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An Experimental Investigation on Pervious Concrete

[1] BHARATHI G, [2] RUBESH M, [3]SANJAY KUMAR S, [4]SATHISH KUMAR S
[1]*(Assistant Professor of Civil Engineering, Dhanalakshmi Srinivasan College of Engineering & Technology, Chennai-603104)*
[2 3 4] *(UG Student, Department of Civil Engineering, Dhanalakshmi Srinivasan College of Engineering & Technology, Chennai-603104)*

ABSTRACT: *Pervious concrete means high porous concrete used for storm drainage. The curing plays a major role in developing the concrete micro structure. This project deals with the comparative study of atmospheric curing and water curing without any admixture for porous concrete. materials for the study were collected and tested for its properties. mix destination for mixes taken under study was found. special mix design were done and specimens were cast and tested for 7 and 28 days of compressive strength and 28 days for flexural and split tensile strength. the results were compared with atmospheric curing and water curing and conclusion is made*
KEYWORDS: Pervious & porous concrete, compressive strength, flexural strength, split tensile strength, atmospheric curing

I. INTRODUCTION

1.1 Definition

Pervious concrete is a composite material consisting of coarse aggregate, Portland cement, and water. It is different from conventional concrete in that it contains no fines in the initial mixture, recognizing however, that fines are introduced during the compaction process. The aggregate usually consists of a single size and is bonded together at its points of contact by a paste formed by the cement and water. The result is a concrete with a high percentage of interconnected voids that, when functioning correctly, permit the rapid percolation of water through the concrete. Unlike conventional concrete, which has a void ratio anywhere from 3-5%, pervious concrete can have void ratios from 15-40% depending on its application. Pervious concrete characteristics differ from conventional concrete in several other ways. Compared to conventional concrete, pervious concrete has a lower compressive strength, higher permeability, and a lower unit weight, approximately 70% of conventional concrete.

concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer. When aggregate is mixed together with dry Portland cement and water, the mixture forms fluid slurry that is easily poured and molded into a shape. The cement reacts chemically with water and other ingredients to form a hard matrix that binds the material together into a durable stone like material that has many uses. Often, additives are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing material embedded to provide tensile strength, yielding reinforced concrete. Famous concrete structures include the hoover dam the Panama Canal, and the roman pantheon. The earliest large-scale users of concrete technology were the ancient romans, and concrete was widely used in the Roman Empire. The colosseum in Rome was built largely of concrete dome. Today large concrete structures are usually made with reinforced concrete.

Concrete is a composite material composed of coarse aggregate bonded together with a fluid cement that hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements, such as clement fondue. However, asphalt concrete, which is frequently used for road surface, is also a type of

Fig-1 pervious concrete

1.2 **Uses**

Practical for many applications, pervious concrete is limited by its lack of durability under heavy loads. This lack of resiliency restricts the use of pervious concrete to specific functions. Pervious concrete is limited to use in areas subjected to low traffic volumes and loads. Although once used as load bearing walls in homes (Ghafoori,1995), pervious concrete is now utilized primarily in parking lots but does have limited applications in areas such as greenhouses, driveways, sidewalks, residential streets, tennis courts (limited to Europe), and swimming pool decks.

1.3 Advantages and Disadvantages

Advantage:

- Pervious concrete resists moving under braking vehicles.
- Pervious concrete passes more permeability.
- Pervious concrete is less shrinkage and has low unit weight.
- Pervious concrete is higher thermal insulating values.

Disadvantage:

- Pervious concrete has a lower bonding strength provides lower compressive Strength.
- There is potential for clogging thereby possibly reducing its permeability Characteristics.

1.4 COMPARISION BETWEEEN PERVIOUS CONCRETE AND CONVENTIONAL CONCRETE:

In conventional concrete commonly cement, water, fine aggregate and coarse aggregate were used but in pervious concrete we did not used fine aggregate, only cement, water and coarse aggregate were used.The permeability of the conventional concrete should be as minimum as possible (i.e.) should not permeable the water. But for pervious concrete the permeability of the water is the main concept.The voids present in the conventional concrete should be almost zero; in pervious concrete the voids should be present of about 20 percentages.The strength of conventional concrete is defined by the grade of concrete. The pervious concrete is a special concrete because we are not using the fine aggregate so that the grade of concrete is not defined. The strength is determined for the requirement of purpose of this concrete used.

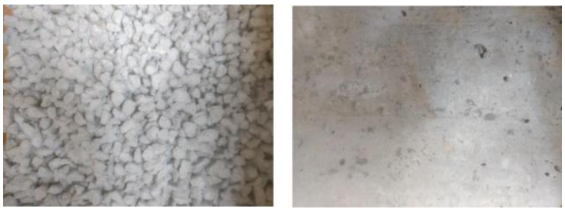

Fig-2 comparison of pervious concrete and conventional concrete

1.6 Curing and its importance

Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration. Curing also control the ambient temperature of hydrating concrete since this affects the rate of hydration. Concrete that allowed to dry out quickly also undergoes considerable early age drying shrinkage. Inadequate or insufficient curing is one of main factors contributing to weak, powdery surfaces with low abrasion resistances. The durability of concrete is affected by a number of factors including its permeability and absorptivity, results of lack of curing. These are related to the porosity of the concrete and whether the pores and capillaries are discrete or interconnected. Whilst the number and size of the pores and capillaries in cement paste are related directly to its water cement ratio, they are also related indirectly to the extent of water curing.

Long-time water curing causes hydration products to fill the pores and capillaries present either partially or completely in turn to reduce the porosity of the paste. Curing is designed primarily to keep the concrete moist by preventing the loss of moisture from the concrete during the period in which it is gaining strength. Curing must be done for a reasonable period of time if the concrete is to achieve its potential strength and durability.

Difference between atmospheric and water curing

Normal water curing requires more amount of water. But in the atmospheric curing the external applications of water is not needed. Because the curing is done with the humidity present in the atmosphere. It is more possible in the area with more humid. In more humidity area wasting of water for curing can be reduced.

II. PROPERTIES OF MATERIAL USED

2.1 **Cement**

Cement is material that has cohesive and adhesive properties in the presence of water. Such cements are called hydraulic cement. These consist primarily of silicates and aluminates of lime obtained from limestone and clay. Ordinary Portland cement (OPC) is used for this study.

Ordinary Portland cement (OPC) is the basic Portland cement and is best suited for use in general concrete construction.

Ordinary Portland cement of 53 is used.

Specific gravity = 3.15.

Fig-3 cement

3.1.1 Initial and final setting time of cement

Before commencing setting time test, the consistency test to obtain the water required to give the past normal consistency. Take 400g of cement and prepare a neat cement paste with 0.85P of water by weight of cement. Gauge time is kept between 3 to 5 minutes. Start the stop watch at the instant when the water is added to the cement. Record this time. Fill the vicat mould, resting on a glass plate, with the cement paste gauged as above. Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared is called test block.Place the test block confined in the mould and resting on the non-porous plate, under the rod bearing the needle. Lower the needle gently until it comes in contact with the surface of test block and quick releases, allowing it to penetrate into the test block. In the beginning the needle completely pierces the test block. Repeat this procedure for quickly releasing the needle after every 2 minutes till the needle fails to pierce the block for about 5mm measured from the bottom of the mould. Replace the needle of the vicat's apparatus by the needle with an annular attachment for final setting time. The cement is considered finally set upon applying the final setting needle gently to the surface of the test block; the needle makes an impression thereon, while the attachment fails to do so.

The initial setting of cement is 30 minutes

The final setting of cement is 24 hours

2.1.2 Fineness of cement

Weigh approximately 400g of cement to the nearest 0.01g and place it on the sieve. Agitate the sieve by swirling, planetary and linear movements, until no more fine materials passes through it. Weigh the residue and express its mass as a percentage of the quantity first placed on the sieve to the nearest 0.1 percent. Gently brush all the fine material off the base of the sieve. Repeat the whole procedure using a fresh 400g sample to obtain. Then calculate the mean value as the percentage nearest to 0.1. when the results differ by more than 1 absolute, carry out a third sieving and calculate the mean of three values.

Fig-4 Fineness test of cement

The fineness test value is 97.25 %

2.1.3 Consistency of cement

Take a 400g of cement and place it in the enamel tray. Mix about 25% water by weight of dry cement thoroughly to get a cement paste. Total time taken to obtain thoroughly mixed water cement paste i.e. "gauging time" should not be more than 3 to 5 minutes. Fill the vicat mould, resting upon glass plate, with this cement paste. After filling the mould completely, smoothen the surface of the paste, making it level with top of the mould. Place the whole assembly under the rod bearing plunger. Lower the plunger gently so as to touch the surface of the test block and quickly release the plunger allowing it to sink into the paste. Measure the depth of penetration.

Fig-5 consistency test

P = (W/C) * 100

The consistency of cement is **36.25 %**

2.2 Coarse aggregate

The crushed aggregate is the strongest and least porous components of concrete. Presence of coarse aggregate reduces the drying shrinkage and the other dimensioned changes occurring on the account of the movement of moisture. Coarse aggregate is gravel which has been crushed, washed and sieved so that the particles vary from 12.5 up to 20mm in size. Coarse aggregate shall comply with the requirement of IS 383-1970. The nominal maximum size of coarse aggregate used in this project is 20mm. coarse aggregate for this study has been brought from the local store located near mamallapuram.

Fig-6 Aggregate

2.2.1 Impact test

The sample aggregates passing 12.5mm sieve and retained on 10mm sieve and dried in an oven for 4 hours at a temperature of 100*C to 110*C. The aggregate are filled up to about 1/3 full in the cylindrical measure and tamped 25 times with rounded end of the tamping rod. The rest of the cylindrical measure is filled by two layers and each layer being tamped 25 times. The overflow of aggregates in cylindrically measure is cut off by tamping rod using it has a straight edge. Then the entire aggregate sample in a measuring cylinder is weighed nearing to 0.01gm. The aggregates from the cylindrical measure are carefully transferred into the cup which is firmly fixed in position on the base plate of machine. Then it is tamped 25 times. The hammer is raised until its lower face is 38cm above the upper surface of aggregate in he cup and allowed to fall freely on the aggregate. Let the original weight of the dry sample be W1gm and the weight of the fraction passing 2.36mm IS sieve be W2gm. The aggregate impact value is expressed as the % of fines formed in terms of the total weight of the sample.

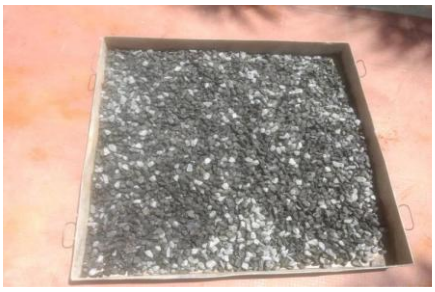

Fig-7 impact test

Table-1: Impact value test

S.no	Details of Sample	Trail 1 Gram	Trail 2 gram	Trail 3 Gram
1	Weight of Cylinder Measure	634	634	634
2	Weight of Aggregate	352	368	344.5
3	Weight of the Aggregate passing 2.36mm Sieve	43.5	47.5	45
4	Weight of Aggregate Retained 2.36mm sieve after the test	308.5	320.5	299.5
5	Aggregate impact value	12.36 %	12.91 %	13 %

Average impact value is 12.76 % which is strong / very tough

2.2.2 Specific gravity

Dry the pycnometer and weigh it with its cap. Take about 200gm of oven dried aggregate passing through 10mm sieve into the pycnometer and weigh it again. Add sufficient de-aired water to cover the aggregate and screw on the cap. Shake the pycnometer well and remove entrapped air if any. After the air has been removed, fill the pycnometer with water completely. Thoroughly dry the pycnometer from outside and weigh it. Clean the pycnometer by washing thoroughly. Fill the cleaned pycnometer completely with water up to its with cap screw on. Weigh the pycnometer after drying it on the outside thoroughly

Table-2 : specific gravity test

Description	Trail-1 Gram	Trail-2 Gram	Trail-3 Gram
Weight of empty mould	590	590	590
Weight of mould + aggregate	1744	1758	1736
Weight of mould + aggregate + water	2103	2143	2092
Weight of mould + water	1416	1416	1416
Result	2.47	2.65	2.44

The specific gravity of the sample is **2.52**

3.2.3 Water absorption

Table-3 water absorption test

s. no	Weight of oven dried Gram	Weight of saturated of specimen gram	Weight of water absorbed Gram	% of water absorption Gram
1	200	202	2	1 %

2.2.4 Abrasion test

First clean and dry sample confirming to one of the grading A to G used for the test. Aggregate weighing 5kg for grading A,B,C or D and 10kg for grading E,F or G may be taken as test specimen and placed in the cylinder. The abrasive charge is also chosen in accordance and placed in the cylinder of the machine, and cover is fixed to make dust tight. The machine is rotated for 500 revolutions for grading's A,B,C and D, for grading's E,F and G, it shall be rotated for 1000 revolutions. After the desired number of revolutions the machine is stopped and the material is discharge from the machine taking care to taken out entire stone dust. Using sieve of size larger than 1.70mm IS sieve, the material is first separated into two parts and the finer position is taken out and sieved further on a 1.7mm IS sieve. Let the original weight of aggregate be weight, weight of aggregate retained on 1.70mm IS sieve after the test be weight.

Table -4 Abrasion test

S.no	Details of Sample	Trial 1
1	**Weight of sample after abrasion test, coarse than 1.70mm IS Sieve**	1078
2	**Percentage Wear**	21.56 %

The average value of abrasion test is **21.56 %**

3.2.5 Shape test
The sample is sieved with the sieves mentioned in the table. A minimum of 200 pieces of each fraction to be tested are taken and weighed. In order to separate flaky materials, each fraction is then gauged for thickness on thickness gauge, or in bulk on sieve having elongated slots as specified in the table. Then the amount of flaky materials passing the gauge is weighed to an accuracy of at least 0.1% of test sample.

% of aggregate passing thickness gauge **15.83 %**

2.2.6 Fineness modules of coursed aggregate

To find the fineness of coarse aggregate took 5000gm of fresh aggregate. First sieved 5000gms of coarse aggregates through IS 20mm and weigh the residue left behind on it and record it. The residue is then sieved through IS 20mm sieve and the left over is weighed and recorded. The above procedure is repeated for the rest of the sieve also. The after tabulating the results, compute the percentage of materials retained on each of the sieve. Calculate the percentage of the material retained on each sieve and the percentage of passing. Compute the fineness modulus of the given aggregate sample.

Fineness modulus of coarse aggregate =(W2/W1)*100

Table -5 Fineness modulus of coarse aggregate

S.no	Sieve size (mm)	Weight of aggregate(g)	weight retained(g)	% of weight Retained	Cumulative% of retained	% of passing
1	20	5000	0	0	0	100
2	12.5	5000	1740	34.8	34.8	65.2
3	10	5000	1899	37.98	72.78	27.22
4	4.75	5000	1303	26.06	98.84	1.16

MIX DESIGNATION AND DESIGN

Mix design for amount of materials needed is designed as per IS 10262:2009. The materials are replaced by its volume and not weight basis. The quantity of each material is calculated for a cubic meter. Mass of materials needed are calculated and the final mix ratio is obtained. For casting specimens the mix proportion is used for batching materials. The quantity of materials for a specific mix per cubic meter can be calculated.

Table-7 mix design

Mix ratio	1:4

w/c ratio	0.3
Cement	427.1 kg/m^3
Aggregate	1708.4 kg/m^3
Water	128.13 Lt/m^3

III. EXPERIMENTAL INVESTIGATION

3.1 FRESH CONCRETE TEST

3.1.1 SLUMP CONE TEST

The internal surface of the mould is thoroughly cleaned and freed from superfluous moisture and adherence of any old set concrete before commencing the test. The mould is placed on a smooth, horizontal rigid and non-absorbent surface. The mould is then filled in four layers each approximately ¼ of the height of the mould. Each layer is tamped 25times rod taking care to distribute the strokes evenly over the cross section. After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod. The mould is removed from the concrete immediately by raising it slowly and carefully in a vertical direction. This allows the concrete to subside. This subside is referred as slump of concrete. The pattern of slump indicates the characteristics of concrete in addition to the slump value. If the concrete slumps evenly it is called true slump. If one half of the cone slides down, it is called shear slump. In case of a shear slump, the slump value is measured as the difference in height between the height of the mould and the average value of the subsidence. Shear slump also indicates that the concrete is non-cohesive and shows the characteristic of segregation.


Fig-19 slump cone test

The slump value of concrete is **30 mm**

3.1.2 Flow table test

The table top is cleaned of all gritty materials and is wetted. The mould is kept on the centre of the table, firmly held and is filled with two layers. Each layer is rodded 25 times with a tamping rod 1.6cm in diameter and 61cm long rounded at the lower tamping end. After the top layer is rodded evenly the excess of concrete which has overflowed the mould is removed. The mould is lifted vertically upward and the concrete stands on its own without support. The table is then raised and dropped 12.5cm 15 times in about 15 seconds. The diameter of the spread concrete is measured in about 6 directions to the nearest 5mm and the average spread is noted. The flow of concrete is the percentage increases in the average diameter of the spread concrete over the base diameter of the mould. The value could range anything from 0 to 150 percent. A close look at the pattern of spread of concrete can also give a good indication of the characteristic of concrete such as tendency for segregation.

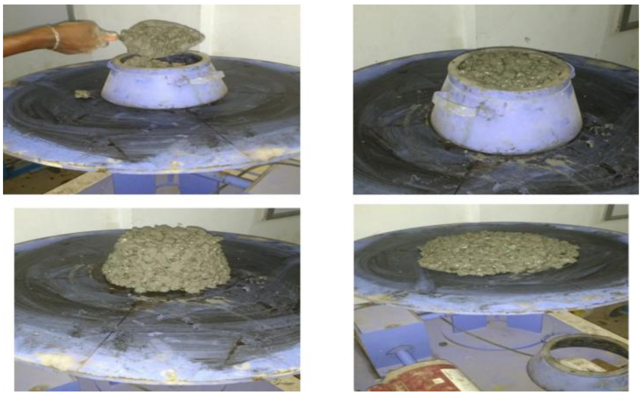

Fig-20 flow table test

The flow percent of the concrete is **10 %**

3.1.3 Compaction factor test

The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap door is opened so that the concrete falls into the lower hopper. Then the trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder. In case of a dry-mix, it is likely that the concrete may not fall on opening the trap-door. In such a case, a slight poking by a rod may be required to set the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut off with the help of plane blades. The outside of the cylinder is wiped clean. The concrete is filled up exactly up to the top level of the cylinder. It is weighed to the nearest 10 grams. This weight is known as "weight of partially compacted concrete". The cylinder is emptied and then refilled with the concrete the sample in layers approximately 5cm deep. The layers are heavily rammed or preferably vibrated so as to obtain full compaction. The top surface of the fully compacted concrete is then carefully struck off level with the top of the cylinder and weighed to the nearest 10gm. This weight is known as "weight of fully compacted concrete".

Fig-21 compaction factor test

The flow percent of the concrete is **93.6 %**

3.1.4 Vee Bee consistometer

Place the slump cone inside the sheet metal cylindrical pot of the consistometer. The glass disc attached to the swivel arm is turned and placed on the top of the concrete pot. The electrical vibrator is switched on and simultaneously a stop watch is started. The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes cylindrical shape. Immediately when the concrete fully assumes cylindrical shape, the stop watch is switched off. The time requires for the shape of concrete to change from slump cone shape to cylindrical shape in seconds is known as vee bee degree.

Table-8 vee bee consistometer

Initial reading on the graduated rod	105 mm
Final reading on the graduated rod	235 mm
Slump	120 mm
Time for complete remoulding, seconds	19 s


Fig-22 vee bee consistometer

S.no	Mix Designation	Trail 1 KN	Trail 2 KN	Trail 3 KN	Average Load at Failure	Compressive strength (N/mm^2)
1	Atmospheric Curing	388	334	427	383.00	17.02
2	Water curing	533	500	466	499.67	22.20

3.2 Hardened concrete test

3.2.1 Compressive strength test

The cubes that are to be tested were taken out from curing tank for 7 and 28 days respectively wiped and left to dry in sunlight. Once it's gotten dry the specimens were shifted to the testing place where the compression testing machine is located and the dimensions of the specimen were noted. It consists of 3 parts namely pumping unit, straining unit and the load measuring unit. The upper compression plate is of steel surface that can be adjusted to touch the specimen. The pressure corners through lower plate from the pressure cylinder the bottom of the machine. The applied load can be measured with a pressure gauge mounted on the front panel. The machines cube bolder is cleaned and the dial is calibrated to zero before testing. The compression testing machine has a maximum capacity of 3000 Kn. When testing the face of cube which was exposed from the start or the face which was named before demoulding was kept in a horizontal position. The cube was placed at the centre of the loading plates so that the load will be parallel. Once finished placing the cube the machine door is closed and it is started the dial gradually rises for increasing in load and stops at the failure load, the loading plate released, reading is noted and the cube is removed. Three cubes of same design were tested and the average of them is chosen as final compression strength.

Table-9 compressive strength test
Compressive strength at 7 days

S.no	Mix designation	Trail 1 KN	Trail 2 KN	Trail 3 KN	Average load at Failure	Compressive strength (N/mm^2)
1	Atmospheric Curing	309	269	318	298.67	13.27
2	Water curing	200	192	189	193.67	8.61

Compressive strength at 28 days

Fig-23 compressive strength test

3.2.2 Split tensile strength test

The cylindrical specimens are allowed to cure for 28 days respectively then were taken out of curing tank before the day of testing. The surface are cleaned and left for drying. The specimens after dried were taken to the testing place where the compression testing machine is located. Before testing the loading plates of the machine were cleaned and the concrete cylinder was kept horizontally where the named face facing the person in front. Once the specimen was positioned for testing the machine door was closed and operated. As the load increases the specimen splits the failure load. The dial on the top of machine shows the failure load at which the cylinder split. Three specimens of the same mix are tested and the average of the failure load is taken into account and the stress was calculated. The tensile stress was calculated using the below formulae.

Table-10 split tensile strength test (28 days)

S. no	Mix Designation	Trail 1 KN	Trail 2 KN	Trail 3 KN	Average load at failure	Split tensile Strength (N/mm^2)

1	Atmospheric Curing	127.48	139.74	132.38	133.2	1.89
2	Water curing	186.32	181.42	178.48	182.07	2.58

Fig-24 split tensile strength test

32.3 Flexural strength test

Prepare the test specimen by filling the concrete into the mould in 3 layers of approximately equal thickness. Tamp each layer 35 times using the tamping bar as specified above. Tamping should be disturbed uniformly over the entire cross section of the beam mould and throughout the depth of each layer. Clean the bearing surfaces of the surfaces of the supporting and loading rollers, and remove any loose sand or other material from the surface of the specimen where they are to make contact with the rollers. Circular rollers manufactured out of steel having cross section with diameter 38mm will be used for providing support and loading points to the specimens. The length of the rollers shall be at least 10mm more than the width of the test specimen. A total of four rollers shall be used, three out of which shall be capable of rotating along their own axes. The distance between the outer rollers shall be 3d and the distance between the inner rollers shall be d. the inner rollers shall be equally spaced between the outer rollers, such that the entire system is systematic. The specimen stored in water shall be tested immediately on removal from water, whilst they are still wet. The test specimen shall be placed in the machine correctly centred with the longitudinal axis of the specimen at right angles to the rollers. For moulded specimens, the mould filling direction shall be normal to the direction of loading. The load shall be applied at a rate of loading of 400kg/min for the 15.0 cm specimen.

Table 11- flexural strength test(28 days)

S.no	Mix designation	Trail 1 KN	Trail 2 KN	Trail 3 KN	Average load at failure	Flexural strength (N/mm^2)
1	Atmospheric Curing	5.10	5.89	5.59	5.53	1.66
2	Water curing	9.42	8.29	8.93	8.88	2.67


Fig-25 flexural strength test

Fig-25 flexural strength test

6.2.4 Permeability test

This test was done by simple method. Clean the pavement Pervious concrete slab of 50cm * 50cm have been made. After the slab has hardened the ponding of cement paste has to be made. The water of 15kg of weight has to be taken. Pour the water into the ponding surface manually. Calculate the time taken using stop watch. Then the calculation for permeability has to be made.


Fig-26 Permeability test

Infiltration = KM/D^2T

The infiltration value is **7.584 m/hr**

IV. CONCLUSION

- The pervious concrete can be used for pavements in the mode of slabs is preferable.
- It gives better permeability of water.
- The workability test was done for the concrete and the results were analyzed.
- The mechanical strength of concrete mainly depends upon aggregate quality and curing methods.
- The atmospheric curing gives better result when compare to water curing for 7 days of compression strength.
- Water curing gives satisfied results at the end of 28 days of compressive, flexural and split tensile strength.
- Using high grade of aggregates and admixtures are suggested to get high strength of pervious concrete.
- Curing using jute bags were preferred at the continental temperature.
- Using of colour pigments increases the aesthetic appearance of concrete.

REFERENCE

CODE BOOKS

- IS 4031 - (part-5) 1998 for cement
- IS 2386- (part-4) 1963 for aggregate test
- IS 10262- 2009 for mix design
- ASTM 1701 for permeability
- IS 4031-(part-1) 1996 for consistency