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Selected test methods for pipes and manholes used in mining areas

As a result of underground deposit extraction, the pipes and manholes that constitute the basic elements of sewage systems are subjected to the influence of near-surface soil layer deformations at the place of their installation. For this reason, these elements intended for the construction of sewage systems in mining areas must fulfil special requirements related to the occurrence of additional loads and displacements. This article presents the pipe and manhole test methods developed at the Central Mining Institute, with a particular focus on elements of large sizes. The results of these tests are applied to assess the suitability of pipes and manholes for use in mining areas.

Key words: *pipes, manholes, tests, mining areas*

1. INTRODUCTION

Mining activity has a negative influence on sewage systems. These systems comprise pipelines constructed from various types of pipes and joints. Waste drainage systems typically consist of pipelines with gravity flow as well as sewage pumping stations and delivery pipelines. Stormwater drainage usually operates using a gravity-based system, though pumping stations are established in the interior basins that are generated in mining areas. Other important sewage system elements also include manholes.

In mining areas, all the aforementioned sewerage elements are subjected to the influence of near-surface soil layer deformations at the place of their installation. For this reason, the elements intended for the construction of drainage utilities must fulfil special requirements related to the occurrence of the additional loads and displacements of these utilities. The goal of this article is to present selected test methods for assessing the suitability of manufactured pipes and manholes for use in mining areas, particularly large diameter ones.

Sewers with gravity flow are constructed using various types of pipes [1], characterised by different coupling systems with elastomer seals. These include pipes with socket and sleeve joints for installation in trenches or for pipeline construction using trenchless methods. The pipes are formed from various materials, such as: concrete, reinforced concrete, stoneware, polymer concrete and cast iron, glass fibre reinforced polyester resins (GRP) as well as thermoplastics, including polyvinyl chloride (PVC), polyethylene (PE) and polypropylene (PP). Manholes are manufactured using prefabricated concrete and reinforced concrete elements coupled using elastomer seals or adhesives, polymer concrete elements coupled using adhesives, GRP elements with sleeve joints, and thermoplastics with monolithic structure or composed of modules coupled by seals. Depending on the manner of interaction with the soil, the pipes and manholes can be divided into flexible and rigid types [1–3].

2. INFLUENCE OF MINING ACTIVITY ON PIPES AND MANHOLES

Mining activity results in deformations of the near-surface soil layer where the sewer pipelines and manholes are installed. From the perspective of the influence of these deformations, great significance is presented primarily by the near-surface soil layer displacement u and deformation ε horizontals, as well as surface curvatures K with a radius R for large-size pipes. Non-uniform depressions w and the associated changes in terrain inclination T, resulting in changing pipeline gradients are also important. Such variations should be factored in at the system design and construction stages by considering the forecasted decreases in terrain inclination and level. A distribution of the near-surface soil layer deformation factors is presented in Figure 1.

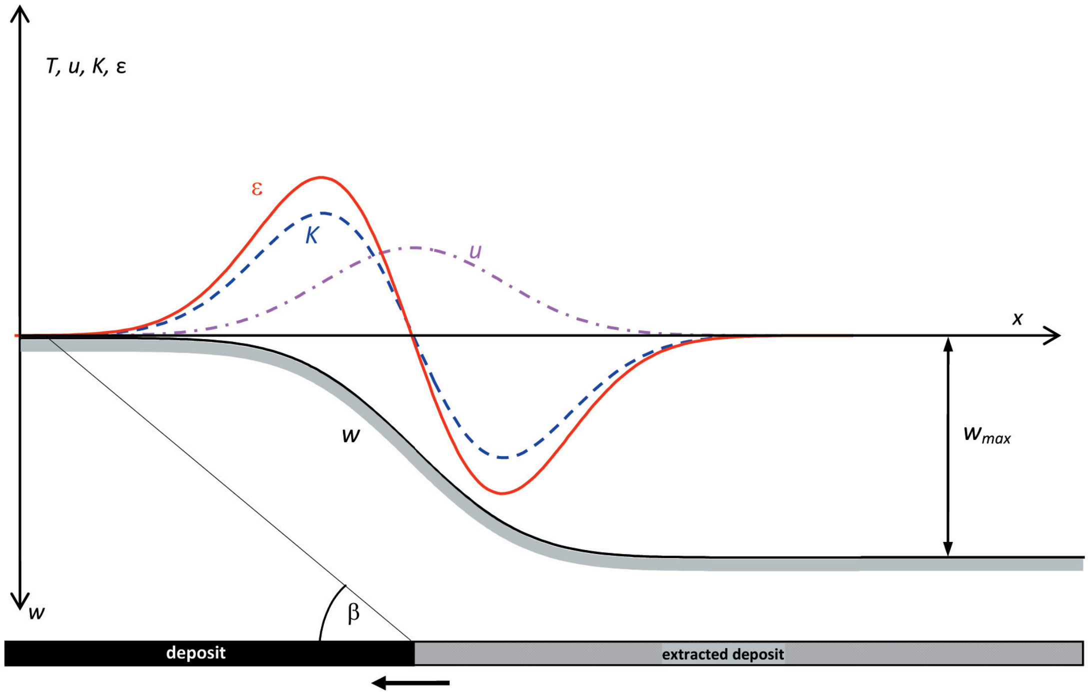

Fig. 1. Diagram of the continuous near-surface soil layer deformation factor values in the area of the mining face [4]: w – terrain depression, u – displacement horizontals, ε – deformation horizontals, K – curvatures (K = 1/R), β – angle of boundary for overhead influence

Depending on the permissible terrain deformation factor values, mining areas with continuous deformations are divided into six categories (Tab. 1).

The characteristic and design values of the deformation factors should be adopted with the inclusion of their random dispersion, characterised by coefficients of variation, as well as safety coefficients [4–6].

In the case of pipelines installed in trenches, the influence of the near-surface soil layer displacement and deformation horizontals in direction of the longitudinal pipeline axis results in the occurrence of longitudinal forces or mutual pipe displacements, whereas the terrain curvatures lead to the mutual angular deviation of the pipes (Fig. 2).

Table 1

Mining area categories [4, 5]

Mining area category	**Deformation factor values**		
	Inclination T [mm/m]	**Radius of curvature R [km]**	**Horizontal deformation ε [mm/m]**
0	$T \le 0.5$	$40 \le \lvert R \rvert$	$\lvert \varepsilon \rvert \le 0.3$
I	$0.5 < T \le 2.5$	$20 \le \lvert R \rvert < 40$	$0.3 < \lvert \varepsilon \rvert \le 1.5$
II	$2.5 < T \le 5$	$12 \le \lvert R \rvert < 20$	$1.5 < \lvert \varepsilon \rvert \le 3$
III	$5 < T \le 10$	$6 \le \lvert R \rvert < 12$	$3 < \lvert \varepsilon \rvert \le 6$
IV	$10 < T \le 15$	$4 \le \lvert R \rvert < 6$	$6 < \lvert \varepsilon \rvert \le 9$
V	$T > 15$	$\lvert R \rvert < 4$	$\lvert \varepsilon \rvert > 9$

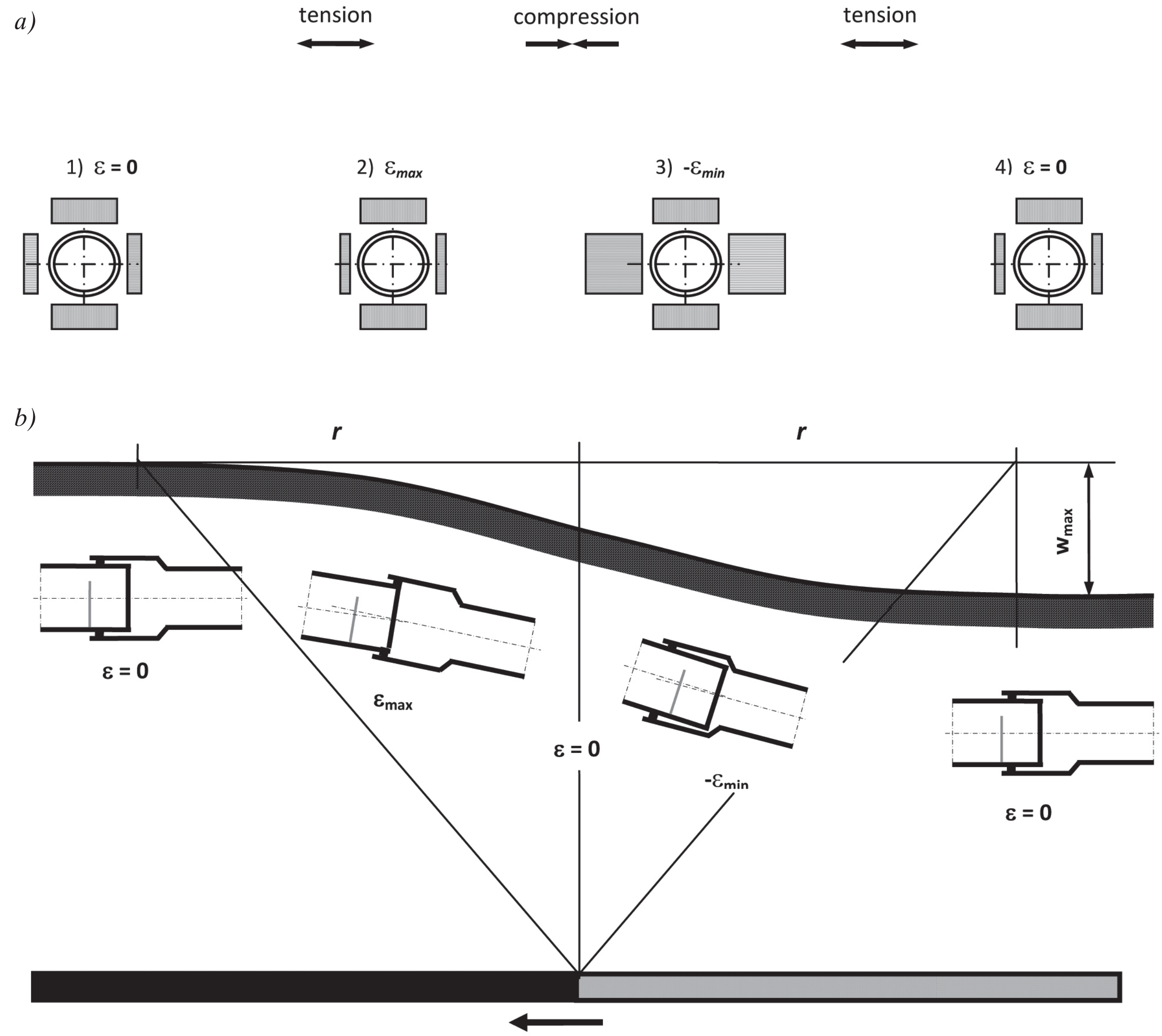

Fig. 2. Influence of mining activity on a pipeline composed of socket pipes with expansion joints: a) transverse pipe load variations in the individual stages of horizontal soil deformation influence; b) pipe displacements and angular deviations in the individual stages of horizontal soil deformation and terrain curvature influence

Pipes used in mining areas should have the appropriate expansion joints for protection against damage (stage 1, Fig. 2b). The pipes undergo outward displacement relative to each other in the area outside the extraction zone as a result of horizontal soil tension (stage 2, Fig. 2b). In the area above the extraction zone, the pipes undergo inward displacement as a result of horizontal soil compression (stage 3, Fig. 3b), which leads to the occurrence of longitudinal compression forces in the absence of expansion joints. After the passage of the horizontal deformation wave, at a distance from the mining face greater than *r*, at $\varepsilon = 0$ the plain end returns to its original orientation (stage 4, Fig. 2b). Therefore, in the case of pipes with socket and sleeve joints, the expansion joints must have appropriate widths selected for the category of the mining area. The forced outward pipe displacement induced by the soil deformations must not result in the loss of joint integrity, whereas the forced inward displacement must not result in damage to the pipes and their joints. Damage may occur when the expansion joint is too small or absent. For this reason, it is necessary to inspect the compensation capability of the pipe joints. This concerns both standard and extended joints used in mining areas.

In the case of sewage systems established using trenchless methods, casing pipes are laid down in immediate contact after installation is concluded (stage 1, Fig. 3b). The influence of mining activity in direction of the longitudinal pipeline axis in the area of the horizontal near-surface soil layer tension results in outward pipe displacement (stage 2, Fig. 3b), whereas in the area of horizontal compression, longitudinal compression forces are induced due to the absence of initial expansion (stage 3, Fig. 3b). However, casing pipes are characterised by high longitudinal compressive strength, as a result of their adaptation to the trenchless pipeline construction methods. In the final stage of the influence of the moving mining face, the horizontal compression is followed by another occurrence of soil tension to a deformation value of ε ≈ 0 at a distance greater than the radius *r* of the boundary of influence (Fig. 3). At this point, the casing pipes undergo outward displacement and expansion gaps appear in their joints (stage 4, Fig. 3b). Due to the influence of further extraction in mining areas characterised by the influence of multiple extraction efforts, casing pipes should fulfil the same requirements as pipes installed in trenches.

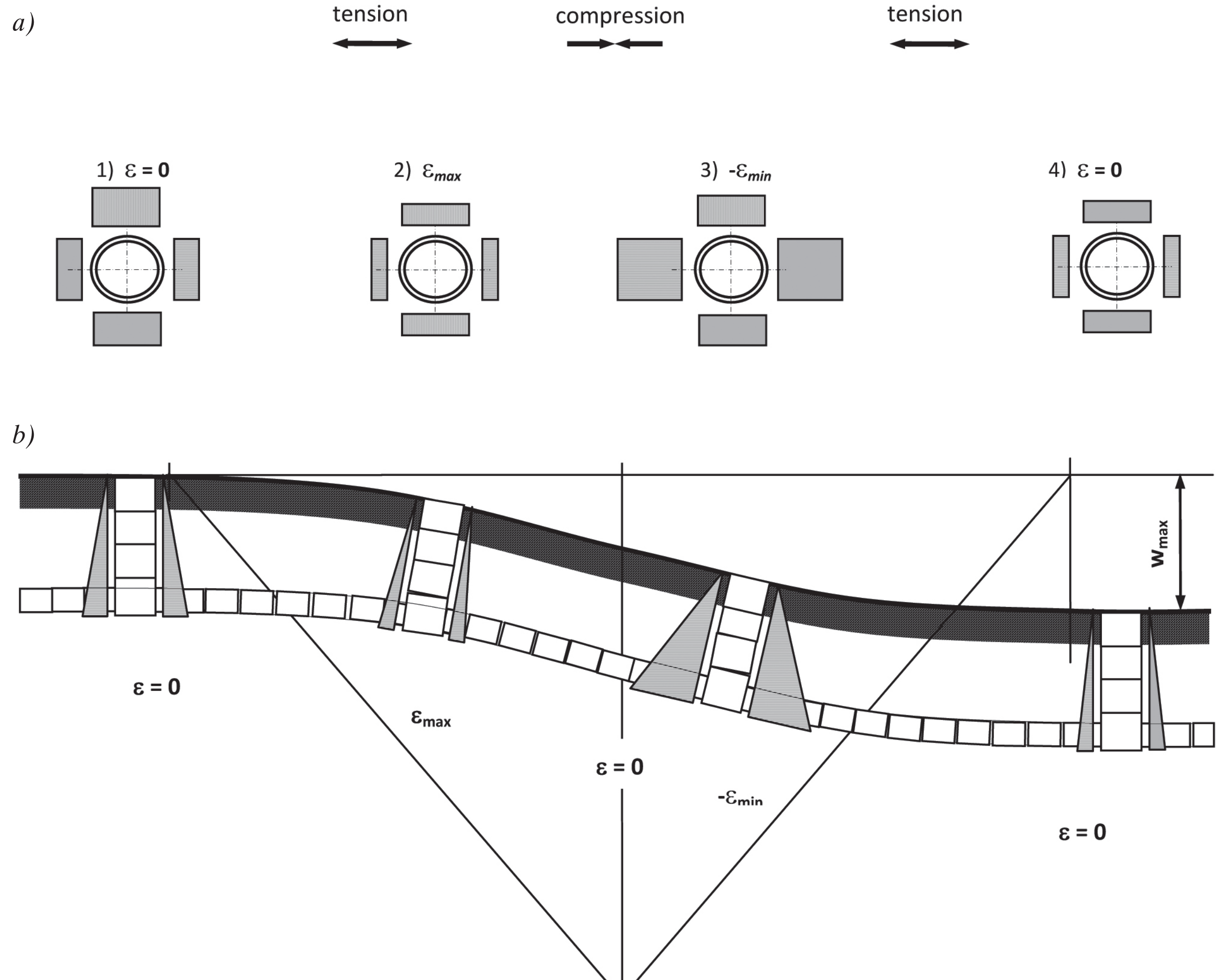

Fig. 3. Influence of mining activity on a pipeline established using trenchless methods and on manholes: a) lateral manhole load variations in the individual stages of horizontal soil deformation influence; b) pipe and manhole element displacements and angular deviations in the individual stages of horizontal soil deformation and terrain curvature influence

In the lateral direction of the longitudinal pipeline axis, the influence of near-surface soil layer deformations results in changes to the transverse pipe loads (Fig. 2a). The initial loads exerted on the pipe cross-section are non-uniform, and the vertical load in cohesionless soil is about two times greater than the horizontal pressure (stage 1, Fig. 2a). There is a decrease of the soil pressure on the pipe in the horizontal tension area to an active pressure in the ultimate limit state of the soil (stage 2, Fig. 2a), whereas the pressure increases by several times in the compression zone (stage 3, Fig. 2a). Increased soil pressure results in greater bending moments and circumferential compression forces exerted on the pipe walls. However, the vertical load undergoes only slight variations as a result of changes to the soil density during the deformation variation. After a full cycle of horizontal deformation is finished, the soil returns to an active ultimate limit state (stage 4, Fig. 2a). Given the great variations and non-uniformity of the loads exerted on the pipe cross-sections, the pipes used in mining areas must therefore have the appropriate crushing strength, while plastic pipes must exhibit the correct ring stiffness.

Similarly to pipes installed in mining areas, the original state of the horizontal forces exerted on the manholes is disrupted as well, though these are uniform (stage 1, Fig. 3a) unlike the initial loads exerted on the pipes. Horizontal soil tension results in decreased horizontal loads (active ultimate limit state) and their low non-uniformity. The most unfavourable load case manifests itself in the area of horizontal soil compression (stage 3, Fig. 3a), as it entails the highest pressure of the soil and its greatest non-uniformity. This results in the greatest horizontal compression forces and bending moments exerted on the manhole walls when subjected to the influence of mining activity. After a full cycle of horizontal deformation is finished, the soil returns to an active ultimate limit state (stage 4, Fig. 3a). Furthermore, the near-surface soil layer deformations may result in deformations of the manhole structures as well as in the mutual displacements and deviations of their elements (stages 2 and 3, Fig. 3b) coupled using seals (e.g. concrete rings and bases). The manhole joints should retain their integrity under such conditions. This is why it is necessary to inspect the integrity of the joints at the angular deviation of the manhole elements coupled using seals, as these do not always fulfil the requirements for application in mining areas.

The test program for pipeline and manhole elements intended for the construction of sewage systems in mining areas should factor in the specifics of their structure, and should particularly encompass testing of:

- the maximum pipe joint compensation while retaining joint integrity,
- manhole integrity at the angular deviation of concrete and reinforced concrete elements coupled by means of seals,
- the ring stiffness or crushing strength of pipes and manhole elements.

The conducted test results and the analysed influence of mining activity are applied to assess the suitability of sewage system elements for use in mining areas.

3. SELECTED PIPE AND MANHOLE TEST METHODS

The following test programs were developed at the Central Mining Institute to assess the manufactured pipe and manhole systems for use in mining areas:

- joint integrity of casing pipes and pipes installed in trenches, including those of large sizes,
- manhole integrity,
- ring stiffness and crushing strength of pipes and manhole elements.

3.1. Drainage pipe joint integrity testing

The integrity test for drainage pipe joints [7], at a given water pressure inside the pipes, is based on the axial displacement of pipe (1) relative to pipe (2) (outward and inward over a path h), which is placed on the ground (Fig. 4–7). These pipes (Fig. 4 and 5) are coupled by means of a sealing system (3). Pipes (1) and (2) are closed on one side using special covers and are capable of withstanding the pressure inside the pipes during testing.

During the test, the pipes typically undergo outward displacement relative to each other as a result of the influence of the water pressure, and compression by means of a hydraulic actuator terminated with a pressure plate (4). Should this method prove ineffective, the outward and inward pipe displacement is accomplished by means of a hydraulic actuator connected to pipe (1) by means of a special (cross-shaped) fixture and additional belts. Such a connection makes it possible to correct the angular deviation of the pipes relative to one another during their inward or outward displacement, or on the contrary – to produce a specific angular pipe deviation should the test require so. The rate of the inward or outward pipe displacement is controlled in such a way so as to maintain the water pressure in the joint at the defined level. This task is very difficult to accomplish, as the coupling of pipes e.g. with a diameter of 1.4 m and a combined height of about 2 m holds over 3000 litres of water, whereas the mass of the entire assembly is over 4 tons.

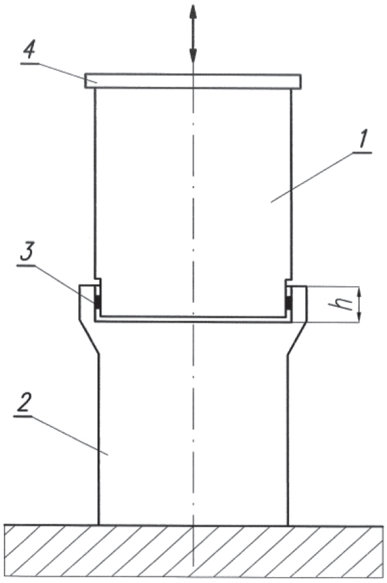

Fig. 4. Socket pipe joint integritytest method

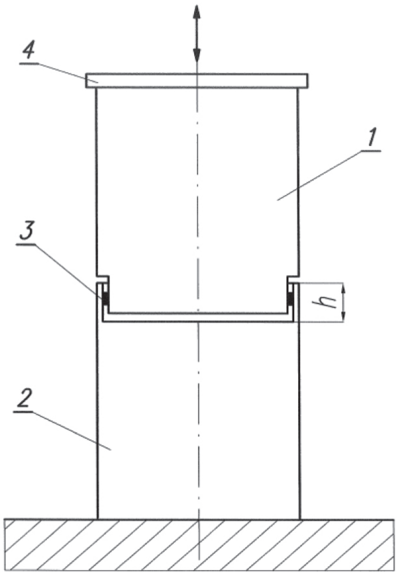

Fig. 5. Casing pipe joint integritytest method

Fig. 6. DN 1000 reinforced concretesocket pipe joint in the test facility

Fig. 7. DN 1300 GRP casing pipejoint in the test facility

The pipe joint is carefully observed during all the testing stages with regard to its integrity (the occurrence of leaks).

3.2. Manhole integrity testing

The manhole integrity test is based on inspecting the integrity between the manhole rings at a given internal pressure and angular deviation. For this purpose, the following elements are placed in succession: the manhole base, at least one ring, and the cover or taper with an entrance hatch. When preparing the manhole for testing, it is very important to seal the openings for connecting pipes or fittings in the base as well as the cover. Special plugs and sheet metal covers with seals are prepared for this purpose and screwed onto the cover or hatch. Before laying a ring onto the manhole base, a wooden panel with the appropriate thickness is typically inserted between these elements, which makes it possible to produce an angular deviation between them. After a cover or taper with an entrance hatch is laid onto the ring, the entire manhole is secured from displacement using belts or other measures (Fig. 8). Thus prepared, the manhole is filled with water at a required pressure of 50 kPa. The pressure should be maintained for 15 minutes. The connections between the manhole elements should not exhibit any leaks.

Fig. 8. Concrete manhole during testing

3.3. Ring stiffness and crushing strength testing

3.3.1. Ring stiffness testing for thermoplastics pipes

The test (Fig. 9) consists in compressing a pipe section (1) between two parallel flat plates (4 and 5) at a defined speed until the vertical pipe deformation reaches a value of 3% of its original internal diameter *d*.

The equipment of the test facility at the Central Mining Institute makes it possible to test pipes with an internal diameter *d* of up to 3.5 m. As per the requirements of the applicable standard [8], the sample length for a diameter range of 1.2 m to 3.5 m should be 1000 mm, and the load rate should equal $0.03\times d$ ±5% mm per minute. The force value and the pipe deflection are recorded during the test, with the latter measured inside the tested pipe. Force (3) and deflection (2) sensors are connected to a digital amplifier, and the measurement data is archived on a computer drive.

Special software was developed to determine the ring stiffness, and its algorithms are based on formulas included in the standard [8], while the test report fulfils the requirements provided in point 10 of the standard.

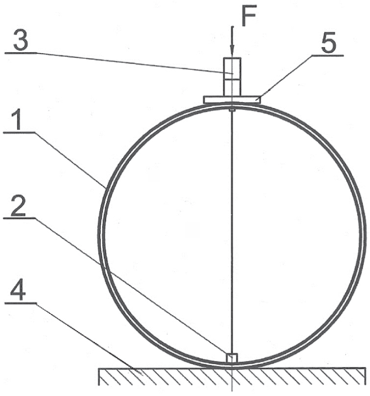

Fig. 9. Ring stiffness test setup diagram

Figure 10 presents example force/deflection courses for a pipe with an internal diameter of 2000 mm, whereas Figure 11 depicts a pipe with an internal diameter of 1500 mm, prepared for testing.

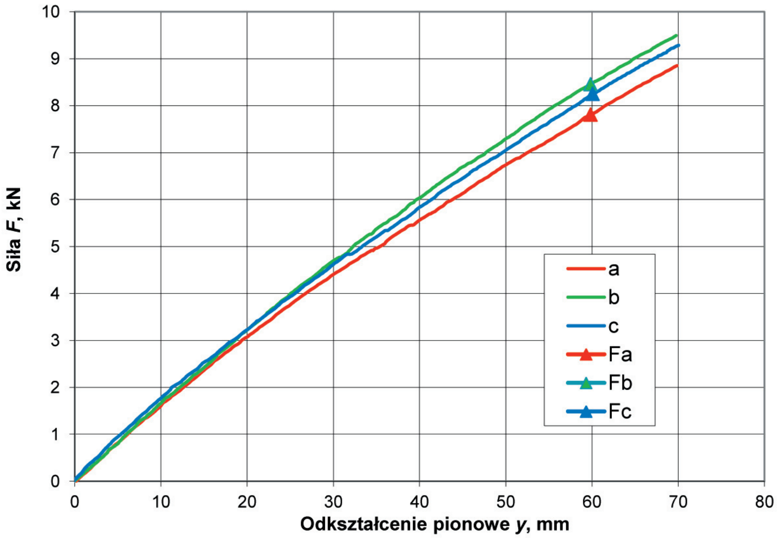

Fig. 10. Example force/deflection courses for a 2000 mm diameter pipe, for 3 samples (a, b, c); Fa, Fb, Fc – force F at the pipe deflection required by the standard

Fig. 11. DN 1500 pipe in the test facility

3.3.2. Concrete ring and pipe crushing strength testing

Similarly to the ring stiffness determination (Fig. 9), the concrete ring and pipe crushing strength test (per standard PN-EN 1916 [9] or PN-EN 1917 [10]) consists in compressing a pipe section (1) between two parallel flat plates (4 and 5) at a defined speed. The lower plate is equipped with a V-shaped support with an appropriate angle. The test is concluded if the test load is achieved, or the pipe undergoes failure (cracks). The test load is a load determined with reference to the minimum crushing load F_n corresponding to the nominal size and strength grade of a given pipe or ring, according to the provisions of standard PN-EN 1916 or PN-EN 1917. The equipment of the test facility at the Central Mining Institute makes it possible to test pipes with an internal diameter d of up to 4.0 m. The force value and the pipe deflection are recorded during the test, and the deflection measurement corresponds to the output stroke of the testing machine actuator. Force and actuator output sensors are connected to a digital amplifier, and the measurement data is archived on a computer drive. Figure 12 presents a concrete ring during the crushing test, whereas Figure 13 depicts an example crushing test chart.

Fig. 12. 1500 mm diameter reinforced concrete ring during the crushing test

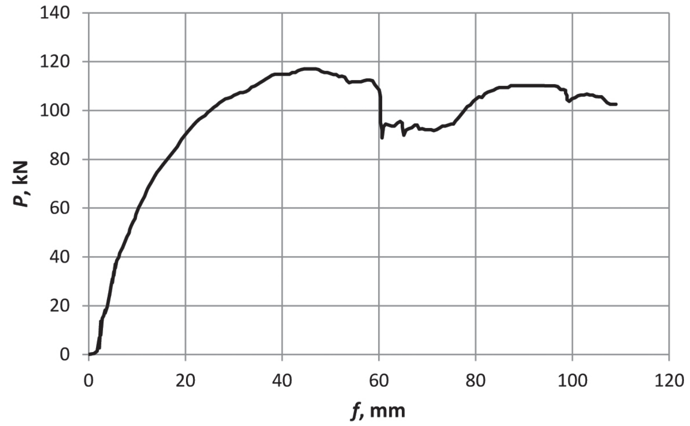

Fig. 13. Example reinforced concrete ring crushing test chart

4. SUMMARY

Mining activity results in near-surface soil layer deformations which exert influence on drainage pipelines by generating additional pipe and manhole element loads and displacements. From the perspective of the influence of these deformations, great significance is presented primarily by the displacement *u* and deformation ε horizontals, as well as surface curvatures *K* in the case of large-size pipes. Variations in terrain inclination are significant as well and should be factored in at the drainage system design and construction stage.

Considering the influence of the near-surface soil layer deformations, the testing of drainage system elements intended for installation in mining areas should encompass the following in particular:

- pipe joint integrity tests with the determination of the maximum compensation of mutual pipe displacements, including potential angular pipe deviations,
- manhole integrity tests with the angular deviation of elements coupled by means of seals,
- ring stiffness tests for flexible carrier pipes and manhole risers formed from plastics,
- crushing strength tests for rigid pipes and manhole elements.

Methods for carrying out the above tests were developed at the Central Mining Institute, with particular focus on large-size elements of the manufactured drainage systems. The conducted test results and the analysed influence of soil deformation are applied to assess the suitability of drainage system elements as well as the conditions for their installation in mining areas.

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References

[1] Madryas C., Kolonko A., Wysocki L.: *Konstrukcje przewodów kanalizacyjnych*. Oficyna Wydawnicza Politechniki Wrocławskiej, Wrocław 2002.
[2] Kuliczkowski A.: *Projektowanie konstrukcji przewodów kanalizacyjnych*. Wydawnictwo Politechniki Świętokrzyskiej, Kielce 2003.
[3] Kuliczkowski A.: *Rury kanalizacyjne Tom II Projektowanie konstrukcji*. Wydawnictwo Politechniki Świętokrzyskiej, Kielce 2004.
[4] Instrukcja nr 12: *Zasady oceny możliwości prowadzenia podziemnej eksploatacji górniczej z uwagi na ochronę obiektów budowlanych*. Główny Instytut Górnictwa, Katowice 2000.
[5] Kwiatek J.: *Obiekty budowlane na terenach górniczych*. Główny Instytut Górnictwa, Katowice 2007.
[6] Instrukcja nr 364/2007: *Wymagania techniczne dla obiektów budowlanych wznoszonych na terenach górniczych*. ITB, Warszawa 2007.
[7] *Metodyka badania szczelności złącza rozbieranego w rurociągach budowanych na terenach górniczych – MBSZR-1*. Główny Instytut Górnictwa, Zakład Badań Urządzeń Mechanicznych, Katowice 2004.
[8] PN-EN ISO 9969:2016 – *Rury z tworzyw termoplastycznych – oznaczanie sztywności obwodowej*.
[9] PN-EN 1916:2005 – *Rury i kształtki z betonu niezbrojonego, betonu zbrojonego włóknem stalowym i żelbetowe*.
[10] PN-EN 1917:2004 – *Studzienki włazowe i niewłazowe z betonu niezbrojonego, betonu zbrojonego włóknem stalowym i żelbetowe*.

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