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Paper on Permeable Pavement Systems

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ABSTRACT

The purpose of this review paper is to compact the wide range and spread the relevant works on permeable pavement systems, and also to deal with the current research and line of works to recommend the future areas of research work, also outlined about the important role of the permeable pavement systems in sustainable urban drainage systems in both the traditional and modern context, and discussed in brief about the permeable pavement systems. Particular emphasise is given for water quality control aspects which includes the microbiological point of view of permeable pavement system and the pollutants. Recent research on the combined geothermal heating and cooling, water treatment and recycling pavement system is promising which are discussed in short. At last the future research and innovations are discussed in briefly.

The intent of this review is to provide stakeholders in storm water management with the critical information that is needed for the foster acceptance of permeable pavement systems as a viable alternative to the traditional systems.

Keywords: permeable pavement system, sustainable urban development system, geothermal heating and cooling system, recycling pavement system, porous pavement, storm water management.

I.Introduction

1.1 Sustainable urban drainage systems :Sustainable

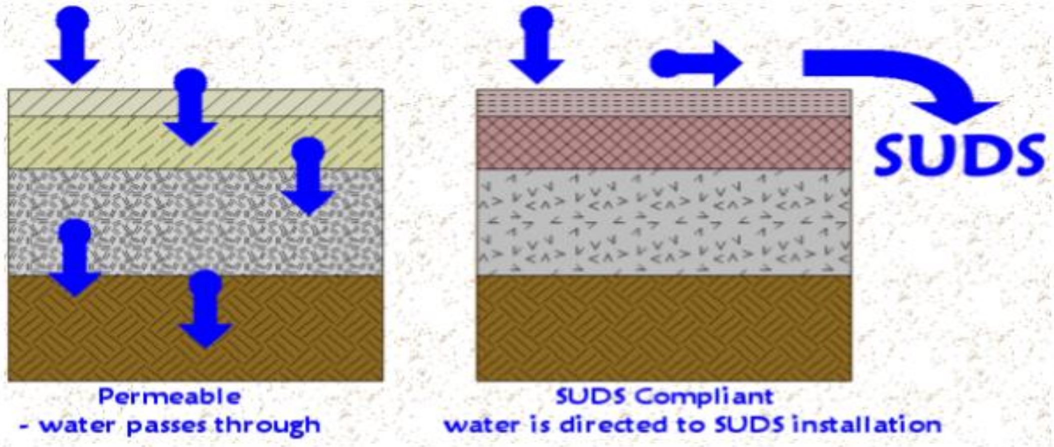
Urban Drainage System is a series of methods for dealing with drainage in a sustainable manner, using technologies that minimise the environmental impact of our lifestyles, buildings, structures and surfaces. Sustainable Urban Drainage Systems challenge the traditional approach of wastewater treatment by optimising the resource utilisation and development of novel and more productive technologies. There are numerous advantages by implementing Sustainable Urban Drainage Systems in our society but a few key pluses are mentioned below. Which are:

- Flood control and better management of storm water at source (source control)
- Pollution control
- Recharging of groundwater regimes and aquifers
- Reduced construction and maintenance costs

- Improved environment.

1.2Technologies of SUDS

There are dozens, 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 subtle difference between these two which is permeable pavements allow water to pass through the paving structure, whereas suds-friendly pavements simply direct surface water to a suds installation such as a soak away, 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 is sent 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. Permeable Paving and SUDS

II.PERMEABLE PAVEMENT SYSTEMS

Permeable Pavement Systems are designed to achieve water quality and quantity benefits by allowing movement of storm water through the pavement surface and into a base/sub base reservoir, the water passes through the voids in the pavement materials (or) through the gap between pavers and provides the structural support as conventional pavement. That's why permeable pavements can be served as an alternative to conventional road and parking lots. These pavements provides the ability to reduce urban runoff and also provide the opportunities to mitigate the impacts of urbanization on receiving water systems by providing at source treatment and management of storm water. Permeable pavement systems have been shown to improve the storm water quality by reducing the storm water temperature, pollutant concentrations and pollutant loading of suspended solids, heavy metals, polyaromatic hydrocarbons and some nutrients. Purposes for using permeable pavement systems instead of using other pavement systems are mentioned as:

Promote storm water infiltration, groundwater recharge, and stream base flow preservation

1. Reduce the discharge of storm water pollutants to surface waters
2. Reduce storm water discharge volumes and rates
3. Reduce the temperature of storm water discharges

2.1 Types of Permeable Pavement Systems

There are generally permeable varieties of asphalt, concrete, and interlocking pavers that means depending upon the type of materials used permeable pavement systems are divided into various types. Which are:

2.2.1PermeableAsphalt

Permeable asphalt, also known as pervious, porous, "popcorn," or open-graded asphalt, is standard hot-mix asphalt with reduced sand or fines and allows water to drain through it. It generally consists of fine and coarse aggregate stone bound by a bituminous-based binder coarse

2.2.2 Permeable concrete

Permeable concrete, also known as pervious (or) porous concrete, gap-graded (or) enhanced porosity concrete, is concrete with reduced sand or fines and allows water to drain through it. . Pervious concrete pavement is a unique and effective means to address important environmental issues and support green, sustainable growth by capturing storm water and allowing it to seep into the ground, porous concrete is instrumental in recharging groundwater, reducing storm water runoff.

2.2.3 Permeable interlocking concrete pavement

Permeable interlocking concrete pavement (PICP) consists of manufactured concrete units that reduce storm water runoff volume, rate, and pollutants. The impervious units are designed with small openings between permeable joints.

2.2.4 Concrete grid pavers

Concrete grid pavements “green parking lots” provide a cool, green surface as shown in (Figure. 2.) Solution for vehicular access lanes, emergency access areas, and overflow parking areas, and even residential driveways. Grids are proven contributors to reduced ambient urban temperatures thereby contributing to reduced heat island while taking in some rainfall and runoff.

2.2.5 Plastic Reinforcement Grid Pavers

Plastic reinforcement grid pavers also called geocells, consists of flexible plastic interlocking units that allow for infiltration through large gaps filled with gravel or topsoil planted with turf grass. A sand bedding layer and gravel base-course are often added to increase infiltration and storage.

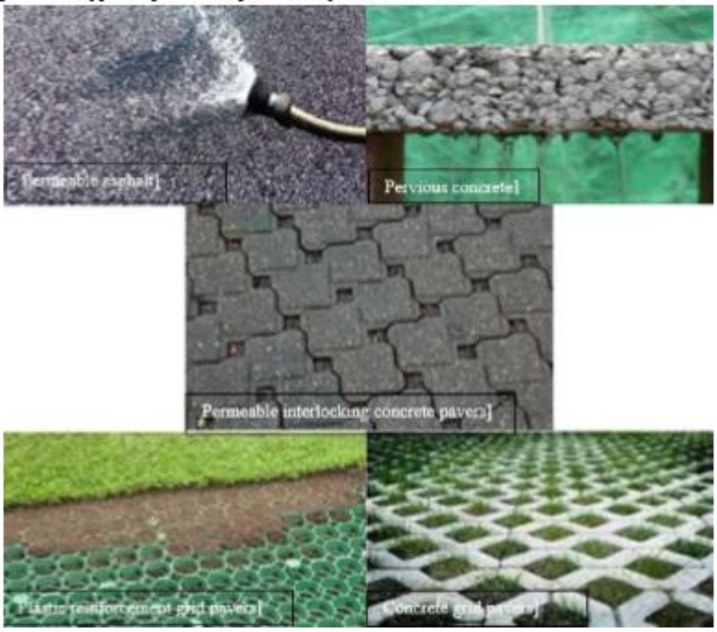


Figure. 2. Figure showing different types of permeable pavement systems

III.RESEARCH AND WORKS.

3.1. Combined Geothermal Heating and Cooling effect

3.1.1. Introduction to Geothermal Heat Pumps.

The technology has many names: ground source heat pump (GSHP), ground coupled heat pump (GCHP), geothermal heat pump (GHP), geo-exchange (GX), Earth energy system. Geothermal heat pumps (GHP) or geo exchange systems are commonly used in North America, China, Japan and some European countries. Most GSHP use refrigerant to move unwanted energy (i.e. heat) out of buildings during summer and into them (if required) during winter 3.1.2. Integration of PPS with Geothermal Heat Pumps Environment not only prevents and reduces the risk of flooding and pollution of watercourses, but also reduces energy costs by the application of a green energy source (earth energy) which adds many other environmental benefits . Permeable pavement engineering is an effective and simple method of providing structural pavements whilst allowing storm water to infiltrate freely through the surfaces for temporary storage, storm attenuation, dispersal and reuse. Permeable pavement systems (PPS) are a sustainable urban drainage system (SUDS) whereby water from urban runoff can be treated by filtration and sedimentation for recycling, harvesting or reuse purposes. Geothermal Heat Pumps (GHPs) also referred to as ground source heat pumps are receiving increasing interest because of its potential to reduce primary energy consumption, reduce emissions of greenhouse gases and thus reduce the effects of climate change

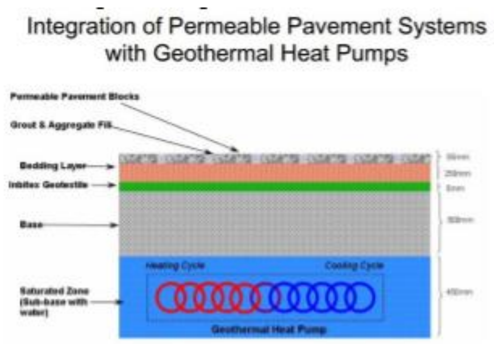


Figure.3 Cross section of PPS **Figure.4 . Process of heat transfer in GHP**

3.1.3. Health risks associated with permeable pavement systems.

Various applications of PPS have been tested in the UK. The main pollutant used was mineral engine oils containing hydrocarbons. Furthermore, a specific geotextile incorporating polymer beads was designed to release nutrients for better microbial community growth and more efficient hydrocarbon removal. this 'self-fertilising' geotextile demonstrates that nutrient sources can be incorporated into a polymer composite to influence positively microbial growth within PPS. Nevertheless, there are serious health concerns associated with PPS water (particularly if contaminated with faecal matter), which could potentially be recycled within buildings for toilet flushing and other applications as discussed by the authors previously. Both PPS and GSHP are commercially available applications, but were never used as combined systems in a research project. A combined system has the potential to capture, detain and treat runoff, and to either cool or heat a nearby building at the same time. The sub-base is only heated passively during the summer when hot air with in an adjacent building needs to be cooled down by transferring access heat to below the permeable pavement. The heat is in fact a waste product that has the additional benefit of enhancing biodegradation within the sub-base.

3.2. Water recycling using permeable paving

The physical attenuation of storm water pollutants by permeable pavements with varying designs of geotextile membranes. The research would give an indication as to the effects of contaminants present in urban runoff and the possibility of biodegradation by anaerobic processes occurs. One of the guiding principles of SUDS is centred on mitigating adverse effects of urban storm water runoff such as increased urban flooding and deteriorating receiving water quality. SUDS such as permeable pavements are commonly perceived as an effective source control measure to reduce storm water flows and pollution loads. However, there have only been limited studies aimed specifically at quantifying the effectiveness of utilising permeable pavements as a source control measure. The recycling and reuse of rainwater, using permeable paving as the reservoir for storage, shows great potential in the reduction of mains water use for low grade uses. Water for toilet flushing, landscaping and car washing can be stored in the pavement structure and pumped out for reuse

3.2.1. Rainwater harvesting after storage in permeable

pavements Permeable pavements built to the Hanson Form pave specification have an average storage capacity of around 1m3 per 10m2 of paving with an excavation depth of 500 mm. This storage capacity is easily realised by the provision of a lining system, usually based on a Visqueen-type material. Once the build is complete, accessories such as electric pumps can be added in order to move the water into the house for WC flushing or for external use such as landscaping. The onsite use of rainwater for non-potable purposes in both domestic and industrial settings shows great promise in reducing the need for highly purified mains water. In a domestic setting at certain times of the year, over 50 % of water could be supplied by the use of rainwater, certainly when feeding sprinkler systems in dry weather. The use of a permeable pavement as the storage element in rainwater harvesting makes efficient use of a large potential storage volume, adheres to SUDS principles and value engineering good practice, realising significant savings for the end user.

3.2.2. Contamination of stored rainwater

When rainwater falls onto an urban receiving surface, whether that surface is a roof, road, pavement or car, it usually becomes contaminated relative to the water quality of the original rainfall. This is because rainfall is relatively free of contaminants except for materials like pollen, microbial spores, very fine dust and sometimes dissolved gases such as SO2 and NO2. After falling and coming into contact with surfaces, non-permeable urban surfaces tend to have any pollutants on them scoured off by the rainfall and moved, sometimes quite a large distance from their origin. These measures are very effective in preventing blockages of pipework, but do not remove most of the smaller particles which may find their way into the storage reservoir. These smaller sized fractions include microorganisms typically between 2 and 20 micrometres in size.

3.2.3. Microbiological contamination of harvested rainwater Any microbiological contamination in water harvesting schemes would come primarily from animal wastes from cats, dogs, rodents or birds. The unpredictability of any such contamination episodes is one of the reasons why such phenomena are difficult to study. It is clear that at times the number of potentially harmful microbes in urban water, e.g. faecal coliforms, is high . Potentially there are a number of possible contaminating microbial types in harvested rainwater, of different taxonomic descriptions and which may increase in number under a variety of different conditions.

IV.INNOVATIONS AND FUTURE RESEARCH

To date, the application of permeable pavement systems has been limited to roadways for vehicular travel. Ongoing and future research could potentially allow for new and innovative applications such as with airport runways. There is a myriad of different applications where human's quest for development is hindered by environmental consequences. It is possible that with the use of permeable pavements these events may not be so catastrophic. Landslides are one example. Until recently, landslides were only thought to be associated with high intensity rainstorms on steep inclines. However, recent studies have shown that the threshold of rainfall intensity versus duration for shallow sloped landslides to occur is lower than previous estimates. It was found that the rainfall intensity plays a more important role in increasing the chances for landslides to occur due to the

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sheer quantity of water draining over a short amount oftime . These conditions can be exasperated by human development, which alters the drainage path of the rainwater, increasing the likelihood of a landslide

V.CONCLUSIONS

This paper looked at various studies conducted on permeable pavement systems and their current application. Also discussed about the detailed design of permeable interlocking concrete pavement in brief. Maintenance and water quality control aspects relevant to the practitioner were outlined for permeable pavement systems. The water quality aspects is highlighted. Recent innovations were highlighted and explained, and their potential for further research work was outlined. The recent innovations like development of a combined geothermal heating and cooling, water treatment and recycling pavement system is promising and it is detailed in cut short, future research works are outlined in brief. These permeable pavement systems are changing the way human development interacts with the natural environment. Its application towards parking lots, highways and even airport runways are all improvements in terms of water quality, water quantity and safety.

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