STUDIES ON THE PROPERTIES OF PERVIOUS CONCRETE

Abstract

The purpose of this study is to explore the effect of fine aggregate percentages and cement-to-coarse aggregate ratios on the critical qualities of pervious concrete. Pervious concrete is prepared with the addition of 0%, 10%, or 20% replacement of fine aggregate to the weight of coarse aggregate. Various tests such as mechanical strength test, permeability test, effective porosity test, and absorption test were performed after a curing period of 7, 14, or 28 days. When compared to other combinations, 20% fine aggregate replacement obtained 9.07 MPa of compressive strength and 1.97 cm/sec of permeability. At the same time, the compressive strength with 10% fine aggregate replacement was 7.41 MPa with a permeability of 3.20 cm/sec. Thus, even though the compressive strength was decreased, the pervious concrete achieved desired outcomes with a 10% substitution of fine particles. As a result of its high porosity, which allows water to move through it, it is a good choice for a variety of applications requiring water drainage and environmental considerations.

Keywords: Pervious concrete**,** Compressive strength, Permeability, Void ratio and Porosity, etc.

Authors

V. Sai Neeraja
Assistant Professor
Department of Civil Engineering
Chaitanya Bharathi Institute of Technology (Autonomous)
Proddatur, Kadapa, India.
saineeraja6@gmail.com

Sruthi. S
Associate Professor
Department of Civil Engineering
Chaitanya Bharathi Institute of Technology (Autonomous)
Proddatur, Kadapa, India.
sruthiscivil@gmail.com

Rajendra Kumar. P
Assistant Professor
Department of Civil Engineering
K.S.R.M College of Engineering (Autonomous)
Kadapa, India.
rajendra.p@ksrmce.ac.in

Prudhvi Raj. D. V
Assistant Professor
Department of Civil Engineering
Rajeev Gandhi Memorial College of Engineering & Technology (Autonomous)
Nandyal, India.
prudhviraaj555@gmail.com

I. INTRODUCTION

In recent years, sustainable construction practices have gained significant attention as societies worldwide strive to address environmental concerns and improve the resilience of built environments. Self-compacting concrete by changing the admixtures [1], Geopolymer technology using industrial wastes [2], high strength concrete were all sustainable construction sectors where we can reduce the carbon-di-oxide emission. Among the innovative solutions emerging from this paradigm shift is pervious concrete—a porous material designed to tackle both stormwater management and structural performance challenges. This experimental study delves into the mechanical and durability aspects of pervious concrete, aiming to unravel its capabilities and limitations within the context of modern construction. The usual impermeable characteristic of concrete has frequently caused issues in regulating stormwater runoff, resulting in floods, erosion, and polluting of aquatic bodies. [3] The term "pervious cement" generally refers to an open-graded material composed of Portland cement, coarse aggregate, minimal fine aggregate, admixtures, and water, which exhibits a near-zero slump. When these materials are combined, they form a solid substance with interconnected voids ranging in size from 0.08 to 0.32 inches (2 to 8 millimeters), allowing water to pass through readily. With typical compressive strengths ranging from 400 to 4000 pounds per square inch (2.8 to 28 megapascals), the void content may range from 15 to 35 percent. The drainage rate of pervious concrete pavement varies with aggregate size and mix density, although it typically falls between 2 and 18 liters per minute per square meter (81 to 730 liters per minute per square meter).

Pervious concrete, with its unique capacity to enable water to move through its linked spaces, is an attractive option. This study sets out to discover how this one-of-a-kind material not only helps to successful stormwater management but also has the potential to fulfil structural and durability criteria. The term "pervious concrete" [19] refers to a material with a nearly zero slump that is open-graded and made of Portland cement, coarse aggregate, little to no fine aggregate, admixtures, and water. These components work together to create a material that is hardened and has linked pores that are easily permeable to water and range in size from 0.08 to 0.32 in (2 to 8 mm). The utilization of pervious concrete for rural pavements represents a relatively recent innovation, responding to the escalating challenges posed by declining groundwater levels in rural regions.[4] This study reveals that previous concrete has a lower compressive strength than conventional concrete; compressive strengths in suitable combinations only reached an average of around 1,700 psi (11.72 MPa). Extremely high permeability rates were obtained in virtually all mixes, regardless of compressive strength. [5,6] Compressive strength and split-tensile strength of control mix (OPC) and FaL-G mix increased with decrease in porosity and increased with density of aggregates.

However, OPC has better mechanical strength properties because of enriched bonding between the coarse aggregates. Pervious concrete, as a pavement material, has garnered renewed interest owing to its inherent capacity to facilitate water infiltration, thereby replenishing groundwater reservoirs, and mitigating the adverse effects of storm water runoff. This introductory exploration of pervious concrete pavements comprehensively examines their applications and engineering attributes, encompassing their environmental advantages, structural characteristics, and durability[7,8,9]. It is worth noting that in rural areas, cost considerations assume paramount significance, necessitating a judicious approach that avoids the application of expensive storm water management practices. Pervious concrete, by capturing and enabling rainwater to percolate into the ground, offers an economically viable alternative for addressing these concerns.[10] Pervious concrete (PC) is a composite material predominantly composed of cement, water, and coarse particles with a high permeability. Compared to traditional concrete, it is recognised to offer the advantages of lowering runoff volume and perhaps improving water quality by recharging groundwater [11].

According to the author, by combining latex and sand, it is feasible to create pervious concrete mixtures with sufficient permeability and strength.[12] The author explores the mechanical properties and behaviour of pervious concrete, specifically focusing on its strength, resistance to fracture, and performance under fatigue loading conditions. Pervious concrete's flexural strength is more susceptible to porosity than its compressive strength.[13] This research paper reveals that, the percentage of air voids need for an optimal permeability, the optimum water-cement ratio range, and the quantities of compaction. [14] When compared to dolomite, the greater mechanical characteristics of pervious concrete were due to better mechanical properties of dispersed aggregate and a denser transition zone.[15] The author reveals that the increase in fine aggregate leads in a reduction in void volume, which increases compressive, flexural, and split tensile strength. The angularity number is greater for larger aggregates and decreases as aggregate size decreases. [16] The author demonstrated from the findings that with CFA and FSD as additives in PC developed sufficient strength to be suitable for field use.

II. MATERIALS USED

The most crucial component of concrete is cement since it serves as a binding agent for both coarse and fine materials. The Zuari Cement Company's Ordinary Portland Cement of 53 grade is employed in this investigation. The aggregate that is retained on a 10 mm sieve after passing through a 63 mm filter is referred to as coarse aggregate. In this investigation, 20mm crushed coarse aggregate is used, which is locally accessible. Fine aggregate is referred to be material that can pass through an IS sieve with a 4.75mm opening. In this investigation, river sand that is readily available in the area is used. Design mix of pervious concrete, ACI 522R-10 is used. The mix design for pervious concrete can be done with 0%, 10%, or 20% fine aggregate, per the code. For all blends, the w/c ratio is 0.4, which is constant. The physical properties of materials are given in Table 1 for cement, fine aggregate and coarse aggregate. The results obtained are within their prescribed limit.

Table 1: Physical Properties of Materials

Material	Tests	Result	IS:12269-2013
Cement - OPC	Specific Gravity	3.2	2.9-3.2
	Fineness modulus	5%	<10%
	Consistency	32%	26-33%
	Initial setting time	45 minutes	>30mins
	Final setting time	200 minutes	<600 mins
Coarse aggregates	Specific Gravity	2.813	2.4-3
	Fineness modulus	8.4	6.5-8.5
	Water absorption	0.6%	0.1-2%

Fine aggregates	Specific Gravity	2.5	2.4-3
	Fineness modulus	4	2-4
	Bulking of sand	32% at 4% moisture content	

III. TESTS ON CONCRETE

The compressive testing machine with the most essential restriction of 3000KN was used to measure the compressive strength of pervious concrete according to ASTM C 39. Compressive strength tests were performed on models that had been reestablishing for 7, 14, and 28 days. The splitting unbending nature tests were performed by the Standard Test Strategy for Separating Flexibility of Cylinder molded Significant Models (ASTM C496). Pervious significant instances of strong shapes and chambers tests are tended to in Figure 1. The permeability of the three past significant mixes was settled using the falling-head vulnerability test contraption. In their assessment, the little part of quantifiable voids moved by fluids in their tests was named porosity and how much quantifiable voids between sums notwithstanding entrained or caught air in the substantial paste was named air content.

Thus, the porosity of penetrable concrete could be portrayed unexpectedly. In this audit, for clearness, the quantifiable voids are described as the convincing porosity since this interfaces with vulnerability and the general air content is properly portrayed as complete porosity. The strong still hanging out there by testing the volume of water ousted by tests. The model was without skipping a beat oven dried at 110^{o}C for 24h and a short time later soaked in water for up to 24hrs. By assessing the qualification in the water level while lowering the model, the volume of water repelled by the model (V_d) cannot permanently establish. Deducting (V_d) from the model mass volume (V_b)yields the volume of open pores. This volume was then conveyed as a rate as an effective porosity rate:

Effective porosity, n = $\frac{Vb - Vd}{Vb} \times 100$ %--------(eqn.1)
Then, void ratio, e= $\frac{n}{1-n} X$ 100 % -------------(eqn.2)

The unit weight of the pervious concrete was estimated by ASTM C29 in oven dry circumstances, and water retention was estimated by ASTM C830. The pervious substantial example was solidified, stripped, set in the stove, and dried at 105 ± 50C until the weight was steady. Then the dry weight W_{dry} was estimated, and the example volume V was determined utilizing the unit weight of substantial articulation underneath: Unit weight = $\frac{\text{W dry}}{V} Kg/cu$m------------- (eqn.3)

The oven dried sample was drenched in 20 ± 50C water for 24 h, eliminated, cleaned with a damping fabric right away, and weighed to get the wet mass W_{wet}. The water ingestion was determined by these following conditions:

Water absorption (%) = $\frac{\text{Wwet} - \text{Wdry}}{\text{Wdry}} \times 100$------------- (eqn.4)

Figure 1: Cubes and Cylinder Specimens of Pervious Concrete

IV. RESULTS AND DISCUSSIONS

The compressive strength as per Indian Standards [17] results are shown in Figure 2, where the compressive strength is higher in M3 mix of 9.07 MPa when compared to M1 mix of 7.15 MPa and M2 mix of 7.93 MPa. The results for the split tensile strength as per Indian Standards [18] was achieved at 28-day strength was 2.06 MPa for M3 mix, when compared to M1 mix of 0.99 MPa and M2 mix of 1.66 MPa as shown in Figure 3.

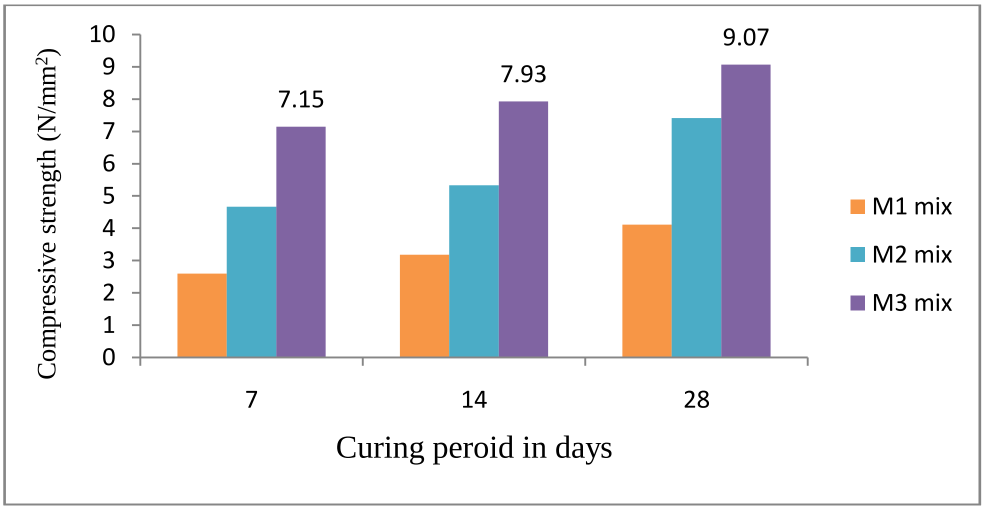

Figure 2: Effect of Curing Period on Compressive Strength

The results obtained from the effect of permeability as per Indian Standards [19] has a good resistance in M1 mix of 4.87 cm/sec, when compared to M2 mix of 3.02 cm/sec and M3 mix of 1.97 cm/sec as shown in Figure 4. The results of compressive strength, split tensile strength, M3 mix has good mechanical properties in M3 mix, whereas when compared with the permeability resistance M1 mix has a good permeability than the strength properties of the mix.

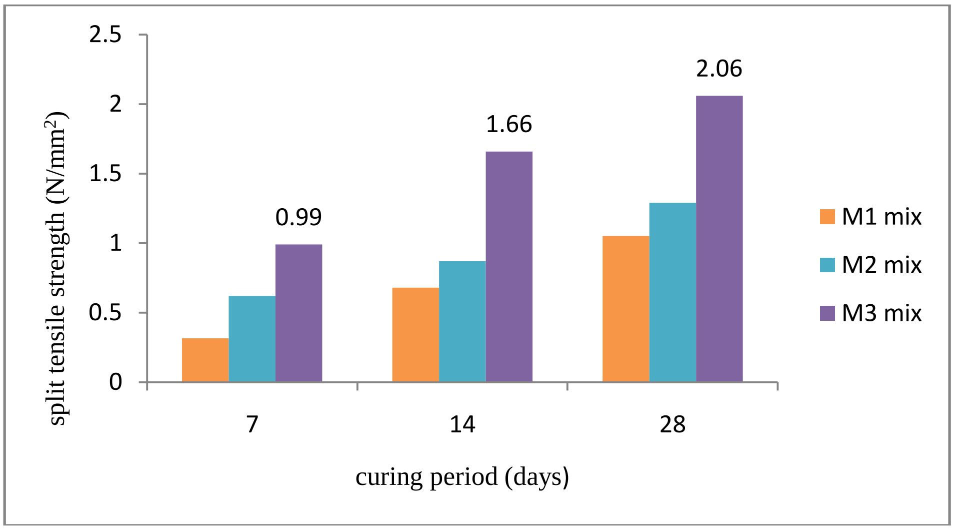

Figure 3: Effect of Curing Period on Split Tensile Strength.

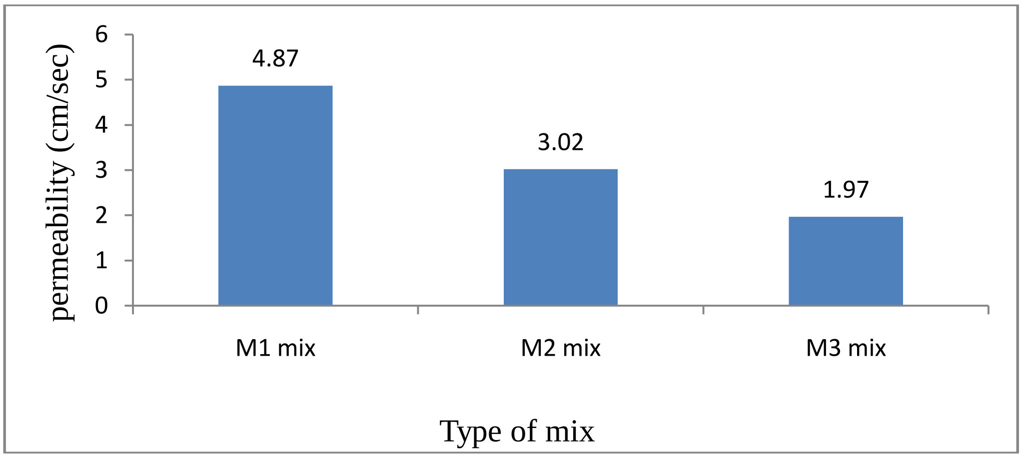

Figure 4: Effect of Fine Aggregate Content on Permeability.

Table 2: Regression Analysis – Compressive Strength and Permeability

Regression Statistics	
Multiple R	0.95300701
R Square	0.90822236
Adjusted R Square	-0.09177764
Standard Error	1.09235008
Observations	2

The regression analysis is given in Table 2, where the co-efficient of determination and the relation were in the acceptable range. The density and water absorption are compared along with theoretical and practical unit weight and the water absorption results are represented in Table. 2 for all the three different mixes. M2 mix has good water absorption when compared with the other two mixes. The effect of fine aggregate on porosity and void ratio [20,21,22], were resulted in Table 4. M3 mix is less porous when compared to the other two variant mixes, by the same time, M2 mix has less void ratio content when compared with the other two mixes [23,24,25]. The results are represented in figure 5.

Table 3: Density and Water Absorption

Mixes	W1 (g)	W sat (g)	V (m^3)	Theoretical Unit weight (Kg/m^3)	Practical unit weight (Kg/m^3)	Water Absorption (%)
M1	6850	7100	3.375×10^{-3}	2029.63	2024.67	3.64
M2	7030	7080	3.375×10^{-3}	2082.96	2074.44	3.28
M3	7086	7355	3.375×10^{-3}	2099.56	2083.93	3.79

Table 4: Effect of Fine Aggregate on Porosity and Void Ratio

Mixes	W1 (g)	W2 (g)	W3 (g)	W4 (g)	V_w=ɤ s	Vv (v_t - v_w)	Porosity (%)	Void content (%)
M1	6850	16960	12635	19735	2.775×10^{-3}	600×10^{-6}	17.78	21.62
M2	7030	16630	12400	19631	2.831×10^{-3}	544×10^{-6}	16.12	19.22
M3	7086	16670	12230	19585	2.915×10^{-3}	460×10^{-6}	13.63	15.73

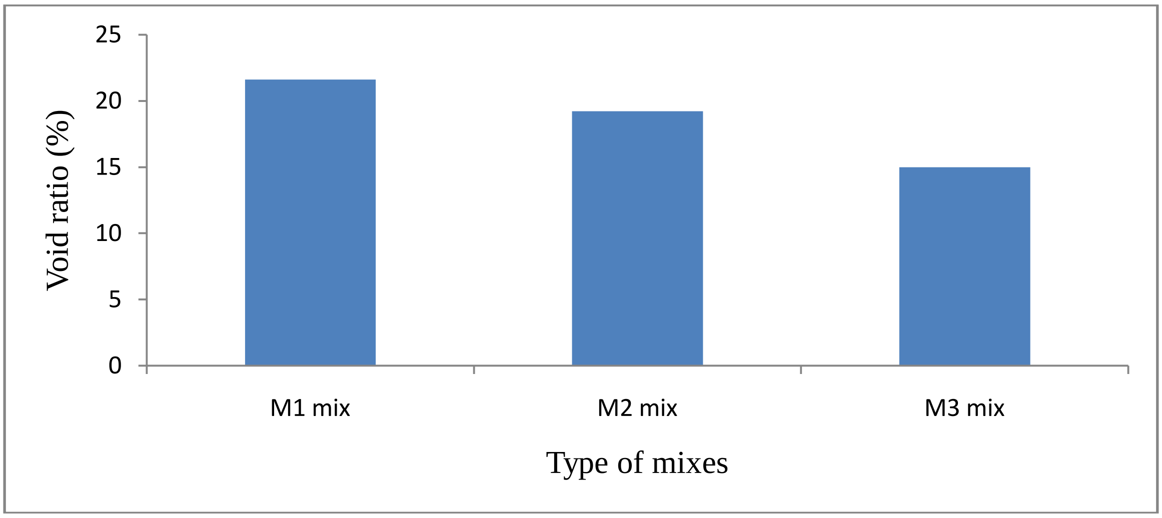

Figure 5: Effect of Fine Aggregate Content on Void Ratio

V. CONCLUSIONS

The following are the findings form the above research study:

- The M3 mix has the highest compressive strength of the three mix, but when permeability is taken into account, the M2 mix is the best mix for compressive strength. Although having a compressive strength of 7.41 MPa, M2 mix has the lowest permeability (1.97cm/sec).

- Similarly to compressive strength, M2 mix is proven to be the ideal mix for split tensile strength by the experiment demonstrated in earlier chapters.
- Water permeability is an essential property of pervious concrete; in this study, the M1 mix had the highest permeability but the lowest strength of the three mixes. As a result, the M 2 mix with a compressive strength of 7.41 MPa and a permeability of 3.02cm/sec is determined to be the best mix.
- Considering the average range of pervious concrete is 15-30% void ratio, mix #2 with 19.22% void ratio and strength of 7.41MPa was found to be optimal in our testing.
- According to the density test findings, we discovered that the densities obtained from both theoretical and practical techniques are comparable. Despite having a lower density than the M2 mix and the strongest strength of the three mixes, the M3 mix will not be considered optimal due to its inadequate porosity. As a result, an M2 mix with a density of 2074.44Kg/m3 is considered optimal.
- Water absorption test findings show that the cement concentration has a significant impact on the absorption of pervious concrete. Among the three mixes, the M2 mix with a water absorption of 3.28% and a moderate cement concentration of 154.77 Kg/m3 is considered the best.
- Based on the foregoing, we believe that an M2 mix with a fine aggregate content of 10% and an aggregate-cement (A/C) ratio of 8.88 and a density of 2074.44 Kg/m3 is optimal.

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