Permeable pavement and stormwater management systems: a review

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Introduction

Climate change and global warming are crucial problems worldwide and, as a consequence, sustainable practices for both energy and water are prominent issues at present. The general function of a permeable pavement is to collect, treat and filter surface runoff to enhance groundwater recharge. Traditionally, permeable pavement systems (PPS) have been used for light-duty pavement due to their insufficient structural loading and geotechnical design considerations. [1,2] PPS are a simple and effective way to facilitate a structurally stable pavement for the use of pedestrian and vehicular traffic, as well as simultaneously address stormwater runoff infiltration, storage and dispersal. [3] PPS can provide sustainable stormwater management by facilitating groundwater recharge, reducing surface runoff, reusing stormwater and preventing the pollution of stormwater for a wide range of commercial, residential and industrial areas. Management considerations for stormwater from urban areas, parking lots, footpaths, open marketplaces and highway shoulders are important and integrated components in the design of these pavement systems. A permeable and porous pavement is capable of capturing water on the pavement surface and then allowing it to infiltrate into the subgrade layer and groundwater, which is one of the best stormwater management systems. Conventional road pavement is generally impervious; consequently, it accumulates a large amount of runoff water during a storm, which contains pollutants from transportation and related activities. [4,5]Apermeable pavement provides a better solution to reduce the significant pavement runoff volume and pollutants associated with runoff water. [6–9]

Urban stormwater runoff and sustainable drainage systems (SUDS), such as permeable pavement, have been a major consideration in stormwater management practice. The sustainable drainage management of runoff is a green approach involving the collection, storage, treatment and reuse of stormwater runoff. Permeable pavement is a good stormwater runoff management solution for a wide variety of urban, commercial and industrial areas, and is designed for light-duty and frequent use; however, the systems do allow for a wider range of uses. [10] Although the combined application of permeable pavement and ground source heat pumps (GSHP) is commercially available, to date, there is limited research. [11] Geothermal energy systems have been increasing in recent decades around the world, to reduce harmful gas emissions and provide a renewable energy source. The sub-base of permeable pavement can be used as a geothermal resource by applying appropriate technology and geothermal heat pumps, which enable the extraction or injection of heat to the subsoil at relatively low temperatures through heat exchange systems, usually filled with water.

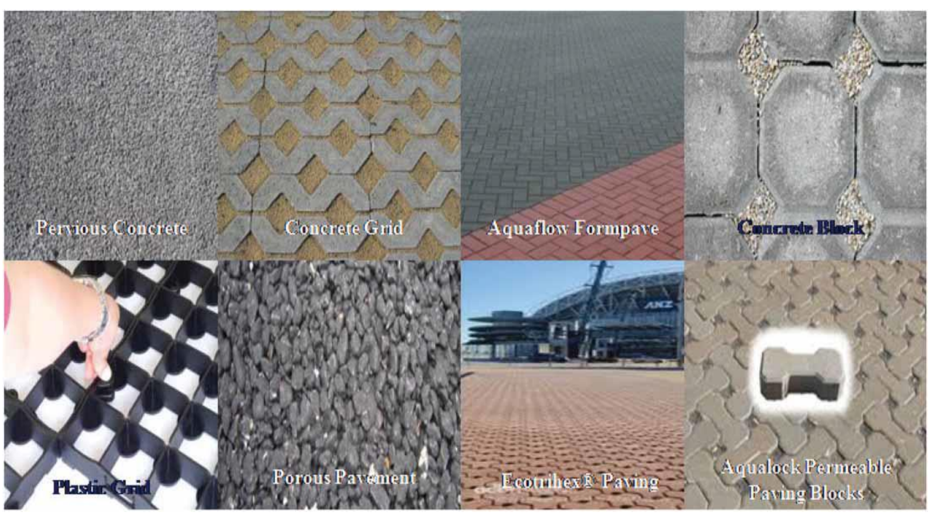

Figure 1. Some common types of permeable pavement systems.

Permeable pavement systems

PPS are a very effective management practice for a wide range of pollution control in stormwater (Figure 1). They facilitate infiltration for large areas with a structurally safe pavement for use by pedestrians, or shopping areas, park areas and driveways as well as areas with moderate traffic use. [2] A common principal of permeable pavement in the case of stormwater management is the collection, treatment and infiltration of stormwater to support groundwater restoration. PPS are a good solution, particularly in sustainable drainage systems, for recycling of stormwater and control of contamination fromharmful substances, such as hydrocarbons and heavy metals. [12,13] The aggregate size of the sub-base and base should be precise so that the permeable pavement can quickly drain runoff and store the water to avoid flash floods

Hydraulic performance was assessed for a permeable highway shoulder pavement to capture stormwater runoff onto the surface pavement. [14] HYDRUS software was used to simulate the performance based on unsaturated flow theory. The hydraulic properties of subgrade soil and pavement materials were used as input for the simulation, and the critical thickness of layers of aggregates was fixed according to the simulation results to avoid overflow on the surface pavement. Sensitivity analysis indicated that 1.5m depth of aggregate was sufficient to capture the runoff without pooling on the pavement surface.

Concrete blocks

Precast grid or block-shaped concrete with open voids was used for permeable pavement to allow infiltration. Installation can be by hand or by a mechanical process. Generally, the voids of the block are filled with crushed gravel or stone, or topsoil and turf. Several common concrete blocks – Turfstone®, UNI Eco-Stone® and Unilock® – were used to investigate the runoff volume. [12,15–17] The results indicated that the runoff volume was significantly lower than for asphalt driveways.

Plastic grids

Plastic grids used for PPS have gained popularity in recent years. These grids provide more void space for filling materials than concrete blocks. Concrete block pavers are mostly impervious, whereas the plastic grids are mostly pervious. The voids of the grids are filled in the same way as concrete blocks. Grasspave® and Gravelpave® plastic grids were used by Brattebo and Booth, [12] in which topsoil and turf were used for Grasspave® grid, and crushed gravel was used in the Gravelpave® grid. The monitoring data showed that apparently no surface runoff was obtained at that site. Grassy Paver™ plastic grid showed 93% less stormwater runoff compared with the asphalt lots. [8]

Pervious/porous pavement

Pervious concrete is made by omitting the fine aggregate from the concrete mixture. Parking lots installed with pervious concrete have been used successfully in many places. [18–20] Although there have been some problems with the installation of the material, the pavement was successful in allowing infiltration of stormwater runoff. Evaluation and comparisons were made on water storage capabilities of different types of pervious pavement in 45 places in Spain. [21] Pervious materials had a significant effect on the behaviour of pervious pavement. In addition, the surface materials of pervious pavement made a greater contribution to water management than a geotextile layer. Analysis of variance techniques were used to explain the relationship of storm runoff management capacity of different pervious pavements with weather conditions. The correlations of water management capacity were significant (86%) between the porous asphalt and porous concrete pavement, whereas the plastic grid pavers indicated poor correlation with other pavements.

Generally, porous pavements consist of a porous surface for the top layer, and drainage materials are placed beneath to filter the surface runoff. Porous pavement applications are

limited in some cases to fine-grained soils, due to its performance.
The performance of porous pavement on clay soils
was investigated by Dreelin et al., [8] who compared the
performance between an asphalt parking lot and a porous
pavement parking lot of grass pavers. The results showed
that the runoff of porous pavement was 93% less than the
asphalt lot.Turbidity was significantly less and conductivity
was significantly higher for the porous pavement lot compared
with the asphalt pavement lot. Moreover, metal and
nutrient concentrations were significantly reduced by both
types of pavement.
Full text available at :
http://www.tandfonline.com/doi/abs/10.1080/09593330.2013.782573#.UrDsvSeA_5M