**Studies on the properties of pervious concrete**

**V. Sai Neeraja 1, Sruthi.S2, P. Rajendra Kumar3 and D V Prudhvi Raj4**

1Assistant Professor,2Associate Professor, Chaitanya Bharathi Institute of Technology(Autonomous),

3Assistant Professor, K.S.R.M.College of Engineering(Autonomous) and 4Assistant Professor, Assistant Professor, RGM Engineering College(Autonomous)

saineeraja6@gmail.com , sruthiscivil@gmail.com, Rajendra.p@ksrmce.ac,in, prudhviraaj555@gmail.com

**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.

**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 phrase "pervious concrete" usually refers to a near-zero-slump, open-graded material made up of Portland cement, coarse aggregate, little or no fine aggregate, admixtures, and water. When these materials are combined, they form a solid substance with linked holes ranging in size from 0.08 to 0.32 in. (2 to 8 mm) that allow water to travel readily through. With average compressive strengths of 400 to 4000 psi (2.8 to 28 MPa), the void content might range from 15 to 35%. The drainage rate of pervious concrete pavement varies with aggregate size and mixture density, although it normally falls between 2 and 18 gal./min/sq.ft. (81 to 730 L/min/m2). 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 anaverage ofaround 1,700 psi (11.72 MPa). Extremely high permeability rates were obtained in virtually all mixes, regardless of compressive strength. [5,6] Compressive strength andrsplit tensilerstrength ofrcontrol mix (OPC) and FaL-G mix increased with decrease in porosity and increased withrdensity of aggregates. However,rOPC hasrbetter mechanical strengthrproperties rhan FaL-G because of enrichedrbonding betweenrthe 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 findingsthat with CFA and FSDasadditives in PC developed sufficient strength to be suitable for field use.

**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.For the mix design 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 |  |

**TESTS ON CONCRETE**

The compressive testing machine with the highest capacity of 3000KN was used to measure the compressive strength of pervious concrete according to ASTM C 39. Compressive strength tests were performed on samples that had been curing for 7, 14, and 28 days. The splitting tensile strength tests were performed according to the Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens (ASTM C496). Pervious concrete specimens of cubes and cylinders samples are represented in Figure 1. The permeability of the three previous concrete mixtures was determined using the falling-head permeability test apparatus. In their research, the fraction of measureable voids migrated by fluids in their experiments was termed porosity and the sum of measureable voids between aggregates plus entrained or entrapped air in the cement paste was termed air content. In other words, the porosity of porous concrete could be defined differently. In this study, for clarity, the measureable voids are defined as the effective porosity since this relates to permeability and the overall air content is accordingly defined as total porosity. The effective porosity was determined by testing the volume of water displaced by samples. The sample was firstly oven dried at 110oC for 24h and then immersed in water for up to 24hrs. By measuring the difference in the water level before and after immersing the sample, the volume of water repelled by the sample (Vd) can be readily determined. Subtracting Vd from the sample bulk volume (Vb) yields the volume of open pores. This volume was then expressed as a percentage as an effective porosity percentage:

Effective porosity, n = $\frac{Vb-Vd}{Vb}×$ 100%--------(eqn.1)

Then, void ratio, e= $\frac{n}{1-n}$𝛸 100 % -------------(eqn.2)

The unit weight of the pervious concrete was measured according to ASTM C29 in oven-dry conditions, and water absorption was measured according to ASTM C830. The pervious concrete specimen was hardened, stripped, placed in the oven, and dried at 105 ± 50C until the weight was constant. Then the dry weight Wdry was measured, and the specimen volume V was calculated using the unit weight of concrete expression below:

Unit weight = $\frac{W dry}{V}$𝐾𝑔/𝑐𝑢m-------------(eqn.3)

The oven dried specimen was immersed in 20 ± 50C water for 24 h, removed, wiped with a damping cloth immediately, and weighed to obtain the wet mass Wwet. The water absorption was calculated by these following equations:

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



**Figure 1. Pervious concrete specimens of cubes and cylinders**

**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. 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 2. Effect of curing period on compressive strength**

**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], 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. The results are represented in figure 5.

**Table 3. Density and water absorption**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Mixes** | **W1****(g)** | **W sat****(g)** | **V****( m3)** | **Theoretical****Unit weight****(Kg/m3)** | **Practical unit weight****(Kg/m3)** | **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)** | **Vw=ɤ s** | **Vv****(vt - vw)** | **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**

**CONCLUSIONS**

The following are the findings form the above research study

1. 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).
2. Similarly to compressive strength, M2 mix is proven to be the ideal mix for split tensile strength by the experiment demonstrated in earlier chapters.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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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