Experimental Study of Properties of Pervious Concrete as a Pavement Material

V.G.Khurd, Nitish M. Patil

***Abstract*—Pervious concrete also referred to as "No-fine Concrete" or "Porous Concrete" is material comprised of narrowly graded coarse aggregates, cementitious materials, water and admixture and in some cases fibers. Carefully controlled amount of water and cementitious materials are used to create a paste that forms a thick coating around aggregate particles without flowing off during mixing and placing. The pervious concrete is a special high porosity concrete that allows water from precipitation and other sources to pass through, thereby reducing the runoff and recharging ground water level. Its void content ranges from 18 to 35%, compressive strength from 4Mpa to 30Mpa. The infiltration rate is fall in range of 100 to 750 liter per m^2. And due to high void content pervious concrete is also lightweight with density 1600 Kg/m3 to 2100 Kg/m3. Pervious concrete traditionally used in parking areas, area with light traffic, pedestrian walkways and green houses, contributing to sustainable development. In present paper the various mixes of previous concrete were prepared with different amount of aggregates, cement and fly ash to find the properties like compressive strength, permeability and flexural strength to check its suitability as pavement material..**

***Index Terms*— No fines Concrete, Porosity, Infiltration Rate, fly ash, Sustainable development**

I. INTRODUCTION

Pervious concrete also referred to as "No-fine Concrete" or "Porous Concrete" is material comprised of narrowly graded coarse aggregates, cementitious materials, water and admixture and in some cases fibers. Pervious concrete has been in use for more than 50 years in a variety of applications, recent EPA regulations are causing many owners and designers to reexamine applications of this unique material. Pervious concrete pavement is recognized as a structural infiltration BMP by the EPA for providing first flush pollution control and storm water management. The US green building council (USGBC) through its Leadership in Energy and Environmental design (LEED) Green Building rating system promotes sustainable construction of buildings. A pervious concrete pavement qualifies for LEED credits and is therefore sought by owners desiring for a high LEED certification [1]. Pervious concrete paving reduces the runoff from paved areas, which reduces the need for separate storm water retention ponds and allows the use of smaller capacity storm sewers. Pervious concrete also naturally filters storm water and can reduce pollutant load acting into streams, ponds and rivers. Pervious concrete functions like storm water retention basin and allows the storm water to infiltrate the soil over a large area thus facilitating recharge of precious ground water supply locally. All of these benefits lead to more effective land use. In addition pervious concrete is suitable for sound absorption [2] and vegetation growth [3]. Fly ash can replace a portion of Portland cement in pervious concrete; it provides improved placing and finishing characteristics including improved workability & durability of the pervious concrete [4] Some common applications of pervious concrete are Parking lots, Sidewalks, pathways, tennis courts, green house floorings, shoulder drains, permeable base under a normal concrete pavement and low volume roads.

Figure1. Pervious concrete block

II. Material for Pervious Concrete

Ordinary Portland cement is mainly used for the pervious concrete, however the use of blended cement, eco-cement and cement supplementary materials\ (fly ash, pozzolan, ground-granulated blast furnace slag and silica fume) are reported [5] [6]. Gravel and crushed aggregate are used as coarse aggregate in single size or narrow gradation size. The amount of fine aggregate is critical in the production of pervious concrete mix since the fine aggregate can reduces the porosity and hence permeability of concrete. All types of chemical admixtures could be used to achieve modification of the concrete properties.

III. Mix Proportion of Pervious Concrete

The water to cementations materials ratio for pervious concrete is from 0.30 to 0.40. Tennis et. al.[7] recommended that water to cement ratio should be determined based on the ability of the pervious concrete to shape into a ball with one's hands. Since the pervious concrete workability is sensitive for amount of water, so that it should be controlled strictly. Aggregate to cementitious materials ratio is 4:1 to 4.5:1 by mass, as indicated by Ghafoori, N., and Dutta, S [8].

IV. Specification of Pervious Concrete

A pervious concrete mix basically consists of conventional concrete making materials with a high void content between 15% and 30%. The open and interconnected

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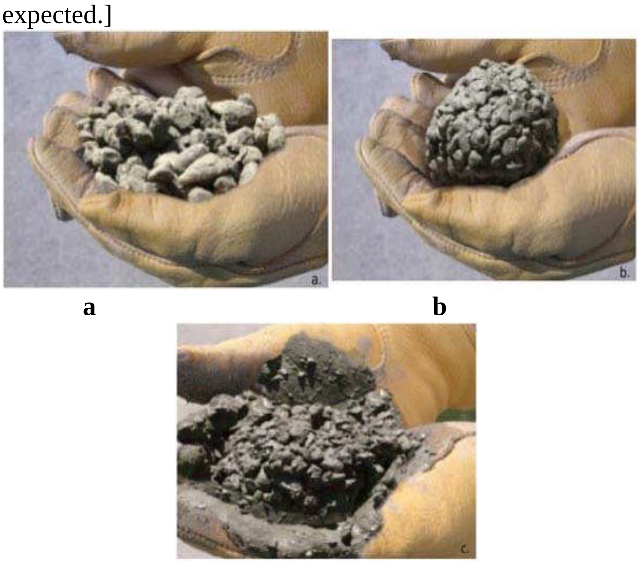
pore structure contributes to the high permeability property of pervious concrete. The mean water permeability of pervious concrete is normally between 1mm/s and 10mm/s compared to 10-9mm/s for the conventional concretes. The high void content in pervious concrete contributes to a low compressive strength and the strength varies between 5MPa and 20MPa. Due to lack of strength, pervious concrete is not suitable for the construction of highways or heavy traffic concrete roads. Similar to the conventional concrete, strength and permeability of pervious concrete are influenced by factors such as, mix compositions, types of component materials and void content. Workability of pervious concrete is quite low[7][8]. During construction with pervious concrete, a roller compaction is much appropriate to achieve uniformity. The density of pervious concrete is approximately 1900kg/m3. The void content required in pervious concrete for high permeability is between 15% and 25%. The mean compressive strength of this concrete ranges from 3.5 MPa to 35.5 MPa [7][8][9]. An increase in the aggregate content reduces the compressive strength [8] Drying shrinkage of pervious concrete occurs sooner but it is lower than that for the conventional concrete as reported by Matasu et. al.[5]. The average permeability of pervious concrete is from 5mm/s to 20mm/s, although there is no standard value is recommended. ACI[8] adopted the falling head method (Fig. 4) developed by Neithalath et. al. [2]. The permeability is calculated using Darcy Law. However, Neithalath et. al.[2] pointed out that there is no definitive relationship between void content and permeability, even though a relationship is expected.]



a **b** **c**

Figure2. Workability assessments for pervious concrete

V. Properties of Pervious Concrete

Similar to the conventional concrete, strength and permeability of pervious concrete are influenced by factors such as, mix compositions, types of component materials and void content. Workability of pervious concrete is quite low[7][8]. During construction with pervious concrete, a roller compaction is much appropriate to achieve uniformity. The density of pervious concrete is approximately 1900 kg/m3. The void content required in pervious concrete for high permeability is between 15% and 25%. The mean compressive strength of this concrete ranges from 3.5 MPa to 35.5 MPa [7][8][9].

VI. Durability of Pervious Concrete

There is no published research on the durability of pervious concrete as pointed out by report of pervious concrete ACI [10] According to Tennis et. al. [7], acid and sulphate resistance for pervious concrete is similar to conventional concrete. Nevertheless, pervious concrete can be more influenced than conventional concrete because of its high volume and low strength characteristics. So far, deterioration of pervious concrete under service conditions was not reported. The most significant problem of pervious concrete is clogging of the permeable pores which lead to a dramatic decrease of permeability. To solve this, maintenance and surface sweeping are required. The surface ravelling of pervious concrete might be happened very early stage mainly caused by heavy load, so that if there is optimum compaction and curing techniques, surface ravelling could be reduced [5]. However, ACI[10] claimed that there is limited information of long-performance of pervious concrete.

VII. Experimental Investigation

7.1 Material:

Ordinary Portland cement and low calcium fly ash were used as cementitious material in this study. 10mm single sized crushed river gravel was used as coarse aggregate. Coarse river sand was used as fine aggregate.

7.2 Mix Proportions of Pervious Concretes

The mix proportion for pervious concrete of 1.0: 4.0 : 0.35 (cementitious materials : coarse aggregate : water) was based on the properties of trial mixes. Four trials mixes with the water cement ratios of 0.25, 0.30, 0.35, and 0.40 indicated that the water to cement of ratio of 0.35 was suitable for the forming ball with the fresh pervious concrete. Conventional structural grade concrete mixes were also produced and tested for properties comparison with pervious concrete. Both types of concretes were produced having 100% Portland cement (Mix 1) and 80% Portland cement and had 20% of fly ash (Mix 2), as cementitious materials in the concrete.

Table 1: Mix proportions of pervious concrete with and without fly ash

Proportion	F.A. %	C.A. %	Fly Ash %	W/C	C.A./Cement	F.A./Cement
PC1-A	0	100	0	0.35	4	-
PC2-A	5	100	0	0.35	3.7	0.3
PC3-A	10	100	0	0.35	3.6	0.4
PC1-B	0	80	20	0.35	4	-
PC2-B	5	80	20	0.35	3.7	0.3
PC3-B	10	80	20	0.35	3.6	0.4

7.3 Mixing of Concrete, Casting and Curing of Test Specimens:

Concrete batches were mixed in a pan-type of mixer. A number of standard 150mm cubes and 150mm diameter and 150mm long cylinder specimens were cast in steel moulds for

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compressive strength testing and for water permeability tests on hardened concrete at appropriate ages. All the specimens were demolded after 24 hours and stored in water at 20°C.

7.4 Testing of Hardened Concrete:

Compressive Strength Test:

Compressive strength test was performed according to IS: 516:1999. For the pervious concrete, three standard 150mm cubes were used. The specimens were capped with dental plaster on both loading surfaces. The specimens were cured in water (20°C) until the testing. The compressive strength reported are the average of three results.

Table 2: Compressive strength test results

Proportion	Density (Kg/m^3)	After 14 days	After 28 days
		Average Compressive Strength (N/mm^2)	Average Compressive Strength (N/mm^2)
PC1-A	2051.85	10.04	12.75
PC2-A	2069.63	17.49	24.15
PC3-A	2125.93	22.08	28.12
PC1-B	2007.78	17.30	25.09
PC2-B	2079.26	15.77	25.33
PC3-B	2110.82	15.13	25.01

Water Permeability Test:

Constant head method was used to measure the water permeability of pervious concrete. Fig. 3 shows the schematic diagram of the permeability test. The water heads adopted were 100,150and 200mm. The test cylinders were covered with sponge rubber to stop water leakage is the transverse direction. The cylinders were placed in the PVC pipe and tightened by buckles. Under a given water head, the permeability testing was carried out when steady state of flow was reached. The amount of water flowing through the specimens over 30 seconds was measured and the permeability coefficient was determined using Darcy's Law equation, given below

$$\frac{Q}{A.T.w} = \frac{k.H}{t} \qquad -(1)$$

Where,

A = cross-sectional area of cylinder
Q = quantity of water collected over 30s
w = density of water (1000kg/m^3)
T = time (30s)
k = water permeability coefficient
H = difference of water head
And t = length of specimen

Flexural Strength Test:

Flexural strength test was performed according to IS: 516:1999[11]. For the pervious concrete, three standard 150mm x700mm beams were used. Test specimens stored in water at a temperature of 24° to 30°C for 48 hours before testing were tested immediately on removal from the water whilst they are still in a wet condition. The flexural strength of the specimen was expressed as the modulus of rupture *f*b, which, if '*a*' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, was calculated to the nearest 0.5 kg/sq cm as follows:

$$(f_b) = \left(\frac{pl}{bd^2}\right) \qquad -(2)$$

When '*a*' is greater than 20.0 cm for 15.0 cm specimen, or greater than 13.3 cm for a 10.0 cm specimen.

Table 3: Flexural Strength and permeability results of pervious concrete with variable water heads.

Proportion	Flexural Strength (N/mm2)	Permeability (mm/sec)		
		200mm	150mm	100mm
PC1-A	2.59	4.50	5.98	8.07
PC2-A	3.98	3.58	4.44	7.44
PC3-A	4.25	3.59	4.52	7.12
PC1-B	2.97	3.70	4.50	6.83
PC2-B	4.20	3.76	4.35	6.95
PC3-B	4.10	3.71	4.37	6.50

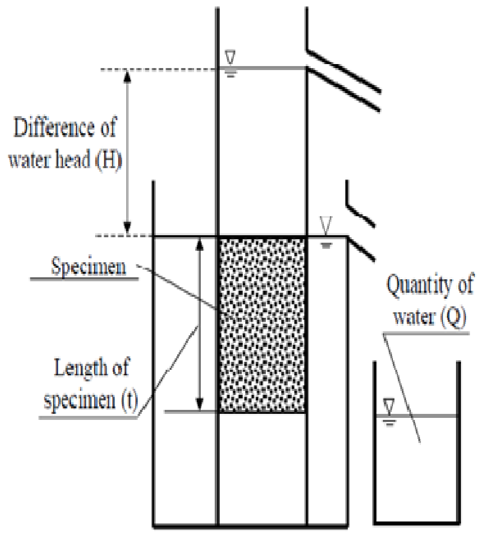

Figure 3: Constant head water permeability test

Figure 4: Constant head water permeability test

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Set up in laboratory.

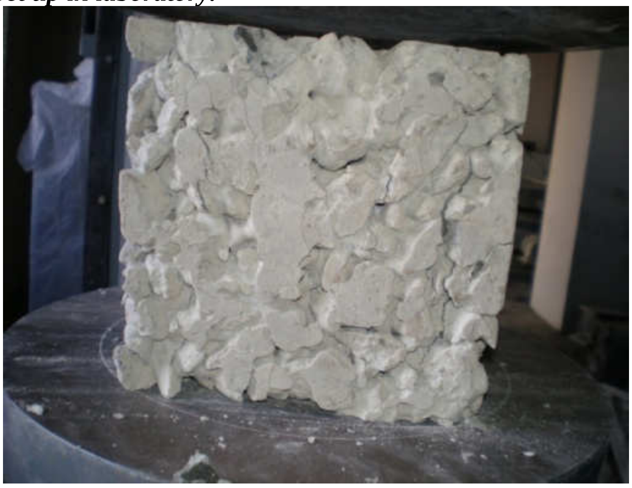

Figure 5: Test specimen for compressive Strength test

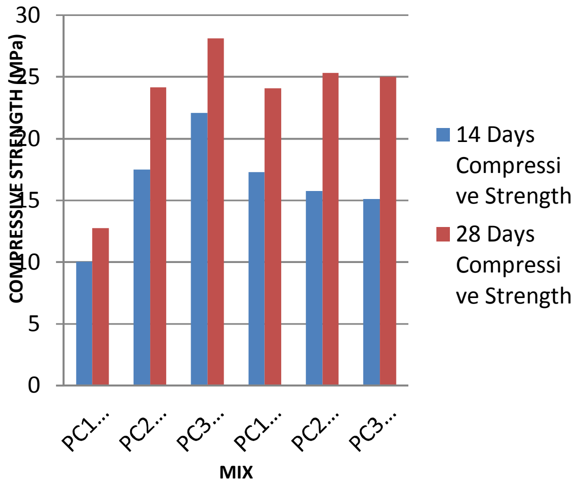

Figure 6: compressive strengths of pervious mixes

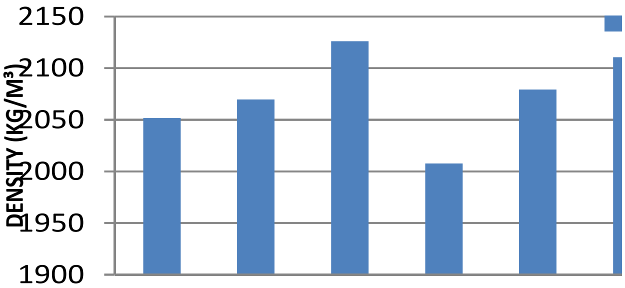

Figure 7: Density of pervious concrete

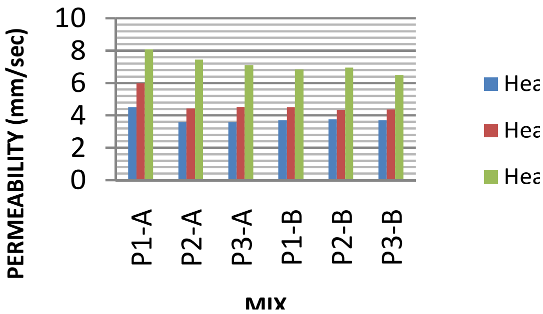

Figure 8: Permeability of various pervious mixes

Figure 9: Flexural failure of beam section

VIII. Results and Discussion

Table 2 summarizes the compressive strength for conventional concrete and pervious concrete, with and without cement replacement, after 14 and 28 days of water curing. All types of pervious concrete mixes improved in strength with the increase in the age of concrete. The compressive strength of mix PC-3A (10% fine aggregate) showed 120% increase over PC-1A (0% fine aggregate). Replacement of 20% cement with fly ash showed a 98% increase in compressive strength over mix PC-1 A.

Fig. 8 shows the relationship between type of mix and permeability. Significant drop in permeability was noted with the decrease in the void content as a result of increase in fine aggregate percentage. Further analysis of the results indicated that pervious concrete with 20% fly ash showed a decrease in the water permeability and more tests are required to be undertaken to confirm this trend. Table 3 shows increase in flexural strength with increase in % fine aggregate. The mix with 10% fine aggregate showed 64% increase of flexural strength over concrete without fine aggregate and decrease of permeability by 11.8%. As expected, the density of concrete increases with the increase in fine aggregate percentage

IX. Conclusion

Based on the experimental investigation into the properties of pervious concrete, the following conclusions are made: Pervious concrete could be made with conventional concrete making materials to have permeability between 4mm/s and 8 mm/s. Cement replacement with fly ash contributed to the reduction in long term strength of pervious concrete similar to that noted with the conventional concrete. Since the water permeability as the main criterion for the pervious concrete, fly ash can be used in the production of pervious concrete to achieve an environmentally friendly concrete. The flexural strength of pervious concrete with fine aggregate is lower than the strength requirement of highway pavements therefore this concrete is suitable for light traffic pavements and can be a applicable for village roads in India.

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