Case-study. Monitoring deformation of new pipes in soils containing Neogene clay

V. Boiko *(Institute of Hydromechanics' National Academy of Science of Ukraine, Ukraine)*, ***V. Boiko*** *(The City University of New York, USA)*, ***A. Han*** *(National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukraine)*, ***T. Khlevniuk***, ***O. Chala*** *(Institute of Hydromechanics' National Academy of Science of Ukraine, Ukraine)*

SUMMARY

The pipelaying in Chernivtsi city, Ukraine, was carried out with a trenchless method at a depth of approximately 5 m in Neogene clay. After completion of the works (in a day) a teleinspection of the pipeline was carried out and it was determined: in the first section the geometry of the pipe was not broken; on the second section - broken: gradual deformation in the vertical plane; on the third section the geometry of the tube is bro-ken: gradual deformation in the horizontal plane; on the fourth section the geometry of the tube is broken: gradual deformation in the horizontal plane. After some time, the second teleinspection was carried out: two branches of the new sewer pipes were deformed practically throughout the whole length of the plots. The ap-proximate value of the residual pressure was at least 0.33 MPa at a depth of 5 m, which was the cause of the deformation of the tubes. High values of pressures, especially horizontal ones, which were registered in many exploring and mine openings in Chernivtsi region of Ukraine, were sometimes ten times higher than those of the vertical pressures. High values of subsidence as a result of shrinkage may be of significant hazard to buildings and structures because the value of average subsidence for brick buildings with reinforced belts should not exceed 15 cm.

Introduction

Landslides are a major threat for human life, facilities, infrastructure and natural environment in many regions of the world. During the decade 2000–2009 natural disasters destroyed ap-proximately one million facilities and affected about 2.5 billion people all around the globe. The landslide frequency of about 20 major events per year in Europe is higher in comparison with floods, earthquakes and cyclones (Lacasse, 2013). All 50 States and the U.S. territories are subjected to landslides and other ground-failure problems. Landslide hazards have changed from moderate to high in 36 States (The U.S. Geological Survey Landslide Hazards Program 5-Year Plan 2006-2010. U.S. Department of the Interior. U.S. Geological Survey 2010). Landslides in the USA are a serious hazard. They cause the substantial human and financial losses estimated at 25…50 deaths and $1–$3 billion per year (National Landslide Hazard Mitigation Strategy: A framework for loss reduction/ Circular 1244. U.S. Department of the Interior.).

Landslide processes in Ukraine occupy the first place in the scale of damage. In general, about 23.1 thousand landslides were detected in Ukraine as of 12.01.2011 and 17.4 thousand – as of 12.01.1997. Thus, there was an increase in the number of landslides of 1.3 times and increase of 3 times takes place over the last 30 years. The issues of assessment of slopes stability and landslides originating in complex soil conditions have been described in numerous works of foreign researchers: Terzaghi, Lollino, Lacasse (2013), Bobrowsky, Cassagli, Barla and many others. Among national researchers the following scientists should be mentioned: Ginzburg, Ivannik (2011, 2015, 2017), Kaliukh (2018, 2019), Mencl (1971), Polevetskyy (2009), Trofymchuk (2017), Zaruba (1971), Ziangirov (1979), Vlasyuk (2015, 2019), Zhukovskaya (2015, 2019), Zhukovskyy (2019) and many others. The case study from practice in Chernivtsi will be described below: deformation of new sewage system pipes laid partially through the Neogene clay slope.

Examples

Private company has performed construction of outside water supply and sewage system in Chernivtsi city. The sewage route should go under Storozhynetska Street that is on the slope consisting mainly of Neogene age clay soil. The works planned to be cut-and-cover. Neogene clay bulk density exploring has been implemented - 23-24 kN/m^3. During detailed study of the project it was revealed that sewage trench should be more that 5 m in some places. Since Storozhynetska Street is an important road in Chernivtsi city, there is no possibility to arrange an alternative way. Therefore, the decision to find another way using modern technologies of horizontal drilling for sewage pipelaying has been made. The works were performed in the following sequence (fig.1): 1) preliminary drilling of the well about 80 mm in diameter using water; 2) reaming up to 350 mm in diameter using water; 3) lying of the pipe about 200 mm in diameter using 250 mm expansion head. Installation of the pipe about 80 mm in diameter with maximum possible inner pressure of P=0,6 MPa. After works completion (in 24 hours) the teleinspection of sewage pipeline has been carried out and the following has been identified (fig.1):

1. The shape of the pipe has not been affected on the site 1-II;

2. On the site 2-3 the shape of the pipe has been deformed: delayed deformation in vertical plane towards outside drainage pit 3 (pipelaying was carried out from pit II to pit III);

3. On the site 3-4 the shape of the pipe has been deformed: delayed deformation in vertical plane towards outside drainage pit 4 (pipelaying was carried out from pit III to pit IV);

4. On the site 5-4 the shape of the pipe has been disrupted: delayed deformation in vertical plane towards outside drainage pit 5 (pipelaying was carried out from pit IV to pit V);

After that the works were performed on the opposite side of Storozhynetska Street. The second pipe was deflected in the same way.
After the case analysis it was revealed that the works site is on the **slope**, pipe deformation took place in **Neogene clay** only. On the site 1-2 where the pipe route went through loamy soil, pipe deformation did not take place (fig.1).

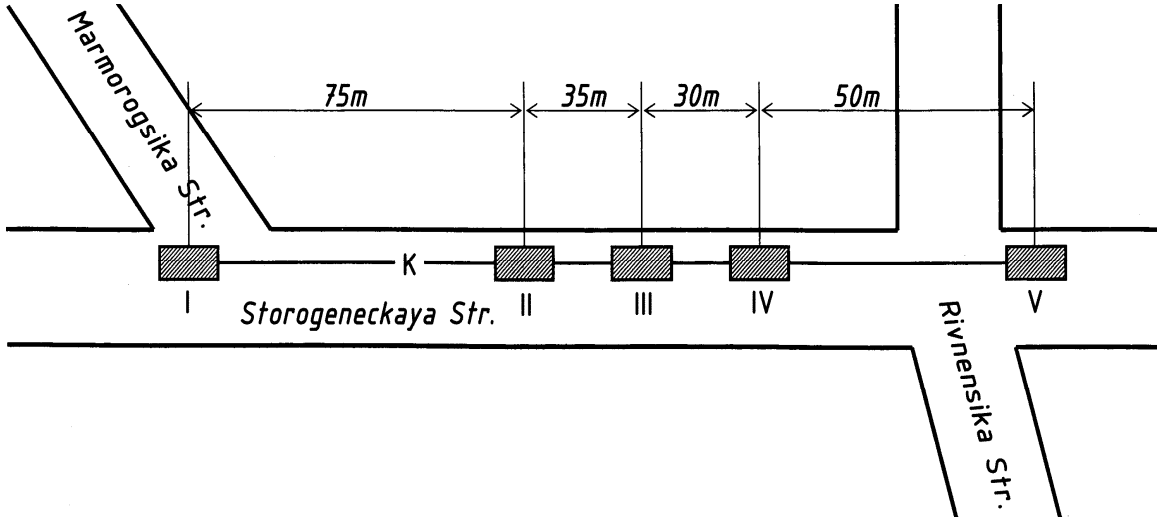

Figure 1 *Sewage pipelying scheme*

Let us analyse using back calculation what pressure could cause such pipe deformation. Taking into account horizontal well diameter 350mm to the drilling depth 5-6 m ratio, we can consider it as a tunnel. Maximum pressure on the tunnel walls (pipe) could be $3p_z$, where p_z is soil pressure Zaruba, Mencl (1971). As for our case, the natural pressure is approximately 0,1 MPa. Maximum possible pipe inner pressure is 0,6 MPa. It should hold pipe external pressure nearly 1,2 MPa. Let us accept possible maximum horizontal pressure that caused deformation as 1,3 MPa.

As a result of back calculation, we can state that pressure caused pipe deformation is 0,33 MPa. The question that has to be answered is: How 0,33 MPa pressure can be at the depth of 5 m if the natural pressure is 0,1 MPa?

Anticipation № 1 – Residual ancient pressure. PhD Polevetskyy (2009) explains the above case as follows: according to the researches carried out by Czech scientists Zaruba, Mencl (1971), increased horizontal pressure in the soil are often observed as residual one from ancient pressure when covering them layer thickness reached some hundreds meters. Such cases can be observed in Neogene age clay Zaruba, Mencl (1971), where residual horizontal pressure was registered. High horizontal pressure is often observed in bow areas. Such pressure could be of modern origin related to neotectonic processes Polevetskyy (2009). Residual horizontal pressure action results in cracks formation within the slope. Neogene age clay is marine deposits. Pressure under which they have been formed was significantly higher that they are now, being raised by tectonic and bared by erosive processes. Residual pressures in clay also have been fixed during development of Toktogulske water reservoir on Narina River.

Anticipation № 2 – Softening of Neogene age clay as a result of watering during underground trenches digging. As it is known, natural geological processes (erosion, denudation, raising tectonic movements) as well as engineering human activity cause change in the rock stress state that is accompanied by their softening. The character and intensity of softening are defined by the degree of stress state change (differential pressure) as well as rock strength in the conditions of their occurrence. The main factor of rock softening is natural pressure release, as a rule acts slowly during natural geological processes and relatively fast during construction and mining works (deep excavations

design, tunnel boring and shaft sinking, etc.). One of the characteristics of Neogene age clay is its peculiarity to expand during watering. Expansion index is defined by mineral and grading of clay soil, its consistency – moisture, and percent composition of clay fractions less than 0.005 mm. Soil raising as a result of softening of nominal unit volume could be more than 14 cm. P. Ziangirov (1979) made a conclusion that for surface thickness of clay soil of 6-10 m there is no balance between operating natural pressure and porosity-moisture, and properties of surface thickness are mainly defined by soil over consolidation as a result of shrinkage, diagenesis, grouting and mineral formation processes.

Conclusion

Case study of deformation of new underground sewage trenches and pipes in Chernivtsi city in the slopes composed of Neogene age clays. To our opinion, the main reason is Anticipation № 2 – technology of horizontal holes drilling and reaming using great amount of water. As a result of watering the Neogene age clay swelling took place that caused deformation of underground trenches and sewer pipes. As a result of teleinspection of trenching the site on Storozhynetska Street in Chernivtsi city, the pipes and both trenches were deformed practically throughout the whole length of the new sewage lines in the slope composed mostly of Neogene age clay.

References

Ivanik, O. (2015). Principles and methods of the regional landslide hazard assessment based on analysis of the rock mass stress-strain state. In *14th EAGE International Conference on Geoinformatics - Theoretical and Applied Aspects, Geoinformatics 2015*. European Association of Geoscientists and Engineers, EAGE. https://doi.org/10.3997/2214-4609.201412393

Ivanik, O., Shevchuk, V., & Lavrenyuk, M. (2011). Complex technique of the comprehensive assessment of the hazardous geological processes impact on the nature-technical systems. In *Geoinformatics 2011 - 10th International Conference on Geoinformatics: Theoretical and Applied Aspects*. European Association of Geoscientists and Engineers, EAGE.

Ivanik, O., Shevchuk, V., Lavrenyuk, M., & Ivankevich, G. (2017). Regional and local forecasting of landslides and debris flows and assessment of their impact on infrastructure objects. In *11th International Scientific Conference on Monitoring of Geological Processes and Ecological Condition of the Environment*. European Association of Geoscientists and Engineers, EAGE. https://doi.org/10.3997/2214-4609.201800076

Kaliukh I., Fareniuk G., Fareniuk I. (2018). Geotechnical Issues of Landslides in Ukraine: Simulation, Monitoring and Protection. In: Wu W., Yu HS. (eds) Proceedings of China-Europe Conference on Geotechnical Engineering. Springer Series in Geomechanics and Geoengineering. Springer, Cham, DOI: https://doi.org/10.1007/978-3-319-97115-5_124

Kaliukh, I., Dunin, V., & Berchun, Y. (2018). Decreasing Service Life of Buildings Under Regular Explosion Loads. *Cybernetics and Systems Analysis*, 54, 948–956. DOI: https://doi.org/10.1007/s10559-018-0098-9

Kaliukh, Y.I., Vusatiuk, A.Y. (2019). Factorization in Problems of Control and Dynamics of Lengthy Systems. *Cybernetics and Systems Analysis*, 55, 274–283. https://doi.org/10.1007/s10559-019-00132-9

Lacasse, S. (2013). 8th Terzaghi Oration Protecting society from landslides – the role of the geotechnical engineer. *Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering,* 15-34, ECSMGE, Paris.

National Landslide Hazard Mitigation Strategy: A framework for loss reduction (n.d.). Circular 1244. U.S. Department of the Interior. Access: https://www.hsdl.org/?view&did=487848

Polevetskyy, V. (2009). The Regional features of landslide protect structures and landslides of the Chernivetska area. *Thesis ... Cand. Techn. Sci.: 05.23.02 "Bases and Foundations"*. SE RIBK, Kyev.

The U.S. Geological Survey Landslide Hazards Program 5-Year Plan 2006-2010. (n.d.). U.S. Department of the Interior. U.S. Geological Survey. Access: https://www.hsdl.org/?view&did=30534

Trofymchuk, O., Kaliukh, I., Berchun, V. (2017). Landslide Stabilization in Building Practice: Methodology and Case Study from Autonomic Republic of Crimea. In: Mikoš M., Arbanas Ž., Yin Y., Sassa K. (eds) Advancing Culture of Living with Landslides. WLF 2017. Springer, Cham. DOI: https://doi.org/10.1007/978-3-319-53487-9_69

Vlasyuk, A., Zhukovskaya, N. (2015). Mathematical Simulation of the Stressed-Strained State of the Foundation of Earth Dams with an Open Surface Under the Influence of Heat and Mass Transfer in the Two-Dimensional Case, *Journal of Engineering Phys-ics and Thermophysics,* 88, 2, 329–341. https://doi.org/10.1007/s10891-015-1197-3

Vlasyuk, A., Zhukovskaya, N. Zhukovskyy, V. (2019). About Mathematical Modelling Of Spatial Deformation Problem Of Soil Massif With Free Surface in 2019. *IEEE 14th International Conference on Computer Sciences and Information Technologies (CSIT),* Lviv, Ukraine, Sep. 2019, 128–131.

Zaruba, K., Mencl, V. (1971). Inzhenernaya geologiya. Hardcover.

Ziangirov, P. (1979). The volumetric deformability of clay soils. Science, Moscow.