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Experimental Study on Pervious Concrete as a Drain Cover Slab

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Abstract*: *The experimental study on the pervious concrete as a drain cover slab influence the use of cement, fine aggregate, coarse aggregate, steel fibers & fly ash to form porous concrete. The objective of the study is to find out the best pervious concrete slab composition with good strength and infiltration rate. This objective is achieved by an experimental study on properties, behavior, permeability, and durability on four different mix samples and two different mix type slabs are compared to conventional pervious concrete. Materials used for the Mix are OPC -53grade, Fine aggregate with grade II of river sand and Material sand, Coarse aggregate of 12.5mm - 20mm, crimped steel fibers, plasticizer as Dew-bond P99 with 1:4.75 cement to Coarse aggregate ratio. The mix of M1, M2 M3, and M4 are prepared with the W/C ratio of 0.34 with water reducing admixture. The mix is compared with each other on strength, permeability. Based on the results the Slab mix is selected and studied as slab specimen for their strength, infiltration. The test is carried out based on the Indian standards and ASTM for permeability test.The results obtained show sustainable and good strength pervious concrete slab.

Index Terms: pervious concrete, pervious slab, Drain cover slab, porous concrete, stormwater management.

I. INTRODUCTION

Pervious concrete is a combinational mix of cement, coarse aggregate, water and admixture for bonding. Pervious concrete creates a very porous medium that allows water to drain to the underlying surface. Pervious concrete is an eco-friendly pavement is also known as a little or no fine aggregate. The void containing pavement, will not give more strength, so it is used in parking areas, sidewalks or footpaths, internal roads connecting one or two buildings or campus roads[1-10].

This pervious material replaces impervious pavement surface, by allowing stormwater to infiltrate directly, providing natural filtration of water treatment. pervious concrete has a high percent of void gaps of 15%-30% which can infiltrate storm water from any type of storm runoff. pervious concrete is also introduced as a sustainable practice because it can reduce the runoff to the drainage system and can increase the recharge to the groundwater as well. One drawback though for the porous concrete is the lack of structural strength and very less compressive strength. careful mix design and construction have to be special care to achieve the required strength needed.

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II. MATERIALS

Pervious concrete influence the strength and mechanical properties based on material, high cement and water/cement ratio will make a good cement paste and the gradation of coarse aggregate gradation. The pervious concrete are most widely prepared using round aggregate with good cement paste and required workability using admixtures. The Coarse aggregate of angular index are were good in tensile strength which requires more cement paste for good workability and they have high bond with void. For the study pervious concrete are made with ordinary Portland cement of 53grade,coarse aggregate ,aggregate passing in 20mm sieve and retained on 12.5mm sieve is used with high angular aggregate. The fine aggregate of river sand and Material sand are added with 8 % to coarse aggregate [15] and 5% Fly ash is replaced with cement [19], Crimped steel fibers added to 0.15 of total cement content are made to Four mix types includes the normal conventional pervious concrete to compare mix properties. The Indian code IS456-2000 is followed for concrete preparation and curing..

A. *Test on Material properties*

The used material in the pervious concrete are tested on material properties with according to IS and obtained values are shown in Table I, Table II and Table III

Table I- Cement properties

Description	**Obtained result- IS 4031:1996**
Specific gravity	3.16 g/cc
Fineness	8.33 %
Standard consistency	32
Initial setting time	42 minutes
Final setting time	7hrs 30minutes

Table II- Coarse aggregate properties

Description	Obtained result- IS: 2386:1963
Specific gravity	2.874 g/cc
water absorption	0.69 %
Bulk density	1614.89 Kg/ m^3

Table III- Fine aggregate properties

Description	Obtained result- IS: 2386:1963	
	River sand	Material sand
Specific gravity	2.319 g/cc	2.443 g/cc
water absorption	4.7 %	3.9
Bulk density	16.7 Kg/ m^3	10.71 Kg/ m^3
Particle size distribution	3.811% -Well graded	4.13% -Well graded
Grading Zone	Zone 1	Zone 1

B. Aggregate

The pervious concrete mix proportion are the important part to obtain strength so select the suitable proportion of materials to obtain porosity and permeability of concrete. The various study on the fine aggregate adding in concrete is found by trail and error methods and 8 % of fine aggregate showed the improvement in concrete ,so 8 % of fine aggregate as River sand and Material sand is selected. The coarse aggregate are studied based on the gradation of aggregates, with using many percentage of 2 different aggregate combination. so, coarse aggregate is selected by the aggregate passing by 20mm sieve and retained by 12.5mm sieve. The mix proportion and water to cement ratio are studied in many trail and error methods . As, the mix proportion is not standard the mix of 1 : 4.75 cement to Coarse aggregate with 0.34 water to cement ratio adding water reducer for the total mix[17].

C. Sample preparation

The concrete are prepared into 28 cube specimens with 4 mix types as M1, M2, M3 and M4 for the testing of concrete strength and 4 cylinder are specimens with 4 mix are prepared for testing. From the cube and cylinder test the mix are selected to cast 4 slab specimens for comparative strength test with normal conventional pervious concrete. The concrete are prepared by mixing the cement, coarse aggregate, fine aggregate and fibers with water ,and water reducer as required. All samples are prepared by the ASTM C192 accordingly. The curing of pervious concrete samples for 7 days and 28 days is done by special methods like spraying the water and wrapped in thin polythene sheets under laboratory conditions.

III. TEST METHOD

A. Fresh density of concrete

The pervious concrete is mixed according to the specifications of the ASTM C192 (2016). Before placing the pervious concrete mixes in sampling, the fresh pervious concrete density of the mixture was determined as specified in ASTMC1688 (ASTM, 2014) .

B. *Compressive strength test*

The compressive strength of pervious concrete samples are determined by performing a compression strength test as per IS456(2000). The test procedure for Compression strength of concrete by preparing concrete cubes of size 100 x 100 x 100 mm are cast ,as the coarse aggregate used is below less than 20mm with 4 mix type of a pervious concrete mixture for 7days and 28 days.

C. Split tensile strength test

The tensile strength of sample determined by cylindrical sample by test procedure as per IS5816(1999). Concrete cylinders of size 100mm dia and 200mm height are cast with 4 mixes with their age of 28days.

D. Flexural strength test

The flexural strength of slab is tested by Three-point loading method. The test is conducted on slab sample of two types of mixes for the conventional pervious concrete slab and other mix type with size 600 x 400 x 50mm and for 900 x 400x 70 mm size the slab with G.I mesh

E. Porosity test

The ratio of voids in the pervious concrete to the total volume of sample is the porosity. The porosity are measured in hardened Pervious Concrete specimens as per the ASTM C1754 (2012)**.** The test is performed by taking the oven dried weight of the sample(M_d). The size of the sample (height and width) to obtain the volume of sample (V). Density of Hardened sample is obtained as the oven dried mass to the volume of the sample ratio (M_d/V). To find obtained porosity, each samples was submerged in water tank for minimum 30 min, after 30 min the submerged mass of each sample was noted (M_w). The volume of the solids was obtained by dividing the difference between the dried and submerged weight by the water density (ρ_w). as porosity (P) was calculated using the formula[7] and the setup

$$P= (1- \frac{(\boldsymbol{Md-Mw})}{\boldsymbol{\rho w * v}}) \text{ X } 100$$

F. Permeability test

The most important features of the pervious concrete allowing the percolation of water passing the porous medium. The test is done by the constant Head method and Falling head method

G. Falling-Head method

The stand pipe over the mix samples of pervious concrete is placed ,they are tight sealed over the top of the sample surface to avoid water loss at sides. The permeability test on the samples is carried by the water filled into the sample along the stand pipe as the top level is reached and the other side of outlet is closed to maintain water level. The waterfalls once the valve is opened. The falling of water from initial and the time is noted as zero and when the head reached to the final level of water the time is noted as shown in Fig.1. The time is used to determine permeability by formula[16]

$$K=\frac{a.L}{A.t} ln \frac{ho}{ht}$$

where, K= coefficient of permeability (cm/sec)
a= stand pipe area (cm^2)
L= sample length(cm)
A= sample surface area (cm^2)
t= Elapsed time of the test(sec)
ho= head at start of test(cm)
ht= head at end of test (cm)

Fig.1- Test setup for falling head Method

H. Constant Head Method

The stand pipe over the mix samples of pervious concrete is placed ,they are tight sealed over the top of the sample surface to avoid water loss at sides. The permeability test for samples is done by the flowing the water in stand pipe at constant quantity of water level maintaining and allowing the water flow into the samples along the stand pipe. water level maintained at the desired water head in the inlet pipe. The water flowing in maintained by outlet valve. The discharging water can be determined by the measure volume of water collects in the water container over period of time at a constant head of flowing water as shown in Fig 2. The coefficient of permeability k in an cm/s is calculated by [16],

$$K=\frac{Q*L}{A*h*t}$$

where, K= coefficient of permeability (cm/sec)

Q - volume of water collected in total (mm^3)
L - sample length (mm)
A - cross-sectional area of samples (mm^2)
h - constant water head (mm)
t - taken time(sec)

Fig.2- Test setup for Constant head Method

F. Infiltration rate test for slab

The infiltration tests carried over the slab samples as per the ASTM C1701 is the standard infiltration test for pervious concrete. The test contains of four main procedure by infiltration ring installation, pre-wetting the concrete, testing the concrete and calculating the results. The ring is fixed to surface with no gaps so maintain the water infiltrate effectively. As the water is poured in these ring by maintaining the level of water. The standard water quantity of 8 pounds that 3.62 kg of water is used if the time has taken is less than 30seconds.proceed the test same as in different place. If the time taken is greater than 30seconds then the quantity of water to be infiltrated is 40pounds or 18.14kg.so the water level is maintained as per marking level by using 8pounds of water and time noted for water to infiltrate on the surface as shown in Fig.3. The test is set up and Infiltration rate formula is

$$I=\frac{K*M}{D^2*t}$$

where, I= infiltration rate of concrete (mm/hr)
M= water mass (kg)
D - Diameter of the ring [mm]
T - time taken to infiltrate[sec],
K= 4583666000 SI constant

Fig .3- Test setup for Infiltration rate of sample (a) placement of ring, (b) Water is poured in the ring

IV. Results and Discussions

The effects of all PC mix types with respect to compression strength, porosity, permeability on cube samples and infiltration rate on slab samples were tested and obtained values are shown in Table IV.

Table IV - Pervious concrete mix mechanical properties

Mix	Compressive strength (N/ mm^2)		Split tensile strength(N/ mm^2)	Porosity %	Permeability (cm/s)	
	7 days	28days	28 days		Falling head	Constant head
M1	3.1	7.76	0.36	28.18	2.61	0.2667
M2	4.13	13.7	1.07	26.42	2.39	0.2551
M3	3.43	12.93	1.11	25.7	1.97	0.2523
M4	3.86	11.36	0.92	23.15	2.01	0.2479

A. Mechanical properties -Compressive strength

In compression strength for 7 days and 28 days of all type of mix is determined. Hence It showed that there is a compression strength value for 7day and 28 days exhibit a stable increase in compressive strength for all mix type of pervious concrete mixes are increased the observed values of increase in percentage that M1 is 60% increase in compression strength from 7days to 28 days, M2 type is increased with 70% from 7 days to 28 days, M3 type is increased with 73% from 7 to 28 days strength and M4 is increased with 66 % from 7 to 28 days strength.

An appreciable increase in compressive strength for the addition of fine aggregate 8% with river sand and M. sand showed a higher percentage of strength increased. It can be concluded that pervious concrete with M2 type provide huge improvement in compressive strength at the 28 days as compared to conventional pervious concrete and other Types of the mix.

B. Mechanical properties -Split tensile strength

In obtained values of split tensile strength for conventional pervious concrete and all other mix types of M2, M3, M4. The split tensile strength obtained for conventional pervious concrete is 0.36 MPa which is very lower compared the other 3 types of mix. The strength of split tensile obtained for mix 3 is 1.11 MPa and M2 with 1.07 MPa. which is shows that the fine aggregate addition with steel fibers are good in split tensile compared to mixes.

C. Fresh density

The fresh density of measured data as shown in Table 7 indicate that the density of Pervious concrete of mix Types about 1500–2000 kg/m^3, it is lower than that of conventional concrete. The porous in pervious concrete makes concrete lighter. We can say that density of concrete decreased relation to total porosity increases with 20% shows density changes. The density of pervious concrete mix decreased with the increasing of porosity percentage.

Table V- Density of concrete

Mix Type	Fresh density Kg/m^3	Aggregate size
M1	1583.6	20mm-12.5mm
M2	1880	20mm-12.5mm
M3	1888	20mm-12.5mm
M4	1866.7	20mm-12.5mm

D. Permeability Test- Falling head & Constant head

The falling head Permeability test are taken for the 15 cyclic times ,so obtained value ranges from 2.42 Cm/s to 2.79 cm/s for the M1 type with mean value of 2.61 cm/s and 1.94cm/s to 2.61 cm/s for the M2 type with mean value of 2.39 cm/s,1.82cm/s to 2.13 cm/s for the M3 type with mean value of 1.97 cm/s and for M4 type ranges from 1.91cm/s to 2.14cm/s with mean value of 2.01 cm/s. Permeability mainly depends on the size of aggregates and additional material interconnected to pores structure. The conventional pervious concrete mix with no additional composition shows higher permeability and compared to another type of pervious mix M2 has higher permeability ranges.

The Constant head Permeability test are taken for the 15 cyclic times ,so obtained value ranges from 0.264 Cm/s to 0.28 mm/s for the M1 type with mean value of 0.2667cm/s and 0.253 cm/s to 0.257 cm/s for the M2 type with mean value of 0.2551cm/s,0.251cm/s to 0.254 cm/s for the M3 type with mean value of 0.2523 cm/s and for M4 type ranges from 0.242cm/s to0.251cm/s with mean value of 0.2479 cm/s. Permeability mainly depends on the size of aggregates and additional material interconnected to porous structure. The conventional pervious concrete mix with no additional composition shows higher permeability and compared to other types of pervious mix M2 has higher permeability ranges.

E. *Flexural strength of slab*

The flexural strength obtained by the slab sample of Mix M1 and M2. The flexural strength of the slab is tabulated in Table VI

Table VI - Flexural strength of slab

Type of mix	Slab Sizes	Age of sample **Days**	Flexural strength **(MPa)**
M1	600 x 400 x 50 mm	28	0.252
	900 x 400 x 70 mm	28	0.130867
M2	600 x 400 x 50 mm	28	0.3672
	900 x 400 x 70 mm	28	0.261735

F. Infiltration rate on slab

The slab sample mix M1 and M2 are compared based on the obtained surface infiltration for the cyclic 25 times. The infiltration rate of conventional pervious concrete is ranging from 12.84 cm/s to 8.25cm/s with the average infiltration rate of 11.25cm/sec The infiltration rate of M2 type ranges from 12.78 cm/s to 6.44 cm/s with the average infiltration rate 10.01 cm/s. From this, we can infer that M2 type is showing the infiltration rate sufficient for drain purpose compared to convention pervious concrete.

G. Clogging test on slab by infiltration test

The water mass is mixed With silt content for 20% and 10 %. The surface infiltration test is carried as the silt water and the cyclic performance of 25 times is determined. slab sample M1 and M2. It clearly shows they are a slight decrease in infiltration rate from 1 cycle to the 25th cycle. The20% silt on M1 type slab sample range from 6.93 cm/sec to 9.36cm/sec and 10% silt infiltration range from 7.28cm/sec to10.61cm/sec in this graph we can infer that there is a decrease in infiltration rate at the middle and high or equal at the end of the cyclic test. For M2 slab is tested for infiltration rate with 20% silt the range from 5.25cm/sec to 6.59cm/sec and 10% silt ranges from 5.48cm/sec to 6.59cm.sec.

H. Relation study between Void, Porosity, Density ,Permeability and compression strength

The mix types compared to see the relationship between the density vs void of the pervious concrete. This shows clearly their proportional to one other than the density of concrete decreases the void content is high, same as the increase in density of concrete the void content is decreased. This shows the M1 type is the low density of 1583.66 kg/m^3 with the void of 26.4% .while the other mix types the density ranges from 1800-1888 kg/m^3 with the void of 20.29% to 22.12%.

I. Void and porosity

The obtained void and target void percentage. Then porosity of concrete with the range 28.18% to 23.15% which is acceptable porosity. The void obtained is range from 26.4% to 20.29% for all type of mix.

From these, we can infer that the void content is proportional to porosity when the void increase porosity increase.

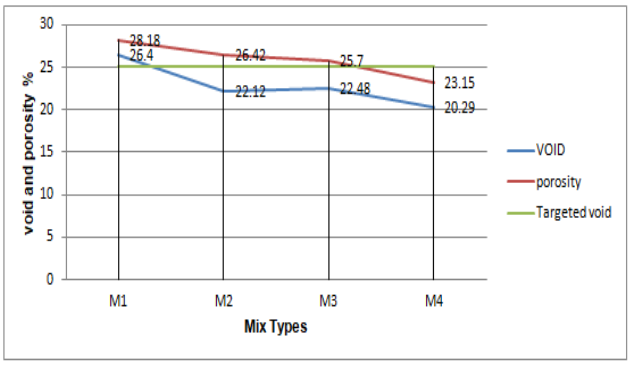

Fig.4 - Void vs Porosity

J. Graphical representation

In the **Fig.5** it shows the comparison of M1 pervious concrete mix with other 3 Mix for 7 and 28 days compressive strength, infer that M1 mix is low performed. In **Fig.6** it shows the density of pervious concrete and compressive strength, infer that density increase compressive strength also increased in pervious concrete mix. In **Fig.7** and **Fig.8** the cyclic performance of permeability tested with two methods, infer that both shows M1 has high permeability due to high void. In **Fig.9** and **Fig.10** shows the infiltration rate for slab samples , infers that addition of silt in water to infiltrate showed reduce in infiltration rate.

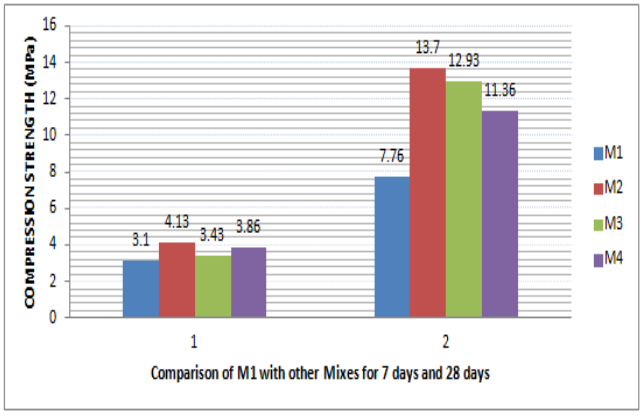

Fig.5- Compressive strength of mix for 7 & 28 days

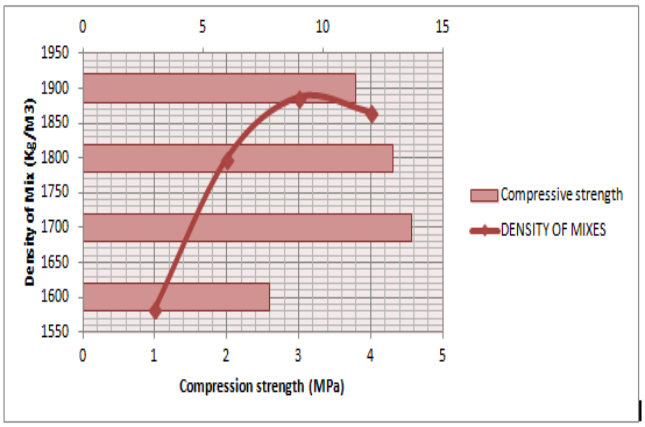

Fig.6- 28 days compressive strength vs density of all mix

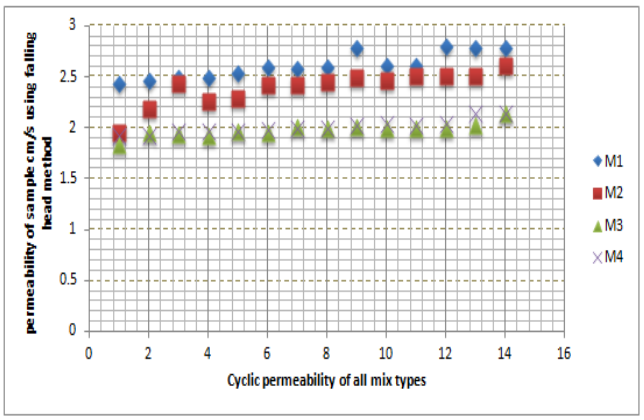

Fig.7- Cyclic permeability of all mix by Falling head method

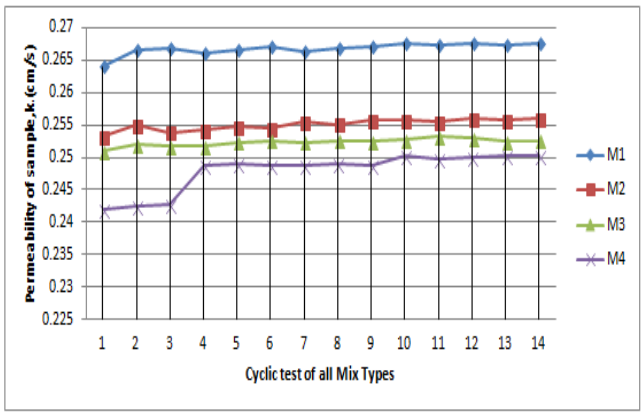

Fig.8- Cyclic permeability of all mix by constant head method

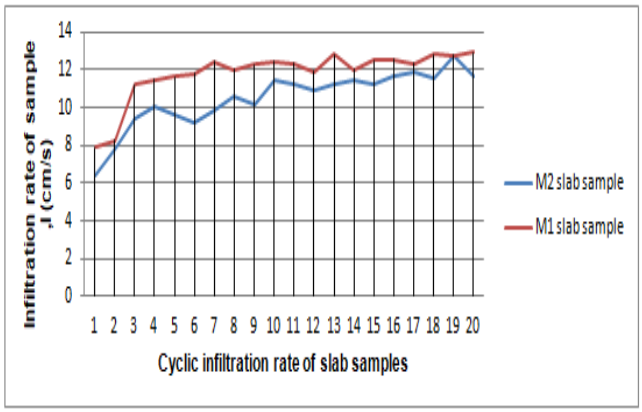

Fig.9 - Cyclic Infiltration rate of all mix

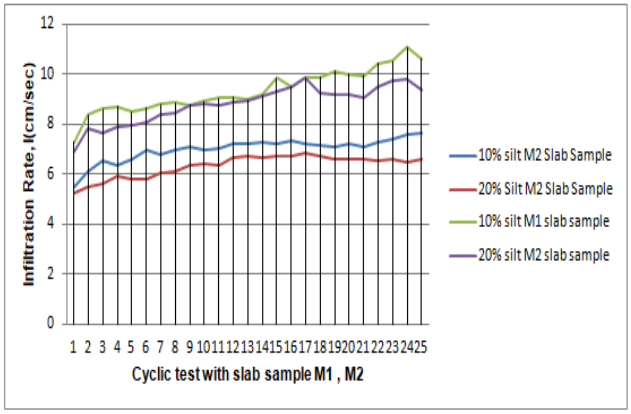

Fig.10- Cyclic Infiltration rate of slab sample with 10% & 20% silt

V. CONCLUSION

The strength related test performed to find mechanical properties of pervious concrete conventional mix and other three type mix. The compressive strength showed higher at M2 type mix compared to M1 conventional pervious concrete. In split tensile strength with M2, M3 type where similar more or less and showed good strength while compare M1 type mix. This infers that using of fine Aggregate combination with steel fiber showed strength. In durability property test showed the water absorption is very less in M1 type and higher in M2 type. It infers that the fine aggregate sample has absorbed water higher.

In the density test M1 type has very less density and M3 type has higher density. The addition of material to conventional concrete will increase in the density and reduce the void. The permeability values show the higher permeability in conventional pervious concrete M1 type and M2 type showed higher permeability while comparing with M3, M4 type. The M2 type permeability is 1.95 cm/sec which is sufficient for the drain surface infiltration test is carried for hardened concrete slab samples. The infiltration rate is high in M1 type and also High in M2 type when compared to another type of mixes. This infiltration rate 10.006 cm/sec of are very much sufficient to drain the water.

The clogging parameter of slab samples is tested for performance by adding the 20% silt and 10% silt containing water mass. The infiltration rate is tested for a cyclic period of times which shows a slight decrease in rate and normal after some cycles The flexural strength of the slab is tested by the 3-point loading. The values of strength are low compared to normal traditional concrete. But the strength compared with conventional pervious mix M1 to M2 type mix. It showed very good improvement in strength. This concrete can be used with certain limits. The void, porosity of all mix samples are tested for the examination of the targeted void percentage. The void and porosity obtained by the sample are within 20%-30% as per the requirements.

Maintenance of the pervious slab

The regular maintenance is required for these type of slab because the efficiency of the pervious concrete reduces in the cyclic usage has the voids will be clogged .The removal clogging will help the pervious concrete to Infiltrate the runoff effectively.

The maintenance process to restore pervious concrete slab are

- A regenerative vacuum sweeper
- Power blowing and
- Pressure washing

Researchers say these type of maintenance process can restore 80% to 90% of the permeability under some conditions

The wide range use of pervious concrete in recent decades as road pavements, parking lots etc. all over the world has attracted the researchers to do research on the study of pervious concrete in different aspects and different scenarios. This paper showed the research work carried on pervious concrete and their findings, future scopes. These studies can help to develop or provide a solution for major problems in pervious concrete. These lead to learning the properties of pervious concrete as pavement material, design aspect and right implementation for an efficient outcome.

Overall, the past & recent studies showed the importance of pervious concrete in stormwater management, ground recharge, filtration requirements. But this pervious concrete slab can be a solution. So, I conclude the possible suggestion of replacing the conventional drain cover slab along the stormwater drains or the open runoff drains to fulfill by the pervious concrete drain cover slab.

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