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# LOADS OF SEWER MANHOLES WITHIN MINING AREA

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**ABSTRACT**

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| **Purpose** | The purpose of this paper is to present the method of taking into account additional external horizontal loads acting on sewer manholes within mining areas, caused by the impact of horizontal strains on the subsurface soil layer. |
| **Methods** | The determination of the dependencies of the changes in the cross-sections of flexible manholes' riser pipes (with different circumferential stiffness) on the values of horizontal soil strains, based on laboratory tests. |
| **Results** | The results include formulas for determining the values of external horizontal loads acting on sewer manholes within mining areas, in particular flexible manholes made of thermoplastics. |
| **Practical implications** | The results will be used for the assessment of conditions in which sewer manholes can be used within mining areas – and will be beneficial when considering the following: design, protection and assessment of resistance to horizontal strains. |
| **Originality/ value** | The presented method is an original concept. It enables the determination of additional external horizontal loads acting on sewer manholes within mining areas, in particular the flexible manholes made of thermoplastics. It also enables the determination of dependencies of changes in the cross-sections of risers of flexible sewer manholes (with different circumferential stiffness) on the horizontal soil strains. |

**Keywords**
*sewer manholes, loads, mining area*

## 1. INTRODUCTION

The impact of mining deformations in subsurface soil layer on the structure of sewer manholes is manifested mainly by the interaction of horizontal strains. This interaction may result in the bearing capacity of the components of manholes being exceeded, causing them to fail as well as leading to changes in the shape of cross-sections from the flexible (deformable) objects. In the case of modular manholes made of plastics, prefabricated concrete or reinforced-concrete elements, the interaction can also cause angular deviations of such elements and even a loss of tightness.

The evaluation of the conditions in which the sewer manholes can be used within mining areas consists of determining the foundation depth for the expected values of horizontal strains in subsurface soil layer as well as the type and condition of the soil. In order to determine this depth, it is necessary to know the values of the external horizontal loads. These values constitute the basis for the calculation of bending moments and axial forces acting on the walls of such objects and, afterwards, they are compared with their bearing capacity. These loads are also used for determining the values of the relative deformation of the flexible manhole cross-section, which is compared to the permissible deformation (Kalisz, 2010).

This paper focuses on the impact of horizontal strains in subsurface soil layer caused by underground mining on the walls of, both flexible and rigid, sewer manholes. It was assumed that the level of groundwater is does not reach the bottom of the manhole. The exemplary results of preliminary laboratory tests concerning the impact of horizontal soil strains on models of flexible risers of sewer manholes made of plastics with different circumferential stiffness have been presented. As in the case of pipelines (Mokrosz, 1998), the cross-section deformability of the riser of a sewer manhole means its susceptibility to change of shape under the impact of unevenly distributed external horizontal forces. This change affects the values and distribution of external loads which are induced by soil. An important parameter, which characterizes the flexibility of sewer manholes made of plastics, is the circumferential stiffness of the manhole riser pipes, determined based on test results (Rydarowski & Walczak, 2000). These riser pipes are characterized by the following stiffness classes: 2, 4, 8 as well as 12 and 16 kN/m$^2$.

## 2. IMPACT OF HORIZONTAL SOIL STRAINS ON THE WALLS OF SEWER MANHOLES

### 2.1. The initial state of loads of flexible and rigid manholes

It is assumed that the distribution of external horizontal loads on sewer manholes with a circular cross-section is even before mining deformations in subsurface soil layer occur and their value increases along with the foundation depth of the manhole (Fig. 1a and Fig. 1b). In the case of sewer manholes made of plastics, a slight unevenness of loads on their circumferences can occur. This is caused by the uneven compacting of the non-cohesive soil layers of backfill. The stresses in the soil layer at a depth of $z$ amount to (Wiłun, 2013)

$$\sigma_{11} = \gamma\, z + q_n + q \tag{1}$$

and

$$\sigma_{22} = \sigma_{33} = \xi_0\ \sigma_{11} = \xi_0\ (\gamma\, z + q_n + q) \tag{2}$$

where:

$\sigma_{11}$ – vertical stress of soil,
$\sigma_{22}$ – horizontal stress of soil at the main direction $x$ (Fig. 2),
$\sigma_{33}$ – horizontal stress of soil at the main direction $y$ (Fig. 2),
$\xi_0$ – at rest soil pressure coefficient,
$\gamma$ – unit weight of soil,
$z$ – foundation depth of the analysed cross-section of the manhole,
$q_n$ – surface weight,
$q$ – useful load of surcharge over the analysed cross-section of the manhole.

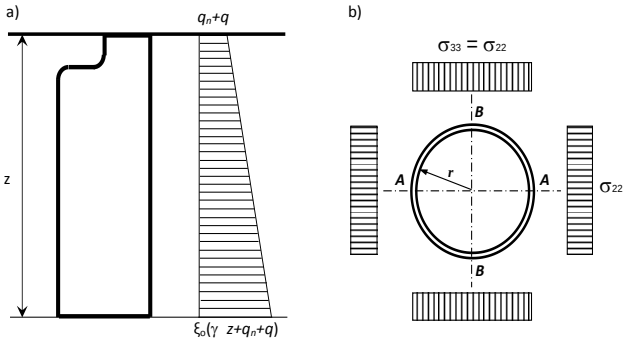


**Fig. 1.** Distribution of loads along with the foundation depth of the manhole – a, distribution of loads on the circumference of the manhole – b

External horizontal loads on sewer manholes lead to the creation of circumferential compressive forces in their walls. Thermoplastics are materials with viscoplastic properties and thus, they creep under loads. The walls of manholes deform and thus, the diameter of manhole riser pipes reduces slightly. The soil, around the manholes, loosens which leads to an active limit state. The lateral soil pressure coefficient reduces to the limit value $\xi_r$ (Petroff, 1994) which is assumed in static calculations instead of the at rest soil pressure coefficient $\xi_0$. In such cases, 21% of load unevenness at the circumference of such objects is assumed.

### 2.2. Loads of flexible and rigid manholes

Depending on the position of the exploitation edge, the impact of horizontal soil strains around the walls of a sewer manhole can be separated into three stages: horizontal soil loosening, compacting and loosening again.

#### 2.2.1. Rigid manholes – loosening of the subsurface soil layer

Loosening of the subsurface soil layer results in the reduction of external horizontal loads on objects buried within it, both in a parallel and perpendicular direction to the exploitation edge. At the same time, the horizontal loads on the walls of objects are unevenly distributed and it contributes to changes in axial forces and bending moments. In contrast to flexible objects, deformation of the cross-section of rigid manholes is so small that it has no impact on the values and distribution of the uneven loads acting on them (Mokrosz, 1998). During the horizontal loosening of the subsurface layer of non-cohesive soil for the horizontal strains of 2–3 mm/m, an active limit state occurs.

The horizontal stresses acting in a perpendicular direction to the exploitation edge (x-axis, Fig. 2) are determined according to the following formula

$$\sigma_{22}^r = \xi_r\ \sigma_{11} \tag{3}$$

Changes in horizontal stresses are as follows:

$$\Delta\sigma_{22}^r = \xi_0\ \sigma_{11} - \sigma_{22}^r = (\xi_0 - \xi_r)\ \sigma_{11} \tag{4}$$

and

$$\Delta\sigma_{33}^r = \nu\Delta\sigma_{22}^r = \nu\ (\xi_0 - \xi_r)\sigma_{11} \tag{5}$$

Then

$$\sigma_{33}^r = \xi_0\sigma_{11} - \Delta\sigma_{33}^r = \xi_0\sigma_{11} - \nu\Delta\sigma_{22}^r = \left[\xi_0 - \nu(\xi_0 - \xi_r)\right]\sigma_{11} \tag{6}$$

thus, the difference of horizontal stresses $\Delta\sigma$, acting on the walls of rigid manholes at the soil loosening stage, assuming that $\sigma_{33}^r > \sigma_{22}^r$ as well as $\sigma_{\min} = \sigma_{22}^r$ and $\sigma_{\max} = \sigma_{33}^r$, amounts to

$$\Delta\sigma = \sigma_{\max} - \sigma_{\min} = \sigma_{33}^r - \sigma_{22}^r = \left[(\xi_0 - \xi_r)\ (1-\nu)\right]\sigma_{11} \tag{7}$$

where:

$\xi_r$ – active soil pressure coefficient,
$\nu$ – Poisson's ratio.

#### 2.2.2. Rigid manholes – compacting of the subsurface soil layer

Compacting of the subsurface soil layer results in an increase in the values of the external horizontal loads on rigid manholes buried in it. In extreme cases, the pressure value can reach the value of passive pressure – in non-cohesive soils with deformations of 30–35 mm/m. In the immediate vicinity of the walls of the rigid manholes, there is a significant concentration of horizontal soil strains which results in a spatial deformation state and spatial stress state within that area, however slight changes in the values of vertical stresses are ignored. Changes in horizontal stresses $\Delta\sigma_{22}^z$ and $\Delta\sigma_{33}^z$ during soil compacting, taking into account the concentration of horizontal strains $\bar{\varepsilon}$ defined with the coefficient $k_0$ (Kwiatek, 1998), can be determined based on the following dependences

$$\Delta\sigma_{22}^z = -\frac{2G\bar{\varepsilon}}{1-\nu} = -\frac{2Gk_0\varepsilon}{1-\nu} \tag{8}$$

and

$$\Delta\sigma_{33}^z = \nu\Delta\sigma_{22}^z = \nu(\sigma_{22} - \xi_0\sigma_{11}) = -\frac{2G\nu\varepsilon}{1-\nu} \tag{9}$$