Analysis of Flow Characteristics in Sewerage System

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Abstract.
In the present study, two parameters, the per capita flow and the design criterion, were investigated. The investigation was performed on a manhole located between the library and sports complex within Universiti Malaysia Pahang, Gambang campus (UMP Gambang) where field monitoring of sewage flows was conducted. ISCO 2150 area-velocity flowmeter was used to collect the flow data and Flowlink 5.1 software was used for data retrieval as well as display. Calibration of the flowmeter was done in the Hydraulics and Hydrology Laboratory of UMP Gambang. The study duration was from November 2014 to February 2015. Each set of data consists of sewage flow readings every 5 minutes for duration of two weeks. The same data measurement interval was applied to the rainfall data, collected through an ISCO 675 rain gauge. From the results obtained, both the parameters investigated were found to be lower than their respective values stated in the Malaysia Standard MS1228:1991. After analysis of the results, it can be concluded that the flow characteristics in the sewerage system studied is sufficient to cater to the population equivalent in the study.

Introduction

Sewerage system is a main consideration in any residential, commercial, and industrial development because it can enhance the environment through the disposal of wastewater. Moreover, it can also prevent floods through removal of rain water. Sewerage systems are located underground, which transport residential, commercial and industrial sewage to a wastewater treatment plant [1]. This research was conducted using area velocity method. The purpose of this research is to verify the suitable design criterion and by extension the parameters for sewerage system as recommended in MS 1228:1991. Other than that, this research also studies the effect of rainfall on sewerage flow pattern in the sewerage system and analyzes the flow characteristics in the sewerage system in UMP area to advance the proper way for cost minimization.

Study Area

The current study is more focused on facilities, industrial and commercial areas where determination of flow characteristics was conducted in a manhole (MH 07) located between the UMP library and sports complex in Gambang. Based on the drawing which was provided by UMP Holdings Bhd, population equivalent (PE) was calculated as 1473.

Selection Criteria of the Sewer Line

To define a suitable sewer pipeline in this research, there are some considerations that need to be taken into account when selecting the sewer line [2]:

- There is no lateral connection in the sewer line.
- There is no backflow and turbulence happening in the sewer line.
- The sewer flow inside the sewer line is steady and has little head loss.
- The manhole must be near to the sewerage treatment plant.

Governing Equation

After PE was determined, data was extracted from the flowmeter and, several equations were implemented from MS 1228:1991 used to design the sewerage system. Per capita flow and peak flow factor are the parameters that were needed to analyse flow characteristics in the sewer system. Equation (1) shows the calculation for per capital flow,

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

where, Q_{pcf} is per capita flow by unit with m^3/day/person, Q_{ave} stands for average daily flow obtained from data by unit with m^3/day and PE is the population equivalent. The peak flow in the sewerage system can be calculated by using Equation (2),

$$Q_{peak} = PFF \; x \; Q_{ave} \quad (2)$$

where, Q_{peak} is the peak flow in m^3/day, PFF is the peak flow factor, and Q_{ave} as stated before. The peak flow factor equation was implemented from MS 1228:1991 [3] and shown in Equation (3),

$$PFF = K \left(\frac{PE}{1000}\right)^{-0.11} \quad (3)$$

where, K is known as the design criterion in sewerage system and PE as described previously. To determine the value of design criterion, Equations (1), (2), and (3) were combined and rearranged to get Equation (4).

$$K = \frac{Q_{peak}}{(Q_{pcf} \; x \; PE)\left(\frac{PE}{1000}\right)^{-0.11}} \quad (4)$$

According to MS 1228: 1991 Clause 3.6 and Clause 3.2, value of design criterion, K will be taken as 4.7, while per capita flow, Q_{pcf} will be taken as 0.225 m^3/day/person [3]. To obtain the objectives, two parameters K and Q_{pcf} are needed for verification in this research.

Equipment Used

In this study, flow metering system was adopted to determine the flow characteristics. The equipment adopted is ISCO area velocity flowmeter model 2150 as shown in Figure 1. Meanwhile, ISCO 674 Rain Gauge was used to measure rainfall volume. Flowlink 5.1 was used to analyze the data and to retrieve the data by using Flowmeter Cable Adaptor from flowmeter to computer [4]. Flowrate data and rainfall data were collected at 5 minutes intervals, to make it more precise and accurate [5].

Figure 1. ISCO Area-Velocity flowmeter model 2150

Calibration of the Equipment used

Calibration of flowmeter and batteries were done in the Hydrology and Hydraulic Laboratory of UMP Gambang. The purpose of checking the flowmeter is to make sure it is ready to use and its batteries are working. Flowmeter was calibrated and compared with results from the open channel apparatus. Moreover, calibration of the equipment is to make sure the data collected is accurate and precise. After the flowmeter calibration was done, the following observations were made:

- There is a waiting time of around 1 to 2 minutes from switching the open channel on to recording the results from the flowmeter. It is because the flowmeter is slow to capture the change in flow rate when the velocity of flow is changed.
- Average percentage error of depth between ISCO 2150 flowmeter and open channel is 1.45%.
- Average percentage error of flow rate between ISCO 2150 flowmeter and open channel is 4.79%.

Result and Discussion

The flowmeter was installed in a selected manhole (MH 07) and the data was collected continuously from 17 November 2014 to 9 February 2015. Furthermore, every set of data was collected for 2 weeks with the interval of 5 minutes between each measurement reading. The continuous data was recorded in the form of depth, velocity, and flowrate of wastewater in MH 07. Same goes to rainfall data measured by the ISCO 674 Rain Gauge which was installed in the field of Residential College 2 within UMP Gambang compound. The total time recorded in this whole research is 2016 hours of flowrate data and rainfall data. The data were recorded on both weekdays and weekends. The detail of each set of data will be shown in hydrograph. The Q_{peak} and Q_{ave} can be calculated after data was collected including weekdays and weekends. The result is shown in Table 1 for all 6 sets of data from the study. From the summary of the result Table 2 shows the lowest Q_{peak} as 174.70 m^3/day from MH 07-05, while the highest Q_{peak} was 405.48 m^3/day from MH 07-03. Meanwhile, Q_{ave} in this research from the lowest is from the data set MH 07-05 at 86.16 m^3/day whereas the highest value is from data set MH 07-03 which is 163.41 m^3/day. Once flowrate data by interval of 5 minutes was determined Q_{peak} and Q_{ave}, and then Q_{pcf}, PFF, and K can be calculated by using Equations (1), (2), (3), and (4).

Per Capita Flow Contribution, Q_{pcf}

The average flow and peak flow using unit of m^3/day were calculated for all of the data sets. The data will be analysed in two-week blocks. The PE of the sewer line was calculated as mentioned in Section 2, so per capita flow can be calculated using Equation (1). From Equation (4), design criterion can be calculated after the per capita flow and peak flow were determined. Moreover, after design criterion was calculated from Equation (4), peak flow factor can be determined from Equation (3). Table 2 shows the detail of data collection for each set of data from MH 07.

Table 1. Data collected from manhole (MH 07)

Data Set	Time interval of data [minute]	Duration of 1 set of data [days]	Duration of Data collection [hours]	Rainfall during the time
MH07-01	5	14	336	Yes
MH07-02	5	14	336	Yes
MH07-03	5	14	336	Yes
MH07-04	5	14	336	Yes
MH07-05	5	14	336	Yes
MH07-06	5	14	336	Yes

Table 2. Flow characteristics for each data set from the study

Data Set	Peak Flow Q_{peak} [m^3/day]	Average flow Q_{ave} [m^3/day]	Population Equivalent PE
MH07-01	240.45	93.71	1473
MH07-02	268.36	101.72	1473
MH07-03	405.48	163.41	1473
MH07-04	296.87	122.50	1473
MH07-05	174.70	86.16	1473
MH07-06	223.43	102.72	1473

From Table 2, these values were compared with MS 1228:1991. From the comparison of peak flow and average flow obtained in this research with MS 1228:1991, the MS 1228:1991 will result in higher values of 1492.73 m^3/day for peak flow and 331.43 m^3/day for average flow compared to the values obtained from the current study. Those values were calculated using existing per capita flow and design criteria from MS 1228:1991 which are 0.225m^3/day/person and 4.7. A similar comparison was made for the per capita flow in Table 3. The per capita flow was found to be between 0.0585 m^3/day/person and 0.1109 m^3/day/person. These per capita flow values were compared to MS 1228:1991 and the result shows that the MS 1228:1991 has a higher value of 0.225 m^3/day/person [3] compared to the values found in the current study.

Design Criterion, K

A similar activity was performed to calculate design criterion using Equation (4) and the results are shown in Table 4. The values for the design criterion vary between 2.12 and 2.75. The results were compared to that recommended in MS 1228:1991. The actual design criterions that were calculated were lower than the design criterion value of 4.7 given in MS 1228:1991 [3].

Peak Flow Factor, PFF

Peak flow factor can be calculated using Equation (3) mentioned in the above. Table 5 shows the result of each set of data from Equation (3). After the calculations, the values of peak flow factor vary between 2.03 and 2.64. The peak flow factor calculated based on MS 1228:1991 is 4.5, which is higher compared to the actual peak flow factors calculated in Table 5.

Table 3. Per capita flow for the study

Data Set	Average flow Q_{ave} [m^3/day]	Population Equivalent PE	Per Capita Flow Q_{pcf} [m^3/day/person]
MH07-01	93.71	1473	0.0636
MH07-02	101.72	1473	0.0691
MH07-03	163.41	1473	0.1109
MH07-04	122.50	1473	0.0832
MH07-05	86.16	1473	0.0585
MH07-06	102.72	1473	0.0697

Table 4. Design criterion for the study

Data Set	Peak Flow Q_{peak} [m^3/day]	Per Capita Flow Q_{pcf} [m^3/day/person]	Population Equivalent PE	Design Criterion K
MH07-01	240.45	0.0636	1473	2.68
MH07-02	268.36	0.0691	1473	2.75
MH07-03	405.48	0.1109	1473	2.59
MH07-04	296.87	0.0832	1473	2.53
MH07-05	174.70	0.0585	1473	2.12
MH07-06	223.43	0.0697	1473	2.27

Table 5. Peak flow factor for the study

Data Set	Population Equivalent PE	Design Criterion K	Peak Flow Factor PFF
MH07-01	1473	2.68	2.57
MH07-02	1473	2.75	2.64
MH07-03	1473	2.59	2.48
MH07-04	1473	2.53	2.42
MH07-05	1473	2.12	2.03
MH07-06	1473	2.27	2.18

Flow Pattern

In this study, hydrograph will be shown to provide more information about the result. Hydrographs will be plotted in the form of flowrate by unit liters per day and rainfall in millimeter. In Figure 2, it shows the period of 17 November 2014 4pm to 9 February 2015 4pm. In On 23 December 2014 2pm, the hydrograph has shown the highest peak flow and highest rainfall volume in the study. The hydrograph shows the same characteristic, which is the peak flow will happen around 11.45am on weekdays if there is no rainfall distribution. This may occur because of people going to toilet before lunch or students going to toilet after class. On weekends, the hydrographs show very little flow, due to the reason weekends are not working hours and not lecturing time, so there are no people working in the office and no students going to classrooms. The effect of rainfall on sewerage flow pattern in the sewerage system will also be analysed in this study, so the objective is achieved. The high volume of rainfall was happened continuously from 21st to 24th December 2014, hence the hydrograph showing the flowrate on 23 December 2014, Tuesday, 2pm having the highest peak within the period. The possible reason for this is because of the rain infiltrating into the soil and then flowing to the sewer line. Other than that, there are some negative values for the flowrates measured. This may happen due to the flow being below the sensor detection limit, probably because the flow was too small. Besides that, this will also happen when rubbish blocked the sewer line, so the wastewater flow is too slow when it reached MH 07.

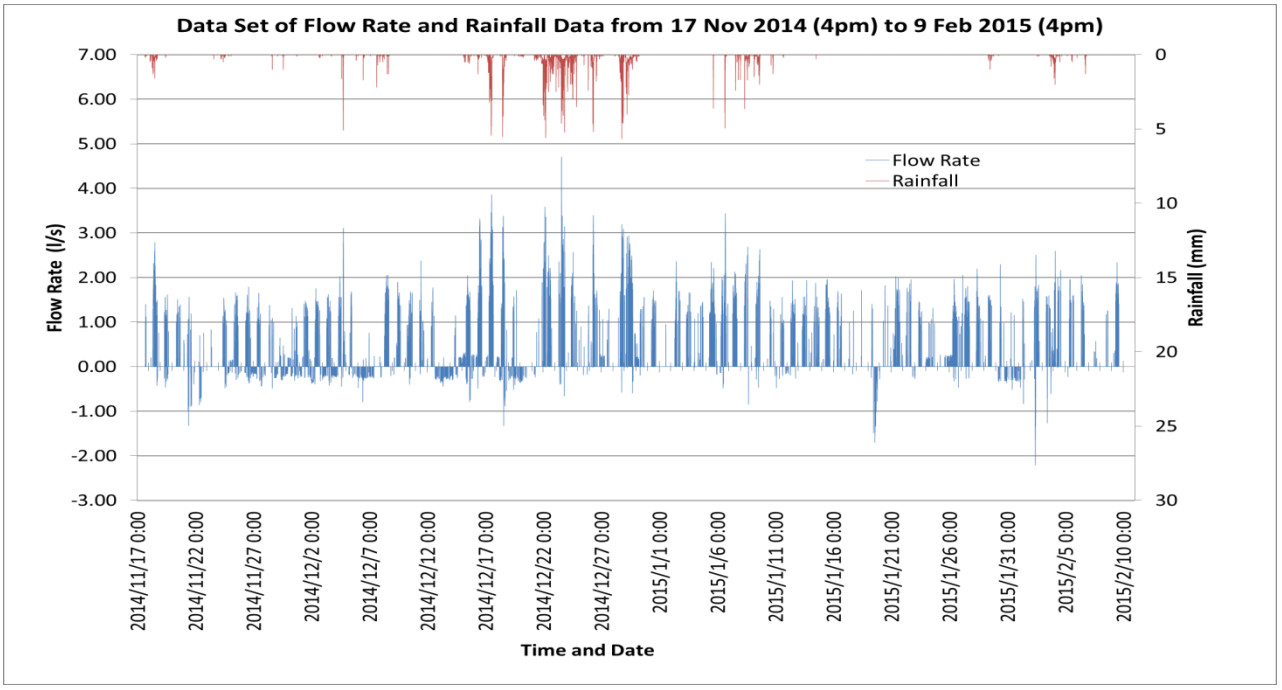

Figure 2. Result analysis from 17 Nov 2014, 4pm to 9 Feb 2015, 4pm

Conclusion

In this research, two parameters, the per capita flow and the design criterion, were assessed, so the objectives were achieved. Both parameters were found lower than the values stated in MS 1228:1991. The average per capita flow in this research is 0.076 m^3/day/person while MS 1228:1991 shows 0.225 m^3/day/person [3]. Same goes to design criterion, average of design criterion in this research is 2.49, while MS 1228:1991 stated 4.7 [3]. From the analysis and the comparison, they show that the sewer pipeline in UMP area was designed for high flow capacity. Thus, more cost can be saved for future development by using the new parameters. Other than that, rainfall is also one of the factors to be considered during design due to the fact that rainfall will influence flowrate of waste water in the sewer line.

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