

EFFECT OF PAVEMENT THICKNESS AND AGGREGATE GRADATION ON RUNOFF PURIFICATION EFFICIENCY

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ABSTRACT

The purification of porous asphalt pavement to mitigate runoff pollution is a critical area of research in sustainable urban development. This investigation aims to explore various techniques and materials for enhancing the purification capacity of porous asphalt pavement, thereby reducing the impact of pollutants on receiving water bodies. The study involves laboratory experiments and field testing to assess the efficiency of different purification methods. Laboratory experiments focus on analyzing the pollutant removal capacity of porous asphalt pavement under controlled conditions. Various pollutants commonly found in urban runoff, such as heavy metals, hydrocarbons, and suspended solids, are introduced to simulate realistic pollution scenarios. This research is to evaluate filtering capacity in addition to quality rainwater filtered by these models for pore asphalt pavement models. Three layers were constructed using pore asphalt mixes in addition to two models consisting of porous layers resulting in porous pavement constructions. The collection data was place in two phases: directly from sky by utilising rainfall and subsequently utilising street runoff gathered. Disposals were monitored including pH, dissolved oxygen, ammonia, phosphorus, nitrite,

aluminium, chromium, copper, zinc iron. The content phosphorus, iron, aluminium, zinc, nitrite, chromium, copper in addition to pH were increased, while dissolved dose oxygen in one model was not significantly changed. Ammonia was decrease red for both rainfall in addition to storm water runoff quality analyses.

Keywords: different purification methods, porous asphalt pavement, runoff pollution, urban runoff

INTRODUCTION

Porous asphalt pavement parking lots were used to reduce storm water runoff from new developments. With today's concern for water quality, streambed erosion from development runoff, and a need to recharge vital underground aquifers, many of today's agencies are significantly revising storm water runoff requirements on developments. Porous asphalt pavements offer developers and planners a new tool in their toolbox for managing storm water. These pavements, used mostly for parking lots, allow water to drain through the pavement surface into a stone recharge bed and infiltrate into the soils below the pavement. Such pavements have been proving their worth since the mid-1970s, and recent changes in storm water regulations have prompted many consulting engineers and public works officials to seek information about them.

The permeable mix allows water to flow through the pavement and drain out the sides. This significantly reduces splash/spray from vehicle traffic and reduces glare from daylight or headlights. Another benefit of OGAC when used on highways is a reduction in vehicle noise. The concept is simple: Construct storm water detention basins under the street and parking structures. These basins are designed to collect storm water from structures, pavements and other areas of a development and hold the water until it can percolate into the soil. Porous asphalt pavement is then placed over the top of these basins. These pavements are designed to let the water flow through them and into the detention basin. Porous asphalt pavements are of great interest to site planners and public-works departments. With the proper design and installation, porous asphalt can provide cost-effective, attractive pavements with a life span of more than twenty years and at the same time provide storm water management systems that promote infiltration, improve water quality, and many times eliminate the need for a detention basin. The performance of porous asphalt pavements is similar to that of other asphalt pavements. And, like other asphalt pavements, they can be designed for many situations. Asphalt pavements become too soft under strong sunlight on hot summer days but very brittle during cold nights in winter. Heavy traffic on the soft asphalt paving causes permanent deformation to the pavement, known as "rutting". Cracking of the pavement develops during winter months when the asphalt binder becomes too brittle. This means the asphalt binder works well only within its application window, within which it is visco-elastic enough to

dissipate stress exerted by the traffic. Polymer modification extends this application window, mostly increasing visco-elasticity at high temperature. Cold aggregates can be used, thus significantly reducing the energy consumption. Optical and scanning electron microscope techniques were applied to understand the curing mechanism of the SBR latex modified, cationic asphalt emulsion. The study demonstrates that the modified asphalt emulsion with the SBR latex is not just an emulsion of the polymer-modified asphalt, but rather the emulsion containing dispersed latex particles. Latex particles remain in the aqueous phase and spontaneously transform into a continuous microscopic polymer film surrounding asphalt particles upon curing.

LITERATURE REVIEW

A.J. Kriech (2022) Normally constructed asphalt and concrete pavements were found to release low levels of contaminants during their life. However, deposition from atmospheric pollutants and materials dispersed by vehicles on pavements do have a measurable impact on the quality of storm water runoff. These tend to be expressed in initial flush from storm water events. Reuse of old pavements at end of life tend to have little environmental impact when recycled. However, because of deposition of pollutants over their life these materials can have an impact when used in unbound layers of the pavement or in storage before reuse. Water quality can be improved by porous pavements, which allow infiltration of water and drainage to lower layers, thereby filtering many pollutants in storm water runoff. The challenge is preventing the high initial pavement porosity from plugging over time. Pavement sealers containing coal tar pitch have high levels

of polycyclic aromatic compounds and have been shown to impact aquatic life negatively and produce sediment build up in ponds and streams.

Jiawen Liu (2021) biochar is currently applied in many low-impact development measures, such as biofilters and filter strips. However, its application in permeable pavement is limited. Due to the wide range of raw material sources, biochar may also contain nutrients and heavy metals. Whether its leachate will cause contamination during application remains unknown. Based on the static leachate contamination test, this study first evaluated the leachate contamination risks of three types of biochar and porous asphalt mixture (PA) with three biochar fillers. Through the pavement infiltration test, the purification performance of PA with biochar fillers and filter layers was further analysed. The results show that biochar contains nitrogen and phosphorus, and the leaching contamination of coconut shell is the most obvious; when the biochar is applied as a filler in PA, the leaching contamination decreases, while the pollutant purification performance is not obvious; when 3–5 mm rice straw biochar is used as a filter layer, the removal rate of total suspended solids can be 100%, but it is accompanied by more serious nitrogen and phosphorus leaching, and the greater the thickness, the more serious the degree of leaching.

Xue Zhang (2021) With the rapid development of cities, more attention has been paid to the stormwater runoff pollution on roads. In this paper, a kind of photocatalytic water purification pavement coated with nano-TiO₂ was developed, which could improve the water purification performance of porous concrete. Through removal rate analysis of

three typical pollutants, the improvement of its water purification performance was evaluated. The skid resistance of road surface and durability of purification effect were also studied by using pendulum apparatus and artificial accelerated aging method. The results showed that the removal rates of COD, TP and NH₃-N could reach 50%, 60% and 40%, respectively. The application of photocatalytic coating would reduce skid resistance of pavement relatively. Besides, appropriate increase of nano-TiO₂ content will improve the weather resistance. This study will provide useful insights for the preparation of nano-TiO₂ photocatalytic coatings for porous cement concrete to improve the water purification effect of roads.

Weiping Chen (2020) Permeable pavements, as additive structures that have a good capability for runoff and pollutant reduction, are extensively used for sustainable urban drainage techniques. However, the exact mechanisms of runoff retention and pollutant reduction of a permeable pavement system remain unclear and so, it has become an ongoing issue and motivation for hydrologists and design and structural engineers. In this research paper, a suite of four scale-based runoff plots representing permeable pavements were designed with different permeable surface types and gravel layer thickness treatments, and coupled with simulated rainfall experiments to analyze the impacts of structural factors of permeable pavements on runoff retentions and pollution reduction. Importantly, there was no statistical significance for the time to runoff and runoff retention between the permeable bricks and porous concretes for the analyzed rainfall events. The thicker gravel layers significantly delayed runoff

generation and increased runoff retention percentages. Runoff pollutant load reduction rates of total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP) were varied between permeable bricks and porous concretes.

Masoud Kayhanian (2019) In the future, permeable pavements including the full depth permeable pavement (FDPP) will be part of an integrated sustainable transportation program. When designed properly, FDPP can be used as an alternative best management practice (BMP) for stormwater runoff management. From a practical point of view, FDPP must maintain specific characteristics throughout the life of the pavements: (1) have adequate subgrade reservoir capacity to capture runoff volume, (2) surface pavement remain highly permeable and unclogged, (3) allowing minimum permeability of subgrade soil to infiltrate the captured runoff, and (4) assuring no adverse impact on underground water. During the past ten years the University of California Pavement Research Center (UCPRC) conducted numerous research studies to address some of the above critical questions related to the application of permeable pavement with respect to the highway stormwater runoff management.

Maintenance of Pervious Concrete Pavements

For pervious concrete pavement surface maintenance and permeability renewal regular maintenance should be considered. Surface maintenance includes the removal of debris, soil from the surface. Surface distress developed on the pavement such as cracks, ravelling and sealing are also included in surface maintenance. To help prolong the service life, an active maintenance program is found to be beneficial in pervious concrete pavements.

Over time, dirt and debris can get trapped and get lodged within the voids of the pervious concrete pavement. With the dirt and debris creating an impervious layer within the pervious concrete pavement, water can then become trapped. The surface infiltration rates (SIR) of permeable pavements decline with time as sediment and debris clog the pore spaces. Effective maintenance techniques are needed to ensure the hydraulic functionality and quality water benefits of this storm water control. It should include visual inspection of the pervious pavement to ensure that it is clean of debris and sediments, and that it will dewater between rains. Routine maintenance cleaning procedure would include blowing. Routine maintenance may help prevent more stubborn clogging by keeping sediments from becoming ground deep into the pavement's void structure.

Pollutant Removal by Permeable Pavements

Typical storm water pollutants in urban runoff include a large suite of pollutants that range from particulate sediments to organic hydrocarbons in a dissolved phase. Most pollutants in urban storm water are derived from wet and dry deposition of industrial, vehicular, and residential-sourced pollutants. It was shown that by identifying sources of pollutants in urban catchments, steps can be taken to limit nutrient and metal loadings to receiving waters. In a study of tropical urban catchments, showed that most storm water pollutants in residential areas came from lawns and gardens, and in industrial zones from factory and workshop lots. In a comprehensive study on urban storm water samples from the Birmingham, AL, area, found that organic pollutants such as Polycyclic Aromatic Hydrocarbon

loadings were greatest from parking lots and areas where vehicles are serviced. This study also showed that of all areas and pollutants considered, storage areas and parking lots were the most toxic per a micro bics-suggested toxicity protocol. analyzed pollutant loads from nine cities in Korea and showed that the highest nutrient loads per unit area came from high-density residential areas; metals and organic pollutants were not evaluated. However, a study of highway runoff detected a large fraction of new organic contaminants several that have yet to be fully characterized. Four mechanisms are broadly understood to impact pollutant fate within permeable pavements.

Maintenance of Permeable Pavements

The maintenance of permeable pavements is important for ensuring that design standards or performance goals are maintained over time. showed that the maintenance of porous asphalt quantified through measured surface infiltration rates was highest when the pavements were cleaned with industrial hand-held vacuum cleaning, pressure washing, and milling. However, at the jurisdictional scale, the more common commercially-available practices to clean permeable pavements tend to be mobile street sweepers, broadly classified as mechanical, vacuum, and regenerative air street sweepers. The process by which street dirt is dislodged from the pavement surface and transported to a holding hopper defines street sweeper nomenclature. Mechanical street sweepers, the oldest of the three technologies, employ rotating brushes that dislodge particles from the street surface onto a moving belt. Vacuum sweepers use high vacuum suction technology in place of the moving belt to move street dirt from pavement to hopper. With an air

regenerative street sweeper, the most recent of these technologies, percussive blasts of air dislodge particulate matter off the street into a boundary layer a few centimeters off the pavement surface, where they are entrained by a high vacuum suction hose and transported to the hopper.

Types of porous pavement

There are three basic types of porous pavement, which are generally suitable as an alternative to the traditional impermeable surface: Both porous asphalt and pervious concrete are modified versions of the standard material where void space is created within the material to allow water to percolate through the pavement. This void space is created by removing a large portion of the fine aggregate in the mix design. Permeable interlocking concrete pavers, while not porous themselves, contain joints filled with small uniformly graded aggregate which allows for the passage of water. Other porous surfaces such as grass and gravel pavers are also available depending on the usage of the surface and vehicle loading. These systems consist of rigid grids which are then filled with gravel or turf grass.

METHODOLOGY

To conduct an investigation on the purification of porous asphalt pavement to runoff pollution, you can follow the methodology mentioned below:

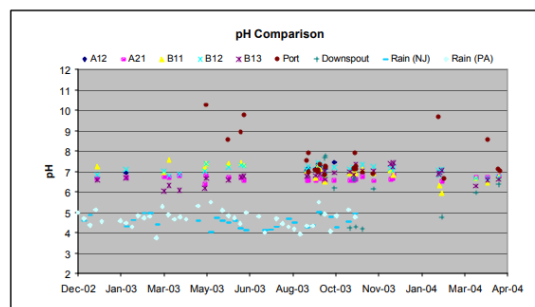
Identify previous studies on the purification efficiency of porous asphalt pavement. Review relevant design guidelines and specifications for porous asphalt pavement.

Select a suitable study site where porous asphalt pavement is already implemented or can be constructed. Consider factors such as traffic volume, land use, pollutant

sources, and accessibility. Design and set up experimental plots or sections with porous asphalt pavement. Consider the size and number of plots based on the study objectives and available resources. Determine the parameters to be measured, such as pollutants (e.g., heavy metals, hydrocarbons), sediment, pH, conductivity, and turbidity. Establish a sampling plan for both runoff and infiltrated water from porous asphalt pavement and control sections. Define the frequency and duration of sampling events, considering different weather conditions and seasons. Two steps of data processing were carried out. First, by utilizing the moisture from the atmosphere, and then by using the stream of storm water. The lath and pavement models were installed in plastic boxes for the evaluation of the drainage properties, first subjected to rainfall and then to storm water runoff.

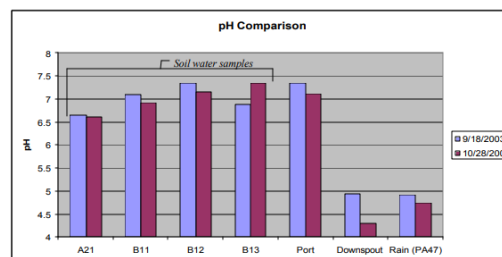
RESULTS AND DISCUSSIONS

The pH of each sample was calculated for each tempest included in this analysis. The findings are presented in Graph 1 throughout the study time. Graph also shows the average weekly rainfall pH of the most recent available data for two areas, PA47 and NJ99 Between December 2002 and October 2003, for every week. National Atmospheric Deposition Program data for these two locations was collected (NADP). The pictures illustrate their views. Pre-penetration acid rainfall is neutralised as seen in figure most significant findings with regards to pH production. The pHs of the harbour and lysimeters tests are generally two to three units higher in pH than the VU 62 acid rainwater. Port and ground water values have reached a pH of 7 reliably.



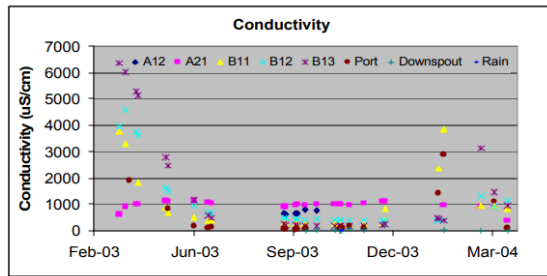
Graph 1: Comparison of pH levels

The pH rise can be caused by river runoff that comes into touch, until it is reached in the infiltrate plant, with calc stone aggregate. CaCO_3 (calcium carbonate), which essentially increases the pH extracted river, can dissolve within the beds. The fact that pH has been substantially altered prior to soil penetration is not considered to have an impact on rushing out of acidic tempest water.



Graph 2: Comparison of pH results from two storm events

The acidity of the storm water, along with the infiltration into narrow areas of storm water, leads to the eventual forming sinkhole. In this specific application, it is conceived that the acidity of water is more crucial as storm water is infiltrated over wide region instead of a localised area. Future on-site experiments should be carried out to assess the rate of CaCO_3 or saturation of the infiltration water. Contact with the calcareous aggregate is assumed in infiltrated beds to reduce the aggressiveness of stormwater to CaCO_3 enough, thus decreasing the risk for sinkhole development.



Graph 3: Conductivity results

Swisher found that interaction with the lime aggregate in the beds was necessary to reduce acidity and soil water samples overall aggression of the tempest water, in a comparable research study in Penn State University, a karst topography field.

CONCLUSION

Porous asphalt pavement has demonstrated effective purification capabilities for runoff pollution. It allows water to infiltrate through the pavement surface and into the underlying layers, where contaminants are filtered and treated. The porous structure of the asphalt pavement promotes natural processes of filtration, adsorption, and biological degradation, which help remove pollutants such as oils, heavy metals, and suspended solids from the runoff. The use of porous asphalt pavement can significantly reduce the quantity and velocity of runoff, minimizing the risk of flooding and erosion while preventing the transport of pollutants into nearby water bodies. The performance of porous asphalt pavement in purifying runoff pollution can vary depending on factors such as pavement design, maintenance practices, and local environmental conditions. Regular inspection, cleaning, and maintenance are essential to ensure its optimal functionality. Incorporating additional treatment measures, such as sedimentation basins, bio filtration systems, or detention ponds, can complement the purification

capabilities of porous asphalt pavement, further enhancing its pollutant removal efficiency. Porous asphalt pavement offers a sustainable solution for managing storm water runoff, as it not only helps purify the water but also reduces the need for costly and extensive drainage infrastructure.

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