# LÍBEZNICE TUNNEL – CHANGE IN DESIGN CONCEPT AS A RESULT OF ADJUSTMENTS TO THE GRADE OF THE HIGH-SPEED RAILWAY LINE

M. Svoboda

*SAGASTA s.r.o., Prague, Czech Republic*

ABSTRACT: The Líbeznice tunnel project on the RS4 Podřipsko high-speed line (Prague-Balabenka – Lovosice) represents a significant step in the preparation of a new generation of railway infrastructure in the Czech Republic. The 3,400 m long tunnel is designed for operating speeds of up to 250 km/h and has been fully developed using BIM methodology. Sagasta s.r.o. participates in the project as a subcontractor to Metroprojekt a.s.

During the design process, a fundamental change in the concept occurred, prompted by the requirement to minimise interference with the landscape and protect the recreationally valuable area around the Líbeznice stream. The vertical realignment of the track led to a transition from the originally very shallow cut-and-cover tunnel (2,910 m) to a combination of cut-and-cover construction in an open excavation and a 600 m long NATM-mined section. This modification required changes to the structural and technological design, including an increase in the number of escape structures, modifications to the drainage system, and optimisation of the structural form.

## 1. INTRODUCTION

In the Czech Republic, five sections of high-speed railways (HSR) with a total length of 768 km are planned, of which 483 km are currently in the design stage. Sagasta s.r.o. is preparing project documentation for the RS1 HSR Moravská brána section (Rokytnice junction – Prosenice), including the Čekyňský tunnel (450 m) and the Vinarský tunnel (800 m). Simultaneously, Sagasta participates as a subcontractor of Metroprojekt a.s. in the design of tunnel structures on the RS4 HSR Podřipsko section (Prague-Balabenka – Lovosice). The Ledčice tunnel (1,450 m) and the Líbeznice tunnel (3,400 m) are planned within this section, the latter being the longest of the four.

This paper focuses on the Líbeznice tunnel, whose design underwent substantial conceptual modifications during project development. The project was developed using BIM methodology.

## 2. DESIGN DEVELOPMENT AND ALIGNMENT MODIFICATIONS

The project underwent repeated modifications in response to changes in the railway alignment. The most significant change was the lowering of the track alignment to preserve the recreationally valuable area around the Líbeznice stream. This triggered a series of further modifications, including the extension of the tunnel, a change in construction method, an increase in the number of escape structures, and adjustments to the structural concept.

The original design envisaged the entire tunnel as a very shallow cut-and-cover double-track structure with a reinforced concrete frame. The structural frame protruded above the existing ground level along its entire length, and a short section was located on an embankment with a culvert for the Líbeznice stream. The maximum excavation depth was 9.0 m and the total tunnel length was 2,910 m. The structure was backfilled with a minimum 1.0 m thick cover. Two escape structures were designed. The horizontal alignment consisted predominantly of a 3,000 m radius curve, with an initial straight section of approximately 381 m followed by a 270 m transition curve. The longitudinal profile was continuously descending in the direction of chainage, which was advantageous for drainage.

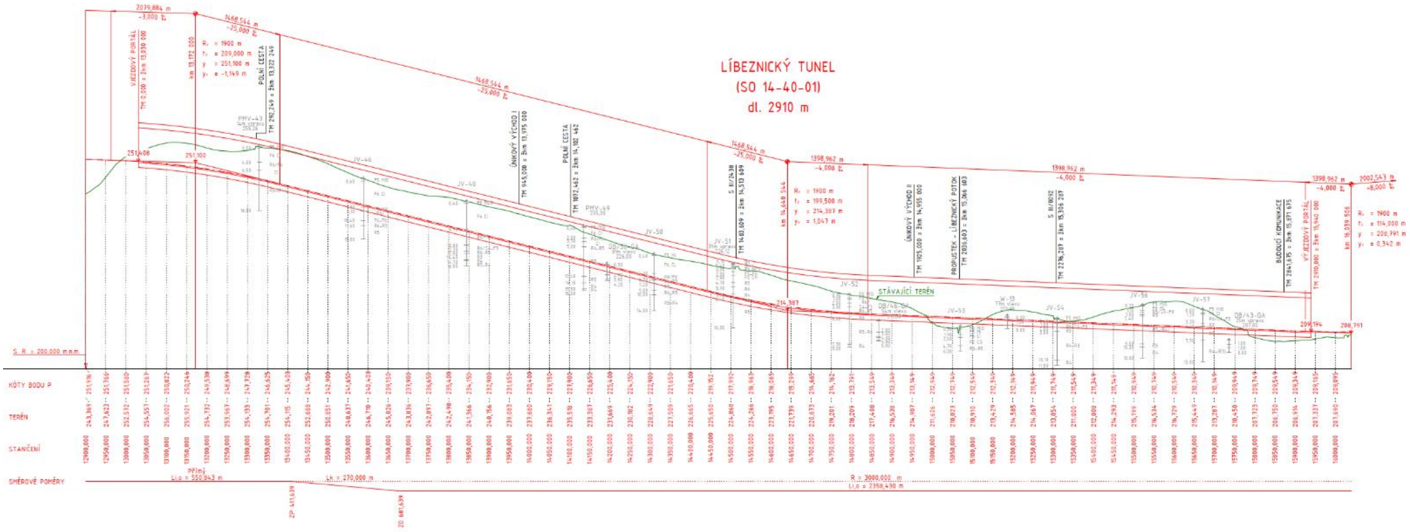


Figure 1: Longitudinal section of the original solution

## 1. REVISED DESIGN FOLLOWING VERTICAL REALIGNMENT

Lowering the track alignment by approximately 15 m at the critical location resulted in a fundamental change in the overall concept. The tunnel was extended by 490 m to a total length of 3,400 m, requiring the addition of a third escape structure. At the lowest point of the new alignment, where the overburden reaches its maximum, a 600 m long section is designed to be excavated using the New Austrian Tunnelling Method (NATM).

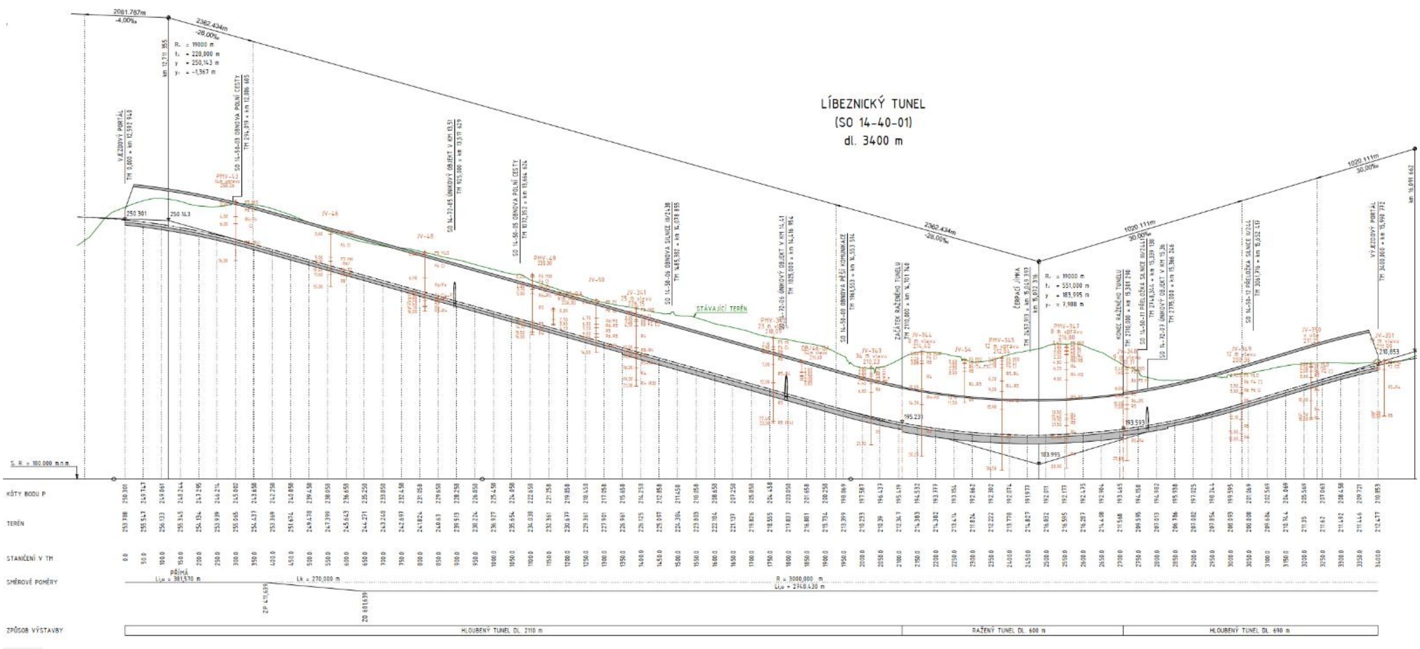


Figure 2: Longitudinal section of the new solution

The cut-and-cover frame structure was replaced by an arch structure founded on a base slab in the cut-and-cover sections and by a closed arch structure with a continuous invert in the mined section. The track now follows a valley vertical curve with the lowest point located approximately three-quarters along the tunnel length. The mined section is designed with a fully tanked waterproofing system without lateral drainage.

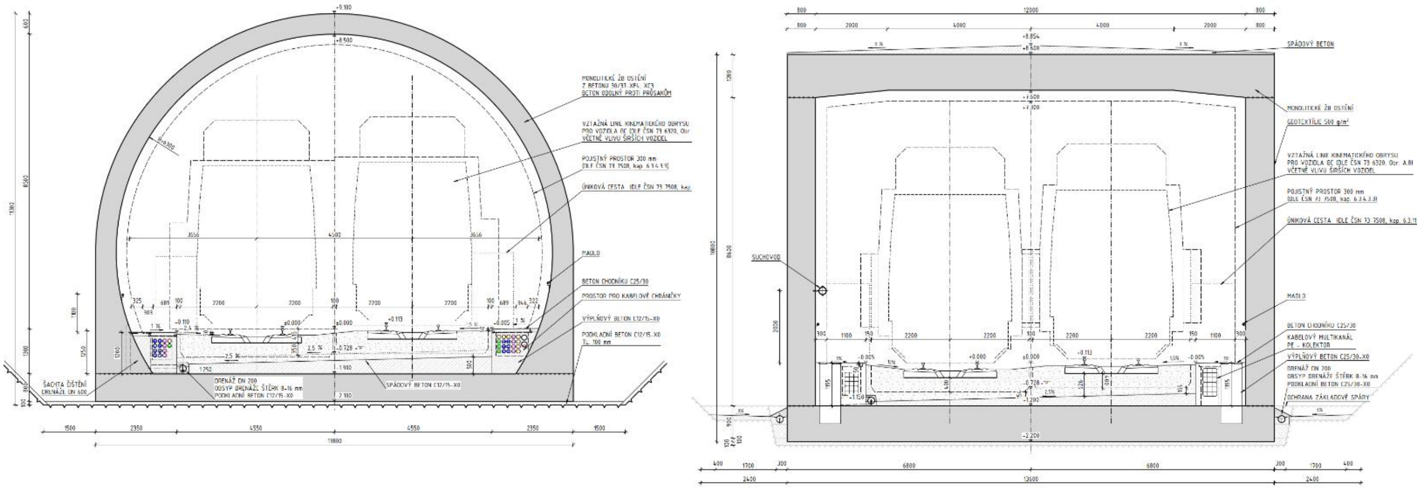

Figure 3: Left - Typical cross-section of the new solution, Right - Typical cross-section of the original solution

## 2. DRAINAGE AND WATERPROOFING

Drainage of the track bed is provided by an internal drainage system running along the left-hand evacuation walkway (in the direction of chainage). The drainage is conveyed via inspection chambers located in the walkway to a retention tank situated at the lowest point of the tunnel. The tank is equipped with pumps allowing water to be discharged to the surface if necessary.

For emergency situations, a watertight prefabricated emergency sump is provided beneath the integrated rescue system area at the third escape structure. Contaminated water will be transported for environmentally compliant disposal. Under normal operation, only condensed water will be discharged, posing no environmental risk.

In the cut-and-cover sections, watertight concrete is used due to the risk of membrane damage during backfilling and the significant structural thickness (600 mm at the crown). In the mined section, a conventional membrane waterproofing system with a protective layer is applied.

## 3. CUT AND COVER SECTION

Engineering geological investigations confirmed complex geological conditions. Excavation will encounter loess and gravel in upper layers, underlain by marlstone, sandstone and siltstone of varying degrees of weathering.

The excavation, with depths ranging from 6 to 21 m, is designed with sloped sides due to its location outside urban areas. Slopes of 3:1 are applied in Proterozoic rocks, 1:1 in Cretaceous marlstone and 1:2 in Quaternary loess deposits. Steeper slopes will be stabilised by soil nailing and shotcrete, while Quaternary deposits will be protected by erosion control mats. The total excavation volume is approximately 1.1 million $m^3$, of which about 750,000 $m^3$ will be reused for backfilling.

The structure comprises a 600 mm thick vault and a 900–1,200 mm thick base slab, depending on overburden and formation conditions. The structure is designed in C30/37 watertight concrete. Concreting blocks are 10 m long.

## 4. MINED (NATM) SECTION

The 600 m long mined section is located where the overburden ranges from 7.5 m at the portals to a maximum of approximately 14.7 m. Four support classes are defined: SEC 4, SEC 5a, SEC 5b and SEC 5c. Higher support classes are expected near the portals, while SEC 4 applies to approximately 420 m of the section. The excavated cross-sectional area is 145 $m^2$.

In SEC 4, the face is divided horizontally into top heading, bench and invert, with a continuous invert arch. In SEC 5a and SEC 5b, additional face support is provided using bearing plates tensioned against IBO anchors installed in the face. In SEC 5c, the top heading is divided vertically into two parts. The primary lining thickness is 250 mm in SEC 4 and 300 mm in SEC 5 classes. The secondary lining features a 350 mm thick crown with a radius of 6,300 mm and a variable thickness invert up to 1,200 mm at mid-span.

## 5. AERODYNAMICS, SAFETY AND TECHNOLOGICAL EQUIPMENT

The tunnel cross-section is significantly influenced by aerodynamic requirements for a design speed of 250 km/h. Adequate cross-sectional area is required to limit the piston effect, maintain passenger pressure comfort, and minimise micro-pressure waves at the portals. Recesses typical of conventional railway tunnels are omitted, except for space required for the retention tank.

The design was complicated by the fact that the Czech standard ČSN 73 7508 applies only up to 160 km/h, requiring close coordination with the High-Speed Rail Division of the Railway Infrastructure Administration.

The tunnel is equipped with three evenly spaced escape structures. Each consists of an evacuation corridor, a technical room and a stair shaft leading to the surface. Depths range from 13.5 m to 18.5 m. Surface evacuation areas are connected by newly designed access roads. Both portals and all escape structures include technical facilities for HV and LV distribution and tunnel control systems.

## 6. CONLUSION

The Líbeznice Tunnel is an illustrative example of how modifications to vertical alignment can fundamentally affect the character of a structure. The realignment led to a comprehensive redesign, including tunnel extension, a change in construction methodology and structural form. Upon completion, the Líbeznice Tunnel will be among the first railway tunnels in the Czech Republic systematically designed for operating speeds exceeding 200 km/h.

***Ing. Martin Svoboda***
***SAGASTA s.r.o.***
***Martin.Svoboda@sagasta.cz***