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"OPTIMIZATION OF MIX DESIGN OF PERVIOUS CONCRETE AND ITS TESTING"

A PROJECT

Submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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To

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"Optimization of Mix Design of Pervious Concrete and its Testing"** in partial fulfillment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering and submitted to the Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by **Ankit Walia (131618), Aditya Goel (131624), Gaurish Singhal(131684)** during a period from July 2016 to May 2017 under the supervision of **Dr. Rajiv Ganguly** Associate Professor and **Mr. Abhilash Shukla** Assistant Professor, Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

Pervious concrete is a concrete with high porosity used for concrete flat work applications that allow water from precipitation and other sources to pass directly through, thereby reducing the runoff from a site and allowing ground water recharge. This porosity is attained by a highly interconnected void content.

The project shows the effect of porosity and strength of various mix designs of permeable concrete and also gives the variation of permeability of permeable concrete due to strength and porosity of the permeable concrete. All these parameters are determined as specified in various standards code. And an optimized pervious concrete is formed form the best possible combination of strength and porosity.

Keywords:

Mix Design, Porosity, Strength, Permeability, Optimization.

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CHAPTER 1

INTRODUCTION

1.1 Background

Porous concrete is a composite material comprising of coarse aggregate, Portland cement, and water. It is not quite the same as regular cement in that it contains no fines in the underlying blend. The aggregate as a rule comprises of a solitary size and is fortified together at its purposes of contact by a glue shaped by the cement and water. The outcome is a solid with a high rate of interconnected voids that, when working accurately, allow the quick permeation of water through the solid. Not at all like customary solid, which has a void proportion somewhere in the range of 3-5%, porous concrete can have void proportions from 15-40% relying upon its application.porous concrete characteristics differ from conventional concrete in several other ways.Contrasted with ordinary concrete, porous concrete has a lower compressive quality, higher porousness, and a lower unit weight, around 70% of traditional concrete.

1.2 Problem statement

In the rains, the problem of water logging in urban areas is of prime concern. During driving the driver faces the problem of water splash during rains. The concreted pavements and parking lots/spaces have decreased area for natural water ingress in soil and thus have increased the load on the drainage system.

Pervious concrete can be of at most use in these types of problem. It is found that pervious concrete can help in increasing the quality of surface runoff and act as system for rain water harvesting.

1.3 Objectives

The objectives of this project are:-

- Preparing and modifying permeable concrete to increase its strength
- Optimizing the mix on basis of strength and permeability
- Compare the results with ordinary permeable concrete and the pavement requirement as per IRC
- Determination of infiltration rate and strength of permeable pavement

1.4 Scope

The scope of the project will be to produce a permeable concrete of appropriate strength and checking its permeability in the initial stage only. It does not include the effect of loadings over time on strength and blockages of pore due to intrusion of small particles on permeability.

CHAPTER 2

LITERATURE REVIEW

Urbanization has a detrimental effect on surface waters. Increased runoff rates from impermeable surface areas have increased peak flow through stream channels, causing erosion and stream bank instability. Runoff from impervious surface areas carries pollutants, such as sediments, nutrients, and heavy metals, into surface waters. One storm water management option is to minimize the amount of a project's impermeable surface by utilizing permeable pavement. Permeable pavement does it and moreover is found to improve the quality of runoff.

- **Filed survey of permeable surface infiltration rates : Eban Z. Bean; William F. Hunt; David A. Bidelspach (2007)**
  - In case of concrete grid paver surface the infiltration rates due to clogging reduced by 89%, Infiltration capacity could be regenerated by regular maintenance either by vacuum sweeper or pressure washing
  - In case of permeable interlocking pavers and permeable concrete the reduction in infiltration was 99 % due to their proximity to disturbed soil conditions

- **Effective curve number and Hydraulic design of pervious concrete storm water systems: Stuart S. Schwartz (2010)**
  - The thickness of sub base was decided by freeze and thaw risk and timely drawdown of the infiltrated water.

- **Characteristics of Silica Fume Concrete : P.Y. Pawade, Anurag Jain (2015)**
  - 10% is the maximum dosage of silica fume permitted by A23.6 Canadian standard.
  - It fills pore for interpartical arrangement and betters the aggregate-paste bonding.

- **Evaluation of structural performance of pervious concrete in construction : S. O. Ajamu, A. A. Jimoh, J.R. Oluremi (2012)**
  - Permeability and strength of pervious concrete using coarse aggregate of 9.375 mm and 18.75 mm with aggregate cement ratio of 6:1, 8:1, 10:1
  - 6:1 give highest compressive strength and 10:1 give highest permeability
  - 9.375 mm has higher compressive strength and 18.75mm had higher permeability

- **Permeable Pavement: Research Update and Design Implications: William F. Hunt, Kelly A. Collins (2008)**
  - Clay soils do not provide as much structural support as sandy soils, on average.
  - The gravel layer underlying nearly all pavement types will need to be deeper in clay soils than in sandy soils.

- **Use of Pervious Concrete In Construction Of Pavement For Improving Their Performance : Mr. V. R. Patil, Prof. A. K. Gupta, Prof. D. B. Desai (2010)**
  - Pervious concrete reduce the inflow of pollutant through storm runoff
  - Scope of adding silica fumes to increase the 28-day flexural strength keeping the permeability factor in mind.

- **Design of eco friendly pervious concrete : M. Harshavarthana Balaji, M.R.Amarnaath, R.A.Kavin (2014)**
  - The mix design with aggregate and cement ratio of 3 has the maximum strength.
  - This mix design has the required void ratio for the water seepage. So we can choose this mix design for the application purpose.

- **Performance Assessment of permeable Friction Course (PFC) Mix modified with Cement as Filler Material: Arijit Kumar Banerji, Antu Das (2008)**
  - The PFC mixes has exhibited good volumetric properties and permeability.

Air voids content were found to be more than 20% and coefficient of permeability more than 100 m/day for the mixes at a binder content of 5.0 and 5.5%.

- In the mixes with binder content of 5.0% and 5.5%, the mean values of UAL(unaged abrasion loss) and AAL (aged abrasion loss) were found to be within the acceptable limits of 20% and 30% respectively, while the mix with 4.5% satisfies the AAL criteria only.

- **Pervious Concrete Pavement Performance in Field Applications and Laboratory Testing: Vimy Henderson(2010)**

  - With proper mix designs and construction practices pervious concrete pavement can perform in the Canadian climate.
  - Loading of pervious concrete with sand material generally decreases the permeability and the quantity of sand has not been noted to strongly effect the changes in permeability.
  - The use of salt solutions on pervious concrete pavement can decrease the permeability and lead to paste loss on surface aggregate.

- **Permeable Pavement Systems: Kolluru Hemanth Kumar(2008)**

  - Description different types of permeable pavement systems with their strength and void ratio
  - Improvement in the quality of water with permeable pavement system

- **Quick Surface Infiltration Test to Assess Maintenance Needs on Small Pervious Concrete Sites (2011): Mark Dougherty, P.E.; Michael Hein, P.E., M.ASCE; Brent A. Martina; and Bruce K. Ferguson**

  - The QFIT method requires a small amount of water (4 L or less), a stopwatch, and a tape measure. The water is poured steadily onto the level surface of dry PC pavement as the time to empty the entire volume is recorded. On dry, level pavement, a dark, roughly circular water stain indicates the area of infiltration. Downward vertical flow is assumed. Depth of water infiltrated is estimated by dividing volume of water poured by measured water stain area. SIR is derived by dividing estimated depth of water by recorded pour time.

– The two infiltration test methods evaluated in the paper showed uniformly comparable results above a QFIT SIR threshold > 500 cm\h. The QFIT method thus can be recommended for comparison and ranking of small-scale PC pavement sections above the threshold SIR value temporally, to determine the need for maintenance cleaning.

CHAPTER 3

MATERIALS USED AND METHODOLOGY

3.1 Cement

The cement that we had used for the mix designing of permeable concrete is Ordinary Portland Cement 53 as per IS: 12267 – 2013. And has following properties:

Cement grade	-	53
Specific Gravity	-	3.02
Fineness of cement	-	3.15
Consistency	-	35%
Initial Setting Time	-	120 minutes (maximum)
Final setting	-	600 minutes (maximum)

3.2 Aggregates

3.2.1 Coarse Aggregates

The size of coarse aggregate that we have used for mix design is of size 10mm to 20 mm. And the various properties of the coarse aggregates used are as follows:

Aggregate Impact Value	-	18.85%
Los Angeles Abrasion value	-	33.78%
Crushing value	-	25.36%
Specific Gravity	-	3.00
Bulk density	-	1.50
Source	-	Dumehar, Solan, H.P.

All the values obtained are in desired as per IS: 2386:1963.

Fig. 3.1 Coarse Aggregates (size 10 -20mm)

3.2.2 Fine Aggregates

Since we are making mix design of permeable concrete, so we are not using any fine aggregates.

3.3 Water

Fundamentally "the strength of concrete is governed by the nature of the weight of water to the weight of cement in a mix, provided that it is plastic and workable, fully compacted, and adequately cured". And the water that we have used for mix design making is tap water.

3.4 Water Reducers/ Super Plasticizers

It is high range water reducers called type “F” by ASTM. These are sulfonated naphthalene formaldehyde condensates. The properties of plasticizer are:

Standard - IS: 9103- 1999, ASTM C494

Appearance - Dark Brown Liquid

Relative density - 1.17 Kg/l

Dosage -0.5% to 2% by weight of cement, Stir well before use

- 

Fig 3.2 Sikament 2002 NS

3.5 Silica fume

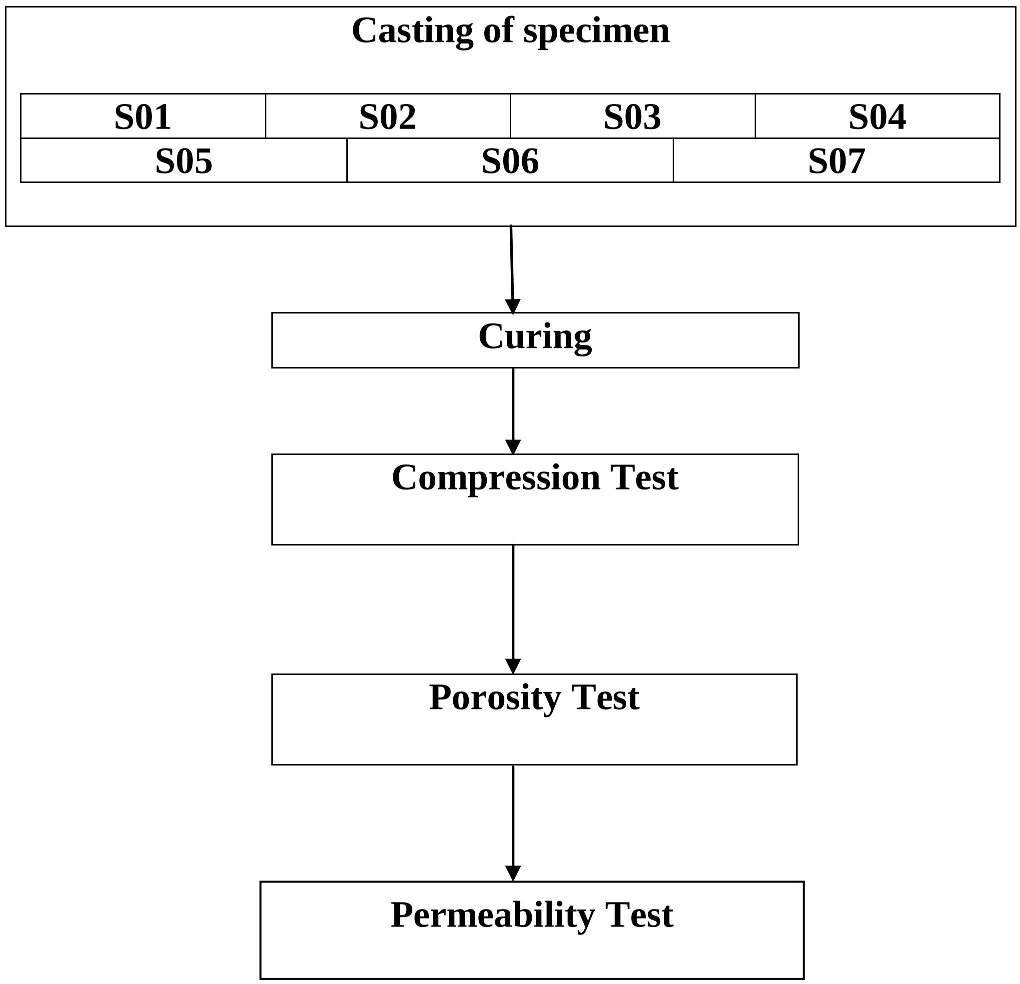
Silica fume is a byproduct of ferrosilicon alloys and is useful for concrete because of its chemical and physical properties, it is very reactive pozzolan. Concrete contain silica fume have high compressive strength and can be very durable. Placing, finishing, and curing silica-fume concrete require special attention on the part of the concrete contractor.

Dosage: - Not more than 10% by the weight of cement.

Fig. 3.3 Silica fume

3.6 Flow Chart of Laboratory Work

Following diagram shows the flow chart of the lab work.



CHAPTER 4

EXPERIMENTAL SETUP AND PROJECT WORK

4.1 Introduction

Testing assumes a critical part in controlling the quality the concrete work. Precise testing of the crude materials, fresh concrete and hardened concrete is an indivisible piece of any quality control program for concrete which accomplishes higher proficiency of materials utilized and more noteworthy confirmation of the execution of the concrete. The test technique utilized ought to be straightforward , immediate and convienient to apply

.

IS: 516 (1959): Method of tests for strength of concrete is used for testing compressive strength of concrete.

Standard method for calculating the infiltration rate of in placed pervious concrete as per **ASTM C-1701**

4.2 Casting of specimen

Table 4.1 Mix Design

Sample	Aggregate cement ratio	Water cement ratio	Plasticizer	Silica fume
S01	6:1	0.3	-	-
S02	6:1	0.26	-	-
S03	6:1	0.25	1% by weight of cement	-
S04	4:1	0.3	-	-
S05	4:1	0.3	-	5% by weight of cement
S06	3:1	0.3	-	-
S07	3:1	0.3	-	5% by weight of cement

4.2.1 Mixing

Considering approximately 2.75kg of concrete for each cube, calculations were performed and individual weights of different materials required for each mix were found. Each material was weights found above for different mix of concrete on various days.

4.2.1.1 Bucket mixing method

This method required 2 sturdy buckets of required volume, tamping rod, trowel and measuring cylinders (for water).

Aggregates are washed and weighed according to the mix requirement and then transferred to the bucket. Cement, weighed according to mix, is dry mixed with the aggregates using tamping rod. After dry mixing, water is added slowly and mixed with tamping rods. Finally the mix is transferred to the other empty bucket and vice-versa.

This process is followed for at least 15 times or till the concrete is mixed evenly whichever occurs earlier.

Fig 4.1 Bucket Mixing

4.2.2 Casting

Mix was filled in properly assembled and oiled moulds. Concrete was placed in 3 layers, each layer being tamped 15-20 times. After one day the specimens were de-moulded and placed for curing in the tank.

4.3 Test for compressive strength of concrete

This part of project deals with the procedure for determining the compressive strength of concrete specimen.

4.3.1 Apparatus

4.3.1.1. Compression testing machine

Testing machine may be of any reliable type, of sufficient capacity for the test and capable of applying the load with specified rate. The bearing faces of the platen shall be at least as large as and preferably larger than the normal size of the specimen to which the load is applied. Also the platen face should be plain, rigid and hardened. Also the permissible error should not be greater than ± 2% of the maximum load.

Fig 4.2 Compression Testing

4.3.1.2. Moulds

100*100*100 mm cubes which are prepared according to BS 1881: Part 108:1983 and tested according to BS 1881: Part 116:1983.

Fig. 4.3 Moulds (size 100*100*100 mm)

4.3.2 Testing procedure

Specimens are removed from the water tank and surface dried. These are placed in the CTM taking care that the bearing surfaces are clean off any loose material and axis of specimen should be carefully aligned with the centre of load applying platen.

Applied loading rate: - 4 tonne/min.

The maximum load on the specimen is recorded and appearance of concrete and any unusual features in type of failure shall be noted.

Fig.4.4 Casted cubes

4.3.3 Calculations

$$\textbf{Compressive strength} = \frac{\textbf{Maximum load}}{\textbf{Area of the specimen}}$$

4.4 Test for Porosity

4.4.1 Apparatus

- Container (open on one side)
- Bucket
- Measuring cylinder
- Iron wire

4.4.2 Procedure

Container is filled full to the brim and the amount of water in it was measured.

The cube is tied with wire and placed in the container placed in the bucket gently lowering the cube in the container. The cube is taken out of the container gently not disturbing the setup and held on it for some time to drain the water trapped. Now the amount of water in the container is measured.

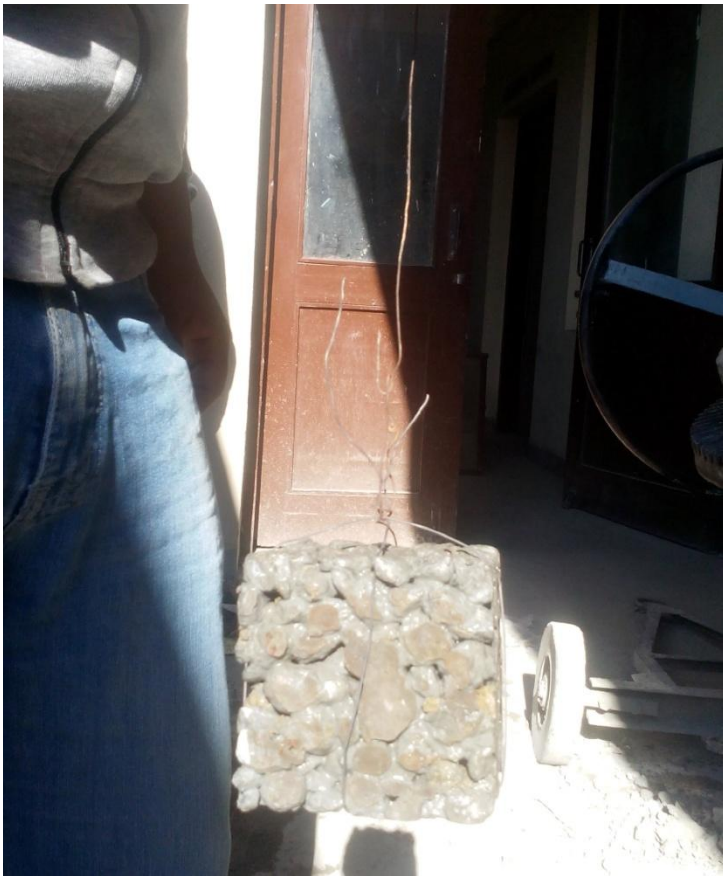


Fig4.5 Cube with Wire Cage

Fig 4.6 Porosity setup

4.4.3 Calculations

$$Vs = Vi - V_f$$

$$Vv = V - Vs$$

$$n = \frac{Vv}{V} * 100$$

Where

V_s = Volume of solids (ml)

V_i = Initial volume of water in container(ml)

V_f = Final volume of container (ml)

V_V = Volume of voids (ml)

V = Volume of cube (ml)

n = Capillary Porosity in percentage

4.4.4 Readings

Table 4.2 Porosity Readings

Sample	Initial Volume (ml)	Final Volume (ml)	Volume of solids (ml)	Volume of voids (ml)	Volume of cube (ml)	Porosity (%)
S01	4370	3650	720	280	1000	28
S02	4370	3625	742	258	1000	25.8
S03	4370	3602	768	232	1000	23.2
S04	4370	3576	794	206	1000	20.6
S05	4370	3568	802	198	1000	19.8
S06	4370	3555	815	185	1000	18.5
S07	4370	3552	818	182	1000	18.2

4.5 Tests for Permeability of cubes

4.5.1 Apparatus

- Stopwatch
- Measuring Cylinder
- Cardboard
- M seal
- Bucket

The apparatus was prepared shown below:-

Fig4.7 Permeability Setup

4.5.2 Procedure

Samples are prepared by taping them on four sides properly to not allow the water to runoff through the sides. The bottom edges are sealed using the m- seal and tapes so that water flows only through the specimen not through the spacing on sides. On the top side pieces of cardboard are taped tightly which are protruding from the top to allow the water to stand on the top of the cube. The cubes are placed in the bucket over a stand. Now a designated amount of water is filled in the apparatus. The water is allowed to flow from the apparatus carefully not letting it fall out or get waste and the time to empty the apparatus is noted.

Fig 4.8 Cubes prepared for permeability test

4.5.3 Calculations

$$\boldsymbol{f} = \frac{\mathbf{V_W} * \mathbf{10^6} * \mathbf{3600}}{\boldsymbol{t} * \boldsymbol{A}}$$

Where

f = Infiltration Rate (mm/hr)

V_w = Volume of water (liter)

t = Time taken to empty the apparatus (s)

A = Area of the cube surface (mm^2)

4.5.4 Readings

Table 4.3 Infiltration Reading

Sample	Volume of water (l)	Time (s)	Area of cube surface (mm^2)	Infiltration rate (mm/hr)
S01	2.8	30.0	10000	33580
S02	2.8	31.2	10000	32291
S03	2.8	32.4	10000	31094
S04	2.8	42.3	10000	23829
S05	2.8	45.8	10000	22008
S06	2.8	50.1	10000	20135
S07	2.8	52.5	10000	19182

4.6 Test for Permeability of Permeable Concrete

Standard method for calculating the infiltration rate of in place pervious concrete as per ASTM C-1701

4.6.1 Significance and use of test

- To find out the reduction in the infiltration rate over the year at the same location
- The results of infiltration are valid only for localized area.
- The influence on in -place infiltration rate due to sealing of void near the bottom of pervious concrete is not measured

4.6.2 Apparatus used

Infiltration ring- A cylindrical shaped ring open at both finishes. The ring might be rigid, water tight and should have a width of 300 ± 10 mm with a base tallness of 50 mm. The base edge of the ring ought to be even. The inward side of the ring might be set apart with two lines at a separation of 10 and 15 mm from the base of the ring.

Balance - Scale accurate to 10 g.
Container – 20 liter capacity
Stop watch – accurate 0.1 s.
Plumber Putty
Water

Fig. 4.9 Infiltration Ring Markings

Fig. 4.10 Casted Slab

4.6.3 Procedure

- **Infiltration Ring Installation** – broom off trash and other non-seated material from the surface of pavement. Apply the plumber putty around the bottom edge of the ring and place it onto the pervious concrete surface being tested. Plumber putty creates a watertight seal.

- **Pre-wetting** – Pour the water at sufficient rate into the ring to maintain a head between two marked lines. Use 4 liter water. Begin stop watch as soon as the water hit the pervious concrete surface. Stop timing when free water is no longer present on pervious surface.

- **Test** – After pre-wetting the pavement test shall the start within 2 minutes. If the elapsed time in the pre-wetting stage is less than 30 s, use 18 ± 0.5 liter of water. If elapsed time is more than 30 s, than use 3.6 ± 0.5 liter of water. Pour the water in to ring to maintain a head between the two marked line and until the measured amount of water has been used. Start the stop watch as soon as the water hit the pervious concrete surface. Stop timing when free water is no longer present on pervious surface. Record the testing duration (t) to the nearest 0.1 s.

Fig.4.11 Infiltration Setup

Fig. 4.12 Infiltration Test

4.6.4 Calculation

$$f = \frac{K * M}{D^2 * t}$$

Where:

f = 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 concrete, s

k = 4583666000 in SI Units

4.6.5 Reading

Internal diameter of infiltration ring = 300 mm
Height of infiltration ring = 180cm
Pre-wetting time = 15 s
Time required for measured amount of water to infiltrate the concrete = 49.2 s
Mass of infiltrated water = 18 Kg

Hence, **Infiltration Rate = 18632 mm\h**

CHAPTER 5

RESULTS

Table 5.1 - COMPRESSIVE STRENGTH 7 DAY

Sample	Aggregate cement ratio	Water cement ratio	Plasticizer	Silica Fume	Compressive strength In MPa (7day)
S01	6:1	0.3	-	-	5.5
S02	6:1	0.26	-	-	7.6
S03	6:1	0.25	1% by weight of cement	-	7.9
S04	4:1	0.3	-	-	7.8
S05	4:1	0.3	-	5% by weight of cement	8.5
S06	3:1	0.3	-	-	12.7
S07	3:1	0.3	-	5% by weight of cement	13.1

Table 5.2 - COMPRESSIVE STRENGTH 28 DAYS

Sample	Aggregate cement ratio	Water cement ratio	Plasticizer	Silica Fume	Compressive strength in MPa (28day)
S01	6:1	0.3	-	-	8.4
S02	6:1	0.26	-	-	10.8
S03	6:1	0.25	1% by weight of cement	-	10.9
S04	4:1	0.3	-	-	11.2
S05	4:1	0.3	-	5% by weight of cement	11.8
S06	3:1	0.3	-	-	17.8
S07	3:1	0.3	-	5% by weight of cement	18.4

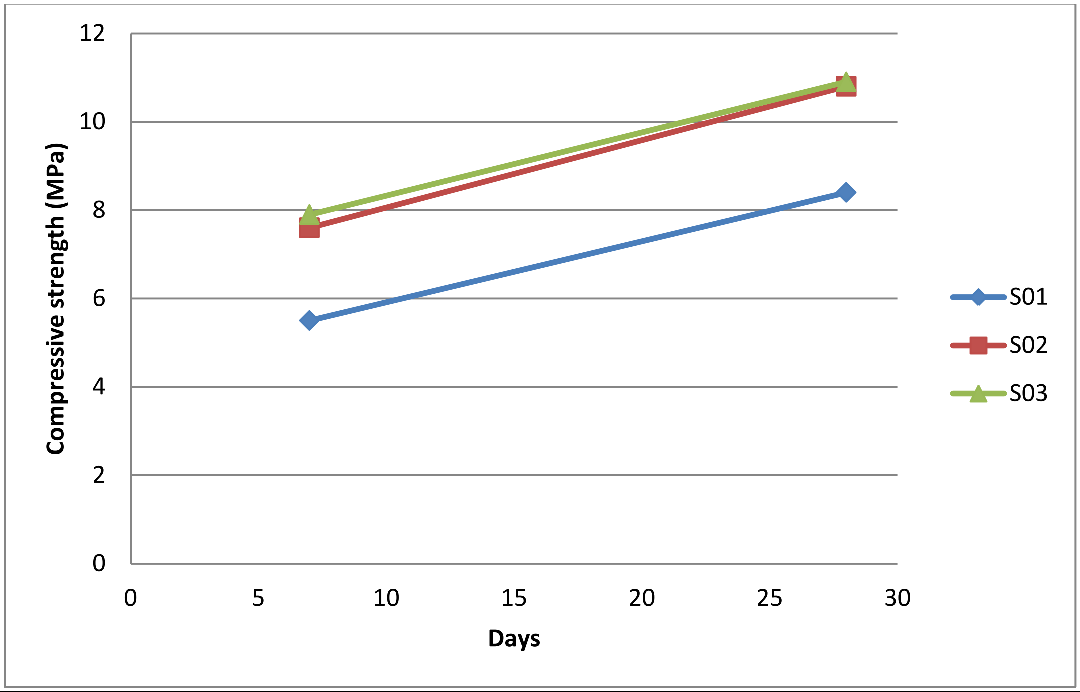


Fig. 5.1 Compressive strength comparison of cement aggregate ratio 6:1

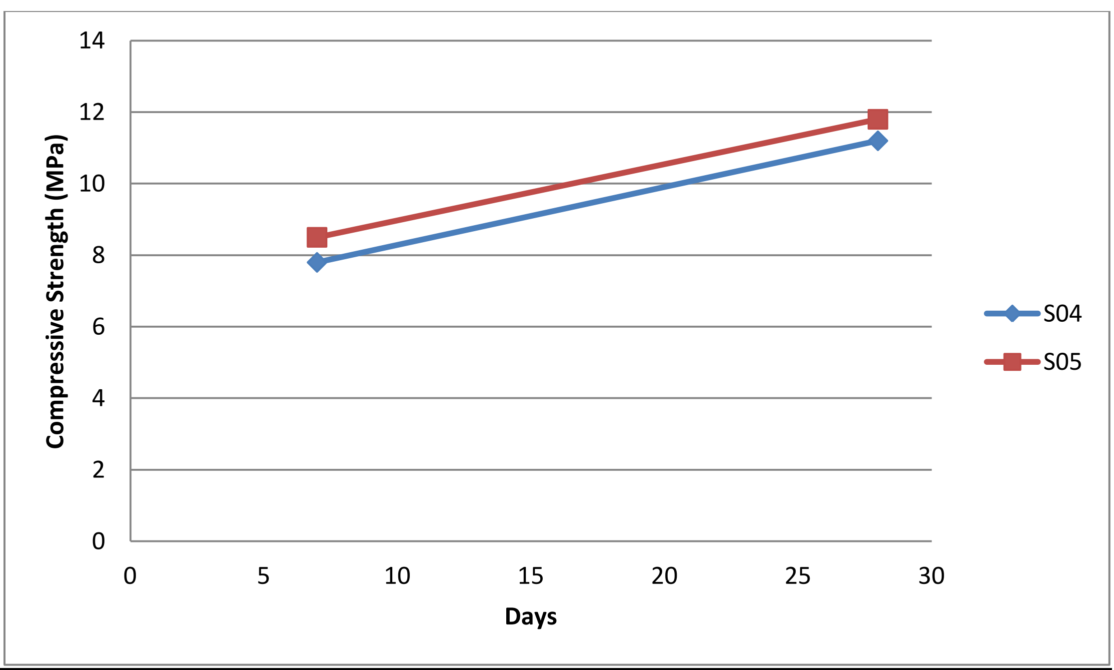


Fig. 5.2 Compressive strength comparison of cement aggregate ratio 4:1

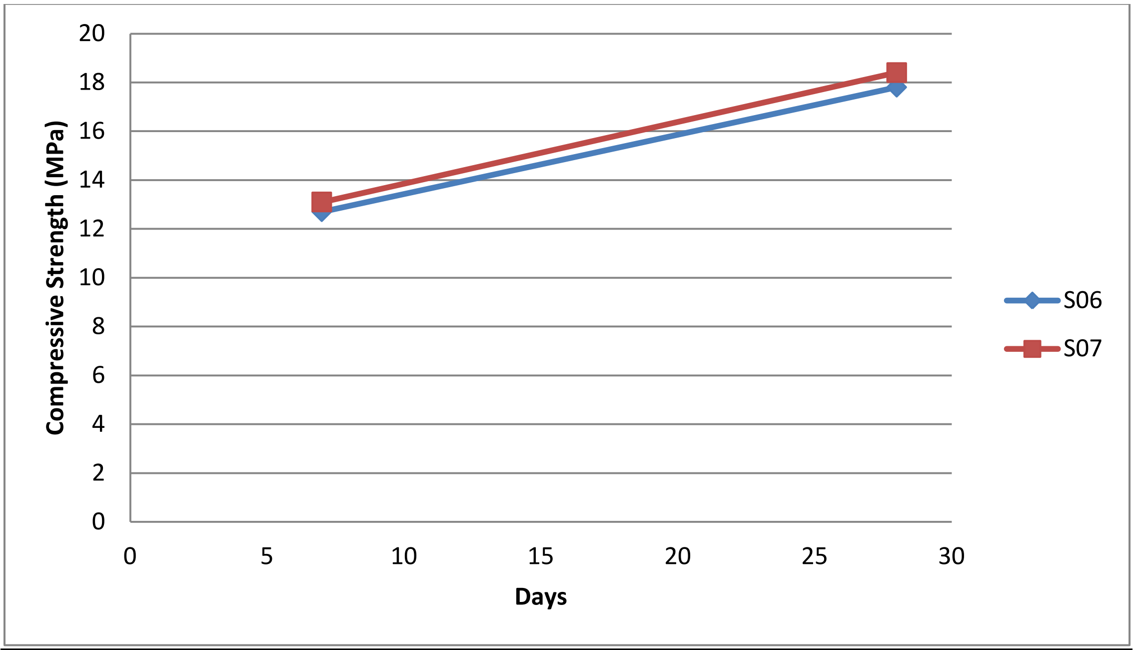


Fig. 5.3 Compressive strength comparison of cement aggregate ratio 3:1

Table 5.3 – Porosity

Sample	Aggregate/ Cement ratio	Water / Cement ratio	Capillary Porosity	Compressive strength in MPa (28 Day)
S01	6:1	0.3	28	8.4
S02	6:1	0.26	25.8	10.8
S03	6:1	0.25	25.2	10.9
S04	4:1	0.3	20.6	11.2
S05	4:1	0.3	19.8	11.8
S06	3:1	0.3	18.5	17.8
S07	3:1	0.3	18.2	18.4

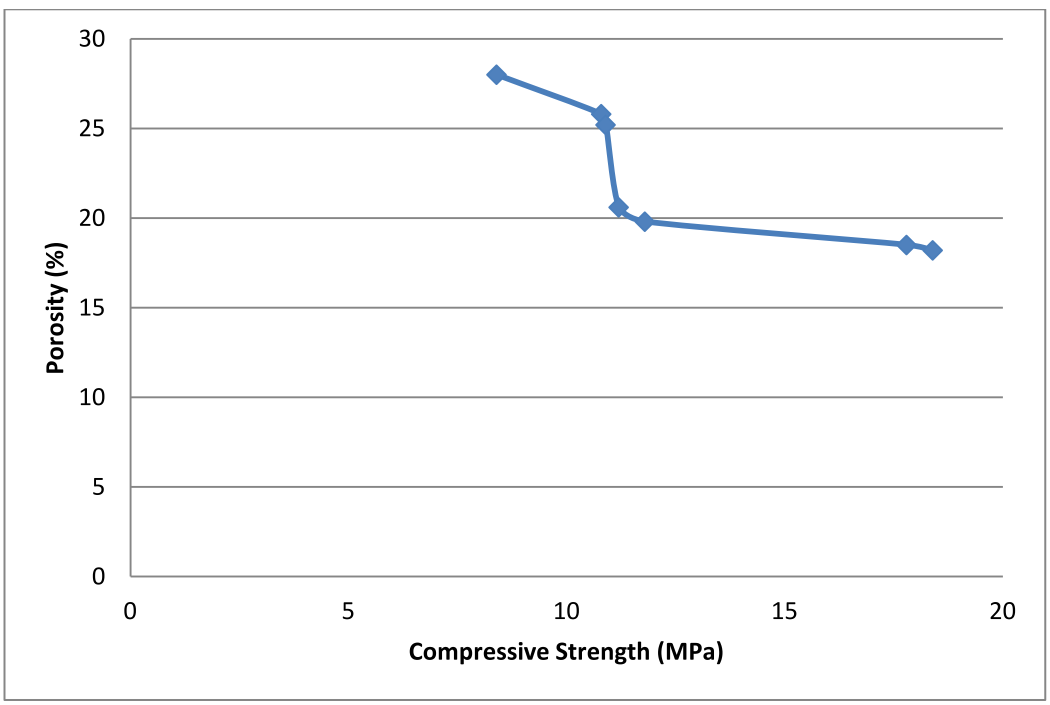


Fig 5.4 Porosity v/s Compressive Strength (28 day)

Table 5.4 – Permeability

Sample	Aggregate/ Cement ratio	Water / Cement ratio	Permeability (mm/ hr)	Compressive strength in MPa (28 Day)
S01	6:1	0.3	33580	8.4
S02	6:1	0.26	32291	10.8
S03	6:1	0.25	31094	10.9
S04	4:1	0.3	23829	11.2
S05	4:1	0.3	22008	11.8
S06	3:1	0.3	20135	17.8
S07	3:1	0.3	18632	18.4

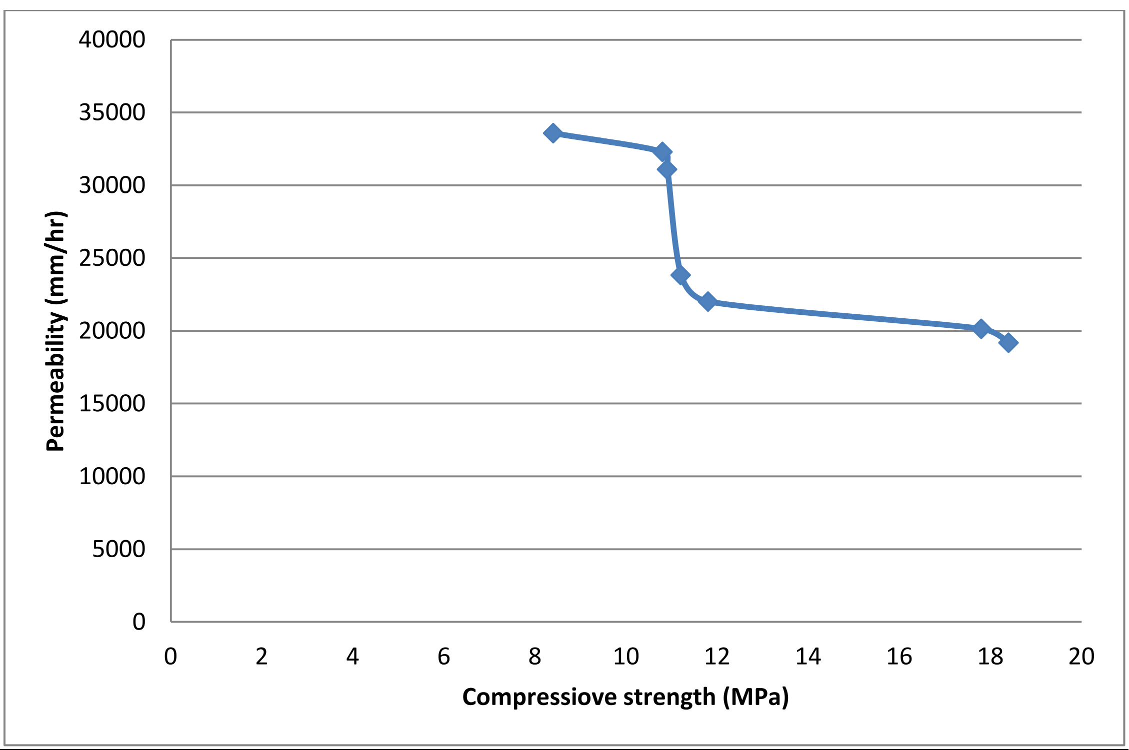


Fig. 5.5 Permeability v/s Compressive Strength

CHAPTER 6

FUTURE WORKS

Effect on Permeability with Time and Site Conditions:

Work needs to be done on:

- The effect of permeability of the pavement due to the intrusion of soil and other micro particles in the pores
- The time to completely block the pores
- Ways of rejuvenating the permeability
- Effect of soil and other site conditions on the pavement's performance

CHAPTER 7

CONCLUSIONS

- Permeable concrete made from aggregate/cement ratio 3:1 has 28 day compressive strength of 18.4 MPa and 4:1 has compressive strength of 11.8 MPa and 6:1 has compressive strength 10.9 MPa.
- Permeable concrete made from aggregate/cement ratio of 3:1 has porosity 18.2% and 4:1 has porosity 19.8% and 6:1 has porosity 23.2%.
- The aggregate/cement ratio of 6:1 produced permeable concrete of higher permeability with infiltration rate of 31094mm\hr and of 4:1 has 28110 mm\hr and 3:1 has 19182 mm\hr respectively.
- ASTM 1701c infiltration ring test gave the infiltration rate of 18632 mm/hr which is comparable to our cube test results.
- The smaller the size of coarse aggregate should be able to produce a higher compressive strength and at the same time produce a lower permeability rate.
- The considered aggregate/cement ratios are found to be useful for a pavement that requires low to moderate compressive strength and high permeability rate.
- Finally, further study should be conducted on the pervious concrete pavement produced with these material proportions to meet the condition of increased abrasion and compressive stresses due to high vehicular loading and traffic volumes.

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