

FAILURES OF SEWER PIPES MADE OF PVC / УШКОДЖЕННЯ КАНАЛІЗАЦІЙНИХ КАНАЛІВ ВИКОНАНИХ З ПВХ ТРУБ

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This paper presents the field measurements results of sewer pipes made of PVC, which were newly laid in the ground. The research was carried out applying CCTV (Closed Circuit Television) inspections, which was performed during the construction works acceptance of the sewer pipes some weeks or months after their laying in the ground. More than 11 km of sewers from 11 cities in Poland were analyzed. The analysis was carried out based on the research conducted among other things by Kielce University of Technology. A detailed analysis of specific flexible pipes failures was carried out. Failures, which occurred most frequently and on the highest percentage of the sewer pipe lengths were identified. The failures were classified according to the intensity of their occurrence and caused danger. Class 1 covers the greatest failures and the highest level of danger, class 5 covers minor failures with the lower level of danger. The technical condition of the investigated sewers was assessed by classifying the particular sections to one of 3 groups: G 1 – without failures, G 2 – with failures in 5th class, G 3 – with failures in classes 1st- 4th. The most probable reasons for failures were presented.

Key words: sewers, CCTV inspections, PVC pipes failures.

Подано результати досліджень каналізаційних каналів з ПВХ труб, нещодавно прокладених в землі. Дослідження проведені за допомогою відеоспостереження (Closed Circuit Television, CCTV), що було виконане протягом прийому каналів перед початком їх експлуатації. Проаналізовано понад 11 км каналізаційних каналів в 11 містах Польщі. Аналіз виконано на підставі досліджень, зокрема Політехнікою Свентокшискою м. Кельце. Детально проведено аналіз специфічних ушкоджень для гнучких труб, а також ушкоджень, що найчастіше зустрічаються для значного процента по довжині досліджуваних каналів. Пошкодження поділено на п'ять класів в залежності від інтенсивності їх прояву і від величини створеної ними загрози. Перший клас характеризує найбільше пошкодження і найвищий ступінь загрози, а п'ятий – найменше пошкодження з найнижчим ступенем загрози. Виконано оцінку технічного стану досліджуваних каналізаційних каналів шляхом класифікації окремих відрізків до однієї з трьох груп: G1 – без ушкоджень, G2 – з ушкодженнями п'ятого класу, G3 – з ушкодженнями I-IV класів. Вказані можливі причини виникнення тих ушкоджень.

Ключові слова: каналізація, CCTV інспекція, аварії труб з ПВХ.

Introduction

The subject of the analysis are the results of sewer pipes made of PVC, which were newly laid in the ground. The research was carried out applying CCTV (Closed Circuit Television) inspections, which was performed during the construction works acceptance of the sewer pipes before starting their exploitation. 11388 m sewers from 11 cities were analyzed. The number of inspections, which varied according to places, streets and diameters was 43, and the total number of the inspected sewer sections was 336.

So far analysis of technical condition of concrete and clay sewers exploited for a long time (described among other things in [1,2,3,4]) have been carried out in the Department of Sanitary Systems and Installations in Kielce University of Technology. In [5] there were presented photos of typical failures of PVC pipes inspected applying CCTV.

Additionally, the new element of this paper is assessing the sewer failures in 5 groups, which vary according to intensity of their occurrence. The division into 5 groups is based on the proposed classification of failures, which is based on the German guidelines ATV-A 149, that was partly modified. In ATV-A 149 guidelines they did not include failures, such as among other things local dent in the pipe from the sharp stones in the backfill and buckling.

The principles of the failure classification

The proposed classification contains 27 various failures. The term of sewer pipe failure is understood as coming from the state of efficiency to inefficiency. The state of inefficiency is understood as failing to fill the requirements for the sewer pipe [6]. The failures were divided into 4 groups. In group 1 “blocking of the flow” there were placed failures which are important for the hydraulic-exploitation and in some cases also environmental aspect. The failures places in the 1st group are listed below:

- z_p – movable sediment,
- z_s – immovable sediment,
- z_k – roots of trees,
- z_w – house drains or sealing that jut out in the pipe interior,
- z_z – obstacles in the flow which occur together,
- z_r – other pipes in the sewer,
- z_d – improper connection.

In the 2nd group „leakages and displacements of the sewers”, there were placed failures influencing mainly environmental assessment of the sewer, which are connected with infiltration and exfiltration, influencing in some cases hydraulic-exploitation and static strength aspect. They are listed below:

- n – infiltration,
- n_u – sealing that juts out in the interior,
- n_n – accretion caused by infiltration,
- n_w – spalling of the pipes in the joint from the construction period,
- e_p – circumferential displacements,
- e_r – longitudinal displacements.

Factors decreasing the load capacity of the sewer’s construction both for the rigid and flexible sewers were placed in the 3rd group. They are listed below:

- w_s – wear of the bottom or sides of the construction,
- w_k – corrosion of the pipe’s wall,
- w_{rl} – scratches and longitudinal cracks,
- w_{rp} – scratches and circumferential cracks,
- w_{ru} – scratches and oblique cracks,
- w_u – loss of the parts of construction layer,
- w_z – falling in of the parts of the construction,
- w_f – deformation of the cracked sewer.

To factors decreasing the load capacity of the sewer belong also failures placed in the 4th group “specific failures of the flexible sewers”, which occur only in flexible sewers made of plastics. They are listed below:

- t_d – deflection of the top,
- t_t – buckling,
- t_w – local dents.

The 5 th group includes the classification of the house drains:

- p_w – house drains that jut out in the interior,
- p_u – damaged house drains,
- p_o – correct house drains.

The failures from groups 1 – 4 were divided into 5 classes according to the intensity of their occurrence and the caused danger. Class 1 includes the largest failures and the highest danger, class 5th minor failures with the lowest danger. The quantitative ranges of the failures in individual classes were developed taking into account the diligence criterion of taken actions to eliminate them. That is why:

Class 1 includes the failures which require immediate rehabilitation or replacement,
 Class 2 includes the failures which should be eliminated in a short-term period,
 Class 3 includes the failures which should be eliminated in a medium-term period,
 Class 4 includes the failures which should be eliminated in a long-term period,
 Class 5 includes the acceptable failures which do not require taking any actions to eliminate them.

The research results

The summary results of the intensity of occurrence of various failures were presented in 2 graphs (in figures 1 and 2), showing separately the linear failures in percentage (fig. 1) and the point failures in units/100m (fig. 2).

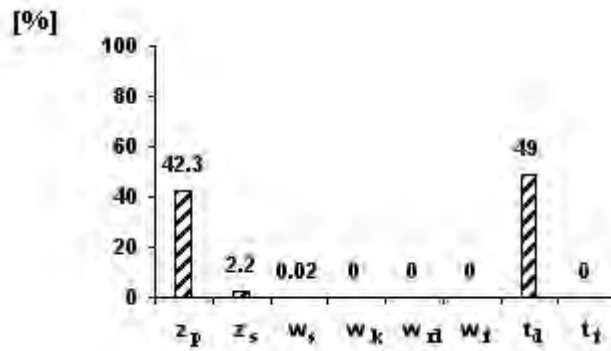


Fig. 1. The summary results of the investigation of various linear failures

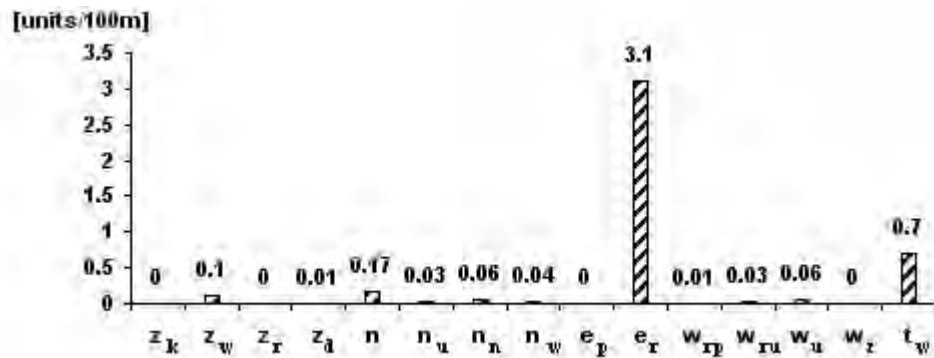


Fig. 2. The summary of the intensity of occurrence of the various point failures in units/100 m

As it is shown in figures, the linear failures, which occurred on the considerable length of the sewers are: the deflection of the top (49,0%), the movable sediment (42,3%) and immovable sediment (2,2%). The following figures present those failures divided into classes of intensity of their occurrence.

Figure 3 shows the percentage fraction of the sewers length with the movable sediment with the division into classes of failures. The sediment signed by the symbol z_p and show the percentage of the occupied sewer cross section fulfills successively the condition in classes 1 to 5: $z_p \geq 50$ (class 1), $35 \leq z_p < 50$ (class 2), $20 \leq z_p < 35$ (class 3), $5 \leq z_p < 20$ (class 4), $z_p < 5$ (class 5).

Figure 4 presents the per cent share of the sewer length with the observed deflections of the top with the division into the classes of failures. The deflection of the top is signed by the symbol t_d and expressed in per cent. It fulfills successively the condition in classes 1 to 5: $t_d \geq 40$, $25 \leq t_d < 40$, $15 \leq t_d < 25$, $6 \leq t_d < 15$, $t_d < 6$, where t_d is calculated from the equation:

$$t_d = \frac{d_{w1} - d_{w2}}{2} : \frac{d_{w1} + d_{d2}}{2} \quad (1)$$

where d_{w1} and d_{w2} are the lengths of the minor and major axis of ellipse.

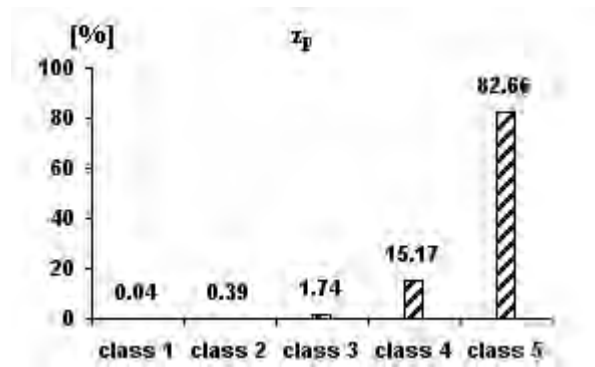


Fig. 3. The movable sediment z_p with the division into the classes of failures

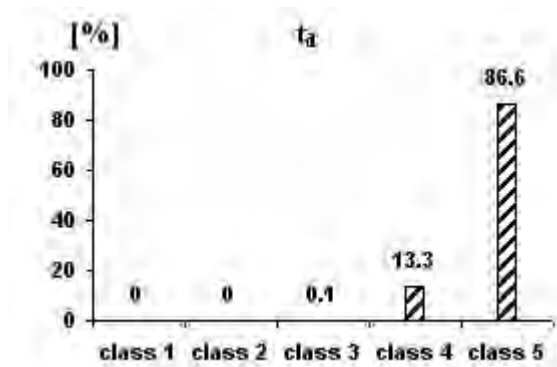


Fig. 4. The deflection of the top t_d with the division into the classes of failures

Figure 5 presents the per cent share of the sewer length with the immovable sediment with the division into classes of failures. The immovable sediment signed by the symbol z_s and expressed in the percentage of the occupied sewer cross-section fulfills successively the condition in classes 1 to 5: $z_s \geq 50$, $35 \leq z_s < 50$, $20 \leq z_s < 35$, $5 \leq z_s < 20$, $z_s < 5$.

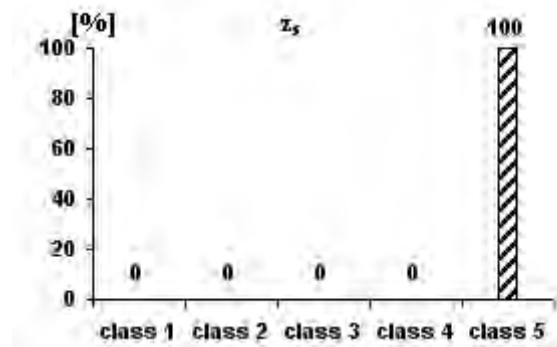


Fig 5. The immovable sediment z_s with the division into the classes of failures

The other observed linear failures were less than 0.5% of the sewer length. Because of the fact that it is a slight per cent, they were not shown in figures.

The point failures, which occurred quite often were the longitudinal displacements, which were 3.1 piece/100m. The other failures were observed more rarely than 1 piece/100 m of the Sewer length. However, worth mentioning are: local dents 0.7 piece/100 m, infiltration 0.17 piece/100 m, Figure 6 presents the per cent share of the longitudinal displacements, which was signed by the e_r in five classes of failures. The division into classes is as follows:

Class 1 – the direct contact of the sewer interior with the ground or when $r_1 > 100\% l_k$, where r_1 – longitudinal displacement, l_k – the length of the pipe bell,

Class 2 – the sealing is visible in the pipe bell and $l_k < r_1 \leq 100\% l_k$,

Class 3 – the sealing is visible in the pipe bell and $25\% l_k < r_1 \leq 50\% l_k$,

Class 4 – the sealing is not visible in the pipe bell and $25\% l_k < r_l \leq 50\%$, l_k

Class 5 – the sealing is not visible in the pipe bell and $r_l \leq 25\% l_k$.

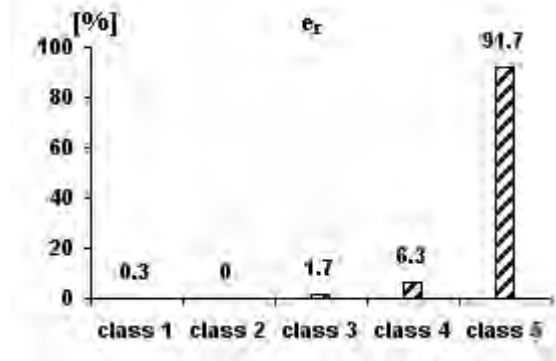


Fig. 6. The longitudinal displacements e_r with the division into the classes of failures

The local dents from e.g. sharp cobblers, signed by a symbol t_w were included in four groups of failures, in which the depth of dent is measured in [mm] and equal successively: $t_w \geq 20$ (class 1), $15 \leq t_w < 20$ (class 2), $10 \leq t_w < 15$ (class 3), $t_w < 10$ (class 4). Figure 7 presents assigning the observed local dents of PVC pipes to particular classes.

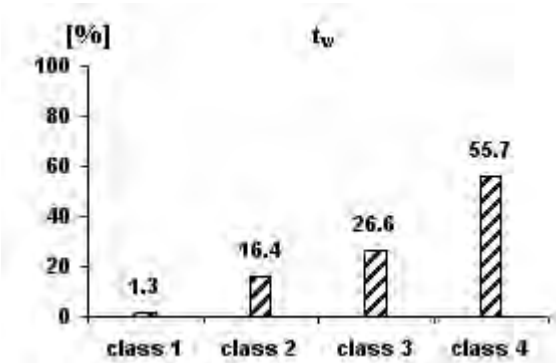


Fig. 7. The local dents t_w with the division into classes

Figure 8 shows the per cent share of various groundwater infiltration cases into the sewer, signed by the symbol n , taking the following division into classes of failures:

- Class 1 – intensive inflow or injection of groundwater, sometimes dribbling with the ground,
- Class 2 – minor inflow of groundwater without the ground,
- Class 3 – dribbling of groundwater without the ground,
- Class 4 – groundwater dripping in drops,
- Class 5 – moisture from the groundwater.

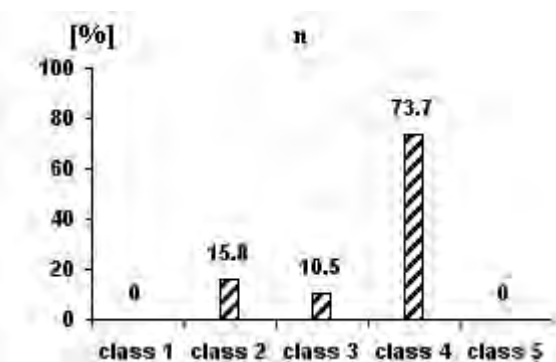


Fig. 8. Groundwater infiltration n into the Sewer interior with the division into the classes of failures

Figure 9 shows the per cent share of the observed house drains or sealing that jut out in the interior. This failure was signed by the symbol z_w and expressed in the per cent of the occupied sewer cross-section. It fulfills the following requirements, successively for classes from 1 to 5: $z_w \geq 50$ (class 1), $35 \leq z_w < 50$ (class 2), $20 \leq z_w < 35$ (class 3), $5 \leq z_w < 20$ (class 4), $z_w < 5$ (class V).

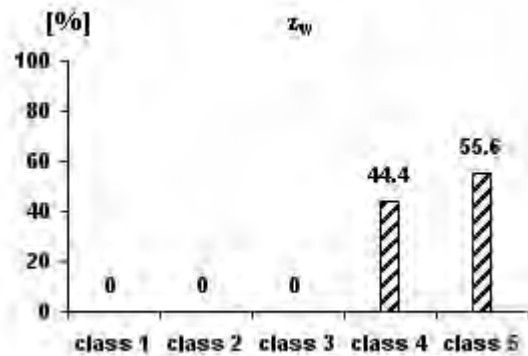


Fig. 9. House drains or sealing that jut out in the interior z_w with the division into the classes of failures

Assessment of the analyzed sewers technical conditions

The basic linear failures of PVC sewers newly laid in the ground were: the deflection of the top, movable sediment, and to less extent immovable sediment. The basic point failures included: longitudinal displacements, and to less extent local dents, infiltration as well as house drains or sealing that jut out in the interior.

The sediments in the bottom of the sewer, which come from the construction period, were connected in most cases with improper longitudinal gradient of the sewers. More than 80% of those sediments were assigned to 5th class of failures, because they occupied less than 5% of the sewer cross-section. To 4th class there was classified 15.17% of the sewer length which were occupied by the sediments, to 3rd class 1.74%, to 2nd class 0.39%, to 1st class only 0.04% of the sewer length which was occupied by the movable sediment occupying more than 50% of the sewer cross-section. Figure 10 shows the movable sediment, which was classified to 4th class of failures.



Fig. 10. The movable sediment, which was classified to 4th class of failures

Figure 11 shows four examples of the improper sewer longitudinal gradients. On X- axis there was shown the distance of the analyzed sewer section in [m] measured from the manhole to manhole, on Y-axis the registered difference in the height of the sewer bottom between the particular point on the sewer section and the 1st manhole in [cm].

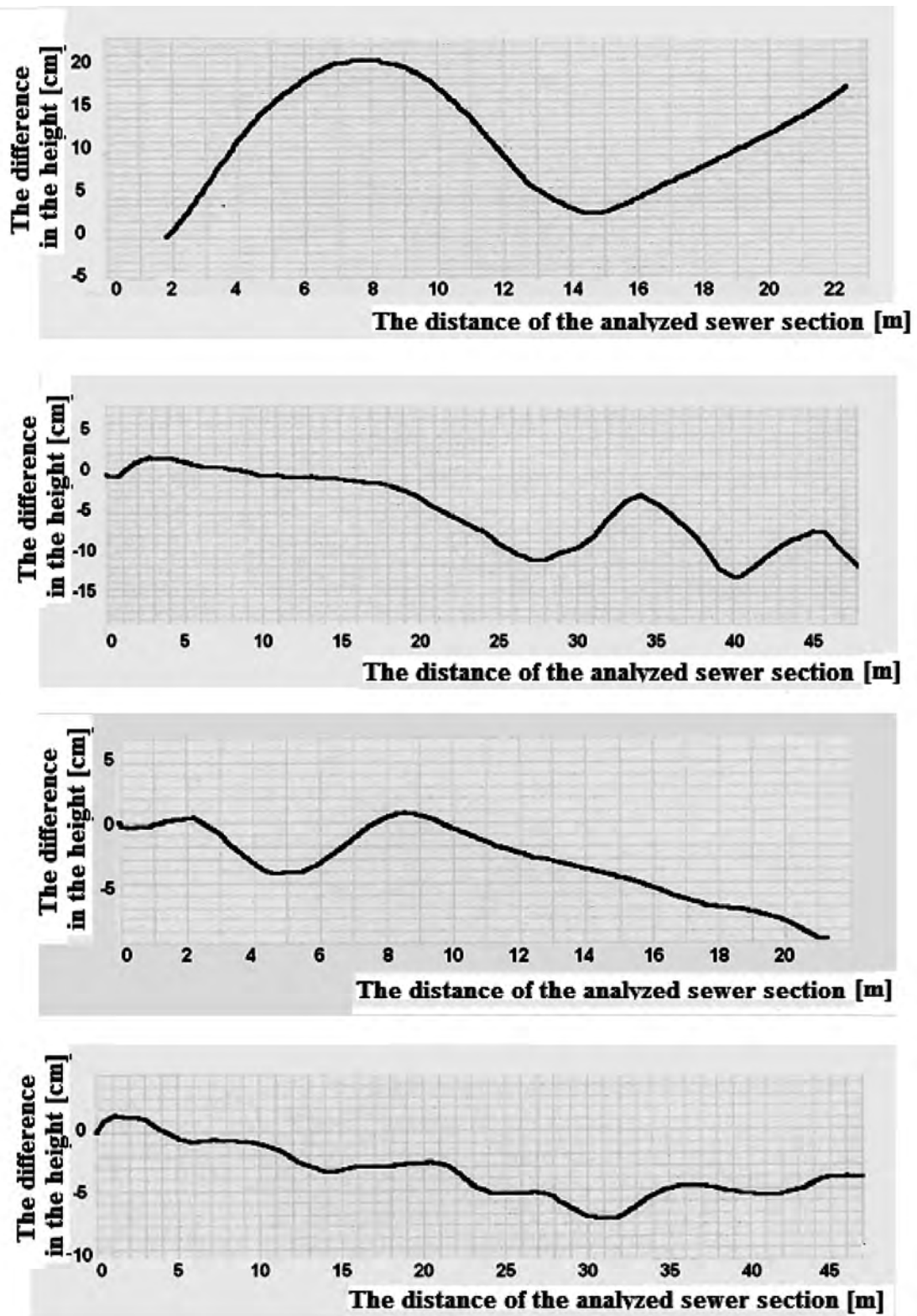


Fig. 11. Improper longitudinal gradients of the sewers

The deflection of the pipe's top was observed on the considerable pipe's length. In 86.6% they were minor deflections, lower than 6%, qualified to 5th class of failures. To 4th class of failures there were classified 13.3% of the deflected pipes, where deflections were more than 6% and less than 15%. According to the proposed classification only 0.1% of the deflected pipes were classified to 3rd class. Their deflection was more than 15%. The deflection of the top of the pipe classified to the 4th class was shown in figure 12.



Fig.12. The deflection of the top of the pipe in the 4th class of failures

The point failures which were most commonly observed were: longitudinal displacements. The most of the longitudinal displacements (91.7%) was observed in the 5th class of failures. Only in one place (1st class – 0.3%) there was the direct contact of the interior of the pipe with the ground, shown in figure 13. Low one-sided longitudinal displacements (5th class) are shown in figure 14. It indicates the improper longitudinal slope.

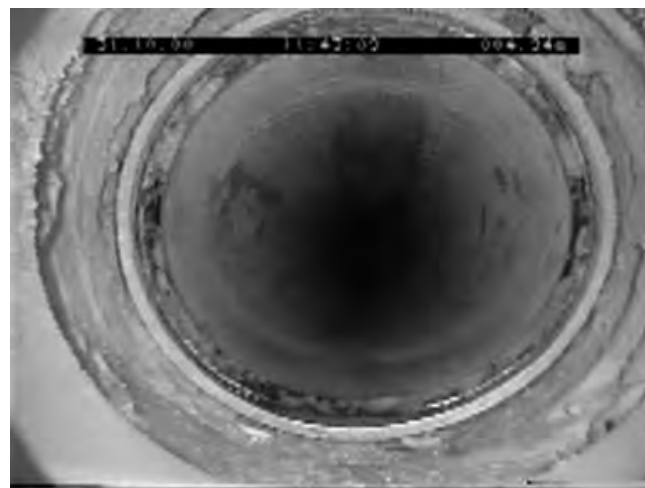


Fig. 13. The longitudinal displacement in the 1st class of failures



Fig. 14. One sided longitudinal displacement in the 5th class

The groundwater infiltration to the pipe interior was observed only in one city. The water dripping was observed in 73.7%, which classified this failure to the 4th class, the dribbling of the water was observed in 10.5% (3rd class), the inflow of water into the pipe interior was observed in 15.8% (class 2).

More than half of the observed local dents e.g. from the cobbles were classified to the 4th class of failures. Less of the failures (26.6%) were classified to the 3rd class, much less (16.4%) were classified to the 2nd class. One dent of 1.3% was classified to 1 st class and was larger than 20 mm. The examples of the local dents are shown in figure 15.

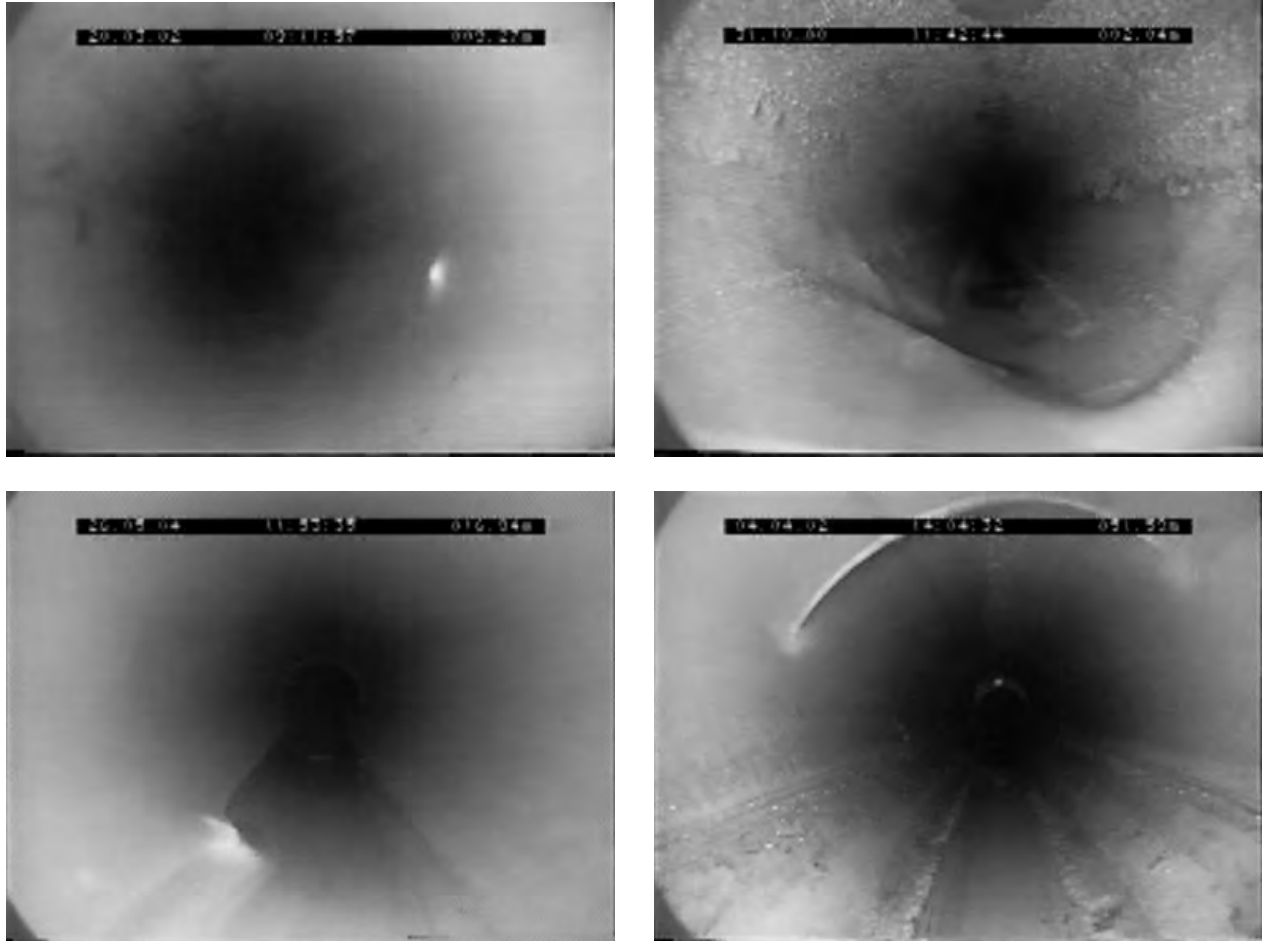


Fig. 15. The examples of the local dents of the pipe



Fig. 16. The house sewer that juts out to the pipe interior

The house drains or the sealing that jut out to the interior in 55.6% occupied less than 5% of the pipe cross section and were classified to the 5th class of failures. 44% of those obstacles in the flow were classified to the 4th class, as they occupied more than 5% but less than 20% of the pipe interior. In figure 16 there is shown the house drain that juts out to the pipe's interior and unables the progress of the camera. In figure 17 there is shown the sealing which juts out of the connection.



Fig. 17. The sealing that juts out from the place of pipe connection to the pipe interior

The minor percentage of the house drains was improper: 1.8% were jutting out to the interior, 9.2% were faulty, 89% were correct. The research results involving the connections are shown in figure 18.

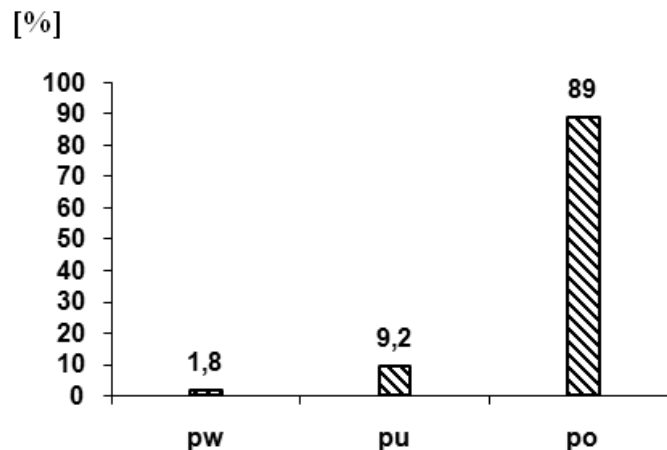


Fig. 18. The correctness of the connections: p_w – the house drains that jut out to the pipe interior, p_u – the house drains that are faulty, p_o – they correct house drains

Figure 19 presents the division of the surveyed sewer sections into the three groups:

- G 1 – the sections without the pipe failures,
- G 2 – the sections with the pipe failures included in the 5th class,
- G 3 – the sections with the pipe failures included to classes 1-4th

To the group G 1, that included the correct sewer sections (without any failures) there were classified only 9% of the Sewer sections. To the group G 2, that included one or several types of failures involved in the 5th class of failures there were classified 42% of the sewer sections. In case of long-exploited sewers pipes with such minor failures do not qualify to the rehabilitation. In case of the sewers newly laid in the ground it is a matter of discussion of those pipes should be taken to exploitation or not. In the standard concerning the requirements when sewer construction works acceptance should be adjusted the rules of sewer construction works acceptance for the sewers with the failures classified to the 5th class of failures. In the group G 3 there was a almost half of the sewer sections (49%), which had the larger failures, classified to classes from 1 to 4. Those sections are not qualified to the acceptance.

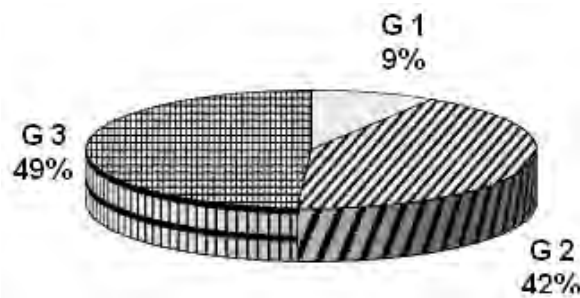


Fig. 19. The percentage of sewer sections from the groups: G 1 – without failures, G 2 – with failures in the 5th class, G 3 – with failures in classes 1 – 4

Closing remarks

The analysis of the research results of sewer pipes made of PVC, which were newly laid in the ground indicates their very poor technical condition. Those sewer should be correct, without any failures. Yet, as it was shown in this paper, large percentage of them is qualified to rehabilitation or replacement prior to starting their exploitation.

The basic reason of the observed failures is improper pipe laying in the ground, connected with not obeying the specific of the plastic pipes laying. The basic mistake is the lack of the proper longitudinal gradient of the pipe, which causes the sedimentation process. Some of the failures, e.g. the oblique scratches, loss of the parts of the construction layer, were connected with the improper transportation, storage and shifting of the pipes on the building site, which caused the point strokes.

In one of the 12 cities in which the pipes were investigated, it was found out that the dimension of the applied PVC pipes is inconsistent with the standard (the variable wall thickness in the perimeter), which contributed to the occurrence of the leakages after pipe laying in the ground.

The local dents observed in the investigated sewers indicate the careless carrying out the sand bedding and sand backfill of the pipes.

The research which was carried out indicated the need to popularize the rules of plastic pipes laying in the ground, more careful quality control during the construction phase and proper supervision.

Carrying out the CCTV inspections of all sewers which are taken to exploitation is needed. It is widely common that the sewers taken to the exploitation are not inspected or inspected only on chosen sections, instead of carrying out the inspection on the all sewer sections.

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