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Modelling of StormPav Green Pavement System with Storm Water Management Model and InfoWorks Collection System

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Abstract: Prior to any construction work related to stormwater, it is preferable to involve a computer-based modelling. This paper outlines two different computer-based modelling tools to model a green technology named StormPav Green Pavement. In determining befitting software for use, two key factors are considered: (i) fast model construction (ii) provision of an affordable design model. To meet these key factors, the Storm Water Management Model (SWMM), and InfoWorks Collection System (CS) are deployed in this study. The predictive results of the two models are compared for different design storm durations under 10-year Average Recurrent Interval (ARI). The predictive results suggest that both models are compatible. Yet, SWMM is preferable to model StormPav Green Pavement as it could provide reasonably fast model construction and the software tool is an open source software used worldwide.

***Index Terms*: Computer-aided design, flow rate, permeable road, urban drainage, velocity.**

I. INTRODUCTION

StormPav Green Pavement is a form of Industrialized Building System (IBS) product patented by [1] that could be a revolution on how the conventional asphalt road is built. It is a new form of permeable road [2] that focuses to overcome the shortcomings of impervious characteristics of conventional asphalt roads. For instance, flash flooding [3-5], and road damages due to water ponding [6] are mostly caused by imperviousness of asphalt roads.

StormPav, in short, is also a multi-purpose structure, which integrates road and drainage structure. This structure is formed by merging multi-units of single modular units as shown in Figure 1 which consists of three precast concrete pieces. Top layer is for supporting of passing vehicles and permeating water atop into hollow cylinder through a service inlet. Middle layer is a collection hollow cylinders to provide spaces for storing and draining purposes. Besides that, the spaces between each unit also provide additional spaces for water flowing. Bottom layer is the raft foundation with service inlets to allow infiltration. Stormwater flows out of the StormPav system either by evapotranspiration of water, infiltration into native soil beneath it or/ and by outflow through outlet structure. Yet, in this paper, evapotranspiration and infiltration are excluded, so as to concentrate solely on the stormwater storage and conveyance purposes.

Before putting any further commitment on actual construction, computer simulation is a common practice to determine the workability of a system under study [7]. To determine an appropriate software to model StormPav Green Pavement System, two key factors are considered which included (i) fast model construction and (ii) budget for software purchase and maintenance fees. Modelling software being utilized are discussed in the next section.

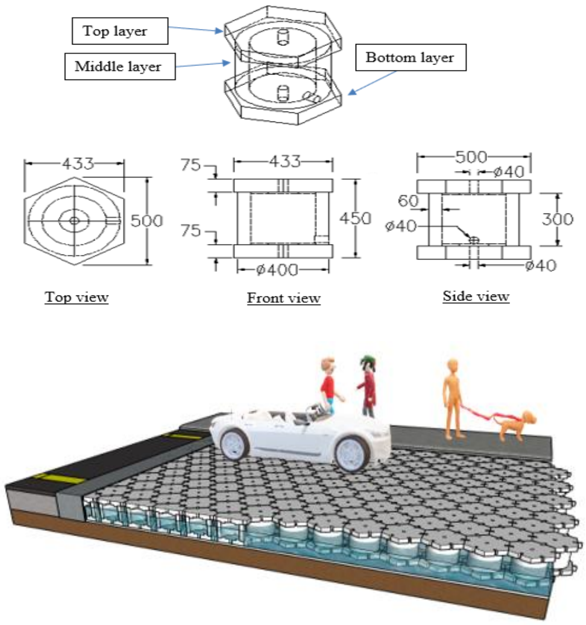

Fig. 1: StormPav Green Pavement

II. MODELLING SOFTWARES

Two stormwater modelling tools, namely SWMM, and InfoWorks CS are chosen to model StormPav.

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SWMM is a hydrologic and hydraulic model, provided by the United States Environmental Protection Agency, EPA. SWMM is a dynamic rainfall-runoff model implemented for single event or long-term simulation of runoff quantity and quality from mainly urban study and of backwater effects and reverse flow [8]. The model was introduced in the early 1970's and has continuously been updated since then. The latest official version is SWMM V5.1.013. The runoff component of SWMM is generated from a series of sub-catchments that receive precipitation.

InfoWorks CS is a stormwater modelling tool, developed and introduced by Wallingford Software UK. It combines a relational database with geographical analysis to provide a single environment for network modelling [9]. Comparing to SWMM, InfoWorks CS provides a more stable fully dynamic engine [10]. InfoWorks CS incorporates so called Workgroups, for example, network workgroup containing model network, rainfall workgroup containing rainfall events, and run workgroup containing different runs of the models [11].

III. METHODS

This paper demonstrates a case study of typical commercial area (Figure 2) as it involves a realistic scenario that could simulate StormPav before any further detailed studies are carried out. A stretch of urban road lined by two rows of commercial premises is chosen. The catchment covers an area of 0.399 ha. The StormPav is designed and positioned between two rows of premises (Figure 2) which is covered up to 0.0918 ha. The design of the StormPav omits the need of conventional front drains.

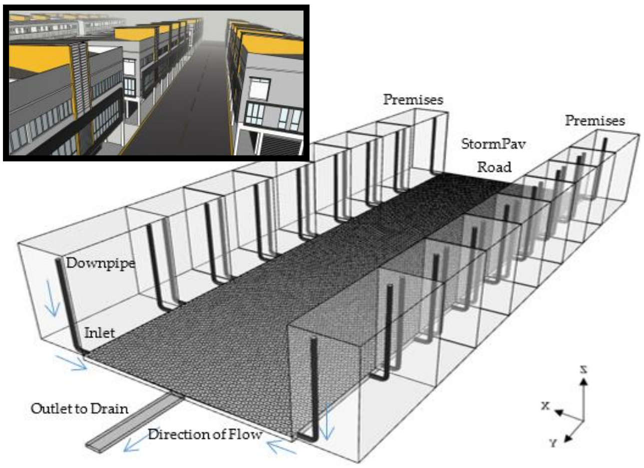


Fig. 2: Typical commercial area

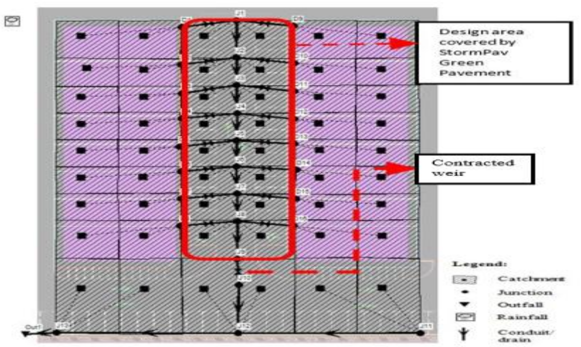


Fig. 3: Models created in SWMM (left), InfoWorks CS (right)

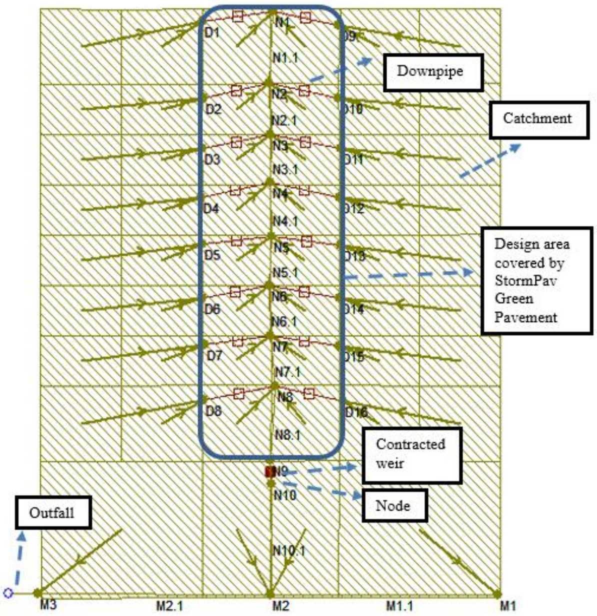
The surface runoff generated from the road catchment is permeated into the StormPav and the roof catchment is flowing into the StormPav by downpipes. The downpipe diameters used are 100 mm and 125 mm. Larger size is allocated to the corner lot of the commercial premise as its sub-catchment is larger than the intermediate lots. The sizes are decided based on the market availability that commonly used for downpipe. The stormwater shall be detained in the StormPav before it is being discharged via a weir. The contracted weir outlet size is designed as 190mm x 700mm and culvert across the main road is constructed to link to the main drain.

10-year ARI design rainfall is designed as the StormPav is classified under minor system [12]. A set of design storm durations are considered as in Table 1.

Table 1. Design rainfall durations

Rainfall durations (min)	Rainfall depth (mm)	Rainfall durations (min)	Rainfall depth (mm)
10	30.1	60	101.3
15	40.3	120	146.8
30	66.2	180	178.4

SWMM and InfoWorks CS could not represent every single unit of StormPav. Therefore, authors simplify the void spaces within the StormPav as a rectangular tank after the solid concrete components are subtracted [13-15]. StormPav is represented by a series of rectangular closed conduit. Models are constructed in both software as in Figure 3 and the predictive results are compared.



IV. MODELLING RESULTS

Models results are compared in term of the stormwater volume filling up the StormPav, velocities and flow rates in different locations of the StormPav as shown in Figure 4.

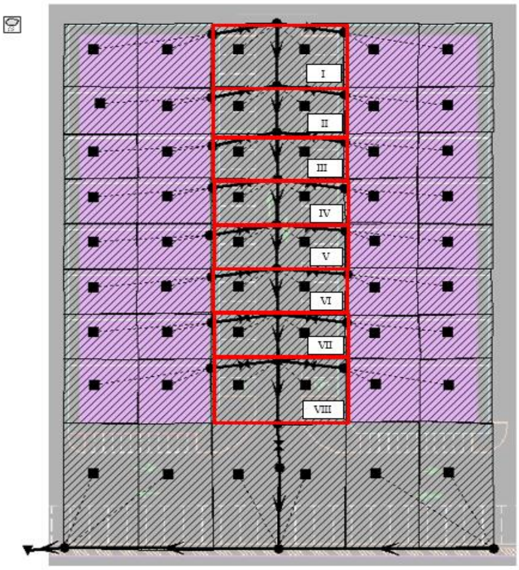


Fig. 4: Designated locations for extracting data

The stormwater volume in the StormPav is contributed from the roof catchments as well as the road catchments. Predicted volume to fill in the StormPav from the two models are presented in Table 2. It is reported that the volumes under different design storm durations are well matched. This increases the confidence level of both models generated by different tools.

Table 2. Predicted volume filling

Storm Durations, min	Predicted Volume Filling, m^3	
	SWMM 5	InfoWorks CS
10	94.6	93.4
15	125.7	124.5
30	206.5	204.3
60	312.8	312.0
120	452.6	451.4
180	550.4	549.1

The peak velocities and flow rates at each location with varying stormwater durations are summarized and reported in Table 3 and Table 4 respectively. The peak velocities and flow rates predicted by these two models are found to be in close range. Besides that, it is noticed that, larger magnitudes of velocity and flow rate are reported when approaching the weir outlet in both models. Yet, low magnitude of velocity and flow rate are found to act as the energy dissipation within the system itself.

Both models report that, Stretch VIII marks the highest velocities and flow rates regardless to the design storm durations. This is due to the fact that, stormwater is eventually accumulated in this stretch before discharges out of the system. Besides that, both models generate the lowest velocities and flow rates at Stretch II and I respectively. The lowest velocities produced in Stretch II is because this stretch is allocated in upper catchment and the catchment size is smaller than the Stretch I. On the other hand, the lowest flow rates are found in Stretch I in both models is because it is the initial stretch of the system before the stormwater flows downstream.

Figure 5 and Figure 6 present the stormwater velocities and flow rates respectively at one of the pinpointed locations of the system. Although it can be seen that the curves generated from these two models are slightly different in shape, it is considered to be acceptable for design purposes. The difference may due to although SWMM and InfoWorks CS apply the same hydraulic one-dimensional Saint-Venant Equations, they implement different algorithms for solving the Saint-Venant Equations.

Location: V

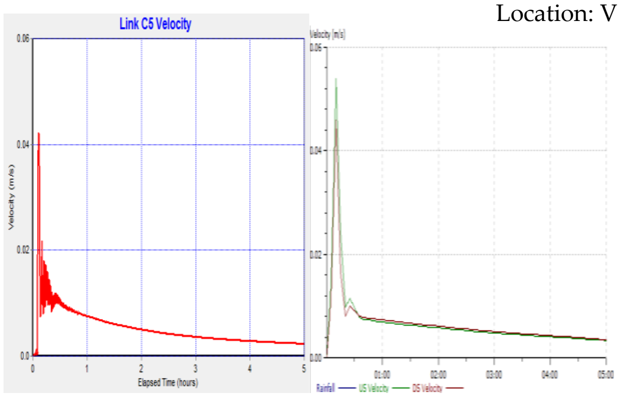


Fig. 5: Generated velocity in SWMM (left) and InfoWorks CS (right)

Location: V

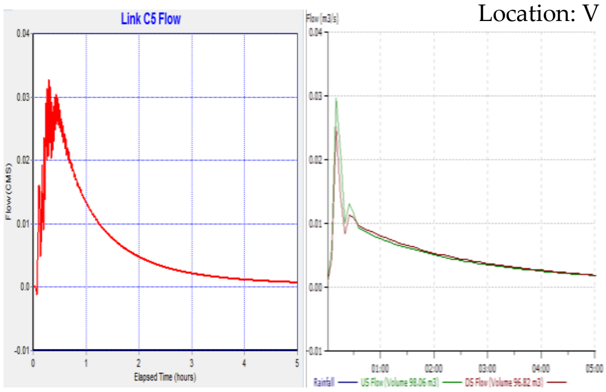


Fig. 6: Generated flow rate in SWMM (left) and InfoWorks CS (right)

V. CONCLUSION

StormPav has been modelled by using SWMM and InfoWorks CS and the predicted results are compared. The simulations are performed under 10-year ARI with different design storm durations. Results show that both models done by these two tools are compatible. To model StormPav does not require a complex and high stability software tool, and thus, both models can be constructed with reasonable fast. However, the cost of the InfoWorks CS may be too high for some modellers who wish to use the model occasionally without purchase cost involved. Thus, SWMM 5 is preferable to be considered to model StormPav as the USEPA licensed software is a freely available software.

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Table 3. Predicted velocity within the StormPav

Storm durations, min	Tools	Flow Velocity, m/s							
		I	II	III	IV	V	VI	VII	VIII
10	SWMM 5	0.051	0.036	0.044	0.050	0.053	0.059	0.060	0.079
	InfoWorks CS	0.034	0.036	0.043	0.050	0.051	0.058	0.062	0.105
15	SWMM 5	0.045	0.032	0.039	0.044	0.047	0.052	0.054	0.072
	InfoWorks CS	0.034	0.036	0.044	0.050	0.048	0.053	0.059	0.094
30	SWMM 5	0.043	0.029	0.035	0.040	0.045	0.047	0.051	0.068
	InfoWorks CS	0.030	0.033	0.040	0.043	0.043	0.049	0.056	0.085
60	SWMM 5	0.030	0.020	0.023	0.026	0.029	0.031	0.033	0.049
	InfoWorks CS	0.028	0.029	0.033	0.031	0.036	0.047	0.047	0.068
120	SWMM 5	0.019	0.011	0.012	0.013	0.015	0.016	0.017	0.027
	InfoWorks CS	0.018	0.013	0.017	0.021	0.025	0.029	0.035	0.051
180	SWMM 5	0.035	0.021	0.024	0.028	0.031	0.034	0.036	0.052
	InfoWorks CS	0.024	0.026	0.029	0.033	0.038	0.040	0.044	0.062

Table 4. Predicted flow rate within the StormPav

Storm durations, min	Tools	Flow Rate, m^3/s							
		I	II	III	IV	V	VI	VII	VIII
10	SWMM 5	0.016	0.018	0.022	0.024	0.023	0.024	0.023	0.023
	InfoWorks CS	0.015	0.018	0.022	0.026	0.026	0.028	0.034	0.039
15	SWMM 5	0.018	0.018	0.021	0.023	0.024	0.026	0.027	0.030
	InfoWorks CS	0.020	0.022	0.026	0.029	0.033	0.036	0.037	0.041
30	SWMM 5	0.021	0.021	0.024	0.029	0.033	0.036	0.039	0.046
	InfoWorks CS	0.021	0.020	0.022	0.026	0.030	0.032	0.032	0.043
60	SWMM 5	0.022	0.022	0.027	0.033	0.040	0.046	0.052	0.063
	InfoWorks CS	0.022	0.020	0.022	0.024	0.026	0.028	0.030	0.044
120	SWMM 5	0.016	0.021	0.027	0.032	0.039	0.046	0.053	0.060
	InfoWorks CS	0.015	0.014	0.016	0.019	0.023	0.027	0.031	0.038
180	SWMM 5	0.009	0.015	0.020	0.026	0.032	0.038	0.043	0.052
	InfoWorks CS	0.008	0.010	0.014	0.018	0.022	0.025	0.029	0.035

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