CUT AND COVER RAILWAY TUNNELS AS PART OF THE EXTENSION OF TERMINAL 2 AT VÁCLAV HAVEL AIRPORT

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ABSTRACT: Václav Havel Prague Airport will undergo extensive modernization in the upcoming years with the aim of significantly increasing its capacity. One of the essential parts of this modernization is the extension of the terminal buildings, which envisages a significant increase in future check-in areas. This will be most evident in Terminal 2, which will be expanded by a new check-in hub and a new pier D. As part of the entire modernization a new railway connection between the airport and Kladno and the centre of the capital is also planned, which is to adequately replace the original idea of extending the metro line leading to the airport. Part of this railway complex also runs directly under the extended Terminal 2 and is immediately connected to the newly designed cut-and-cover railway station of Václav Havel Airport. This paper describes a small but important part of this project, which consists of a pair of single-track cut-and-cover tunnels. With a length of 240 m, it is a small scale in terms of volume but due to its complexity, limitations and interactions, with many other related structures, it is also a very demanding engineering task.

1. MODERNIZATION OF PRAGUE AIRPORT

Václav Havel Prague Airport (hereinafter referred to as VHPA) is awaiting extensive modernization in the next few years, the aim of which is to fundamentally increase the capacity of the most important airport in the country, in the first phase up to a twofold. It envisages the extension of both existing terminals and the related transport and technical infrastructure, including the integration of the railway connection into the airport's layout (Fig. 1).

Figure 1: Visualization of VHPA modernization (red – railway projects, blue – parking houses, orange – new runway, green – extension of Terminal 1 and 2)

Terminal 2 will be further extended with a new check-in hub and a new pier D. In this first phase of the VHPA modernization, the following activities will take place:

- some parking houses will be demolished, and new ones will be built in their place;
- the elevated road leading cars to the departure halls will be completely rebuilt;
- the entire pre-airport area will be connected by a covered walkway led on a steel bridge structure, the so-called skywalk;
- Terminals 1 and 2 will be completely extended (including the necessary facilities and infrastructure) and the functions of the Terminals will subsequently change – Terminal 1 will be for passengers within Schengen, Terminal 2 will be for non-Schengen check-in;
- finally, the already mentioned new railway connection will consist of a series of cut-and-cover tunnels and a railway station (ŽST) (NOVÁK, M., HANSL, V., PLATIL, J., HLAVÁČEK, D., 2023), which will also be located in the airport forecourt.

After 2030, the construction of a parallel runway should also begin, which will allow a significant increase in the capacity of handled flights. Their number has been steadily increasing in the last few years and has reached historically high numbers. For this reason, the modernization and expansion of the VHPA is necessary and despite the high investment costs it has a significant economic potential for the national economy. Part of this extensive system of projects is also a relatively small project of a pair of single-track tunnels leading under the future extension of Terminal 2, which the authors will present in more detail in the following text.

2. PROJECT SPECIFICS

In the previous chapter, it was outlined that the VHPA modernization project is quite expensive and complicated. A large number of structures are prepared in various temporal and spatial continuities by various entities and at different stages of project documentation, which require diverse and necessary interactions. On the Terminal 2 extension project (currently at the stage of documentation for building permit or documentation for joint permitting according to the Line Act respectively DUSL) association of four large studios Valbek, RA15, D3A, CMC are involved with more than 25 subcontractors (including V-CON, responsible for the cut-and-cover tunnels project). On the investor's side it is also not only one entity, but a pair of clients consisting of Prague Airport and Správa železnic (national railway infrastructure manager), which have different deadlines and normative requirements. Whether they relate to temporal and spatial coordination, load cases, fire safety, ventilation concepts, methods of foundation of individual buildings and securing construction pits, as well as insulation against water and vibrations or measures against the effects of stray currents, etc.
In the case of the pair of cut-and-cover tunnels under Terminal 2 extension, the project preparation requires the closest coordination especially with adjacent railway station project at one end and with the consecutive (also cut-and-cover) three-tube tunnel under the airport runway on the other end. There are five other related objects above and below the tunnels:

- An elevated road, the foundations of which extend into the area for the construction pit of cut-and-cover tunnels;
- an exit vestibule for passengers towards Terminal 2 located just above the ceiling of the tunnels;
- the buildings of the extension of the Terminal 2, which also interacts with the area of the construction pit for railway tunnels (Fig. 2);

- the so-called skywalk, i.e. a steel bridge structure bringing passengers to the terminal from the parking houses;
- An underground collector which supplies the current Terminal 2 with energy and which has to be bypassed under the tunnels as it is now in collision with their route.

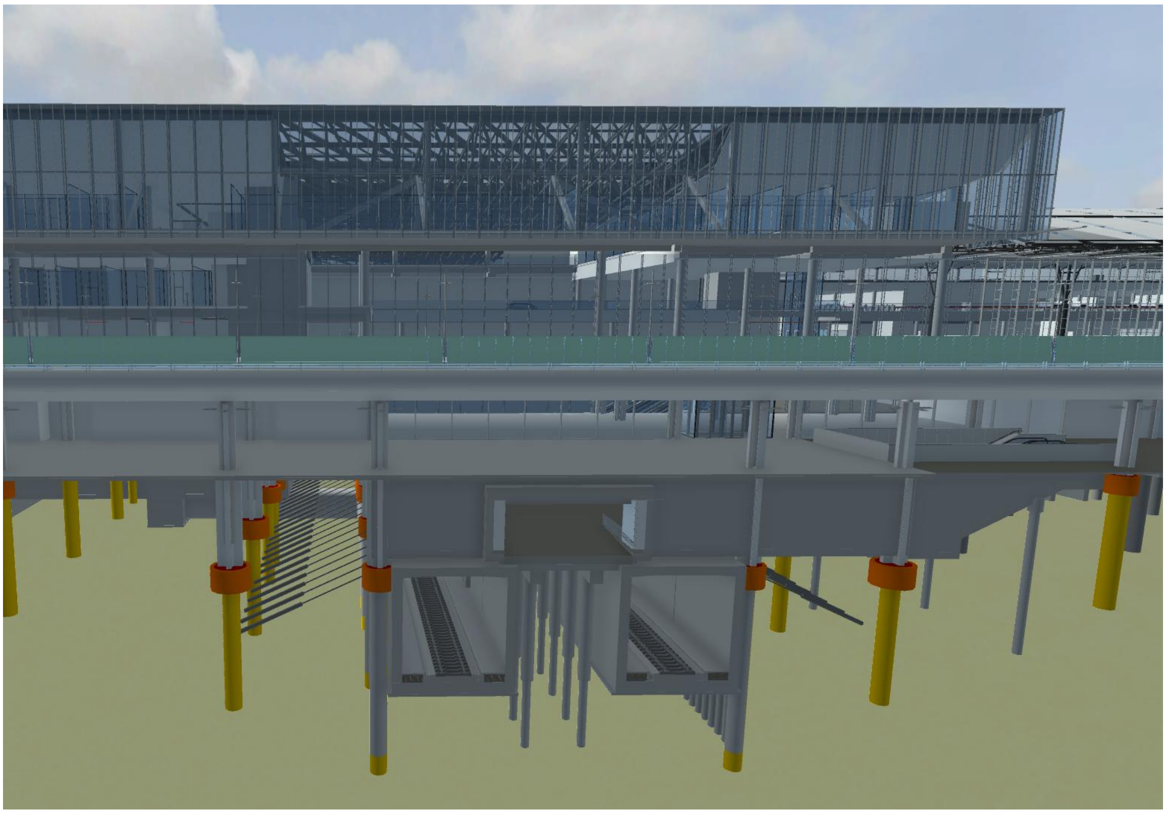

Figure 2: 3D model with a depiction at the site of a pair of tunnels, a vestibule, an elevated road and a building of the Terminal 2 extension

Design work of this scale and nature requires the use of sophisticated procedures with extensive and time-consuming coordination across projects and professions. A significant help in this regard is the BIM approach required by both investors, which has proven to be an effective tool for coordinating such a demanding package of interrelated projects (Fig. 3).

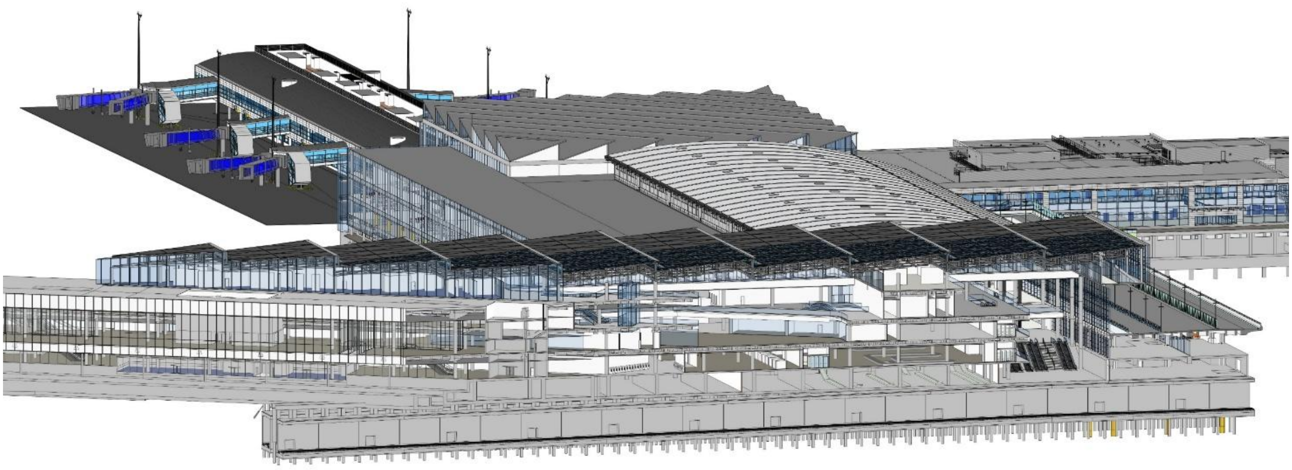

Figure 3: An example of a comprehensive BIM model at the point of passage of railway tunnels running under the completion of the Terminal 2 extension

In addition to the above, the entire project must respect other specifics and limitations given by the unique character of the projected work, e.g.:

- risk and safety analyses affecting the structural design of structures;
- non-traditional load cases and means of transport used (aircraft, specific airport equipment);
- taking into account the maximum maintenance of airport operations during construction;
- minimizing the impact on air traffic control (views from the control tower, interference with radio communication and radio navigation systems).

3. GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS

The rock environment in which the tunnels will be dug consists of the Quaternary cover and the pre-Quaternary bedrock. Recent deposits and Quaternary sediments reach a thickness of up to 4 m. The Quaternary cover consists mainly of loess and loess loams. These are clayey soils. The Pre-Quaternary bedrock is formed by Upper Cretaceous sediments in the “bělohorské” formation – sandy marlstones (marlstones) with spongylit inserts (the thickness of these positions is most often up to 1 m). Cretaceous rocks are subhorizontally stratified and rest discordantly on underlying Palaeozoic and Proterozoic rocks, which, however, have not been found and occur only at greater depths. The rocks of the pre-Quaternary bedrock are not weathered evenly, the degree of weathering is locally variable and the transitions are gradual. The average thickness of the entire “bělohorské” formation of Sandy Marlstones is usually over 15 m, in the area of interest it has been verified by a survey in the range of about 20 m. Marls weathered into brownish-yellow clay-sandy loam with fragments of weathered mother rock. Mostly clayey weathering passes into the subsoil into thinly plate-shaped decayed marls and deeper into solid, bench-like separating positions. Completely weathered (decomposed) rocks have a firm consistency, are slushy and freezing. (KUBÁT 2022).

Table 1: Overview of geotechnical types of the site of interest, modified by the authors according to (MERTOVÁ, L.2023)

Age	Genetic type	Lithological type	Classification by ČSN 73 6133	Thickness (m)
Quaternary	Loading	Soil character deposits	Y, F6 CIY, S4 SMY, F2 CGY, etc.	0,9–5,0
	Deluvial sediments	gravel-clay soils	F2 CG, F1 MG	0,2–2,2
	Aeolian sediments	clay soils	F6 CI, F7 MH	0,3–3,1
Chalk	Sediments of the “korycanské” formation	completely weathered marlstone	R6	1,0–12,3
	Sediments of the “bělohorské” formation	completely to heavily weathered marlstone	R5	1,5–2,1
		slightly weathered to healthy marlstones/marls	R4, R3, R3/R2	1,5–19,0

The groundwater level was not reached in the entire area of interest. The aquifer of the “bělohorské” marls has not been detected and the aquifer of the “korycanské” sandstones occurs only at greater depths, below the level of the planned bottom of the construction pit.

4. PARAMETERS OF CUT-AND-COVER TUNNELS

The project of a pair of cut-and-cover railway tunnels is divided into two stages due to the coordination of construction and links to other related projects. In the so-called stage 0, the first 50 meters of tunnels located in the area under the elevated road and exit vestibule of the railway station, which are closely adjacent to the building of the cut-and-cover railway station itself, are designed. This phase was even designed at the stage of detailed design docuemnation (PDPS). It consists of the first five blocks of concreting of 10 meters each, which are led at a zero slope and at a constant axial distance of 15 m. Another 190 meters of tunnels, i.e. stage 1 (DUSL), also maintain this constant distance from each other, but are already led downwards in the direction from the railway station at a slope of 15 ‰, (Fig. 4).

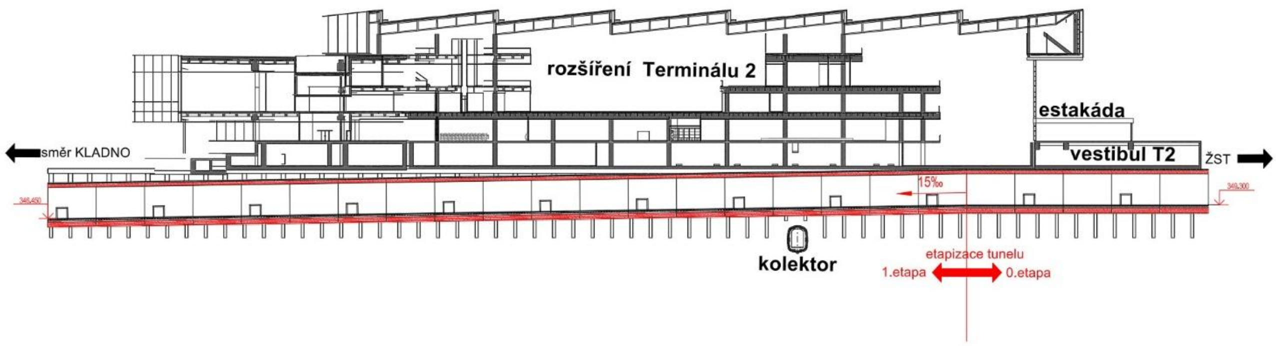

Figure 4: Longitudinal section of the tunnel tube at the site below the future terminal extension

The load-bearing structure of single-track tunnels consists of a pair of separate reinforced concrete monolithic frames with a slab ceiling structure with corner haunches. The concrete grade is C30/37 XF2, XC3 (CZ), the reinforcement is designed grade B500B. The bottom base plate is 800 mm thick. The walls have a constant thickness of 700 mm. The ceiling slabs have haunches where the thickness goes from 700 mm at the walls to 600 mm towards the tunnel axis. The standard length of individual tunnel blocks is 10 m with construction joints between the blocks. The tunnel structure will be dilated from the neighbouring structures (railway station, adjoining three-aisle tunnel) by expansion joints. Within each second block, a safety niche is designed according to ČSN 73 7508 so that their axial distance does not exceed 20 m (Fig. 5).

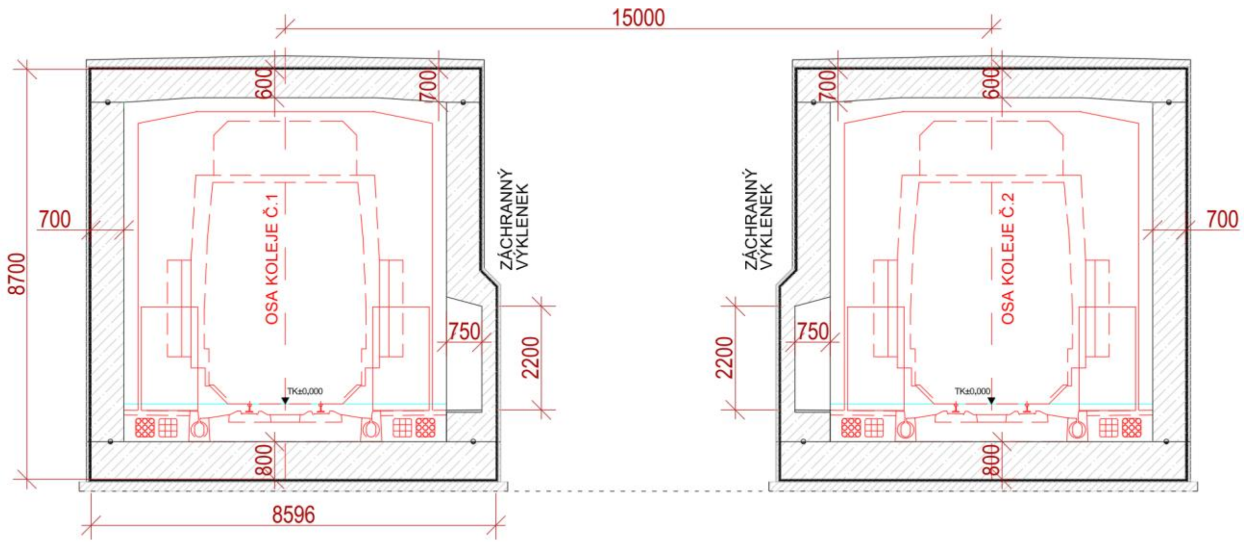

Figure 5: Cross-section and geometry of a pair of cut-and-cover tunnels at the location of niches

Due to the geometric constraints resulting from the fixed axial system of the elevated road foundations, these niches are situated for both tunnels towards the intermediate space between them. The tunnel is protected from water and stray currents by reverse waterproofing foil and protective geotextile with a recycled rubber mat around the entire perimeter of both tunnel tubes. To protect the structures from structural noise and vibrations, the tunnel will be insulated in the section under the vestibule by using vibro-insulating elastomer bearings/plates 30 or 60 mm thick. These will be placed under the fixed track, under the foundation slabs of both railway tunnels and further on the outer face of the tunnel walls in places where contact with the foundation structures of the elevated road pillars occurs. In addition, to reduce vibrations, the space between the ceiling of the tunnels and the foundation slab of the vestibule is left unfilled.

5. SECURING A CONSTRUCTION PIT FOR CUT-AND-COVER TUNNELS

The space for the pair of tunnels will be dug in an open construction pit 9.5–13 m deep from the level of the first basement of the future extension of Terminal 2. This construction pit will be secured using anchored (1–3 levels, depending on the decreasing depth and level of the tunnels) free-standing pile walls offset from the future tunnel structure. The pile wall will consist of piles Ø 760 mm at an axial distance of about 1.5 m and piles Ø 900 mm in places under the pillars of the elevated road and under the foundation of the skywalk structure. Due to the necessity of bridging the structure of the exit vestibule foundation slab and the building of the extended Terminal 2 above the tunnel tubes (with a span of up to 25 m), local support is proposed between the tunnels by means of pairs of pillars at distances of about 4 m, which copy the grid of the above-ground skeletal arrangement of the load-bearing structure and are longitudinally connected at the point of contact with the vestibule slab by a continuous beam.

6. CONCLUSION

The above-described project of a pair of single-track railway tunnels, which will run under the future expanded Terminal 2 as part of the extensive modernization of the VHPA, is a minor task in terms of the volume of work, but in terms of coordination and a number of non-standard interactions with other related structures, it is a very interesting and demanding engineering task. Its successful implementation is conditioned and directly influenced by several related buildings, which as a whole are to fundamentally improve the comfort of passengers from and to the VHPA.

7. ACKNOWLEDGMENTS

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