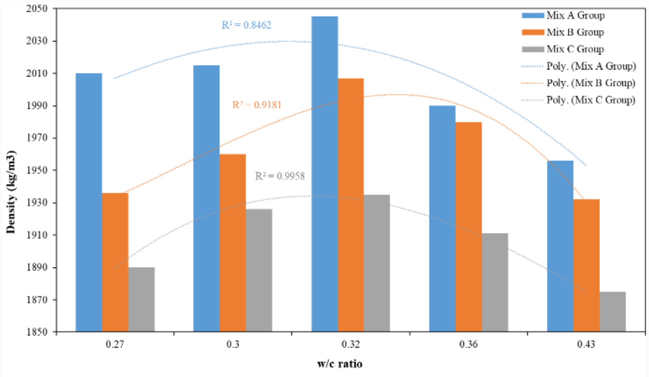

Fig. 3 Impact of W/C ratio on the dry density for all mixes

As demonstrated, this non-uniform distribution of cement paste lowers the bonding strength between cement and aggregates, which leads to reduced compressive strength and uneven permeability (McCain & Dewoolkar, 2010; Yang, 2011). This effect was most pronounced in Mixes A5, B5, and C5, where paste migration caused weaker top layers and random permeability variations

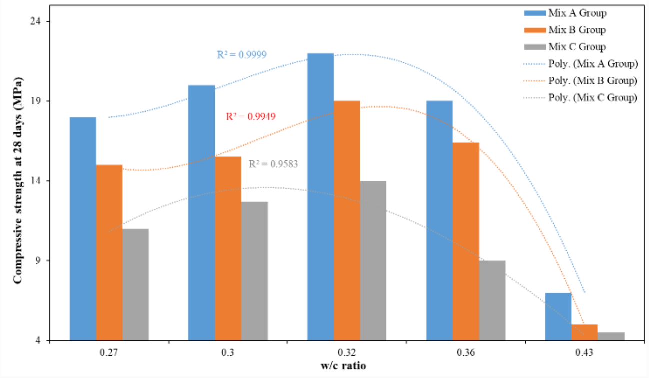

Fig. 4 Influence of W/C ratio on compressive strength for all mixes

A high cement content leads to filling void structures and accumulating cement paste, which subsequently reduces both porosity and infiltration rate in pervious concrete. The permeability coefficient was recorded at 10.2, 9.3, and 7.6 mm/s for mixes with W/C ratios of 0.27, 0.3, and 0.32, respectively. Additionally, increasing the cement content from 270 to 440 kg/m^3 led to an approximate 20% decrease in the permeability coefficient for W/C ratios of 0.27, 0.3, and 0.32. The study also indicated that the minimum acceptable porosity ranged between 20% and 22% at a W/C ratio of 0.32 (see Fig 5 and 6). A strong correlation was identified in Fig. 5 between the porosity and W/C, with $R^2 \approx 0.98$.

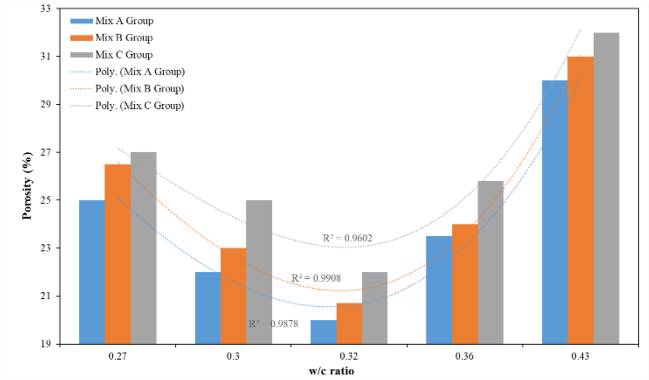

Fig. 5 Porosity versus W/C ratio

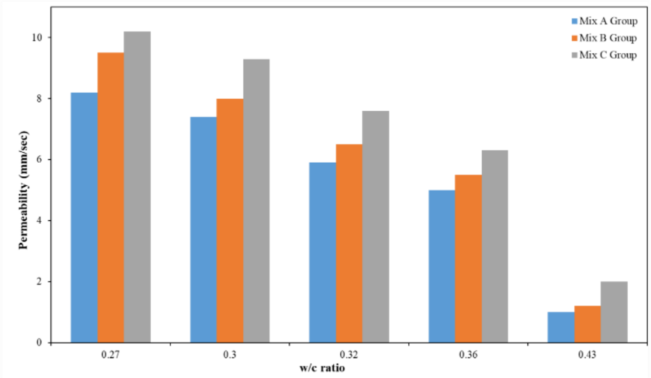

Fig. 6 Permeability versus W/C ratio

3.3 Relationships of pervious concrete

The impact of the porosity percentage on dry density and compressive strength of all concrete mixtures with different mix proportions is displayed in Fig. 7 and Fig. 8. As expected, the increase in void content from 20% to 32% were associated with a decrease in dry density from 2045 kg/m^3 to 1875 kg/m^3 and a reduction in compressive strength from 22 MPa to 4.5 MPa Greater cement content had a positive relationship with compressive strength, density, and negative relationship with porosity. The main reason for this phenomenon is the cement paste micro-filler effect, that increases the particle cohesion between aggregate and the overall structure of concrete.

The coefficient of determination (R^2) for the relationship between porosity and dry density (Fig. 7) was approximately 0.85, suggesting a strong correlation and consistent trend across the corresponding mixtures. An R^2 value of ≈ 0.90 between compressive strength and porosity is also found, as shown in Fig. 8, highlighting a significant inverse correlation between these two parameters. As porosity increases, this significant correlation indicates that compressive strength decreases, which is mainly influenced by lower bonding both between auger fill and paste as well as within the paste itself, thus impacting mechanical performance across all formulations.

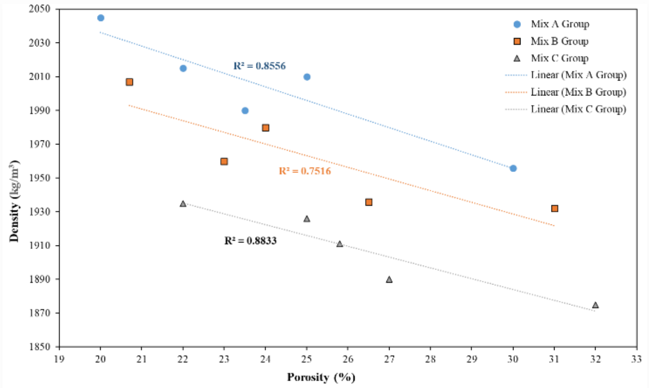

Fig. 7 Influence of porosity percentage on dry density for all mixtures

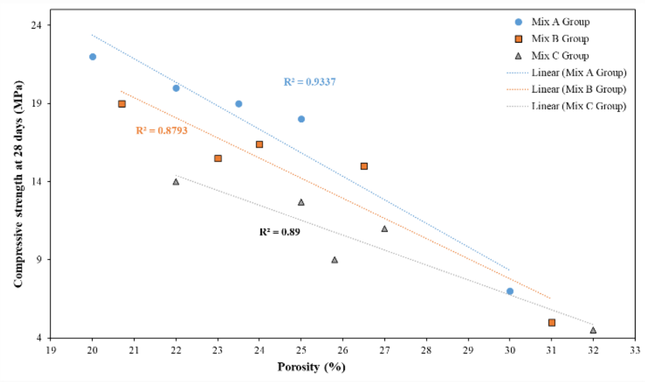

Fig. 8 Influence of porosity percentage on compressive strength for all mixtures

In this way, the relationship of compressive strength and dry density is shown by Fig. 9. All mixtures exhibit a uniform trend of increasing the compressive strength with increasing density. A maximum dry density of 2045 kg/m^3 and compressive strength value of 22 MPa (higher range of cement and lower A/C ratios) was obtained. Vertically, relationship between the density and compressive strength was observed within the limits of 37 kg/m^3 and 1875 kg/m^3; respectively this minimum density corresponds to a compressive strength of 4.5 MPa. The results indicate that concrete with higher cement content and lower A/C ratios are denser and more cohesive, translating to greater compressive strength.

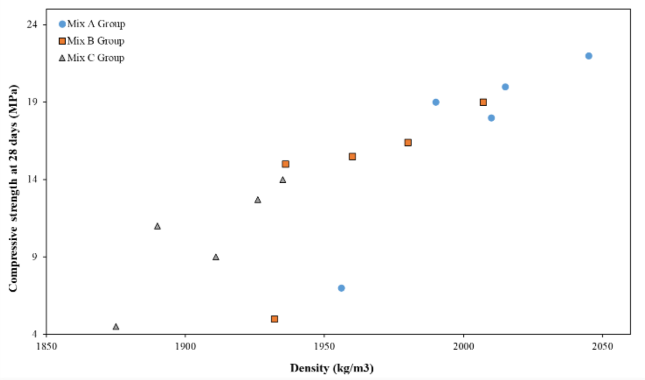

Fig. 9 Relationships between density and compressive strength in pervious concrete

Fig. 10 illustrates the influence of total porosity on the permeability coefficient. Several factors directly influence permeability, including hydraulic conductivity, aggregate gradation and type, cement content, compaction level, W/C ratio, and A/C ratio. The results indicate that higher permeability coefficients were achieved with higher A/C ratios, as increased aggregate content contributes to larger void structures. However, there is noticeable variability in the permeability data (Y-axis), as permeability primarily depends on air void connectivity or "effective porosity," which determines the continuous pathways allowing water flow. Notably, a higher void ratio does not always guarantee a higher filtration rate, as void connectivity plays a crucial role. At 27% porosity, the highest recorded permeability coefficient was approximately 10.2 mm/s. However, as porosity increased from 27% to 32%, the permeability coefficient significantly decreased from 10.2 mm/s to 2 mm/s, indicating that excessive porosity may lead to disrupted void connectivity, reducing water flow efficiency

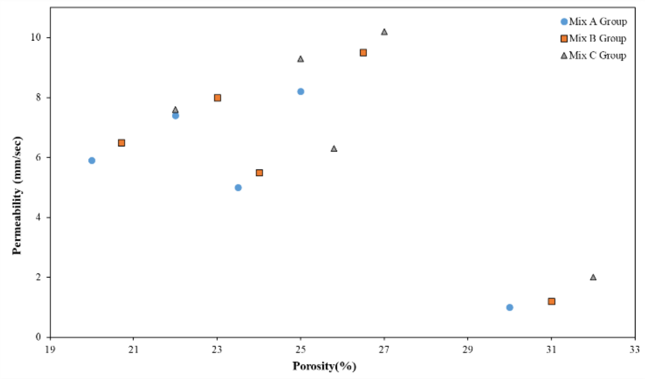

Fig. 10 Impact of total porosity on the permeability coefficient

The investigation produces outcomes and insights that align with past research on pervious concrete while delivering important enhancements and fresh perspectives. Optimal mix proportions were identified - specifically an ideal water-to-cement ratio of 0.30-0.32 and an aggregate-to-cement ratio of 4.0-4.5, resulting in the best harmony between compressive strength (up to 22 MPa) and permeability (5.9 - 7.6 mm/s). These conclusions agree with previous recommendations by researchers such as Güneyisi et al. (2016) and (Sahdeo et al., 2020), yet this study stands out through testing a broader matrix of 15 mix designs, exceeding the typical 3-6 in earlier works. Moreover, a notable contribution is empirically recognizing and quantifying cement paste drainage as a crucial failure mechanism in excessive W/C mixes (>0.36), an issue noted qualitatively before (e.g., (Yang, 2011)) but not evaluated directly. The research also deepens comprehension of trade-offs between porosity, strength, and permeability. A strong inverse link (R2 ≈ 0.90) between porosity and compressive strength was observed, alongside a nonlinear relationship between porosity and permeability governed by void connectivity, or "effective porosity." This expands on NeithAlAth et al. (2010), who modelled pore structures without explicitly connecting them to mix proportions or paste migration effects. For instance, Mix A5 exhibited a sharp permeability decline to 1 mm/s despite sustaining 30% total porosity, due to paste clogging that damaged void continuity. Finally, the study delivers precise insights into cement content effects: while higher cement content (up to 440 kg/m3) boosted strength, it significantly lowered permeability by approximately 20%, because of surplus paste filling the voids. This trade-off refined earlier guidance from Tennis et al. (2004), who suggested a ceiling of 415 kg/m3, by identifying 354 kg/m3 as a more effective compromise for applications requiring moderate strength and adequate drainage.

This investigation, while yielding helpful additions, has several constraints that invite prospects for future analysis. First, the material scope was confined to ordinary Portland cement (OPC), leaving out supplementary cementitious materials (SCMs) like fly ash or slag, which may progress the ecological sustainability of porous concrete (Ali et al., 2023). Upcoming studies ought to integrate SCMs and recycled components to bolster circular economic goals, as spotlighted by Al-Luhybi and Qader (2021). Additionally, durability testing was not led-particularly, the analysis did not assess freeze-thaw resilience or clogging possibility, which are vital for long-term functioning (Kevern J.T., 2008). Long-term function under real-world environment conditions should be the concentration of future work. Lastly, the exploration was led at a research centre scale, which may not precisely mirror field performance because of diversity in compaction and curing techniques. To enhance applicability, pilot-scale trials such as permeable concrete installations in parking lots are recommended to validate and refine the proposed mix designs.

Regardless of these constraints, the discoveries have strong, useful relevance for designers and professionals. The outcomes plainly demonstrate that preserving a water-to-cement (W/C) ratio under 0.36 helps prevent paste drainage, which can jeopardise both strength and permeability. A target porosity range of 20-22% was found to offer an ideal balance between mechanical performance and drainage capacity. Additionally, using cement content in the range of 300-350 kg/m3 is suggested for moderate-strength applications such as pedestrian pavements, ensuring sufficient load-bearing capacity without substantially decreasing permeability. These guidelines furnish a functional foundation for designing more durable and efficient porous concrete structures in real-world settings.

4. Conclusions

In this study, around 15 different mixes of zero sand concrete (pervious concrete) were conducted in order to examine the main characteristics of produced concrete. For that reason, an experimental plan was designed with a group of tests such as compressive strength, porosity, permeability, and dry density and the potential relationships among them all of these tests were performed on 28th age concrete test samples. the mechanical and permeability coefficient properties produced concrete were affected by the dissimilar material proportion. A good correlation was observed between porosity-dry density, and porosity-compressive. The major observation can be listed as below:

1. The dry density values recorded in Table 2 were compared with the guidelines set forth by ACI 55R, as a result the dry density values of zero-sand pervious concrete mixtures fell within these ranges. The maximum dry density value was found to be 2045 kg/m^3 for approximately 20% porosity level. The maximum porosity of 32% corresponded to the lowest density of 1875 kg/m^3. These results show a clear relationship between a higher aggregate-to-cement (A/C) ratio and lower cement content in reducing dry density. The optimum water-to-cement (W/C) ratio was found to be 0.32.
2. Compared to conventional concrete, a higher void content in pervious concrete resulted in a lower compressive strength. Since a constant value of W/C of 0.32 was used to isolate the effect of cement dosage, it was observed that the compressive strength of the mix with 440 kg/m^3 of cement was about 36% higher compared to that of the mix with 270 kg/m^3 cement.
3. The Water-to-Cement (W/C) ratio is one of the most important variables impacting the quality and performance of pervious concrete. Mixed slurry-like fresh concrete with well-regulated water content is needed to ensure adequate fluid functionality for avoiding blockage of the interconnected void network. This is due to insufficient water proportioning can result in the segregation of cement paste with the cement paste settling at the base of the specimen. The targeted cement content, W/C and A/C ratio to produce an environmental concrete able to reach acceptable mechanical properties without lessening permeability are found in the ranges of 300–350 kg/m^3, 0.30–0.32, and 4.0–4.5, respectively.
4. The permeability characteristics of pervious concrete were significantly affected by W/C ratio and cement content. The paste contents and void volume imbalance in the mixture limited the flow of water, resulting in lower permeability for mixtures with lower A/C ratio in powder urs. Despite that, permeability criteria defined in ACI 55R was met by all mixes, excluding the mixtures A5, B5, and C5 and permeability reduction in these mixtures can be attributed to scum down migration and accumulation in the body of the specimens.
5. It was also clear that, with an increase in dry density and compressive strength, there was a decrease in both the permeability coefficient and total void ratio.
6. The correlation flanked by permeability and porosity was investigated. The R-square was around 0.82, a good indication can have understood from R value concerning the relation between permeability and porosity, which is strongly affected by continuous porous that release water within the microstructure of pervious concrete known as ‘‘effective porosity’’, So basically, the higher ‘‘effective porosity’’, the higher permeability performance.
7. Compaction techniques and cement paste distribution play a crucial role in enhancing the performance of pervious concrete. Improper compaction or paste drainage can lead to weaker aggregate bonding and reduced permeability.
8. Optimizing cement and water content allows for the development of more efficient mix designs, improving durability and environmental sustainability while maintaining the desired mechanical and hydraulic properties for practical applications. These findings contribute to the advancement of sustainable construction materials, reinforcing the potential of pervious concrete in modern infrastructure

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