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An Experimental Study on Compressive Strength, Void Ratio and Infiltration Rate of Pervious Concrete

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***Abstract*— Due to enormous improvement in construction industry and infrastructure, maximum metro cities in India are getting covered with impermeable concrete pavements. Concreting tends to environmental problems such as fall of recharge of rainwater into the ground hence continuous reduction in water table which leads to water crisis during summer. Installing Pervious Concrete pavement instead of impervious concrete for low traffic volume, we can solve the reduction of water table issue. Pervious Concrete is a low impact, environmentally friendly and sustainable paving option. Pervious Concrete is an unusual type of concrete made by the mixture of water, cement and open graded coarse aggregate. Typically it has very little to no fine aggregates content and has just enough cementations paste to coat the aggregate particle while maintaining the interconnectivity of the voids. Pervious concrete is also known as porous concrete, permeable concrete, no-fines concrete, gap graded concrete, enhanced porosity concrete. In the pervious concrete the void content is in the range of 15 to 22% compared to 3 to 5 % in conventional impervious concrete pavements.**

This paper represents the experimental methodology and experimental results related to compressive strength, void content and infiltration rate. Testing various mix designs of Pervious Concrete, results were determined and analyzed. Cube size of 150mm x 150mm x 150mm is prepared to investigate compressive strength, void ratio and infiltration rate. Different concrete mix proportion such as 1:5, 1:6, 1:1:5 and 1:4:5with different size of gravels such as 9mm to 12mm should be used to check these properties of pervious concrete.

Keywords*— *Pervious concrete pavement, compressive strength, voids ratio, infiltration rate

I. INTRODUCTION

Increasing in infrastructure development and resulting increase in urban storm water over the past few decades have led to increase in pollution and runoff problems. As more available land area in the major cities gets paved over, a maximum quantity of rainfall ends up falling on impermeable surfaces such as parking area, driveways, sidewalks, and highways rather than to pass into the ground. This leads to environmental issues such as erosion, decrease in ground water table, pollution of rivers, lakes, and coastal waters as rainwater flowing across pavement surfaces picks up everything from oil and grease spills and chemical fertilizers.

One of the simple solution to avoiding these problems is to install the Pervious Concrete pavement which allows water to percolate through its pores reducing surface runoff and offering durability; unlike Conventional Concrete or asphalt pavement

A. What is Pervious Concrete?

Pervious Concrete is an unusual type of concrete made by the mixture of water, cement and open graded coarse aggregate, which permits rain and storm water runoff to percolate through it. It acts as a filter to trap and remove pollutants from storm water run-off. This allows the sun's heat to evaporate volatile materials leaving the remaining solids to be disintegrate by microbial action.

It is usually a mixture of 9mm to 13mm average diameter aggregate, cement, small quantity of fly ash or blast furnace slag, admixtures and water. Pervious Concrete contains voids and these voids are held together by cement paste, after the installation. A typical Pervious Concrete pavement has a 15-22% void content and allows 0.1 to 0.3 cubic meter of water per minute to pass through each square meter.

Controlled quantity of water and cementitious materials are used to produce a paste that creates a thick coating around aggregate particles without washing off during placing, mixing and adequate compacting. Using just enough paste to coat the particles gives rise to a system of interconnected voids which further allows seepage of water through interstices. Hence it is used as a very high permeability structural concrete that drains. Pervious Concrete is also light in weight, with density between 1600 to 1900 kg/m^3, because of high void content.

B. Pervious Concrete Pavements: The Environmentally Friendly Choice

Paved surfaces are so common in urban areas today that we do not realize the impact they have on water quality and the health of the environment. The problems include erosion, decrease in water table and pollution of rivers, lakes, and sea waters as rainwater across pavement surfaces gets mixed up with everything from oil and grease spills and artificial fertilizers.

One of the solution to avoid these problems is to percolate natural water into the soil which can be done by Pervious Concrete. Rather than building pavements with Conventional Concrete or asphalt, Pervious Concrete - a material that offers the essential durability while retaining rain water runoff and replenishing local watershed systems should be considered.

II. EXPERIMENTAL WORK

Pervious Concrete is a mixture of Cement, Coarse Aggregate / Gravel and Water. No Fine Aggregates are used for making pervious concrete. Sometimes retarders and admixtures are used to achieve adequate strength and durability of pervious concrete. In this paper, Pervious Concrete has been casted with different concrete mix proportion such as 1:5, 1:6 with 9 mm to 12 mm gravel size with OPC 53 Grade Cement.

A. Experimental Material and Equipment Specifications

- Cement : 53 Grade ACC cement
- Aggregate: Aggregate size between 9mm-12mm (passing through 12 mm sieve and retained on 10mm sieve)
- Sand: Clean and natural
- Water : Clean and potable water
- Super plasticizer : Sunanda Polytancrete NTG
- Retarder: Sugar
- Mould : cubical mould of size 15cm x 15cm x 15cm
- Concrete Mixer Type: Pan mixer
- Steel tamping rod: 16mm diameter 0.6m long along with bullet ends
- Proctor hammer: 5.1 cm diameter, height of dropping- 450 mm
- Curing : using jute bags
- Compressive strength testing machine

B. Trial mix

In this chapter different mix designs and various test performed on Pervious Concrete are presented. Further effects of admixtures and retarders as well as different curing methods are presented.

Trial No. 1

Mix design	Cement /aggregate ratio	Water cement ratio	Remark
M1	1:5	0.32	1. Retarder=0.15% of cement wt. 2. Super plasticizer= 2.5% of cement wt. 3.Machine Mixing, Compaction by tamping rod and Vibrations
M2	1:6	0.38	1. Retarder=0.15% of cement wt. 2. Super plasticizer= 0.5% of cement wt. 3.Machine Mixing, Compaction by tamping rod and Vibrations
M3	1:1:5	0.32	1. Sand Content (1:1:5)= 6.29kg 2. Retarder=0.10% of cement wt. 3.Superplasticizer= 1.5% of cement wt 4.Machine Mixing, Compaction by tamping rod and Vibrations

Table 1 Trial No.1 Mix Design

Note: weight of cement is 6.29 kg, number of cube are 3 and sugar is used as a retarder.

Trial No.2

Mix design	Cement /aggregate ratio	Water cement ratio	Remark
M1	1:5	0.32	1.Hand Mixing, Compaction by tamping rod , No Vibrations
M2	1:6	0.38	1.Hand Mixing, Compaction by tamping rod , No Vibrations
M3	1:1:5	0.32	1.Hand Mixing, Compaction by tamping rod , No Vibrations 2. Aggregate size between 10mm to 12mm

Table 2 Trial No.2 Mix Design

Note: Weight of cement is 4.49 kg, number of cube are 2

Trial No.3

Table 3 Trial No.3 Mix Design

Note: Weight of cement is 4.49kg, number of cube is 1.

Mix design	Cement /aggregate ratio	Water cement ratio	Remark
M1	1:5	0.32	1.Hand Mixing, Compaction by tamping rod and Proctor hammer No Vibrations

Trial No.4

Table 4 Trial No.4 Mix Design

Mix design	Cement/Aggregate ratio	Water cement ratio	Remark
M1	1:4:5	0.34	1.Hand Mixing, Compaction by tamping rod and Proctor hammer No Vibrations

Note: Weight of cement is 4.49kg, number of cube is 1.

C. Test Performed

1) Compressive Strength Test

The most common of all test on hardened concrete is a compressive strength test, because it is an easy test to perform, and also because many of the desirable characteristic of concrete are qualitatively related to its strength but mainly because of the intrinsic importance of compressive strength of concrete in structural design. The strength test results may be affected by variation in type of test specimen; specimen size; type of mould; curing; preparation of the end surfaces; rigidity of testing machine and rate of application of test.

In the compression test, the cube, while still wet, is placed with cast faces in contact with platens of the testing machine, i.e. the position of cube when tested is at right angles to that as-cast. The load on cube should be applied at a constant rate of stress equal to 0.2 to 0.4MPa/sec. Compressive strength is also known as crushing strength.

In case of Pervious Concrete, cubes are kept for curing under wet jute bags or immersed in water till for 28 days. Compressive strength test is carried out at the age of 7^{th} day, 14^{th} day and 28^{th} day. The compressive strength test is carried out under compressive testing machine

The failure pattern of cube is observed and results of compressive strength of Pervious Concrete cube are presented in chapter below. Specimen stored in water shall be tested immediately on removal from water and while they are still in wet condition.

2) 2 Void Ratio

The void ratio of Pervious Concrete is measured on 6^{th} day and 27^{th} day after casting of Pervious Concrete in following steps:

1. Pervious Concrete cube is wrapped up with polythene covering all its vertical faces and bottom face and leaving only the top face open.
2. To make sure that Pervious Concrete cube is watertight; it is further wrapped up with tape covering all its vertical faces and bottom face.
3. Cube covered on its five faces and open at top face is placed on a flat horizontal surface and water is poured from the top.
4. To make sure that covering polythene does not expand due to lateral pressure of water it is pressed by hands while water is being poured. Water is poured till all the voids are filled and water surface matches with the top face of Pervious Concrete.
5. Once pouring of water is stopped and all voids are filled, Pervious Concrete is turned upside down and all the water is allowed to drain out of Pervious Concrete cube and collected into a container.
6. Volume of water collected in container is measured and it is equal to the volume of voids in cube, using it and volume of Pervious Concrete cube, void ratio is found out.
7. Void ratio = volume of voids/volume of cube x 100.

3) 3 Infiltration Rate

The infiltration Rate of Pervious Concrete is measured on 6^{th} day and 27^{th} day after casting of Pervious Concrete in following steps:

1. Pervious Concrete cube is placed in a polythene bag such that top circumference of cube and that of polythene bag coincide; polythene bag is selected such that its length is more than three times that of Pervious Concrete cube.
2. After placing cube in a polythene bag such that its circumference and that of bag coincide it is wrapped up in the bag covering all its vertical faces with the help of tape and leaving top face open outside, bottom face open inside the bag and care is also taken to make sure that covering around cube is watertight. Remaining length of the polythene bag which is not wrapped around Pervious Concrete cube is kept free to contain water which would be poured in from top face and percolate through Pervious Concrete cube and fall into free part of bag through bottom face.
3. Measured volume of water (approx. 6-8 liters.) is poured in from top face into the polythene bag through Pervious Concrete cube.
4. After pouring is completed polythene bag with Pervious Concrete cube inside it is turned upside down and all the water inside it is allowed to percolate through Pervious Concrete cube and time is measured required for draining out all the water.
5. With the help of measured volume of water, time required for draining out all the water and cross sectional area of cube Infiltration rate of Pervious Concrete is found out.
6. Infiltration rate = Measured volume of water (in L)/ C/S area of cube (in m^2)/ time

Required for draining out entire vol. of water (in min.)

D. EXPERIMENTAL RESULT

Trial No.1

Table 5 Trial No.1 Mix Design Results

Mix Design	Compressive Strength (Mpa)			Void ratio (%)	Infiltration rate (l/min/m^2)
	7th day	14th day	28th day		
M1	5.23	6.65	6.87	5.7	259
M2	6.18	6.64	7.89	5.9	285
M3	8.88	15.6	19.46	6.2	300

Trial No.2

Table 6 Trial No.2 Mix Design Results

Mix Design	Compressive Strength (Mpa)			Void ratio (%)	Infiltration rate (l/min/m^2)
	7th day	14th day	28th day		
M1	5.55	6.23	7.43	19.97	1512
M2	7.46	7.58	7.84	20.47	1864
M3	9.33	11.26	14.10	14.67	1239

Trial No.3

Table 7 Trial No.3 Mix Design Results

Mix Design	Compressive Strength (Mpa)			Void ratio (%)	Infiltration rate (l/min/m^2)
	7th day	14th day	28th day		
M1	13.42	13.8	14.11	14.47	939

Trial No.4

Table 8 Trial No.4 Mix Design Results

Mix Design	Compressive Strength (Mpa)			Void ratio (%)	Infiltration rate (l/min/m^2)
	7th day	14th day	28th day		
M1	11.65	13.42	13.64	17.86	1312

III. CONCLUSION

An experimental study evaluating strength and permeability characteristics of a pervious concrete mix design is presented. The experimental work included compressive strength tests, void ratio and infiltration rate test on clean specimens. The experiments were performed on specimens of size 150mm x150mm x150 mm cube.

- For a particular mix examined, compressive strength ranges between 4MPa and 19MPa with an average of about 12MPa.
- Similarly void ratio ranges between 6% to 20% with an average of about 14%
- Infiltration rate ranges between 300 l/min/m^2 and 1900 l/min/m^2 with an average of about 1200 l/min/m^2.
- Overall it is observed that when void ratio increases, infiltration rate also increases and compressive strength decreases and vice versa.
- Strength of Pervious concrete is less than that of conventional concrete of nearly same mix design but pervious concrete has very high degree of permeability as compared to conventional concrete's which is nearly zero.

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