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Investigation on permeability characteristics of pervious concrete

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ABSTRACT

Abstract: Concrete is widely used structural material consisting essentially of a binder and a mineral filler. Concrete has been the leading material since it was used and is bound to maintain its significant role in the upcoming future due to its durability, adaptability to any shape and size and many other applications. It is a composite material produced by mixing cement, an inert matrix of sand and gravel or crushed stone. Pervious concrete is a type of concrete that has a low water-cement ratio and contains none or very little amount of sand. In the present paper, the behavior of pervious concrete has been studied experimentally to reduce urban heat island effect and sustainable solution. Various specimens were prepared with Cement/Aggregate (C/A) ratio of 1:3 and 1:5 by adding super plasticizers (0.2% & 0.3%) and varying size of aggregates. The water-cement ratio was kept constant 0.30. Different properties of pervious concrete e.g. compressive strength, split tensile strength, rebound hammer test at 28 days and Infiltration rate test for C/A ratio of 1:3 and 1:5 have been studied experimentally. Experimental results showed that the strength of pervious concrete decreased with the increase in C/A ratio and also the permeability is decreasing with the increase in strength i.e., with the decrease in C/A ratio.

Keywords— *Permeable concrete, Cement/Aggregate ratio, Super plasticizer, NDT test, Infiltration Rate test*

1. INTRODUCTION

Pervious concrete has the same basic constituents as conventional concrete, 15 -30% of its volume consists of interconnected void network, which allows water to pass through the concrete. In the absence of fine aggregates, pervious concrete has connected pores size range from 2 to 8 mm, and the void content usually ranges from 15% to 25% with compressive strength of 2.8 MPa to 28 MPa. Pervious concrete can be used in a wide range of applications, although its primary use is in pavements which are in residential roads, alleys and driveways, low volume pavements, low water crossings, sidewalks and pathways, parking areas, tennis courts, slope stabilization, sub-base for conventional concrete pavements etc.

1.1 Objectives of the project

The objectives of this work are:

(a) To find out a variation in compressive strength of pervious concrete blocks at varying C/A ratio.
(b) To investigate the permeability characteristics of pervious concrete blocks.
(c) To compare the Infiltration rate for Cement/Aggregate ratio of 1:3 and 1:5.

2. LITERATURE REVIEW

Nader Ghafoori conducted extensive research on various aspects of pervious concrete. In one study, he investigated various sites throughout the United States that have utilized pervious concrete paving systems. His investigation led to a comparison of compressive strength attained at each of these sites [2].

V.M. Malhotra concluded that the compressive strength of pervious concrete was dependent on the water-cement ratio and the aggregate-cement ratio [3].

Meininger studied the effect of different aggregate sizes (10mm and 19mm) on hardened properties of non-fine concrete and the results showed that compressive strength reduces with increase in aggregates size, which corresponded with the results found from Yang and Jing (2003). It claimed the decrease of aggregate size led to higher pervious concrete strength, resulting from the increase of the interface strength between the aggregate and cement paste [4].

Paul Klieger performed experiments studying the effects of entrained air on the strength and durability of conventional concrete. Although never utilizing the number of voids seen in pervious concrete (15%-35%), his research clearly shows the impact the presence of air has on the performance of concrete [5].

3. METHODOLOGY

(a) Collection of materials required for the study was done.
(b) Testing of materials was done to determine their properties. Mix design was done using the obtained data. Mixing of the materials is accomplished as per the mix design.
(c) The materials required to prepare pervious concrete are mixed properly and is filled in the moulds in 2 layers and compacting them by giving 20 blows for each layer with the standard proctor rammer. The pervious concrete moulds are prepared for two different cement/aggregate ratios.
(d) They have left aside and are demoulded after 24 hours and are placed in water for curing for a period of 28 days.
(e) These blocks are tested for compressive strength, flexural strength, split tensile strength and permeability.
(f) Nondestructive testing methods like Rebound Hammer test are also conducted for each block.

4. MATERIAL AND EXPERIMENTAL INVESTIGATION

4.1 Raw materials used

The various raw materials used are:

(a) Ordinary Portland cement (OPC grade 53 cement)
(b) Coarse aggregate (Aggregates passing through 10mm and retained on 6.3mm IS sieve)
(c) Conplast SP430 super plasticizer is a chloride free, superplasticsing admixture based on selected sulphonated napthalene polymers

The raw materials used are tested for various characteristics. Cement is tested for Standard Consistency, Initial Setting Time, Fineness, Specific gravity, and Soundness. Coarse aggregates are tested for specific gravity, abrasion resistance, Crushing value and impact value and water absorption. To perform the experimental investigation on cubes, cylinders and slab (Infiltration test), initially, the materials (ingredients of the mix) were tested for characterization of its physical properties and the same is verified for its suitability to use it in the mix design. Laboratory tests were performed on mixes for evaluation of performance characteristics.

4.2 Mix design

Aggregate size = 6.3mm, Water/Cement ratio=0.30
C/A Ratio = 1:3, Air voids = 20%
Weight of Cement = 467.739 Kg/m^3
Weight of aggregate = 1403.216 Kg/m^3
Weight of Water= 140.322 Kg/m^3

4.3 Casting of pervious concrete

(a) The concrete mixture which is mixed in mixing machine is taken into the metal pan. The concrete mixture is then placed in the moulds in two layers and each layer is given 20 blows with the standard proctor rammer to compact the mixture thoroughly.

Fig. 1: Compaction with standard proctor rammer

(b) After placing in the mixture in moulds the moulds are left over for 24 hours. After 24 hours the specimens are demoulded and kept in curing tank for curing.
(c) The specimens are left in curing tank for 28 days. After 28 days the specimens are removed from the curing tank and are dried.
(d) The tests like compressive strength, split tensile strength and permeability were done on the specimens.

5. RESULTS AND DISCUSSION

5.1 Aggregates

Aggregates were used from the local quarry. The physical properties of aggregate obtained through laboratory test are shown in Table 1 and found to be satisfactory.

Table 1: Test results for physical properties of coarse aggregates

Property	**Laboratory Results**
Abrasion resistance value	21.12 (%)
Aggregate impact value	24.46 (%)
Aggregate Crushing value	21.81(%)
Flakiness Index	13.2 (%)
Elongation Index	21.63(%)
Specific gravity	2.7
Water absorption	0.25 (%)

5.2 Cement

Cement was tested in the laboratory and its properties are shown in table 2.

Table 2: Test results for physical properties of Cement

Property	Laboratory Results
Standard Consistency	31 (%)
Fineness of cement	2.6 (%)
Specific gravity	3.01
Soundness of cement	2mm

5.3 Tests on Hardened pervious concrete

The various tests conducted on pervious concrete are

1. Rebound hammer test
2. Split tensile test
3. Compressive strength test
4. Infiltration rate test

5.3.1 Rebound hammer test is conducted on both cylindrical and cubical specimens after 28 days

Table 3: Rebound hammer test results on cylindrical specimens

C/A ratio	Rebound index	Compressive strength (MPa)
1:3	29	24
	21	12
	28	22
1:5	20	10
	19	10
	22	13

Fig. 2: Rebound hammer test on a specimen

Table 4: Rebound hammer test results on cubical specimens

C/A ratio	Rebound index	Compressive strength (MPa)
1:3	43	48
	43	48
	42	46
1:5	24	16
	33	30
	37	37

5.3.2 Split tensile test conducted on cylindrical specimens

Table 5: Split tensile test results on cylindrical specimens

C/A ratio	Peak load (KN)	Peak stress(MPa)
1:3	97.8	5.5
	97.2	5.4
	97.0	5.4
1:5	45.2	2.5
	42.7	2.4
	70.1	3.9

Fig. 3: Split Tensile test on specimen

5.3.3 Compressive strength test is conducted on cubical specimens

Table 6: Compressive Strength test results on cubical specimens

C/A ratio	Peak load (KN)	Peak stress (MPa)
1:3	351	15.6
	572.2	25.4
	488.0	21.6
1:5	333.4	14.8
	256.3	11.3
	264.7	11.7

Fig. 4: Compression test on a specimen

5.3.4 Infiltration rate test

Infiltration rate test is conducted on small slabs 23cm X30cm. According to ASTM C 1701, the infiltration rate of the pervious concrete is calculated by using the following formula.

$$I = KM / D^2 t \quad (1)$$

Where, I = Infiltration rate, mm/h
K = Constant=4,583,666,000 in SI units
M = Mass of infiltrated water, Kg
D = Diameter of infiltration ring, mm
t = Time required for measured amount of water to infiltrate the concrete

For C/A ratio of 1:3

t = 57 sec, M = 1 Kg, D = 71 mm

$$I = \frac{4{,}583{,}666{,}000\ x\ 1}{71^2 x\ 57}$$

=15952 mm/h
= 0.44 cm/s

For C/A ratio of 1:5

t = 28 sec, M = 1 Kg, D = 71 mm

$$I = \frac{4{,}583{,}666{,}000\ x\ 1}{71^2 x\ 28}$$

I = 32474 mm/h
= 0.90 cm/s

Fig. 5: Infiltration rate test setup

Fig. 6: Previous concrete

6. CONCLUSIONS

- From the test results, it can be concluded that the permeability and the compressive strength of the concrete dependents on the C/A ratio, size of aggregate, Water/Cement ratio.
- As the C/A ratio increases the Infiltration rate of the pervious concrete increases.
- At 1:3 C/A ratio mix the compressive strength of concrete is 65% more when compared with 1:5 C/A ratio mix. This indicates that as C/A ratio increases the compressive strength of the previous concrete decreases.
- From the NDT test (Rebound hammer test), the Compressive strength of a cube value for 1:3 C/A ratio mix is 43% more than for 1:5 C/A ratio mix and that of for a cylinder it is 41.6% more than that of 1:5 C/A ratio mix.
- The Split Tensile strength value is almost 57.6% more for the 1:3 C/A ratio mix.

7. FUTURE SCOPE

Regarding its durability performance, there is a concern about the freezing and thawing and deicing salt resistance of pervious concrete [1], which deter its wider application in colder climates. Nevertheless, there have been a number of previous concrete pavement projects in wet and freezing environments, demonstrating good field performance over several years. Thus, more research is needed to address this issue, especially regarding the appropriate test methods that should be used to evaluate the frost and salt frost resistance of pervious concrete.

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