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AN EXPLORATORY GALLERY FOR LUKA TUNNEL ON THE D3 MOTORWAY

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Abstract. The Luka tunnel is designed for the 0302 Jílové – Hostěradice section of the D3 motorway. This has a length of 1843 m and will consist of two tunnel tubes of T 9.5/100 category. It is proposed that a 1354 m long exploratory gallery be put in place in the left-hand tunnel tube. It will be used for detailed geotechnical exploration in a rock environment that has been negatively affected by past mining activities. The exploratory gallery will be constructed using a procedure that will limit the possible stability risks during its excavation. The knowledge gained from the excavation of the gallery and from the comprehensive survey operations undertaken will serve as the essential basis for the reliable design and safe construction of the tunnel tubes. The current state of the D3 motorway differs greatly along its individual sections. The more southerly located sections D 305/II (Nová Hospoda) to D 309 (Úsilné) are in operation. Section D 310 Úsilné – Hodějovice with the České Budějovice bypass is under construction, and the construction in the direction of Austria has not yet proceeded [1]. The situation is very disappointing particularly in the Central Bohemian region, even though exploration operations are underway to a limited extent in sections D 301 to D 305/I, as construction has not yet started due to problems with obstructions or objections by activists of various types. The problem is that it is demonstrable that the existing road I/3, which is also part of the main international road route E55, is already completely inadequate both in terms of capacity and in terms of its alignment running through several developed residential complexes. After the completion of the D3 motorway, this road will be usable as an alternative diversion route without major modifications in the event of a required closure of the motorway.

Keywords: D3 motorway, exploratory gallery, horizontal boreholes, Luka tunnel, undermined area.

1. Introduction

The D3 motorway connects to the existing southern segment of the Prague City Ring Road, continues south to the České Budějovice bypass and connects to the Austrian road network at the border of the Czech Republic. The nominal length of the D3 motorway amounts approximately to 172 km and is divided into thirteen basic sections (Figure 1), with seven additional sub-sections.

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Figure 1. Basic sections of the D3 motorway (modified from [1]).

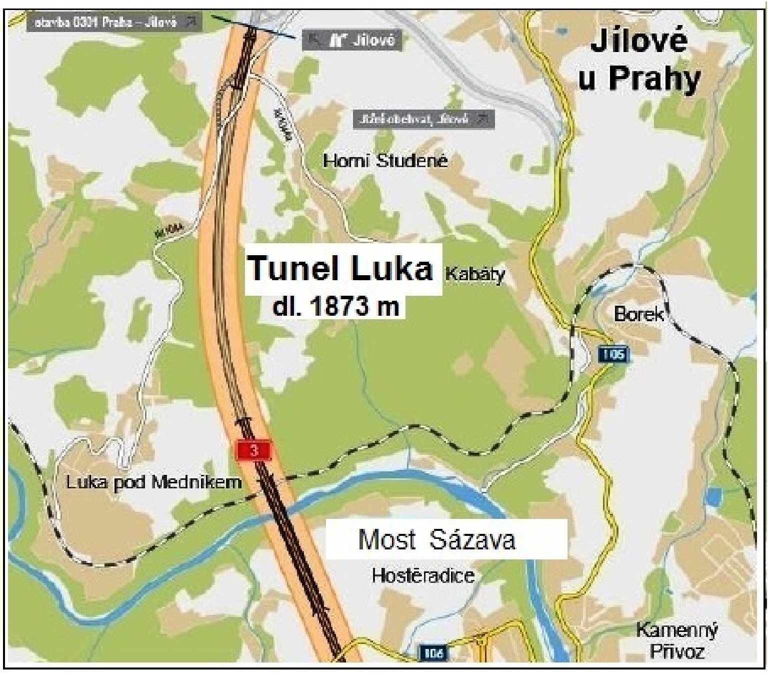

Figure 2. Luka tunnel in Jílové u Prahy – Hostěradice section (modified from [1]).

veloped residential complexes. After the completion of the D3 motorway, this road will be usable as an alternative diversion route without major modifications in the event of a required closure of the motorway.

Eight tunnels are expected to be built along the entire length of the D3 motorway. Seven mined tunnels are part of the Central Bohemian section of the motorway (Libeř tunnelland – length of 1517 m, Kamenná Vrata – length of 1690 m, Luka – length of 1843 m, Hostěradice – length of 377 m, Vršky – length of 177 m, Krňany – length of 432 m). The cut-and-cover Pohůrka tunnel (999 m long), which is part of the České Budějovice motorway bypass, is currently under construction. The Luka tunnel is located in section D 302 Jílové Praha – Hostěradice (Figure 2). It consists of two unidirectional tunnel tubes T-9.5/4.80 with seven safety cross passages. Near the village of Horní Studené, the motorway route passes through the Luka Panský Vrch hill tunnel, with the highest overburden over 60 m (Figure 3), and rises to the surface before the Sázava River valley. The route crosses the Sázava valley via a bridge with a main span of 250 m, at a height of 100 m above the river. The proposed route of the D3 motorway and the Benešov approach road runs outside the developed areas of the individual municipalities and mainly runs across agricultural and forest land in the area affected.

The Luka tunnel is not only the longest of the tunnels mentioned above, but also it is most likely to be the riskiest in terms of excavation, and so it is necessary to pay special attention to the exploration, design and construction work that it involves.

2. Engineering geological and hydrogeological conditions

In terms of geology, the area of interest is located in the northernmost part of a belt of volcanic rocks of Upper Proterozoic age, termed the Jílové zone, which is part of one of the oldest formations of the geological unit of the Bohemian Massif. The beginning of this geological forming of the Jílové region falls into the youngest part of the Proterozoic period (700 to 540 million years old). In its current form, the Jílové zone is made up of basalts, andesites, dacites, rhyolites and their tuffs, through which bodies of sub-volcanic albitic granites penetrate. This complex of mostly very fine-grained, in places also porphyritic rocks, affected by folding and schist-forming processes, is intersected by numerous systems of younger rock veins – lamprophyres, microdiorites and diabases in the Jílové belt trending predominantly NNE-SSW, and by veins of porphyries and porphyrites of the Variscan age, trending mainly transversally E-W. The original character of the rocks of the Jílové belt was changed by a schist-forming process and regional recrystallisation associated with the Cadomian orogeny at the turn of the Proterozoic and the Paleozoic Eras and by the thermal effects of contact metamorphism associated with the origination of the Variscan granitoids of the Central Bohemian pluton before the end of the Paleozoic Era (approximately 350 million years). Rocks in the vicinity of veins and reticulated veins are metamorphosed by the action of thermal solutions, which gave rise to gold-bearing ore [3]. Along the tunnel line, the massif is built by metabasalts, gabbros, rhyodacites and tuffs, through which ore veins penetrate in the transverse direction. The strength of the rocks is

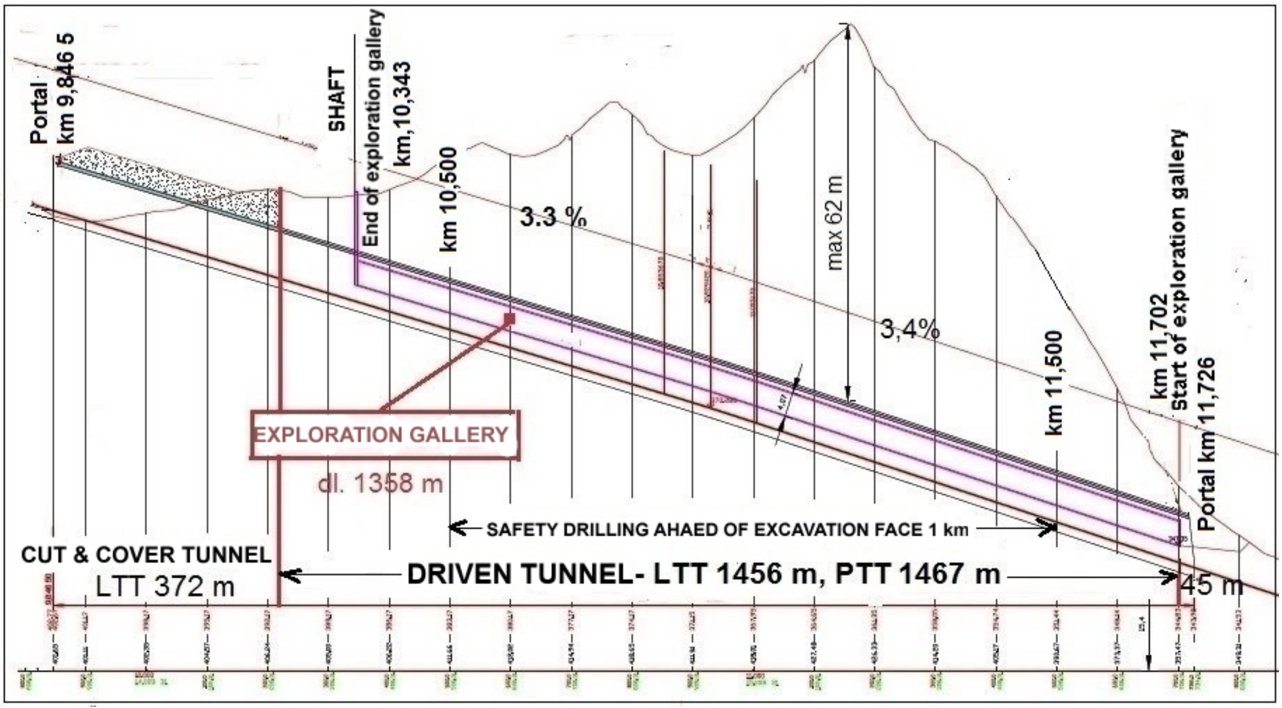

Figure 3. Schematic longitudinal section through Luka tunnel with the exploratory gallery (modified from [2]).

generally high to medium, and only in the area of the northern portal does their strength involve decreases. However, the massif is affected by numerous wider fault zones and tectonic lines, the actual occurrence and character of which will adversely affect the excavation of the tunnel. Approximately ten of these faults were detected by the geophysical survey.

A significant risk from the point of view of tunnel excavation is posed by the existence of past mining activities related to the historic gold mining in the part of the area through which the tunnel passes for a length of approximately 1600 m. In the area of the Jílové belt, gold was mined over several periods. The last attempt at gold mining took place in the 1960s at the Bohuliby mine. However, gold mining was not very successful or economically profitable, so the Bohuliby mine closed its operations in 1968. The planned route of the Luka tunnel passes under Panský Vrch hill, which is unfortunately the area with the least explored remains of historic mining. The occurrence of ancient mining workings in the area of Panský Vrch hill is evidenced by places of surface depressions (so-called pinges), which are formed on the surface of the area as a result of the collapse of old mine adits [2]. The risk of striking unknown mine spaces during tunnel excavation must be eliminated by excavation of the exploratory gallery and systematic safety drilling ahead of the excavation face.

During World War II, military production took place underground in the given area,(about which there is no detailed information), which increases the risk of the occurrence of unknown underground spaces.

The two galleries on the 1st and 2nd mining floors, which were excavated from the Bohuliba mine in the 1960s, are an exception to the degree of exploration of this area. They are well described. The gallery on the 2nd floor is at an altitude of 235.26 m above sea level, and in plan it crosses with the Luka tunnel at the point where the horizontal alignment of the tunnel is at an altitude of 380.17 m a.s.l. Due to the difference between the elevations of approximately 145 m, this gallery will not have any effect on the excavation of the tunnel. The corridor on the 1st floor of the mine is at an altitude of approximately 321.32 m. In ground plan, this gallery crosses the proposed Luka tunnel approximately at the point where the horizontal alignment of the tunnel is located at an altitude of 373.2 m above sea level. The difference in elevations amounts approximately to 52 m, so even this gallery should have no major influence on the excavation of the tunnel.

Hydrogeological conditions are significantly influenced by the undermined area. Groundwater is bound to the surface deposits and the zone of surface disintegration of fissures. The direction of flow is roughly conforming to the terrain, and drainage runs through tributaries to watercourses and springs. The locations of the springs are bound to the crossing of significant fissure systems and valleys. A significant volume of groundwater is contained in old mine workings, which are usually filled with stagnant groundwater reserves. Controlled drainage into the Sázava River is mainly restricted to newer workings from the 19th and 20th centuries. Mining workings affect the overall circulation of groundwater, for which they represent preferred ways. The area of the massif under the Luka tunnel is permanently drained by old mining workings.

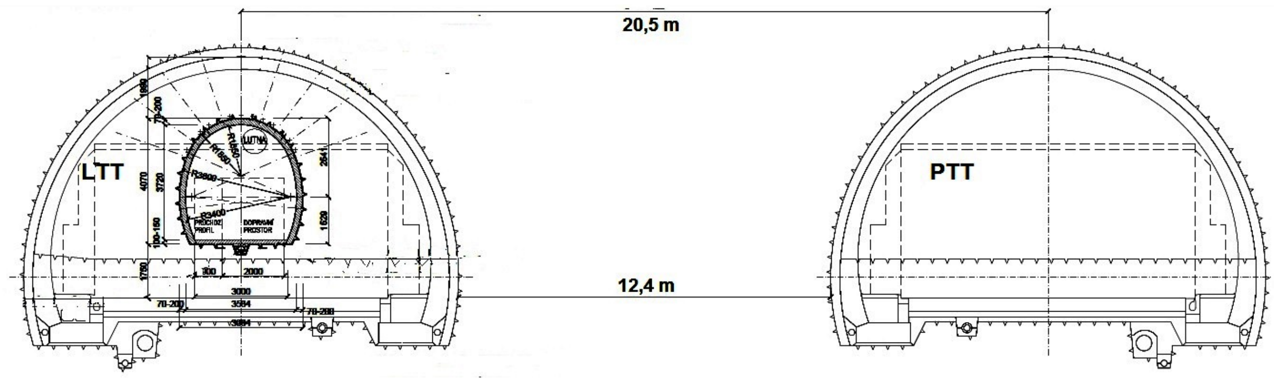

Figure 4. Cross-section with the position of the basic exploratory gallery (modified from [3]).

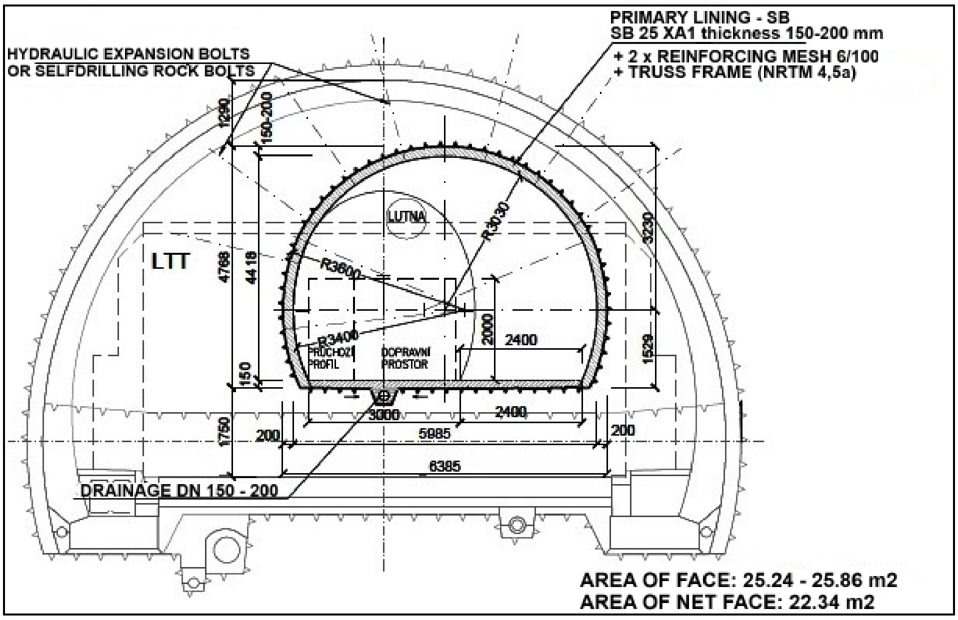

Figure 5. Cross-section through exploratory gallery in passing bays (modified from [3]).

3. The exploratory gallery

1. **Exploratory gallery design**
   Excavation of the exploratory gallery proposed by the design [3] will be carried out at a length of 1358 m from the southern portal in the left-hand tunnel tube (LTT), without connection with the future primary lining of the tunnel. The uphill driving is advantageous both from the point of view of drainage of the face and the transport of muck to the portal. Trackless haulage is assumed. The exploratory gallery will be driven from the construction site utility, located in the area of the future Tábor (southern) portal of the tunnel. At the end of the gallery, a shaft is designed in front of the northern portal, which will serve, among other things, for ventilation of the gallery after its completion (Figure 3).The cyclic excavation will be carried out using blasting.

   The cross-section of the basic exploration gallery will be horseshoe-shaped, approximately 3.75 m high, 3.0 m wide, with an excavated area of 13.8 m^2; the lining will be without invert (Figure 4). The self-supporting capacity of the massif will be increased using radial rockbolts. Due to the expected length of the exploratory gallery, passing bays are designed at approximately 175 m intervals. They will be approximately 25 m long and 5.40 m wide. The passing bays will allow for the passing of means of muck transport and the bringing of material and mechanical equipment. The excavated area of the gallery in the passing bay is equal to 25.9 m^2 (Figure 5).

2. **The use of a gallery for exploration in the area of interest**
   Due to the detection of an unfavourable combination of engineering geological and hydrogeological conditions within the undermined area, it is clear that the main risks for the excavation of the Luka tunnel result primarily from the possibility of encountering unknown mining workings, and which is associated with the risk of inrush of water and water-saturated material. Smaller risks follow from encountering extraordinary structural faults and fault zones. These risks need to be checked by

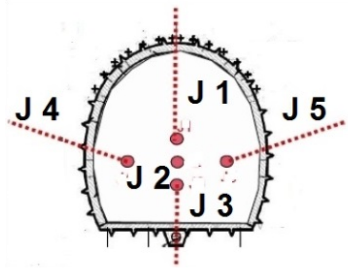

Figure 6. Arrangement of safety boreholes ahead of the face in cross-section (modified from [3]).

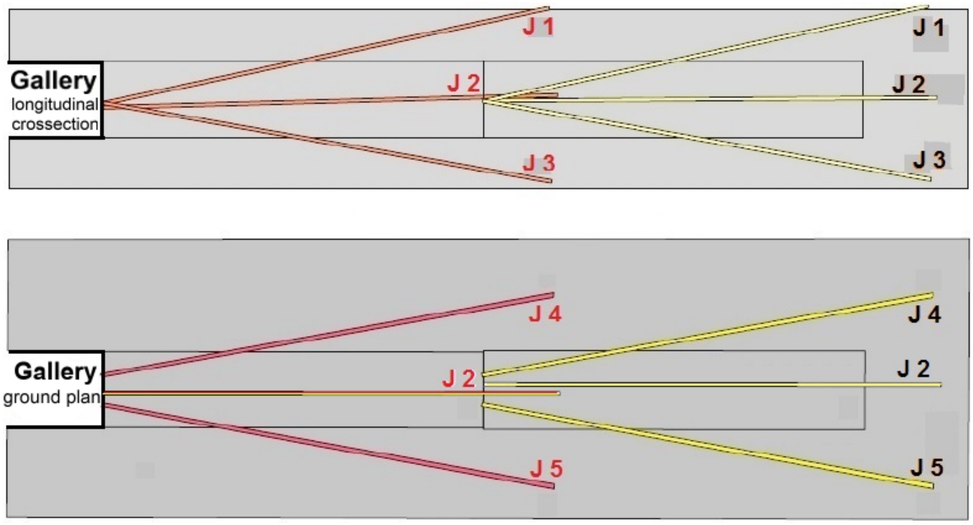

Figure 7. Longitudinal and plan arrangement of safety boreholes ahead of the face (modified from [3]).

driving an exploratory gallery.

In general, an exploratory gallery is a very effective continuous survey method not only for obtaining conclusive knowledge about the geological structure of the rock massif. It also provides fundamental knowledge about the stability and deformation behaviour of the massif. However, it is necessary to keep in mind the so-called influence of scale, given by the ratio between the dimensions of the excavation face of the exploratory gallery and the dimensions of the partial faces of the sequential excavation of the final working. The stability and deformation behaviour of larger excavation faces (especially in the case of the horizontal excavation sequence) is often worse in comparison with the excavation of the exploratory tunnel; that the tendency to create overbreaks in fractured massifs increases. An important advantage of the construction of the exploratory gallery is the direct detection of the stability of the unsupported excavation around and on the excavation face during excavation, the verification of the tendency of the rock massif to create overbreaks, the testing of the rock breaking technique and excavation support elements, as well as the assessment of the maximum possible excavation advance rate.

The hydrogeological behaviour of the massif is verified directly in the excavation by the exploratory gallery. The water-bearing character of the massif negatively affects the mechanical properties of the rock. It reduces the stability of the excavation indirectly proportionally to the increase in inflows into the working. It is desirable during the survey to determine the sections of probable inflows to the future tunnel and to determine their rates and nature. The danger of increased inflows comes in fractured hard rocks and faults. In this sense, the most dangerous are karst formations and undermined areas, in both cases with possible inrushing of water-bearing inconsistent ground. In the event of their possible occurrence, it is necessary to verify the danger zones (or, after their indication in advance, by geophysical measurement) from the exploratory gallery using frontal subhorizontal boreholes into the face-advance core, which allows for a reliable determination of marked inhomogeneities, fault zones, cavities and caverns.

It was this procedure that was proposed for the exploratory gallery regarding the Luka tunnel [3]. Five 24 m long, 65 mm-diameter safety boreholes ahead of the excavation face will be carried out from the gallery during excavation, with the central sub-horizontal borehole being cored and the remaining inclined boreholes non-cored. Their orientation and lengths are designed in such a way that they indicate in the advance core of the exploratory gallery excavation the occurrence of old mine workings with a possible danger of an inrush of water or a water-bearing material from the old mine adits, in addition to significant fault zones in the massif. The pre-drilled sections are designed to be 24 m long; the pre-drilled holes at the connection of the sections are designed to overlap 3 m (Figures 6, 7). The total length of the pre-drilling section is assumed to be 1 km long (see Figure 3), with 235 pieces of pre-drilled holes.

4. Conclusions

In order to ensure the safety of underground work in the area with the remains of historic mining activities, and especially to prevent any unexpected striking of water-bearing old water-containing mine workings, it is absolutely necessary to carry out boreholes into the area of future mining, in a relatively quite considerable long section (10 500–11 500 km). By fulfilling this legitimate requirement, the risk of an emergency during the course of excavation of the gallery and the future tunnels is significantly reduced. Other exploration activities and monitoring will be carried out on an increased scale according to unfavourable local conditions.

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