Investigation of Sewage Flows in Universiti Malaysia PAHANG's Sewerage System

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***Abstract*—Sewerage systems have long been one of the most critical infrastructure to any development project. The study presented here is part of a research that aim to evaluate the flow characteristics in sewerage systems. Sewage flow data was collected from a sewerage catchment within Universiti Malaysia PAHANG using an area-velocity flowmeter. The data obtained were extracted using a software associated to the flowmeter and analyzed for both dry and wet periods. The results show that the peak or maximum flow for the wet period with a rainfall intensity of 2.5 mm was twice as high for the dry period. The design criterion value back-calculated for the wet period was also twice the value for the design criterion value back-calculated for the dry period. This demonstrates that rainfall has an important effect on flows in sewerage system in that it increases the flow significantly. The *k* value back-calculated for both dry and wet periods were lower than the criterion recommended in Malaysian Standard MS1228:1991, suggesting that the current peak flow factor equation applied by the industry is over-adequate for sewerage catchments servicing the same population equivalent as this study.**

Keywords—design criteria; peak flow factor; sewers; wastewater

I. INTRODUCTION

Sanitary sewer systems which route sewerage separately from storm water or direct runoff are commonly applied in Malaysia. This is in accordance to high rainfall weather conditions throughout the year. This type of sanitary sewer system is basically designed to accommodate the flow of wastewater from domestic and industrial sources rather than other sources. Problems may arise when the flow in the sewer system is not in accordance with specifications laid down in the Malaysian Standard - Code of Practice for Design and Installation of Sewerage Systems (MS1228:1991) [1] such as when infiltration rate is higher than the recommended 50 litres/day/km/mm-diameter or when the *k* value obtained is dissimilar to the criterion used during the design stage.

Several studies have in fact been conducted on the transport of wastewater in local sewerage systems. Reference [2] studied the inflow and infiltration of the sewerage system at Taman Sri Pulai, Skudai with a population equivalent (PE) of 2000 and found that there was high outflow during heavy rain while the design criterion obtained was 2.62 as opposed to the 4.7 used in [1]. Reference [3] conducted a more comprehensive study on inflow and infiltration in medium scale sewerage catchment system. They concluded that infiltration will exceed the limit recommended by [1] when there is heavy rain but will remain within the limit during dry periods. Furthermore, the peak flow factor obtained was lower than the value based on [1]. This led to suggestion for review of the peak flow design equation currently applied in the industry. Subsequent to that, [4] performed a study to evaluate the design criterion for sewerage peak flow factor at SEGi University's hostel without taking into account rainfall. Based on the actual PE on-site as well as the actual per capita flow measured, a *k* value of 2.88 was obtained. After going through the aforementioned studies, it was found that results given were not conclusive enough to get a good overall picture of the sewage flow conditions in local sewage systems.

This study picks up where [2], [3] and [4] left off. The main aim of this study is to analyse the sewerage flow characteristics within Universiti Malaysia PAHANG (UMP) with the option of expanding to areas outside UMP and in the long term, to determine a more suitable peak flow factor for use in the existing MS1228:1991 design equation based on comprehensive data and analysis.

II. METHODOLOGY

A. Study Site

This study comprises of different sites. The analysis and discussion presented in this article is based on data from one of the sites. The site selected is situated within the compound of UMP Gambang campus, at a student hostel known as KK1. The exact manhole in which the measurements were made is located beside block C15 of KK1. The sewer system at the chosen site services mainly the female students staying in KK1. Fig. 1 shows the layout drawing of the fieldwork site. Flowrates in the sewerage system depends on the PE of the said area and based on [1], the PE was calculated to be 942.

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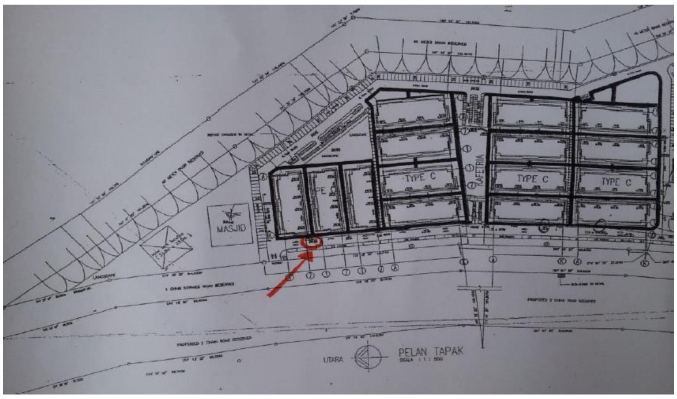

Fig. 1. Site plan layout of KK1

B. Material and Equipment

The equipment used was a portable ISCO 2150 Area-Velocity Flowmeter and a rain gauge of the tipping bucket type. The flowmeter was used to obtain the flowrates of the sewage flowing within the sewer line being measured. After opening the manhole using proper procedures, the main flowmeter unit was tied to a handhold fixed to the manhole wall as shown in Fig. 2, and the area-velocity sensor attached to the main flowmeter unit was fixed to the bottom of the sewer pipe with the help of metal pieces and screws as shown in Fig. 3. Data in the form of flow volume, water velocity as well as water level were measured and recorded automatically at predetermined intervals of 15 minutes. At the same time, the rain gauge in this study was installed at an open field that is also located within the jurisdiction of UMP so the rainfall data obtained was considered representative of the whole of UMP Gambang campus. Rainfall data is important to investigate whether rainfall has any effect on sewage flows.

Fig. 2. Main flowmeter unit attached to handhold in manhole

Fig. 3. Flowmeter sensor fixed to bottom of sewer pipe

C. Governing Equations

According to [1] the peak hourly flow, which refers to the flow required for design of sewers, pumping stations as well as components of the wastewater treatment plant, can be obtained using (1).

$$Q_{peak} = PFF \times Q_{ave} \tag{1}$$

where Q_{peak} represents the peak flow in m^3/day, PFF is the peak flow factor as given in (2), and Q_{ave} is in m^3/day and can be calculated from (3).

$$PFF = k(\mathrm{PE}/1000)^{-0.11} \tag{2}$$

$$Q_{pc} = Q_{ave} / \mathrm{PE} \tag{3}$$

where k is the design criterion, PE is the population equivalent, and Q_{pc} is the per capita flow which refers to flow generated per person and is in m^3/day/person. Equation (3) can be rearranged and, together with (2), substituted into (1) to form another equation which, when rearranged, can be used to calculate the k value as shown in (4).

$$k = Q_{peak} / [(Q_{pc} \times \mathrm{PE})(\mathrm{PE}/1000)^{-0.11}] \tag{4}$$

III. RESULTS AND DISCUSSION

A. Wet/Dry Flow Characteristics

Data of the sewage flows as well as rainfall was collected within the period of 2/5/2014 to 11/5/2014. Two data sets were further sequestered from this period mentioned; 2/5/2014 to 4/5/2014 for the dry period and 9/5/2014 to 11/5/2014 for the wet period. Both data sets were taken for the same days of a week, in this case from Friday to Sunday, in order to make a proper comparison.

Fig. 4 shows the hourly flowrates, condensed into three-hour slots for presentation purposes, and rainfall data versus time for the dry period of 2/5/2014 to 4/5/2014. The graph line for rainfall intensity can be seen to be horizontal due to no rainfall within that period, hence the designation dry period.

Based on Fig. 4, the maximum flowrate was 424.05 m^3/day and was recorded on Friday. This peak flow could be due to Friday prayer activities as the mosque for UMP is located nearby KK1 and probably shares the same sewerage pipelines. The minimum flowrate recorded was 1.04 m^3/day whereas the average flow within this duration is calculated to be 111.2 m^3/day.

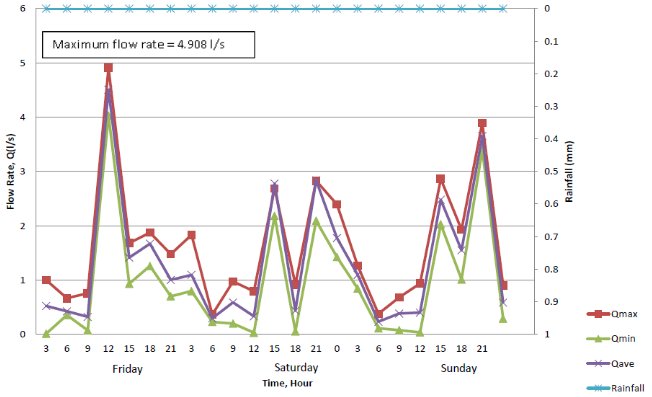

Fig. 4. Graph of flowrate and rainfall intensity against time (2nd May 2014 to 4th May 2014)

Fig. 5 shows a similar graph as in Fig. 4, but for the wet period of 9/5/2014 to 11/5/2014. It can be seen that rain fell on both Saturday and Sunday, causing spikes in the sewage flow measurements. The maximum flowrate was recorded as 848.97 m^3/day at 6pm on Sunday, which coincides with a rainfall intensity of 2.5 mm. Even with a rainfall intensity of 0.2 mm on Saturday around noon, the flowrate already exceeded the high flowrate on Friday. Thus, rainfall has a big influence on the flow of sewage in sewerage systems. The minimum flowrate recorded was 6.31 m^3/day which occurred between 3pm to 6pm regardless whether it was during dry period or wet period, as shown in Fig.4 and Fig.5. The average flow from Fig.5 is 153.19 m^3/day.

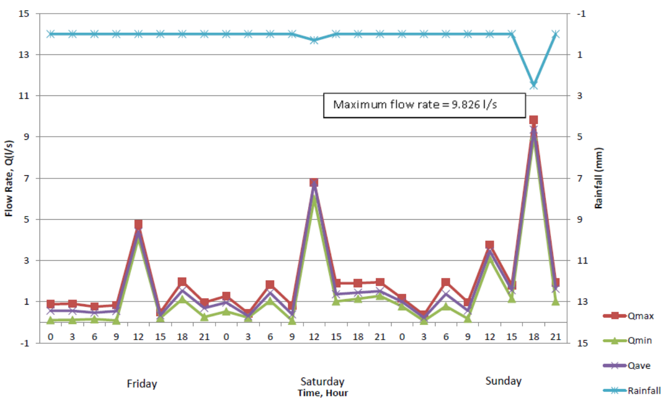

Fig. 5. Graph of flowrate and rainfall intensity against time (9th May 2014 to 11th May 2014)

B. Peak Flow Factor

The *k* value for the wet and dry periods discussed in the previous section is now calculated for comparison. The peak flow factor equation from [1] is used. In the calculations, the per capita flow of 0.225 m^3/day/person is maintained. This is to reduce the complexity of the relationships to be developed later.The PE and peak flow on the other hand are based on the data collected. Table I shows the design criterion *k* calculated for both the wet and dry periods.

TABLE I. DESIGN CRITERIA BASED ON FIELD DATA

Period	**PE = 942, Flow Per Capita = 0.225 m^3/day/person**	
	Peak Flow (m^3/day)	***k***
Dry	424.05	1.99
Wet	848.97	3.98

Based on Table I, the *k* value obtained during the dry period was about 57.7% lower than the 4.7 used in [1] whereas the *k* value obtained during the wet period was around 15.3% lower. Regardless whether the period is wet or dry, the design criterion measured from the field are both lower than 4.7. This indicates that using the peak flow factor equation in [1] may be overdesigning the capacity of the sewerage system since the higher the design criterion, the higher the design peak flow will be. Table I also shows that rainfall may influence the result calculations as the *k* value obtained during the wet period was twice as high as the *k* value obtained for the dry period.

IV. CONCLUSION

In summary, rainfall has a big influence on the flows in a sewerage system. This is likely due to infiltration of the rainwater into the sewerage system through cracks, faulty joints or manholes [5]. The influence of rainfall is most apparent by comparing Fig. 4 with Fig. 5. A rainfall of 2.5 mm intensity caused the maximum flowrate to double that of the maximum flowrate during the period without rainfall. The design criterion for the sewerage system studied was found to be significantly lower compared to the usual criterion value used in [1] for both dry and wet periods. More studies of this nature needs to be performed and the results compiled and analyzed before any calls for revision of the current peak flow design equation be made to the authorities.

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