Estimation of Parameters and Flow Characteristics for the Design of Sanitary Sewers in Malaysia

KAMRAN ANSARI*, ZAHEER AHMED ALMANI*, AND NAEEM AZIZ MEMON*

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ABSTRACT

Determination of the flow characteristics is very important for the design of sanitary sewers in any area. In the present study these are determined in the running sewers for the two parameters; per capita flow contribution and the peak flow factor. ISCO area - velocity flow meter model 4250 is used for this purpose. The flow meter, before being used in the running sewers, is calibrated first in the Hydraulics and Hydrology Laboratory of the UTM (Universiti Teknologi Malaysia). During the study the flow meter is installed inside the manhole in 10 different phases in the months of June, August, September, and October 2005 to monitor the sewage flow running in it. Continuous data is recorded in the flow meter during the process and the recorded time varies between 47 hours 25 minutes and 128 hours 35 minutes. The rainfall data is also collected during the same time using an automatic rain gauge which recorded rainfall at every five minutes of interval. Both the parameters thus calculated are then compared with the Malaysian Standard for sewer design i.e. MS 1228:1991. The results show that higher values of these parameters are being used in the design of sanitary sewers and extensive study needs to be carried out to review these values for future use.

Key Words: **Flow Characteristics, Peak Flow Factor, Per Capita Flow Contribution, Sewer Design**

1. INTRODUCTION

A sewerage system is basically a system consisting of pipes of various lengths and diameters connected together for the disposal of all kinds of wastewater including domestic, commercial and industrial to the treatment services. A major portion of the capital investment of any community is done in the sanitary sewer system which plays an important role in ensuring public health and environmental protection. The flow of wastewater in the sewers varies continuously throughout the day. For the design of wastewater collection, disposal and treatment services determination of flow rates in the system are of fundamental importance, Metcalf, et. al. [1]. Dependable data on existing and future flows must be obtained if these facilities are to be designed in a proper way so as to minimize the associated costs. In situations where the wastewater flow rates are unavailable or limited data is available then these have

* Assistant Professor, Department of Civil Engineering, Mehran University of Engineering & Technology, Jamshoro.

to be developed from the water records and other related record. Local practice for the design of sewers in Malaysia follows MS 1228 [2] which specifies the sewer size according to following Equation (1):

$$Q_{\text{peak hourly}} = K\left[0.225\frac{m^3}{(day-person)} \times PE\right]\left[\frac{PE}{1000}\right]^{-0.11} \quad (1)$$

where PE is Population Equivalent, and K is peak flow factor commonly taken as 4.7 and 0.225 $m^3/(day\text{-}person)$ is per capita flow contribution

The field verification of peak flow factor K equal to 4.7 and per capita flow contribution of 0.225 m^3/(day-person) is the subject of the present study.

2. STUDY AREA

The study for the determination of flow characteristics is conducted in two residential areas of Johor Bahru, Malaysia, in the vicinity of UTM. Two running sewers were selected in TSP (Taman Sri Pulai) and TU (Taman Universiti) localities with PE (Population Equivalents) of 1705 and 3456 respectively. Manhole MH11 was selected in the TSP area whereas manhole MH299 was chosen in the TU area.

3. SELECTION CRITERIA OF THE SEWER LINE

The choice of the sewer line was done keeping in view the following considerations:

(i) There is no lateral inflow into the sewer at that point.

(ii) There is no backflow taking place at that point due to any reason what so ever.

(iii) There is minimum loss of head there.

(iv) There is no turbulence in the flow.

(v) The line caters for a population equivalent of 1000 to 10,000.

4. EQUIPMENT USED

The flow characteristics in the running sewers were determined using the ISCO area velocity flow meter model 4250. The rainfall measurement was done through ISCO 674 rain gauge, which is connected to the ISCO 4250 area velocity flow meter, recording rainfall measurement every five minutes of interval. The data is retrieved from the flow meter with the help of the software; ISCO Flow Link 4.1for Windows [4]. Fig. 1 shows the picture of the flow meter used during the study.

5. CALIBRATION OF THE EQUIPMENT USED

The calibration of the area velocity flow meter was done in the hydrology and hydraulics laboratory of the UTM to confirm its accuracy first before using it in the field. For this purpose Laminar/Turbulance Flow Apparatus by Plint and Partners, UK is used. Two sensors were employed to check the depth of water, flow, and velocity in the channel

FIG. 1. ISCO AREA-VELOCITY FLOW METER MODEL 4250

(i) manually by using Manning's graph and (ii) by flow meter at the same time to check for the errors, if any, in the equipment. The following results were observed after going through whole procedure.

(i) The flow meter is unable to detect the true values of velocity and discharge in the channel when the depth is less than or equal to 29mm.

(ii) The depth of flow in the channel is found accurately by the flow meter.

(iii) For Sensor No. 1 the minimum and maximum errors found were 6.56% at a depth of 65mm and 31.35% at a depth of 35mm respectively.

(iv) For Sensor No. 2 the minimum and maximum errors seen were 1.12% at a depth of 86mm and 20.45% at a depth of 50mm respectively.

(v) The average percent error for Sensor No. 1 was 15.06% and that for Sensor No. 2 was 13.03%.

6. RESULTS AND DISCUSSION

The flow meter was installed in manhole MH11 in TSP residential area, with a population equivalent of 1705, in eight different periods in the months of June, August and September 2005 whereas it was installed in MH299 in TU area, with a population equivalent of 3456, in the months of September and October 2005 in two phases. Continuous data was recorded in the flow meter for the depth, velocity and discharge of flow in the sewer every five minutes of interval. Fig. 2 shows the picture of the flow meter installed in manhole MH11 of TSP area.

The minimum and maximum times of recording are 47 hours 25 minutes and 128 hours 35 minutes respectively. The data was recorded both on the weekdays as well as weekends to ascertain the variation on the flow between the two. It may also be mentioned that the data recording time include both dry and wet periods so that a clear picture may be derived for the flow characteristics. The details of each phase of data collection from the two manholes are given in Tables 1-2. The rainfall data was also continuously recorded near the respective manholes using ISCO 674 rain gauge during the same period.

The $Q_{peak\ hourly}$, $Q_{minimum\ hourly}$ and $Q_{average\ hourly}$ were calculated for all the phases of data collection separately for weekdays and weekends. The results are shown in Table 3 for all the ten phases of the study. The $Q_{peak\ hourly}$ varies between 0.73 and 5.12 liters/sec for the weekend periods whereas it varies between 0.73 and 5.84 liters/sec for the weekdays' periods. The $Q_{minimum\ hourly}$ is found to be from a minimum value of 0.23 liters/sec to a maximum value of 3.75 liters/sec for the weekend periods whereas it is found to be from 0.06-3.30 liters/sec for the weekdays' periods. The same exercise is done for flow Q average hourly which is seen to vary between the extremes values of 0.44 and 4.41 liters/sec during the weekends and between 0.38 and 4.61 liters/sec during the weekdays.

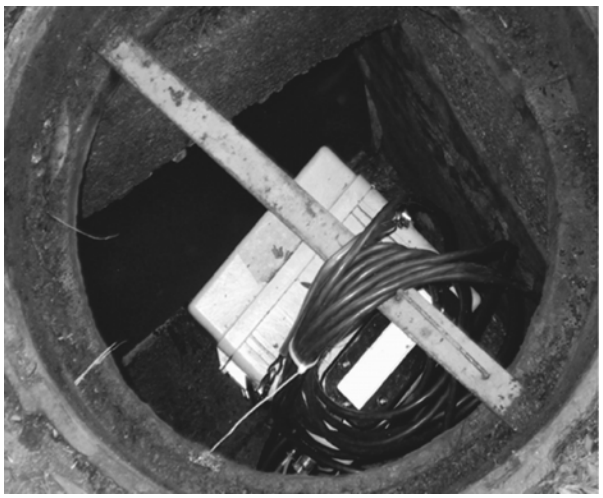

FIG. 2. FLOW METER INSTALLED IN MANHOLE MH11 IN TAMAN SRI PULAI AREA

6.1 Per Capita flow Contribution

The average flow in liters/sec and m^3/sec are calculated for all phases of the study for the two sewerage lines. The data is separated for the weekends and weekdays so as to analyse the difference of usage for the two periods. The PE for each line are already known. Using the average flow and PE for each phase of the study, per capita flow contribution in m^3/day is thus calculated. The values of the average flow and per capita flow

TABLE 1. DETAILS OF DATA COLLECTION FOR THE STUDY FROM MANHOLE MH11

Data ID	Duration of Data Collection	Rainfall During the Time	Weekday/Eeekend
MH11-01	82 Hours and 40 Minutes	Yes	Both
MH11-02	77 Hours and 40 Minutes	No	Both
MH11-03	84 Hours and 15 Minutes	No	Both
MH11-04	72 Hours and 15 Minutes	No	Both
MH11-05	48 Hours and 50 Minutes	No	Weekdays only
MH11-06	119 Hours and 55 Minutes	Yes	Both
MH11-07	47 Hours and 25 Minutes	Yes	Both
MH11-08	113 Hours and 10 Minutes	No	Both

TABLE 2. DETAILS OF DATA COLLECTION FOR THE STUDY FROM MANHOLE MH299

Data ID	Duration of Data Collection	Rainfall During the Time	Weekday/Weekend
MH299-01	121 Hours and 50 Minutes	Yes	Both
MH299-02	128 Hours and 35 Minutes	Yes	Both

TABLE 3. FLOW CHARACTERISTICS FOR ALL THE PHASES OF THE STUDY

Data ID	Weekend Flow (l/s)			Weekdays Flow (l/s)		
	$Q_{Peak\ Hours}$	$Q_{Minutes\ Hours}$	$Q_{Average\ Hours}$	$Q_{Peak\ Hours}$	$Q_{Minutes\ Hours}$	$Q_{Average\ Hours}$
MH11-01	0.83	0.23	0.55	0.73	0.27	0.54
MH11-02	0.73	0.23	0.44	0.73	0.06	0.38
MH11-03	2.78	1.31	2.13	2.90	1.37	2.17
MH11-04	2.82	1.57	2.16	2.59	1.32	1.99
MH11-05	NA	NA	NA	3.01	1.22	2.28
MH11-06	3.03	1.42	2.34	3.08	1.09	2.28
MH11-07	4.32	0.14	3.04	3.12	1.01	2.31
MH11-08	NA	NA	NA	3.89	1.87	3.06
MH299-01	3.26	2.09	2.61	4.70	3.30	3.98
MH299-02	5.12	3.75	4.41	5.84	2.86	4.61

contribution for each phase of study during the weekend periods are shown in Table 4. The average flow in liters/sec varies between 0.44 and 4.41 for the eight sets of data. Two data sets did not include and weekend days. The per capita flow contribution in m^3/(day-person) is found to have a minimum value of 0.022 and a maximum value of 0.154. These values are then compared with the Malaysian Standards MS 1228 [2]. The comparison shows that the per capita flow contribution as found through the study is lower than the value given by Malaysian standards for sewer design.

A similar exercise is done to calculate the per capita flow contribution for all the sets of data during the weekdays' periods (Table 5). The average flow during the weekdays is found to vary between 0.38 and 4.61 liters/sec. Whereas the per capita contribution is found to vary between 0.019 and 0.155 m^3/day-person. These values are again compared with the Malaysian Standards MS 1228 [2] and the results show a similar trend as witnessed during the weekends.

6.2 Peak Flow Factor

The maximum flow for each set of data is calculated separately for the weekends and weekdays periods. The average of the two is then calculated and is used with per capita contribution to find the peak flow factor (K). Table 6 shows the peak flow factors in the last column for each set of data collected during the study. The peak flow factor is found to vary between the extreme values of 2.02 and 4.35 and the average value being 2.84. These values are compared with the Malaysian Standards MS1228 [2]. The comparison shows a lower value for the peak flow factor than the Malaysian standard which is 4.7.

6.3 Flow Pattern

Graphs are also plotted for the hydrographs of flow against time for all the sets of data to ascertain the flow pattern in the sewer lines. Fig. 3 shows hydrograph for the monitoring of flow rate inside manhole MH299 and rainfall in its vicinity during the monitoring period of 22nd to 27th

TABLE 4. PER CAPITA FLOW CONTRIBUTION DURING THE WEEKENDS

Data ID	Average Flow (l/s)	Average Flow (m^3/day)	PE for Line	Per Capita Flow Contribution
MH11-01	1.37	118.37	1705	0.069
MH11-02	0.44	38.02	1705	0.022
MH11-03	2.13	184.03	1705	0.108
MH11-04	2.16	186.62	1705	0.109
MH11-05	NA	NA	NA	NA
MH11-06	2.34	202.18	1705	0.119
MH11-07	3.04	262.66	1705	0.154
MH11-08	NA	NA	NA	NA
MH299-01	2.61	225.50	3456	0.065
MH299-02	4.41	381.02	3456	0.110

September 2005. Analysis is however done on 24 hour basis for the weekend and weekday flows separately. Rainfall in the vicinity of the manhole is also recorded and plotted to see its effect on the flow in the sewer. During weekdays the graph shows a peak in the flow around 7:30 am in the morning and then there is low flow continuously until around 7:30 pm in the evening. These two peaks show the timings of the people getting ready to go to their offices and schools etc in the morning and coming back from work and taking a bath in the evening. Fig. 4 shows a typical hydrograph on a weekday in manhole MH11. There was no rainfall witnessed on that day.

TABLE 5. PER CAPITA FLOW CONTRIBUTION DURING THE WEEKDAYS

Data ID	Average Flow (l/s)	Average Flow (m^3/day)	PE for Line	Per Capita Flow Contribution
MH11-01	0.54	46.66	1705	0.027
MH11-02	0.38	32.83	1705	0.019
MH11-03	2.17	187.49	1705	0.110
MH11-04	1.99	171.94	1705	0.101
MH11-05	2.28	196.99	1705	0.116
MH11-06	2.28	196.99	1705	0.116
MH11-07	2.31	199.58	1705	0.117
MH11-08	3.06	264.38	1705	0.155
MH299-01	3.98	343.87	3456	0.100
MH299-02	4.61	398.30	3456	0.115

TABLE 6. MAXIMUM FLOW, PER CAPITA FLOW CONTRIBUTION AND PEAK FLOW FACTOR FOR EACH SET OF DATA

Data ID	Weekend		Weekdays		Average		Per Capita Flow	Peak Flow Factor (K)
	Q_{max} (l/s)	Q_{max} (m^3/day)	Q_{max} (l/s)	Q_{max} (m^3/day)	Q_{max} (l/s)	Q_{max} (m^3/day)	Contribution m^3/(day-person)	
MH11-01	2.20	190.08	1.40	120.96	1.800	155.520	0.048	2.02
MH11-02	1.90	164.16	1.50	129.60	1.700	146.880	0.021	4.35
MH11-03	5.10	440.64	6.20	535.68	5.650	488.160	0.109	2.79
MH11-04	5.50	475.20	5.80	501.12	5.650	488.160	0.105	2.57
MH11-05	N.A.	N.A.	7.10	613.44	7.100	613.440	0.116	2.92
MH11-06	5.50	475.20	10.00	864.00	7.750	669.600	0.118	3.14
MH11-07	5.90	509.76	6.00	518.40	5.950	514.080	0.136	2.09
MH11-08	N.A.	N.A.	8.50	734.40	8.500	734.400	0.155	2.62
MH299-01	6.40	552.96	10.90	941.76	8.650	747.360	0.0825	3.00
MH299-02	8.90	768.96	13.80	1192.32	11.350	980.640	0.1125	2.89

During weekends the graph shows a different picture of flow during the morning hours instead of instant peak in the flow around 7:30 am in the morning there is continuous high flow for a longer duration from 7:30-10:00 am. In the evening however there is not much change in the flow pattern and a single peak is observed around the same time as seen during the weekdays. The morning continuous high flow for nearly two hours shows that on weekends people don't wake up at the same time and tend to relax before going to bathroom. In the evening after spending their day in household works or a day out with family they again take a bath before taking their dinners. Fig. 5 shows a typical hydrograph on a weekend in manhole MH11. There was again no rainfall witnessed on that day.

The effect of rainfall on the flow pattern is also analysed during the study. Fig. 6 shows the hydrograph in manhole MH11 on a weekday when there was substantial rainfall in the area. It is clearly seen that apart from the two peaks in the flow in the morning and evening, another peak is visible just after the rainfall. This may be due to the infiltration and inflow of the rain water into the sewerage system.

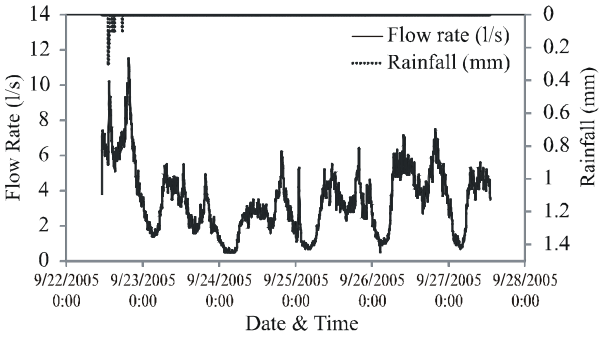

FIG. 3. HYDROGRAPH SHOWING THE MONITORING OF FLOW INSIDE MANHOLE MH299 ALONG WITH RAINFALL IN THE VICINITY

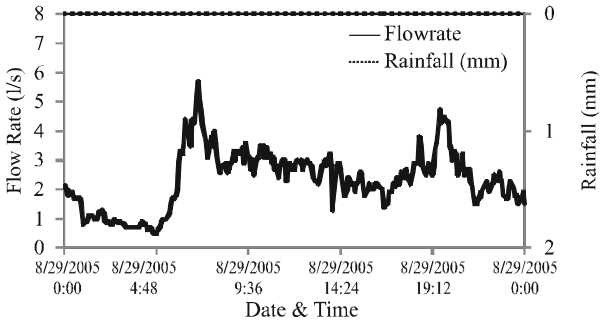

FIG. 4. TYPICAL HYDROGRAPH IN MANHOLE MH11 ON A WEEKDAY ON 29TH AUGUST 2005 BEING A MONDAY

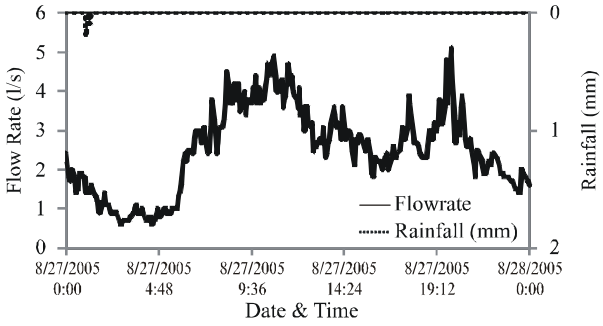

FIG. 5. TYPICAL HYDROGRAPH IN MANHOLE MH11 ON A WEEKEND ON 27TH AUGUST 2005 BEING A SATURDAY

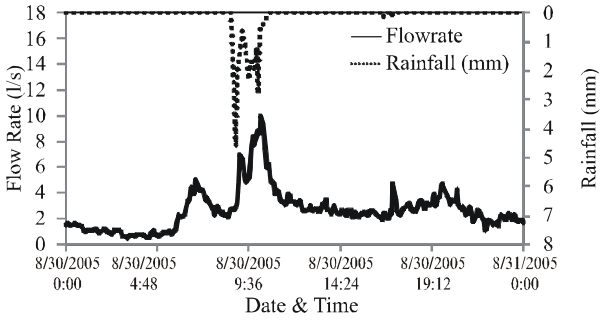

FIG. 6. HYDROGRAPH IN MANHOLE MH11 ON A WEEKDAY ON 30TH AUGUST 2005 WITH INFLUENCE OF RAINFALL

7. CONCLUSIONS

Two parameters for the design of sanitary sewers, per capita flow contribution and peak flow factor, were assessed during the study. Both these factors were found to be lower than the values as given by the Malaysian Standards MS1228. The mean value found for the per capita flow contribution was 0.096 m^3/day-person which is given as 0.225 m^3/day-person in MS1228. Similarly a mean value of 2.84 is found for the peak flow factor which is given as 4.7 in the Malaysian Standards.

An analysis is also carried out for the flow pattern in the two lines which shows a different pattern of water usage during the weekdays and weekends. Also a large influence of the rainfall is witnessed which may be over burdening the treatment plants.

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