TO DEVELOP METHOD TO FIND OUT PERMEABILITY AND VOID RATIO FOR PERVIOUS CONCRETE

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Synopsis

Concrete is one of the most widely used material in the construction industry. Also many roads are made of concrete base. Many problems are their related to concrete roads in which one of the most leading problem is waterlogging. As there are many uncertainties in rainfall, designed rainwater collection pipe fails due to excessive rainfall and due to which waterlogging over roads occurs. The development of pervious concrete offers promising signs for a change in the way of producing concrete pavements. Void content and permeability of cube was carried out and also void content and permeability of cylinder was carried out. It was found that as the void content increases, permeability increases while compressive strength decreases.

***Keywords**: Void ratio, Permeability, Falling head method*

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1. INTRODUCTION

Pervious concrete which has an open cell helps significantly to provide high permeability due to its interconnected pores. Pervious concrete is a special type of concrete with a high porosity used for concrete at work applications that allows water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing groundwater recharge. Pervious concrete is made using coarse aggregates with little to no fine aggregates.

In Pervious concrete, accurately and well-proportioned amounts of water and cementitious materials are used to create a cementitious paste that forms a thick coating around the aggregate particles. A pervious concrete mixture contains little or no sand, which creates a structure having a good amount of void content. By using sufficient cementitious paste for coating and binding the aggregate particles together creates a structure of highly permeable, interconnected voids that allows water to drain off quickly.

2. LITERATURE REVIEW

2.1 Void Content

Void content for pervious concrete ranges from 15% to 35%. More porosity leads to a high permeability of pervious concrete.
Figure 2.1 shows a general relationship between void ratio and 7-days & 28-days compressive strength. Compressive strength of pervious concrete reduces as the void ratio increases. For pervious concrete, the void ratio mostly depends on porosity.

2.2 Compressive strength

The Pervious concrete has high void content. Due to this, the compressive strength of pervious concrete is lower than that of the conventional concrete. The average compressive strength of pervious concrete is around 15 MPa, while the lowest strength of 2.5 MPa and the highest strength of 34.5 MPa are achieved.
Gyanen.Takhelmayum&Suresha S.N [1] achieves a compressive strength between 4.3-9.7 MPa at 7-days and between 7.9-13.2 MPa at 28-days. The cement content is varying from 250-375 kg/m3 It is shown in Figure 2.2 and Figure 2.3.
As per Tennis et.al [2] pervious concrete mixtures attains a compressive strengths in the range of 3.5 MPa to 28 MPa. Typical values are about 17 MPa. The actual on-place compressive strength is a_ected by the properties and typical range of ingredient materials along with placement techniques and site conditions. The aveage compressive strength of pervious concrete is around 20 MPa while the lowest is of 2.5 MPa.

2.3 Permeability

Permeability directly depends on the void content of pervious concrete. As the void content increases the permeability increases.
C. Lian and Y. Zhuge[3] found that the trend of permeability is inverse to that of compressive strength for pervious concrete. The minimum point takes place at w/c ratio of 0.34, where the permeability is down to 1.22 mm/s.Taking the value of 0.34 as a threshold, once the amount of water overran this threshold, the permeability of pervious concrete went up straight, reaching 8.42 mm/s. It is shown in figure 2.4.

Falling Head Test Method

The falling head method recommended by ACI and developed by Neithalath et al.[4] is used to determine the water permeability of pervious concrete. The schematic diagram of the falling head method for permeability testing is given in figure 2.5.
The falling head method by Neithalath et al. [4] measures the time taken by water level to fall from initial water head (H1) to the final water head (H2), and waterpermeability is then calculated using Darcy's First Law.

3. EXPERIMENTAL PROGRAMME

3.1 Materials Used

The materials used were cement of 53 grade OPC, coarse aggregate passing through 20mm IS sieve and retained in 10mm IS sieve and tap water.

3.2 Mix Proportion

The mix proportioning for pervious concrete is different than the usual mix design of normal concrete. For pervious concrete mix design code provision is not available. So the mix design is adopted based on the literature review.As per Table 3.1.

3.3 Mechanical Properties

3.3.1 Compressive Strength

The compressive strength of pervious concrete is evaluated on a 2000 kN capacity compressive testing machine. For the compressive strength test, cubes of size 150 mm x 150 mm x 150 mm were tested.

Compressive strength (MPa) $=\frac{P \times 100}{A}$ (3.1) where,

P = Failure load of cube (kN)
A = cross sectional area of cube (22500 mm2)

3.3.2 Void Ratio

3.3.2.1 Void Ratio by Theoretical Approach

(ASTM C1688)

The void content is measured according to ASTM C1688 [5]. The void content is measured as follows.

$$\text{Void content (\%)} = \frac{T - D}{T} * 100 \quad (3.2)$$

$$D = \frac{Mc - Mm}{Vm} \quad (3.3)$$

$$T = \frac{Ms}{Vs} \quad (3.4)$$

where,
Mc= mass of measure filled with concrete
Mm = mass of measure
Vm = volume of measure
Ms = total mass of all materials batched
Vs = sum of absolute volume of each ingredient equal to the quotient of mass of thatingredient divided by the product of its specific gravity times the density of water
Sample Calculation

This sample calculation includes Size B aggregates with 300 kg/m3 with 0.3 w/c ratio and 0% sand. The value below is average of 5 cubes.
Mc– Mm = 32.04 kg
Vm= (5 * 0.003375) = 0.016875 m3
D = 1898.66 Kg/m3
Ms = [5.56875 + 22.275 + 1.67025] = 29.514 kg
Vs = 0.01165766 m3
T = 2531.7249 kg/m3
% void content = 25%

3.3.2.2 Void Ratio By Practical Approach

1. Weigh the dry concrete sample.
2. Weight the empty container.
3. Fill the container with water at initial level and weigh it.
4. Place the dry sample inside the water container (approx. 5 min).
5. Empty the water upto initial level and weigh it.

Wsdry = Dry Concrete weight

Wc = weight of empty container

Wc+w = Weight of container with water at initial level

Ww1 = Wc+w -Wc= mass of water (3.5)

Wc+w+s = weight of container with sample with water at initial level

Ww2 = Wc+w+s- Wc – Wsdry= weight of water in the container (3.6)

Ww3 = Ww1 - Ww2 = Mass of water displaced (3.7)

Vw = Ww2/γw (3.8)

$$\% \text{ of voids} = \frac{Vs - Vw}{Vs} * 100 \quad (3.9)$$

3.3.3 Permeability

For the measurement of the permeability instrument suggested by the ACI is setup. The falling head method was used to measure the water permeability. Figure 3.1shows the schematic diagram of the permeability test. 300 mm and 450 mm waterheads were adopted for measuring permeability. For measuring permeability cylinderof size 150 x 150 mm are casted. Cylinder are casted in the PVC pipe. Water permeability is then calculated using Darcy's First Law. The equation is as follows:

$$K = \frac{a\,H}{A\,t} * (\log\frac{H1}{H2}) \quad (3.10)$$

Where,

k = Coefficient of water permeability

a= cross-sectional area of graduated cylinder

A= cross-sectional area of specimen

H = height of the specimen

t = time

H1 = the initial water head

H2 = the final water head

4. RESULTS AND DISCUSSION

It was found that permeability is directly proportional to void content as the void content increases permeability also increases and vice-versa. The average compressive strength was around 9 MPaas shown in table 4.1, Void content was nearly 29.8%as shown in table 4.2while permeability was ranging from 18- 22 mm/sas shown in table 4.3.

Fig 4.1 shows the relation between Permeability v/s void ratio

Fig 4.2 shows the relation between compressive strength v/s void ratio

5. CONCLUSION

Following are the conclusions draws out from this work

- The average value of permeability ranged between 15 mm/sec and 24 mmm/sec , which is within the expected range found in literature.
- Compressive Strength value which is also within the desirable range of 7 MPa to 12 MPa.
- Fig. 4.1 shows the relation between the Void ratio and Permeability. As the Void ration increases the Permeability also increases.
- Fig. 4.2 shows the relation between the Void ration and Compressive strength. As the Void content increases the Compressive strength decreases.

6. NOTATIONS

a= cross-sectional area of graduated cylinder

A= cross-sectional area of specimen

ACI = American Concrete Institute

ASTM = American standard for Testing Material

H = height of the specimen

H1 = the initial water head

H2 = the final water head

k = Coefficient of water permeability

kN = kilo newton

Mc = mass of measure filled with concrete

Mm = mass of measure

mm = millimeter

MPa = mega pascal

Ms = total mass of all materials batched

OPC = Ordinary Portland Cement

PVC = Polyvinyl Chloride

t = time

Vm = volume of measure

Vs = sum of absolute volume of each ingredient equal to the quotient of mass of thatingredient divided by the product of its specific gravity times the density of water

Vw = Volume of Water

Wc = weight of empty container

Wc+w = Weight of container with water at initial level

Wc+w+s = weight of container with sample with water at initial level

Wsdry = Dry Concrete weight

Ww1 = mass of water

Ww2 =weight of water in the container

Ww3 = Mass of water displaced

γ_w= Unit weight of water

7. REFERENCES

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8. TABLES AND FIGURES

8.1 Figures

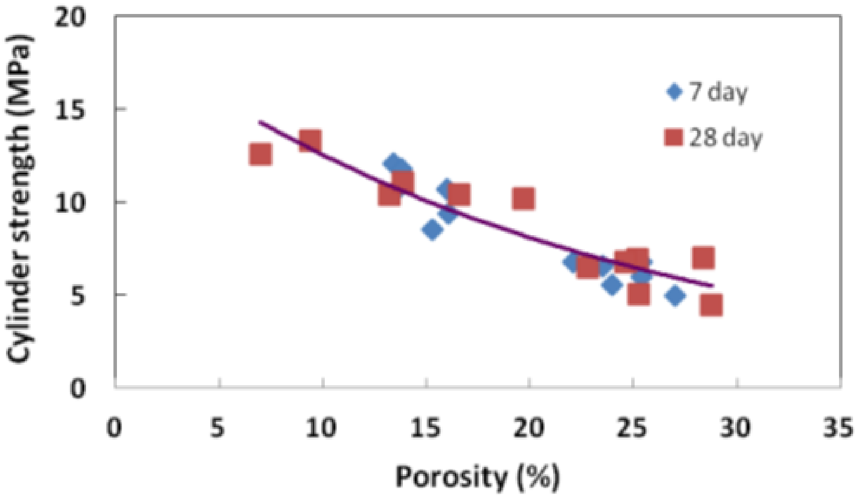

Figure 2.1: Relationship between void ratio and compressive strength

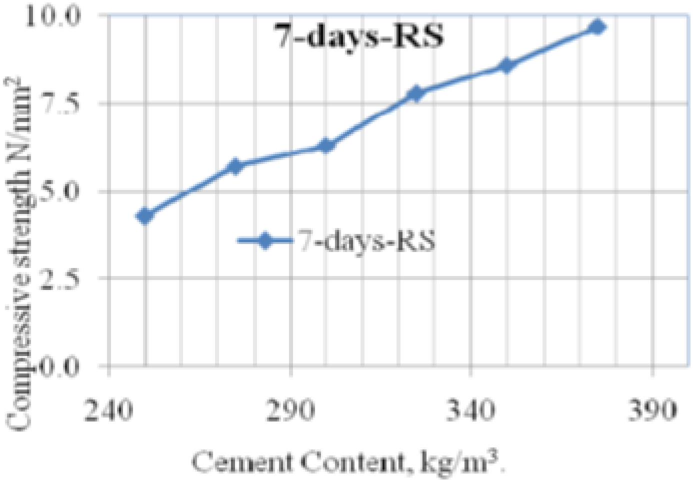

Figure 2.2: Compressive strength for a curing period of 7-day.

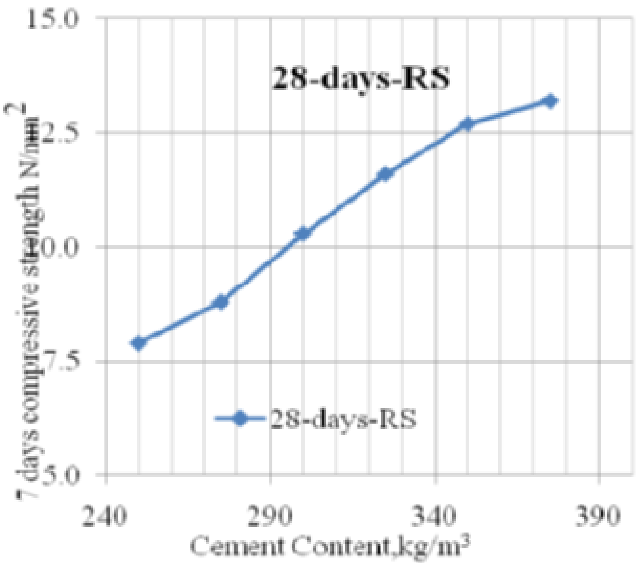

Figure 2.3: Compressive strength for a curing period of 28-day

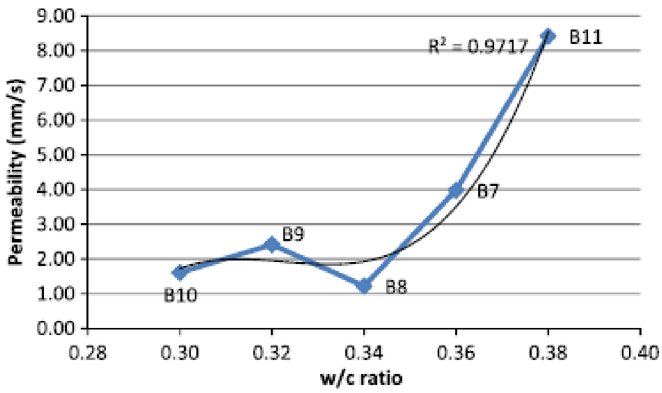

Figure 2.4: Relationship between w/c ratio and permeability

Figure 3.1: Falling head method for permeability testing

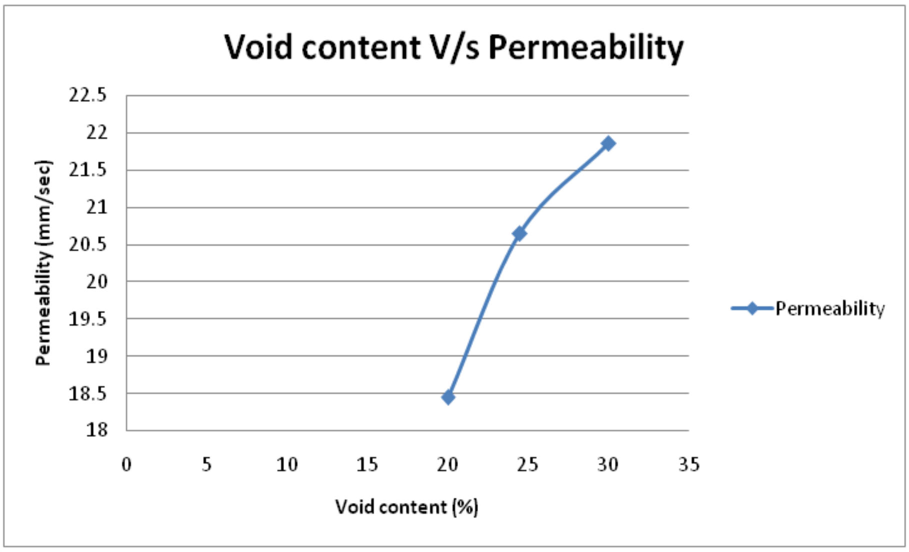

Fig 4.1 Relation between void content and Permeability

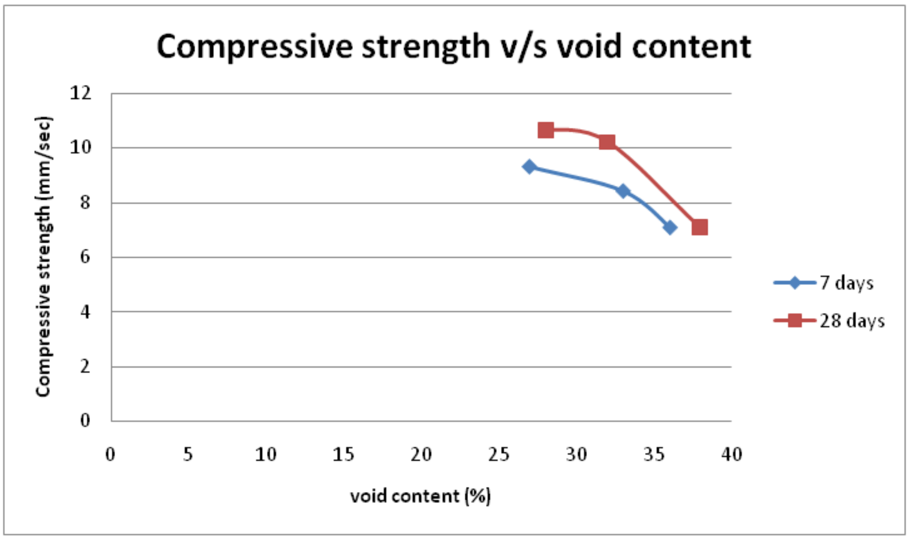

Fig 4.2 Relation between compressive strength v/sVoid content

8.2 Tables

able 3.1 Mix Design

Materials	Quantity
Cement	300 kg/m3
Aggregate / Cement ratio	1 : 4
Water / Cement ratio	0.30
Sand	0%

Table 4.1 Compressive strength

	7 days				28 days			
	Cube 1	Cube 2	Cube 3	Average	Cube 4	Cube 5	Cube 6	Average
Weight (kg)	6.5	6.11	6.31	6.31	6.3	6.54	6.2	6.35
Load (kN)	160	210	190	186.6	240	230	160	210
Density (kg/m3)	1926	1810	1870	1869	1866	1938	1837	1880
Strength (MPa)	7.11	9.33	8.44	8.30	10.67	10.22	7.11	9.33

Table 4.2 Void Ratio Calculation

Sample no.	Wsdry	Wc	Wc+w	Ww1	Wc+w+s	Ww2	Ww3	Vw	Vs	%
Cube										
1	6.31	0.92	11.13	10.21	15.29	8.06	2.15	0.00215	0.003375	36
2	6.50	0.92	11.13	10.21	15.18	7.76	2.45	0.00245	0.003375	27
3	6.11	0.98	11.57	10.59	15.45	8.36	2.23	0.00223	0.003375	33
4	6.54	0.98	11.58	10.6	15.69	8.17	2.43	0.00243	0.003375	28
5	6.30	0.98	11.58	10.6	15.61	8.33	2.27	0.00227	0.003375	32
6	6.2	0.98	10.98	10	15.1	7.92	2.08	0.00208	0.003375	38
Cylinder										
1	5.04	0.98	9.58	8.6	12.5	6.48	2.12	0.00212	0.00265	20
2	5.10	0.98	9.70	8.72	12.8	6.72	2	0.002	0.00265	24.5
3	5.2	0.98	9.80	8.82	13.15	6.97	1.85	0.00185	0.00265	30
Average Void Content (%) = 29.8										
All Weight (W) are in kg. All Volume (V) are in m3										

Table 4.3 Permeability by falling head method

Cylinder No.	Head (mm)	Time (sec)	Permeability(mm/sec)	Avg.
1	300	20	18.45	20.31
2	300	18	20.64	
3	300	17	21.85	