Geotechnical problems of expressway construction in landslide area in East Slovakia

Les problèmes géotechniques de la construction de voie rapide dans une zone de glissement de terrain en Slovaquie orientale

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ABSTRACT: Recently, Slovakia has experienced a significant increase in construction of road network, especially expressways and highways. One of the important projects being designed in the Eastern Slovakia is also N-S interconnection by an expressway R4 from the border with Poland to the border with Hungary. The total length of the highway section located in Slovakia will be 108 km. The greatest risk comes from the landslide occurrence. It is so especially in the zone of the outer flysch zone, which the northern part of the R4 leads through. The article presents geotechnical problems during the construction of one section of R4, by-pass road around city Svidník, where over 50% of the construction area are leading through landslides. Activation of landslides were significant especially in the areas with road embankments. Slope stability failures are discussed in detail in the article, as well as the remediation works. The paper summarizes stability problems associated with design and execution of embankments in landslides areas.

RÉSUMÉ : Récemment, la Slovaquie éprouvait une augmentation significative de la construction du réseau routier, en particulier les autoroutes et les voies rapides. L'un des projets importants conçus dans la Slovaquie orientale est l'interconnexion N-S par la voie rapide R4 de la frontière avec la Pologne à la frontière avec la Hongrie. La longueur totale de la section autoroutière située en Slovaquie sera de 108 km. Le plus grand risque provient de l'existence de glissement de terrain. C'est le cas particulièrement dans la région de la zone extérieure du flysch, que la partie nord de la R4 traverse. L'article présente des problèmes géotechniques lors de la construction d'une section de R4, route de contournement autour de la ville de Svidník, où plus de 50% de la zone de construction traversent les régions de glissements de terrain. L'activation des glissements de terrain a été importante surtout dans les zones avec des remblais de route. Les défaillances de stabilité des pentes sont discutées en détail dans l'article, ainsi que les travaux d'assainissement suivants. La stabilité des pentes a été analysée en utilisant les démarches suivantes: Le document résume les problèmes de stabilité liés à la conception et à l'exécution de coupes et de digues dans des zones avec les glisse-ments de terrain.

KEYWORDS: landslides, slope stability, geotechnical monitoring, road embankments.

1 INTRODUCTION.

Recently, Slovakia has experienced a significant increase in construction of road network, especially expressways and highways. One of the important projects being designed in the Eastern Slovakia is also N-S interconnection by an expressway R4 from the border with Poland to the border with Hungary. The total length of the highway section located in Slovakia will be 108 km (Fig. 1).

The communication line should be a compartment of a so-called Via Baltica corridor, which shall connect Lithuania, Poland, Slovakia and Hungary. The section proposed at the Slovak territory will attain a total length of 99, 5 km.

Figure 1. Location of expressway line R4 in the Eastern Slovakia

The article presents in detail the geotechnical problems facing the R4 section construction, a by-pass road around city Svidník (19 km south from the Polish border). This section was the first part of the R4 expressway built north of the city Prešov (construction during 2007-2010). The greatest risk comes from the landslide occurrence, approximately 50 % of the route of the 4, 5 km section in question is in landslide area.

2 GEOLOGICAL CONDITIONS AND LANDSLIDES IN THE LINE OF EXPRESSWAY R4 NEAR THE TOWN SVIDNIK.

In the territory geological setting, the Palaeogene sediments of the Outer Flysch Belt (Marschalko , Müllerová, 2002) which are covered by Quaternary sediments – deluvial sediments take part. The claystone facies play a prominent role in several formations of the Outer Flysch Belt. The proportion of claystones and sandstones ranges from 8:1 to 10:1. Deluvial deposits situated on rocky Flysch subsoil reach the thickness of 15m and they are often damaged by landslides processes. As much as 49% of the Svidnik bypass interferes with landslides deluvia. They are of a very varied character and they are composite of deluvial clays, debris and decomposed claystones.

From the point of view of slope deformation activity, the landslides are mostly inactive - potential, while landslides toes interfering with the valley of river Ladomirka are mostly active. However, an incorrect construction intervention can also cause the potential landslides in the Outer Flysch Belt to become active (Kopecký et al, 2011; Marschalko and Müllerová, 2002).

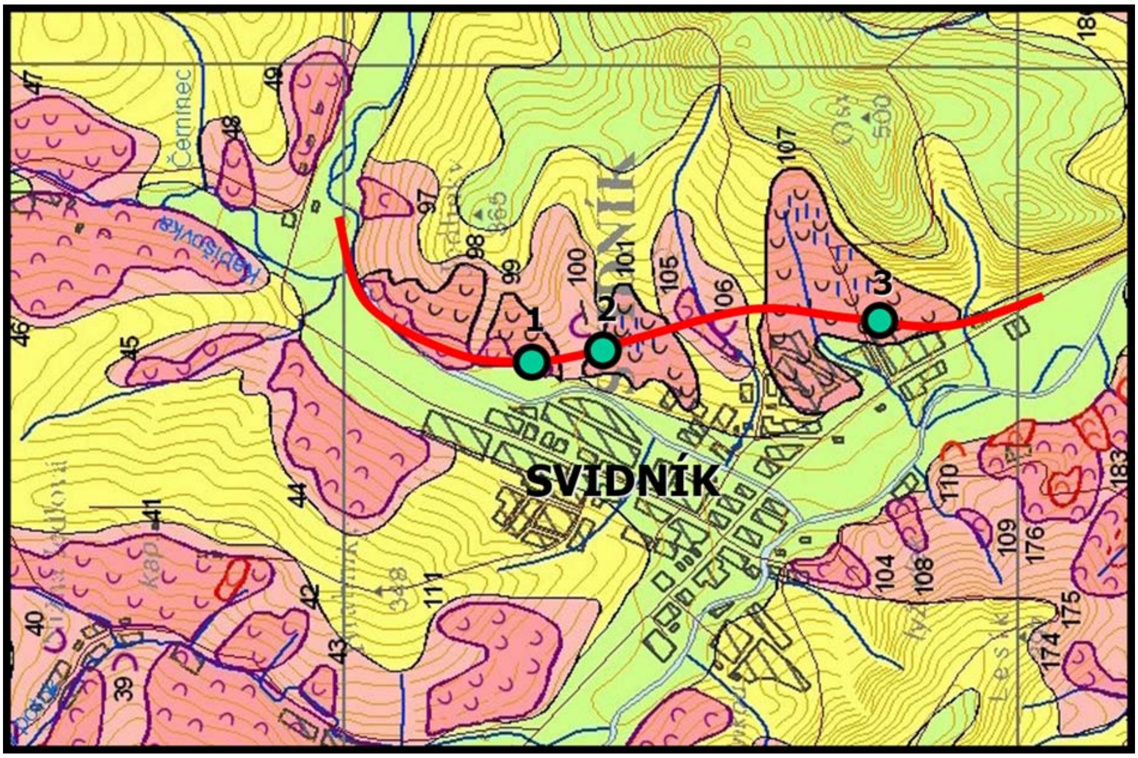

Figure 2. The route of the 4,5 km section of the R4 expressway (red line) passing through landslides. Discussed local issues are marked by numbers

3 PROBLEMS OF EMBANKMENT CONSTRUCTION IN LANDSLIDES AREA

A part of landslides became active during the construction of the discussed Svidnik bypass in years 2007 – 2010, mainly in the areas of embankment construction. In this chapter, we present 3 sites of the stated problems (Fig. 2) while focusing on site No.1 at 3.275 km in detail.

3 .1 *Embankment at 3.275 km – Site No.1*

The slope, upon which the embankment was built (approximately 8.0 m high), is an old landslide extending into the route of the R4 expressway at 3.15 to 3.52 km (Fig. 2) with length of about 400 m and width of 200 to 350 m. The landslide itself originated during the erosion of river Ladomirka. It is proven by the insertion of landslide toe into the river sediments (Fig. 3).

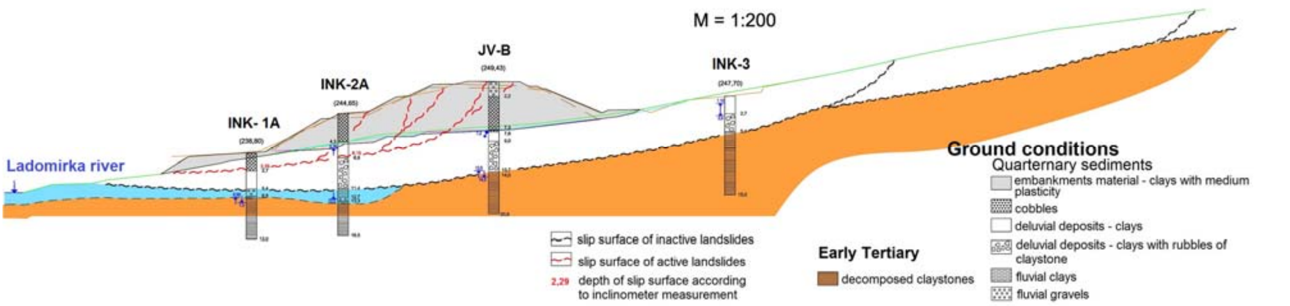

Figure.3. Engineering-geological profile of the landslide with embankment in 3,275 km

Detailed analysis showed that the first and, in the light of the further development, the critical deformations of the embankment happened before it was built to the final height in August 2008. Afterwards, cracks extending as far as the right side of the road appeared in June 2009. A significant activation over the existing slip surfaces and the complete destruction of the embankment (Fig. 4) occurred during the excavation of longitudinal depth drain at the foot of the embankment in July 2009.

The course of slip surface of the embankment landslide (Fig. 3) was interpreted on the basis of inclinometer measurements results and slip surface ends in the top of the embankment. It was discovered that the slip surface intervened into the embankment soil up to 2 m and thus the embankment

Figure 4. Comparison of the cracks in the road (scarp zone of landslide) between 5/6/2009 and 13/7/2009

construction did not make the slip surface of older landslides active (about 5-7 m below the original terrain – ground surface). Stability calculations confirmed that the rigidity of the embankment itself had an impact on the overall stability.

Moreover, they confirmed that the main cause of the failure is a slow creep deformation of body of the embankment along the ground. The slip surface of older landslides was therefore not made active by the embankment construction. The fact that the subsoil of the embankment was not improved before the construction is thus the critical condition of formation of the embankment landslide. It was requested by the conclusion of engineering- geological investigation.

The speed of the embankment construction certainly had its share on the failure of the embankment body. The first part of the embankment in 2008 and also the second part in the spring of 2009 were finished in a very short time. Sudden additional load of subsoil caused a steep increase in pore pressure in the soil forming the embankment subsoil, which was saturated with groundwater.

In the end, dismantling of the original embankment and construction of drainage ribs in the original embankment subsoil was the solution of remediation geotechnical works. The embankment was built again after the drainage ribs construction and it shows no further deformation up to now.

3 .2 *Embankment at 2.9 km – Site No.2*

To decrease the cost of the construction, it was decided to shorten the length of bridges, which meant construction of higher embankments on the slopes above the bridging valleys of side tributaries of the river Ladomirka. This way, the embankment was built on an active landslide at 2.85 to 2.95 km. Shortly after the embankment construction, a crack has appeared there which copied the scarp zone of landslide (Fig. 5) precisely. There was a movement of Gabion Wall at the foot of the embankment by about 60 cm, while the slip surface was extruding the bottom of the stream, causing the risk of the closure of the valley and damming the stream.

This situation was resolved by removing the embankments with landslides and extending the bridge by two fields.

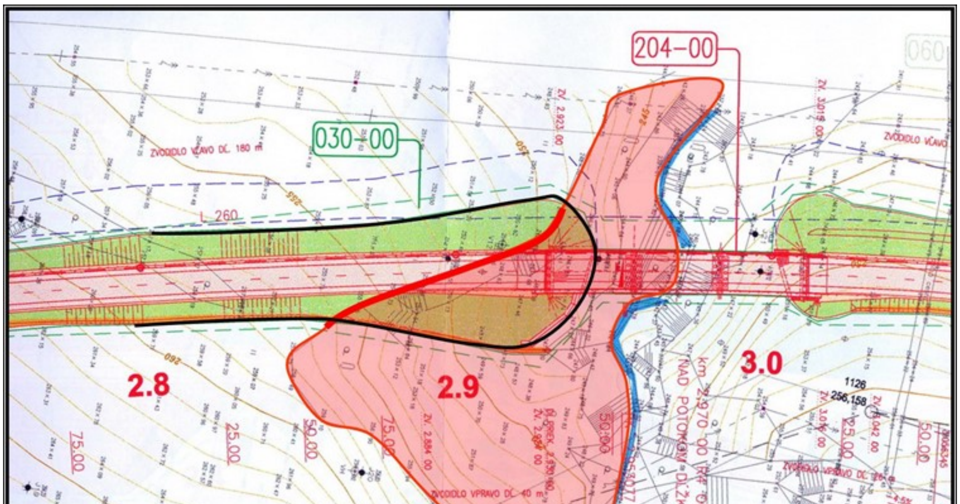

Figure 5. Location of embankment cone of bridge support on the active landslide (red area).

3 .3 *Embankment at 0,85-1,05 km – Site No.3*

An embankment with a merging lane with height of 8 m was built at the site No.3 (Fig. 2). The embankment was built on a potential landslide of considerable proportions, but unlike in the case of the site no.1, it was not on the landslide toe.

Cracks of a horseshoe shape appeared on the asphalt surface shortly after it was laid down (Fig. 6). Movement of the body of the embankment along the original subsoil (about 1.0 to 2.0 m below the original ground surface) was detected by subsequent inclinometer instrumentation. As in the case of site No.1, there was no modification of the subsoil before the embankment construction.

Figure 6. Cracks in embankment at approximately 0.9 km

The final solution to ensure the stability of the embankment with its subsoil was executed by construction of an anchored pile wall with height of 10 meters (Fig. 7).

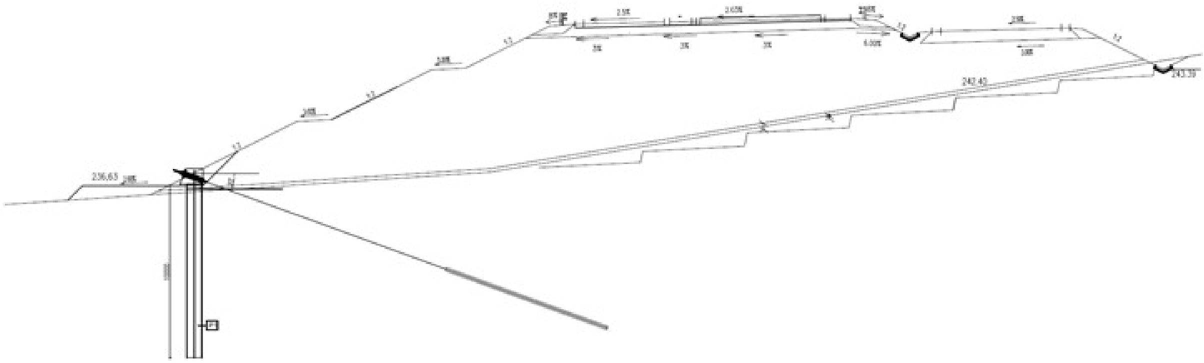

Figure 7. Embankment remediation by anchored pile wall at landslide toe

4 CONCLUSION

In this article, we wanted to point out the risk of embankments construction of transport structures in landslide areas. Landslides can close roads or cause the need for major repairs and they can greatly increase road construction or maintenance costs (Turček, Súľovská, 2014, Şengör et al., 2013, Bankim Mahanta et al., 2016). While at the site No. 2 it was clearly the unsuitable alignment of motorway and location of the embankment in landslide area, at the sites No. 1 and No. 3 the reason of failure of the embankment bodies after their construction was absence of adjustments to their subsoil and relatively short construction time.

The ongoing geotechnical monitoring on site R4 expressway shows success of remediation geotechnical works of disturbed embankments.

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