BRADLEY UNIVERSITY

The Performance and Sustainability of Permeable Pavement

Progress Report on the Work Performed Under IAPA Scholarship

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INTRODUCTION

Permeable pavement is an innovative paving technique that allows stormwater to pass through the surface, into the subbase, and percolate into the ground or find its way to a drainage system. This sustainable technique has been shown to reduce stormwater runoff, keep solids and pollutants from flowing into drainage facilities, naturally filter and recharge stormwater to ground water, reduce the damage caused to pavement overtime by puddles, noise reduction, improvement in urban heat island effect, decrease the amount salt needed on pavement during icy or snowy conditions, and condense the number or area of drainage facilities needed to sustain a newly paved area. While the benefits seem to be endless, the sustainability and performance of pervious pavement is still questioned within the industry.

The installation of permeable pavement is often more challenging and sensitive than the process of laying asphalt or pouring concrete. For the design of permeable pavement systems to be maximized, there would be no grade within the space. Porous pavement requires maintenance, typically annually. Landscaping materials such as mulch or sand cannot be near pervious pavement. Finally, permeable pavements cannot withstand as heavy of loads as traditional pavements.

Permeable pavements function best within parking lots, multi-use paths, sidewalks, trails, shoulders, and alleys (Hein and Schaus 2016). The high void ratio results in lower load bearing capacity. Trucks and high speed vehicles are not ideal users for permeable pavement designs.

LITERATURE REVIEW

The recharge of ground water is a sustainable feature of permeable pavement. In other cases approximately 50 percent to 93 percent of stormwater has been able to enter the soil and recharge groundwater through permeable pavement (Ahiablame et al. 2012). This capability is especially helpful during peak rainfall intensities because porous pavement can decrease the demand of stormwater systems by allowing stormwater to infiltrate the pavement and underlying soil instead of causing stormwater drainage systems to reach capacity or overflow.

In addition to reducing the volume of runoff, pervious pavement can filter nutrients and pollutants from the initial flush of stormwater runoff. Studies have seen permeable asphalts, concretes, and pavers removed between 0 percent and 94 percent of toxins from the infiltrated stormwater preventing those toxins from entering the groundwater or stormwater system (Ahiablame et al. 2012). Polluted oils from vehicles sit on top of pavement until a rainfall causes the oil to wash away. Typical pavements cause this oil to flush into the storm sewers will the runoff, but permeable pavement allows the oil to enter the subgrade and soil naturally instead of polluting the runoff.

Pervious pavement has shown to have just as long as a life-span as impervious pavement, likely due to elimination of ponding effects and application of pervious pavement in use with lower capacity loads. Nonetheless, permeable pavements' long life-span is an economic benefit. Minimal repairs are needed for permeable pavement. Monitoring and maintenance of the pavement overtime does create a cost to ensure that the permeable pavement continues to work as efficiently as it is designed for. Depending on the void ratio, aggregate used and debris presence, porous pavements may need to be vacuumed or power-washed a few times a year (Dylla and Hansen 2015).

Permeable pavements produce further sustainable results by being made of recycled materials, local materials, and being created on site to help eliminate excess pavement after construction. While traditional pavement can possess some of these benefits, the high void content allows for more freedom in choosing materials in design ("Benefits" n.d.).

For climates similar to Peoria's, pervious pavement has proven to perform well in the summer and winter seasons. Permeable concrete is lighter in color absorbing less solar heat. Additionally, the voids create openings to release the heat that may be stored to reduce heat island effects in Peoria and areas like it. The winter benefits of permeable pavement come from the reduced need for salt during the snow season. Ice and snow are likely to melt on porous pavement and drain through the pavement, while snow blocks storm drainage entrances and melted snow puddles on traditional pavement. The puddled melted snow and slush also risk refreezing and creating icy conditions on traditional pavement. Deicing salt should not be used on permeable pavement as it would clog its voids and would require additional maintenance. Year-round permeable pavement is beneficial to drivers during rainfall because it eliminates hydroplaning, inclement visibility due to wet pavement, and puddles causing tire spray ("Benefits" n.d.).

PURPOSE

The purpose of this research is to illustrate the aspects of permeable pavement's sustainability and drainage performance, specifically for the urban area of Peoria, Illinois. Additionally, the following questions will be addressed:

How much stormwater can permeable pavement drain? How long will the porous pavement take to drain through the surface and subbase? Can permeable pavement eliminate the need for drainage structures and detention basis? What other impacts do the porous pavement make? What are the sustainable benefits of pervious pavement? How do they compare to the sustainable benefits of traditional pavement? These questions must be considered in the assessment of the performance and sustainability of permeable pavement techniques.

METHODS

This study focuses on assessing the infiltration performance of permeable pavement with a local application with supplementary review research outlining the performance and sustainability characteristics.

Here, the inflow rate was evaluated to look into the performance of the pavement in a climate like Peoria. For this modeling the runoff through the permeable pavement was considered, therefore, the independent variables included are 24-hour rainfall depth, contribution area, and drainage area runoff coefficient. The Santa Barbara Unit Hydrograph (SBUH) method was used to find the runoff hydrograph for the Peoria roadways if all of the paved roads in Peoria were considered to be permeable ("Appendix C.1 Santa Barbara Urban Hydrograph Method" 2014). Variables for this evaluation can be entered in a hydrograph calculator (Table 1) and can be justified and assumed. In Table 1, a post-developed 24-hour rainfall depth of 3 inches was chosen based on 2-year 24-hour rainfall for central Illinois (Hershfield n.d.). The contribution area is the area of paved roadways in Peoria found to be 229.41 miles approximated for two lane roads at twelve feet wide lanes by the 2013 "Illinois Highway and Street Mileage" manual. The runoff coefficient was chosen to be 0.3 as pervious pavement has a typical runoff of 25 percent to 35 percent.

Table 1. Independent variables in porous pavement modeling.

Post-developed 24-Hour Rainfall Depth =	3	in
Contribution Area =	29070835	sf
Drainage Area Runoff Coefficient =	0.3	

With the appropriate application of the hydrograph and independent variables inflow rate, inflow volume, and runoff depth can be calculated using the equations below.

$$Inflow\ rate = Runoff\ coefficient * \frac{Rainfall\ intensity}{12 * 3600} * Contribution\ area$$

$$Inflow\ volume = 600 * Inflow\ rate$$

$$Runoff\ depth = Inflow\ volume * \frac{12}{Contribution\ area}$$

RESULTS

At the maximum intensity at 50 minutes after hour 7, the inflow rate and volume were determined to be 196.23 cubic feet per second and 117736.9 cubic feet, respectfully, with a runoff depth of 0.0486 inches. The storm ends in 24 hours, and by 30 hours, the system is done infiltrating and is ready for the next storm. From the pavement, the stormwater could percolate through the pervious sublayers into the native underlying soil to recharge groundwater. Table 2 displays the performance of the pervious pavement with the hydrograph method.

Table 2. Permeable pavement modeling with SBUH.

Time	Time	SBUH Rainfall Depth	Rainfall Intensity	Inflow Rate	Inflow Volume	Runoff Depth
(hours)	(min)	(in)	(in/hr)	(cfs)	(cf)	(in)
0	0	0.0000	0.00	0.00	0	0
	10	0.0120	0.07	14.54	8721.3	0.0036
	20	0.0120	0.07	14.54	8721.3	0.0036
	30	0.0120	0.07	14.54	8721.3	0.0036
	40	0.0120	0.07	14.54	8721.3	0.0036
	50	0.0120	0.07	14.54	8721.3	0.0036
1	60	0.0120	0.07	14.54	8721.3	0.0036
7.833333	470	0.1620	0.97	196.23	117736.9	0.0486
12	720	0.0216	0.13	26.16	15698.3	0.00648
24	1440	0.0120	0.07	14.54	8721.3	0.0036
30	1800	0.0000	0.00	0.00	0.0	0
72	4420	0.0000	0.00	0.00	0	0

Traditional pavement is considered to produce 90 percent runoff from a storm of this size. With permeable pavement averaging just 30 percent runoff, permeable pavement is considered to reduce typical stormwater runoff. Depending on the design, some traditional pavement runoff can be redirected onto porous pavement to reduce the storm sewer responsibility.

Once stormwater enters soil's saturation zone it is then considered to be groundwater. When sites with traditional pavement are placed on undeveloped land, the natural water cycle is destroyed in that area. Because the rain and snow that would normally turn into groundwater now turns into stormwater that is collect by drainage systems.

Using permeable pavement without a drainage system, instead of traditional pavement, can recharge the groundwater similarly to a natural, untouched area. Of course, when the natural soil of an area is disturbed the porosity of the soil can be altered impacting the groundwater recharge capabilities. With the proper hydrologic and structural design, pervious pavement can assist an area in recharging groundwater and maintain the natural water cycle.

DISCUSSION & CONCLUSION

The need for drainage structures would be decreased in this hypothetical Peoria assessment because of the decrease in stormwater running off the pavement into drainage system and through the water treatment process. The reduced storm sewer input could reduce the overall need for detention basins for developments. Urban areas like Peoria gather much of the city's water supply from groundwater aquifers. Allowing stormwater to percolate through the porous pavement and recharge the groundwater supply causes the system to mimic the natural water cycle and eliminates certain filtering processes that the soil layers perform. As shown in the empirical research, pervious pavement has the capacity to drain stormwater similarly to how the in-situ soil takes in rainwater.

Permeable pavement structurally performs much like traditional impermeable pavement when applied to low axial loads roadways and low speed roadways. Permeable pavement thrives as a pavement for multi-use paths, parking lots, and sidewalks. Replacing those current pavement applications in Peoria with porous pavement would reduce the demand of stormwater systems and would increase Peoria's sustainability rating as a whole. Other urban areas would also benefit from implementing pervious pavement into proposed designs. The increased monitoring and maintenance of permeable pavement compared to traditional pavement can reap the hydrological and sustainable benefits over time.

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