AN EXPERIMENTAL STUDY ON COMPRESSIVE STRENGHT AND PERMEABILITY OF POROUS CONCRETE WITH THE USE OF FLY ASH FOR THE PAVEMENT PURPOSE

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Abstract: Many places were covered with impermeable surfaces like cement concrete road and bitumen road it leads to major impact on the ground water level. Pervious Concrete pavement is one of the most effective way to minimize this issue and to improve the ground water table. Pervious concrete is an open graded structure in which rain and storm water is permitted through interconnected voids. Porous concrete is a permeable material which is a mixture of coarse aggregate, cement, water and little amount of sand or no sand along with or without admixtures. Porous concrete is a new and most useful concept to increase the ground water table. The main aim of this work is to study the compressive strength and permeability of porous concrete by replacing the cement by fly ash with different amount.

Unconfined compressive strength tests and permeability test were carried out on pervious concrete specimens with fly ash contents of 0%, 10%, 20%, 30%, 40% by weight of the total cementitious materials.

***Index Terms* – Porous concrete, fly ash, compressive strength, permeability.**

I. INTRODUCTION

1.1 GENERAL

"Porous concrete is a special type of concrete which is highly permeable used for concrete flat work applications that allows rain and storm water from precipitation and other sources to pass through it, thereby reducing the runoff from a site and increasing the ground water table." It is also known as "no-fines concrete" and is mixture of Portland cement, coarse aggregate, water, chemical admixtures, and little or no sand.

Pervious pavements are also known as porous pavements. In this pavement systems are provided inter-connected network of void spaces. Pervious pavements are an important role play towards improving the ground water table.

1.2 OBJECTIVE OF PRESENT WORK

The main objective of this study is to investigate the effects on the compressive strength and permeability of pervious concrete with and without the use of fly ash.

The following objectives are analysed in this study: -

1.The parameters that affect the compressive strength of pervious concrete will be analysed.
2.The potential use of pervious concrete containing a large portion of fly ash will also be discussed.
3.Different amount of cement like (0%, 10%, 20%, 30%, 40%) is replaced by fly ash and check the compressive strength.
4.Check the how-to compressive strength of porous concrete is increased with time.
5.Comparing the compressive strength results of all samples at a different time period of 7,14 and 28 days.
6.Compare the permeability test results of all porous concrete block samples.

II. LITERATURE REVIEW

Yang J. and Jiang G. (2003) have evaluated the experimental study on properties of pavement material. In the present study porous material were introduced for roadway application. By introduction of smaller sized aggregate, super plasticizer and silica fume can enhance the strength of the pervious concrete. It is concluded that the material can achieve maximum compressive strength of 50 MPa and the flexural strength 6 MPa. Controlling the pressing force to keep the unit weight of 1900-2100 kg/m3 can ensure good wear penetration.

Chouhan J.S, Jain A.K and Goliya S.S. (2011) have studied the effect of shape of aggregate on compressive strength and permeability properties of pervious concrete. It found that the strength and permeability of pervious concrete depend upon the shape and size of the aggregate and water to cement ratio. It may be concluded that for all sizes of aggregates and compressive strength of pervious concrete vary inversely with the angularity number of the aggregate. Similarly, for all types of aggregates pervious concrete mix prepared using smaller size of aggregates demonstrated higher compressive strength.

Fu T C (2014) have studied the influence of aggregate size and binder material on the properties of pervious concrete. Specimens were prepared by altering parameters such as aggregate sizes, binder materials and the amounts of binder used and subsequently tested by using permeability, porosity, mechanical strength, and soundness tests. The results indicated that the water permeability coefficient and connected porosity decreased as the amount of binder used increased and increased with increasing aggregate size. In the mechanical strength test, the compressive, splitting tensile and flexural strengths increased as the amount of binder used increased and decreased with the increase of aggregate size.

Maguesvari M.U. and Narshima V.L., (2013) have Studies on characterization of pervious concrete for pavement application. The study gives a preliminary idea about the influence of fine aggregate and coarse aggregate on the properties of pervious Concrete. The raw materials used are OPC type-1 and fine aggregate size between 4.75 -9mm, 9-12.5 mm, 12.5-16 mm, 16-19.5 mm. The mixes were made by maintaining water cement ratio of 0.34, cement content is 400 kg/m3 and aggregate cement ratio is 4.75:1. The study concluded that, the compressive strength is noted 10-26 N/m2 when the angularity number varied from 8 to 4. Similarly, coefficient of permeability increases form 0.4 cm/sec to 1.26 cm/sec when the angularity number is in the range of 4 to 8.

III. MATERIALS

3.1 PORTLAND CEMENT

All materials that go into pervious concrete mix are essential, but the cement is very often the most important because it is usually the delicate link in the chain. The function of cement is first of all to bind the fine aggregate, coarse aggregate and admixtures together and second to fill up the voids in between sand and stone particles to form a compact mass. It constitutes only about 20 percent of the volume of porous concrete mix; it is used as a binding material and is the only scientifically controlled ingredient of porous concrete. Any variation in its quantity affects the compressive strength of the pervious concrete mix.

TABLE 3.1: PROPERTIES OF OPC 43 GRADE CEMENT

Sr. No.	Characteristics	Values Obtained Experimentally	Values specified by IS 8112:1989
1.	Specific Gravity	3.14	-
2.	Standard Consistency, percent	28	-
3.	Initial Setting Time, minutes	152	30 (minimum)
4.	Final Setting Time, minutes	261	600 (maximum)
5.	Compressive Strength 7 Days 28 Days	38.2 N/mm2 47.3 N/mm2	33 N/mm2 (minimum) 43 N/mm2 (minimum)

3.2 COARSE AGGREGATES

The aggregate which is retained over IS sieve 4.75 mm is called as coarse aggregate. The coarse aggregates may be of following types: - Crushed gravels or stone obtained by crushing of gravel or hard stone or uncrushed gravels or stones resulting from the natural disintegration of rocks. Partially crushed gravel or stone is obtained as a product of blending of above two types. The coarse aggregates used in the present study were a mixture of two locally available crushed stones of 20 mm sizes.

TABLE 3.2: PROPERTIES OF COARSE AGGREGATES

Characteristics	Value
Color	Grey
Shape	Angular
Maximum size	20 mm
Specific Gravity	2.69
Water Absorption	0.50%

3.3 FLY ASH

Fly ash is the residue obtained from combustion of pulverized coal collected by the mechanical or electrostatic separators from the fuel gases of thermal power plants. Fly ash consists primarily of spherical glassy particles ranging from 1 to 150 micrometers in diameter, out of which the bulk passes through a 45 -micrometer sieve. The fly ash obtained from electrostatic precipitators is finer then OPC.

Fly ash was obtained from Sarini Power Plant which is situated near the Betul district, Madhya Pradesh which is having specific Gravity of 2.3. The fly ash which is obtained for testing purpose is in dry powdery form. It was carried in the required amount in plastic bags and the properties of it is further tested in the civil engineering laboratory.

TABLE 3.3: CHEMICAL COMPOSITION OF C-FLY ASH

S.No.	Chemical Analysis	Class C-Fly Ash (%)	ASTM Requirement (%).
1.	Silicon dioxide sio2	55.3	-
2.	Aluminum oxide al2o3	25.70	-
3.	Ferric oxide, fe2O3	5.30	-
4.	Sio2 + al2o3 + fe2O3	85.9	70.0 minimum
5.	Calcium oxide, cao	5.60	-
6.	Magnesium oxide mgo	2.10	5.0 maximum
7.	Titanium oxide tio2	1.30	-
8.	Potassium oxide k2o	0.60	-
9.	Sodium oxide nao	0.40	1.5 maximum
10.	Sulfur trioxide so3	1.40	5.0 maximum
11.	LOI (1000˚c)	1.90	6.0 maximum
12.	Moisture	0.30	3.0 Maximum.

3.4 WATER

The potable water is generally considered satisfactory for mixing and curing of pervious concrete. Accordingly, potable water was used for making pervious concrete available in material testing laboratory. It was free from any detrimental contaminants and was good potable quality.

IV. MIX DESIGN

The preferred characteristic strength of 15 N/mm2 at 28 days was opted in this study.IS 456-2000, IS: 10262-2009 method was performed in designing the mix. Sums of 45 cubes have been prepared for this experimental work. All set were prepared in control mix in w/c = 0.55. 3 samples from every set of the mix were tested at the age of 7, 14, and 28 days for compressive strength.

As per Indian Standard method of mix design (as per IS: 456-2000, IS: 10262-2009) the mix design of plain concrete is carried Out as: -

- **a)** Design data and test data for material
- **b**) Target Mean Strength of concrete mix
- **c)** Proportion of water-cement ratio
- d) Calculation of water content
- **e**) Determination of cement content
- **f**) Mix calculation.

a) Design data and test data for material (as per IS: 456-2000, IS: 10262-2009)

1 Grade of Concrete: **-** M-15
2 Type of Cement: -PPC grade-43
3 Maximum Cement content: **-** 540 kg/m3
4 Minimum Cement content: **-** 300 kg/m3
5 Maximum nominal size of Aggregate: - 20mm
6 Specific gravity of cement: **-** 3.14
7 Specific gravity of water: **-** 1
8 Specific gravity of coarse aggregate: **-** 2.69
9 Water absorption of coarse aggregate: **-** 0.5%

b) Target Mean Strength of concrete mix

Target mean strength for mix proportioning (f 'ck) = fck + 1.65 σ

Where, f 'ck = Target mean compressive strength at 28 days

fck = Characteristic compressive strength at 28 days and

σ = Standard deviation in N/mm2

From Table-3.5, Standard Deviation, σ = 3.5 N/mm2

Therefore, target strength = 15 + 1.65 x 3.5 = 20.77 N/mm2

TABLE-3.4 STANDARD DEVIATION ACCORDING TO IS 456: 2000 (TABLE-8)

Grade of Pervious concrete	Assumed Standard Deviation in N/mm2
M-10	3.5
M-15	3.5
M-20	4.0
M-25	4.0
M-30	5.0
M-35	5.0

c) Proportion of water-cement ratio

TABLE-3.5 MINIMUM CEMENT CONTENT AND MAXIMUM W/C RATIO WITH EXPOSURE CONDITION WITH THEIR GRADES (AS PER IS: 456-2000)

S. No.	Exposure	Minimum Cement Content (in kg/m3)	Maximum Free Water- Cement Ratio	Minimum Grade of Pervious concrete
1	Mild	300	0.55	M-15
2	Mild	300	0.55	M-20
3	Moderate	300	0.50	M-25
4	Severe	320	0.45	M-30
5	Very severe	340	0.45	M-35
6	Extreme	360	0.40	M-40

According to the table no. 3.5, water-cement ratio is used = 0.55

d) Calculation of water content

TABLE-3.6 MAXIMUM SIZE OF AGGREGATE WITH MAXIMUM WATER CONTENT (A/C TO IS 10262-2009)

S.No.	Maximum Size of Aggregates (mm)	Maximum Water Content (Liter)
1	10	208
2	20	186
3	40	165

Maximum water content for 20 mm aggregate = 186 liter

Hence opted water content = 186 liter

e) Determination of cement content

Cement content = water content/ water cement ratio

Cement content = 338.18 kg/m3

(as per IS code IS: 456-2000 from table no. 3.6)

Minimum cement content = 300 kg /m3

338.18 kg /m3 > 300 kg /m3

Hence ok

f) Mix Calculations: -

The mix calculations per unit volume of pervious concrete according to IS code shall be as follows:

Volume of pervious concrete = 1 m3 ……… eq. 1

Volume of cement $= \frac{\text{Mass of cement}}{\text{Specific gravity of cement}} \text{ X } \frac{1}{1000}$

$= \frac{338.18}{3.14} x \frac{1}{1000} = 0.107$ m3 ……………. eq. 2

Volume of water $= \frac{186}{1} x \frac{1}{1000} = 0.186$ m3 ..………. eq. 3

Volume of all aggregate = [eq. 1 – ({eq. 2 + eq. 3})]

= 0.706 m3 ………………… eq. 4

In this experimental work, Volume of total aggregate is distributed to 60% for the coarse aggregate and 40% for the fine aggregate.

Mass of coarse aggregate = (eq. 4) x Volume of coarse aggregate x Specific gravity of coarse aggregate x 1000

= 0.706 x 0.60 x 2.69 x 1000

= 1139.48 kg

Mass of fine aggregate = (eq. 4) x Volume of fine aggregate x Specific gravity of fine aggregate x 1000

= 0.706 x 0.40 x 2.69 x1000

= 759.65 kg

And finally, for the porous concrete, fine aggregate is completely removed and instead of fine aggregate 75% of its mass is replaced by coarse aggregate and rest 25% is replaced by cement.

A) Cement content = 338.18 kg/m^3 + 25% mass of fine aggregate

= 338.18 kg/m^3 + 25% x 759.65 kg/m3

= 528.09 kg/m3

B) Coarse aggregate content = 1139.48 kg/m^3 + 75% mass of fine aggregate

= 1139.48 kg/m^3 + 75% x 759.65 kg/m3

= 1709.21 kg/m3

TABLE-3.7 PROPORTION OF DIFFERENT MATERIALS IN OUR MIX

Cement	Coarse aggregate	Water
528.09 kg/m3	1709.21 kg/m3	186 liters
1	3.24	0.35

TABLE- 3.8 DESIGN MIX PROPORTION

Sample	Fly Ash %	Cement kg	Fly Ash in kg	CA kg	Water Liters
1	0	528.09	0	1709.21	186
2	10	475.28	52.81	1709.21	186
3	20	422.47	105.62	1709.21	186
4	30	369.66	158.43	1709.21	186
5	40	316.85	211.24	1709.21	186

V. PROCEDURE FOR PERMEABILITY TEST OF POROUS CONCRETE BLOCK

According to ASTM C1701, the experimental procedure consists of the following steps:

1) **Infiltration ring installation: -** The pavement surface was cleaned and plumber's putty was applied around the bottom edge of the infiltration ring in order to seal its perimeter.
2) **Pre-wetting: -** 3.60 kg of water were poured into the ring, maintaining a constant head of water between 100 and 150 mm from the pavement surface. We measured the time taken between the water coming into contact with the surface and it fully infiltrating the pavement.
3) **Test: -**The test started within 2 min after the pre-wetting stage; 3.60 kg of water were utilized again when the elapsed time measured during the pre-wetting stage was above 30 s. Otherwise, 18.00 kg were poured into the ring. The time was recorded following the same procedure indicated in the previous step.

The permeability was obtained by the following equation:

$$I= KM/D^2T$$

Where,
I = Infiltration rate, mm/h,
M = Mass of infiltrated water, kg,
D = Inside diameter of infiltration ring, mm,
t = time required for measured amount of water to infiltrate the surface, s,
K = constant value 4,583,666,000 in SI units.

VI. RESULT AND DISCUSSION

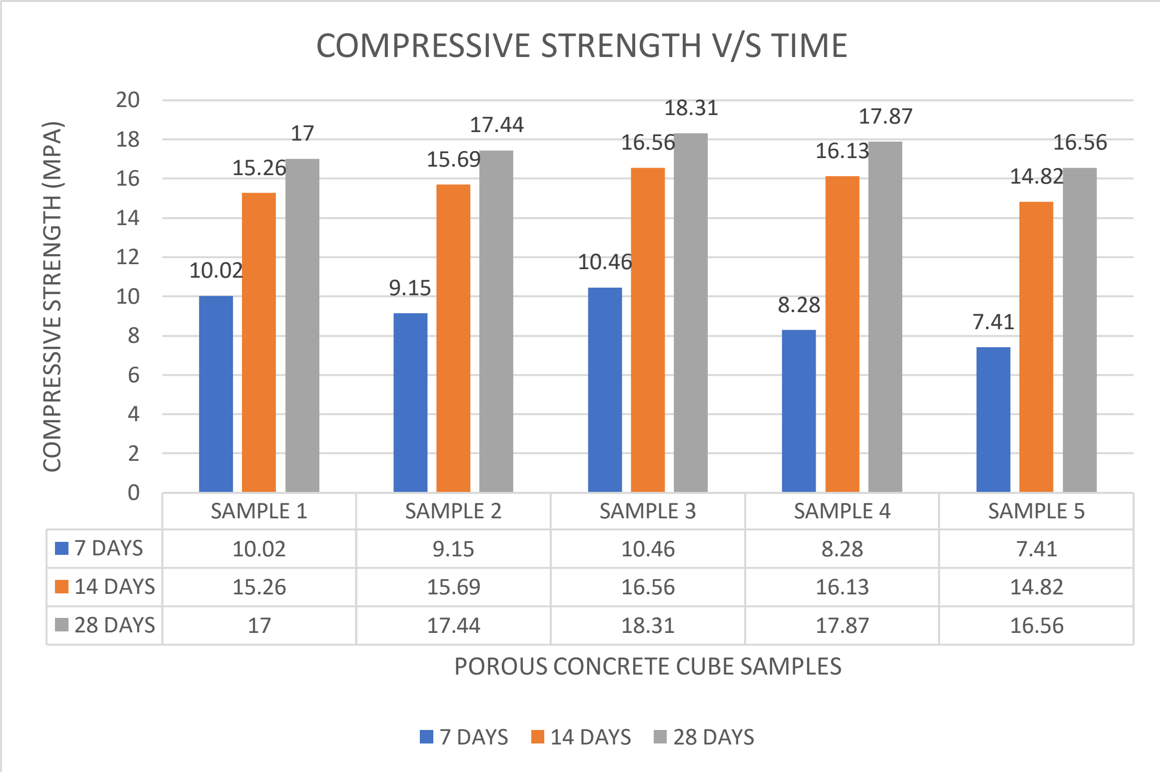
This chapter deals with the observation of the results from the various tests conducted on pervious concrete for use as pavement quality pervious concrete. The results are compared with the pervious concrete mixes with 0%,10%,20%,30% and 40% replacement of cement with Fly Ash. The strength and permeability characteristics of pervious concrete containing Fly Ash discussed in this chapter.

6.1 EXPERIMENTAL RESULTS FOR COMPRESSIVE STRENGTH

Table 3.9 COMPARISON OF TOTAL RESULT OF ALL SAMPLE

COMPRESSIVE STRENGTH ON DAYS	COMPRESSIVE STRENGTH OF SAMPLE Ist (100% CEMENT & 0% FLY ASH) (MPA)	COMPRESSIVE STRENGTH OF SAMPLE 2nd (90% CEMENT & 10% FLY ASH) (MPA)	COMPRESSIVE STRENGTH OF SAMPLE 3rd (80% CEMENT & 20% FLY ASH) (MPA)	COMPRESSIVE STRENGTH OF SAMPLE 4th (70% CEMENT & 30% FLY ASH) (MPA)	COMPRESSIVE STRENGTH OF SAMPLE 5th (60% CEMENT & 40% FLY ASH) (MPA)
7 days	10.02 MPA	9.15 MPA	10.46 MPA	8.28 MPA	7.41 MPA
14 days	15.26 MPA	15.69 MPA	16.56 MPA	16.13 MPA	14.82 MPA
28 days	17.00 MPA	17.44 MPA	18.31 MPA	17.87 MPA	16.56 MPA

GRAPH 6.1 COMPARISON OF ALL SAMPLE RESULTS WITH 7,14 & 28 DAYS COMPRESSIVE STRENGHT



6.2 PERMEABILITY TEST RESULTS

TABLE 3.10 PRE-WETTING STAGE TEST RESULT FOR 3.60 KG WATER MASS ON DIFFERENT POROUS CONCRETE BLOCK

SAMPLE	% OF FLY ASH USED	WATER MASS (KG)	INFILTRATION RING DIAMETER (mm)	TIME TO INFILTRATE (sec)
SAMPLE 1	0%	3.60	130	21.11
SAMPLE 2	10%	3.60	130	22.32
SAMPLE 3	20%	3.60	130	23.33
SAMPLE 4	30%	3.60	130	24.11
SAMPLE 5	40%	3.60	130	25.03

Time taken to infiltrated of water from infiltration ring is less than 30 sec, that why according to ASTM C1701, within 2 minutes of pre-wetting, we poured 18 kg of water in infiltration ring through that we can calculated the permeability of porous concrete block.

TABLE 3.11 PERMEABILITY TEST RESULT FOR 18 KG WATER MASS ON DIFFERENT POROUS CONCRETE BLOCK

SAMPLE	% OF FLY ASH USED	WATER MASS (KG)	INFILLTRATION RING DIAMETER (mm)	TIME TO INFILTRATE (sec)	INFILTRATION RATE $I = KM/D^2T$ (mm/hr)
SAMPLE 1	0%	18	130	92	**53065.33**
SAMPLE 2	10%	18	130	94	**51936.28**
SAMPLE 3	20%	18	130	95	**51389.59**
SAMPLE 4	30%	18	130	96	**50854.28**
SAMPLE 5	40%	18	130	98	**49816.44**

VII. CONCLUSION

1) At zero percentage replacement of fly ash the 7,14 and 28-days compressive strength values are 10.02 MPA, 15.26 MPA and 17.00 MPA respectively.
2) At 10 percentage replacement of fly ash the 7,14 and 28-days compressive strength values are 9.15 MPA, 15.69PA and 17.44 MPA respectively.
3) At 20 percentage replacement of fly ash the 7,14 and 28-days compressive strength values are 10.46 MPA, 16.56 MPA and 18.31 MPA respectively.
4) At 30 percentage replacement of fly ash the 7,14 and 28-days compressive strength values are 8.28 MPA, 16.13 MPA and 17.87 MPA respectively.
5) At 40 percentage replacement of fly ash the 7,14 and 28-days compressive strength values are 7.41 MPA, 14.82 MPA and 16.56 MPA respectively.
6) It is observed that there is an increment in compressive strength of 7.70% at 20% replacement of cement by fly ash at 28 days testing.
7) After the 20% replacement level the compressive strength started reducing. So, the optimum replacement of fly ash in porous concrete is 20%.
8) Permeability of porous concrete is reduced with increment of the replacement of cement by fly ash.
9) Cement is denser as compared to fly ash that why fly ash fill the voids of porous concrete block and get reduced the permeability.
10) 0% fly ash sample has highest permeability and value of permeability reduced with the increment of fly ash.

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