CONSIDERATION ON HYDRAULIC REABILITATION OF ACCESSIBLE WASTEWATER COLLECTORS

Cristian Florin SCRIPCARIU[2], [2] PhD Student, Technical University "Gheorghe Asachi" of Iasi, Romania
Mihail LUCA PhD eng. Professor, e-mail mluca2004@yahoo.com, Technical University,,Gh. Asachi", Mangeron Dumitru Str. 63, 770800, Iasi, Romania, Tel./Fax +040 232 270804,

***Abstract**: Accessible sewer collectors in service present a high degree of aging. Rehabilitation of accessible collectors can be differentiated by size and type of wastewater transported. Accessible sewer collectors (large and circular, ovoid, bell or mixed cross section) present specific measures for rehabilitation. Rehabilitation Technology can be with or without digging ditches. Accessible collectors may be rehabilitating with inner and outer works. Hydraulic rehabilitation requires flow parameters analysis for modified geometric sections. Hydraulic rehabilitation requires the analysis of collector walls roughness and its influence on the flow velocity. Research has indicated important changes to the flow section due to silting and hydrodynamic erosion processes. The flow sections were geometric transformed from curved shapes to mixed shapes (curves and lines).The changes of geometrical cross section caused the decreasing of velocity and transported flow by about 15 ... 28%.*

Keywords: *sewage collector, mixed section, roughness, hydraulic rehabilitation.*

1. Introduction

Wastewater sewerage systems produced in Romania were designed and built in different periods of time. In their design were used various technical concepts, specific to different stages of economic development and political life in Romania. In execution of accessible sewerage network were used diverse of materials (stone, basalt, concrete, reinforced concrete). The main share in the realization of accessible collectors is hold by plain concrete and reinforced concrete.

Accessible sewerage collectors present the longest operation life. Construction and installation of sewage system present aging in different stages. Shares of the site are felt like an ongoing degradation processes of structural parameters of the collector.

A special issue presents the main and discharge collectors by their large size of the flow section and operational process parameters. The large dimensions allow the collector to be visit and performing any repairs. Accessible collectors shows ovoid, bell or mixed (curves and lines) flow section type. Most of the sewerages are in the last stage of operation. This stage is represented by the rapid aging of the structural elements of the sewerage network. This causes serious implications on operating expenses. They can sometimes be higher than the costs for the construction of a new collector.

Due to structural and functional changes of operation parameters the old sewerage systems present water losses. Water losses lead to geotechnical characteristics changing of the site, the settlement phenomena and environmental pollution. The silting of the flow section changes functional parameters of the collector. Significant changes to the flow section are determined by hydrodynamic erosion processes. Flow sections in some collectors have changed their geometric shapes; the curves have turned in mixed forms (curves and lines). The geometric changes of the flow section determine decrease of velocity and transported flow by the collector.

2. Research on behaviour in service of wastewater accessible colectors

Visiting collectors have made on a series of construction of sewerage systems in Iasi and Pascani [Luke M., 2005]. Theoretical and experimental studies carried out have some data on the parameters and operation of the accessible collectors in use for a long period of time. Among them we can mention:

A. Results on the structural condition of the accessible combined sewer system:

- Some of the collectors have a long life service (60…40 years);
- Collection and transportation of municipal waste water and rain water is achieved through the use of old material sewage and old production technology;
- A number of materials used in sewage shows a pronounced aging, which causes the appearance of fissures and cracks in the building structure;
- Their location on commonly used transit routes causes building damage and appearance of fissures and cracks in the raft even walls and the cover plate;
- Some materials used to build the sewerage have relatively small exploitation duration and require high maintenance and repair costs.

B. Results on the hydraulic regime of accessible combined sewer system:

- The continuous silting process requires the wastewater transport through a section with the hydraulic characteristics in order to obtain a permissible velocity.
- Intense filing phenomena have changed the geometrical shape of the flow section, its slope, roughness, which determinate slowing of velocity and transportation flow;
- The presence of cracks in the raft and wall causes a water exchange with the exterior and vice versa;
- Water losses determines suffusion phenomena the site, affecting the stability of the sewerage;

a b

Fig. 1. Degradation of the flow section through silted accessible sewer drains;
a- cemented silting; b - silting during concentration and cementation.

Accessible sewerage collectors show essentially the same defects as those non-accessible. Mostly it notes that:

- tubes misalignment caused by the actions of embedding medium;
- silting flow path with different materials transported by water flow and their cementation;
- the fail determined by suffusion phenomena formed in the site;

a b

Fig. 2. Damage to the sewage collectors domes visitors from concrete; a - collapse of the cover plate of a bell type sewerage; b - degradation of concrete on the underside of the cover plate to an ovoid type sewerage.

- Fissures and cracks in structural components of the sewerage;
- Holes and openings in the collector produced by mechanical intervention on site;
- Uneven settlements because of water loss;
- Wall degradation caused by the action of tree roots etc.

a b

Fig. 3. Damage wall of the accessible sewage collector; a - fissures and cracks; b - The degradation of concrete by mechanical action on the outside.

The analysis of the above ensues that a large part of the wastewater discharge collectors must undergo extensive rehabilitation and upgrading of structural components, or assemblies.

3. Hydraulic-mathematical simulation model of flow in changed cross section collectors

For analysis of hydraulic parameters changed by flow path degradation was made with a hydraulic-mathematical soft for free flow.

The calculation model was initiated to specific sections of flow of accessible sewage collectors. The calculation model answers the hydraulic requirements imposed by accessible collectors affected by silting and hydrodynamic erosion phenomena. The repair works changes the geometry of the collector flow section collectors. On the classical section made of curves are added straight lines and results a polycentric section.

In some cases in time is shown a significant change to the geometric shape of the free flow section. The multitude of phenomena, hydraulic, mechanical, chemical, etc., leads to a new geometric shape. Knowing the time evolution of the flow section requires the determination of hydraulic parameters witch direct influence on the geometric dimensions. Thought these parameters can be noticed the debit, speed, load loss and roughness coefficient. Some of hydraulic parameters changed in time may present hazardous values may be hazardous to those initially set.

The calculation is based on the observations and measurements made in the flow section of accessible sewage collectors from Iasi and Pascani sewage systems. Flow sections are changed by silting processes and technological works. The long work service contributed to the degradation of the collectors flow section collectors. Virtual circular section given by design (ovoid, bell) is replaced at the bottom with a polycentric section.

Work Stages of the computing model are [Scripcariu C. Fl., 2008]:

1. Determination of the perimeter coordinates (y, z) which borders the area of flow change (for example, bell-formed area from a- at the bottom of a segment of a circle with a radius R_1, the center O_1 (0, R_1), the chord with length B ζ height; b - a semi-circle in the upper part with a radius R_2 = B/2 and the center O_2 (0, ζ), Fig.4)

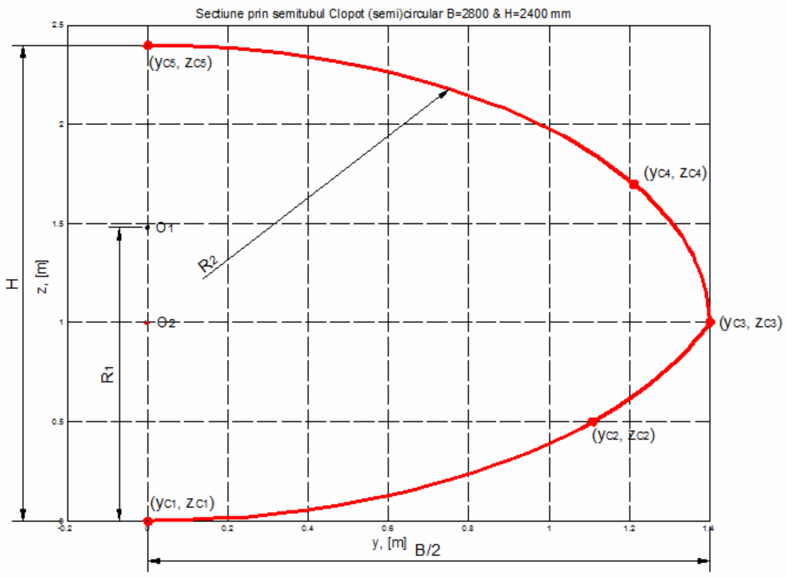

Fig. 4. Calculation method for a bell type collector with non-standardized ratio dimension

The design parameters ζ and R_1 can be evaluated according to the size of representative B and H with the following relations:

$$\zeta = H - B/2,\ R_1 = \frac{B\left[\beta^2 + (2-\beta)^2\right]}{4\beta(2-\beta)},\ \text{cu}\ \beta = \frac{B}{H} \quad (1)$$

The semicircular bell type profile is completely determined by 5 points (Fig no.4) by the coordinates (y_C, z_C),

$$(y_C, z_C) \in \left\{(0,0), \left(\sqrt{\zeta(4R_1-\zeta)}/2, \zeta/2\right), (B/2, \zeta), \left(B\sqrt{3}/4, B/4+\zeta\right), (0,H)\right\} \quad (2)$$

2. Mathematical Modeling of hydraulic characteristics of modified geometric shape collector :free flow width, $B(h)$ or $B(z)$; wetted perimeter, $P(h)$ or $P(z)$; cross sectional area, $A(h)$ or $A(z)$; hydraulic radius, $R_h(h)$ or $R_h(z)$; the center of gravity ordinate of the section, $z_G(h)$ or $z_G(z)$; velocity the module, $W(h)$ or $W(z)$; the flow module, $K(h)$ or $K(z)$.

In the case of sewerage pipes sections consisting of Na ≥ 2 arcs of a circle and / or line segments the analytical expressions for each of the functions $B(h)$, $P(h)$, $A(h)$, $R_h(h)$, $z_G(h)$, $W(h)$ and $K(h)$ need to be show the number of N_a functions piecewise-defined:

$B_i(h)$, $P_i(h)$, $A_i(h)$, $R_{hi}(h)$, $z_{Gi}(h)$, $W_i(h)$ and $K_i(h)$, cu $z_i - z_{C0} \le h \le (z_{i+1} - z_{C0}), (i = 1,..., N_A)$ (3)

Where z_{C0} (usual $z_{C0} = 0$) is the collectors raft level, and z_i and z_{i+1} ordinates delimiting points lower or higher, arc or the segment i.

The considered collectors present symmetry after a longitudinal vertical plane. It follows an outline of the cross semi-full cross section completely determined by an odd number of points, N_M set of coordinates:

$$(y_C, z_C)_k,\ k=1,2,\ldots, N_M \quad (4)$$

3. To determine the functions (3) we followed next steps:
   a. Expressions analytical deduction for circles and / or support of the N_A arcs and/or line segments;
   b. determination of N_A+1 points which border the lower and upper N_A arches and / or line segments, (y_i, z_i), (i=1, 2, ..., N_A+1);
   c. Analytical expressions deduction on sections for HIDRAULICO hydraulic-functional characteristics of sewage collectors.

4. Determination of analytical expressions for hydraulic-functional characteristics sewerage collectors. For each geometric and hydraulic characteristic was determined the characteristic equation for changed section type. For analysis there were used polycentric curved sections. These are presented in detail in [Scripcariu C. Fl., 2008].

5. The software running for obtaining data bell type flow sections also considered nonstandard hydraulic- mathematical model.

6. Design software for developed for the model study was called Profil_Arce_Cerc_Seg_Dreapta.m. The program was tested for classic collector sections and sections Non-standard bell

Research followed elaboration of model calculations for polling type polycentric networks that are commonly found in sewage systems. Calculation programs obtained for determining operating data derived from ovoid and bell section.

4. Results obtained

The software Profil***_Arce_Cerc_Seg_Dreapta.m*** has been ruled for no standardized bell type sewerage B/H=2800/2400 mm and the surface roughness given by the coefficient k = 74 (n = 1 / k = 0.0135). The results obtained are represented in analytical relations for each geometric and hydraulic parameter. The equations obtained were plotted to generalize and for their quick use in calculation.

Table 1. Representative point coordinates of the canal contour

N°	**1**	2	**3**	4	**5**
yC & y, [m]	**0**	1,1091	**1,4000**	1,2124	**0**
zC & z, [m]	**0**	0,5000	**1,0000**	1,7000	**2,4000**
n = [0,0190 0,0170]					

The maximum absolute and relative values for hydraulic parameters R_h, W and K and for absolute water depth *h and relative h/H*, which are touched by these parameters are centralized and are listed in columns 6 ÷ 8.

Since the roughness is uneven on the contour of the enclosed canal the depths corresponding to maximum values for hydraulic radius R_h and module of velocity W are different.

Table 2. The maximum values of geometric and hydraulic parameters

		Geometric Parameter			Hydraulic parameter			
		B [m]	*A* [m^2]	z_G [m]	*P* [m]	R_h [m]	*W* [m/s]	*K* [m^3s^{-1}]
1		2	3	4	5	6	7	8
Max. Value	Abs.	2,8000	5,1239	1,1916	8,0701	0,7785	46,3037	225.6850
	Rel.	-	-	-	-	1,2262	1,1232	1.0685
h, [m]		1.0142	2,4000	2,4000	2,4000	1,9381	1,9983	2,2594
h/H, [-]		0.4226	1,0000	1,0000	1,0000	0,8075	0,8326	0,9414

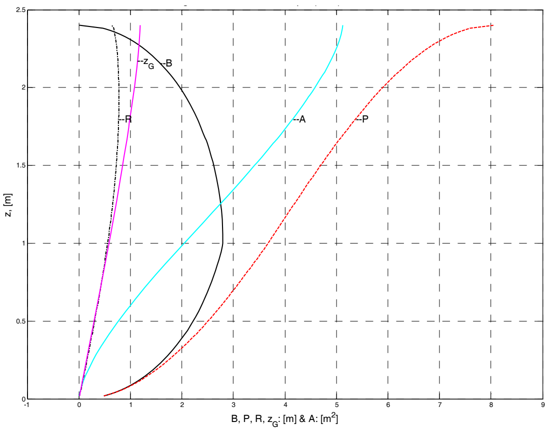

Fig. 5. Characteristics of the of the flow section (A, P, R z_G) to the non-standard bell section B / H = 2800/2400 mm

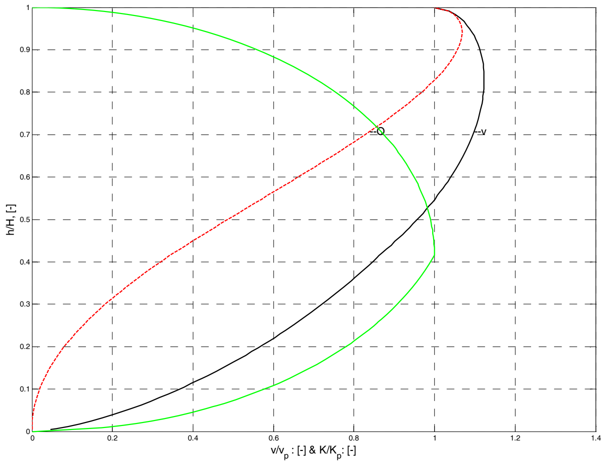

Fig. 6. Flow characteristics (Q) and velocity (w) on non-standard bell section B / H 2800/2400 mm

According with the analysis and measurements made in the field have revealed the following for the shape of the flow section: the lower part is represented by a straight line

5. Conclusions

1. Main sewage collectors and "visit" outlet type shows a relatively high exploitation period which causes great implications in operation and high exploitation expenses.
2. Knowledge of geometrical and hydraulic parameters for operating process control requires the development of hydraulic-mathematical calculation models.
3. Calculation software developed allows the exact calculation of geometrical and hydraulic parameters and hydraulic for a modified bell sections collector and diagrams are helpful in approximate solving of sizing - check problems.
4. Calculation software developed has the advantage of allowing the exact calculation of the collector operating parameters taking into account the roughness variation roughness on wetted perimeter.
5. The mathematical model developed could be generalized to obtain functional-hydraulic characteristics (B = fB (h), P = CF (h) A = fA (h), Rh = FRH (h) zG = FZG (h) W = FW (h) and K = fK (h)) ($B = f_B(h)$, $P = f_P(h)$, $A = f_A(h)$, $R_h = f_{Rh}(h)$, $z_G = f_{zG}(h)$, $W = f_W(h)$ şi $K = f_K(h)$) to closed sections of sewer polycentric type.

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