An Experimental study on pervious concrete as a pavement layer

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***Abstract*— Concreting everywhere leads to environmental issues such as reduction in the discharge, which makes the life at major cities miserable. The solution to minimize this problem is by installing pervious concrete pavements instead of impervious concrete or asphalt pavements for low volume traffic areas. This paper explains in detail about the use of pervious concrete as pavement material. In this study, we considered mix proportion of pervious concrete from reference mix of M40 in that by changing the fine aggregate content to 0-18% by replacement method. i.e. the fine aggregate volume is replaced by coarse aggregate volume in mix proportion, there will be no change in volume of aggregate hence we had difficulty in finding volume of cement paste occupying volume of voids, because volume of aggregate and volume of cement paste will be constant in proportions ,therefore we found relationship of varying fines with permeability , porosity(without cement paste) , failure load and compressive strength . As it satisfies the criteria of using it of sub-base for concrete pavement as permeable and dry lean concrete sub base.**

***Index Terms*— pervious, miserable, asphalt, permeability, porosity.**

I.INTRODUCTION

Pervious concrete is a special high porosity concrete used for flatwork applications that allows water from precipitation and other sources to pass through, thereby reducing the runoff from a site and recharging ground water levels. Its void content ranges from 18 to 35% with compressive strengths of 3 to 28 MPa (28 to 281 kg/cm^2). The infiltration rate of pervious concrete will fall into the range of 720 litres per minute per square meter.

In previous concrete, carefully controlled amounts of water and cementations materials are used to create a paste that forms a thick coating around aggregate particles. A pervious concrete mixture contains little or no sand, creating a substantial void content. Using sufficient paste to coat and bind the aggregate particles together creates a system of highly permeable, interconnected voids that drains quickly. Both the low mortar content and high porosity also reduce strength compared to conventional concrete mixtures, but sufficient strength for many applications.

Renewed interest in pervious concrete is an increasing emphasis on sustainable construction. Because of its benefits in controlling storm water runoff and pollution prevention. The light colour of concrete pavements absorbs less heat from solar radiation than darker pavements, and the relatively open pore structure of pervious concrete stores less heat helping to lower heat island effects in urban areas. Trees planted in parking lots and city sidewalks offer shade and produce a cooling effect in the area, further reducing heat island effects.

II. MATERIAL PROPERTIES OF PERVIOUS CONCRETE

A.CEMENTITIOUS MATERIALS

As in traditional concreting, ordinary Portland cement, 53 grade (I.S-12269, 1989) and PPC (IS1489: Part I 1991) may be used in pervious concrete. In addition, supplementary cementations materials such as fly ash and natural pozzolans ground-granulated blast furnace slag, and silica fume may be used. Testing materials through trial batching is strongly recommended so that proper proportions for the desired concrete performance (which includes setting time, rate of strength development, porosity, and permeability, among other traits) can be established.

B. AGGREGATES

Commonly used gradations of coarse aggregate include (20 mm to 4.75 mm) and (12.5 to 2.36 mm) are to be used as per IS 383:1970. Singlesized aggregates up to 1 in. (25 mm) also have been used. Specific property of the coarse aggregate is about 2.70 and crushing value is about 20.50 %. Larger aggregates provide a rougher concrete surface, while smaller aggregates provide a smoother surface that may be better suited to some applications, such as pedestrian walkways. As in conventional concrete, pervious concrete requires aggregates to be close to a saturated, surface-dry (SSD) condition. It should be noted that control of water is important in pervious concrete mixtures. Water absorbed from the mixture by aggregates that are too dry (less than SSD) can lead to mixtures that do not place or compact well.

C. WATER

Water to cementations materials ratios from 0.27 to 0.30 are used routinely with proper inclusion of chemical admixtures, and w/c ratios as high as 0.40 have been used successfully. The relation between strength and water to cementations materials ratio is not clear for pervious concrete. Unlike conventional concrete, the total paste content is less than the voids content between the aggregates. Therefore, making the paste stronger may not always lead to increased overall strength. Water content should be tightly controlled. The correct water content has been described as giving the mixture sheen, without flowing off of the aggregate. A handful of pervious concrete formed into a ball will not crumble or lose its void structure as the paste flows into the spaces between the aggregates.

D. *ADMIXTURES*

Chemical admixtures are used in pervious concrete to obtain special properties, as in conventional concrete. Because of the rapid setting time associated with pervious concrete, retarding or hydration-stabilizing admixtures are used commonly. Air-entraining admixtures can reduce freeze-thaw damage in pervious concrete.

Table.1 Materials Proportions of Pervious Concrete

MATERIALS	PROPORTIONS
Cementations materials	270 to 415 kg/m^3
Aggregate	1190 to 1480 kg/m^3
Water-cement ratio (by mass)*	0.27 to 0.30
Aggregate-cement ratio (by mass)*	4 to 4.5:1
Fine-coarse aggregate ratio (by mass)	0 to 1:1

III. ENGINEERING PROPERTIES

A. PROPERTIES OF FRESH CONCRETE

The plastic pervious concrete mixture is stiff compared to traditional concrete. Slumps, when measured, are generally less than 20 mm, although slumps as high as 50 mm have been used. When placed and compacted, the aggregates are tightly adhered to one another and exhibit the characteristic open matrix. For quality control or quality assurance, unit weight or bulk density is the preferred measurement because some fresh concrete properties, such as slump, are not meaningful for pervious concrete. Conventional cast cylinder strength tests also are of little value, because the field consolidation of pervious concrete is difficult to reproduce in cylindrical test specimens, and strengths are heavily dependent on the void content. Unit weights of pervious concrete mixtures are approximately 70% of traditional concrete mixtures. Concrete working time typically is reduced for pervious concrete mixtures. Usually one hour between mixing and placing is recommended. However, this can be controlled using retarders and hydration stabilizers that extend the working time by as much as 1.5 hours, depending on the dosage.

B. PROPERTIES OF HARDENED CONCRETE

1) Density and porosity: The density of pervious concrete depends on the properties and proportions of the materials used, and on the compaction procedures used in placement. The density is about 1600 kg/m^3 to 2000 kg/m^3 are common, which is in the upper range of lightweight concretes. A pavement 125 mm thick with 20% voids will be able to store 25 mm of a sustained rainstorm in its voids, which covers the vast majority of rainfall events. When placed on a 150-mm thick layer of open-graded gravel or crushed rock sub base, the storage capacity increases to as much as 75 mm of precipitation.

2) Permeability: The flow rate through pervious concrete depends on the materials and placing operations. Typical flow rates for water through pervious concrete are 0.2 cm/s to 0.54 cm/s with rates up to 1.2 cm/s and higher having been measured in the laboratory.

3) Compressive strength: Pervious concrete mixtures can develop compressive strengths in the range of 3.5 MPa to 28 MPa, which is suitable for a wide range of applications. Typical values are 17 MPa. As with any concrete, the properties and combinations of specific materials, as well as placement techniques and environmental conditions, will dictate the actual in-place strength. Drilled cores are the best measure of in-place strengths, as compaction differences make cast cylinders less representative of field concrete.

4) Flexural strength: Flexural strength in pervious concretes\ generally ranges between about 1MPa and 3.8MPa. Many factors influence the flexural strength, particularly degree of compaction, porosity, and the aggregate: cement (A/C) ratio. However, the typical application constructed with pervious concrete does not require the measurement of flexural strength for design.

5) Durability: Because of the rougher surface texture and open structure of pervious concrete, abrasion and raveling of aggregate particles can be a problem, particularly where snowplows are used to clear pavements. This is one reason why applications such as highways generally are not suitable for pervious concretes. However, anecdotal evidence indicates that pervious concrete pavements allow snow to melt faster, requiring less plowing. Most pervious concrete pavements will have a few loose aggregates on the surface in the early weeks after opening to traffic. These rocks were loosely bound to the surface initially, and popped out because of traffic loading. After the first few weeks, the rate of surface raveling is reduced considerably and the pavement surface becomes much more stable. Proper compaction and curing techniques will reduce the occurrence of surface raveling.

IV. METHODOLOGY

A. Determination of porosity

Porosity of pervious concrete specimens can also be determined using the difference in weight between the dry sample and the weight of the immersed sample, similar to the method described in ASTM C 140 as shown in equation

$$Vr = [1- (W1- W2)/ \rho w\ Vol] \times 100$$

Where,

Vr = total void ratio, %,

W1= weight immersed (lbs or kg),

W2= dry weight (lbs or kg),

Vol = nominal sample volume based on dimensions of the sample (ft3 or m3), and

ρw= density of water (lbs/ft3 or kg/m3).

B. Determination of permeability

Permeability of pervious concrete can be measured in the laboratory by several means. A falling head permeameter is commonly used for convenience. The cylindrical sample is prepared such that no water flows along the side of the specimens and water flows from top to bottom of the specimen. Water is added to the graduated cylinder to fill the specimen and the drain pipe, up to the initial head level, with the valve closed. The valve is then opened and the time required for water to fall from an initial head to a final head is measured (Figure.1) [Neithalath, Weiss and Olek, 2003; Kevern, Schaefer, Wang and Suleiman, 2008]. The average coefficient of permeability (k) is determined using equation 2.2, based on Darcy's law principle of flow in homogeneous porous material.

$$K=(a\ L\ /A\ t)\ \log(h2/h1)$$

Where,

k = coefficient of permeability, in./s or cm/s,

a = cross-sectional area of the pipe, in2 or cm2,

L = Length of sample, in. or cm,

A = cross-sectional area of the sample, in2 or cm2,

t = time for water to drop from h1 to h2, s,

h1 = initial water level, in or cm, and

h2 = final water level, in or cm.

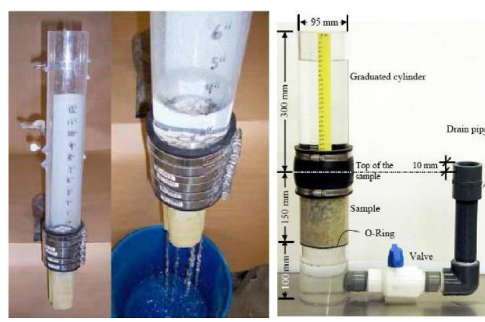

Fig .1 Permeability of pervious concrete

V. RESULTS & DISCUSSIONS

A. Evaluation volume of voids

As percentage of fines increases, the volume of voids gets decreased because fines fill the space between the aggregate as we are increasing the fines.

$$y = -0.000x^3 + 0.006x^2 - 0.058x + 0.357$$

Above equation shows volume of voids is the function of fines content. So with the known fines content we can find the respective volume of voids value.

B. COMPRESSIVE STRENGTH

Pervious concrete mixtures can develop compressive strengths in the range of 500 psi to 4000 psi (3.5 MPa to 28 MPa), which is suitable for a wide range of applications. Typical values are 2500 psi (17MPa). Below tabular column shows the compressive strength of the pervious concrete mix at the ages of 7 and 28 days. Each result showed the mean of three identical cube tested at the same age of each concrete mixture.

Compressive strength increases when percentage of fines increases in pervious concrete.

7 DAYS, y = 0.021x2 + 0.011x + 7.643

28 DAYS, y = 0.024x2 + 0.026x + 11.19

Above equation shows compressive strength is the function of fines content .So with the known fines content we can find the respective compressive strength value.

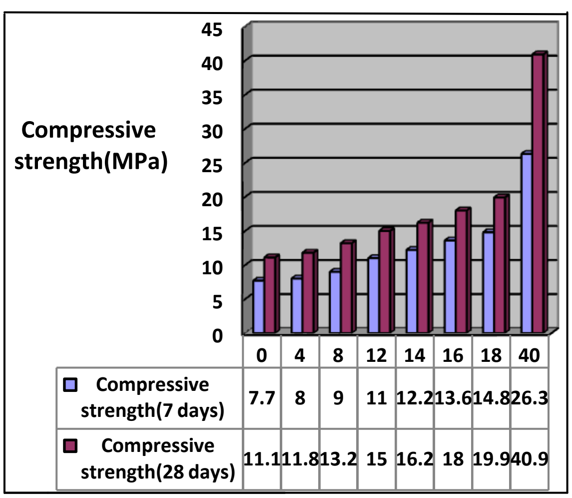

Fig 2.Compressive strength v/s % Fines

C. PERMEABILITY

Permeability decreases when percentage of fines increases.

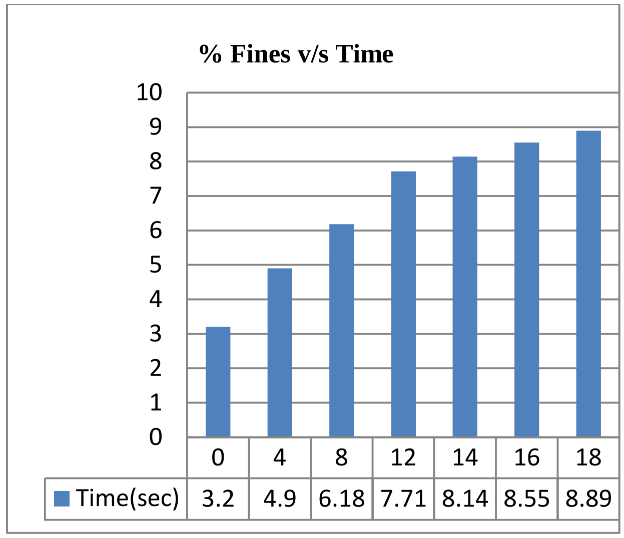

Fig 3. % Fines v/s Time

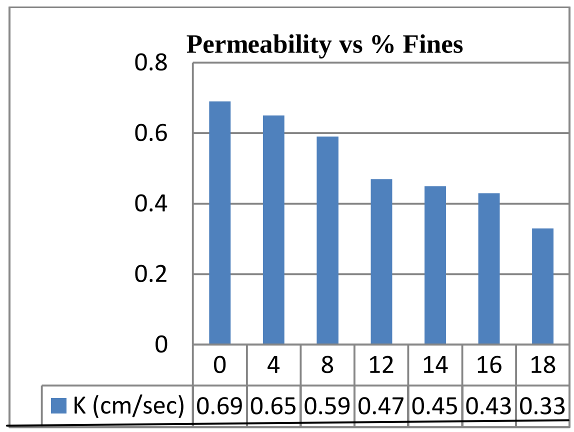

Fig 4. Permeability v/s % Fines

As percentage of fines increases it fills the void between the aggregates though the volume is same, hence the permeability will decreases.

$$y = -0.000x^2 - 0.01x + 0.693$$

Above equation shows permeability is the function of fines content, so with the known fines content we can find the respective permeability value.

D. Failure Load

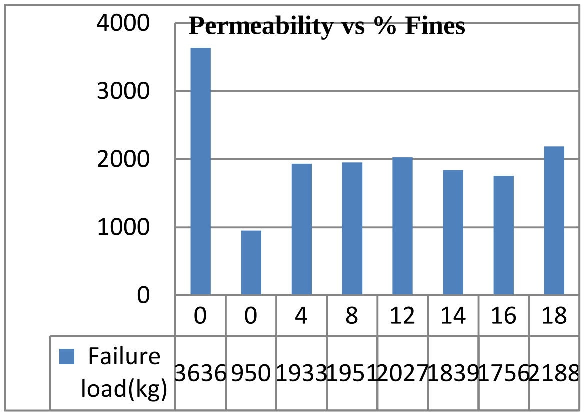

Fig 5. Failure load and % Fines

As percentage of fines increases, the maximum allowable load to the pervious sample also increases.

$$y = -5.603x^2 + 143.0x + 1135$$

Above equation shows failure load is the function of fine content, so with the known fines content we can find the respective maximum allowable load value.

VI. CONCLUSION

Based on the experiments carried out the following are concluded,

1) As percentage of fines increases, the volume of voids gets decreased given by ,
   $\mathbf{y = -0.000x^3 + 0.006x^2 - 0.058x + 0.357}$
2) Compressive strength increases when percentage of fines increases in pervious concrete which is given by the following expressions
   7 DAYS, $\mathbf{y = 0.021x^2 + 0.011x + 7.643}$

   28 DAYS, $\mathbf{y = 0.024x^2 + 0.026x + 11.19.}$

3) Permeability decreases when percentage of fines increases. The following expression is obtained,
$\mathbf{y = -0.000x^2 - 0.01x + 0.693.}$

4) As percentage of fines increases, the maximum allowable load to the pervious sample also increases given by , $\mathbf{y = 5.603x^2 + 143.0x + 1135.}$

Pervious concrete can also be used as permeable sub base. In recent years, several highway agencies experienced with or specified, drainable pavement systems for heavy duty pavements where past experience has indicated the potential of pavement faulting and pumping. These permeable sub base course are designed to carry the water away rapidly.

As per IRC57:2010 Dry lean concrete should have a minimum compressive strength of 10 MPa , here pervious concrete with 10% fines got more than 10 MPa. Hence pervious concrete can be used as pavement material as dry lean concrete.

Dry lean concrete(DLC) is basically a sub base which acts to prevent mud pumping and give a support for construction equipment and also enhance the pavement performance under frost condition .Mud pumping is the forceful displacement of a mixture of soil and water that occurs under slab joints , cracks and pavement edges.

Hence pervious concrete can be used as pavement material as a sub base course.

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