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To Improve the Ground Water Level using Pervious Concrete

Abhilash L. Kamdi[a], Kunal A. Ramteke[a], Nareshkumar G. Nagpure[a],
Rakesh N. Gautam[a], Vishal B. Mandal[a], Prof. M. B. Khamgaonkar[b]
[a]*U. G. Student, TulsiramjiGaikwad-Patil College of Engineering and Technology, Mohgaon, Nagpur, INDIA*
[b]*Assisstant Professor, TulsiramjiGaikwad-Patil College of Engineering and Technology, Mohgaon, Nagpur, INDIA*

***Abstract*—Pervious concrete pavement consist of cement, coarse aggregate and water. Thus basically pervious concrete may not be conventional concrete but it is a concrete where, instead of fine aggregate, coarse aggregate are used. But as the properties resemble with concrete it is called "Pervious concrete".Pervious concrete has become significantly popular during recent decades, because of its potential contribution in solving environmental issues. Pervious concrete is a type of concrete with significantly high water permeability compared to normal weight concrete. It has been mainly developed for draining water from the ground surface, so that storm water runoff is reduced and the groundwater is recharged. In present scenario, particularly in the urban area, roads in the societies are prepared with impervious layer of concrete. If this will be the trend then day will come when impervious surface create huge amount of runoff which may not carried by storm water drain due to large discharge. Unlike conventional concrete, which has a void ratio anywhere from 3-5%, pervious concrete can have voids ratio from 15-40% depending on its application. This paper presents an investigation of properties of pervious concrete with replacement of coarse aggregate by fine aggregate, comparison of compressive strength, flexural strength between pervious concrete and conventional concrete and also determination of permeability of pervious concrete.**

Keywords*—pavement; permeability; runoff; discharge; void ratio

I. INTRODUCTION

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. Portland cement pervious concrete (PCPC) is gaining a lot of attention [1]. Various environmental benefits such as controlling storm water runoff, restoring groundwater supplies, and reducing water and soil pollution have become focal point in many jurisdictions across the United States [2]. Portland cement pervious concrete is a discontinuous materials, admixtures and water. By creating a permeable surface, storm-water is giving access to filter through the pavement and underlying soil, provided that the underlying soil is suitable for drainage.

The benefits offered by pervious concrete are it decreases the flooding possibilities, especially in urban areas, recharges the ground water level, reduces puddles on the road and improves the water quality through percolation. On the other hand, pervious concrete have some disadvantages like low strength due to high porosity, high maintenance requirement, limited uses as a load bearing unit due to its low strength, etc. [3].

In 2003, Paul Klieger [4] performed an experiment for studying the effect of entrained air on the strength and durability of pervious concrete. The voids seen in pervious concrete were 15%-35%. His research clearly shows the impact the presence of air has on the performance of the concrete. He concluded that the reduction in compressive strength with the presence of air decreases as the size of aggregate decreases and the cement content decreases. These are both due to the reduction in water. The compressive strength of the pervious concrete is strongly depend on the water cement ratio, the aggregate cement ratio, aggregate size, compaction, curing. Experiment also indicates that the pervious concrete is most beneficial and should be restricted to areas subjected to low traffic volume. The test machine used was hydraulically power, the upper bearing block was stationary, while the lower bearing block moved up to compress the specimen. Researchers disagree as to whether pervious concrete can consistently attain compressive strength equal to conventional concrete.

Pervious concrete is a special high porosity concrete used for flatwork applications and other source to pass through there by reducing the run-off from a site and recharging ground water levels. Durability and water absorption are important properties of pervious concrete.Test result obtained by Darshan S. S. et. al. [5] indicates that pervious concrete made by 1:6 concrete mix proportion has more durability and less water absorption and pervious concrete made by 1:10 mix proportion has more water absorption and less durability and hence the durability and water absorption are inversely proportional to each other.Permeable pavement are filters, filters removal particles from fluids, as more particles are removed the flow rate is reduced and maintenance is required to restored the flow rate. The rate of clogging of a filter is based on the initial permeability and pore size, type and amount of material to be filtered, rate of the fluid carrying the material, and the level of service requiring regeneration of the filter. The controlling aspect are the initial permeability of the pavement, the amount of additional surrounding storm-water design to infiltrate through the surface, the amount of soil in the storm-water, and the slope of the pavement. With all the factors, the maintenance required for permeable pavement is highly site dependent.

Gravel is an important commercial product, with a number of applications. Many roadways are surfaced with gravel, especially in rural area where there is little traffic or less wheel load. Globally, so many roads are surfaced with gravel, which are used in concrete especially in Russia, which cover 4, 00,000 km of gravel roads. Gravel is formed as result of the weathering and erosion of rocks. Gravel is an alternate material in place of the aggregate which in turn used for making concrete when it is properly mixed with cement water. Gravel is used for making a special concrete like “Pervious Concrete” and for that purpose, especially 3/4 inch (18.75 mm) and 3/8 inch (9.375) gravel has been taken. For obtaining these two type of gravel from the available quantity sieve analysis has been carried out. Specific gravity, water absorption and bulk density of gravel is also found out. Gravel become compacted and concrete into sedimentary rock called as a conglomerate. Mostly gravel is produce by quarrying and crushing hard wearing rocks, such as sandstone, limestone, or basalt. Quarries where gravel is extracted are known as gravel pits. Gravel has certain properties which have to check before it should be used in concrete. Basic properties of gravel are sieve analysis for the Gradation of Gravel, specific gravity, water absorption and bulk density. All these properties of gravel are determined before the gravel has been used in concrete, because all these properties are directly affected on design and behavior of concrete. Properties of gravel determine by performing all these tests according to IS code. Gravel which is used for the building as well as road industry obtained from rocks excavated from quarries. Dynamites are used for blasting of these rocks and then break this gravel to the required size with the help of mechanical crusher. Most of the gravels are rounded and sub angular in their appearance [6].

Our cities are being covered with building and the air-proof concrete road more and more, in addition, the environment of city far from natural. Because of the lack of permeability and air permeability of the common concrete pavement, the rainwater is not filtered underground. Without constant supply of water to the soil, plants are difficult to grow normally. In addition difficult for soil to exchange heat and moisture with air; therefore the temperature and humidity of the earth’s surface in large cities cannot be adjusted. This brings the phenomenon of hot island in city. At the same time, plash on the road during rainy day reduce the safety of traffic of vehicle and foot passenger. The research on pervious pavement material has begun in developed countries such as the US and Japan since 1980s. Pervious concrete pavement has been used for over 30 years in England and United State. Pervious concrete is also widely used in Europe and Japan for roadway applications as a surface course to improve skid resistance and reduce traffic noise. However, strength of material is relatively low because of its porosity. The compressive strength of material can only reach above 20-30 MPa. Such materials cannot be used as pavement due to low strength. The pervious concrete can only be applied to squares, footpath, parking lots, and paths in park. Using selected aggregate, fine materials, admixtures, organic intensifier, and by adjusting the concrete mix proportion, strength and absorption resistance can improve the pervious concrete greatly [7].

In order to resolve the run-off of rainwater resource, to prevent the spoliation of ecology, and to reduce the effect of heat island, the search for a suitable mix design of the pervious concrete for Taiwan is not a trivial issue. The main purpose of this study is to find the most suitable pervious concrete mix for pavement engineering. The two experiments included in this study are 1. Test the suitable mix design of pervious concrete and 2. Test certification in the field construction of pervious concrete on parking lot. Pervious pavement composed 8-in surface layer (pervious concrete) and a 4-in base layer (gravel) were made. The result showed that the compressive strength of the two pervious concrete core specimen from test certification in the field construction (parking lot) exceeds the ordinary concrete structure specimen (175 kg/cm^2). The field permeability test for the parking lot is about 1000 ml/15sec. the water penetration of the above pervious concrete is very good and no cracks were present on surface. Therefore, it is an environmental-friendly material for pavement. Pervious concrete was referred to as parking lot pavement material in the central Florida area as early as the 1970s. The concept developed as a mean of handling the enormous quantity of water runoff within a parking lot during a heavy rain or storm; pervious concrete allows the water to percolate into the ground under the pavement. The Environmental Protection Agency (EPA) in United State has adopted a policy that the use of pervious concrete pavement as a part of their best management practice as a way for communities to mitigate the problem of storm water runoff. Pervious concrete parking lots have also been selected as an integral solution on the problem of hot pavements in the Cool Community Program. The hot pavement bring the phenomenon of heat island effect in the big city [8].

No-fines concrete admixtures subjected to impact compaction are studies under unconfined compression, indirect tension, and static modulus of elasticity; and the result are interpreted as functions of mixture proportion. The effect of impact-compaction energies, consolidation techniques, and mixture proportions, curing types, and testing conditions unphysical and engineering properties are presented. in recent year no-fines concrete pavements have become increasingly popular as an effective storm-water management device in areas the received frequent and sometime extensive rainfall. The most popular application is that of light-traffic-volume roadways such as parking lots, residential roads, driveways, and sidewalks. Traditional approaches to storm-water management have concentrated primarily on detaining and retaining run-off on-site to reduce flooding and pollution. Urban land developers are required to provide adequate run-off treatment systems, improving the quality of run-off discharge into surface water, and maintaining the recharge level of the aquifer. These regulations often required extensive land area for detention basins and continuous maintenance of functionally deterioration and extensive exfiltration devices. The aim of this paper is to present the result of a pilot study undertaken to examine the extent to which compacted no-fines concrete can be used as a paving materials for construction of parking lots, low-traffic-volume roadways. No-fines concrete is a composite material and containing carefully graded coarse aggregate bonded together by a paste of Portland cement and water. The aggregate is generally a single size, usually 9.5 or 19 mm (3/8 or 3/4 in.), with a cement contained sufficient adequate strength without reducing the porosity [9].

A laboratory study evaluating strength and permeability characteristics of porous concrete mix is presented. The experiments include compressive strength tests and falling head permeability tests on clean specimens. Falling head permeability were repeated after introducing some sand-salt mixture on the top surface of the specimens as a simulation of winter surface applications. The experiment were performed on specimen of three sizes : 7.62 cm, 10.16 cm, and 15.24 cm in diameter to examine if the test result were influenced by the size of the specimens. Multiple specimens were tested for a particular size. For the particular mix examined, the compressive strength ranged between about 4.5 MPa and 7.6 MPa with an average of about 6.2 MPa. Permeability test result yielded hydraulic conductivity ranging between 0.68 cm/s and 0.98 cm/s with an average about 0.87 cm/s. all of the above values were within the expected range found in the literature. The reduction in the hydraulic conductivity was about 15% with the surface application of the sand-salt mixture. The observed variation in the properties were also similar to those reported in the literature. Any effects arising from the size of specimen on the test result could not be distinguished from those arising from normal variations among specimen. The disadvantage of porous concrete pavement are perceived to be lower strength and durability that can sometimes occur in these system, which may lead to a service life that is shorter than that of the designed life. However, several studies have shown that adequate strength can be achieved for a variety of applications in which porous pavement would be useful, especially low-volume traffic areas such as parking lot. In these areas the benefits of porous concrete pavement system can outweigh the perceived limitations, as low-volume areas have a smaller strength demand and act as point sources for storm-water pollution [10].

This paper presents an investigation of properties of pervious concrete with replacement of coarse aggregate by fine aggregate, comparison of compressive strength, flexural strength between pervious concrete and conventional concrete and also determination of permeability of pervious concrete.

II. MATERIAL USED

The cement used wasPlain Cement Concrete (P.C.C.) confirming to IS-4031:1988 [6] refer Table 1.PCC is type of cement and is a fine powder produced by grinding in clinker. It has been possible to upgrade the qualities of cement by using high quality lime stone, modern equipment, maintaining better particle size distribution, finer grinding and better packing. A chemical admixture i.e. Super-plasticizer “Polycarboxylic ether” was used confirming to IS-9103: 1999 [7]. The aggregates provide about 75% of the body of the concrete and hence its influence is extremely important. Coarse aggregates of specific gravity of 2.74 and fine aggregate of2.38were used for casting of pervious concrete cubes. The material properties of coarse aggregates

TABLE I. Properties of Cement

Sr. No.	Characteristics	Values specified by IS code
1	Specific Gravity	2.65
2	Standard Consistency (in %)	33%
3	Initial Setting Time (in min.)	33 (min.)
4	Final Setting Time (in min.)	600 (max.)

TABLE II. Physical Property of Coarse Aggregate

Sr. No.	Aggregates Characteristics	Value
1	Color	Grey
2	Shape	Angular
3	Maximum Size	20 mm
4	Minimum Size	10 mm
5	Specific Gravity	2.65
6	Fineness Modulus	3.35
7	Water absorption	1.02 %

TABLE III. Trial Proportions

Trial	Cement(Kg)	Water(Kg)	C.A.(Kg)	F.A.(Kg)	Super-Plasticizer(Kg)	SilicaFumes(Kg)	G.G.B.S.(Kg)	LatexPolymer(Kg)
Trial-1 (C.C.)	15.96	5.586	49.21	30.16	0.319	-	-	-
Trial-2 (P.C.)	15.96	5.586	79.37	000	0.239	0.600	0.300	0.200
Trial-3 (30%)	15.96	5.586	53.74	7.328	0.239	0.600	0.300	0.200
Trial-4 (15%)	15.96	5.586	57.58	3.48	0.239	0.600	0.300	0.200

TABLE IV. Gradation of Coarse Aggregate, (IS:383)

IS Sieve size (mm)	weight of Coarse Aggregate Retained				Percent retained	cumulative percent retained	percent passing
	Determination no.						
	I	II	III	Avg.			
1	2	3	4	5	6	7	8
20	00	00	00	00	00	00	100
16	44	52	46	47.3	4.73	4.73	95.20
12.5	492	536	454	494	49.40	54.13	45.87
10	396	320	408	374.7	37.47	91.60	8.40
4.75	60	86	82	76.0	7.60	99.20	0.80
Pan	08	06	10	8.0	0.80	100	00

TABLE V. Physical Property of Fine Aggregate

Sr. No.	Characteristics	Values
1	Specific Gravity	2.38
2	Bulk Density (gm/cc)	1753
3	Fineness Modulus	3.35
4	Water Absorption	0.89

TABLE V. Gradation of Fine Aggregate, (IS:383)

IS Sieve size	weight of fine Aggregate Retained				Percent retained	cumulative percent retained	percent passing
	Determination no.						
	I	II	III	Avg.			
1	2	3	4	5	6	7	8
10 mm	0	0	0	0	0	0	100
4.75 mm	10	15	12	12.33	1.233	1.233	98.76
2.36 mm	15	20	17	17.33	1.733	2.966	97.83
1.18 mm	56	50	56	52	5.2	8.166	91.83
600 µ	179	170	160	169.6	16.96	25.132	74.86
300 µ	370	360	360	363.53	36.35	61.462	38.53
150 µ	330	340	350	340	34	95.4621	4.538
75 µ	20	40	30	30	3	98.462	1.538
Pan	20	5	15	13.33	1.333	100	0

III. RESULTAND DISCUSSION

1. Slump Test

Slump test is used to determine the workability of fresh concrete. The test is popular due to the simplicity of apparatus used and simple procedure. Unfortunately, the simplicity of the test often allows a wide variability in the manner that the test is performed. The slump test is used to ensure uniformity for different batches of similar concrete under field condition, and to ascertain the effects of plasticizers on their introduction. In India this test is conducted as per IS 1199-1959.The slump test result is a slump of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete. The test is carried out using a mould known as a slump cone or Abrams cone. The cone is placed on hard non-absorbent surface. This cone is filled with fresh concrete in three stages, each time it is tamped using a rod of standard dimension. At the end of the third stage, concrete is struck off flush to the top of the mould. The mould is carefully lifted vertically upwards, so as not to disturb the concrete cone Concrete subsides. This subsides is termed as slump, and is measured in to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >100 mmThe internal surface of the mould is thoroughly cleaned and applied with a light coat of oil. The mould is placed on the smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of the mould. Each layer is tamped 25 times by the rounded end of the tamping rod. After the top layer is rodded, the concrete struck off the level with a trowel. The mould is removed from the concrete immediately by rising it slowly in the vertical direction. The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured. The slump height observed were 180, 100, 90 and 70 mm [8].

Fig. 1. Slump Test on concrete

2. Compression Strength

For cube test two types of specimen ether cubes of 15*15*15 cm or 10*10*10 cm depending upon the size of aggregate are used. Cubical moulds of size 15*15*15 cm are used for this work.This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of this specimen should be made even and smooth. Under pure uniaxial compression loading, the failure cracks generated are approximately parallel to the direction of applied load with some cracks formed at an angle to the applied load. Practically, the compression testing system rather develops a complex system of stresses due to end restraints by steel plates.It is quite clear that due to Poisson's effect, cube or cylinder specimens undergo lateral expansion. The steel plates don't undergo lateral expansion to the same extent that of concrete. There exits deferential tendencies of lateral expansion between steel plates and concrete cube faces as a result of which tangential forces are induced between the end surfaces of the concrete specimen and the adjacent steel plates of the testing machine. The degree of platen restrain on the concrete section depends on the friction developed at the concrete-platen interfaces, and on the distance from the end surfaces of the concrete. As a result, in addition to applied compressive stress, lateral shearing stresses are also effective in the concrete specimen. Effect of this shear decreases toward the center of cube, so that sides of cube have near vertical cracks at cubes center or completely disintegration so as to leave a relatively undamaged central core. At the degree of end restrain depends on the friction at the interfaces, this frictional value can be eliminated by applying grease, graphite or paraffin wax to the bearing surfaces of the specimen. It helps the specimen to undergo a large and uniform lateral expansion and eventually splits along its full length.Referring to Table IV, an increase in compressive strength was observed at 0% replacement of fine aggregate is maximum. But compressive strength was observed at 100% replacement of fine aggregate is minimum [9].

TABLE IV. Compressive Strength of Concrete

Type of Concrete	**Average Compressive Strength (N/mm^2)**
Conventional	55.853
Pervious	12.510
Pervious with 30% sand	21.512
Pervious with 15% sand	12.802

3. Flexural Strength

Flexural test is calculated on the concrete beams to measure its flexural strength. The beams of 100*100*500 mm respectively and was tested on Flexural Testing Machine. Flexural strength studies were carried out at the after 7, and 28 days curing by cold water or by conventional method curing.The flexural strength was strongly affected by water/cement ratio which comes into play when a road slab with inadequate subgrade support is subjected to wheel loads and/ or there are volume changes due to temperature/ shrinkage.Equal loads are applied at the distance of one-third from both of the beam supports. It include equal reaction same as the loading at both the supports. Loading on beam is increase in such a manner that rate of increase in stress in the bottom fiber lies within the range of 0.02 MPa& 0.10 MPa. The lower rate being for low strength concrete and the higher rate for high strength concrete.From the above loading configuration it is clear that at the middle one-third portion, in between two loading, beam is subjected to pure bending. No shear force is induced within this portion. It is this portion of beam where maximum pure bending moment of Pd/2 is induced accompanied by zero shear force.An increased in flexural strength was observed at 0% replacement of fine aggregate is maximum [9]. But flexural strength was observed at 100% replacement of fine aggregate is minimum as shown in Fig. 1.

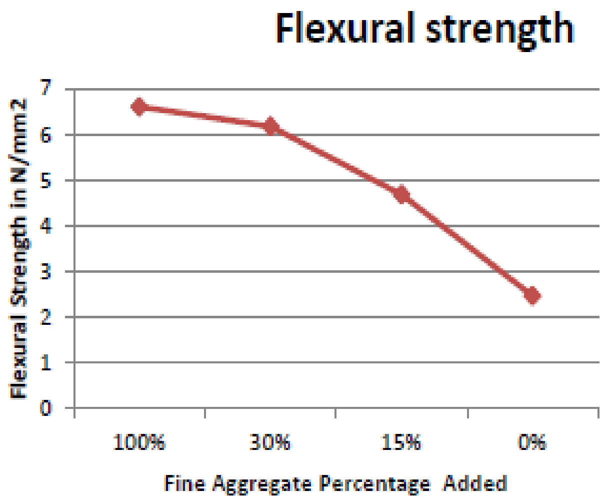

Fig. 2. Flexural strength of concrete

Fig. 3. Hardened Concrete

3. Permeability test

Permeability test was conducted specially for the pervious concrete block to know the permeability/ infiltration rate of the pervious concrete. Which is useful for future further pavement work of the pervious concrete. In the concrete block having different percentages (30% and 15%) of fine aggregate, hence the permeability concrete cubes gradually decreases. The method described do not measure permeability directly but produce a “permeability index”, which is related closely to the method of measurement. In general, the test method used should be selected as appropriate for the permeation mechanism relevant to the performance requirements of the concrete being studied. Various permeation mechanism exist depending on the permeation medium, which include absorption and capillary effects, pressure differential permeability and ionic and gas diffusion.The permeability test was performed by using “infiltration Rate Method”. An increasing in permeability was observed at different percentage remove of fine aggregate. The maximum permeability was measured was 100% removal of fine aggregate as compared to addition of 30% and 15% fine aggregate in pervious concrete. The experimental setup conducted in concrete laboratory. The permeability test performed by using “infiltration rate method” [10].

Fig. 4. Permeability Test

IV. CONCLUSION

The strength, durability and permeability characteristics of concrete mixtures have been computed in the present work by replacing 100%, 85%, 70% Fine aggregates with coarse aggregate, Cement and adding admixtures. On the basis of present study, following conclusions are drawn.

1] Workability of concrete mix get decreases with removal of fine aggregate.

2] Permeability of pervious concrete mix decreases with increasing fine aggregates.

3] With increase of fine aggregates (15% and 30%) the compressive strength of concrete mix will be increased but permeability of the concrete mix get decreases.

4] With increase of fine aggregates (15% and 30%) the flexural strength of concrete mix will be increased but the permeability of the concrete mix get reduced.

5] With 100% fine aggregate removal the permeability of the pervious concrete will be.

6] Strength of the pervious concrete which is depends upon porosity and unit weight of concrete.

7] Considering the observed value of compressive strength which is less than the traffic load so it is recommended to use lighter traffic load.

8] Compressive strength of pervious increase and water permeability decrease with the increase of fine aggregate in pervious concrete.

9] Pervious concrete it will improve the ground water level, absorbed the atmospheric heat and reduce the storm water runoff.

10] The smaller size of coarse aggregate should be ability to produce a higher compressive and flexural strength.

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