IAPA Research Paper

Identifying a Sustainable Way of How Pervious Pavement Can Be Used for Construction

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January 2020

Table of Contents

Introduction

Every day, whether the location is a bustling city filled with millions of people or a more rural town with a couple hundreds, roads are being used to transport items, livestock, or oneselves from one destination to another. Everyday roads are used continuously and are designed to withstanding minimum to heavy loads of traffic at a time. Roadways are also designed to be strong against weathering and cracking due to particles absorbed into the roadway material, freezing, then expanding. Roadways can consist of either concrete or asphalt pavement and depending on the location and other conditions one material can be more beneficial for a roadway project than the other. However, one thing to consider is the idea of rainwater. When rainfall occurs, water can infiltrate into the ground, however, if the material is unable to retain the rainfall, then runoff can occur. Runoff (surface runoff) is excess flow of water due to stormwater (rainwater). When runoff occurs, the Earth's surface (i.e., roadways, sidewalks) can accumulate stormwater due to impervious areas that cannot absorb it into the ground, thus making it difficult for people and the environment.

Background

<u>What is Porous Pavement?</u>

Porous (permeable) pavement is a paved surface or area that consists of a specific material mix which allows rainwater to pass through into the ground's surface due to high porosity. With porosity and

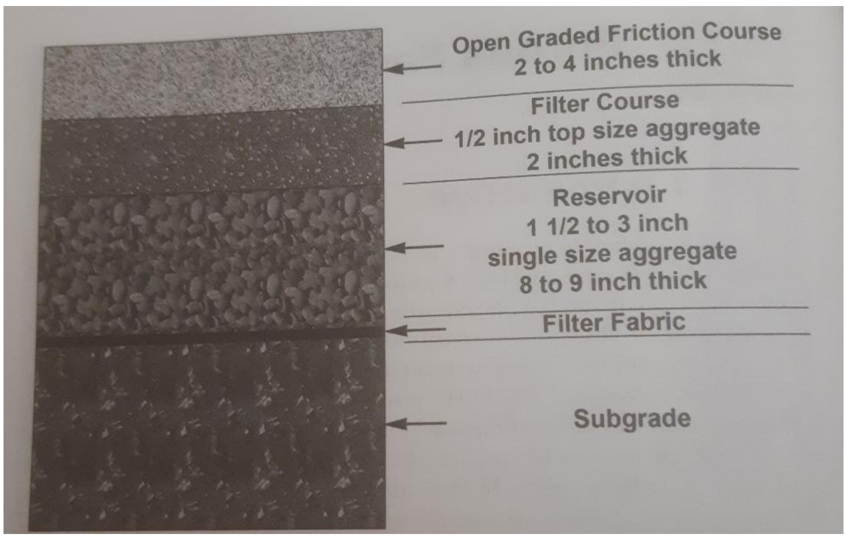

Figure 1. Layers of Porous Pavement (*The Asphalt Handbook*)

permeability being significantly high enough, hydrology, rooting habitats, and other environmental aspects are impacted due to infiltration (*Porous Pavements*). As rainwater infiltrates the ground's surface, runoff is reduced, thus, positively affecting the location at which porous pavement can be utilized. As seen in figure one, the general format of a porous pavement is shown.

Is Porous Pavement Sustainable to Work With?

Porous pavement is made to be used to lower the amount of runoff that can occur during infiltration of rainwater. Given it provides valuable aspects for hydrology and for the environment, porous pavement can become an asset suitable for construction projects for engineers. However, is porous pavement suitable and sustainable to work with? Simply speaking, yes, civil engineers have used porous pavement for projects, but one thing that should always be taken into consideration are the conditions of the environment and of the project that would indicate whether porous pavement can be used.

As stated, porous pavement allows water to infiltrate, decreasing the amount of runoff on the surface. This is mainly due to the amount of percent air voids within the porous pavement mix. Air voids are described as "small pockets of air between the coated aggregate particles in the final compacted HMA [Hot Mix Asphalt]". Generally, in design mix of HMA, around 4 percent of air voids level is used (*Porous Pavements*). This allows room for any additional expansion (from increase of temperature), or bleeding of the material after construction (compaction). However, what differentiates a regular HMA design from a porous asphalt design is the size of the air voids. While the air voids in a regular design are small, those of a porous asphalt design are larger to allow water to pass through the material and into the subsoil. In the same matter, the air void content and density of the material are inversely related. When a mix has a higher density, the amount of voids would be low. Therefore, in a porous asphalt mix, it's density will be significantly be less than of a regular mix because it is designed to allow water to infiltrate (higher air voids).

Acknowledging the density of a mix is important due to how the compacted finish product would sustain from traffic. Mixes with a higher density result in a much stronger pavement. Since porous pavement can be lower in density that signifies thar its strength is less than of a much denser mix being used. So then, is porous pavement suitable to work with? Due to a lower density, it's strength would not be able to withstand a high-density traffic. However, this does not indicate that porous pavement cannot be used. Porous pavement in fact, can be suitable for areas where they are not constantly at use (heavy truck traffic) such as "low-volume roadways, sidewalks, driveways, and parking lots" ("Permeable Pavement."**)**. Since porous pavement have a lower density, thus a weaker strength, it's durability can be viewed as less. However, by using porous pavement in areas that don't necessarily need a higher density such as sidewalks, or parking lots, then it's durability can be extensive for many years until any maintenance is necessary.

When designing for porous pavement, other things to consider is the environment. Generally, the climate, topography, and soil characteristics are necessary to ensure that the porous pavement is suitable to design and work with. For example, if there was a customer who wishes to have porous pavement used in a location that has an extended period of heavy rainfall with soil infiltration higher than 0.50 inches per hour, then the usage of porous pavement would not withstand such conditions. This is because the rate of infiltration can be higher than the rate at which the water can drain and how much can be retained during a storm water period. Therefore, percolation tests should be conducted within the area of interest to understand the subgrade and soil conditions. By understanding those conditions, a model can be designed in a way that the subgrade soil would have an infiltration rate of at least 0.50 inches hour for a 25-year/24-hour storm event (*The Asphalt Handbook*). Besides soil conditions and storm events, another topic of consideration is wind, dust, and snow. Regions that have snowfall, loose soil, and/or heavy winds should not use porous pavement as the voids that allow water to infiltrate can be clogged due to those particles.

Modeling/Simulation Programs

Many engineers take up a form of modeling or simulation to help them visualize how their project would turn out. Specifically, within porous pavement, modeling programs can help simulate a storm event given proper conditions such as infiltration rates and soil conditions to see if their design is suitable for their project. HydroCAD for example can be used to simulate infiltration of water into porous pavement.

What to Consider When Modeling in HydroCAD?

HydroCAD is a stormwater modeling program. When using HydroCAD to model porous pavement, it is necessary to understand how the pavement would behave under various conditions and what those modeling the program would want to see. Specifically, three general scenarios can be modeled: no surface runoff, complete surface runoff, and partial runoff. No surface runoff deals with water infiltrating continuously, causing there to be an “ideal scenario” at which the surface runoff is zero. Complete surface runoff on the other hand indicates that there will be runoff throughout the model and no infiltration would occur. In this case, porous pavement would prove to not be suitable (*Modeling Pavement*). However, in between both scenarios, is partial runoff which can be modeled in an event where infiltration occurs as well as some runoff, this generally can be caused due to the seasonal change in weather.

Purpose

This research paper will focus on how we are able to design with the use of porous pavement. This research paper will focus on the use of HydroCAD to model a partial runoff for a 25 year/24-hour storm event and see whether the use of porous pavement is suitable and sustainable within Carbondale, IL given an area of 2,500 sf.

Method and Procedure

Method

HydroCAD will be the method at with this research will be conducted. Therefore, the materials necessary for this research are:

- Data of rainfall from Carbondale, IL
- HydroCAD Modeling

Procedure

- Open HydroCAD.

- From the main menu, select view>Storm Distribution.
- Select "Sample" storm. From there a file of various sample storms will appear.
- Select the desired rainfall storm of a "25-year/24-hour" storm.

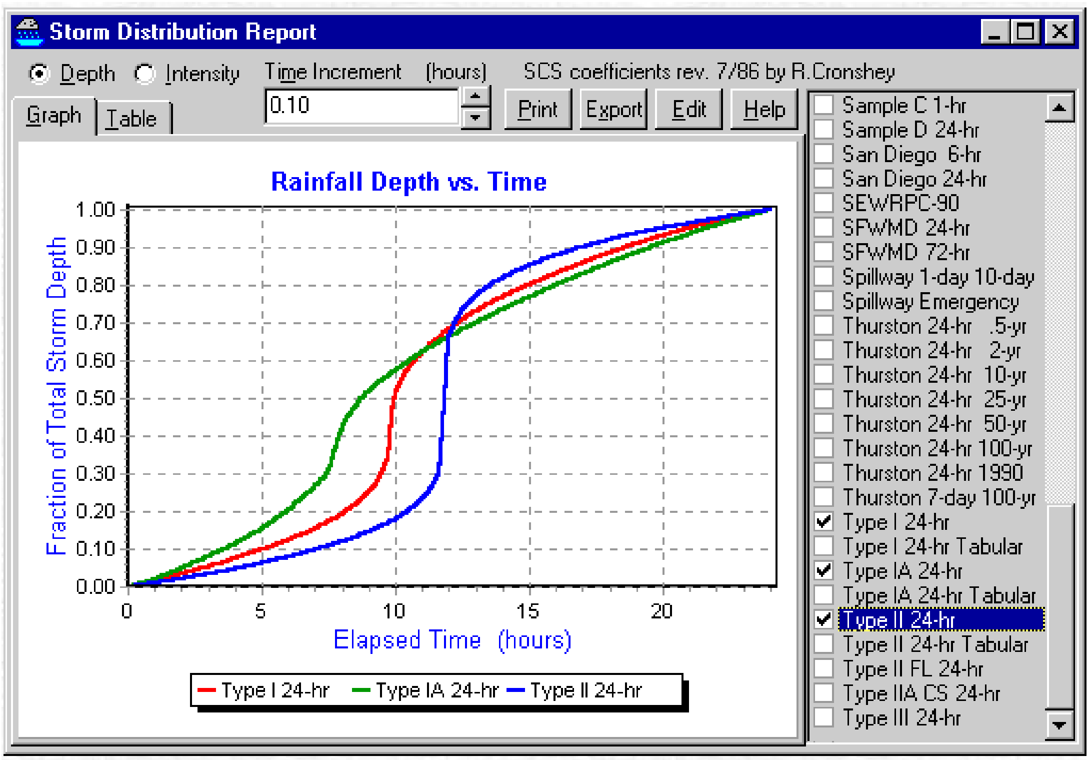

Figure 2. Storm Distribution Report example provided from HydroCAD

Data

Data necessary to conduct this research was to obtain information regarding the region of the City of Carbondale, IL. Specifically, data was gathered by the Illinois State Water Survey website which has a series of data collected over the years as well as documents of rainfall (in inches) that has occurred within each region of Illinois. This research conducted used the data collected within the South region of Illinois from which Carbondale, IL is located in as shown in figure 1. Within the report, data of Rainfall (in inches) for a given recurring time interval of the storm event was provided as well. Figure 2 indicates the storm event duration and the sections with corresponding codes. Since this research focuses on a 24 hours storm and within the South zone of Illinois, the storm code used was 8 and the sectional code was 10 to further help indicate the rainfall of that zone found in Figure 3. Based on the storm and zone, when identifying the amount of rainfall (inches) for a given recurrence interval of a 25-year storm event, it was found

Figure 3. Map of the Regions within Illinois

that 6.23 inches of rainfall occurred. Therefore, this value was further used to identify if porous pavement construction within Carbondale is suitable.

Storm codes

1 – 10 days
2 – 5 days
3 – 72 hours
4 – 48 hours
5 – 24 hours
6 – 18 hours
7 – 12 hours
8 – 6 hours
9 – 3 hours
10 – 2 hours
11 – 1 hour
12 – 30 minutes
13 – 15 minutes
14 – 10 minutes
15 – 5 minutes

Sectional (zone) codes

1 – Northwest
2 – Northeast
3 – West
4 – Central
5 – East
6 – West Southwest
7 – East Southeast
8 – Southwest
9 – Southeast
10 – South

Figure 4. Recurring Periods in relation to Sections of Illinois

Rainfall (inches) for given recurrence interval

Storm code	*Zone code*	*2-month*	*3-month*	*4-month*	*6-month*	*9-month*	*1-year*	*2-year*	*5-year*	*10-year*	*25-year*	*50-year*	*100-year*
1	1	2.14	2.60	2.97	3.50	4.02	4.37	5.23	6.30	7.14	8.39	9.64	11.09
1	2	2.02	2.48	2.80	3.30	3.79	4.12	4.95	6.04	6.89	8.18	9.38	11.14
1	3	2.27	2.78	3.13	3.68	4.23	4.60	5.60	6.91	7.89	9.24	10.36	11.90
1	4	2.10	2.58	2.92	3.43	3.93	4.29	5.12	6.27	7.10	8.19	9.10	10.18
1	5	2.13	2.62	2.96	3.48	4.00	4.35	5.15	6.21	6.97	8.04	8.90	9.92
1	6	2.16	2.65	2.99	3.52	4.05	4.40	5.35	6.62	7.45	8.66	9.79	11.26
1	7	2.30	2.80	3.16	3.70	4.27	4.64	5.58	6.80	7.61	8.66	9.70	10.87
1	8	2.22	2.74	3.09	3.63	4.18	4.54	5.54	6.80	7.80	9.20	10.44	11.81
1	9	2.30	2.88	3.23	3.80	4.33	4.75	5.74	7.09	8.07	9.54	10.68	11.79
1	10	2.55	3.15	3.58	4.21	4.84	5.26	6.36	7.81	8.90	10.34	11.36	12.50
2	1	1.76	2.12	2.38	2.76	3.17	3.45	4.13	5.10	5.91	7.21	8.36	9.97
2	2	1.66	1.98	2.24	2.60	2.99	3.25	3.93	4.91	5.70	6.93	8.04	9.96
2	3	1.92	2.30	2.56	2.97	3.41	3.71	4.57	5.80	6.65	7.90	8.95	10.50
2	4	1.77	2.12	2.37	2.78	3.20	3.48	4.17	5.11	5.84	6.96	7.98	9.21
2	5	1.75	2.10	2.37	2.75	3.15	3.42	4.12	4.96	5.67	6.76	7.65	8.78
2	6	1.77	2.13	2.39	2.78	3.19	3.47	4.19	5.32	6.20	7.44	8.53	9.93
2	7	1.85	2.22	2.50	2.90	3.31	3.63	4.34	5.33	6.11	7.28	8.37	9.65
2	8	1.85	2.21	2.49	2.90	3.31	3.62	4.40	5.46	6.34	7.68	8.88	10.68
2	9	1.90	2.29	2.59	3.00	3.45	3.75	4.48	5.57	6.50	7.91	9.16	10.57
2	10	2.09	2.52	2.83	3.29	3.77	4.10	4.99	6.20	7.21	8.45	9.45	10.82
3	1	1.58	1.90	2.11	2.45	2.82	3.06	3.73	4.67	5.42	6.59	7.64	8.87
3	2	1.53	1.83	2.02	2.34	2.70	2.93	3.55	4.44	5.18	6.32	7.41	8.78
3	3	1.72	2.05	2.28	2.64	3.02	3.30	4.08	5.11	5.87	6.97	7.95	9.48
3	4	1.59	1.91	2.12	2.44	2.80	3.05	3.70	4.55	5.26	6.15	7.25	8.16
3	5	1.61	1.93	2.16	2.48	2.85	3.10	3.71	4.57	5.20	6.17	6.97	7.83
3	6	1.63	1.95	2.16	2.50	2.88	3.13	3.81	4.85	5.68	6.84	7.76	8.92
3	7	1.62	1.90	2.15	2.50	2.87	3.12	3.73	4.64	5.32	6.39	7.35	8.54
3	8	1.67	1.97	2.20	2.54	2.93	3.22	3.94	4.92	5.74	6.97	8.12	9.55
3	9	1.73	2.02	2.25	2.62	3.00	3.27	3.92	4.92	5.75	7.05	8.23	9.40
3	10	1.88	2.25	2.49	2.87	3.30	3.59	4.36	5.48	6.34	7.53	8.54	9.52
4	1	1.47	1.74	1.93	2.24	2.58	2.80	3.42	4.28	4.96	6.07	7.02	8.07
4	2	1.44	1.70	1.90	2.18	2.49	2.70	3.30	4.09	4.81	5.88	6.84	8.16
4	3	1.61	1.88	2.09	2.42	2.76	3.01	3.68	4.56	5.50	6.45	7.56	8.80
4	4	1.48	1.76	1.95	2.25	2.58	2.81	3.38	4.19	4.86	5.78	6.62	7.51
4	5	1.51	1.77	1.95	2.26	2.57	2.82	3.40	4.16	4.77	5.66	6.40	7.16
4	6	1.52	1.81	2.00	2.30	2.64	2.87	3.49	4.45	5.21	6.28	7.12	8.19
4	7	1.52	1.78	1.98	2.30	2.64	2.87	3.42	4.26	4.88	5.84	6.75	8.00
4	8	1.57	1.85	2.06	2.38	2.75	2.97	3.59	4.52	5.26	6.43	7.36	8.81
4	9	1.59	1.87	2.07	2.40	2.76	3.00	3.60	4.52	5.28	6.48	7.58	8.62
4	10	1.75	2.08	2.31	2.65	3.02	3.30	4.00	5.03	5.80	6.93	7.86	8.79
5	1	1.40	1.64	1.80	2.08	2.36	2.57	3.11	3.95	4.63	5.60	6.53	7.36
5	2	1.38	1.61	1.76	2.03	2.31	2.51	3.04	3.80	4.47	5.51	6.46	7.58
5	3	1.53	1.77	1.95	2.24	2.56	2.79	3.45	4.29	4.93	6.07	7.04	8.20
5	4	1.39	1.63	1.80	2.04	2.32	2.52	3.02	3.76	4.45	5.32	6.08	6.92
5	5	1.36	1.58	1.75	2.00	2.27	2.47	3.01	3.71	4.26	5.04	5.87	6.61
5	6	1.42	1.66	1.84	2.10	2.38	2.59	3.11	3.93	4.65	5.57	6.46	7.45
5	7	1.40	1.63	1.78	2.07	2.35	2.55	3.03	3.80	4.44	5.37	6.23	7.41
5	8	1.49	1.73	1.90	2.20	2.48	2.71	3.28	4.13	4.76	6.02	7.07	8.21
5	9	1.44	1.68	1.85	2.12	2.41	2.62	3.16	4.00	4.62	5.79	6.71	7.73
5	10	1.63	1.91	2.10	2.41	2.74	2.97	3.62	4.51	5.21	6.23	7.11	8.27

Figure 5. Rainfall (inches) of Recurring Intervals

Calculations

Using the data provided from the Illinois State Water Survey, calculations for "Inflow Rate" and "Runoff Depth" were made using runoff coefficients between 0.25 to 0.40.

$$\text{Rate of Inflow} = 0.25 * \frac{6.23}{12*60*60} * 2500 = 0.0901$$

$$\text{Depth} = 54.08 * \frac{12}{2500} = 0.2596 \text{ inches}$$

Results

Table 1.

Rainfall (in.)	Runoff Coefficient	Area (sf)	Rate of Inflow (cfs)	Volume (cf)	Depth (in.)
6.23	0.25	2500	0.090133102	54.07986111	0.259583333
6.23	0.26	2500	0.093738426	56.24305556	0.269966667
6.23	0.27	2500	0.09734375	58.40625	0.28035
6.23	0.28	2500	0.100949074	60.56944444	0.290733333
6.23	0.29	2500	0.104554398	62.73263889	0.301116667
6.23	0.30	2500	0.108159722	64.89583333	0.3115
6.23	0.31	2500	0.111765046	67.05902778	0.321883333
6.23	0.32	2500	0.11537037	69.22222222	0.332266667
6.23	0.33	2500	0.118975694	71.38541667	0.34265
6.23	0.34	2500	0.122581019	73.54861111	0.353033333
6.23	0.35	2500	0.126186343	75.71180556	0.363416667
6.23	0.36	2500	0.129791667	77.875	0.3738
6.23	0.37	2500	0.133396991	80.03819444	0.384183333
6.23	0.38	2500	0.137002315	82.20138889	0.394566667
6.23	0.39	2500	0.140607639	84.36458333	0.40495
6.23	0.40	2500	0.144212963	86.52777778	0.415333333

Conclusion

The purpose of this research paper is to identify if porous pavement is suitable for civil engineers to work with. By understanding the soil characteristics, weather, and region, the idea of porous pavement can be used for areas that have low volume traffic. Based on the data provided from the Illinois State Water Survey, within the South part of Illinois the rainfall recurrence of a 25-year/24-hour storm event was 6.23 inches. By modeling around that value using an area of 2,500 sf, rate of inflow, volume, and depth of the inflow and runoff, respectively were calculated between 0.25 to 0.40 runoff coefficient. This was done to identify at which point a possibility of using porous pavement can be used. As mentioned, when modeling, the subgrade soil should have an infiltration rate of at least 0.50 inches hour for a 25-year/24-hour storm event. Thus, based on Table 1, the rate of inflow (infiltration) is 0.10094 cfs with a runoff coefficient of 0.28, making it suitable for this storm event. The idea of HydroCAD being used was to then help evaluate if the data collected of rainfall matches or disregards the idea of the usage of porous pavement.

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