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Storm Water Management to Permeable Pavement Runoff

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Abstract- **Uncontrolled storm water runoff not only creates drainage problems and flash floods but also presents a considerable threat to water quality and the environment. These problems can, to a large extent, be reduced by a type of storm water management approach employing permeable pavement systems (PPS) in urban, industrial and commercial areas, where frequent problems are caused by intense undraied storm water. PPS could be an efficient solution for sustainable drainage systems, and control water security as well as renewable energy in certain cases. Considerable research has been conducted on the function of PPS and their improvement to ensure sustainable drainage systems and water quality. This paper presents a review of the use of permeable pavement for different purposes. The paper focuses on drainage systems and storm water runoff quality from roads, driveways, rooftops and parking lots. PPS are very effective for storm water management and water reuse. Moreover, geotextiles provide additional facilities to reduce the pollutants from infiltrate runoff into the ground, creating a suitable environment for the biodegradation process. Furthermore, recently, ground source heat pumps and PPS have been found to be an excellent combination for sustainable renewable energy. In addition, this study has identified several gaps in the present state of knowledge on PPS and indicates some research needs for future consideration.**

Index Terms- **Permeable Pavement; Porous Pavement; Geotextiles; Ground Source Heat Pump (GSHP); Sustainable Drainage**

I. INTRODUCTION

Sustainable urban drainage systems

A sustainable drainage system (SUDS) is designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharges. The term sustainable urban drainage system is not the accepted name, the 'Urban' reference having been removed so as to accommodate rural sustainable water management practices. Increasing urbanization has caused problems with increased flash flooding after sudden rain. As areas of vegetation are replaced by concrete, asphalt, or roofed structures, the area loses its ability to absorb rainwater. This rain is instead directed into surface water drainage systems, often overloading them and causing floods. The idea behind SUDS is to try to replicate natural systems that use cost effective solutions with low environmental impact to drain away dirty and surface water run-off through collection, storage, and cleaning before allowing it to be released slowly back into the environment, such as into water courses. This is to counter the effects of conventional drainage systems that often allow for flooding, pollution of the environment – with the resultant harm to wildlife –and contamination of groundwater sources used to provide drinking water. The paradigm of SuDS solutions should be that of a system that is easy to manage, requiring little or no energy input (except from environmental sources such as sunlight, etc.), resilient to use, and being environmentally as well as aesthetically attractive. Examples of this type of system are basins (shallow landscape depressions that are dry most of the time when it's not raining), rain-gardens (shallow landscape depressions with shrub or herbaceous planting), swales (shallow normally-dry, wide-based ditches), filter drains (gravel filled trench drain), bioretention basins (shallow depressions with gravel and/or sand filtration layers beneath the growing medium), reed beds and other wetland habitats that collect, store, and filter dirty water along with providing a habitat for wildlife. Originally the term SUDS described the UK approach to sustainable urban drainage systems. These developments may not necessarily be in "urban" areas, and thus the "urban" part of SuDS is now usually dropped to reduce confusion. Other countries have similar approaches in place using a different terminology such as best management practice (BMP) and low-impact development in the United States,[8]and water-sensitive urban design in Australia .

SuDS use the following techniques:

[1] Source control
[2] Permeable paving such as pervious concrete
[3] Storm water detention
[4] Storm water infiltration
[5] Evapo-transpiration (e.g. from a green roof)

A common misconception of SuDS systems is that they reduce flooding on the development site. In fact the SUDS system is designed to reduce the impact that the surface water drainage system of one site has on other sites. For instance, sewer flooding is a problem in many places. Paving or building over land can result in flash flooding. This happens when flows entering a sewer exceed its capacity and it overflows. The SuDS system aims to minimise or eliminate discharges from the site, thus reducing the impact, the idea being that if all development sites incorporated SuDS then urban sewer flooding would be less of a problem. Unlike traditional urban storm water drainage systems, SuDS can also help to protect and enhance ground water quality.

Technologies of SUDS

There are dozens, if not hundreds of different suds applications, ranging from reed-bed treatment systems for Polluted water, to settlement ponds for sediment, to simple swales and filter drains. Schemes are usually site- specific, Taking a range of core technologies and using them either singly or in combination to create and application that deals With the surface water drainage for a particular site. One of such technology is permeable paving or permeable Pavement systems, but there is a suitable difference between these two which is permeable pavements allows water To pass through the paving structure, whereas suds-friendly pavements simply direct surface water to a suds installation Such as a soakaway, a swale, etc. The permeable pavement systems and suds are differentiated in the figure. 1. Suds-compliant pavements which can be defined as any pavement from which surface water issent to a suds installation from where it may have the opportunity to drain to ground or be temporarily stored rather Than being directly channelled into the public sewer system or an open watercourse

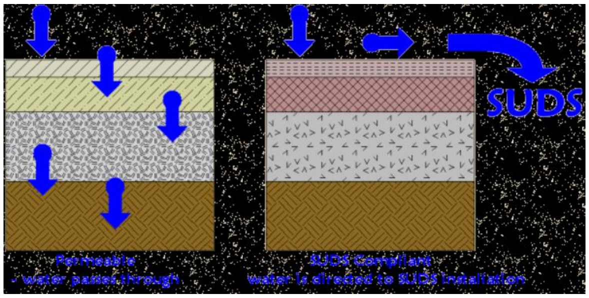

Figure. 1. Difference between Permeable Paving and SUDS.

OBJECTIVES

Permeable pavement offers a number of environmental benefits. Increasing the amount of storm water infiltrated can result in lower stream flow levels after storm events, increased stream base flow due to increased groundwater recharge, and increased stream stability through reduced stream velocities and peak flows. The benefits of providing stream stability range from erosion control to maintaining the habitat necessary for aquatic life. As permeable pavement eliminates standing water, other noticeable benefits include improved braking, reduced hydroplaning on roadways, and resistance to freeze/thaw conditions. Evaporation from beneath the permeable pavement can produce a cooler surface helping reduce the heat island effect often experienced in urban settings. Permeable pavement can also aid in the health and development of urban trees by providing root systems with greater access to water and air.

The materials used in permeable pavement and its foundation are capable of retaining soluble and fine particulate nutrients, sediments, heavy metals, and other pollutants from storm water runoff thus improving the quality of water that enters surface waters and ground waters. Coarse particulate removal is not advised due to issues with clogging, so some pre-treatment may be required in addition to regular maintenance. Some storm water pollutant loads may also be reduced as permeable pavements can act like a bio filter where microorganisms break down contaminants.

II. METHODOLOGY

Minimum Depth Method

1. Compute the depth of the stone reservoir ($\boldsymbol{dp}$).

$$\boldsymbol{dp} = \frac{(\mathrm{Qc})\left(\frac{\mathrm{Ac}}{\mathrm{Ay}}\right) + \mathrm{P} - \mathrm{f(T)}}{\mathrm{Vr}}$$

$\boldsymbol{dp}$ = depth of stone reservoir (in)
Qc = runoff from contributing area (in)
Ac = contributing area (ft2)
Ap = permeable pavement surface area (ft2)
P = design rainfall (in)
f = infiltration rate (in/hr)
T = fill time (hr)
V_r = void ratio of stone reservoir

Not that void spaces typically range between 30 and 40 percent, although it is recommended that the exact value be obtained from the supplier.

2. Compute the maximum allowable depth of the stone reservoir (d_{max}).

$$d_{max} = \frac{(\mathrm{f})(\mathrm{T_s})}{(V_r)}$$

d_{max}= Maximum allowable depth of stone reservoir (in)
$\mathrm{T_s}$ = Maximum allowable storage time (hr)

Check the design feasibility:
• Is $\boldsymbol{dp} \leq d_{max}$=?
• Is the bottom of the aggregate at least 2 ft above the seasonal high water table?
• If no to either, reduce design storm depth or increase permeable pavement surface area.

Minimum Area Method

1. Compute the maximum allowable depth of the stone reservoir (d_{max}).
2. Select $\boldsymbol{dp}$ so that it is less than or equal to d_{max} and bottom of aggregate is
3. at least 2 ft above seasonal high water table.
4. Compute the minimum required surface area (Ap).

$$A_p = \frac{\left(\frac{\mathrm{Q_c}}{12}\right)(\mathrm{A_c})}{(\mathrm{V_r})\left(\frac{\mathrm{d_p}}{12}\right) - \left(\frac{\mathrm{p}}{12}\right) + \left(\frac{\mathrm{f}}{12}\right)(\mathrm{T})}$$

Following either method, complete the following:

1. Determine the minimal structural base thickness.
2. Check for minimum separation between bottom of structural base and seasonal high water table.
3. Select the geotextile filter fabric for soil separation.

PROCEDURE

- There are two different process of permeable pavement methods minimum depth method and minimum area method.
- In first process Compute the depth of the stone reservoir ($\mathrm{d_p}$).
- In second process Compute the maximum allowable depth of the stone reservoir (d_{max}).
- In third process Compute the maximum allowable depth of the stone reservoir (d_{max}).
- $\mathrm{d_p}$ is less than d_{max}.
- The structural base thickness. In this example, assume a structural base thickness of 16 in. is required for expected loadings and frost conditions. This is thicker than the 12.0 in. required.

Table no 1:Different Permeable Pavement Specifications

Material	Specification	Notes
Permeable Interlocking Concrete Pavers	Surface open area: 5% to 15%. Thickness: 3.125 inches for vehicles. Compressive strength: 55 Mpa. Open void fill media: aggregate	Must conform to ASTM C936 specifications. Reservoir layer required to support the structural load.
Concrete Grid Pavers	Open void content: 20% to 50%. Thickness: 3.5 inches. Compressive strength: 35 Mpa. Open void fill media: aggregate, topsoil and grass, coarse sand.	Must conform to ASTM C 1319 specifications. Reservoir layer required to support the structural load.
Plastic Reinforced Grid Pavers	Void content: depends on fill material. Compressive strength: varies, depending on fill material. Open void fill media: aggregate, topsoil and grass, coarse sand.	Reservoir layer required to support the structural load.
Pervious Concrete	Void content: 15% to 25 %. Thickness: typically 4 to 8 inches. Compressive strength: 2.8 to 28 Mpa. Open void fill media: None	May not require a reservoir layer to support the structural load, but a layer may be included to increase the storage or infiltration.
Porous Asphalt	Void content: 15% to 20 %. Thickness: typically 3 to 7 in. (depending on traffic load). Open void fill media: None.	Reservoir layer required to support the structural load.

III.RESULT ANALYSIS: DIFFRENCE IN PLAN AND COST

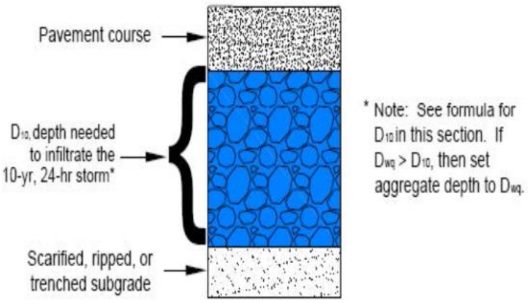

Figure 2 : Infiltrate the 10-yr, 24-hr storm.

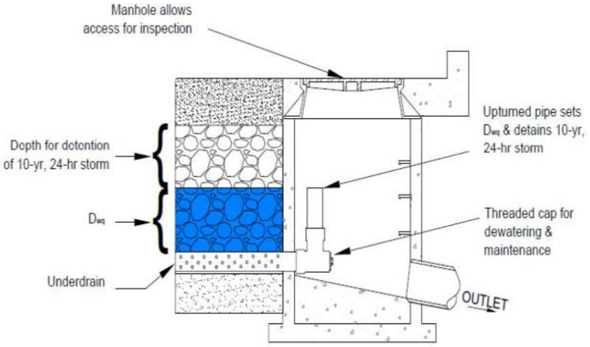

Figure 3: Detail via under drain with upturned elbow

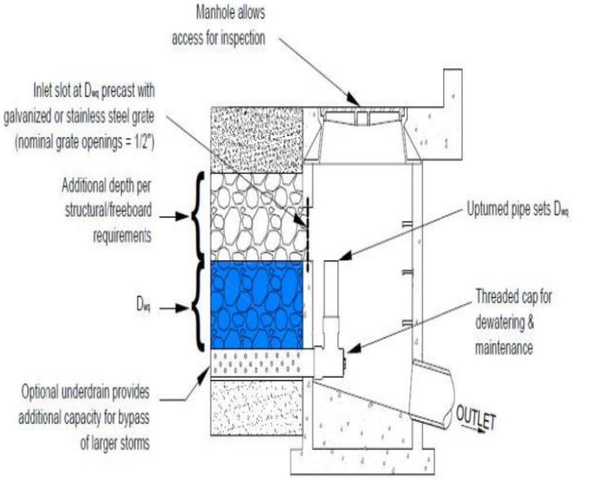

Figure 4: Bypass via subsurface openings in manhole structures.

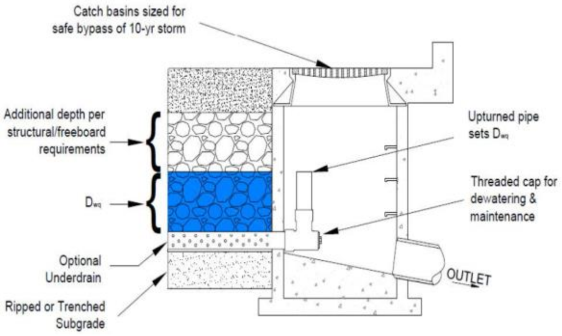

Figure 5 : Bypass via catch basin (PC & PA only) .

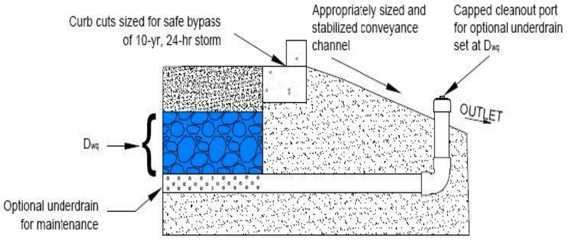

Figure 6 : Bypass via curb cut and conveyance (PC only).

•COSTING AND RATE ANALYSIS FOR PEAMEABLE PAVEMENT:

Paving costs for each of the three scenarios was estimated. Unit costs for construction were estimated based on recent bids for similar work by local contractors. A summary of the costs is given below.

Table no: 2 Costing and rate analysis of permeable pavement

2017 values			
Surface Type	Limitations/ Application	Material average Cost / ft^2	Average Life (years)
Porous Asphalt	low weight capacity	*Rs. 72.23*	17.5
Pervious Concrete	Small to large projects	*Rs. 433.43*	25
concrete pavers	Small to large projects	*Rs. 722.38*	25-30

DRIVEWAY			
	Length	Width	
Material	(Feet)	(Feet)	Cost
Pervious concrete	252	25	Rs.27.30 lakh
		20	Rs.21.84 lakh
Porous asphalt	252	25	Rs.4.55 lakh
		20	Rs.3.64 lakh
Permeable pavers	Paver	4”x4”	Rs.45.50 lakh
Plastic grid reinforced gravel	Geocell	9	Rs.7.5 lakh
Conventional concrete	4	4	Rs.4.4 lakh
Conventional asphalt	3	6	Rs.2.3 lakh

IV. CONCLUSION

In general, porous asphalt and pervious concrete are cost competitive, particularly where larger areas are involved. This is primarily due to the fact that no drainage is required. For smaller areas, such as the driveway, where drainage was not included in the cost, non-porous alternatives were less.

The most expensive alternative in all scenarios were permeable interlocking concrete pavers. This was due to the fact that placing the pavers is much more labor intensive. However, this could still be a preferred alternative where a highly ornate, ornamental finish is desired.

Gravel reinforced with a geo-cellular grid tended to be the least expensive. However, this low initial cost comes with the drawback that periodic maintenance of the surface will be needed to maintain the gravel surface. The decision to select porous versus non-porous paving depends on the particular needs of the owner, site specific constraints, and the proposed use of the improved area. Based on this review, porous pavements are cost effective or close to cost neutral alternatives when all development costs are considered.

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