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INVESTIGATION OF DESIGN FLOW IN SEPARATE SEWER SYSTEMS OF KUANTAN, PAHANG

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ABSTRACT

Flow design parameters such as per capita flow and design criterion are significant in the design of sewerage systems. Malaysian sewerage systems are designed according to the Malaysian Sewerage Industry Guidelines (MSIG). Wrong consideration of flow design parameters brings negative effects in terms of construction cost, human health and environmental issues. The purpose of this research is to analyze and compare the per capita flow as well as design criterion in the sewerage systems of Kuantan, Pahang to their counterpart in the MSIG. Flowrate data was collected from two residential areas, Taman Pandan Damai and Bandar Putra with duration of 49 days. Population equivalent (PE) survey was done at the selected site locations. The resultant PE is 2244 and 1694, respectively. ISCO 4250 Area Velocity Flowmeter was used to collect real time flowrate data with intervals of five minutes. Flowrate data is analyzed separately for weekday and weekend. The average per capita flow result obtained from the sites is 0.277m^3/day/person which is 23% higher than the 0.225m^3/day/person stated in MSIG. Meanwhile, the results of average design criterion was 3.02, 36% lower than the 4.7 mentioned in MSIG. This indicated that the design of the sewerage systems in Taman Pandan Damai and Bandar Putra were effective and is more than enough to cater to the PE surveyed. More data, especially from long-term period collection, is desirable to determine whether revision of the flow design parameters in MSIG is needed.

Keywords: Peak flow factor; design criterion; separate sewer system.

1 INTRODUCTION

Sewerage system is a system composed of several sewer lines (Yap et al., 2016). Its function is to transport sanitary water from residential, industrial and commercial areas to sewerage treatment plants (Rahman et al., 2007). In Malaysia, the separate sewerage system is commonly applied. Guideline for the design of sewerage systems used in Malaysia is contained in the Malaysian Sewerage Industry Guidelines (MSIG) which incorporates the Malaysian Standard Code of Practice for Design and Installation of Sewerage Systems. A sewerage system should be designed for optimum flow (Swamee, 2001). The highest peak flow and large per capita flows need to be considered (Ridenour and Lacy, 1932). Flow design also depends on the wastewater flow contributed by the population equivalent (PE) (MSIG, 2009). The MSIG incorporates the sewer design from MS 1228:1991. However, MS 1228:1991 itself is based on British Standard BS 8005:1987 (Ngien and Ng, 2013; MS 1228:1991). BS 8005:1987 has been revised twice since it was first published, with the latest version in the form of BS EN 752:2008. The design parameters such as design criterion, peak flow factor and per capita flow should be based on the condition of climate, topography, and geography of the country (Ngien and Yap, 2017). Based on this scenario, the current sewerage system design parameters should be verified and checked for suitability in Malaysia. The objective of this research is to analyze and compare the per capita flow as well as design criterion in the sewerage systems of Kuantan, Pahang to their counterpart in the MSIG.

Literatures of similar studies that have been conducted in Malaysia are quite limited. One study that was performed at Skudai, Johor Bahru discovered that the parameters per capita flow and design criterion were 57% and 40% lower than the values stated in MS 1228:1991, respectively (Ansari et al., 2013). Another study done by Rahman et al. (2003) also points toward lower parameter values than recommended in the standard. This group of researchers (Rahman et al., 2003) also extended their study to include water inflow and infiltration parameters in the sewer pipeline. In Kuantan, a research has been conducted in the area of Gambang for five months. The results showed that the parameters investigated were also lower than those in the MS 1228:1991, which led the authors to suggest that more construction cost can be saved by adopting new design parameters (Yap and Ngien, 2015). Internationally, a study was conducted to investigate a small sewerage catchment in Cairo, Egypt where the peak flow factors were estimated and compared using three different methods. The

authors mentioned that different plant components should be designed according to their critical peak condition (Iman and Elnakar, 2013).

1.1 Principle of design flow

Flow design parameters such as per capita flow and design criterion are significant in the design of sewerage systems (Zhang et al., 2005). Wrong consideration of flow design parameters may bring negative effects in terms of construction cost, human health and environmental issues (Ngien and Yap, 2017). The value of per capita flow and design criterion are determined through the following equations that are provided in the MSIG. Per capita flow, Q_{pcf} can be calculated by using Eq. [1],

$$Q_{pcf} = \frac{Q_{ave}}{PE} \quad [1]$$

Where Q_{pcf} has a unit of m^3/day/person. Q_{ave} means average daily flow in the sewer line with unit of m^3/day, and PE is population equivalent and has no unit. Eq. [2]. shows the calculation of peak flow in sewer pipelines (Yap and Ngien, 2015),

$$Q_{peak} = PFF \; x \; Q_{ave} \quad [2]$$

Where Q_{peak} stands for daily peak flow with a unit of m^3/day, while PFF refers to the peak flow factor that is unitless. Based on MSIG, the PFF can be calculated using Eq. [3],

$$PFF = k \, (\frac{PE}{1000})^{-0.11} \quad [3]$$

Where k is known as the design criterion with a value of 4.7. It can be calculated by using Eq. [4], which is a combination of Eq. [2] and Eq. [3].

$$k = \frac{Q_{peak}}{(Q_{ave}) \, (\frac{PE}{1000})^{-0.11}} \quad [4]$$

As mentioned in MSIG, the design criterion$k$, is prescribed with the value 4.7 in Clause 21.1.14.II. Meanwhile, per capita flow Q_{pcf} is stated as 0.225 m^3/day/person in Clause 2.1.14.I. To accomplish the research objective, these parameters were studied at the study locations.

2 METHODOLOGY

2.1 Site review

This study requires fieldwork at residential areas in Kuantan, Pahang. Collaboration was set up with Indah Water Konsortium Sdn. Bhd. (IWK). IWK is the sole national sewerage company in Malaysia. There are few site locations that had been monitored in this research, but two residential areas were discussed in this paper, Taman Pandan Damai and Bandar Putra. The criterion for the selection of sewer line to be studied was that the manhole has to be the last manhole before the sewerage treatment plant in order to capture the sewage flow from the whole residential area. Thus, critical flow can be determined. Moreover, the condition of manhole must be clean enough, thus the reading would not be affected by obstacles. The manholes were selected at Taman Pandan Damai and Bandar Putra was MHk and MH92b, respectively. Population equivalent survey was done in those areas. The result of the surveys showed that Taman Pandan Damai, and Bandar Putra have PE of 2244, and 1694, respectively.

2.2 Equipment and material used

Ultrasonic technology that adopts the Doppler Effect was used in this research. ISCO 4250 Area Velocity Flowmeter attached to a Low Profile Sensor was installed in the selected manhole at site locations. Before the installation, flowmeter calibration was done at the Hydraulic and Hydrology Laboratory at University Malaysia Pahang (UMP). The results of the flowmeter calibration were incorporated into the analysis section. The flowmeter functioned to collect data in terms of flowrate, velocity as well as water depth of the sewage water in the sewer pipeline at intervals of five minutes. Five minutes of interval data collection is more precise compared to more than 30 minutes (Yap et al., 2016). The condition of sewer flow in sewer pipeline and weather are unexpected. The interval of time being smaller is more valuable to this study. Flowlink software version 5.1 was adopted to retrieve and analyze data from the flowmeter.

3 RESULTS AND DISCUSSIONS

This research was conducted for 49 days and the data was separated into weekdays, weekends and both for the analysis. Table 1 presents the details of the monitored site locations. Data collected at Taman Pandan Damai was divided into three sets from 25 November 2015 to 11 December 2015. The data collected at Bandar Putra was divided into five sets with the period investigated from 11 March 2016 to 8 April 2016.

Table 1. Information summary of the site locations.

Site Location	Data Set	Monitoring Period	Weekday/Weekend
Taman Pandan Damai	MHk-01	26 Nov 2015 - 3 Dec 2015	Both
(PE: 2244)	MHk-02	5 Dec 2015 - 6 Dec 2015	Weekend
	MHk-03	7 Dec 2015 - 11 Dec 2015	Weekday
Bandar Putra	MH92b-01	11 Mar 2016 - 13 Mar 2016	Both
(PE: 1694)	MH92b-02	14 Mar 2016 - 20 Mar 2016	Both
	MH92b-03	21 Mar 2016 - 23 Mar 2016	Both
	MH92b-04	31 Mar 2016 - 3 Apr 2016	Both
	MH92b-05	4 Apr 2016 - 8 Apr 2016	Weekday

3.1 Per capita flow, Q_{pcf}

In this study, Q_{pcf} was calculated by using the average daily flow obtained from the sites divided by the PE surveyed in the area, as displayed in Eq. [1] previously. Table 2 shows the calculated results of Q_{pcf} for each data set and each site.

Table 2. Tabulated data of Q_{pcf}.

Site Locations	Data Set	Average daily flow, Q_{ave} (m^3/d)	Per capita flow, Q_{pcf} (m^3/d/person)
Taman Pandan	MHk-01	405.75	0.181
Damai	MHk-02	749.00	0.334
(PE: 2244)	MHk-03	603.97	0.269
Bandar Putra	MH92b-01	547.99	0.323
(PE: 1694)	MH92b-02	487.96	0.288
	MH92b-03	501.11	0.296
	MH92b-04	501.10	0.296
	MH92b-05	439.84	0.260

From Table 2, it can be seen clearly that the result of Q_{pcf} during weekend at Taman Pandan Damai was the highest with the amount of 0.334 m3/day/person compared to the data sets of MHk-01 and MHk-03. In overall, the Q_{pcf} data was measured from Taman Pandan Damai was 0.261 m3/day/person which was 16% and this was slightly higher than 0.225 m3/day/person mentioned in MSIG. Meanwhile, there was only one set of Q_{pcf} data that was lower than the value stated in MSIG and it came from data set MHk-01. By comparing weekday to weekend, the Q_{ave} was relatively higher during weekends than weekdays.

Moreover, the result of Q_{pcf} at Bandar Putra was tested and the same result as Taman Pandan Damai with higher value than value mentioned in MSIG obtained. The range of per capita flow results from the location was 0.260 m3/day/person to 0.323 m3/day/person. The overall result of Q_{pcf} was calculated at Bandar Putra with amount of 0.293 m3/day/person. This may have been due to high wastewater flow through the monitored sewer pipeline from the residents of Bandar Putra. The resultant per capita flow from both locations was calculated as 0.277 m3/day/person which is still 23% lower than 0.225 m3/day/person in the MSIG.

3.2 Design criterion, k

Peak flow and average daily flow were obtained from sites and input into Eq. [4] to get the result of k, which is the main parameter in designing a sewer line. Table 3 shows the calculation of design criterion from the monitored sites. Based on the result shown, the k obtained from field data was lower than 4.7 stated in the MSIG in all the data sets. The highest k value was found in Taman Pandan Damai at MHk-01. This could have happened due to Q_{ave} being indirectly proportional to$k$. When Q_{ave} increase, k will relatively decrease. Design criterion from data set MHk-01 was the highest among all the sets of data from both locations. The average k at Taman Pandan Damai was calculated to be 3.38. Meanwhile, the amount of average k at Bandar Putra was only 2.65 which is lower compared to Taman Pandan Damai. The resultant k calculated from all data sets from the sites was 3.02 which is 36% lower than 4.7. The sewer lines investigated in Taman Pandan Damai and Bandar Putra were effective and enough to cater to the amount of PE there.

Table 3. Design criterion calculation.

Site Locations	Data Set	Peak flow, Q_{peak} (m^3/d)	Average daily flow, Q_{ave} (m^3/d)	Design Criterion, k
Taman Pandan Damai (PE: 2244)	MHk-01	1571.10	405.75	4.23
	MHk-02	1315.96	749.00	1.92
	MHk-03	2203.29	603.97	3.99
Bandar Putra (PE: 1694)	MH92b-01	1242.09	547.99	2.40
	MH92b-02	1142.29	487.96	2.48
	MH92b-03	1036.20	501.11	2.19
	MH92b-04	1410.74	501.10	2.98
	MH92b-05	1333.50	439.84	3.21

3.3 Flow pattern

Flow pattern of the three different site locations were investigated. Figure 1 shows the average flow, maximum flow and minimum flow analyzed in a day at Taman Pandan Damai. Based on Figure 1, it can be seen clearly the amount of daily flowrate at early of the day from period of 4am to 9am morning is higher compared to the end of the day from period of 9am to 12am midnight at Taman Panda Damai. However, there is another peak flow that occurred at 11.50am. This may happen and it does not rule out the high amount of rainfall that occurred and inflow to sewer pipeline at the time during the investigated period.

Figure 2 shows the daily flow pattern in Bandar Putra from 11 March 2016 to 8 April 2016. It can be seen clearly the peak flow happened at 5.20am morning. The peak flow in between the period from 5am to 9am was high compared to over the entire period. The high volume of sewage flow was detected in monitored manhole. This may happened due to residents preparing to go to work or school at the period, thus higher amount of wastewater was detected. It does not rule out the high amount of rainfall involved, because the peak flow was too high over the period. Another peak occurred during the period from 6pm to 8pm evening. This may happened due to residents coming back from work or school where sanitary activities were done.

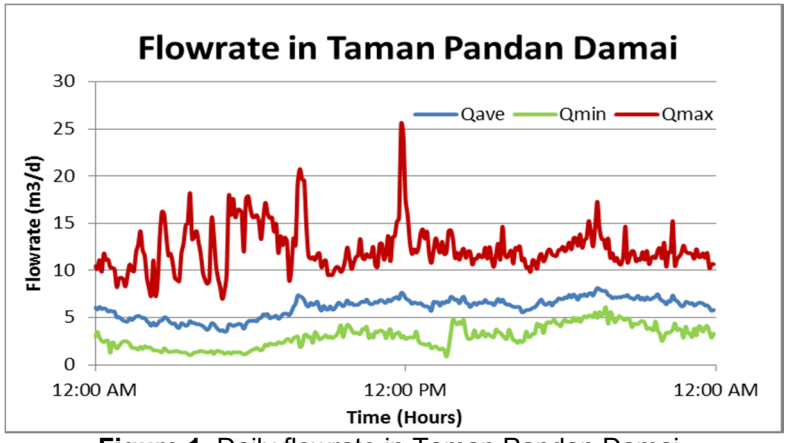

Figure 1. Daily flowrate in Taman Pandan Damai.

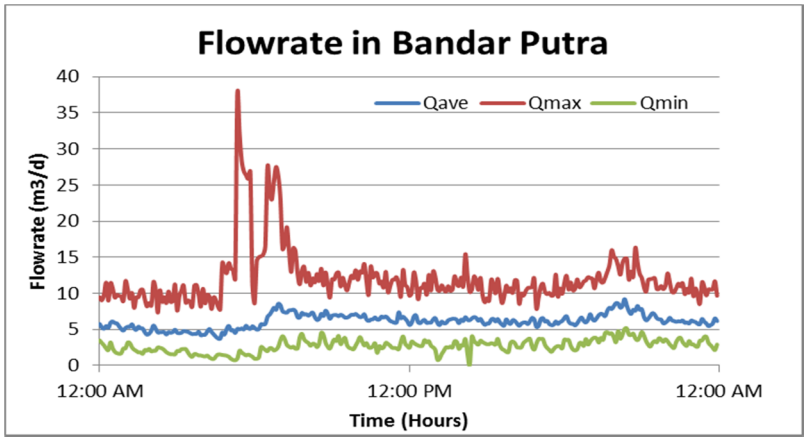

Figure 2. Daily flowrate in Bandar Putra.

4 CONCLUSIONS

The present study was designed to determine and compare the per capita flow as well as design criterion in the sewerage systems of Kuantan, Pahang to their counterpart in the MSIG. The objective was achieved. The overall average per capital flow, Q_{pcf} in this study is measured at 0.277 m^3/day/person, which is 23% higher than the 0.225 m^3/d/person stated in MSIG. Meanwhile, the resultant design criterion, k obtained from this study was 3.02, 36% lower than 4.7. This study has found that generally the sewer lines in the areas studied are sufficient to cater to the PE of those sites. Sanitary flow in sewer line is unpredictable, hence long term period investigations are necessary, with added input such as real time rainfall intensity data.

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REFERENCES

Ansari, K., Almani, Z.A. & Memon, N.A. (2013). Estimation of Parameters and Flow Characteristics for The Design of Sanitary Sewers in Malaysia. *Mehran University Research Journal of Engineering & Technology*. 32(1): 95-102.

BS (British Standard). (2008). *EN 752:2008*. *Drain and Sewer Systems Outside Buildings*. BSI, London, UK.

BS (British Standard). (1987). *BS 8005:1987*. Sewerage. *Guide to New Sewerage Construction*. BSI, London, UK.

DESA (Department of Economic and Social Affairs) (2016) Population Division. See http://countrymeters.info/en/Malaysia (accessed 12/8/2016), United Nations.

Imam, E.H. & Elnakar, H.Y. (2013). Design Flow Factors for Sewerage Systems in Small Arid Communities. *Journal of Advanced Research*. 5, 537-542.

MS (Malaysian Standard). (1991). *MS 1228:1991: Malaysian Standard Code of Practice for Design and Installation of Sewerage System*. Standards and Industrial Research Institute of Malaysia (SIRIM), Cyberjaya, Selangor, Malaysia.

MSIG (Malaysian Sewerage Industry Guidelines). (2009). *Sewer networks & Pump Stations*. Volume 3. Edition 3rd. Malaysia, Suruhanjaya Perkhidmatan Air Negara (SPAN), Selangor, Malaysia.

Ngien, S.K. & Ng, S.P. (2013). An Evaluation of the Design Criterion for Sewerage Peak Flow Factor at SEGi University Hostel. *SEGI Review*. 6, 65-71.

Ngien, S.K. & Yap, H.T. (2017). Flow Design of Sewerage System–A Case Study in Taman Pandan Damai, Kuantan. *Indian Journal of Science and Technology*, 10(2), 1-4.

Rahman, N.A., Alias, N., Salleh, S.S.M. & Samion, M.K.H. (2007). Evaluation of Design Criteria for Inflow and Infiltration of Medium Scale Sewerage Catchment System. *Technical Report*. UTM: 74281/2007.

Rahman, N.A., Jasmi, M.A., Hamid, M.H.H.A. & Baki, A.M. (2003). Kajian Aliran Masuk dan Penyusupan Dalam Sistem Pembetungan di Taman Sri Pulai, Skudai. *Jurnal Teknologi*. 39 (B): 17-28.

Ridenour, G.M. & Lacy, I.O. (1932). Institutional Sewage and Sewage Flow Characteristics. *Sewage Works Journal. ASCE*, 4(6), 1046-1053.

Swamee, P.K. (2001). Design of Sewer Line. *Journal of Environmental Engineering*. *ASCE*, 127(9), 776-781.

Yap, H.T. & Ngien, S.K. (2015). Analysis of Flow Characteristics in Sewerage System. *Applied Mechanics and Materials*. 802(1), 599-604.

Yap, H.T., Ngien, S.K. & Ahmad, S.W. (2016). Assessment on Inflow and Infiltration in Sewerage Systems of Kuantan, Pahang. *2nd International Congress on Technology - Engineering & Science*, 28 - 29 July 2016, Kuala Lumpur, Malaysia.

Yap, H.T., Ngien, S.K., Othman, N.B., Ghani, N.A.B.A.A. & Rahman, N.B.A. (2016). Parametric Investigation in Malaysian Separate Sewer Systems. *Proceedings of the Institution of Civil Engineers-Municipal Engineer*, 1-8. Thomas Telford Ltd.

Zhang, X.Y., Buchberger, S.G. & Zyl, J.E. (2005). A Theoretical Explanation for Peaking Factors. *Impacts of Global Climate Change. ASCE,* 1(1), 1-12.

