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*Miloslav Kopecký**

EXPECTED GEOTECHNICAL PROBLEMS ON EXPRESSWAY R4 IN EAST SLOVAKIA**

1. Introduction

Today Slovakia has experienced an unprecedented boom in preparation and construction of highways and expressways. According to data provided by National Highway Company in the period of 2008–2013 there should be constructed about 300 km of highways and expressways (more than 50% through PPP — "Public Private Partnership" projects).

Among the projects under design in the Eastern Slovakia an important task is also N–S interconnection by an expressway R4 (in combination with highway D1 — Fig. 1) from the border with Poland to the border with Hungary.

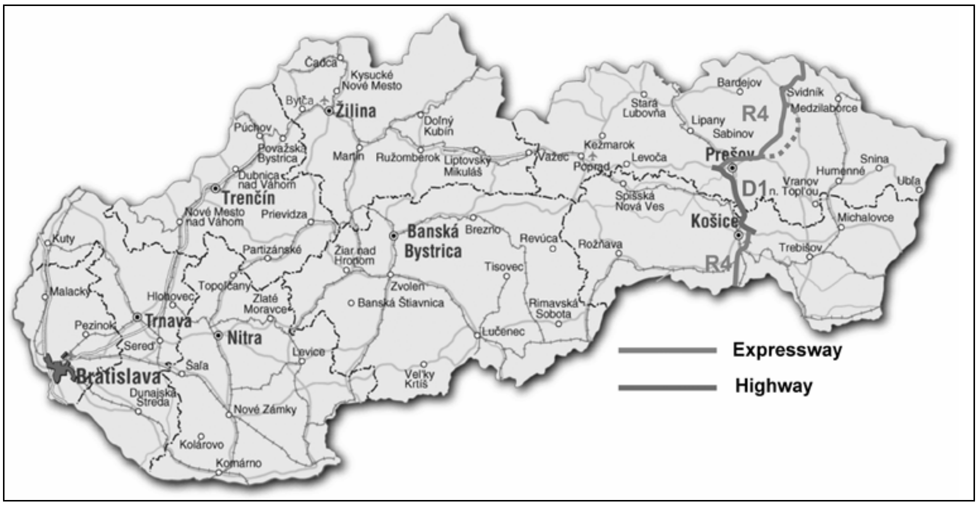

Fig. 1. Location of expressway line R4 in the Eastern Slovakia

* Faculty of Civil Engineering, Slovak University of Technology in Bratislava, Bratislava
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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 108 km. At the border with PR the R4 will conjoin the express communication S-19.

2. Geological conditions and landslides in the line of expressway R4

The northern part of the R4 expressway (Prešov — Poland) is located in the area with complex geological and tectonical settings. In the vicinity of the town Prešov (Fig. 2) the expressway leads through inner Carpathian flysch zone.

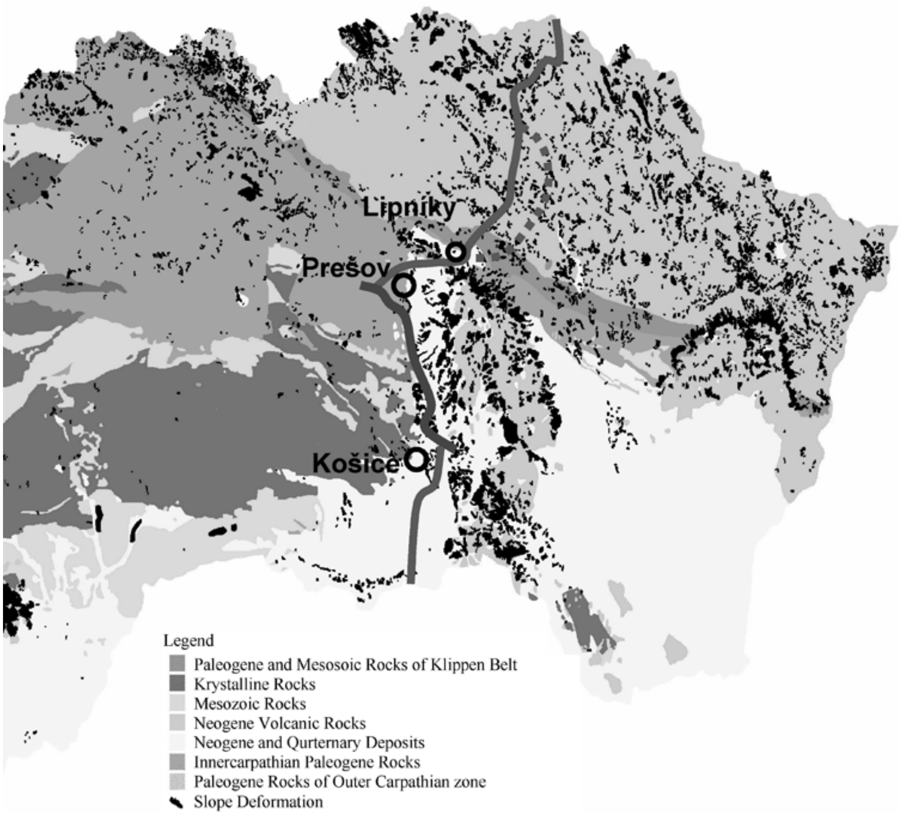

Fig. 2. Landslide occurrences with respect to the geology in the routing of R4

The formations of altering sandstone and claystone are not folded and are dipping with angle less than 20°. Eastward of Prešov in the routing of the expressway there are Neogene deposits with dominance of siltsone passing gradually to fine-grained sandstone, which is poorly litified. Northward of Lipníky the R4 expressway goes through narrow zone of NW–SE orientated Clippen Belt, which is made of Paleogene and Neogene sediments. From the Clippen Belt toward to the border with Poland the expressway lead through a hilly country made of rocks of the outer flysch zone. The flysch formations are there strongly folded and tectonically damaged.

Southern part of the R4 expressway in the section Košice — border with Hungary leads through Košice basin filled with Neogene deposits — clay, sand and gravel covered with deposits of the river Hornád. Final part of the expressway near the border with Hungary leads through slopes of hilly country made of Neogene deposits with chaotic bed sequences.

Occurrence of landslides and their relation to the expressway routing is the critical factor for selection of the best expressway alternative (in the stage of study and preliminary engineering geological site investigation) and later also for its construction. As can be seen at the Figure 2, the landslides affect especially slopes made of Paleogene deposits of the outer flysch zone, especially those where claystone is in dominance. According to the landslide activity the potential landslide are the most common. Active and stabilized landslides are rare. In the Clippen Belt and inner flysch zone the landslides are less common. The landslides are quite common also near the border with Hungary in the Neogene deposits.

3. Engineering geological investigation for variant comparative assessment of the section of the R4 communication line

Most of the R4 expressway sections are recently in the stage of designing (evaluation of the alternative solutions). According to the example of one section, which is under construction recently, a critical influence of geotechnical problems for selection of the best variant solution can be illustrated. The paper presents the assessed 8.5 km long sector (Fig. 3) of the above mentioned communication R4.

The section represents only a part of one from several variants of the link between Prešov and Svidník. The orange variant (with the red section assessed by the author of this paper), which is situated in the corridor between the national road E-371, seems to be more convenient from the viewpoint of the environmental impact as the blue variant (Prešov — Stropkov — Svidník). However, the realization of the blue variant is more convenient from the viewpoint of transportation.

The 8.5 km long section was proposed in 2 variants (Fig. 4) on both flanks of the Radomka River valley, with 4 municipalities along the road line. For each variant there was realized in preliminary engineering geological investigation [1].

3.1. Engineering geological conditions along the road line of the assessed variants

In the territory geological setting there take part the Palaeogene sediments of the Outer Flysch Belt [2], which are covered by Quaternary sediments.

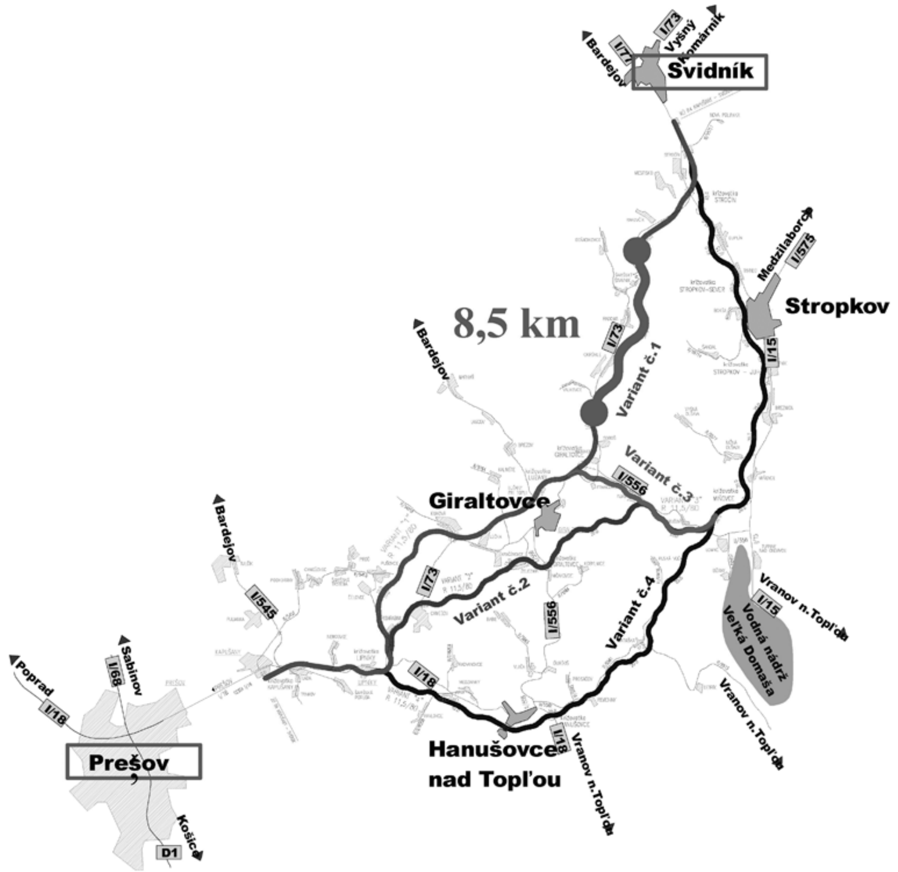

Fig. 3. Assessed variant as one of several subvariants of the link between Prešov and Svidník communication line R4

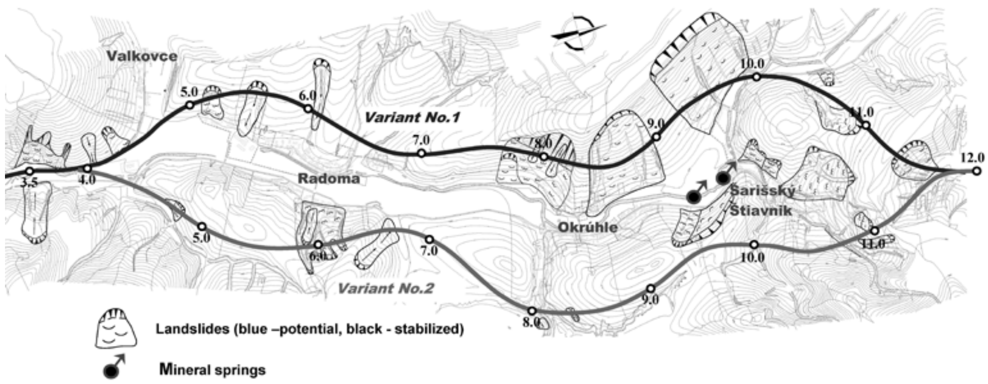

Fig. 4. Plan preview of variant solutions for R4 communication

In several formations of the Outer Flysch Belt; a prominent role plays the claystone facies. The proportion between claystones and sandstones ranges from 8:1 to 10:1.

The stratification of the Palaeogene Complex varies strongly and it can significantly change within several metres. Besides tectonic failures there is amply disturbed and decomposed the uppermost part of the Flysch Formation due to weathering processes. The eluvium's thickness attains an average of around 3 m and at sites of tectonic failures and below terrace sediments even up to 10 m.

Quaternary sediments cover the Palaeogene rocks and they make up the surface parts of the territory. According to their genesis and character we distinguish: Deluvial and terrace sediments and sediments of alluvial plain.

Among the more frequent geodynamic phenomena present along the routes of the assessed variants we rank first of all sheet erosion and vertical (gully) erosion. On the slopes with suitable geological and hydrogeological conditions there occur slope movements [2] dominantly landslides and earthflows (Figs. 4 and 5).

Fig. 5. Typical landslide in the area

3.2. Comparison between the realizations of individual variants

Although both assessed routes are crossing similar geological environment (Outer Flysch Belt), the tectonic evolution and erosion-accumulation processes have formed different engineering geological and geomorphological conditions on the opposing flanks of the Radomka River valley. Consequently, the effect of the assessed routes upon the rock environment depends first of all from the direction and altitude of the road line emplacement, and the last but not least the landslide occurrence.

3.2.1. The impact upon the rock environment

The overview of all the impacts and necessitated mitigation measures is presented in the Tabs. 2 and 3. Taking into account the technical impact within the rock environment and consequent mitigation measures we may discriminate the following critical sections along the assessed routes.

TABLE 1
Critical section of variant No. 1

Km	Section length [m]	Road line of the communication	Negative geotechnical impacts	Proposed mitigation measures
5,0–5,2	200	fill through escarpment	instability the expressway body	dewatering drains
7,7–8,25	550	fill (height of 20 m) atop the escarpment	landslide instability of the territory and the communication itself	dewatering boreholes Instead fill – bridge with deep foundations
8,5–8,8	300	fill through the landslide	jeopardized expressway	dewatering drains and boreholes
8,8–8,95	150	cut in the landslide	jeopardized slope stability	revetment walls and dewatering boreholes
10,8–11,6	800	deep cut (34 m) – at both sides with landslides	jeopardized slope stability, landslides at both sides, large area engaged	anchored pile walls, revetment walls, dewatering boreholes
In total	2000			

TABLE 2
Critical section of variant No. 2

Km	Section length [m]	Road line of the communication	Negative geotechnical impacts	Proposed mitigation measures
5,8–6,1	300	bridge through landslide territory – gully erosion	jeopardized bridge supports	anti-erosion measures, deep foundations
10,9–11,3	400	cut (18 m deep)	slope instability, larger area engaged	pile walls and revetment walls
In total	700			

From the both tables it is evident, that the variant No. 1 involves considerably longer critical sections. First of all we have to point at the technically and economically challenging section in the km 10.8–11.6 (34 m deep cut). Likewise we have noted the crossing of the landslide area by the variant No. 1 in the km 7.7–8.25.

From the above analysis it follows unequivocal recommendation of the variant No. 2 against the variant No. 1 realization.

3.2.2. Groundwater impact

It was necessary to validate separately the impact of designed variants upon ordinary groundwaters and mineral waters.

Ordinary groundwaters

The impact of communication can come in being during the execution of cuts, protective measures against landslides (groundwater drainage) and during construction of embankments at sites of erosion gullies crossing. There could be jeopardized the springs, which serve for supplement of the local population by potable waters. The realized investigation has led to a conclusion that the impact upon ordinary groundwaters after communication construction for both variants should be similar; however the most notable changes could occur after realization of the 34 m deep cut in the scope of the blue variant.

Mineral groundwaters

These were comprehensively assessed by the hydrogeological study [4]. From the study it follows that:

- From the geological–tectonical and hydrogeological point of view the variant No. 1 seems to be more convenient. The road line in the scope of this variant is situated out of infiltration, accumulation and discharge areas of the mineral waters.
- In opposite to the aforementioned the variant No. 2 is situated in tectonically predisposed territory, conveyed through infiltration and accumulation area of the mineral waters. However, taking into account $NaHCO_3$ chemical type of the mineral waters, total mineralization around 6.0 g/l we assume, that the formation of the mineral waters occurs in a deeper rock environment and the communication construction in the scope of this variant will not deteriorate the mineral waters sources.
- The communication construction according the alternative (tunnel) variant is the most unsuitable from the hydrogeological point of view. Its construction would be realized within the infiltration area of the mineral waters, which would unavoidably lead to groundwater drainage by the tunnel gallery. Consequently, this could jeopardize the mineral water genesis and lead to extinguishment of springs of ordinary groundwaters.

4. Conclusions

The construction of the first section of the expressway R4 proved how important role for selection of the best expressway variant is played by the expected geotechnical problems — their solving dictates the cost for the expressway construction. The greatest risk will be the landslides in the zone of outer flysch zone. The mentioned assumption was fully proved by construction of the bypass of the town Svidnik, which is recently the only R4 section under construction.

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