Analysis of the methods of calculation of the reliable flows in rainwater drainage on the example of two differently managed areas.

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Abstract

This work is a comparison of the methods of calculating reliable flows in rainwater drainage. The aim is to determine the amount of outflow from the catchment area of an area with a natural, small water reservoir and from the catchment area of a densely built-up city by means of various calculation methods and to compare and analyse the results obtained. In this study, two most frequently used calculation methods were analysed: the fixed rainfall intensity method and the limit intensity method. As an example, three different values of calculated rainfall "q" determined according to Bogdanowicz Stachy formula and Błaszczyk's formula for different probabilities of rainfall occurrence and its duration were taken. The analysis shows that the calculated flow rate takes slightly higher values determined with the limit intensity method for both areas. The difference is greater the larger the flows, which is a perfect example of the analysed area of a densely built-up city.

Keywords: **authoritative rain intensity, stormwater drainage, constant rainfall method, boundary intensity method, rainwater, land use.**

Introduction

Many factors influence the design of rainwater drainage systems. Currently there are many ways and methods how to do this. Please note that there is no single method that is completely correct. Everything depends on the type of land use, i.e. whether there is a lot of greenery in the area under consideration, whether there are water reservoirs, geographical location, weather conditions etc. Depending on the specific geographical and meteorological information, it is possible to calculate the probability of the amount of rainwater effluent, taking into account all external factors, and also how it can be discharged later. There are two main methods of calculating the amount of run-off from the catchment area. The first is the fixed rainfall intensity method, while the second is the limit intensity method. Depending on the land use, one method is more accurate and gives a reliable measurement from the other. This paper analyses different calculation methods for the amount of rainwater runoff due to the diversity of the land.

Methodology

Authoritative rain intensity

When calculating the catchment area flow rates, it is necessary to take into account some information that shows the amount of rainfall in a given area. These have an impact on the diameter of the rainwater channels, as well as on their speed, slope and filling of the channel. For this purpose, the so-called calculation rainfall is used, otherwise known as the "measured rainfall" [1].

It is assumed that the above mentioned rainfall is a rainfall of unlimited range, i.e. it covers the entire catchment area. It is additionally constant in time and the same for the whole area of intensity. It appears with a specific, assumed for a given area frequency and lasting, determined from above or calculated (if necessary) time.

The unit of intensity of the rainfall q is given in dm3/(s*ha).

The value of q can be presented in several ways:

- Determining the value of „q” from the formulae
- Adopting a fixed recommended value „q” for the region concerned
- Determining the value of „q” using the relation q(tm,p)

where:

t_m - the measured duration of the rain,

p - probability of rainfall [%],

Formulas for determining the value of the intensity of a reliable rainfall:

- Bogdanowicz Stachy formula
- Błaszczyk formula

Błaszczyk's formula is currently the most frequently used precipitation model for sewer design in Poland. Although this calculation model dates back to 1954, it raises many doubts as to the correctness of the method [5].

Therefore, two conclusions can be drawn showing the imprecision of this calculation model. The first one is the fact that Błaszczyk assumed 67 years as the observation period for this event, when in practice it lasted only 37 years. This had an impact on the values of intensities for the assumed probabilities of exceedance, which in effect were lower than the values obtained for the full observation period.

The second conclusion confirming the inaccuracy of the method is that showing the only parameter of the model was inconsistent with the graphical form described. This had an impact on the 100% probability of exceeding, where its value was very distant from the experimental data [5]. Consequently, Błaszczyk's formula should be treated with some wink of an eye as to its accuracy, and it looks as follows:

$$q = \frac{6{,}631\sqrt[3]{\mathrm{C}\,H^2}}{\mathrm{tm}^{0{,}67}} \quad [\mathrm{dm}^3/(\mathrm{s}*\mathrm{ha})]$$

where:

C - frequency of exceeding the rain once in a given intensity [years],

H - average annual precipitation height [mm],

tm - the exact duration of the rain,

For an average annual precipitation height of H = 600 mm, the formula is presented in sequence:

$$q = \frac{470\sqrt[3]{C}}{tm^{0,67}} \text{ [dm}^3\text{/(s*ha)]}$$

The C parameter in the formula in question tells us about the frequency of occurrence of precipitation, which is expressed in years. In short, it means what period of time the determined rainfall intensity value „q" will be exceeded. The frequency C is related to the probability relationship p of the formula below:

$$C = \frac{100}{\mathrm{p}}$$

where:

p - probability of rainfall of a given intensity [%].

The parameter p specifies the number of times the value of a given q has been reached or exceeded in 100 years.

The most commonly used methods of calculating the outflow from the catchment area are [1, 2, 3, 4]:

- The constant rainfall method
- The boundary intensity method

The constant rainfall method

This method assumes that it is constant in time and space, assuming that the rainfall intensity covers the whole area of occurrence [3] and the duration of rainfall is usually 10 or 15 minutes. This method is used in conceptual studies and for small catchments. It is a simplified method, assuming that the duration of rainfall is equal to the average flow time in a rain collector.
In this case, the calculation flow over the section is determined from the following formula:

$$Q = \Psi * \varphi * q * F \quad \text{[dm}^3\text{/s]}$$

where:

Ψ - drain coefficient [-]

φ - drain delay factor [-]

q - the intensity of the rainfall is reliable [l/(s*ha)]

F - catchment area [ha]

The φ delay factor in the formula, otherwise known as the retention factor, consists of taking the retention action into account and can be described by the following formula:

$$\varphi = \frac{1}{\sqrt[n]{F}}$$

where n is a dimensionless coefficient depending on the geometric shape of the catchment;

I'm taking the following values:

- n = 8 for dense catchments and for large slopes,

- n = 6 for average conditions (the length of the catchment twice as long as its width, slopes allow to reach the runoff velocity of about 1.2 m/s) - this value was used for calculations,

- n = 4 for small slopes and an extended catchment area.

The boundary intensity method

In the limit intensity method used in Poland, it is assumed that a reliable stream of precipitation volume [1], in the analyzed section of the channel, occurs with a certain delay in relation to the moment of the beginning of precipitation (after the so-called dry weather), by the time necessary for it to occur:

- Field concentration woven, t_k
- The retention time in t_r channel,
- Flow time in the channel t_p - from the beginning to the design section

The flow rate in the duct is expressed by the formula:

$$Q = \Psi * q * F \quad [dm^3/s]$$

where:

Ψ - drain coefficient [-]

q - the intensity of the rainfall is reliable [l/(s*ha)]

F - catchment area [ha]

This method is used for the methods of so-called successive approximations. The calculation time of the duration of the measurable rain should not be less than 10 minutes. What is more, it has a logical sense, first of all, to calculate for already invested areas.

The table below shows an exemplary summary of the calculations of the outflow rate from the catchment area described by the methods described for the area with a water reservoir and for the densely built-up area of the city - for various levels of the measured rainfall.

TYPE OF TERREN	CONSTANT RAINFALL METHOD			THE BOUNDARY INTENSITY METHOD		
	Calculation flow [dm^3/s],			Calculation flow [dm^3/s],		
	q= 154 [dm^3/(s*ha)]	q= 169 [dm^3/(s*ha)]	q= 220 [dm^3/(s*ha)]	q= 154 [dm^3/(s*ha)]	q= 169 [dm^3/(s*ha)]	q= 220 [dm^3/(s*ha)]
AQUATIC TANK	100,48	110,26	143,54	104,44	114,62	149,20
CITY - densely built up	238,41	261,63	340,58	302,43	331,88	432,04

Figure 1 Summary of calculated flows by two methods and for two differently managed areas.

Results

It can be noted that the constant rainfall method is a more simplified method.

An important information is the fact that in the limit rainfall method the delay factor is omitted from the calculation, which makes the method itself slightly less accurate compared to the fixed rainfall method. The higher value of q, the higher the calculation flows come out. From the table above it can be concluded that the diversity of land use also has an impact on the calculation flows. The more dense a city with less green areas, the calculation flows have significantly higher values. Regardless of the assumed value q, the difference between the results obtained after performing the calculations by both methods is the same.

Conclusion

The aim of the study was to compare the methods of calculation of the reliable flows in rainwater drainage depending on land use. It is clear that in the case of land where there is a large water reservoir and a lot of greenery, the method of constant rainfall intensities will be more effective. However, when considering the case of a city with a densely built-up area, the constant rainfall intensity method may give more reliable results. In summary, these conclusions apply to specific buildings of the area and for specific rainfall. In different cases with different meteorological conditions and other buildings - the results and calculation methods may differ. Each case of rainwater design should be treated and considered individually.

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