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STUDY ON PERVIOUS CONCRETE

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ABSTRACT

Now-a-days most of the urban areas are covered with impermeable surfaces. During heavy rains or floods the water flowing on the surface is causing discomfort for the users. In the areas where the drainage system is poor, it is causing severe flooding of low lying areas. At these sorts of situations, it is important to have the surface as permeable one, which is nothing but the surface of pervious concrete. Compared to conventional concrete, pervious concrete should have more voids, which is achieved by the little or absence of fine aggregate. The significant property of the pervious concrete is Permeability.It is the property which allows the water to seep through the concrete. But there are very limited standards to measure this property. Specifically there is no clear laboratory test yet to measure permeability of pervious concrete. We measure the unique feature of pervious concrete that is its permeability and also try to increase the strength of permeable concrete without affecting its percolation characters. Tests were being carried out for the mixes with zero fine aggregate and with water/cement ratios from 0.3 to 0.35. We also tested the characteristics for a little quantities of sand i.e., 5%, 10% and 15% of total aggregate for optimum water/cement ratio obtained from our tests. In order to test the permeability of pervious concrete, as there is no special apparatus the permeability apparatus for testing the soil permeability is used, in which, soil is replaced with concrete specimenof suitable dimensions. For zero fines aggregate, it was observed that on decreasing water/cement ratio, the coefficient of percolation increases up to the w/c ratio 0.32 and then itdecreases slightly. It shows maximum coefficient of percolation at the w/c ratio 0.32 at which strength is also maximum comparatively. Hence we found that the optimum water/cement ratio for pervious concrete mix is 0.32

Keywords: Pervious Concrete, Permeability, Soil Permeability Apparatus, Affect on Strength, Fine Aggregate Quantity.

Introduction

Paved surfaces exist everywhere in urban areas these days. But we need to consider the impact they have on the ground water recharge. As the black topped surfaces in the urban area are increasing day by day large amount of rain water is accumulating up on the impervious surfaces such as parking lots, drive ways and sidewalks rather than seeping into the soil. This creates an imbalance in the naturalwater flow and leads to problems such as erosion, floods, water table depletion, and pollution of water bodies as rain water rushing across pavement surfaces picks up everything such as oil, grease, chemical etc.A solution for these problems is to reduce the installation of the impervious surfaces that block the natural water from percolating into the soil. Instead of using impervious surfaces, it is more advantageous to construct them with pervious concrete.

Pervious concrete is an environmental friendly building material and Environmental Protection Agency (EPA) has identified it as a best management practice for storm water management.

Pervious concrete is a special type of concrete with interconnected voids which allows water from precipitation and other sources to pass directly through it, while maintaining the adequate strength[4]. But the strength which can be attained by

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pervious concrete is insufficient to use it as the pavement material for normal roads having said that, it can be used as a paving material for parking areas, areas with light traffic, streets of residential areas and pedestrian walk ways. Instead of preventing infiltration of water into the soil, pervious pavement assists the process by capturing rainwater in a network of voids and allowing it to percolate into the underlying soil. Pervious concrete reduces the runoff from the paved areas, which reduces the need for separate storm water management system like storm drains, and considerably reduces the pressure on storm water sewers.As pervious concrete pavement acts as an infiltration basin, which allows storm water to infiltrate the soil over large area, it thus facilitates the recharge of ground water supplies naturally[5]. A pervious concrete pavement allows the transfer of both water and air to root systems allowing trees to flourish even indeveloped areas. It provides solution for many storm water problems.

In pervious concrete, as the water flow takes place through the voids it requires more number of voids when compared to very dense structure like conventional concrete. Generally the fine aggregate is used in the conventional concrete to fill up the voidsbetween the coarse aggregate, where as in pervious concrete the presence of voids is necessary so, fine aggregate is either removed completely or a little quantity is used. But the absence of fine aggregate affects the strength of the concrete. Hence the mix is to be prepared in such a way that hardened concrete should have required permeability without affecting the strength of concrete to a greater extent.

After hardening, density and porosity are the important properties which are to be examined, as these two are related with strength and permeability. Generally the range of porosity that is commonly reported for pervious concrete is 15-30%, which depends on compaction method adopted in addition to mixture proportions. The density of pervious concrete varies from 1600kg/m3 to 2000kg/m3. The permeability depends on the materials size and placing operations.

MIX DESIGN

To design the mix proportion of pervious concrete there is no IS standard available, but various researchers, authors implemented an arbitrary design procedure based on selecting a particular aggregate to cement ratio for the required target strength (and only applicable to 20mm aggregate)[2]. Some researchers implemented the design mix based on their past experiences.

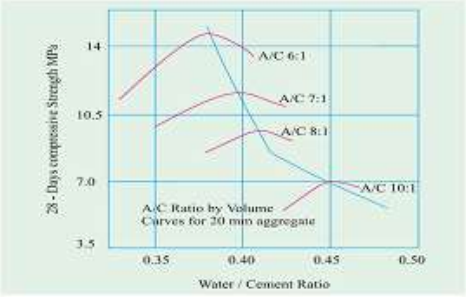

Fig from [1]

To design the pervious concrete a standard code is available in U.S.A i.e. ACI522R-10 which involves an absolute volume concept and is based on a single variable b/b0.

We tried to design the mix based on IS-10262 by implementing some changes in volume of all in aggregates and water/cement ratio (Instead of dividing volume of all in aggregates into coarse and fine aggregate volume, we completely took it as coarse aggregate volume). The cement

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paste content is a driving factor for the concrete mix design, which is related to the water/cement ratio. If the water/cement ratio is more, as we are using only cement, after casting the slurry settles to the bottom. If the water/cement ratio is less, the cement paste does not provide a sufficient binding between the aggregates. Hence it has to be maintained sufficiently. From the previous studies we infer that pervious concrete contains the maximum water cement ratio of 0.35 so we conducted experiments for different mix designs with varying water cement ratio ranging from 0.30-0.35 (with zero fine aggregate) and conducted strength, permeability and porosity tests to find out the optimum water cement ratio which gives a good balance of strength and permeability.

For M_{20}concrete with 20mm graded aggregate

W/C	WEIGHT OF CEMENT (kg/m^3)	WEIGHT OF WATER (L)	WEIGHT OF AGGREGATE (kg/m^3)
0.35	531.4285	186	1742.2897
0.34	547.0588	186	1728.8924
0.33	563.6363	186	1714.6831
0.32	581.25	186	1699.5857
0.31	600	186	1683.5142
0.30	620	186	1666.3714

Weight's required for one 1000cc mould and three 150x150x150 cubes ($0.011125m^3$)

W/C	WEIGHT OF CEMENT (kg)	WEIGHT OF WATER (L)	WEIGHT OF AGGREGATE (kg)
0.35	5.9121	2.0692	19.3829
0.34	6.0860	2.0692	19.2339
0.33	6.2704	2.0692	19.0758
0.32	6.4664	2.0692	18.9078
0.31	6.6750	2.0692	18.7290
0.30	6.8975	2.0692	18.5383

And after testing the mix proportions with water cement ratios from 0.30-0.35 we found out that the optimum water cement ratio is 0.32 and for that water cement ratio we introduced small amounts of fines (i.e., 5%, 10% and 15%) in the mix proportion in anticipation of increase in strength without effecting the permeability of the concrete so that it can be used similar to normal pavement material.

Fine Aggregate	Weight of fine aggregate (kg)	Weight of Coarse Aggregate (kg)
5%	0.945	17.96
10%	1.89	17.017
15%	2.836	16.071

TESTING PROCEDURE

The main aim of our study is to test the permeability of the pervious concrete and to alter the strength without affecting the permeability. As the key feature of the pervious concrete is related to the permeability, we need to measure the permeability of the permeable concrete. But there is no standard to test the permeability of pervious concrete in laboratory. We came to know that there is a standard test method for the measure of infiltration of pervious concrete as per ASTM C1701 which is used measure the percolation in field. But there is no method to check the performance of pervious concrete in laboratory.

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So we gave a try to test the percolation of pervious concrete by using general permeability apparatus used to test the permeability of the soil where the soil in the apparatus is replaced with pervious concrete specimen of suitable dimensions. The test is conducted under constant head condition. The dimensions of a specimen are 100mm diameter and 127 mm height and the test is performed after curing for 6 days. Compressive strength test is carried out in universal testing machine after curing for 7 days.Which is followed by porosity test and permeability test, as we know that percolation is given by permeability divided by porosity. As we know that the porosity is given by volume of voids divided by total volume (n) $=\frac{VOLUME\ OF\ VOIDS}{TOTAL\ VOLUME}\frac{Vv}{V}$ and volume of voids Vv $=V-Vs$ where Vs is volume of solids. We first calculated the volume of the specimen casted for the permeability test and then we calculated the volume of solid based on the Archimedes principle i.e., volume of water displaced is equal to the volume of the object immersed (here it is equal to volume of solids).

RESULTS AND DISCUSSIONS:

From the tests, we observed permeability and strength as following:

w/c	Co-eff. Of permeability(k) (cm/s)	Porosity(n) n= $(V-V_s)/V$	Co-eff. Of percolation(K_p) (cm/s)	Compressive Strength (N/mm2)
0.35	0.0243	0.2926	0.0830	8.88
0.34	0.0283	0.3778	0.0749	11.11
0.33	0.0231	0.3606	0.064	12.44
0.32	0.0229	0.2540	0.0902	13.33
0.31	0.0223	0.2549	0.0858	11.77
0.30	0.0155	0.2668	0.058	10.66

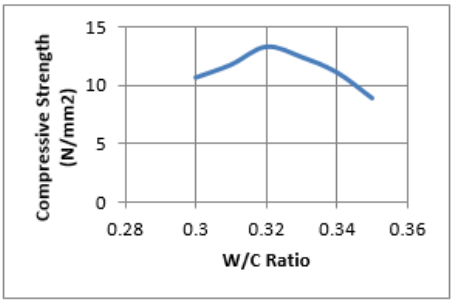

Fig. showing w/c vs compressive strength

Chart Area

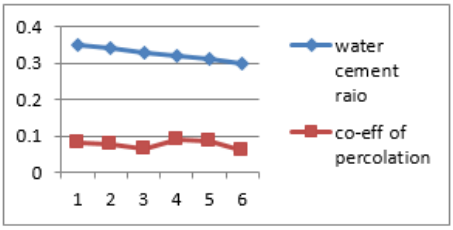

Fig. showing variation of w/c with Kp

From the above table it is clear that w/c ratio of 0.32 is optimum as the percolation and strength are maximum.

We can observe that as the w/c ratio is decreasing, percolation values are decreasing up to w/c ratio of 0.33 and at w/c ratio of 0.32, it reaches its maximum value and then followed a decreasing trend. As we decrease the w/c ratio, the cement content increases, which fills the voids between the aggregates, so there is a decreasing trend in the permeability. As we increase the w/c ratio, the cement content in the mix goes on increasing, where as the weight of the coarse aggregate goes on decreasing (as per our design), so this results in increase in strength up to which

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the cement content is sufficient enough to bind the aggregates, (i.e., up to w/c ratio of 0.32) beyond which even though cement content is increasing the strength is decreasing because of the decreasing coarse aggregate content. Hence we came to the conclusion that the w/c ratio of 0.32 is optimum. Having known the optimum w/c ratio, we try to increase the strength of concrete without affecting its permeability. So we introduce little quantities of fine aggregate i.e., 5%, 10% and 15% and tested for strength and permeability.

Fine aggregate (%)	Co-eff. Of percolation(K_p) (cm/s)	Compressive Strength (N/mm2)
5	0.234	14.81
10	0.2053	15.11
15	0.1099	16.00

Permeability can also be expressed in terms of **Lugeon** value[3]. Generally Lugeon test, which is an in-situ test used to obtain the hydraulic conductivity of the rock masses. It is a constant head type test that takes place in an isolated portion of the bore hole. Water at constant pressure is injected into the rock mass through a slotted pipe bounded by pneumatic packers. During the execution of the hydraulic conductivity, which is expressed in terms of lugeons. The Lugeon value is defined as the water loss of one liter per minute per meter of drill hole and is approximately equal to $1x10^{-7}$. It can be calculated for different pressure using the following formula:

$$Lugeon\ value = \frac{\text{water taken in test}\left(\frac{\text{l}}{\text{min}}\right) * 1.0\ Mpa}{\text{Test pressure}}$$

As the Lugeon value gives the water loss for the rock strata, we found that it is appropriate to measure the performance character of the pervious concrete in the same terms. Here in the constant head permeability test we consider the head as the test pressure and discharge as the water taken in test and express them in terms of Lugeon value.

w/c	Co-eff. Ofpercolation (cm/s)	Lugeon value
0.35	0.083	734.5
0.34	0.0749	697.8
0.33	0.064	670
0.32	0.09015	827
0.31	0.0858	650
0.30	0.058	634

CONCLUSIONS:

- Permeameter used for testing the soil permeability can also be used to measure permeability of pervious concrete.
- To achieve M_{20} in pervious concrete IS:10262 can be used with small changes in design procedure
- As water cement ratio decreases the permeability decreases and strength increases. At the water cement ratio of 0.32 we can get optimum strength and permeability. Hence we can consider 0.32 as optimum water cement ratio for pervious concrete.
- Even without adding any type of admixtures we can nearly achieve M_{15} in no fines concrete
- On adding small amounts of fines we can achieve M_{20} but the percolation of concrete will reduce

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