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Pervious Concrete as an Environment Solution for Storm Water Collection

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Abstract: *Pervious concrete is a new concrete with high porosity which usually used for flat work applications in order to allow water to pass through it, and by that it reduces the volume of direct water runoff from a site and increases the quality of storm water and water pollution. Due to the high flow rate of water through Pervious concrete pavement, rainfall can be captured and percolate into the ground, recharging groundwater, supporting sustainable construction, reducing storm-water runoff, and providing a solution for construction that is sensitive to environmental concerns. In urban areas especially where the land is very expensive, pervious concrete pavement and its sub-base may provide a good amount of water storage capacity which eliminates the need for precipitation runoff containment strategies. This study examines the advantages of using such material to maximize storm-water, minimize flooding and improve water filtration in Nagpur cityby replacing a selected parking lot area in the campus of Anjuman College of Engineering &Technology(ACET), located in Nagpur city of Maharashtra Indiawith Pervious concrete. The findings of this research support that using Pervious surfaces in storm-water management is a sustainable and yet environment friendly way of water storming.*
Keywords: *Pervious concrete,Impervious surfaces, rainwater harvesting, rainwater management, Water Quality.*

I. Introduction

Water is essential for life and plays a major role in creating earth's climate. Rainwater is the major source of sweet water. Fresh water today is a scarce resource, and it is being felt the world over. More than 2000 million people would live under conditions of high water stress by the year 2050, according to the UNEP (United Nations Environment Program), which warns water could prove to be a limiting factor for development in a number of regions in the world. Rain Water Harvesting, is an age-old system of collection of rainwater for future use. As per the Rainwater Harvesting and Conservation manual of CPWD (Central Public Works Department), rainwater harvesting is the activity of direct collection of rainwater for the purpose of direct use and recharge of ground water. However, systematic collection and recharging of ground water, is a recent development and is gaining importance as one of the most feasible and easy to implement remedy to restore the hydrological imbalance and prevent the water crisis.

Many cities over the world are facing an increased neighborhood, both residential and commercial, thus the natural water balance is altered. Storm-water management has become

fig.1.

fig.2

an important issue for municipalities and cities. In built environments with a significant amount of impervious surfaces and pavements, storm-water reaches the receiving water bodies much faster, in greater volume and carries more pollutants than natural conditions. With larger volume of surface runoff, replenishment of groundwater reduces and base flow of the stream also decreases. This research aims to identify the use of Previous Concrete in order to reduce the storm-water runoff in ACET campusand to control water pollution. It also aims to develop a base for new techniques inusing Previous Concrete for flatworks, e.g. paving roads, sidewalks or any non-structural components. As more impervious surfaces are added to the landscape, such as rooftops, roads, and parking lots, more storm-water runoff is achieved. More storm-water runoff means less rain infiltrates into the ground, thus worsening the effects of drought. As storm-water flows across impervious surfaces, it collects various pollutants (e.g. oil, excess nutrients, harmful bacteria). Polluted storm water runs and pours in storm drains affecting aquatic ecosystems and drinking water supplies. Sooner or later it will cost money, costs for a new well, higher water rates, or expensive environmental restoration required by clean water regulations. Pervious concrete allows water to flow through it freely. The primary goal of this research is to implement sustainable ways to recharging groundwater, decrease storm- Figure (1)

water runoff, improve the quality of water and reduce flooding in winterseason. Using Pervious concrete for flatworks construction such as; parking lots, sidewalks and secondary roads in Figure(2)Acet will contribute to achieve this. Figure (1) illustrates flooding onimperviouspavements within Nagpur. This research followed two main assumptions; Using Pervious concrete will help in reducing the overall runoff from an area and will help in reducing the level of pollution contained in runoff. Figures (2): Flooding in Parking Areas in Anjuman college of engineering and technology.

II. Literature Survey

The recent work carried out in better understanding of rain water harvesting concept, the modification of rainwater harvesting technology and use of sustainable materials in rainwater harvesting are critically review to judge the proper usage of pervious concrete in harvesting the rain water. [6] conducted a study of unconfined aquifer response in terms of rise in water level due to precipitation. Cross correlation of rise in water level and precipitation is established. [2]have reviewed the impact assessment of RWH on ground water quality at Indore and Dewas, India. The impact assessment of roof top improve the quality and quantity of Ground Water. [3] investigated the hydrologic performance of permeable concrete paving stone installations of various ages. The primary objective of the studies was to determine the relationship, if any, between infiltration capacity and the age of a permeable concrete paver installation for various land uses and maintenance practices. [2] carried out an experimental study on possibility of using the pervious concrete in to collect the storm water. The compressive strength and the permeability of the pervious concrete in studied and concluded that pervious concrete will be an ideal contribution to increase the usage of storm water in recharging of ground water, and sustainable land management.

Limited amount of work has carried out to use the pervious concrete as sub surface filtration medium in rainwater harvesting for domestic and agricultural purpose. In the present study, an integrated subsurface system has proposed to apply the pervious concrete as effective and long lasting filtration system to harvest the rainwater.

III. Theoretical Background

3.1. Pervious Concrete:-

Porous pavement is found to be an effective measure to mitigate the impact of urbanization on the environment and to develop a more environmentally friendly infrastructure. It will not require any additional space; in parking lots, sidewalks, and driveways and yet provides multiple benefits, i.e. promotes infiltration, reduces peak flows and runoff volume, improves water quality, and reduces thermal pollution, thus helping to maintain ecological balance.“Perviousconcrete"is the material that can be used to construct porous pavements and porous urban surfaces. This type of concrete has high permeability and can replace asphalt or low permeability concrete used for non-structural components in our urban built environments.

3.2. Materials:-

Pervious concrete, mainly consists of the usual Portland cement, water and coarse aggregates (either single-sized coarse or grading between 19 and 9.5 mm).

Cement :- Cement used was Ordinary Portland Cement of grade 43.

Aggregates :- The Coarse Aggregates used was ranging between size of 9.5mm to 12mm.

Water:- The Used for casting should be free from Organic matter. Portable water is considered as the best as per IS 456-2000. Tap water available in the laboratory was used for mixing the ingredients of concrete and curing of specimen.

A concrete mix with cement, coarse aggregate ratio of 1:4 and water cement ratio of 0.35 has been taken as control mix for given design of pervious concrete.

3.3 Application:-

Pervious concrete was first used in 1852, but it started to gain interest recently because of Federal Clean Water Legislation in the USA. This legislation forces municipalities to develop and implement strategies which include a combination of structural and/or non-structural best management practices (BMPs) (Ravindrarajah Yukari, 2010). Other applications that take advantage of the high flow rate through Pervious concrete include drainage media for hydraulic structures, parking lots, tennis courts, and greenhouses. Its high porosity gives it other useful characteristics; it is thermally insulating (for example, in walls of buildings) and has good acoustical properties for sound barrier walls. Most of the reported use of Pervious concrete in the USA is in pavements and sidewalks, but in Europe it has another function as it used as a structural material (Malhotra 1976). Applications include walls for two-story houses, load-bearing walls for high-rise buildings (up to 10 stories), in fill panels for high-rise buildings, sea groins, roads, and parking lots. Table (1) lists examples of applications for which Pervious conncrete has been used successful.

3.4. Properties:-

As mentioned before, differences in Pervious concrete mix and its placement techniques demonstrate a wide range of compressive strength, void ratio, and permeability.

3.5 Requirements

Pervious concrete requires appropriate construction technique in order to ensure its structural adequacy, hydraulic performance, and minimum clogging potential since it has a relatively stiff consistency. The use of a vibrating screed is important for optimum density and strength. After screeding, the material usually is compacted with a steel pipe roller. Tools like bullfloats, darbies, etc. cannot be used in finishing Pervious concrete because those tools tend to seal the surface. Joints, if used, may be formed soon after consolidation, or installed using conventional sawing equipment. Curing with plastic sheeting must start immediately after placement and should continue for at least seven days (Tennis et al. 2004).

3.6. Advantages

Pervious concrete system can have many impacts on the environment including (Sustainable Concrete Canada, Ltd.);

- Eliminating the high cost of underground piping systems

Helping healthy tree growth without breaking pavement surfaces since it allows water, air and nutrients to pass to tree roots.

- Increasing the quantity of water retained on site and penetrate into aquifers thus promoting healthy water levels which sustain our streams and drinking water.
- Eliminating the expense of curbs and gutters while making sites more handicap accessible.
- Preventing pollutants from reaching watercourses which frequantly occur with regular storm water systems during heavy rainfall events.
- Reducing the heat island effect common with development in urban areas when conventional pavement systems are utilized.
- The use of Pervious concrete may lead to LEED credits since it reduces storm water pollution at the source, eliminate or reduce the size of storm sewers, and control storm water runoff.
- According to Tennis et al (2004) Pervious concrete play a noticeable role in reducing noise, minimizing the heat island effect in large cities, and improving skid resistance. utters while making sites more handicap accessible.

3.7. Challenges (Disadvantages)

Many problems related to the pervious concrete need to be studied in order to improve its performance and life, Such as (Gupta and Kim, 2011):

- Clogging: sometimes small sized material such as sand and dirt which carried by storm water, may reduce the effectiveness of the drainage and permeability of the concrete. This issue can be solved by repeated power washing the slabs in order to unclog the concrete pores
- Abrasion resistance: Pervious concrete has poorer mechanical properties than conventional concert. Pervious concrete is oversensitive to abrasion failure caused by the surface course being worn off or crushed under traffic loads.

- Freeze and thaw: If Pervious concrete is exposed to very low temperature, there is a big chance that the concrete would undergo extensive freeze-thaw cycles if the placement was fully saturated. This may cause pressure on the thin cement paste surrounding the aggregates and accordingly loss of durability. Recently, many researchers such as Kevern et al, (2008) are developing this kind of concrete to overcome this challenge.

3.8. Environmental Benefits

As mentioned earlier, Pervious concrete pavement provide a useful storm-water management tool since it collects oil, anti-freeze, and other automobile fluids that can be washed into streams, lakes, and oceans when it rains. Moreover, Pervious concrete collects what is known as the “first flush” of rainfall and “treat” the pollution prior to release. Due to its environmental benefits; it helps earning a credit point in the U.S. Green Building Council’s Leadership in Energy and Environmental Design (LEED). It also helps in lowering heat island effects in urban areas due to two main points; the amount of absorbed heat from solar radiation is smaller than usual pavements (since its light color), and the relatively open pore structure of Pervious concrete stores less heat (Ibid). Pervious concrete pavement is ideal for protecting trees in a paved context; since Pervious concrete surfaces prevent air and water getting to the roots and adjacent trees while permitting full use of the pavement

IV. Experimental Programme

Experimental programmme consists of preparation of pervious Concrete andanalyzingvarious experimental results. Compressive strength, splittensile strength, porosity and permeability of precious concrete are studied to assess the suitability of previous concrete as filtration medium in rainwater harvesting.

4.1 Compressive strength

Compressive strength is a very important parameter for deciding on the concrete quality and performance.

A)Load=230KN(7days)

Cube size:- 150x 150 x 150 mm

Calculation:- Compressive strength = 230000/(150x150)

= 10.22 N/sq. mm

Fig.3

B)Load=340KN(28days)

Cube size:- 150x 150 x 150 mm

Calculation:- Compressive strength = 340000/(150x150)

= 15.111 N/sq. mm

2)Porosity:-Porosity is the ratio of volume of voids to the total volume of specimens. The total porositywas measured using the water displacement method based on the Archimedes’ principle of buoyance, which states that the buoyancy force is equal to the weight of fluid displaced. The total porosity includes both closed and open pores and can be measured using the buoyancy float apparatus. The dry mass, submerged mass, and total volume, must be known to calculate the porosity value.

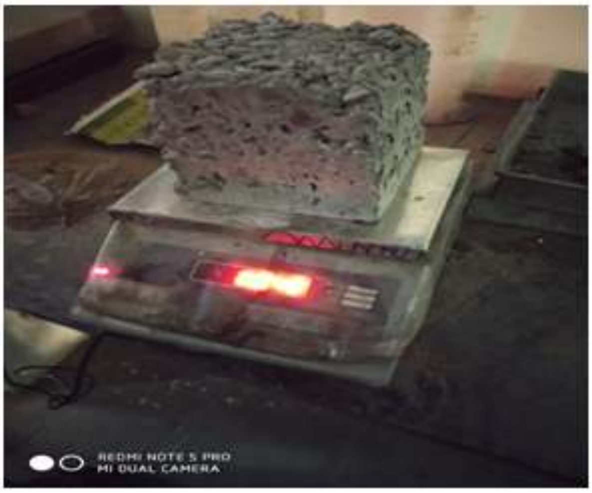

Fig.4

$$p=\left[1-\left(\frac{W_1-W_2}{\rho_w V}\right)\right]\times 100\%$$

Where:
p - Total porosity of pervious concrete [%]
W_1 - weight of a pervious concrete sample air-dried for 24 hours [kg]
W_2 - weight of a pervious concrete sample submerged in water [kg]
V - Volume of a pervious concrete sample [mm^3]
r_w- density of water [kg/mm^3].

n = [1- (10.7-8.04)/(1000x0.15x0.15x0.15)] x 100
= 21.185

3) SPLITTENSILESTRENGHTTEST:-

Tensilestrengthisoneofthebasicandimportantpropertiesofconcrete.Amethodofdeterminingthetensilestrengthofconcreteusingacylinderwhichsplitsacrosstheverticaldiameter.Itisanindirectmethodof testingtensilestrength ofconcrete.Thesplittensilestrengthwastestedoncylindricalspecimens100mmindiameterand300mminheight,after28 daysofcuringaccordingtoASTMC496
Formulaforfindingsplittensilestrength,(ft)
Ft=(2P)/(□DL)
P=Compressiveloadatfailure
L=lengthofcylinder
D=Diameterofcylinder(mm)
Ft=2×75000/(π×100×300)
=1.592kN/sq.m

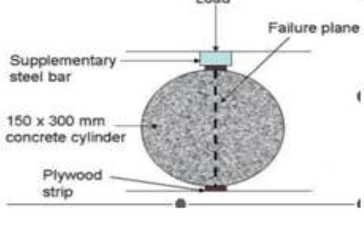

Fig. 5 fig. 6

4) Permeability test:-
ASTM C1701 is the standard infiltration test for pervious concrete.
The test consists of four main components: Installing the infiltration ring, prewetting the concrete, testing the concrete and calculating the results.

To install the infiltration ring, first clean the surface. The infiltration ring must meet certain size requirements and be marked with two lines on the interior to correctly perform the test.

The ring is then placed on the cleaned surface and secured in place with plumber's putty.

Once secure, pre-wet the concrete and infiltration ring with 8 pounds of water maintaining the head of water between the two marks on the interior of the ring. Begin timing as soon as the water hits the pervious concrete surface. When water is no longer present of the surface, record the elapsed time of the pre-wetting. The time elapsed determines the amount of water to be used in the actual test.

In most cases, 40 pounds of water will be required for the test. Record the weight. Within 2 minutes, add the proper amount of water to the ring. As with the pre-wetting stage, we will begin timing when the water impacts the pervious concrete surface and maintain the water head between the two lines marked on the infiltration ring. Again, when water is no longer present of the surface, record the elapsed time of the test.

With all of our data points collected, we then perform the infiltration calculation using the mass of the water, the diameter of the infiltration ring and time of the test.
With that information we have our final infiltration rate, by using the formula for permeability test.

I = (KM)/(D^2xt)
M = 40lb (water mass)
D = 12in (ring diameter)
T = 102sec (time to infiltration)
K = 126870in (constant)
= 126870x40/(12^2x102)
= 345.51 in/hr
= 345.51x0.0254
= 8.776 m/hr

Fig no 7

V. Methodology:-

This section presents the methodology of the research. It consists of 4 sections; the first sections presents data collection procedures. The second section identifies the variables of research. Data analysis is mentioned in the third section and the fourth section discusses the scope and limitations of the research.

5.1. Data collection:-

Procedures Setting and Process; firstly a suitable area in the acet campus will be selected in order to do the research, the reason for choosing this area lies in its information-richness with respect to the purposes of the study; since dimensions, area and rainfall average are easy to obtain. Then Concrete and asphalt will be replaced by previous concrete on parking lots, concrete pavement, sidewalk and pathways with the 15-35 % void ratio. Finally, climatic data of Nagpur and specifically the Acer area will be collected, listed in the Table shows average precipitation through out year.

Sr.no.	Month	Averageprecipitation(mm)
1	January	6.7
2	February	12
3	March	8
4	April	4
5	May	11.5
6	June	175
7	July	285
8	August	290

Table no. 1

Area of Nagpur City = 227.4 sq. km.
Total annual precipitation = 1050mm
Total vol. of precipitation = 227.4 x 1000000 x 1050/1000 = 238770000 m3

Assume 2sq. km area of application (0.88% of total area)
Precipitation = (2 x 1000000) x 1050/1000 = 2100000

Assume 30% of infiltration through pervious concrete
Volume infiltrated = 2100000 – (30 x 21000000)/100 =1470000 cu. m = 1470 million liters.

VI. Site Details

The site is a parking lot area located in front of Admission and Registration Unit, inside the ACET Campus as shown in Figure (8). Schematic illustration of the site is illustrated in Figure (8) Site Location.

Fig. 8

ConstructionProcess

The construction of the site will be accomplished in three major phases: excavation and asphalt removal, sub-base fill, and the concrete placement.

1.Excavation:-

Parking lot of ACET campus was selected for the application of pervious concrete. The site will be excavated to a depth of 30cm from the top of existing paver surface. The excavation will be done in such a manner so as to accommodate the water collection system. Sets of perforated pipes will be placed under the parking area. Then the site will be filled with 15cm thick pervious concrete slab. This pipes will lead through connections reaching a holding tank for the infiltrated water.

2.Sub-basefill

Once the excavation is complete, 15cm of fractured clear crush with a maximum aggregate size will be set above the sub-grade. This layer should be compacted and measured to gain a uniform depth throughout the placement. This layer is important as it acts as a storage medium and as a filtration system for water passing through the Pervious concrete and as a sub-base for receiving the pervious concrete layer.

3.Concreteplacement:

Pervious concrete will be brought from Concrete plant of Nagpur.A 15 cm of Pervious concrete will be placed on top of the compacted clear crush, see Figure (7).

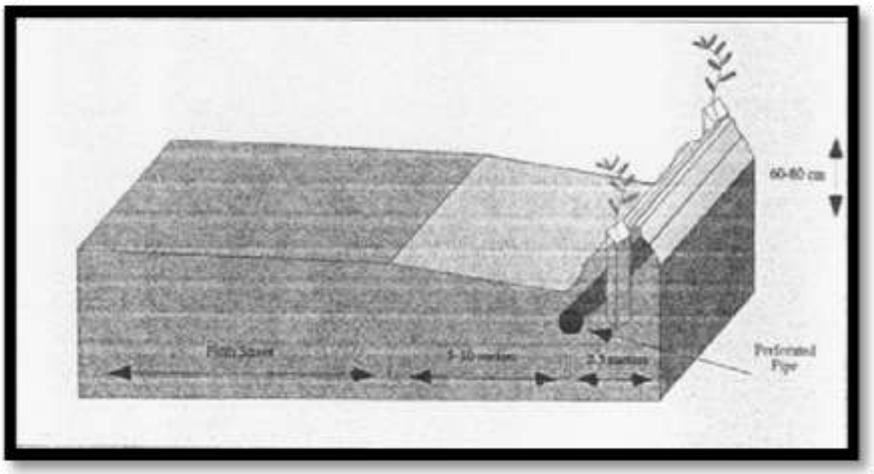

Fig.9

VII. Conclusion:-

Using Pervious concrete will contribute to improving storage capacity at the University of Jordan campus; since the selected parking lot with 2746m2 area is capable of collecting about 392 m3 , this also will definitely reduce flooding and maximize water filtration. Although the selected site is small and flat without giving consideration to slope and topography but it is a useful indication to measure the efficiency of using the previous concrete on larger scale areas. But water pollution calculations and the "first flush" are neglected in our study since they are hard to monitor. Thus Pervious concrete surfaces can improve safety during rainstorms by eliminating ponding and glare at night, spraying, and risk of hydroplaning.

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