Permeable Concrete - A Mind Melting Future of Drive Ways and Parking Lots

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Abstract:
In this project we studied about permeable concrete and its role in the construction field. Another name of permeable concrete is thirsty concrete. It is also called as no fines concrete. As the world's population continues to shift from rural to urban areas, natural drainage systems are being replaced with impermeable mostly concrete that hinder the environment's ability to drain rainwater .In forest 80 to 90 of rain water absorbed back into ground. In urban area that absorption falls to 10% of rainwater. Permeable concrete is a special type of concrete with a high porosity used for concrete flat work application that allow water from precipitation and other sources to pass directly through , thereby reducing the run-off from a site and allowing groundwater recharge. This project would be helpful to replenish water table in ground water aquifer minimize flash flooding and standing water by reducing storm water run-off from pavements ,yards driveways and parking lots. Permeable concrete pavement is air and water permeable, the soil underneath can be kept wet and rainwater can quickly filter into ground, allowing ground water resources to renew in time. Permeable concrete also act as a sound absorption and skid resistance and is therefore suitable for use in rainy and humid environment. However, the prevalence of air voids results in low strength so permeable concrete is suitable for low traffic roads. In this study we sought to determine the comparison of compressive strength, flexural strength and permeability of concrete between pervious concrete with no fine aggregates and pervious concrete with replacement of cement into fly ash by 10%.The result showed that the compressive strength and permeability of no fine concrete exceeds the pervious concrete with fly ash, and the flexural strength in no fine concrete is satisfactory for light traffic less. Hence it is recommended that the no fine concrete is better than the pervious concrete with fly ash for light traffic pavement.

Keywords: *Permeable concrete, Run off, flexural strength, fly ash, permeability.*

I. INTRODUCTION

Concrete is the most commonly used building material in the world. It is estimated that the present consumption of concrete in the world is of the order of 10 billion tones every year. A larger amount of rainwater ends up falling on impervious surfaces such as parking lots, driveways, side-walks, and streets rather than soaking into the soil. This creates an imbalance in the natural ecosystem and leads to a host of problems including erosion, floods, ground water level depletion and pollution of rivers, lakes and coastal water. A simple solution to avoid these problems is to stop constructing pavement with conventional concrete or asphalt and switch to pervious concrete or porous pavement, a material that offers the inherent durability and low life-cycle costs of a typical concrete pavement while retaining storm water runoff and replenishing local watershed systems. Instead of preventing infiltration of water into the soil, pervious pavement assists the process by capturing rain water in a network of voids and allowing it to percolate into the underlying soil. Pervious concrete is a type of concrete that has a low water-cement ratio and contains none or very little amount of sand. It is usually a mixture of 9 mm to 19 mm average diameter aggregate, hydraulic cement, other cementatious materials, admixtures and water. Pervious concrete also naturally filters water from rainfall or storm and can reduce pollutant loads entering into streams, ponds and rivers. So in this way it helps in ground water recharge. Pervious concrete has very high permeability that drains water quickly. Pervious concrete is light weight concrete having weight 1600 to 1900 kg/m3. Pervious concrete which is also known as the no-fines, porous, gap graded and permeable concrete and enhance porosity concrete has been found to be a reliable stone water management tool. By definition, pervious concrete is a mixture of gravel or granite stone, cement, water, little to no sand (fine aggregate) with or without admixtures. When previous concrete is used for paving the open cell structure allows storm water to filter through the pavement and into the underlying soils. In other words, pervious concrete helps in protecting the surface of the pavement and its environment. As stated above, pervious concrete has the same basic constituents as conventional concrete that is 15 % - 30% of its volume consists of interconnected void network, which allows the water to pass through the concrete. Pervious concrete can allow the passage of 3-5 gallons of water per minute through its open cells of each square foot of surface area which is far greater than most rain occurrences. Porous concrete continued to gain popularity and its use spread to areas such as Venezuela, West Africa, Australia, Russia and the Middle East [1]. After World War II, porous concrete became wide spread for applications such as cast -in-place load-bearing walls of single and multistory houses and, in some instances in high-rise buildings, prefabricated panels, and stem-cured block [2]. Also applications include walls for two-story houses, load-bearing walls for high-rise buildings (up to 10 stories) and infill panels for high-rise buildings [3]. [4] Revealed a research on **"**Applicability of no-fines concrete as a road pavement", he concluded that the no fine concrete is a viable material that has the potential to replace the use of traditional concrete pavement in situation where heavy traffic is limited, such as car parks, residential streets, roadways. He also said that the shape of aggregates particle used can dramatically affect the strength of the concrete. [5] studied **"**Pervious concrete in severe exposures development of pollution-reducing pavement for northern cities" and explained that the porous pavement, especially Portland cement pervious concrete(PCPC),helps control pollution discharge by allowing rainwater to rapidly infiltrate into an open graded aggregate sub base and then into the ground [6]concluded **"**Evaluation and Optimization of Durable pervious concrete for use in urban Areas**"** Typically pervious concrete is over designed for permeability based on extreme rainfall events, therefore, it is recommended to improve the material compressive strength and flexural strength at the expense of the permeability. [7] studied the "Effect of rejuvenation methods on the infiltration rates of pervious concrete pavements" has concluded that a pervious concrete pavements in low-traffic urban areas such as parking lots reduce storm water run-off and also minimize water pollution. However there are concern about their expected clogging and consequential reduction of hydraulic performance in the long term. the pervious concrete can be declogged using rejuvenation methods such as vacuum sweeping, pressure washing or a combination of both [8] has conducted **"**Evaluation of structural Performance of Previous Concrete in Construction**"** and concluded that the smaller the size of coarse aggregate should be able to produce a higher compressive strength and at the same time produce a higher permeability. The mixture with higher aggregate cement ratio is considered to be useful for a pavement that requires low compressive strength and high permeability rate. [9] studied on "Investigating porous concrete with improved strength: Testing at different scales" and concluded as porous concrete incorporated a high percentage of meso-size air voids that makes its mechanical characteristics remarkably different from normal concrete. The open structure of the pervious pavement causes a difference in arrival time between direct and reflected sound waves. This difference causes the noise level to have a lower intensity causing pervious pavements to absorb sound [10], [11] shown that a strong, durable pervious concrete mix design that will withstand wet, hard freeze environments is possible. Micro type fibres are most often used to prevent plastic shrinkage cracking and to improve surface abrasion resistance. Optimum dosage rates for micro-type fibers range from 0.9 to 1.8 kg/m^3 which represents 0.07-0.2% by volume [12]. In addition, pervious concrete can contribute toward credits in the LEED® (Leadership in Energy and Environmental Design) rating system for sustainable building construction [13]. Previous research by [14] suggested that 10.2 cm (4") 7 diameter specimens were ideal for hydraulic conductivity testing. In these cases, hydrophobic.

[15] This paper investigates the application of permeable CBP to SuDS schemes in the United Arab Emirates (UAE) and in detail, the world's largest and first application in the Middle East of the Hanson Form pave®, Aqua flow system, covering an area of 196,200m2 in Dubai. The result is a significant reduction in the environmental and economic impacts of an alternative, dedicated surface-water drainage network with its associated requirements for multi-stage pumping stations across a highly contoured site

II. OBJECTIVES

1. To reduce the cost of the permeable concrete by replacing cement by fly ash.
2. Strom water management.
3. To know the performance characteristics of pervious concrete.

III. ENVIRONMENTAL BENEFITS OF PERVIOUS CONCRETE

i. Recharge of local aquifer.
ii. Water budget retention and pollution removal.
iii. Less need for storm sewer.
iv. Green building alternative suitable for many applications.
v. Natural run-off allows rainwater to drain directly to sub surface.
vi. Reduced construction requirements for drainage structures.
vii. Reduce pollution prevents environmental damage. Protects streams and
viii. lakes and allows local vegetations to thrive.

IV. APPLICATION OF PERVIOUS CONCRETE

- Pervious concrete as a road pavement.
- Low volume pavements.
- Side-walks and pathways.
- Residential roads and drive ways.
- Parking lots. Noise barriers.
- Slope stabilization.
- Hydraulic structure.
- Swimming pool decks. Well lining, Tennis courts.

V. MATERIALS USED AND TEST OF PERVIOUS CONCRETE MATERIALS

A. *Physical Properties Of Cement*

Locally available 53 grade of Ordinary Portland Cement conforming to IS: 12269 was used in the investigations.

Table 1 Properties of Cement

S.No.	Properties	Test Result
1.	Normal consistency	32%
2.	Initial setting time	95mins
3.	Final setting time	230mins
4.	Specific gravity of cement	3.15
5.	Soundness	2mm
6.	Compressive strength at 28 days	57.3N/mm^3

B. *Aggregates*

1) *Maximum size of aggregate*

Extending the grading of aggregate to a larger maximum size lowers the water requirement of the mix, so that, for a specified workability and cement content, the water /cement ratio can be lowered with a consequent increase in strength. Experimental results indicated that above the 38.1mm maximum size the gain in strength due to the reduced water requirement is offset by the detrimental effects of lower bond area (so that volume changes in the paste cause larger stresses at interfaces) and of discontinuities introduced by the very large particles. In structural concrete of usual proportions, there is no advantage in using aggregate with a maximum size greater than about 25 or 40mm when compressive strength is a criterion.

C. *Fly Ash*

Cement may be replaced by about 10-30% of fly ash. In this Mix 10% of fly ash is added with mix.

When the cement is replaced by fly ash it offers the following advantage

- Increases late compressive strengths (after 28 days).
- Increased resistance to alkali silica reactions (ASR).Increased resistance to sulphate attack.
- Less heat generation during hydration.
- Increase pore refinement. Increase workability.
- Decrease cost.

D. *Water*

Water is a key ingredient in the manufacture of concrete. Water used in concrete mixes has two functions: the first is to react chemically with the cement, which will finally set and harden, and the second function is to lubricate all other materials and make the concrete workable. Although it is an important ingredient of concrete, it has little to do with the quality of concrete. One of the most common causes of poor-quality concrete is the use of too much mixing water.

VI. TEST ON MATERIALS

A. *Test on cement*

1) *Specific gravity*

Specific gravity is just a comparison between the weights of a volume of particular materials to the weight of the same volume of water at a specified temperature.

The specific gravity of cement is calculated by the following formula.

$$S_g=(w_2-w_1)/(w_4-w_4)-(w_3-w_2)*(0.79)$$

where,

w_1=weight of specific gravity bottle in g.

w_2=weight of specific gravity bottle with about half filled cement in g

w_3=weight of specific gravity bottle with about half filled cement

and rest is filled with kerosene in g.

w_4=specific gravity bottle completely filled with kerosene in g

0.79 =specific gravity of kerosene.

Table 2 Computation Of Specific Gravity Of Cement

S.NO	W_1	W_2	W_3	W_4	SPECIFIC GRAVITY
1.	125.3	188.3	394.7	347.7	3.11
2.	125.3	192.1	398.2	347.7	3.23
3.	125.3	194.9	399.7	347.7	3.12

$Sg = (w_2-w_1)/(w_4-w_1)-(w_3-w_2)*(0.7)$

$=(188.3-125.3)/(347.7-125.3)-(394.7-188.3)x(0.79)$

$=3.11$

Average of this trail = (3.11+3.23+3.12)/3 =3.15.

Therefore the specific gravity of cement =3.15.

B. *Test on aggregate*

2) *specific gravity*

Specific gravity of coarse aggregate can be calculated using the formula given **$Sg=(w_2-w_1)/(w_4+w_2)-(w_1+w_3)$**

W_1= weight of empty pycnometer.

W_2= weight of pycnometer with aggregates.

W_3=weight of pycnometer with water and aggregates.

W_4= weight of pycnometer and water.

Table 3 Computation of Specific Gravity of Coarse Aggregate

S.NO	W_1	W_2	W_3	W_4	Specific Gravity
1.	422	995	1755	1393	2.71
2.	422	992	1752	1393	2.70
3.	422	998	1757	1393	2.71

$Sg=(w_2-w_1)/(w_4+w_2)-(w_1+w_3)$

$=(995-422)/(1393+995)-(422+1755)=2.71$

Average of this trials = (2.71+2.70+2.71)/3=2.70 .

Therefore the specific gravity of coarse aggregates =2.70.

C. Sieve Analysis Test

A sieve analysis is a practice or procedure used " to assess the particles size distribution " of a granular material. Different size of sieves is available but here we used 20mm size in order to increase the voids.

D. Water Absorption Test

Water absorption test is rapid procedure for field determining the percentage of free or surface .Moisture in coarse aggregates and for determining the percentage of water absorption for coarse aggregates of less than saturated surface dry (ssd) conditions.

Table 4 Trails For Computation of Water Absorption of Coarse Aggregate

S.NO	Determination No	Trail 1	Trail 2	Trail 3
1.	Weight of saturated surface dried sample in g	2010	2125	2147
2.	Weight of oven dried sample in g	2000	2113	2136
3.	Water absorption	0.5%	0.56%	0.5%

Water absorption={(saturated surface dry aggregates - weight of oven dried sample/weight of oven dried sample }x100 ={(2010 -2000)/2000}x100 =0.5%
Average of this trail=(0.5+0.56+0.51)/3 =0.5%
Therefore the water absorption of coarse aggregates=0.5%

6.5 Test on fly ash

6.5.1 Specific gravity

Specific gravity of fly ash is calculated using the following formula.

$$S_g=(w_2-w_1)/(w_4+w_2)-(w_1+w_3)$$

where,
w_1= weight of empty specific gravity bottle,
w_2= weight of specific gravity bottle with fly ash.
W_3=weight of specific gravity bottle with water and fly ash.
W_4= weight of specific gravity bottle and water.

Table 5 Computation of Specific Gravity of Fly Ash

S.NO	W_1	W_2	W_3	W_4	Specific Gravity
1.	50	136	240	190	2.38
2.	50	140	248	190	2.36
3.	50	144	262	190	2.35

$$S_g=(w_2-w_1)/(w_4+w_2)-(w_1+w_3)$$
=(136-50)/(190+136)-(50+240) =2.38
Average of this trial =(2.38+2.36+2.35)/3 =2.38
Therefore the specific gravity of fly ash =2.38.

VII. PROPERTIES OF CONCRETE

A. Slump

Slumps, when measured, are generally less than 3/4 inches (20mm), although slumps as high as 2 inches (50mm) have been used. However, slump of pervious concrete has no correlation with its workability and hence should not be specified as an acceptance criterion.

B. Density

It depends on the properties and proportions of the materials used, and on the compaction procedures used in placement. In place densities on the order of 1600 kg/m³ to 2000 kg/m³ are common, which is in the upper range of lightweight concretes.

C. Permeability

The infiltration rate (permeability) of pervious concrete will vary with aggregate size and density of the mixture, but will fall into the range of 2 to 18 gallons per minute per square foot (80 to 720 liters per minute per square meter).

D. Flexture Strength

Flexural strength in pervious concretes generally ranges between about 150 psi (1MPa) and 550 psi (3.8 MPa). The freeze thaw resistance of pervious concrete can be enhanced by the following measures(1). Use of fine aggregates to increase strength and slightly reduce voids content to about 20%. (2). Use of air-entrainment of the paste. (3).Use of a 6 to 18 in. aggregate base particularly in areas of deep frost depths. (4).Use of a perforated PVC pipe in the aggregate base to capture all the water and let it drain away below the pavement.

E. Abrasion resistance

Because of the rougher surface texture and open structure of pervious concrete, abrasion and raveling of aggregate particles can be a problem. This is one reason why applications such as highways generally are not suitable for pervious concretes. Good curing practices and appropriate w/cm (not too low) is important to reduce raveling.

Table 6 Batching of materials

Materials	For 1 cube	For 6 cubes
Cement	2.35kg	14.1 kg
Fly Ash	0.235 kg	1.41 kg
Coarse Aggregate	8.95 kg	53.7 kg
Water	1.057 kg	6.34g

VIII. TEST ON CUBES

Table 7 Compressive strength of cube with no fine aggregate on 7th day

S.NO	Weight (kg)	Load (KN)	Compressive Strength N/mm^2
1.	8.1	445	19.7
2.	7.9	415	18.4
			19.10

Table 8 Compressive strength of cube with no fine aggregate on 14th day

S.NO	Weight (kg)	Load (KN)	Compressive strength(N/mm^2)

1.	8.152	488	21.68
2.	7.674	481	21.35
			21.51

Table 9 Compressive strength of cube with no fine aggregate on 28th day

S.NO	WEIGHT(kg)	Load(KN)	Compressive strength\ (N/mm^2)
1.	8.046	580	25.77
2.	7.903	629	27.95
			26.86

Table 10 Compressive strength of cube with flyash on 7th day

S.NO	WEIGHT (kg)	Load (KN)	Compressive strength (N/mm^2)
1.	7.425	290	12.88
2.	7.392	320	14.22
			13.55

Table 11 Compressive strength of cube with flyash on 14th day

S.NO	WEIGHT (kg)	Load (KN)	Compressive strength (N/mm^2)
1.	7.545	430	19.11
2.	7.520	463	20.5
			19.805

Table 12 Compressive strength of cube with flyash on 28th day

S.NO	Weight (kg)	Load (KN)	Compressive Strength (N/mm^2)
1.	8.152	542	24.08
2.	7.674	565	25.1
			24.5

IX. PERMEABILITY TEST

Permeability coefficient (K) is calculated according to given equation:

Where,

$K= aLAt*\ln h_0/h_1$

K = water permeability

a=cross-sectional area of the tube

A=cross-sectional areas of the specimen

t = time

h_0= the initial water head

h_1= the final water head

Table 13 Permeability of pervious concrete with no fine mix for 28 days

Cement (%)	Fine Aggregate (%)	Days	Average Permeability
100	0	28	28.29

Table 14 Permeability of pervious concrete with fly ash mix for 28 days

Cement (%)	Fly Ash (%)	Days	Average Permeability
90	10	28	20.6

X. RESULTS AND CONCLUSIONS

Table 15 Compressive strength, Flexural Strength and Permeability of no fines concrete and previous concrete

S. N	Type of concrete	No Fines concrete 7 14 28 Days	Pervious concrete 7 14 28 Days
1.	Compressive strength (N/mm^2)	19.105 ,21.51,26. 86	13.55,19.80,2 4.59
2.	Flexural strength (N/mm^2)	2.1,2.31,2. 5	2.48,2.72,3.12
3.	Permeability	28.29	20.6

XI. CONCLUSIONS

Following are the conclusions arrived from the study.

i. The compressive strength of pervious concrete increases as the water/cement ratio decreases..
ii. On comparison, the compressive strength of no fine concrete has a greater compressive strength than pervious concrete.
iii. Compressive strength increases with increase in volume of paste.
iv. The flexural strength of 2 .30 MPa is achieved for M_{20} No fines concrete and 2.77MPa is achieved for M20 pervious concrete with fly ash.
v. Permeability of no fine concrete is more than the pervious concrete with fly ash
vi. 10% of cement is replaced by fly ash. The percentage decrease in compressive strength in pervious concrete is 50 to 75% compared with conventional concrete.
vii. The percentage of void ratio is increased to 4% in pervious concrete as compared with conventional concrete. So that the permeability also high.
viii. By observing, the parameters It has been found that the permeability of pervious concrete increases with reduction in sand and the permeability of pervious concrete decreases with increase in w/c ratio and cement.
ix. It has been observed that the permeability is higher in case of 0% sand compared to conventional concrete.
x. Replacement of Fly ash of 10 % shows decrease in strength from 4% to 28% and permeability.
xi. Pervious concrete pavements are a very cost-effective and environmentally friendly solution to support sustainable construction.
xii. Its ability to capture storm water and recharge ground water. In reducing storm water run-off pervious concrete plays a significant role.

xiii. Pervious concrete is a smart sustainable high potential construction material in the modern construction world.

xiv. Pervious concrete is an ideal solution to control water logging in drive ways and parking lots, to control floods at downstream and sustainable land management.

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