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Modelling of On-Site Stormwater Detention Underneath a Car Porch

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Abstract: This study focuses on the possibility of On-Site Stormwater Detention (OSD) underneath a residential car porch. The space provided in the car porch area can be made good of it by introducing an OSD beneath it to temporary store stormwater from roof during raining in hoping of reducing the surface runoff. The OSD is subjected to 15-minute, 10-year Average Recurrence Interval (ARI) design rainfall. This process in urban hydrology is presented by using Storm Water Management Model (SWMM). Efficiency of the OSD is also investigated by different number of orifice outlets. Modelling efforts report that one orifice outlet is preferable, and it marks approximate 95% discharge reduction at the outfall.

***Index Terms*: OSD, SWMM, orifice outlet, residential car porch, stormwater.**

I. INTRODUCTION

OSD is a type of urban drainage technique which is based on stormwater source control. With a rapid rate of urbanization and industrialization, this technique is intended to reduce the peak discharge by slowing down the surface runoff generated by the increase of impervious area in lots [1-4]. This technique has been widely implemented in Australia since 1991 [5]. Considering the recurrent problems of flooding, many cities have imposed regulations requiring the implementation of OSDs in new developments. Provision of OSDs to reduce peak flow is recommended in Urban Stormwater Management Manual for Malaysia [6]. OSD can be provided as above-ground storage, below ground storages, or a combination of both within a property boundary. Typically, above-ground storages are located in lawns, rooftops and tanks. On the other hand, below-ground storages can be tanks and pipe packages. Despite there is extensive literature on best management practice covering many measures [7-9], OSD underneath residential car porch is yet to be explored. In Malaysia, car porch area is usually quite roomy and taken up a large space at the front of the house as shown in **Figure 1**.

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The car porch area could be good used if stormwater runoff from the roof catchment can be directed to the OSD underneath the car porch. Parameter and possible solutions to the engineering of an OSD underneath a car porch are unknown of at the moment. Outlet of an OSD plays an important role as it controls the discharge being released from the storage structure [10-12]. With the modelling efforts, this paper seeks for the effectiveness and efficiency of utilizing an OSD storage as a stormwater component based on a case study.

Fig. 1: Typical residential car porch design in Malaysia

II. CASE STUDY

This study deals with residential building located at Central City, Kota Samarahan (see **Figure2**). Semi-detached house (**Figure 3**) is chosen for extensive study to determine the effectiveness of the OSD underneath the car porch. A car porch is a requirement for each house in Kota Samarahan as each household is known to own more than one car. In this case study, the car porch provides an area of 16.98m^2**.** This case study is modelled in a disconnected system manner, which is independent of the whole residential area.

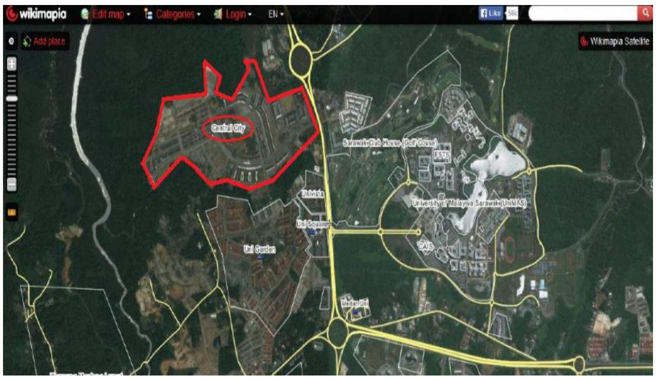

Fig. 2: Location of the current case study

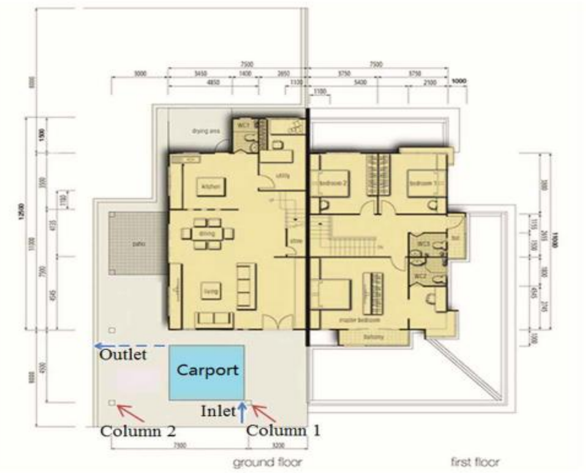

Fig. 3: Top view of the house

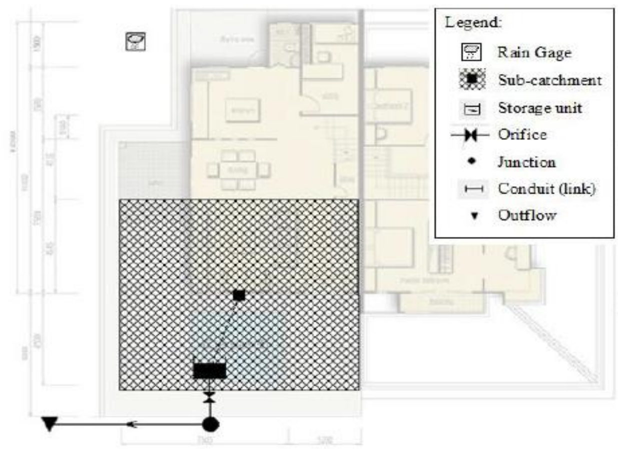

Fig. 5: OSD model

III. ROOF RUNOFF

Stormwater runoff generated from the front area of the roof catchment is considered to drain to the OSD. The roof catchment is calculated at 95m^2. As shown in **Figure 3**, stormwater from roof is conveyed to the OSD through downpipe built into or attached to the column. Stormwater is then being released at the outlet of OSD with a control rate to the house perimeter drain. To optimize the entire car porch area, the OSD (**Figure 4**) is dimensioned to 4.85m x 3.50m x 0.25m. A diameter of 0.10m circular pipe which is available in the market is used as inlet and outlet of the OSD.

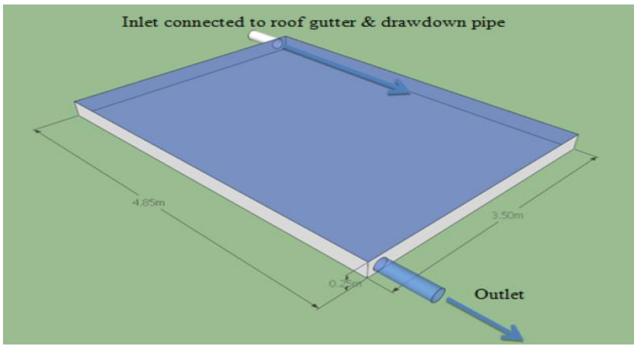

Fig. 4: Dimension of OSD under car porch

A 10-year ARI design rainfall acted on minor system for residential area [6] is considered. 15-minute design storm duration is usually taken in normal practice as the effective catchment is small. However, 30- and 45-minute design duration are also taken into consideration for comparison.

SWMM is used to model the case study as it is a dynamic rainfall-runoff model which is widely practised for modelling of urban water cycle [13-14]. It could provide insights to users in such a way that simulation results could be presented in time series graphical or tabular form and statistical analysis of the simulation results could be displayed. **Figure 5** shows the developed SWMM model.

Analytical calculation by using Rational Method (**Table 1**) is performed and compared with the simulation (**Table 2**) to check if the parameters used in the modelling are appropriate. The computed peak runoffs are matched with those of hand calculations.

Table 1: Maximum Runoff using analytical calculation.

Design Storm Duration (mins)	Rainfall Intensity, I (mm/hr)	Rainfall Depth, P (mm)	Maximum Runoff, Q (m^3/s)
15	180	45	0.00474
30	140	70	0.00369
45	120	90	0.00317

Table 2: Simulated roof runoff of 15-, 30- and 45-minute storm duration

Duration	Runoff, Q (m^3/s)		
	15-minute	30-minute	45-minute
00:15:00	0.00000	0.00000	0.00000
00:30:00	0.00474	0.00000	0.00000
00:45:00	0.00016	0.00368	0.00000
01:00:00	0.00004	0.00369	0.00315
01:15:00	0.00002	0.00015	0.00317
01:30:00	0.00001	0.00004	0.00317
01:45:00	0.00001	0.00002	0.00014
02:00:00	0.00000	0.00001	000004
02:15:00	0.00000	0.00001	0.00002
02:30:00	0.00000	0.00000	0.00001
02:45:00	0.00000	0.00000	0.00000
03:00:00	0.00000	0.00000	0.00000

IV. DESIGN OSD

The OSD is then tested with different numbers of outlets to investigate the efficiency of the proposed OSD in term of total outflow.

Existing condition refers to without OSD which is used as a control to compare with OSD of different numbers of orifice outlets as in **Figure 6**.

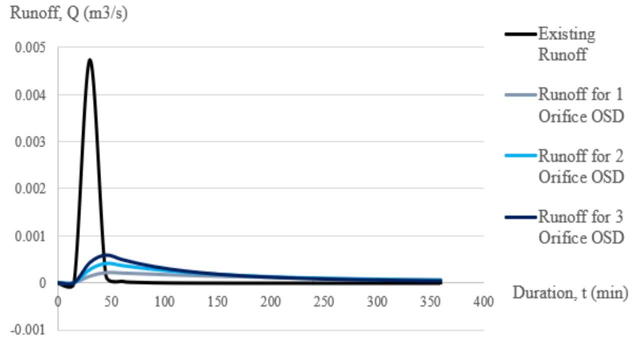

Fig. 6: Comparison of runoff hydrographs with and without OSD in 15-minute design duration.

The peak discharge at the outfall of existing condition (without OSD) marks at 0.00474m^3/s and it happens at approximate 30 minutes of the storm. By implementing OSD underneath the car porch, all the scenarios show reduction in runoff. For scenario with 1, 2 and 3 orifice outlets (with OSD), the peak runoff at the outfall are 0.00023m^3/s, 0.00042m^3/s, and 0.00058m^3/s respectively. Scenario with one orifice outlet marks the highest reduction of discharge that could give to approximate 95% reduction. For all the cases with OSD, the peak runoff is observed at approximate 45 minutes of the storm in which the time to peak is attenuated compared to the without OSD.

Similar pattern is observed for design durations of 30- and 45-minute as shown in **Figures 7** and **8** respectively. The peak discharges at the outfall of existing condition in design durations of 30- and 45-minute are reported at 0.0037m^3/s and 0.0032m^3/s respectively. These happen at approximate 60 minutes and 75 minutes of the storm for 30-minute and 45-minute respectively. For both the cases, peak times are attenuated, and the reductions are significant. However, OSD with one orifice is favourable as it can hold the roof runoff in the OSD for a longer period and marks the highest discharge rate reduction.

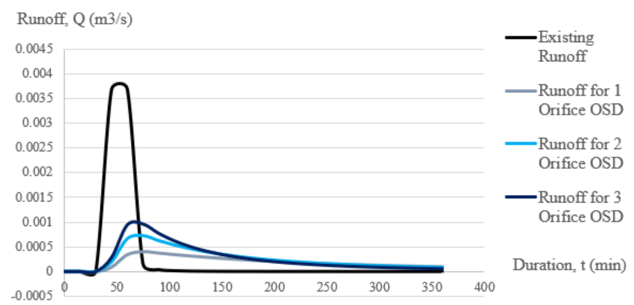

Fig. 7: Comparison of runoff hydrographs with and without OSD in 30-minute design duration.

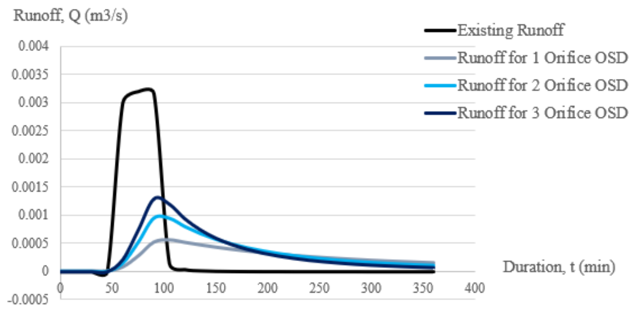

Fig. 8: Comparison of runoff hydrographs with and without OSD in 45-minute design duration.

V. CONCLUSION

Computer simulation efforts reveal the effectiveness of OSD underneath the residential car porch to reduce surface runoff is significant. Regardless of number of orifice outlet of an OSD, the runoff is reduced greatly. Nevertheless, the OSD with one orifice outlet reports the greatest discharge reduction among all. It marks approximate 95% of discharge reduction at outfall. Thus, with applying OSD underneath a car porch, it shows the possibility to minimize the chances of flood events to occur.

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