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Increasing the Strength of Pervious Concrete While Maintaining Permability

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ABSTRACT Pervious concrete is a sustainable construction material developed to mitigate urban issues such as stormwater runoff, reduced groundwater recharge, and surface flooding. This study focuses on the design and experimental evaluation of a pervious concrete mix aimed at achieving adequate mechanical strength while ensuring desirable permeability. The investigation involved selecting suitable aggregates, determining an appropriate water–cement ratio, and incorporating admixtures to enhance overall performance. Compressive strength, tensile strength, and permeability tests were conducted to assess the mix's applicability in pavements and low-traffic areas. The results demonstrated that the proposed mix design offers a practical balance between structural integrity and permeability, highlighting its potential as an environmentally friendly alternative to conventional paving materials. Additionally, the paper discusses challenges encountered during mix design and implementation and suggests directions for future research to enable its effective use in large-scale applications.

INDEX TERMS Pervious concrete, Sustainable Engineering,

I. INTRODUCTION

RAPID urbanization has led to extensive construction of impervious surfaces such as asphalt and conventional concrete pavements, which disrupt the natural hydrological cycle. These surfaces prevent water infiltration, resulting in increased surface runoff, urban flooding, and reduced groundwater recharge. In response to these environmental concerns, there has been a growing interest in sustainable construction materials that support stormwater management. One such material is pervious concrete, a special type of concrete with a high void content that allows water to pass through its structure.

Pervious concrete is composed of coarse aggregates, cement, water, and little to no fine aggregates. Its interconnected pore network enables infiltration of rainwater, making it suitable for sidewalks, parking lots, driveways, and low-traffic roads. In addition to hydrological benefits, pervious concrete can reduce the urban heat island effect, improve skid resistance, and contribute toward LEED (Leadership in Energy and Environmental Design) credits in green building certification systems.

Despite its advantages, the widespread use of pervious concrete has been limited due to challenges in achieving an optimal balance between permeability and mechanical strength. In this study, we focus on the effects of the water-cement ratio on the physical properties of pervious concrete. To this end, two batches of 6 pervious concrete cylinders, with the second batch having a lower water-cement ratio, were made, and tested for compresssive strength, split tensile strength, and permeability. Superplasticizer (SP) was used to increase the workability of the mixes made with the second recipe.

II. EXPERIMENTAL SETUP

Two batches of 6 cylinders each were cast. Common to both batches were the cementitious material which was a mixture of cement and fly-ash in the ratio of 4:1 by mass, coarse aggregates whose sizes ranged from 4.75-9.5 mm, and polypropylene fibres (PPF). The proportions for the rest of the materials used are given in table 1.

III. TESTING METHOD

The samples were tested after 14 and 28 days for tensile and compressive strenghts, and after 28 days for permeability.

A. COMPRESSIVE STRENGTH

The sample was placed in the universal testing machine (UTM) on one of its circular faces, and compressed. The

TABLE 1. Mix Design

	Batch 1	Batch 2
Cement, kg/m^3	280	280
Coarse Aggregate, kg/m^3	1420	1420
Fly-ash, kg/m^3	70	70
Water, kg/m^3	119	95.2
SP, %[1]	—	0.5
PPF, %[2]	0.2	0.2

[1] of cementitious material
[2] of aggregates

pace rate was set to 1.8 KN/s. The compressive strength f_c is calculated with the formula

$$f_c = \frac{P}{A}$$

where P is the maximum force on the sample, and A is the area over which the force is applied.

B. TENSILE STRENGTH

The tensile strength was found using the Brazilian test, in which, the sample was placed horizontally, in between two metal bars oriented parallel to the axis of the sample, inside the UTM. The tensile strength f_t was calculated with the formula

$$f_t = \frac{2P}{\pi LD}$$

where P is the force at the point of failure, and L and D are respectively the length and the diameter of the sample.

C. PERMEABILITY

The tensile strength was found using a makeshift falling head permeameter. By measuring the time taken for the head to move from a height h_1 down to h_2, the permeability k can be calculated using the formula

$$k = \frac{aL}{At} \ln \frac{h_1}{h_2}$$

where a is the cross-sectional area of the standpipe, t is the time taken for the head to fall from h_1 to $h - 2$, and L and A are the dimensions of the sample.

IV. RESULTS

TABLE 2. Compressive and Tensile Strength

	Compressive, *Mpa*		Tensile, *Mpa*	
	14	28	14	28
Batch 1	5.62	7.49	0.71	0.85
Batch 2	8.02	10.08	1.15	1.33

Results of the compressive and tensile tests at the end of 14 and 28 days of curing.

From the results given by table 2, it is apparent that the amount of water used in the mix greatly affects the final strength of the concrete, with the ones having a lower water-cement ratio outperforming the ones with a higher water-cement ratio. The results of the permeability tests shown by table 3 imply that the permeability decreases with the increase in the water content of the mix.

TABLE 3. Permeability

	14	28
Batch 1	2.90	1.73
Batch 2	1.93	1.15

Results of the permeability (mm/s) tests at the end of 14 and 28 days of curing.

V. CONCLUSION

Pervious concrete is shaping up to be a promising solution to the serious environmental caused by the lack of water reclamation by the soil due to the impervious nature of regular concrete, something that paves a large portion of our land. However, the use of pervious concrete is, as of now, limited to pavements and parking lots, due to its relatively low strength. From the tests of the two mixes, it can be seen that strength and permeability are inversely proportional to each other, and that the optimal mix should find a balance between the two. The mix proposed in this paper, although not by any means optimal, comes somewhat close to achieving this, performing reasonably well in permeability, as well as strength tests.

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