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Flow Design of Sewerage System – A Case Study in Taman Pandan Damai, Kuantan

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Abstract

Flow design parameters are important in the sewerage system design. The purpose of this research is to verify the design flow parameters in the sewerage systems within a residential area at Kuantan, Pahang. The residential area selected in this research was Taman Pandan Damai. The population equivalent was surveyed at 2244. This research is in collaboration with national sewage company Indah Water Konsortium Sdn. Bhd. ISCO 4250 Area Velocity Flow meter was installed in the Manhole (MH k) after calibration was done. Real time sewage depth, flow rate and velocity data in the sewer was collected using an ultrasonic sensor attached to the flow meter. The flow design parameters were focused on per capita flow as well as design criterion. Based on the results obtained the average per capita flow was 0.36 m^3/day/person which is 60% higher than the 0.225 m^3/day/person recommended in the Malaysian Sewerage Industry Guidelines. Conversely, the result of design criterion was 2.61, 44% lower than 4.7 which is also stated in the Malaysian Sewerage Industry Guidelines. This indicated that the design of the sewerage system in Taman Pandan Damai was more than capable of catering to the population equivalent serviced in that area. In other words, reduction of sewer pipeline diameters may be possible for future sewerage system design. More comprehensive studies are needed to initiate the review of revised flow design parameters taking into account the rising cost of materials around the world.

Keywords: Design Criteria, Peak Flow Factor, Sewerage Network, Sewer, Wastewater Flow

1. Introduction

Sewerage system is the infrastructure that transfers sanitary water from residential, industrial and commercial areas to sewerage treatment plants[1,2]. There are three types of sewerage system which are separate sewerage system, combined sewerage system and partially combined sewerage system. In Malaysia, separate sewerage system is commonly applied[3]. The local practice for sewerage system design refers to the Malaysian Sewerage Industry Guidelines (MSIG)[4]. In this present study, separated sewerage system is targeted to analyse the design flow. The flow design parameters in MSIG referred to Malaysian Standard Code of Practice for Design and Installation of Sewerage System (MS 1228:1991)[5]. In turn, MS 1228:1991 was produced by referring to British Standard titled Drain and sewer systems outside buildings, Hydraulic design and environmental considerations (BS EN 752:1998)[6] which was applied in the United Kingdom[2]. The parameters such as per capita flow and design criterion may be dubitable depending on the climate, topography and geographical situation in each country. Sewerage system should be designed for optimum flow to avoid overflow in sewerage systems as well as manholes[7]. The capacity of sewer pipelines may be affected if the peak sewage flow is not properly addressed during sewerage system design. Overflow of the untreated sewage will affect environmental protection and human health. High cost of maintenance and construction is needed to repair any defects in a sewerage system[8].

A similar research was conducted in Gambang, Pahang for a period of five months. The results showed the value of the parameters per capita flow and design criterion that were investigated were lower than both values

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mentioned in MSIG Volume 3[9]. The authors suggested that more construction cost can be saved by using the new parameters[9]. Another study was conducted at a small catchment in Cairo, Egypt. The research only estimated and compared peak flow factors to the pumping station of the sewerage system plant using three different methods by Babbit and Baumann, Munksgaard and Young, and Harmon. The finding recommended different plant components to be designed according to their critical peak condition[10]. One other local study was conducted in the hostel of SEGi University. The researchers performed the study by using the method of area velocity. The results showed that actual per capita flow was 35.6% higher than 0.225m^3/day/person and actual design criterion was 38.7% lower than 4.7 stated in MSIG Volume 3[11].

The main purpose of this research is to analyse the per capita flow as well as design criterion in the sewerage systems within Kuantan, Pahang and compare them to their counterpart in MSIG, Volume 3. The objective of the present work is to analysis the relationship between rainfall and flow pattern of sewage in sewerage system.

2. Methodology

2.1 Fundamental of Design Flow

Per capita flow and design criterion are significant in the design of sewerage systems[12]. The per capita flow and design criterion are determined by following equations mentioned in the MSIG[3].

$$Q_{pcf} = \frac{Q_{ave}}{PE} \quad (1)$$

Equation (1) shows the calculation of per capita flow, Q_{pcf} with unit of m^3/day/person. Q_{ave} stand for the average of daily flow collected in the sewer line in unit of m^3/day. PE means population equivalent without unit.

$$k = \frac{Q_{peak}}{(Q_{ave})\left(\frac{PE}{1000}\right)^{-0.11}} \quad (2)$$

Equation (2) shows the equation for design criterion where k is unitless while Q_{peak} means peak flow in sewer line in m^3/day. Based on MSIG, values of Q_{pcf} and k are stated as 0.225m^3/day/person and 4.7, respectively[3].

2.2 Site Study

This study consists of mostly fieldwork. Several residential areas were targeted for investigation of design flow in sewer pipeline, but in this paper the focus is narrowed down to one residential area which is Taman Pandan Damai. Collaboration was done between Universiti Malaysia Pahang (UMP) and Indah Water Konsortium Sdn. Bhd. (IWK). Before this research started, meetings with IWK were necessary to gather more information on characteristics of Taman Pandan Damai. One Manhole (MH k) with a sewer pipeline diameter of 0.225 m was selected. The manhole was the nearest to the sewerage treatment plant. The reason for choosing MH k was because high peak flow of sewage is required. Simultaneously during the data collection, Population Equivalent (PE) survey was done in the area. The PE surveyed amounted to 2244 PE.

2.3 Materials and Equipment

Figure 1 shows the Doppler ultrasonic technology adopted in this study. ISCO 2150 Area Velocity Flow meter was chosen to store real time data such as velocity, water depth and flow rate of sewage water in the sewer line. Figure 2 shows area velocity sensor that was attached to the flow meter to detect and measure the various data mentioned previously. A mounting ring functioned as the platform to fix the sensor in the sewer pipeline, thus the sensor will not be carried away even though high flow of sewage occurs. Flow link software version 5.1 was used to analyse the data retrieved from the flow meter. ISCO 674 Rain Gauge was installed in the compound of the sewerage treatment plant without any cover. The rain gauge was used to collect rainfall intensity and determine the relationship between flow rate and rainfall data.

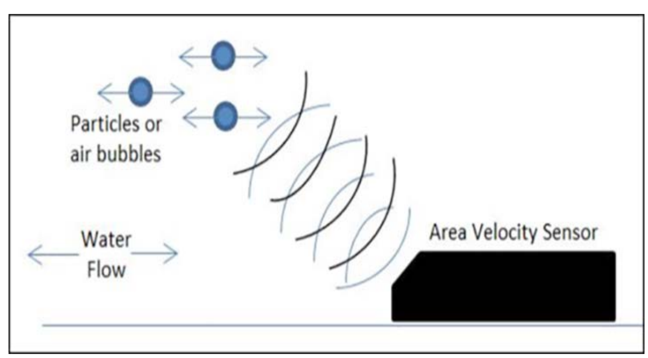

Figure 1. Ultrasonic technology sensor.

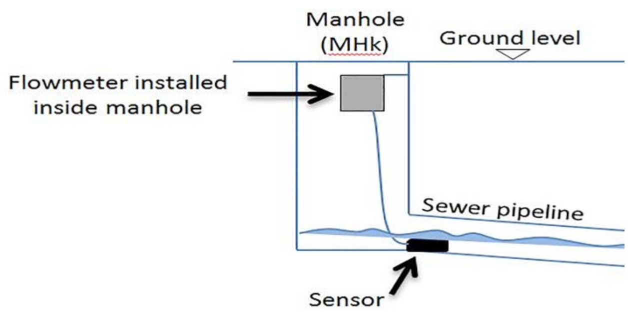

Figure 2. Sensor attached with flow meter and installed in selected manhole.

3. Results and Discussion

This study was conducted for 59 days from 13 December 2015 to 28 January 2016. The results were analysed separately for weekdays and weekends. Table 1 shows the summary of data collected from Taman Pandan Damai.

Table 1. Summary of data from Taman Pandan Damai

Data Set	Date	Weekday/ Weekend
MHk-01	13Dec15 – 20Dec15	Both
MHk-02	21Dec15 – 25Dec15	Weekday
MHk-03	26Dec15 – 31Dec15	Both
MHk-04	1Jan16 – 15Jan16	Both
MHk-05	16Jan16 – 17Jan16	Weekend
MHk-06	18Jan16 – 28Jan16	Both

3.1 Per Capita Flow, Q_{pcf}

Q_{ave} and PE were needed to calculate Q_{pcf} in this section by using Equation (1) as mentioned previously in Section 2.0. PE was the constant with the value of 2244 as surveyed from the site. Table 2 shows the calculation of per capita flow.

According to MSIG Volume 3 Clause 2.1.14, the design parameter per capita flow is 0.225 m^3/day/person. Based on the results, the average per capita flow was 0.36 m^3/day/person which is higher than the value mentioned in MSIG Volume 3 Clause 2.1.14. This phenomenon may have happened due to high rainfall intensity during the monitoring period. When there is high rainfall, the average sewage flow increased relatively compared to when there is no rainfall distributed in data set of MHk-01 and MHk-02.

Table 2. Per capita flow measurement

Data Set	Average flow, Q_{ave} (m^3/day)	Per Capita flow, Q_{pcf} (m^3/day/ person)	Total Rainfall (mm)
MHk-01	728.52	0.325	0.00
MHk-02	663.52	0.296	0.00
MHk-03	933.89	0.416	169.70
MHk-04	869.76	0.388	24.25
MHk-05	835.36	0.372	6.16
MHk-06	841.62	0.375	101.10

3.2 Design Criterion

Design criterion is one of the significant flow parameters in the design of sewerage systems. It can be measured by using Equation (2).

Table 3 shows the design criterion measurement according to the real time data obtained from Taman Pandan Damai. Based on the result, all sets of data were lower than the 4.7 stated in MSIG Volume 3 Clause 2.1.14. The highest value of design criterion occurred in the third set of data, MHk-03 with the value of 3.92. This happened due to the same reason of high rainfall on that day as shown in Table 2. Overall, the average design criterion was 2.61 which are 44% lower than 4.7.This shows that the sewer pipeline monitored was currently efficient to cater to the amount of PE. By comparison of Q_{peak} on weekday and weekend, weekend showed 0.61 times higher flow than weekday. This indicates that more people choose to stay at home during weekends in Taman Pandan Damai.

Table 3. Design criterion measurement

Data Set	Average flow, Q_{ave} (m^3/ day)	Peak flow, Q_{peak} (m^3/ day)	Design criterion, k
MHk-01	728.52	1473.98	2.21
MHk-02	663.52	1163.29	1.92
MHk-03	933.89	3348.60	3.92
MHk-04	869.76	2633.90	3.31
MHk-05	835.36	1397.00	1.83
MHk-06	841.62	1918.77	2.49

3.3 Flow pattern

In this study, flow pattern was presented using a hydrograph. It provides a clear picture to increase efficiency and understanding of readers. Figure 3 shows the flow pattern from 13 December 2015 to 28 January 2016.

According to Figure 3, peak flow occurred on 28 December 2015, 12.25 pm. The amount of peak flow was 38.51 m^3/day. This happened due to a rainfall with total amount of 169.7 mm on that day. This proves that when rainfall occurs, sewage flow rate in sewer pipeline relatively increase.

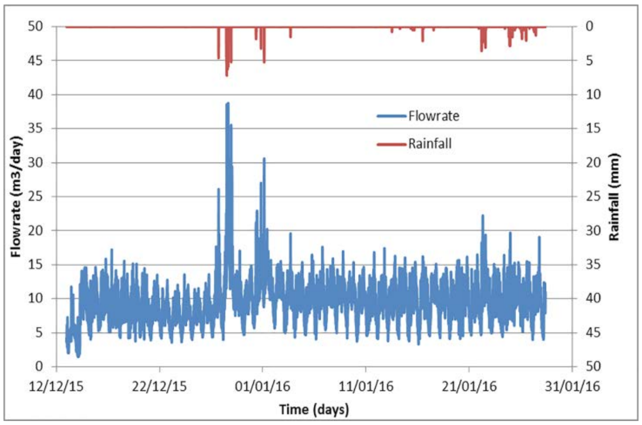

Figure 3. Flow pattern from 13 December 2015 to 28 January 2016.

4. Conclusion

Wrong consideration of flow design parameters may bring negative effects in terms of construction cost, human health and environmental issues. The flow parameters investigated in this study were per capita flow, Q_{pcf} and design criterion, *k*. The results showed that the per capita flow, Q_{pcf} measured was 0.36 m^3/day/person which is higher than the 0.225 m^3/day/person mentioned in MSIG Volume 3 Clause 2.1.14. Meanwhile, design criterion, k was 2.61 which is lower than the 4.7. This study has found that generally the sewer line studied is enough to cater to the PE. The sanitary flow in sewer line is unpredictable. Therefore more similar investigations are necessary before any revision of the design parameters currently in the MSIG Volume III is proposed.

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