CALCULATION OF RAINWATER SEWAGE SYSTEMS

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ABSTRACT

Rain intensity is highly variable, making it difficult to accurate calculation of runoff and the flow rate that results in periodic flooding of streets and squares disturbing the traffic and making material damages. The developed rainwater system calculation method is capable of determining the rainfall maximum flow rates of different surfaces with different surface probability (1-200%) in the whole territory of Latvia. The maximum stormwater flow rates are determined according to the expression based on A.Ziverts' formula that is refreshed by R.Ziemelnieks in the promotion work. The gully between the placing distance ridged edge of the road is determined by the expression which was calculated at the end in this publication. LBN 223- 99 was used for rainwater calculation time for gully flow and the formula for calculating the minimum slope of the rainwater collector. The paper gives the k-values of Latvian towns, depending on the desirable flow of rainwater. The method developed enables the calculation of the maximum rate flow of rainwater in urban areas with different probability and the distance between two adjacent intermediate gullies.

Key words: rainwater, rain flow, surface runoff, gullies.

INTRODUCTION

Media news show that heavy downpours in Riga and other Latvian cities become more intensive year after year. Rain or co-system sewerage systems are not able to carry away all surface waters quickly from the squares and streets having the heavy impermeable cover (Ziemelnieks, Tilgalis, Juhna, 2008). At present, parking places, pavements and roads having the impermeable hard cover increase fast in towns (Ziemelnieks, Tilgalis, 2009). The problems caused by rain waters in the city territories have become actual recently beginning more and more to feel the presence of rain waters in the sewerage systems. The situation becomes worse by connection of the rainwater sewerage collectors to the sewerage networks, which creates an additional load to the sewerage networks of the co-systems and pumping stations during the rain. Pumping and purification of rain waters create additional costs of electro energy for the service establishments. A topical dissolved problem is not yet developed method of rainwater gully trap placement calculation.

MATERIALS AND METHODS

Processing of rain data

This study makes use of the rain observation data from different inhabited locations and towns using the publicly accessible information of the agency of Latvia environment, geology and meteorology (LVGMA) (Tables of Meteorological Observations.., Meteorological and hydrological..). The rain observation data rows were summed up and supplemented in order to improve the existing calculation method of maximum rainwater discharge in the town of Latvia by means of the new k-coefficient. The data of the rain intensity during the warm period from April till September were chosen and used when the downpours with the maximum intensity are observed in Latvia causing the flooding of territories and streets. The precipitation model groups were drawn up selecting the maximum empirical data quantities, in addition by taking into consideration the air temperature regime, the period of warm weather, thus the hard kind of precipitation – snow, ice was not estimated and was excluded from the investigation.

Rainwater discharge calculation methods

The developed rainwater system calculation method is capable of determining the rainfall maximum flow rates of different surfaces with different surface probability (1-200%) in the whole territory of Latvia. The maximum stormwater flow rates are determined according to the expression of the basic formula (1) that is refreshed by E.Tilgalis and R.Ziemelnieks:

$$Q_{max} = q \cdot k \cdot F . \Psi \text{ , } [m^3 \, s^{-1}] \quad (1)$$

where:
Q_{max} – maximal rainfall flow rate, $m^3 \, s^{-1}$;
q – runoff module $l \, (s \cdot ha)^{-1}$ calculated using the formula E.Tilgalis;
k – coefficient depending on the probability of calculation;
F – surface run-off area to be calculated, ha;
Ψ – surface runoff coefficient (0,1-0,95% depending on the surface, Table (1).

The calculation simplified expression of the existing discharge module by E.Tilgalis (Tilgalis, 2004) was used as the calculation basis (2) presuming the length of the specific downpour up to 20 min and its average rain intensity 1 mm min-1.

$$q = 0.13 \cdot \alpha \text{, } [(\text{s} \cdot \text{ha})^{-1}] \quad (2)$$

where:
α - rainfall amount in millimeters (mm), during the period without frost according to the summed up date by A. Zīverts in Table 2.

The kind of material use of the surface cover may be different in the location of use of a conformable area, therefore, the rainwater discharges change. In Latvia the coefficients of surface discharge have not been summed up in literature. The coefficients of rainwater discharge surface for the present surface cover areas are shown in Table 1.

RESULTS AND DISCUSSION

By determining the values of the precipitation intensity of maximum minutes and by specifying the coefficients of surface runoff for different kinds of covering materials, the calculation method of the existing discharge has been improved. The popular method used in Latvia for the calculation of the discharge amount is a simplified method worked out by A.Zīverts and Ē.Tilgalis (Tilgalis, 2004). Using this method it is possible to calculate the discharges with the possibility up to 200%.
In addition, the determined k-coefficient dependent on the calculation possibility was determined based on the previously carried out investigations in the promotion work (R.Ziemelnieks). The method elaborated provides for the possibility to calculate the maximum rainwater discharges in inhabited locations with a different possibility. In the result of the investigation it is possible to conclude that in Latvia it is advisable to use the calculations with the repetition possibility or 25% (frequency of According to the table drawn up by A.Zīverts (Zīverts, 1997) several values of k-coefficients for the inhabited locations of Latvia are determined. improvements was carried out, repetition once in 2 or 4 years).
The gully between the placing distance ridged edge of the road is determined by the following expression:

$$L = \frac{Q_{kan} \cdot E \cdot t_r^{\,1{,}2n-0{,}1} \cdot 10^7}{Z_{mid} \cdot A^{1{,}2} \cdot (a+x)} \text{ [m]} \quad (3)$$

where:
L- inlet spacing between two intermediate gullies (m);
tr - time for water to travel from the furthest point on the road surface to the gully grating (by LBN 223-99, 3-5 min);
F- area included between two adjacent inlets (ha);
Qkan - peak flow approaching the inlet (sub-catchment outlet) (l/s);
Zmid - runoff coefficient (by LBN 223-99,0.29)
A- parameter related by LBN 223-99
n- parameter related by LBN 223-99
a- width of the sidewalk (m)
x- half width of the roadway (m)
E - grate effectiveness of the collect rain water is determined by *UPC* methodology.

Table 1

Coefficients Ψ

Use of areas or type of covering material of surface area	**Coefficient, φ**
Use of areas	
Town office	0.70 - 0.95
Commercial premises	0.50 - 0.70
Populated areas	
Detached house	0.30 - 0.50
Flat in a dwelling house	0.40 - 0.60
Flat(apartments)	0.60 - 0.80
Inhabited suburb district	0.25 - 0.40
Industrial district	
Light industry	0.50- 0.80
Heavy industry	0.60 - 0.90
Parks, green areas, cemeteries	0.10 - 0.30
Railway carriage park, playground	0.20 - 0.40
Meadows for pastures	0.10 - 0.30
Surface area covering material	
Street, pavement covered by asphalt or concrete	0.70-0.95
Concrete area	0.80-0.95
Concrete cobble stone covering	0.70-0.80
Pedestrian pavements and part for transport	0.75-0.85
House roof covering material (depending on material)	0.75-0.95
Grassland having sandy soil composition	
Sandy soil with 2% decline or less	0.05-0.10
Sandy soil with 2%-8% decline	0.10-0.16
Sandy soil with 8% decline or more(precipice, slope)	0.16-0.20
Grassland having clayey soil composition	
Decline 2% or less	0.10 - 0.16
Decline 2%-8%	0.17 - 0.25
Decline 8% and more (precipice, slope)	0.26 - 0.36

Source: Computer applications in hydraulic engineering (basic hydrology-rainfall)(translation report by R.Ziemelnieks)

Recently, the Hydraulic and Hydrological Engineering Section of the Technical University of Catalonia (UPC) promoted a new research line in the field of the road grate efficiency, (DEHMA-UPC, 2004):

$$E = A \cdot \left(\frac{Q}{y}\right)^{-B} \quad (4)$$

where:
Q- total flow approaching the inlet (l/s)
y- hydraulic depth upstream to the grate (mm)
A and *B* are two characteristic parameters related to the grate geometry.
Eq. 4 is the result produced by a series of tests on a platform of 3 m width corresponding to a common lane in Latvia.

Table 2

Values of k-coefficients

No	**City, populated place**	**Duration of observation, years**	**α, rainfall April-September, mm**	**k-coefficient with the possibility**						
				200%	**100%**	**50%**	**25%**	**10%**	**5%**	**1%**
1	Cīrava	33	272	0,75	1,25	1,54	1,92	2,37	2,67	3,35
2	Dagda	27	268	0,75	1,23	1,50	1,84	2,33	2,60	3,30
3	Daugavpils	42	276	0,77	1,27	1,58	1,95	2,40	2,70	3,40
4	Dzērbene	33	428	1,17	2,00	2,47	3,00	3,70	4,12	6,10
5	Gulbene	39	391	1,0	1,77	2,23	2,74	3,40	3,80	4,75
6	Gureļi	37	447	1,23	2,07	2,54	3,15	3,85	4,35	6,65
7	Ieriķi	35	391	1,0	1,77	2,23	2,74	3,40	3,80	4,75
8	Jelgava	50	335	1,0	1,54	1,86	2,37	2,90	3,25	4,00
9	Kabile	41	291	0,80	1,33	1,63	2,05	2,50	2,80	3,57
10	Kolka	57	250	0,71	1,15	1,37	1,73	2,15	2,45	3,10
11	Kosa	25	428	1,17	2,00	2,47	3,00	3,70	4,12	6,10
12	Kuldīga	42	291	0,80	1,33	1,63	2,05	2,50	2,80	3,57
13	Lejasciems	29	484	1,33	2,27	2,74	3,45	4,24	4,63	7,90
14	Liepāja	63	235	0,68	1,05	1,30	1,63	2,03	2,30	2,85
15	Mālpils	38	409	1,12	1,86	2,35	2,85	3,55	3,95	5,60
16	Ogre	31	335	1,0	1,54	1,86	2,37	2,90	3,25	4,00
17	Pilskalne	35	277	0,77	1,27	1,58	1,95	2,43	2,70	3,40
18	Priekuļi	47	409	1,12	1,86	2,35	2,85	3,55	3,95	5,60
19	Ranka	34	391	1,0	1,77	2,23	2,74	3,40	3,80	4,75
20	Rēzekne	37	264	0,73	1,20	2,10	1,82	3,13	2,54	3,22
21	Rīga	71	368	1,00	1,68	2,10	2,60	3,12	3,60	4,50
22	Saldus	27	263	0,73	1,20	1,45	1,82	2,30	2,54	3,18
23	Stāmeriene	38	447	1,23	2,07	2,54	3,15	3,85	4,35	6,65
24	Stende	46	304	0,85	1,37	1,70	2,12	2,64	2,95	3,75
25	Subate	37	228	0,65	1,03	1,27	1,60	1,97	2,19	2,77
26	Užava	25	272	0,75	1,25	1,54	1,92	2,37	2,67	3,35
27	Ventspils	59	298	0,83	1,35	1,65	2,10	2,57	2,85	3,65

Source: Calculated and created by R.Ziemelnieks

$$A = \frac{0{,}39}{A_g^{-0{,}35} \cdot p^{-0{,}13}} (n_t + 1)^{0{,}01} \cdot (n_l + 1)^{0{,}11} \times \quad (5)$$
$$\times (n_d + 1)^{0{,}03}$$

$$B = 0{,}36 \cdot \frac{L}{W} \quad (6)$$

where:
Ag- area that includes the void area of the grate inlet (AH)
p- ratio of the Ag to the AH

nt, nl, nd- are, respectively, the numbers of transversal, longitudinal and diagonal bars
L- length of the grate inlet
W- width of the grate inlet

The rainwater diversion gravity self-flow collector internal diameters were calculated assuming the full pipe filling and a minimum allowable internal pipe diameter of 250 mm (200 mm are usually use for inside section nets) to calculate the minimum pipe slope (LBN 223-99), which will challenge the self-cleaning process of the pipe systems using expression:

$$Q = \omega \cdot \upsilon, \ m^3 s^{-1} \quad (7)$$

$$I_{min} = \tau (\rho \ g \ R)^{-1} \quad (8)$$

where:
τ – flow stress, N/m^2;
ρ – gravity of waste water, kg/m^3;
g –acceleration due to gravity, m/s^2;
R – pipeline filled hydraulic radius, m.

CONCLUSIONS

1. The newly formed formulas (1; 3) and the real values (Tables 1; 2) given offer an accurate calculation of the rainwater discharge.
2. According to the values of k-coefficient numbers obtained, it can be concluded, that one may take into consideration larger possibilities of the consequences of the flood, while choosing the surface covering material with a less repetition possibility.
3. It is recommended to make calculations with 50% probability. The calculation method of the distances between gullies gives designers a new footing based on the hydraulic calculation.
4. The proposed stormwater drainage system calculation method will prevent grave errors of stormwater discharge and gully mutual distance calculations.

REFERENCES

Metodiskie norādījumi lietus kanalizācijas projektēšanā (1983) Komunālās saimniecības pārvaldes ministrija LPSRS projektēšanas institūts „Latkomunālprojekts”, izlaidums HBK -3-83. Rīga: institūts „Latkomunālprojekts”, 66 p.

Meteoroloģisko novērojumu tabulas TMS, Rīga, I-XII, stacijas Nr. 5692410. Laika josla Griničas.\Reģions Zemgale, Stacija: Rīga. Kods: RIAS99PA. Latvijas Republikas hidrometeoroloģijas pārvaldes dabas vides stāvokļa valsts datu fonds jeb LVĢMA.

Hydraulic Department (DEHMA-UPC) (2004). Course of Urban Hydrology. Technical University of Catalonia, Barcelona, Spain.

Ziemeļnieks R., Tilgalis E. (2009) „Calculation method of rainfall flow rate”, LUA Annual 15th International Scientific Conference Proceedings, Research for Rural Development 2009. Jelgava, Latvia University of Agriculture, pp. 315-319.

Ziemelnieks R., Tilgalis E., Juhna V. (2008) „Rainfall effect on sewage co-system activity in Riga”, LUA Annual 14th International Scientific Conference Proceedings, Research for Rural Development 2008. Jelgava, Latvia University of Agriculture, pp.194-199.

Ziemeļnieks R., Tilgalis E. (2009) „Calculation method of rainwater discharge”, LUA 3rd International Scientific Conference Civil Engineering’11. Jelgava, Latvia University of Agriculture, pp. 267-271.

Tilgalis Ē. (2004) *Notekūdeņu savākšana un attīrīšana*: mācību grāmata. Jelgava: LLU, LVAF. 239 lpp.

Zīverts A. (1997) *Ievads hidroloģijā*: mācību palīglīdzeklis, Jelgava: LLU. 111 lpp.

Meteoroloģisko un hidroloģisko novērojumu dati [online] [accessed on 04.01.2010.]. Available: http://www.meteo.lv/public/hidrometeo_dati.html

Noteikumi par LBN 223-99 Kanalizācijas ārējie tīkli un būves: MK noteikumi Nr.214 [online] [accessed on 07.05.2010.]. Available: http://www.likumi.lv/doc.php?id=19996