# EXPERIENCE GAINED FROM THE CONSTRUCTION OF THE FIRST EXCAVATED STATION ON THE NEW METRO LINE D IN PRAGUE – OLBRACHTOVA STATION

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ABSTRAKT:

The completion of the excavation work at Olbrachtova Station, the first bored station on Prague's new Metro Line D, marks a significant milestone in this strategic infrastructure project. The station is located in a densely built-up area of Prague 4 beneath Na Strži Street and was constructed using a new Austrian tunneling method involving multiple construction sites.

Architecturally and technically, it is a complex underground structure consisting of a pair of station tunnels with cross-connections, a service tunnel, and connecting escalator tunnels excavated from the north and south vestibules. The excavation itself took place under challenging conditions in heavily fractured Bohdalec shale and in the immediate vicinity of residential buildings or directly beneath them, which required a combination of a well-designed project, the contractor's experience, strict adherence to technical standards, cooperation among construction participants, and the implementation of modern methods.

Geotechnical monitoring, which was carried out continuously throughout all excavation work, played a key role. Monitoring of deformations in the underground structure, the terrain, and surface buildings allowed for a flexible response to the behavior of the rock mass. Based on these results and the ability to monitor certain parameters online, the excavation and associated measures—such as compensatory grouting with organic-mineral resins or noise reduction—were managed. This approach led to the minimization of settlement in surface structures and a reduction in noise levels for residents in the vicinity of the construction site. The monitoring thus confirmed the correctness of the chosen technological solutions and provided assurance to both the investor and improved noise conditions for residents of the affected area. The high-quality measurement results and experience gained also serve as an important basis for the subsequent construction phases of other stations and tunnel sections on Line D. Previous monitoring conducted through exploratory boreholes similarly contributed to the successful outcome of the station excavation.

The construction of the Olbrachtova station demonstrates that even under exceptionally complex geotechnical and spatial conditions, excavation can be carried out safely, efficiently, and with consideration for the surrounding environment. The excavation of the station tunnels, including the cross-passages and the service tunnel, as well as the southern and northern escalator tunnels, has been successfully completed. The most challenging part was the excavation in the station's northern cross-passage, where seven underground tunnels converge. All load-bearing structures of the southern concourse below the level of the major Prague thoroughfare, Na Strži Street, have also been completed, and traffic has resumed on that street. Work continues at the station on waterproofing, secondary lining, and internal load-bearing structures.

Modern technologies, particularly CDE, 3D modeling, laser scanning, and regular UAV imaging, have greatly benefited construction management. These methods significantly improve spatial coordination, enhance the precision of work execution—including reporting—and accelerate decision-making processes.

Thanks to the cooperation of all construction participants and the use of innovative methods, the project remains on schedule even after three years. Looking ahead, the completion of the permanent reinforced concrete structures of the service tunnel and the northern cross-passage will be crucial. The experience from Olbrachtova confirms that a high-quality design, thorough preparation, rigorous oversight, and the use of modern technologies are essential prerequisites for the successful construction of a metro system in a challenging urban environment.

## 1. METRO D A SECTION I.D1A PANKRÁC - OLBRACHTOVA

The first section of Line D (designated I.D), 10.6 km long, includes these ten stations. The Metro D construction project is divided into several consecutive phases. The first is I.D1a Pankrác – Olbrachtova (currently under construction, scheduled for completion in March 2026). This is followed by I.D1b Olbrachtova – Nové Dvory with access tunnels from the Písnice area (construction has now begun). Next are the construction of cut-and-cover stations and the bored section at Náměstí bratří Synků.

The first section, I.D1a Pankrác – Olbrachtova, is being implemented by a consortium of companies consisting of Subterra a.s., HOCHTIEF CZ a.s., STRABAG a.s., HOCHTIEF Infrastructure GmbH, and Züblin Aktiengesellschaft. The design documentation for the project is being provided by METROPROJEKT Praha a.s. The underground section consists of two stations, an interstation tunnel section, storage and ventilation tunnels, a connecting tunnel to Line C, and cut-and-cover vestibules at ground level. The tunnels are being excavated using the observation method, with a strong emphasis on face anchoring, improving rock mass parameters through pressure chemical grouting, and using rigid primary lining to minimize rock mass deformation. It is being constructed first due to its complexity and the presence of a major transfer hub to Line C. This is a technically demanding solution, reflected in the construction period of approximately 7 years.

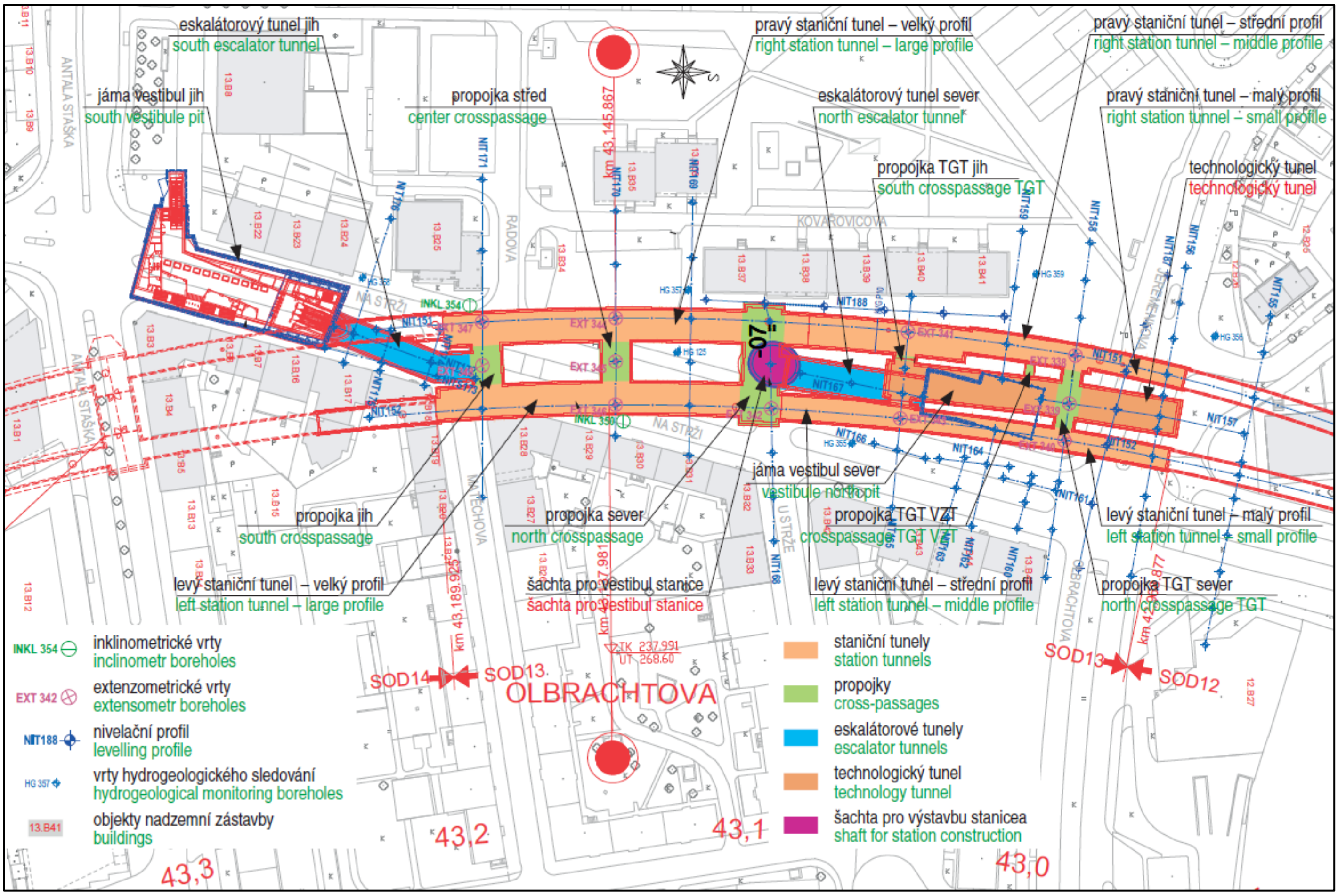

Figure 1: The Olbrachtova Station Area

The above-mentioned challenges also apply to the Olbrachtova station. In terms of the volume of the enclosed space, it is one of the smallest. It is an atypical two-platform station built in a curve under difficult geotechnical conditions beneath the urban area.

## 2. STATION WITH THE WORKING TITLE "OLBRACHTOVA"

The station is located beneath Na Strži Street, between the intersections with Jeremenkova, Olbrachtova, and Antala Staška Streets. The station is excavated at platform level and is divided into a public and a technical section. The public areas consist of two separate station tunnels, connected at the ends of the platforms and in the centre of the station by cross-passages. The technical section consists of two tunnels connecting to the station tunnels and a utility tunnel inserted between them. At ground level, the station has a northern concourse near the intersection of Olbrachtova and Na Strži streets and a southern concourse directly beneath Na Strži Street at the intersection with Antala Staška Street. Both concourses are connected to the underground section of the station by escalator tunnels.

### 2.1. TECHNICAL SOLUTION

Once completed, Olbrachtova Station, whose platform is located 27 meters below ground, will be the only tunnelled station on the Prague Metro with a curved layout. The radius of the right track is 826 meters and the radius of the left track is 800 meters. The platform's design resembles stations with separate side platforms. Thanks to collision-free passenger access to both platforms, it corresponds to stations with an island platform. The total length of the station is 223 meters, and it is located 31 meters underground. Of this, the platform is 100 m long. The station tunnels have a cut width of 10.6 m, a height of 9.2 m, and a cut area of just 89 m$^2$. There are two reasons for this design. The first is the station's low future passenger volume due to the proximity of the Pankrác and Budějovická metro stations. The second is the unfavourable geological conditions (Bohdalec shale), which do not allow for the construction of large-scale excavations typical of single-island stations in close proximity to surface development (Figure 2). Exits from the station open into the cross passages at the ends of the platform.

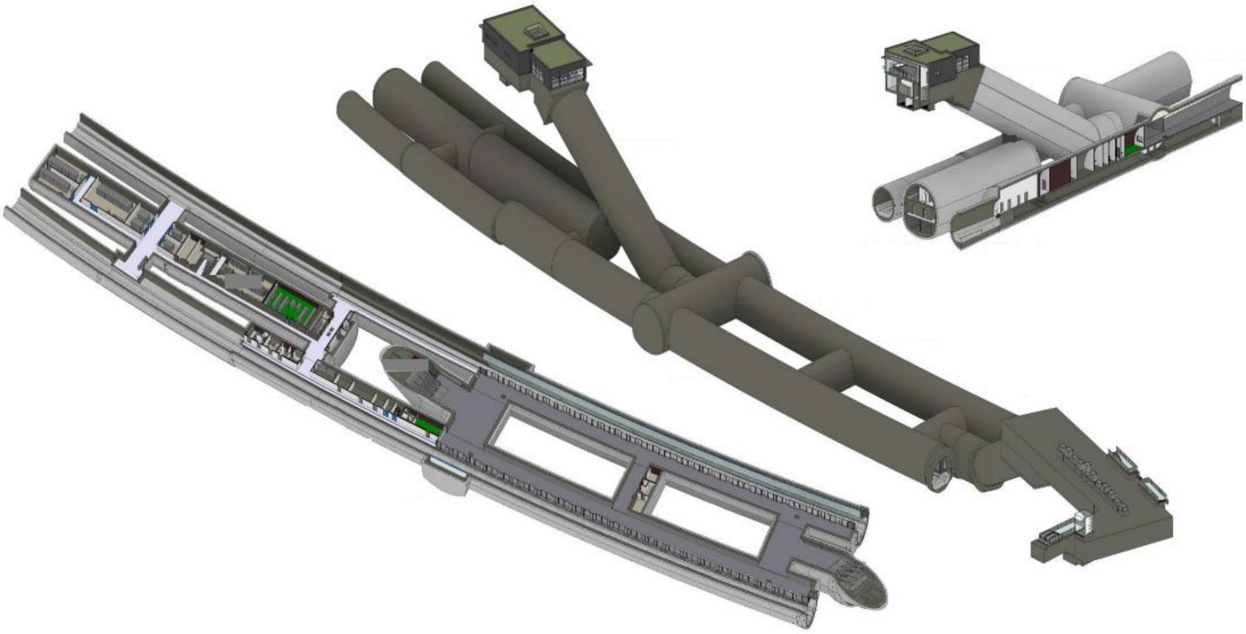

Figure 2: 3D station model

## 3. CONSTRUCTION PROCEDURE

The key structure for the construction of the underground section is the station construction shaft. The shaft is the only access point for carrying out most of the underground work, including the vertical transport of excavated material, supplies, workers, and machinery. Residential buildings are located in its vicinity. Therefore, a 27.5 m x 15.1 m hall was erected over the shaft to house a gantry crane with a lifting capacity of 40 tons. The hall primarily serves as a noise and dust barrier. It will serve this purpose until the installation of the equipment is complete.

### 3.1. SHAFT FOR STATION CONSTRUCTION

The total depth of the shaft is 34.4 m. The first 15 m below ground level are supported by bored piles (Figure 3). Below the level of the piles, the shaft atypically widens gradually so that its structural load is properly distributed to the reinforced pillars of the primary lining of all five adjacent underground structures. These include the connecting tunnel between the north, east, and west sections, both station tunnels, and the north escalator tunnel. From the bottom of the piles, the shaft is secured by a combination of shotcrete lining with KARI mesh and truss frames, together with massive bracing and radial anchoring. The depth of a single excavation section containing all these elements is 1 m. The difficulty of the station's construction lay primarily in the need for constant transfer of machinery between the surface and underground for each work operation in a single section due to the shaft's small dimensions. Construction of the shaft began with pile drilling in July 2022 and was completed at the end of May 2023. It was subsequently backfilled to the level of the bottom of the upper section of the excavation of the northern connecting tunnel (Figure 4).

Figure 3: Drilling of cable anchors in the shaft for station construction inside the soundproof hall

Figure 4: Layout of the north connecting tunnel from the station construction shaft

### 3.2. STATION

The first section to be excavated was the 118 m$^2$ north connecting tunnel. Due to the encountered conditions, this tunnel was constructed in technology class TT5c. In this class, the tunnel is horizontally divided into seven separate excavation sections. Excavation of this section continued through June 2023.

Simultaneously with the excavation of the northern connecting tunnel, short sections of the station tunnels toward Pankrác were also excavated. This ensured the breakthrough of the station tunnels being excavated from Pankrác. After the completion of the northern connecting tunnel excavation, excavation of the left station tunnel toward Krč began in October 2024, followed by the right station tunnel toward Krč in November. Excavation of both tunnels proceeded, based on the encountered conditions, initially in excavation class TT5c, with the excavation divided into seven sub-profiles. Subsequently, due to an improvement in the encountered geotechnical conditions, excavation on both tunnels transitioned to excavation technology class TT5b, with the excavation divided into five sub-profiles.

This simplified and accelerated the tunnelling process, streamlined logistics, and increased the space available for parking the machinery. An essential part of the tunnelling work was the continuous stabilization and improvement of the immediate surrounding area through chemical grouting with DSI Underground Mineral Bolt silicate resin. The face of the excavation was reinforced with pressure-injected face anchor rods spaced every 4 meters. Additionally, a needle umbrella with chemical pressure grouting was installed every two meters. Chemically grouted radial bolts were installed in each excavation section. The rock mass treated in this manner increased the stability of the excavation and significantly reduced inflow into the underground. As a result, settlement of the above-ground structures was reduced. Excavation of both tunnels proceeded simultaneously, with mechanical cutting taking place in one while the excavation in the other was being supported and stabilized. The vertical mining shaft served as a bottleneck for supply operations. For example, the volume of excavated rock alone exceeded 35,000 m$^3$.

Figure 5: Surveying of truss frames at the bottom of the south station connecting tunnel

Figure 6: Drilling of face anchors in the production tunnel

During the excavation of the station tunnels, work began simultaneously on the central cross-passage, with a cross-sectional area of 73 m². The newly excavated structure provided a welcome opportunity for depositing the material needed for the excavation work. After the station tunnels were excavated, their faces were permanently secured at the location of the future breakthrough of the track tunnels. Work on the left and right station tunnels lasted from October 2023 to September 2024. After the completion of the station tunnel excavations, the south cross-passage was also constructed, which additionally includes a connection to the south escalator tunnel (Figure 5). In these areas, contrary to expectations from the station tunnel excavation, very hard shale was encountered during the finishing of the cross-vault of the horizontal section of the escalator tunnel. Mechanical excavation took five times longer here.

As the tunnelling work neared completion, work began on the waterproofing and secondary lining of the station tunnels and tunnel cross-connections. The waterproofing system consists of a 800 g/m² protective geotextile, a 3 mm thick softened PVC membrane with a signal layer, and vertical and horizontal joint strips at the junctions of individual blocks and construction joints. It also includes a backup grouting system. The vault is reinforced with Bretex arch truss frames featuring two layers of KARI mesh (150 × 150/8 × 8 mm) supplemented with spacers. The vault concrete is Class C 30/37 XC1 with a thickness of 500 mm.

The future technical centre, which will handle power supply, operations, and station security, is located within the non-public section of the station tunnels heading toward Pankrác. The technical tunnel (TGT) is divided into a large section with three levels and a small section with two levels. The entire tunnel was excavated from the northern junction of the technology tunnel (Figure 6) after the secondary lining of both adjacent station tunnels had achieved sufficient strength. Excavation proceeded in both directions simultaneously. All excavation work was carried out in technology class TT5c with a vertically segmented crown. With its 124 m² of excavated cross-section, the large profile was the largest excavated structure at the station. Excavation was completed in October 2025, and since then (as of 03/2026), insulation and secondary lining work has been underway.

### 3.3. SOUTH AND NORTH ESCALATOR TUNNELS

Both escalator tunnels were excavated primarily at a downward angle of 30 degrees. The south escalator tunnel has a cross-sectional area of 81 m², with the inclined section measuring 37 meters in length and the horizontal section 18 meters. It is being excavated from the floor of the south underground concourse and will be equipped with three escalators. The north escalator tunnel is longer and has a larger excavation volume. It is being excavated from the floor of the surface vestibule; the inclined section is 49 meters long and has an excavation cross-sectional area of 102 m². In addition to the three escalators, it will also be equipped with an inclined elevator (providing barrier-free access to the station).

Excavation of both escalator tunnels began in the TT5c excavation class with a vertically segmented roof. As the overburden increased and geotechnical conditions improved, the excavation transitioned to the TT5b excavation class without vertical roof segmentation. For the southern escalator tunnel, logistics were designed in the form of a rail-mounted platform for transporting machinery and materials; for the northern tunnels, however, an Ostroj TH 502-M scraper conveyor was selected to remove the excavated material. The method of excavating directly onto the scraper conveyor using an excavator proved to be more efficient. The northern escalator tunnel was secured in its first few meters by a double-row micropile umbrella. This was the first time in the Czech Republic that micropile connection technology using mechanical compaction (DSI) was used.

Excavation of the inclined section of the southern escalator tunnel began in February and was completed in December 2024. The secondary lining was completed in August 2025. The insulation and secondary lining system for both escalator tunnels is similar to that in the station. Excavation of the northern escalator tunnel began in September 2024 and was completed in September 2025, including the vertical connecting shaft to the utility tunnel.

During the excavation of both escalator tunnels, the horizontal section from the station and the adjacent sloped sections of the sidewalls and floor were excavated using a cut-and-cover method from the station, which proved to be significantly more efficient and faster. The secondary lining of the northern escalator tunnel is expected to be completed in June 2026.

### 3.4. UNDERGROUND VESTIBULES

Work on both station concourses proceeded in parallel with the construction of the station itself. These efforts were accompanied by necessary noise-reduction measures due to the proximity of residential areas. These measures primarily consist of noise barriers, sound-absorbing cladding, noise monitoring, and organizational arrangements for noisier construction activities.

The south concourse was excavated at the site of Na Strži Street. Therefore, utility lines were first rerouted (Figure 7). This took place concurrently with the start of construction in April 2022. Depending on the depth, the following were gradually relocated: fiber-optic communication networks, metallic cables for traffic signal control, street lighting, low-voltage electrical cables, 22 kV power cables, driven sewer pipes DN600/1100, low-pressure gas pipelines, water mains, and all connections of these networks to buildings. The portion of relocations necessary to begin work on the vestibule was completed after approximately 14 months in June 2023. In total, nearly 30 relocation projects were carried out in approximately 80 phases. The final relocations were completed alongside the completion of the vestibule's structural shell at the end of 2025.

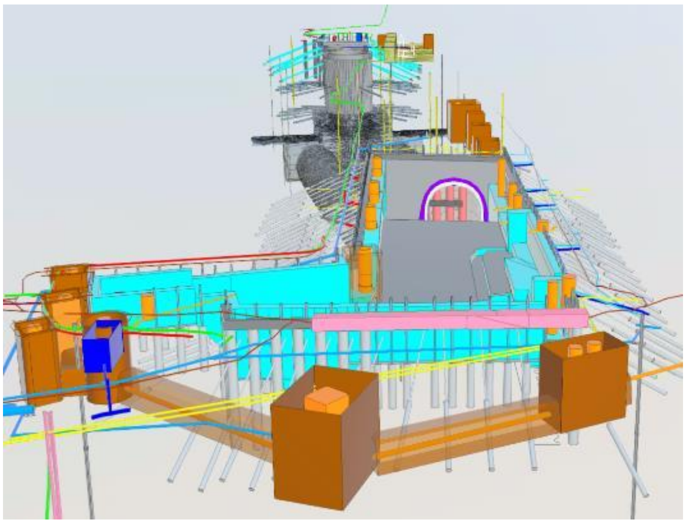

Figure 7: 3D model of the south lobby, including all necessary utility line relocations

Figure 8: A drone view into the pit of the south vestibule, showing the soundproof walls, during the demolition of the south vestibule piles around the south escalator tunnel portal

Work on the south entrance hall began in mid-2023 with the installation of bored piles. The excavation pit for the entrance hall spans the entire width of the traffic lanes on Na Strži Street, which had to be completely closed for 36 months. The construction pit is secured by reinforced concrete piles with diameters ranging from 600 mm to 1,200 mm and beams ranging from HEB 120 to IPN 300, supplemented by a head beam on the piles and tiebacks with cable anchors at two to three anchor levels. Earthwork on the vestibule then lasted from September 2023 to June 2024 (Figure 8). This was followed by work on the waterproofing base layers, insulation, the final reinforced concrete structure, and, in one section, the excavation of the south escalator tunnel. All of this, together with the roadway and sidewalks, was completed in December 2025 without any delays.

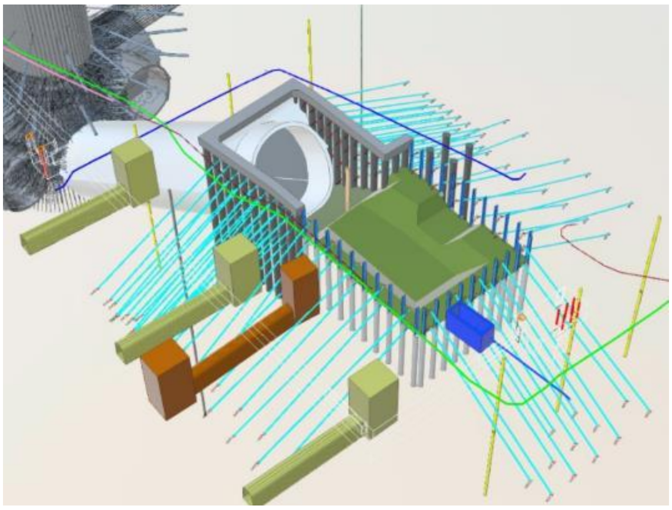

Figure 9: 3D model of the north lobby, including all necessary utility line reroutes and connections;

Figure 10: A drone view into the pit of the north vestibule, showing sound-absorbing cladding on the noise barriers during the grouting of the micro-pile umbrella for the north escalator tunnel

The north vestibule is located on the same construction site as the shaft for the station's construction. In advance, in 2022, the walls of the construction pit were reinforced with 900-mm-diameter drilled reinforced concrete piles and IPE 330 steel struts to mitigate noise. Other shoring elements were like those used for the southern vestibule (Figure 9). Earthwork did not begin until March 2024, after part of the surface construction site area was cleared. This area had previously been used for storage during the excavation of the station construction shaft and the breakthrough of the northern connecting tunnel. Earthwork was completed in August 2024, after which excavation of the north escalator tunnel began (Figure 10). Following the completion of the final structures of the escalator tunnel, work on the concrete foundations, waterproofing, and load-bearing reinforced concrete structures will continue in May 2026.

## 4. GEOTECHNICAL MONITORING

Comprehensive geotechnical monitoring and documentation of the construction of the first section of Metro Line I.D (Pankrác–Olbrachtova) is being carried out by the consortium "Krtek D monitoring," led by SG Geotechnika a.s. in partnership with INSET s.r.o., GeoTec-GS a.s., and PUDIS a.s. Geotechnical monitoring is being carried out due to the high technical complexity of the underground structure and its location in a densely built-up urban environment, combined with difficult geological conditions. The monitoring covers both the underground sections (the tunnel excavation itself and inspection of the primary lining) and the rock environment, surface structures, construction pits for vestibules, and utility networks within the project's zone of influence. The main objective is the ongoing verification of design assumptions, monitoring of construction safety, and the timely identification of risky deformations in both the structures and the surrounding environment.

### 4.1. GEOLOGICAL CONDITIONS

The Olbrachtova station tunnels were excavated in a rock formation consisting of Ordovician shales from the Bohdalec Formation. These shales are significantly tectonically fractured in places and exhibit varying degrees of weathering, which results in degraded mechanical properties of the rock mass. The bedrock is overlain by Quaternary sediments and a layer of anthropogenic fill, which were encountered primarily in the excavated sections of the vestibules and, to some extent, in the escalator tunnels.

The Quaternary cover consists mainly of sediments from the Pankrác Terrace, ranging from sandy loam to gravelly sand. The overburden of the tunnel reaches approximately 24 m, with the thickness of anthropogenic sediments being around 1.5 m and that of fluvial soils approximately 6 m. The groundwater table is located at the interface between the Pankrác Terrace and the Bohdalec Formation.

The tunnels are being excavated using the observation method, with a strong emphasis on anchoring the working face, improving the rock mass parameters through pressure chemical grouting, and using rigid primary lining to minimize deformation of the rock mass. During excavation, detailed engineering-geological documentation of the excavation was systematically carried out underground, supplemented by photographic documentation and a geotechnical report. This report included a drawing of the face, a textual record of the findings, an assessment of the rock mass quality according to the QTS classification, and recommendations for any necessary technological measures for the continuation of excavation. Documentation was prepared for each construction phase.

During excavation, shales of varying quality were encountered, ranging from relatively sound rock (strength classes R3–R4) to significantly tectonically fractured zones (strength classes R5, locally up to R6), with these rock types frequently alternating along the tunnel route.

### 4.2. MEASUREMENT

One of the main activities in underground monitoring is observing the behaviour of the excavation and primary lining immediately after the structure has been excavated. This behaviour is monitored geodetically in three dimensions using so-called convergence measurements. Depending on the size of the cross-section of the excavation, convergence profiles have a varying number of measurement points, typically ranging from 3 points (e.g., for the HVAC cross-passage) to 9 points (for large-profile station tunnels, the north escalator tunnel—ETS, the north cross-passage, and the TGT tunnel). Stress in the primary lining was also monitored underground. Measurements were performed using strain gauges, which were installed in pairs on the back and face of the primary lining in the tangential direction. The maximum measured stress values reached approximately 25 MPa, both in compression and tension.

Structures on the surface within the construction influence zone were monitored using the levelling method; for selected structures, trigonometric measurements were also performed. The settlement trend resulting from the construction was predominantly favourable and, in most cases, remained below the warning state (VS) criteria established by the structural engineer, with total settlement values reaching approximately 10 mm.

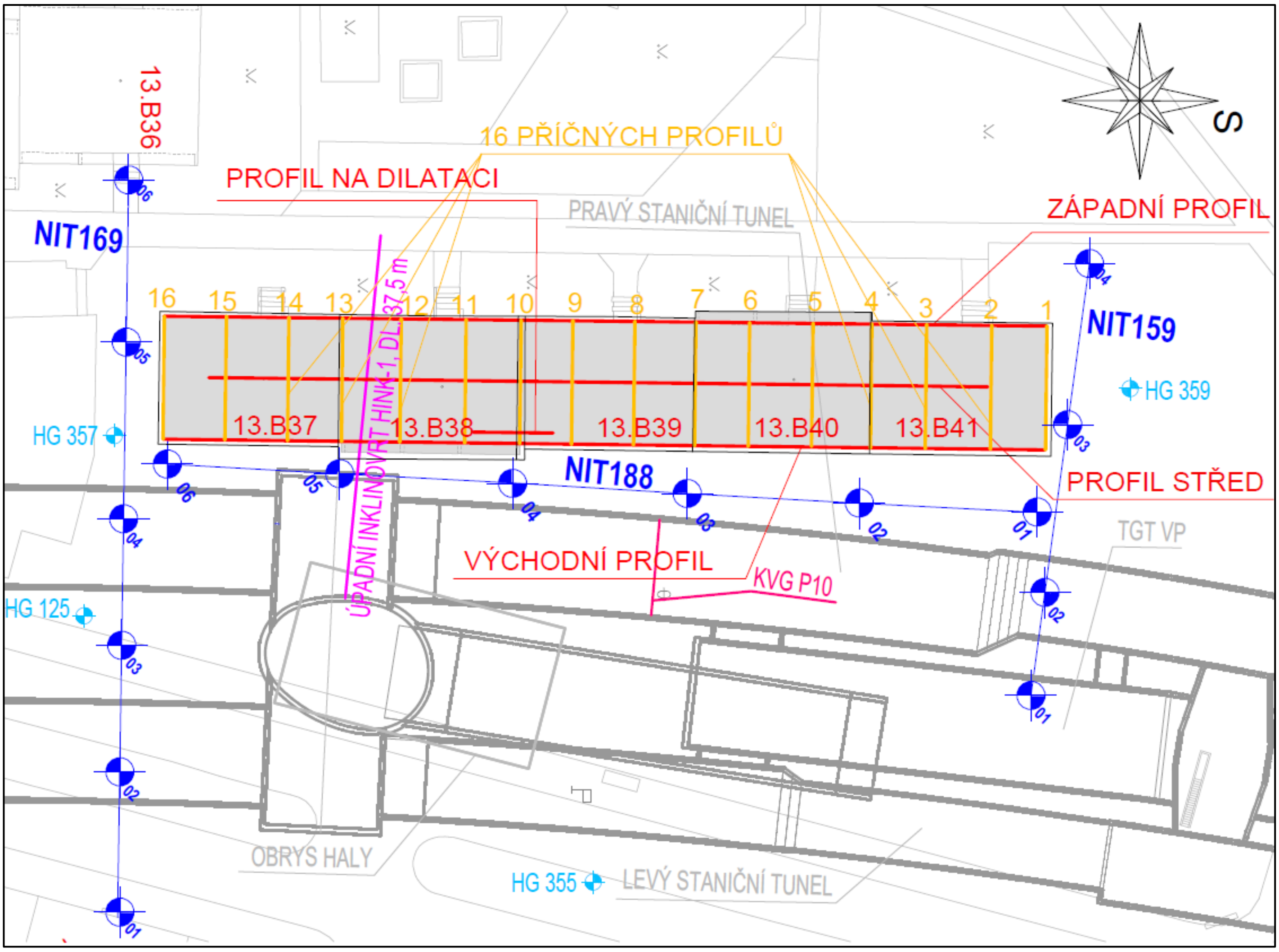

Figure 11: Overview of installed NIV profiles on BD Kovařovicova buildings (13.B37–13.B41)

A specific group of structures in the zone of influence consisted of the Kovařovicova apartment buildings (BD) (13.B37 to 13.B41), for which a slightly different course of deformation was recorded. These are prefabricated apartment buildings from the early 1970s with a single technical basement and eight above-ground floors, constructed using a system of large-format prefabricated panels. The load-bearing structure is hinged at each floor, with the joints between individual prefabricated components potentially serving as critical points. In this type of structural system, the failure of a single load-bearing element can lead to a chain reaction failure of part of the structure, known as progressive collapse, resulting in the partial or even complete collapse of the building (see cases from England or France). These structural systems are therefore particularly sensitive to uneven settlement of the foundations, which can occur as a result of underground construction activities. For this reason, extensive geotechnical monitoring instrumentation was installed in the buildings and their immediate surroundings, and very strict warning thresholds were set for both uniform and uneven settlement of the structure.

During the final phase, the structures were monitored using foundation levelling both externally and internally, trigonometric measurements, and a system of deformmeters and tiltmeters operating in automatic mode using ASD sensors. Simultaneously, ground subsidence was monitored near the structures along two cross-sections (NIT 169 and NIT 159) and one longitudinal section (NIT 188). To monitor deformations in the subsoil, a sub horizontal inclinometer borehole was additionally installed from the northern connecting tunnel (Figure 11).

### 4.3. RESULTS

In general, it can be stated that the development of deformations in the excavation (primary lining), particularly in terms of convergence measurements, was favourable. Both vertical and transverse deformations stabilized below the specified warning state (WS) criteria in most cases. Only a few profiles exceeded WS 1, for example, the KVG P10 profile, whose location is shown in Figure 11.

The results of monitoring at BD Kovařovicovo indicate that foundation deformations remained within favourable values for most of the time, despite the very strictly defined limits for settlement (A = 10 mm) and for uneven settlement (A = 1:1667). These limits were established based on an expert assessment to determine permissible values for deformation characteristics and correspond to Grade 2—a milder failure with minor damage, in which the safety of the structure is not compromised, but limited defects may occur. Warning thresholds were exceeded in some localized areas. To keep deformations below the specified limits, compensatory pressure grouting with organic-mineral resins was performed from underground toward the BD Kovařovicova buildings during construction. The first series took place between November and December 2023, followed by the most extensive phase in March 2024, supplemented by ongoing grouting operations on a smaller scale during continuous excavation. Further grouting was also carried out in February 2025 and at the turn of April and May 2025.

This repeatedly led to an improvement in deformation trends and to a partial uplift of the structures. As excavation of the station and escalator tunnels continued, further gradual deformations occurred, which is an expected phenomenon in underground construction in soft, plastic rock. Following individual grouting stages, local ground uplift of several millimetres was recorded, followed by gradual stabilization.

A robust network of ASD sensors was also used for proper grouting control. Automatic measurements with hourly or ten-minute reading intervals allowed for monitoring and rapid evaluation of the structures' responses to the grouting operations (both ongoing and compensatory) and for the real-time control of both volume and pressure. ASD sensors were also used to monitor the structure's response to external conditions, such as temperature changes or wind loads.

An innovative aspect of the monitoring was the integration of standard geodetic methods with automated systems, particularly tiltmeters, which allow for continuous monitoring of the structure's behaviour. Data from these devices are used to evaluate uneven settlement between individual geodetic measurements, and based on this data, so-called settlement lines can be created, which are subsequently compared with geodetic results and allow for monitoring the structural response of buildings in near real-time during significant underground construction activities, including the presentation of results in the form of animated graphs. These are available to construction participants responsible for the safe execution of excavation work affecting surrounding structures.

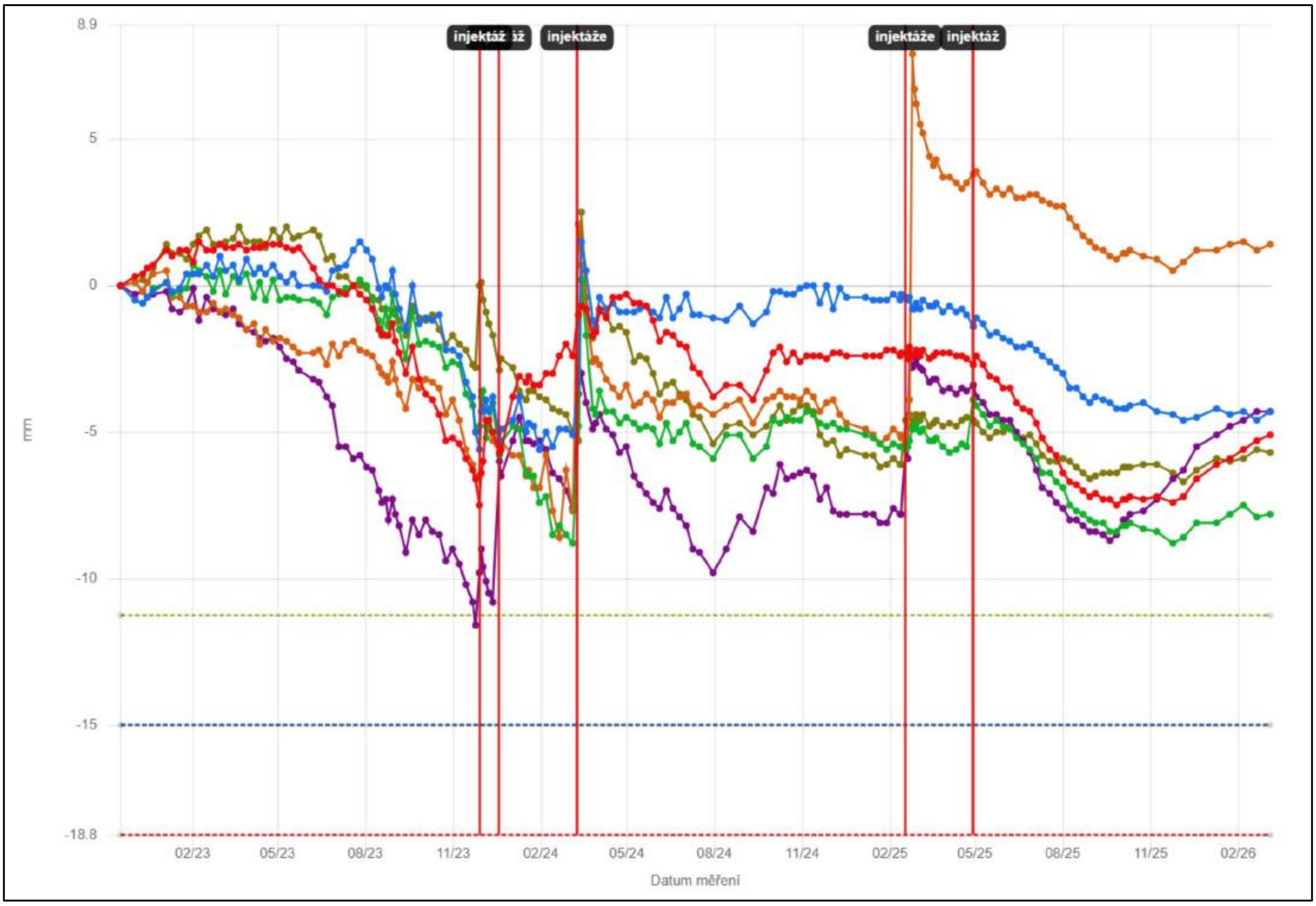

Figure 1: Development of lateral displacement (settlement) in the NIT 188 profile, showing the locations of compensatory pressure grouting

### 4.4. EVALUATION

The current evaluation of all monitored parameters following the completion of the excavation work indicates that the deformation of the BD Kovařovicova structures is gradually stabilizing. However, monitoring of the structures continues, albeit with a reduced number of monitoring points and adjusted measurement intervals, considering the ongoing finishing work on the secondary lining. The results of the evaluation of uneven settlement are also favourable in this regard, as they do not indicate the occurrence of adverse deformations or negative impacts on the structure of the building.

## 5. EXPERIENCE WITH THE IMPLEMENTATION OF 3D TECHNOLOGIES

From the very beginning, the future Olbrachtova station has had access to advanced tools for flexibly managing the project’s spatial coordination and the situation on-site. At the same time, these technologies make it possible to comprehensively document the actual construction progress without unnecessary downtime. This information is centralized in a shared internal data environment, allowing comments to be recorded and shared in one place.

Over the past decade, UAVs (Unmanned Aerial Vehicles), such as drones, have become a readily available means of data collection on construction sites. Periodic aerial photography, point cloud generation, and orthophoto mapping are conducted at the OL1 and OL2 construction sites. Strict measures must be followed when flying UAVs in densely populated areas. The benefits of aerial photography are not immediate; they become apparent only over a longer period of time. By the end of 2025, 43 surveying phases were available. This method provides a simple way to maintain an overview of the construction’s progress and document its various stages. Terrestrial laser scanning is a widely used method for transferring information to the construction’s “digital twin.” From the very beginning of the project, it ensures an accurate record of reality, whether as a basis for measuring the amount of work performed or as a representation of the work completed. Continuously updated spatial data enables faster decision-making processes for project management, allows for determining any actual dimension, and enables comparison with the designed state (model—see Figure 12).

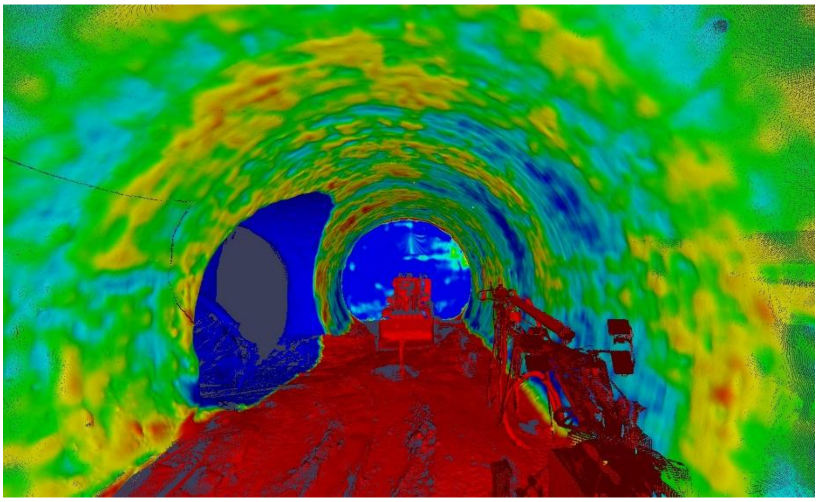

Figure 12: 3D tour of the right station tunnel with a color comparison of the existing lining and the designed condition; the color indicates the extent of the deviation

Combining this data helps refine calculations of the volumes of planned concrete work, as was the case, for example, in the station's south vestibule. The reinforced concrete bracing wall at the portal entrance was poured into single-sided formwork that formed the face of the concrete structure. The back side of the concrete structure was very complexly shaped using piles, shotcrete, tie rods, stiffening beams, and other elements of the pit shoring. Furthermore, the pit shoring underwent changes during construction compared to the design documentation. The modelled structure consisted of the designed face; the back was based on the actual survey of the wall prior to formwork installation (Figure 13).

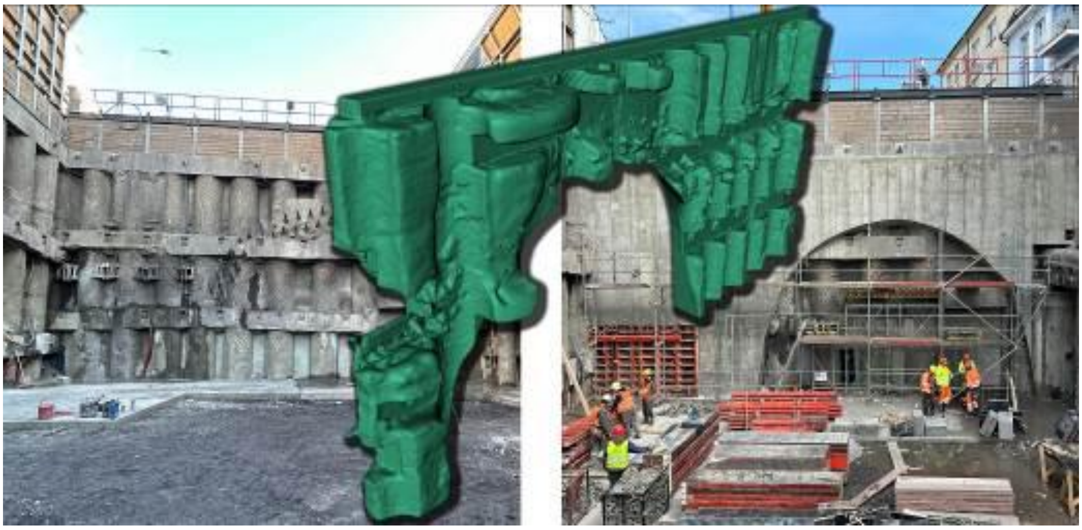

Figure 13: Front wall of the south escalator tunnel – before concrete pouring, structural model, and after concrete pouring

Thus, before the actual concrete pouring of the entire 9-meter-high wall, its exact volume was known, and it differed significantly from the design estimate. This prevented unplanned work extensions into the late hours of the night. Similarly, this method is beginning to be used for the calculation and planning of concrete pours for individual blocks of the secondary lining in station and escalator tunnels. The advantages of this method are particularly evident in complex intersections, where comparing and calculating the exact volume is more complicated than in a straight section of the tunnel (Figure 12).

## 6. VALUATION OF CONSTRUCTION EXPERIENCE

After four years of construction, the excavation work for the station and the escalator tunnels has been successfully completed. The reinforced concrete structures of the south concourse have also been completed. The secondary lining of the service tunnel, the north connecting passage, and the north escalator tunnel remains to be completed. As evident from the list of work completed so far at the

Olbrachtova station, this is a complex engineering project that requires a high level of expertise and innovative approaches from all construction participants. Thanks to the good cooperation of all construction participants, even four years after the start of the project, work is still proceeding according to schedule.

Perhaps even more important is the impact of such a complex structure on its surroundings. Measurement results generally confirmed the favourable behaviour of both the rock mass and the structures, with deformations mostly remaining below warning thresholds. This outcome was the result of a construction procedure appropriately designed by the engineer, its strict adherence by the contractor, and high-quality engineering and design preparation. Close cooperation among all construction participants also played a significant role, with geotechnical monitoring serving as one of their key management tools. This monitoring was conducted continuously throughout the entire construction period and allowed for a flexible response to the behaviour of the rock mass, to any deformations of the monitored structures (both above and below ground), or to noise levels in the area. This approach was one of the fundamental prerequisites for the successful completion of the entire project.

## LITERATURE

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