Flow Characteristics of StormPav Green Pavement System

Ching Vern LIOW, Darrien Yau Seng MAH and M. A. MALEK

Abstract: ***This study focuses on a new feature of StormPav Green Pavement System. Not only it is designed to store stormwater, it could act as a conduit to flow stormwater in a typical commercial environment. This StormPav system is simulated to convey stormwater from roof and road catchments that is subjected to 3-hour 10-year average recurrent interval design rainfall. By applying the visualization technique offered by SolidWorks Flow Simulation, the simulations demonstrate that the StormPav system is capable of conveying and storing stormwater under the studied duration of the design rainfall.***

***Index Terms*: Flow trajectory, Permeable road, SolidWorks, Streamlines, Stormwater.**

I. INTRODUCTION

StormPav Green Pavement System is designed as a form of permeable road [1]. As such, it has a function of stormwater storage [2]. This paper describes a concept beyond stormwater detention to add another new function to the permeable road. A road envisions to flow stormwater.

Generally, a permeable road has a layer of specialized pavement that allows stormwater to percolate through. Under the pavement, it has a layer of storage spaces to temporarily store stormwater. StormPav fits in the concept of permeable road by having multiple precast concrete pieces. It is consisted a top cover, a hollow cylinder and a bottom cover to form a single modular unit as presented in Figure 1.

The top cover with a 40mm service inlet is the permeable pavement layer. The service inlet is able to drain stormwater up to 10,000mm/hour [3]. The hollow cylinder with a 40mm side service inlet is the storage layer. The layer could hold water at a capacity of 0.19m3/m2 of pavement area [2]. The bottom cover functions as a base and its 40mm service inlet allows infiltration to the surrounding soils.

The top and bottom covers are similar hexagonal-shaped plates. The surface area on a single plate is 0.1624m2. Height of each plate is 0.075m. The cylinder has an inner diameter of 0.28m and a thickness of wall of 0.06m. Height of each cylinder is 0.3m. The modular unit is laboratory tested to support up to 10 tons of load. Interlocking the modular units and bordering them with ground beams, it forms a subsurface tank with numerous compartments formed by the hollow cylinders and the spaces in between the cylinders.

Stormwater tank comes in many shapes and sizes. The above-mentioned subsurface tank is designed to withstand 3-hour 10-year average recurrent interval design rainfall; and its field performance is reported in [4]. Its multiple compartments would not deter its capability in detaining stormwater [5]. In fact, adding properly-sized inlet and outlet to the tank would change its configuration from primarily stormwater detention to continuous flow [6,7]. Such a flow mechanism is often observed in, for instances a fairly-compartmental rectangular tank [8], and non-compartmental circular tank [9]. In the case of

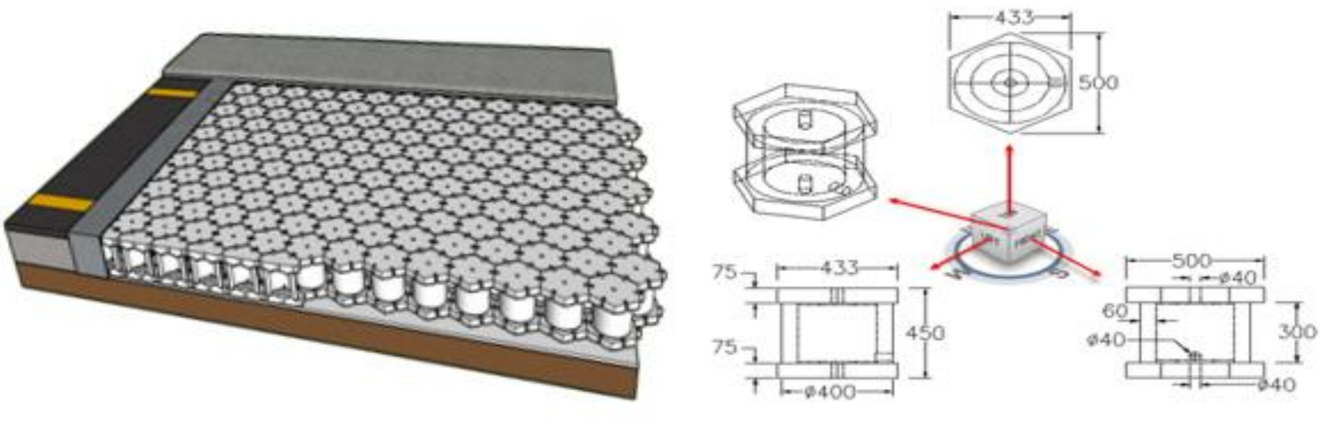

Fig. 1: StormPav Green Pavement System

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densely-compartmentalized StormPav system, its flow patterns in a small-scale system is reported in [10,11], and study into larger-scale StormPav system is attempted here.

II. METHOD

This study is using a case study as it involves realistic situation that allows authors to simulate StormPav system to flow stormwater. A typical commercial area is selected as in Figure 2.

Authors choose a stretch of urban road flanked by two rows of commercial premises. StormPav system is applied as the road, in which the drains in front of the premises are removed. Stormwaters from the roofs are directed to the StormPav system. Assuming the system is symmetrical in nature, half the road shall cater to capture the stormwaters from one row of premises while the other half of the road for the opposite row of premises. Therefore, only half of the road is considered in the simulation.

Three specific flow conditions are specified. Firstly, the upstream corner lot is named Stretch i that shall receive stormwater from the premise (denoted as a) and stormwater intercepted by the road surface (denoted as b). Secondly, the intermediate lot is named Stretch ii that shall receive stormwater from the premise (c), road surface (d) and upstream flow (e). Thirdly, the downstream corner lot is named Stretch iii that shall receive stormwater from the premise (f), road surface (g) and upstream flow (h). Infiltration is excluded in the three conditions to concentrate on the water transport processes.

III. RESULTS

SolidWorks Flow Simulation is applied on the three identified stretches. StormPav is designed to accommodate 3 hours of rainfall. Therefore, simulations demonstrated below are based on 3 hours of design rainfall. The flow trajectories of Stretch i is illustrated in Figure 3.

For Stretch i, the force of stormwater from the premise's roof is dominant than surface water from road. This is because the catchment area of the premise is twice larger than the road catchment. The volume of generated stormwater from the roof is discharged rapidly to the StormPav system. SolidWorks simulates the horizontal flow patterns that indicate the water jets being injected to the system tend to bend toward the exit following the direction of flow.

The section cut a-a of Stretch i provides another perspective about the vertical flow. The SolidWorks model predicts how the stormwater from the road surface entering the hollow cylinder and leaving through the side service inlet. The section cut shows two sizes of rectangular compartments. This is due to the interlocking of the hexagonal plates, in which the larger rectangular compartments are those at the front row, and the small rectangular compartments are those at the back. The water streamlines in between the compartments are the horizontal flows.

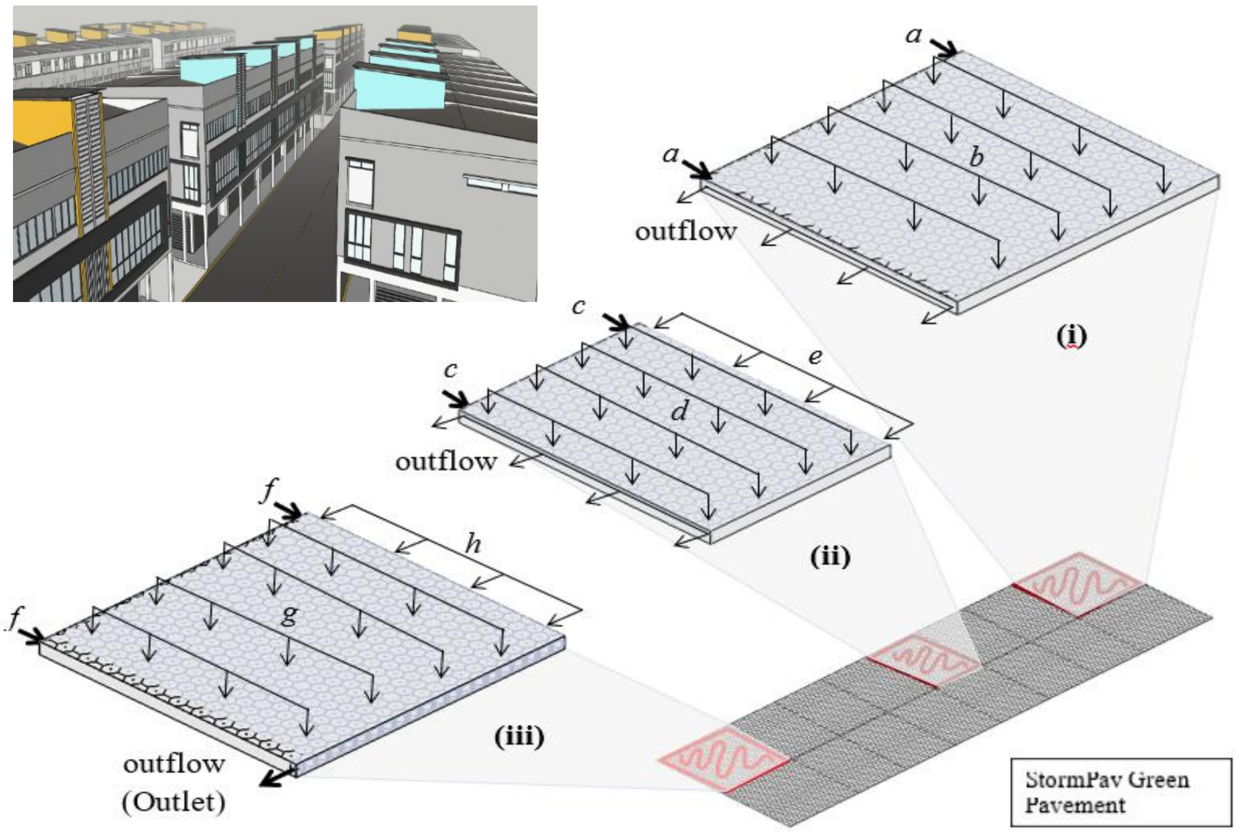

Fig. 2: StormPav Green Pavement System selected for simulation

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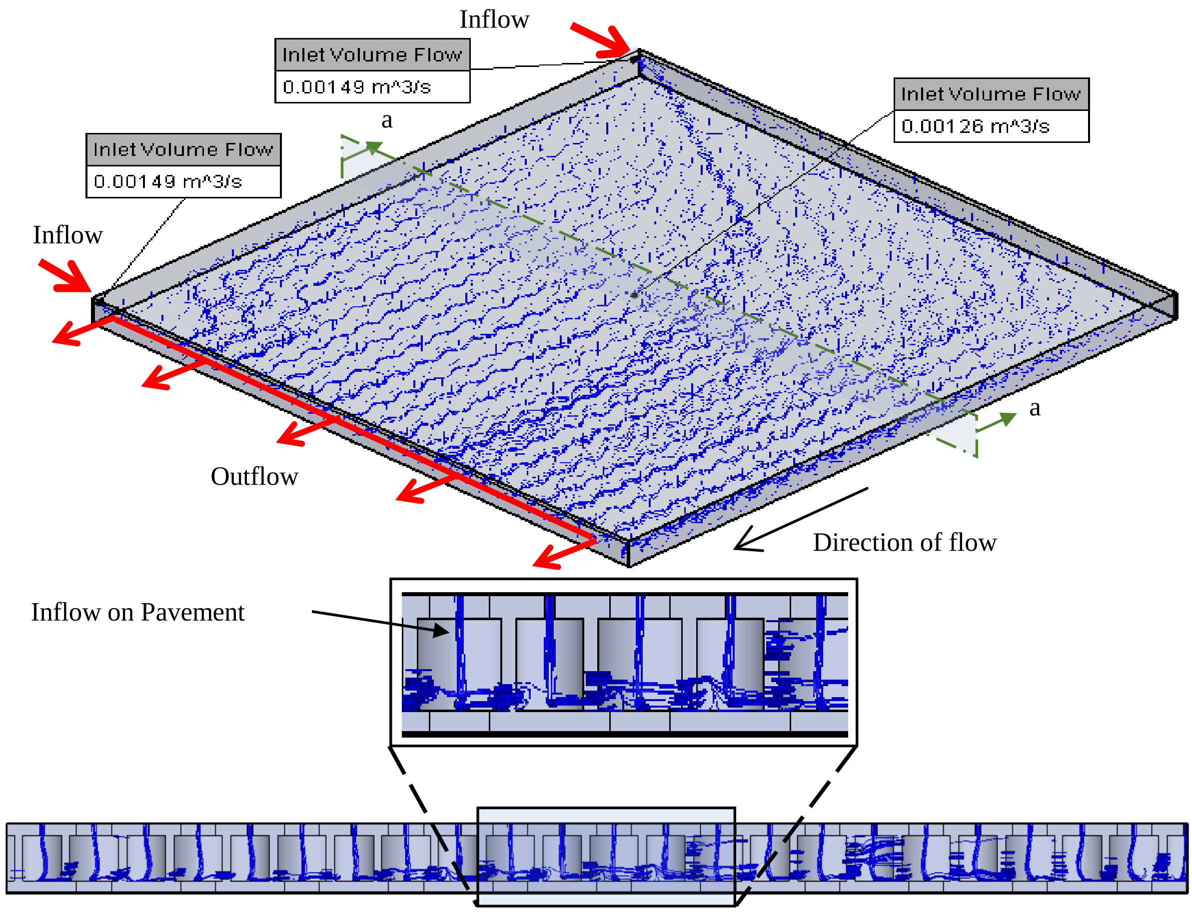

Section Cut a-a

Fig. 3: Flow trajectories of stretch i due to 3-hour 10 year ARI design rainfall

The flow trajectories of intermediate stretch of StormPav system is illustrated in **Figure 4**. In this case, the force of upstream flow is more dominant than the stormwaters from the premise and road surface. The flow trajectories are modelled to run straight toward the exit. Section cut b-b of Stretch ii shows similar patterns in vertical and horizontal flows as the previous stretch.

The flow trajectories of downstream stretch of StormPav system is illustrated in Figure 5. This is the stretch in which stormwaters from the upstream catchments shall eventually reach here before the final discharge point. Upstream flow is the most dominant compared to other stretches. In terms of horizontal flow, the flow trajectories follow the direction of flow and then bend toward the outlet of the StormPav system.

Section cut c-c of Stretch iii shows the occurrence of swirling water streamlines within some of the hollow cylinders. No swirling pattern is observed in the previous stretches. This could be explained that the horizontal flow in the downstream stretch is so dominant that it slows down the stormwater leaving the hollow cylinders.

IV. CONCLUSION

Computer simulation efforts reveal insights to the horizontal and vertical flows within the StormPav system. Horizontal flow from upstream to downstream stretch happens within the tight spaces in between the hollow cylinders. Continuous flow occurs due to these spaces. On the other hand, vertical flows are only occurred within the hollow cylinders. Stormwater detention only happens here but the water leaving the cylinder joins the horizontal flow downstream. However, detained stormwater is increasingly difficult to flow out of the hollow cylinder as the stretch is approaching the downstream end. This is due to the accumulation of stormwater and flow restriction of outlet at the downstream stretch. It implies that special attention should be paid at the design of the downstream stretch to avoid undesired overflowing of stormwater.

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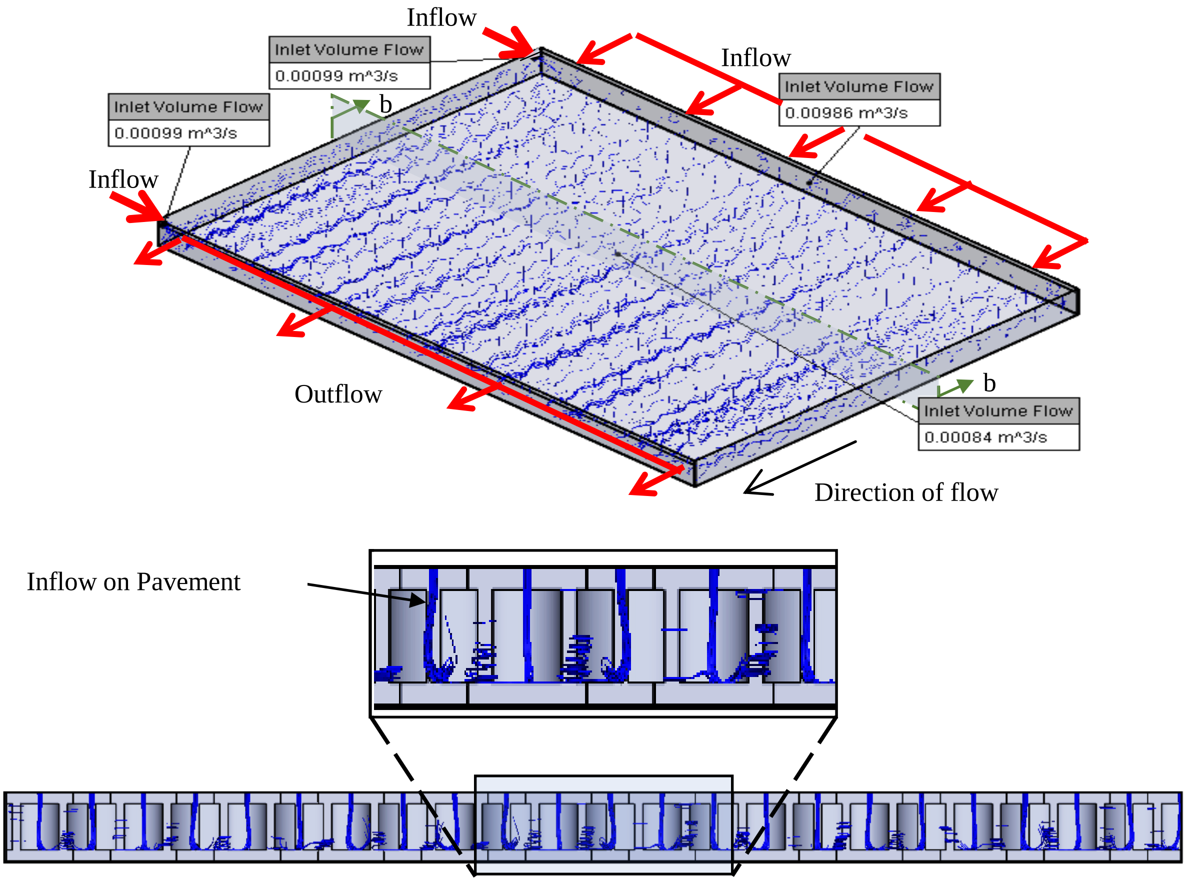
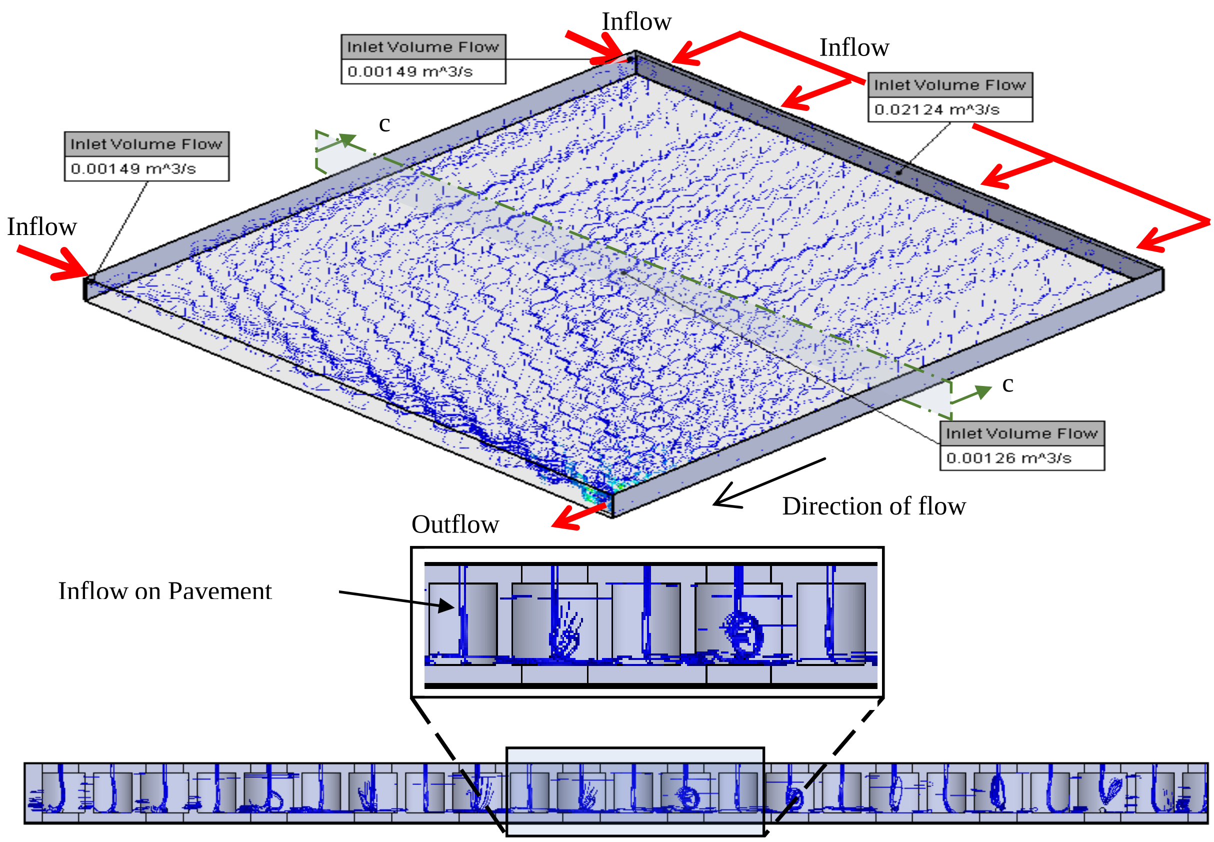


Section Cut b-b

Fig. 4: Flow trajectories of stretch ii due to 3-hour 10 year ARI design rainfall



Section Cut c-c

Fig. 5: Flow trajectories of stretch iii due to 3-hour 10 year ARI design rainfall

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