

# THE PĚTIDOMÍ ROAD TUNNEL IN ČESKÉ BUDĚJOVICE, GEOTECHNICAL, LOGISTICAL AND OTHER CHALLENGES OF THE TECHNICAL DESIGN OF AN URBAN TUNNEL

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**ABSTRACT:** The paper describes the technical design of an atypical urban twin-tube road tunnel with two underground roundabouts in the portal area, which is an exceptionally demanding project due to the requirements for accessibility of the area, geotechnical conditions, construction phasing associated with traffic closures at the marshalling yard, and connections to existing urban development in all directions. The structural design allows for a possible extension of the tunnel to Nádražní Street without interrupting traffic. The construction pit for the tunnel in an environment of waterlogged sediments crosses one of the largest marshalling yards in the Czech Republic, as well as tracks connecting to a passenger station of international importance, and in the area of underground crossings, it extends to the immediate vicinity of urban development. This requires managing the complex phasing of construction in accordance with the requirements of rail transport operators and minimising the negative impact of construction on the functioning of the city. The tunnel structure is designed from leak-resistant concrete with electrical insulation protection against stray currents, which originate from both railway traction lines and trolleybus transport. Buoyancy also plays an important role in the design of the tunnel, as the foundation joint is approximately 12 m below ground level and the groundwater level fluctuates around 2 m below its level. From a transport perspective, this is an urban tunnel, but the tunnel ceiling slab is also an integral part of a wide railway bridge that spans the marshalling yard and the tracks of the passenger station. The technological equipment of the tunnel and the related construction modifications must allow for a possible extension of the tunnel to Nádražní Street with a currently unknown portal location. Construction is expected to begin in 2027.

## 1. INTRODUCTION

The railway divides České Budějovice in a north-south direction and creates a barrier in the urban area that complicates the connection between the eastern and western parts of the city. This is probably why, in 2001, the idea arose to connect the Pětídomí and Suché Vrbné districts with the city centre by means of a road tunnel under the railway station. At that time, it was still a direct underpass continuing from Průmyslová Street on the city centre side, leading to Dobrovodská Street in its eastern part. Since then, there have been a number of modifications and changes in the technical solution. The whole process was significantly accelerated in 2021, when the South Bohemian Region initiated a feasibility study with the aim of finding the optimal route for the tunnel in terms of both transport and urban planning and the technological construction process.

The České Budějovice station is the main passenger station in the region and serves as an important train formation station for freight transport. The result of the feasibility study completed in September 2022 was a variant that the SAGASTA design office subsequently developed into detailed documentation for the issuance of a joint permit (DUSP), under which the tunnel was named Pětídomí. The tunnel is part of the project Relocation of Roads II/156 and II/157, Stage 3, Underpass beneath the railway station, České Budějovice. The scope of the project is evidenced by the number of almost 90 structures, with the tunnel structure further divided into 30 sub-structures and 17 operational units.

In addition to designing the tunnel structure in complex geotechnical conditions, which also includes two underground intersections and ramps leading from these intersections to the surface, it was also necessary to resolve the phasing of construction with a view to minimising closures of both the passenger and marshalling stations, connecting to existing or newly modified local roads and creating conditions to ensure operational safety.

## 2. GEOTECHNICAL CONDITIONS

The information needed for the tunnel design was provided by a detailed geotechnical survey. In most of the 15 core boreholes, the most common soils found under the layer of anthropogenic fill were sands and gravels with a slightly variable fine-grained content. The layer of sand with fine-grained admixtures and loamy sand reaches a thickness of 2 m to 6 m. Below this layer is a layer of gravel with fine-grained admixtures. Deeper probes with a depth of 15-20 m encountered practically impermeable Neogene clays with a permeability of  $10^{-7}$  m/s and lower at a depth of 9-11 m below ground level, whose thickness is estimated at several tens of metres. These are clays of solid consistency, in contact with overburden gravels of stiff to solid consistency with high to very high plasticity.

The free to slightly tense groundwater level is bound to permeable sands and sandy gravels with a permeability coefficient of  $k= 3.41 \times 10^{-4}$  m/s. Its steady level ranges from 1.2 m to 3.7 m below ground level. This aquifer will be hydraulically connected to the Vltava and Malše rivers. The aquifer thickness reaches approximately 8.5 m.

## 3. DESCRIPTION OF THE CONSTRUCTION DESIGN

The Pětídomí Tunnel is a 397 m long twin-tube road tunnel constructed in a construction pit. The length of the tunnel is defined as the longest distance between the portals measured in the northern tunnel tube from the U Lávky portal to the Mánesova portal. The other distances between the portals are shorter, with the shortest being 297 m in the southern tunnel tube between the Mánesova and U Lávky portals. The height of the passage cross-section is 4.2 m. The tunnel is directionally divided in the area under the railway tracks with a width category of T-7.5 according to ČSN 73 7507. In the longitudinal direction, the tunnel grade descends first at a gradient of 4.0% and then 0.7% in the east-west direction up to station km 0.065 181, where there is a height break. From this point, the route then climbs at a gradient of 2.5%. The tunnel includes two underground intersections, "west" and "east", with a total of three entry and exit ramps to the surface. The eastern end of the tunnel is accessed by two ramps to Dobrovodská and U Lávky streets. In the west, one ramp leads to Mánesova Street. To ensure accessibility to the area and connection to existing roads, the ramps have gradients of up to 8%. The overall design of the tunnel is shown in Figure 1.

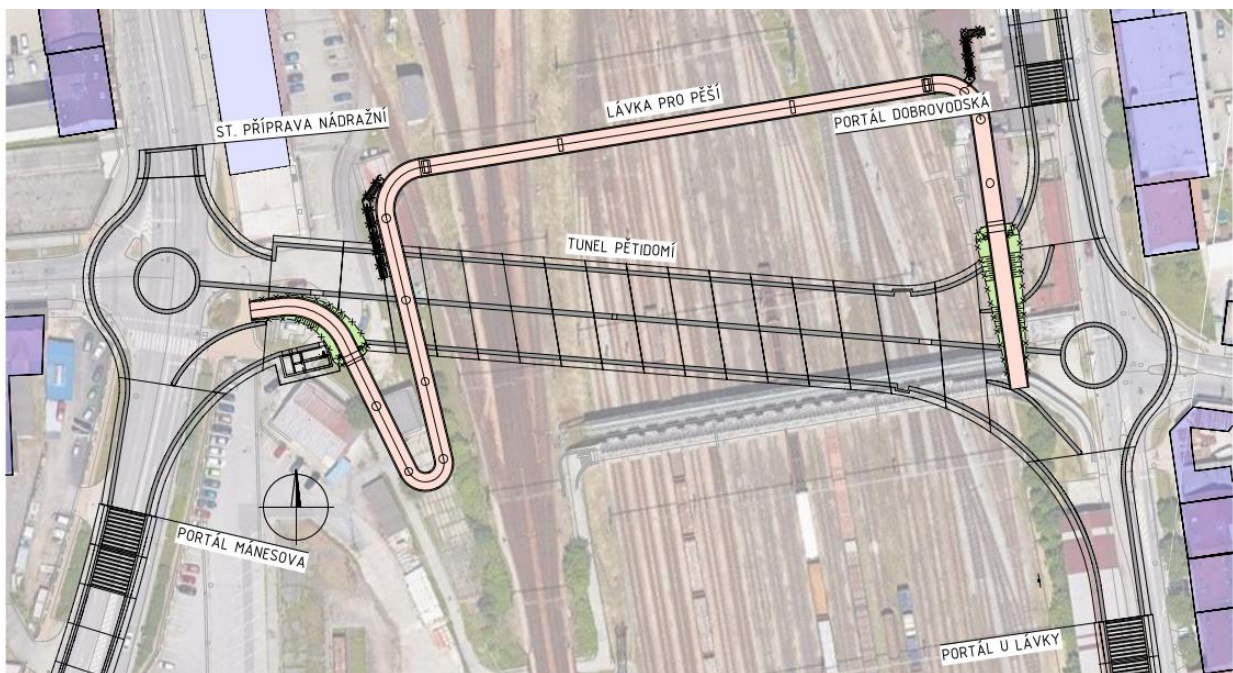


Figure1: Structural diagram of the Pětídomí tunnel with underground crossings

The reinforced concrete U-shaped ramps have variable side wall heights. The position of the portals is determined by the start of the ramp roofing. The tunnel passes under the tracks of the marshalling yard and part of the České Budějovice passenger station. In accordance with the ČSN 73 7507 standard, a

tunnel with a length of < 500 m is classified as short, which determines the requirements for its construction and technological equipment to ensure operational safety.

All structures are constructed in an open excavation pit. Due to the expected geotechnical conditions and the groundwater level approximately 1.5 to 2 m below ground level, the excavation pit will be secured with waterproof sheet pile walls anchored at several levels with prestressed cable anchors. The sheet piles pass through water-saturated Quaternary sediments and are embedded in water-impermeable Neogene clays in their subsoil. Before excavating the construction pit, it is necessary to pump out the groundwater from the area bounded by the sheet piles.

The tunnel lining consists of a reinforced concrete closed frame made of C 30/37 XF4 XC3 XD3 XA2 concrete with a central wall separating the tunnel tubes. The foundation slab is designed with a thickness of 1,500 mm, the perimeter walls with a thickness of 1,000 mm, the central dividing wall with a thickness of 1,200 mm, and the ceiling slab with a thickness of 1,000 mm is locally reinforced with ribs to a thickness of 1,500 mm. The foundation slab extends beyond the perimeter walls by 1,500 mm. This console serves to weigh down the structure with backfill material and contributes to increased resistance to washout. The clear width of the tunnel tubes is 9,800 mm, the clear height is max. 5,750 mm. A sample cross-section of the tunnel is shown in Figure 2.

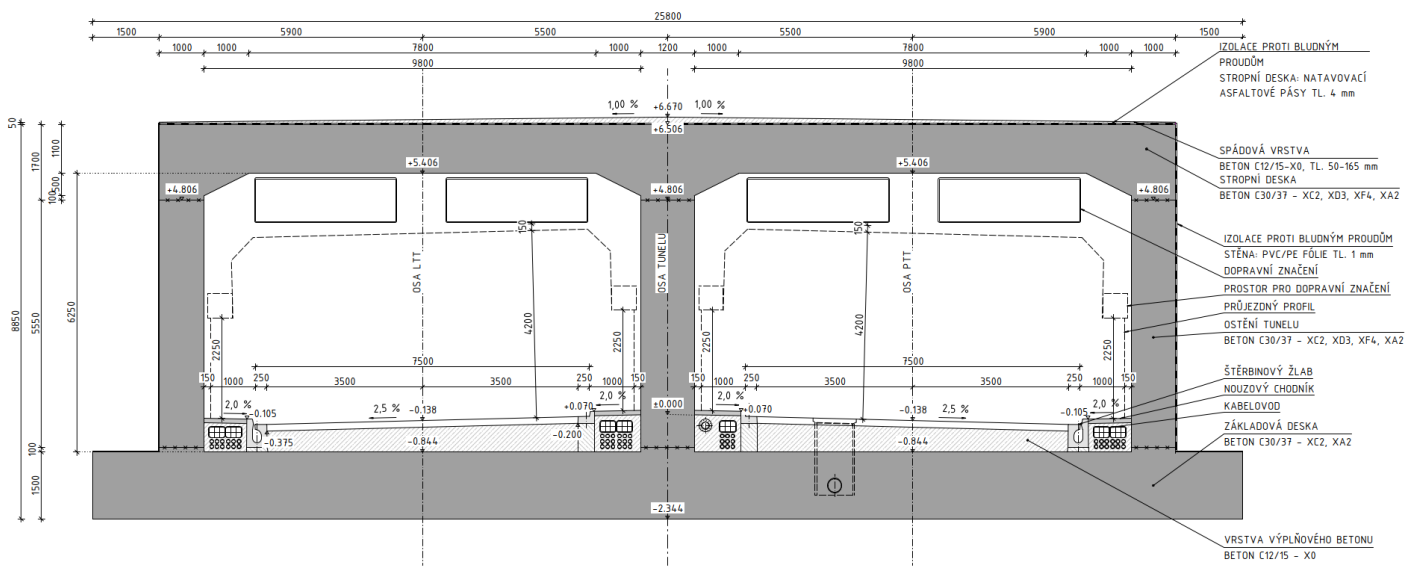


Figure 2: Sample cross-section of the tunnel under the railway track

The tunnel will be constructed in concrete blocks with a maximum length of 10 m with sloping working joints between the concrete blocks. The slope and position of the working and expansion joints correspond to the position of the tracks in the tunnel overburden, as the tunnel is an integrated railway bridge for the railway. Therefore, the aim is to prevent the railway from crossing the working or expansion joints of the tunnel lining. The construction of underground crossings and ramp approaches are of atypical dimensions and sizes.

The water impermeability of the tunnel and ramps is ensured by leak-resistant concrete in combination with internal sealing strips between the concrete blocks. Unlike waterproofing membranes, this allows for easy identification and repair of any leaks. Due to its location below the groundwater level and the risk of "floating", the structure requires buoyancy assessment. Hydrostatic pressure also acts on the sides of the ramps. Therefore, at the deepest point, beams are braced at the top, which are a certain accommodating element in terms of the driver's lighting comfort when exiting or entering the tunnel. (see Figure 3).

The interior equipment includes a fire water supply, service walkways, cable ducts, cable shafts including fire-resistant covers, SOS cabin niches and, last but not least, a road structure with drainage using slotted gutters equipped with self-extinguishing pieces to prevent the spread of flames. In the area of the underground west junction, an emergency exit with a stairwell and cable shaft is designed in the south

tunnel tube, enabling the connection of the operational technology building on the surface with the tunnel's technological equipment.

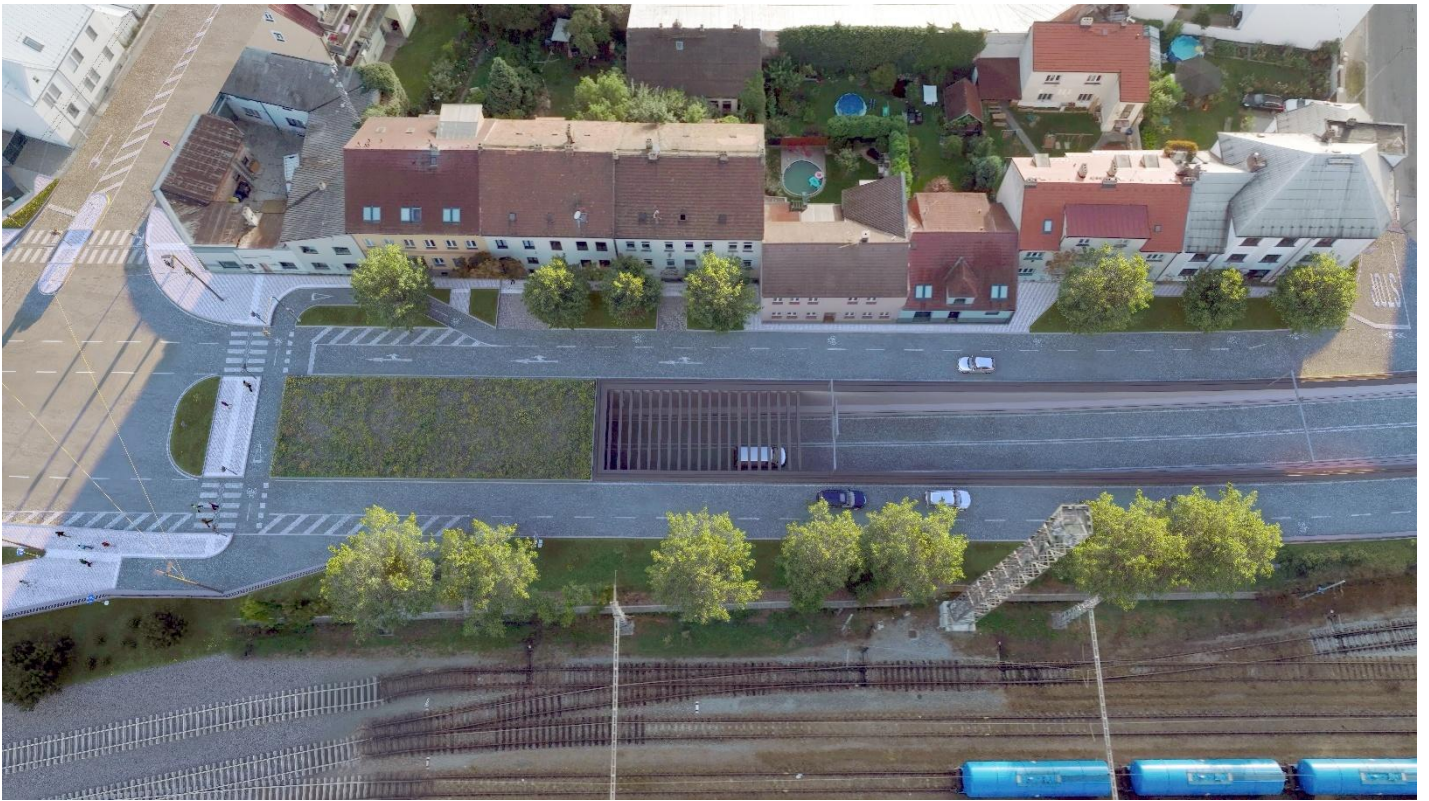


Figure 3: View of the U Lávky portal – upper bracing of the ramp with concrete beams

#### 4. CONSTRUCTION PHASING

Due to the impact of the construction on city life and the intersection of the construction pit with the marshalling yard and passenger station tracks, it was necessary to pay special attention to optimising the construction schedule. In addition to the technical design of the tunnel, the acceptable length of track closures in each stage of construction was one of the most challenging phases of the project. With the participation of specialists in railway construction design, transport technology, ZOV, traction lines, communication and safety equipment, as well as water management structures and other professions, it was possible to work with representatives of the Railway Administration and individual carriers to design a construction procedure that is a compromise between the requirements of the railway operator and the construction possibilities. Construction is taking place in the track area in three stages. The first stage begins in the area of the eastern underground intersection. After completion of the first stage, construction will move to the area of the western underground intersection. To ensure the operation of the passenger station, two temporary bridges must be installed over the construction pit and the tracks must be gradually relocated. The third stage of construction will require the partial removal of excavated soil by rail.

Each stage involves the dismantling of track panels and traction lines, the removal of the railway superstructure, pre-excitation for the installation of sheet pile walls around the entire perimeter of the partial construction pit, the drainage of groundwater, earthworks and anchoring of sheet pile walls, construction of the tunnel's supporting structure, backfilling, and, before work on the next stage begins, restoration of railway operations in the section of the previous stage. Everything is complicated by the fact that before the end of World War II, the marshalling yard was heavily bombed in several waves, and unexploded aerial bombs can be expected not only in the route of the future tunnel, but also in the places where rope anchors are being drilled. The start of earthworks will therefore be preceded by a pyrotechnic survey, which will continue until the construction pit reaches a depth of approximately 6 m.

During the construction phases that do not require the closure of railway tracks, site preparation, demolition, relocation of utility networks outside the construction pit and construction pits for underground intersections, including construction ramps to the bottom of the tunnel, will be carried out. When designing the construction phases, it was also necessary to take into account the limited capacity of temporary storage sites near the construction site and the transport of excavated material to permanent storage sites outside the city. The planned total construction time is approximately 2,200 days.

## 5. ENSURING OPERATIONAL SAFETY

As part of the proposed measures to ensure operational safety, a fire safety solution for the construction was prepared, an operational tactical study demonstrating the possibility of firefighting, and, in accordance with Government Regulation No. 264/2009 Coll., a risk analysis taking into account a basic assessment of emergency scenarios, including structural factors and operating conditions that affect its safety. The most complex risk situations associated in particular with the qualitative assessment of the possibility of transporting dangerous goods were evaluated. Due to the complexity of the underground structure, a risk analysis was prepared even though it is only required by regulations for tunnels longer than 500 m. Figure 4 shows the view of a driver driving up the ramp to the underground intersection.



Figure 4: View from the U Lávky ramp to the "East" underground intersection

Traffic load was considered for the traffic forecast in 2056. Traffic safety is ensured by structural modifications and technological equipment in the tunnel. Structural modifications include, for example, a fire water supply and hydrants, escape walkways, safety signs indicating the direction and distance to the escape point, tunnel connectors or escape structures that shorten the escape route from the accident site to a safe area. The tunnel's technological equipment ensures the required quality of the tunnel environment or enables the identification of an emergency in the tunnel using camera systems or sensors. The individual elements of the tunnel's technological equipment are connected to a control system and further to a central control room, from which it is possible to remotely monitor and, if necessary, control events in the tunnel.

Three connecting passages are located in the central dividing wall of the directionally divided tunnel, serving as escape routes in the event of an emergency. The first connecting passage is located at the western underground intersection, the second approximately in the middle of the dividing wall, and the

third at the eastern underground intersection. The second connecting passage is protected against the spread of fire and smoke by fire-resistant sliding doors. The central connecting passage complies with the dimensional requirements of the ČSN 73 7507 standard, while connecting passages 1 and 3 are larger in size as they house fire hydrants for use in both tunnel tubes. Safety signs on the tunnel walls show those involved in an emergency the shortest route to a safe area. In the case of short tunnels, self-rescue by fleeing persons plays a crucial role, and they usually manage to reach a safe area before the emergency services arrive. It is therefore important to know how to behave in a tunnel in the event of an emergency. The transport of dangerous goods (ADR) and public transport buses are prohibited in the tunnel.

## 6. A PROJECT WITH A VISION FOR THE FUTURE

In accordance with the client's requirements, the tunnel in the area of the western underground intersection has been structurally prepared for extension to Nádražní Street so that the extension can be carried out without interfering with the existing structures of the tunnel, which was already in operation at the time. This concerns both the length of the future tunnel and, in particular, the reserves in the capacity of cable ducts and rooms in the operational technology building for the expansion of the tunnel's technological equipment, the power supply for electric fans and the possibility of connecting a fire water supply. Due to its length exceeding 500 m, the tunnel will be classified as "medium length" after the extension. According to the traffic load forecast, it will be classified in the highest safety category TA and equipped with additional safety features. Lowering Nádražní Street into the tunnel would calm the area in front of the historic station building and allow residents and visitors to make greater use of the newly created space. Figure 5 shows a view of Nádražní Street with the Mánesova portal.



Figure 5: View of Nádražní Street with the Mánesova portal

## 7. CONCLUSION

The Pětídomí tunnel project is extremely demanding in terms of both its technical design in complex geotechnical conditions and the technological construction process and appropriate design of the individual construction stages. The transport solution of a tunnel with underground intersections is unprecedented in the Czech Republic and is also a rather exceptional construction in Europe. This requires extraordinary commitment and a high level of expertise from designers of all professions. A

building permit is currently expected to be issued, and construction is expected to begin in 2026. That is a quarter of a century since the first version of the tunnel project under the railway station. The estimated construction time is six years, and the tunnel is designed for a service life of 100 years. Successful implementation requires extraordinary commitment from all participants in the construction. A construction project of this scale within the city limits will require the designer, contractor and investor to be able to respond to the actual conditions encountered, and the residents and visitors to the city to be patient and tolerant. Once construction is complete, the eastern and western parts of the city will be connected, bringing all the benefits that this will bring to the transport solution for the city of České Budějovice (see Figure 6). For the SAGASTA design team, the Pětídomí tunnel will be another significant transport construction project. A complete overview of the construction is provided in a video available on YouTube after scanning the QR code.



Figure 6: Overall view of the completed construction from the south

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