CHOICE OF THE DESIGN RAINFALL FOR SEWERAGE ASSESSMENT USING ANALYTICAL TOOL DATER IN SLOVAKIA

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ABSTRACT

Storm water management in urbanized areas is currently a global issue. In order to verify the correct functioning of the sewer networks and their objects, it is necessary to regularly assess their hydraulic capacity. Key of assessing the capacity of single and rainwater sewer networks is the calculation of the amount of surface runoff and the selection of a suitable design rainfall model. This article deals with the issue of effective decision making in the choice of the design rainfall for the hydraulic assessment of the sewer systems. DATER (decisive analytical tool for effective rainfall) was used as a analytical tool for rain analysis. This article incorporates case study in town of Vráble. During this research, several meteorological stations have been allocated in the area of interest in order to record actual rainfall data leading to its comparison with synthetic design rainfall.

Key words: *analytical tool, design rainfall, sewer assessment*

1 INTRODUCTION

The problem of storm water management is associated with sewer networks that are directly connected to the environment with combined sewer overflows. Hydrological and hydrodynamic models are used to verify the proper functioning of the sewerage network, but design rainfall is mostly chosen from one or very few measured rainfall. Therefore, design rainfall discharges may not sufficiently represent the real course and, also due to climate change over the last decade, the intensity of actual rainfall. Another factor in the assessment is the spatial variability of the area of interest (Peleg N., 2017),(Bruni G., 2015), in particular the size of the site, the slope of the area surface, the surface retention and other parameters that influence the formation of the sewer districts and the associated drainage curves.

2 DESIGN RAINFALL

When assessing single and rainfall sewer networks, sewage water flow is negligible at times of intense rain, and we use design rainfall to determine the design flow. For hydrodynamic modelling, it is also important to include the spatial variability of the territory reflected in the models by the time shift of the precipitation event within the single sewerage districts (McRobie F.H.,),(Ochoa-Rodriguez S., 2015). Due to the unpredictable nature of meteorological events, it is not always possible for the engineers to record a rainfall event for the selected interest area at a particular time period. An example is the recorded dry period of the last few years in Slovakia. For these reasons, often historical storm events in the models are replaced by mathematical rainfall, so the design rainfall can be easily categorized into 2 groups – i.e. historical and mathematical rainfall. Classification of mathematical rainfall according to their use in the design and assessment of sewer systems in Slovakia is possible in two sub-groups, namely synthetic and block rainfalls.

2.1 Historical rainfall

Historical rainfalls represent recorded storm events that were recorded during the review period in the area of interest. These storms are individually evaluated and further used in hydraulic sewage assessments, but also a long-term measurements can be used as continuous long-term simulation, including dry periods between storm events. The importance of historical rainfalls lies in their use in the calibration of hydrodynamic models of sewer networks. With the usage of meteorological devices suitably located on sewer system objects and their time correlation with rainfall data recorded in the area of interest, it is possible to modify the hydrodynamic model parameters to describe the actual state as close as possible.

2.2 Mathemtical rainfalls

When designing sewer networks with a rational method, we use block design rainfall due to the nature of their progression. Block rainfall has the simplest progression, yet it is furthest from real rainfall progression (Urcikán, P., 2004, p. 210-215). They have constant intensity throughout the duration. For assessing and designing sewer networks, block design rainfall needs to be converted using mathematical calculations into curve-shaped rainfall curves - they have a constantly decreasing intensity over time. In hydrodynamic models where we try to incorporate the time component of the initial surface runoff into the assessment, we reduce the curve by decreasing its initial intensity with respect to surface retention of the area and the runoff coefficient.

Synthetic rainfalls with time-varying intensities simulate the variable course of intensities in the time course of real storm event. Synthetic rainfall represents synthetic hyetograms in order to achieve more accurate solutions compared to more detailed computational methods that describe surface runoff and mathematically simulate non-stationary flow in the sewer network. The intensity profile depends mainly on the type of rainfall. The profile of synthetic rain characterizes its peak, which is defined as the ratio of the maximum intensity of synthetic rain and the average intensity related to the whole duration, as well as the time location of the peak intensity. Synthetic rainfalls can be categorized by individual authors and characterized by different curves of yield curves. Synthetic rainfalls embodied in the DATER program can be classified by their authors: Keifer and Chu, Huff, Šifalda and synthetic rainfall by Yen and Chow.

3 DATER

The DATER (Decisive Analytical Tool for Effective Rainfall) serves as an effective analytical tool for calculation and decision of design rainfall within the urbanized area, which serves as the basis for designing and assessing sewer networks and sewer objects on them. The program includes a comprehensive database of long-term measurements from 68 ombrographic stations in Slovakia, on which basis it is possible to plot the yield curves of block and synthetic design rainfalls for any location in Slovakia. The program was created using the built-in features of EXCEL and the Visual Basic for Applications (VBA) programming language to help the user evaluate the values user sets up and make immediate exports of data in PDF / XLS file formats. The DATER is divided into several worksheets, of which the main focus is on the summary of calculated data and rainfall curves that contain the calculated data of the selected design rainfall. Other sheets include data on historical rainfall, user defined rainfall, data export preview, and a list of calculated curve data, time dependence and design rainfall. After selecting the input data, the user calculates the curve data and program updates the calculated data and draws the rain curves. Tables and charts are dynamic and based on extensive work with pivot tables and charts.

The "SUMMARY" sheet includes basic data on calculated design rainfall, such as curve parameters “K”, “B” and “a” used for the calculation of each design rainfall curve, average and maximum rainfall intensities, maximum intensity location, and total surface runoff from area of 1 hectare.

The reason for the development of the program was to speed up the process of design rainfall calculation, in order to prepare it for their further use - in hydrodynamic models, and for this reason, extensive VBA scripts have been embedded in the program, which simply extract the required PDF and XLS data into separate files. This is the "EXPORT DATA" window that allows the user to select the desired export values. The user chooses the design rainfall/s, according to the periodicity and type of draft rain that he wants to export, and the program itself creates a directory and saves the file of choice.

4 CASE STUDY OF TOWN OF VRÁBLE – PROGRAMM APPLICATION

The arae of interest of this research is the municipality of Vráble, which has no ombrographic station and curve parameters K, B and a were calculated by interpolating values from the 3 nearest localities with their own ombrographic measurements, namely Nitra, Nový Tekov and Svätuša. Interpolation was performed with respect to the direct airline distance of the selected ombrographic stations from the area of interest. Considering the length of actual historical rainfall measurements in the site (about 2 years), periodicity of rainfall p = 0.5 was chosen for the assessment (i.e. rain probability 50% in 1 year). Due to the length of the sewerage network of the municipality of Vráble, the time of concentration of surface runoff in the locality is longer than 15 minutes and therefore according to the Slovak Technical Standard (STN) under number 75 6101 is recommended for the design and assessment the use of the „Bartoška method“, which is a modification of the rational method. Bartoška method considers a block design rainfall, of the duration that is equal to the time of the concentration of the surface runoff. For the above reason, the calculated parameters of the "reduced block rainfall" curve K, B and a are displayed in Tab. 3.1.

Tab. 4.1 Parameters of „reduced block rainfall“ curve K, B,

Curve equation	Curve parameters		
	K	B	a
$q = K * (t^a + B)^{-1}$	2791.3	4.49	0.92

4.1 Assessment of measured datasets

Measured meteorological data have been updated in regular - 2 week long intervals. For the area of interest, the 4 most significant recorded storm events were selected. Yeild curves were plotted for selected recorded storms to show their course, which can be seen in Fig. 1. and also the average intensities, maximum intensities, the maximum intensities set and the total surface outflow from the 1 ha area were calculated.

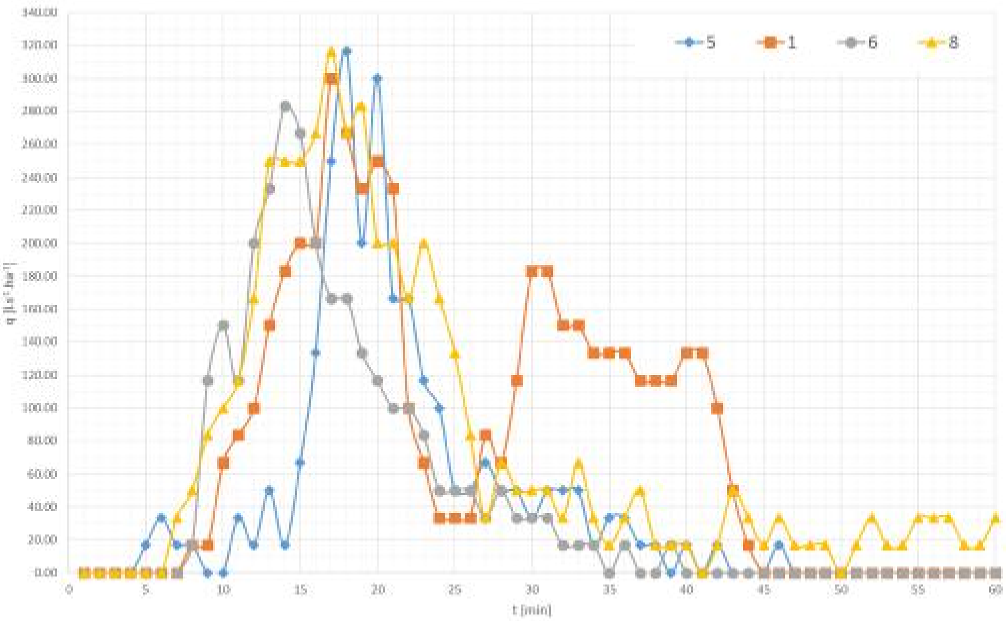

Fig. 1 Course of selected measured storm curves in Vráble

Graphical comparison of yield curve progression of all design rainfall is displayed in Fig. 2.

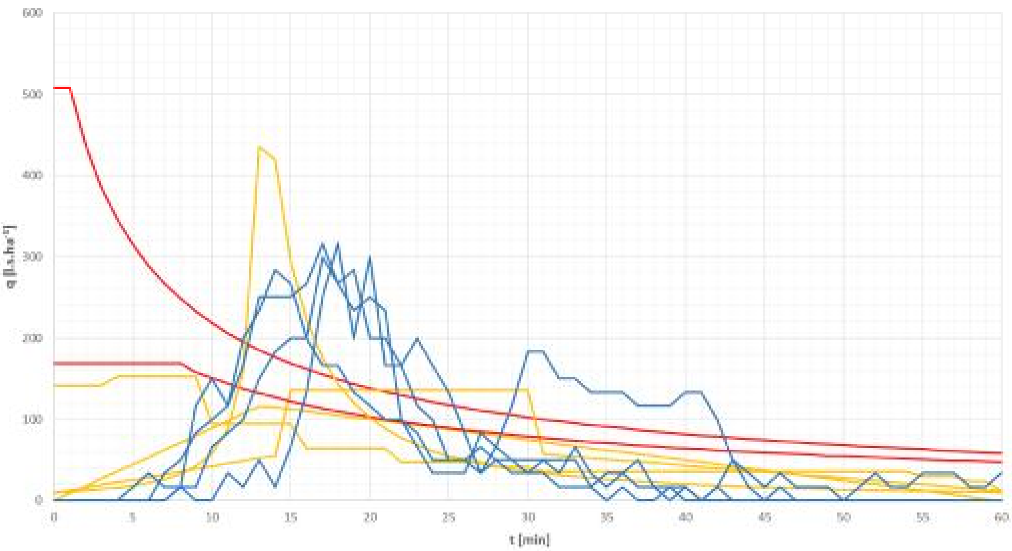

Fig. 2 Curve progression of all design rainfalls including measured historical rainfall data

Due to the large number of curves and the possible oversampling caused by the marks on individual lines, curve and legend designations were off. The blue curves represent historical rain, the orange curves represent synthetic rainfalls, and the red rain is block rain. From the course of historical rainfall curves (blue lines), it is clear that the runoff concentration is mostly concentrated in the 15th-20th minutes of the total rainfall. The peak of rainfall in most cases lasted an average of 7-9 minutes, at which the maximum intensity of reduced block rain could also be transformed. Tab. 1 shows calculated data of all design rainfall curves.

Tab. 1 Calculated data of all design rainfall curves

	design rainfall / author	q_{avg} [1]	q_{max} [2]	q_t [3]	surface runoff [4]
		[l.s^{-1}.ha^{-1}]	[l.s^{-1}.ha^{-1}]	[min]	[m^3.ha^{-1}]
Block rainfall	mon-reduced	145,56	508,14	1	516

	reduced	92.73	169.03	1	327
Synthetic rainfall	Keifer and Chu	57.75	435.76	13	210
	Huff	62.91	153.04	4	225
	Šifalda	60.41	135.38	15	220
	Yen and Chow	57.49	115.94	13	210
Historical rainfall	1	76.78	300.00	17	281
	2	43.17	316.67	18	158
	3	46.99	283.33	14	172
	4	74.86	316.67	17	273

1 – average rainfall intensity
2 – maximum rainfall intensity
3 – peak location
4 – total surface runoff from 1 hectare area

In the case of the assessment of the objects on sewer networks for rainwater retention and leveling the flood waves, rainfall No. 1 and 4 served as the most appropriate of the recorded historical rain due to the highest amount of surface runoff. From this point of view, the most suitable synthetic rain is Huff design rainfall. When assessing the hydraulic capacity of the sewerage network, we focus on the rain with the highest point of intensity, historical rainfalls no.2 and no.4 are appropriate, but from the point of view of the pipeline filling, it is necessary to observe the long-term average intensity of the rain, so for the next assessment, rain no.4 have been selected. From Tab. 1 it is clear that the synthetic rain according to the selected authors has approximately the same average intensity and the total amount of precipitation, and therefore, in the hydrodynamic assessment, their selection is only influenced by the course. Synthetic rainfall according to Keifer and Chu is suitable for assessing the behavior of the sewer system for very intense rainfall, whereas Huff, Šifalda and Yen and Chow rainfalls are better suited for monitoring of the flow of the pipe during the entire rainfall duration.

5 CONCLUSION

The result of hydrodynamic simulations in assessing sewer networks depends on the quality of the measured data and the boundary conditions used for the calculation. When assessing combined or rains sewers, the most important factor is the choice of suitable design rainfall as the sewage flow compared to storm runoff is negligible. When assessing objects for rainwater retention and leveling of flood wave, it is more appropriate to choose the rainfall with a higher total surface runoff and duration, whilst the impact assessment of hydraulic condition of pipeline capacity and pipeline filling is more influenced by the peak maximum and long-term average rainfall intensity. To calibrate the simulation of hydrodynamic models, a sufficient number of recorded historical rainfall events, their evaluation, spatial and temporal analysis are needed. A two-year rainfall measurement series was carried out in the town of Vráble and on the basis of the measured data, the 4 most significant rain events were evaluated, based on which a suitable historical rainfall for the hydrodynamic assessment was selected. For data comparison, both block and synthetic design rainfalls were used to compare the data.

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