BARRIER-FREE ACCESS TO THE JIŘÍHO Z PODĚBRAD METRO STATION – IMPLEMENTATION OF A TECHNICALLY DEMANDING UNDERGROUND WORKS IN THE CITY INTRAVILAN

J. Panuška & P. Velička
STRABAG a.s.

ABSTRACT: The project to make the Jiřího z Poděbrad metro station a barrier-free accessible is an exceptionally challenging underground construction project carried out in a densely built-up urban environment. The new underground spaces include a pair of lift and escape shafts connected by a 72 m long transfer corridor that opens into the central hall of the existing station. The new structures are located in close proximity to existing track tunnels and close to an important building – the Church of the Sacred Heart of Jesus.

The excavation was carried out using the New Austrian Tunnelling Method (NATM) in Ordovician shales with varying degrees of weathering and local tectonic faults. Limited space and the requirement to minimise vibrations led to the use of predominantly mechanised rock breaking, with blasting work kept to a minimum. The excavated material was removed using a crane and mining containers without the possibility of intermediate dumpsite.

The primary lining consisted of sprayed shotcrete with steel mesh, supplemented with bolt reinforcement. The secondary lining was monolithic concrete. The design of the structures was optimised on the basis of finite element calculations, including 3D models, which made it possible to assess the interaction of the new structures with the existing metro tunnels.

The implementation took place under continuous geotechnical monitoring with passportisation of surrounding structures and strict deformation limits.

The article will present in detail the restrictions on the construction site area and the relationship to the surrounding existing structures. It will also describe the excavation process, the waterproofing and the performance of the complex final lining. The connection to the operating station, the geotechnical monitoring system and the evaluation of the deformations achieved in the context of the limit values set by the designer will also be discussed.

1. INTRODUCTION

Barrier-free access to underground metro stations is one of the most technically demanding forms of additional interventions in existing underground structures in an urban environment. These projects are characterised by a combination of new built structures intersecting with operational parts of the metro, with the need to respect strict deformation and dynamic limits, while at the same time minimising the impact of construction on surrounding buildings, utilities and public spaces. In such cases, the contractor faces not only technical challenges, but also to organisational and coordination matters.

The Jiřího z Poděbrad metro station on line A of the Prague metro was put into operation in 1980 as a deep-level, three-valut station with a single exit to the vestibule level. As part of its first comprehensive reconstruction carried out by Strabag a.s. and AŽD Praha s.r.o., the investor decided to build a new barrier-free access to connect the street level with the station platform using a system of lifts and transfer corridors, including an emergency stairs. The implementation of this solution required complex excavation work in a densely populated part of the city near an operating metro station and the Church of the Most Sacred Heart of Our Lord, all within the busy Jiřího z Poděbrad Square in Prague.

The aim of this article is to provide a comprehensive overview of the implementation of the excavated parts of this project from the contractor's perspective. Focus is made on the specifics of construction in a densely urbanised environment, the influence of the geological conditions on the project design, and the experience gained from the implementation of the excavated part and the execution of secondary lining and waterproofing. Last but not least, the text also deals with the final fitting out of the structure with internal structures and technological equipment.

2. DESCRIPTION OF THE CONSTRUCTION SITE

The construction of barrier-free access to the Jiřího z Poděbrad metro station is located in the central part of Prague 3 – Vinohrady, under the landscaped area of the square of the same name. The area is characterised by heavy traffic, high pedestrian traffic, number of buildings and the associated high concentration of utility networks. In addition to its transport function, the public space of the square also plays an important social and recreational role, which placed high demands on the organisation of the construction and, above all, on minimising restrictions for the public. This was also reflected in the small size of the construction site.

The dominant feature of the site is the Church of the Sacred Heart of Jesus, a national cultural wealth. The location of the excavated section of the barrier-free access is a short distance from the church foundations, with the most critical section located directly under the 42-metre-high church tower. This fact, among others, had a fundamental influence on the design of the technological procedures, the choice of rock breaking methods and the setting of strict deformation limits.

Further significant restrictions were imposed by the proximity of an operational underground station and the excavation itself in the closeness of railway tunnels with operating train traffic.

3. PASSPORTISATION AND GEOTECHNICAL MONITORING

Before the start of construction work, a detailed passportisation of the affected structures was carried out, which included not only the Church of the Sacred Heart of Jesus, but also the metro station structure, the sewers, the surface terrain and selected above-ground structures in the zone of potential impact. The passportisation was followed by expert rewievs focused on determining the permissible deformation and dynamic limits of individual structures.

Geotechnical monitoring began well in advance of the start of excavation and continued throughout the construction period. The monitoring mainly included monitoring ground settlement, measuring deformations of surrounding structures, convergence of the primary lining, measuring stress in steel suport frames and measuring the dynamic effects of blasting. All measured values were continuously evaluated and compared with the limit values specified in the project design.

The results of monitoring and the activities of the Monitoring Council served as a key tool for direct construction management. When trends approaching limit values were recorded, the excavation technology, the length of the excavation sections and their securing were adjusted on an ad hoc basis, or the parameters of the blasting work were corrected. This approach proved to be essential for the safe management of excavations in a sensitive urban environment.

4. BARRIER-FREE ACCESS CONSTRUCTION SOLUTION

Barrier-free access is designed as a system of excavated sections connecting the street level with the station platform at a depth of 45 m below ground.

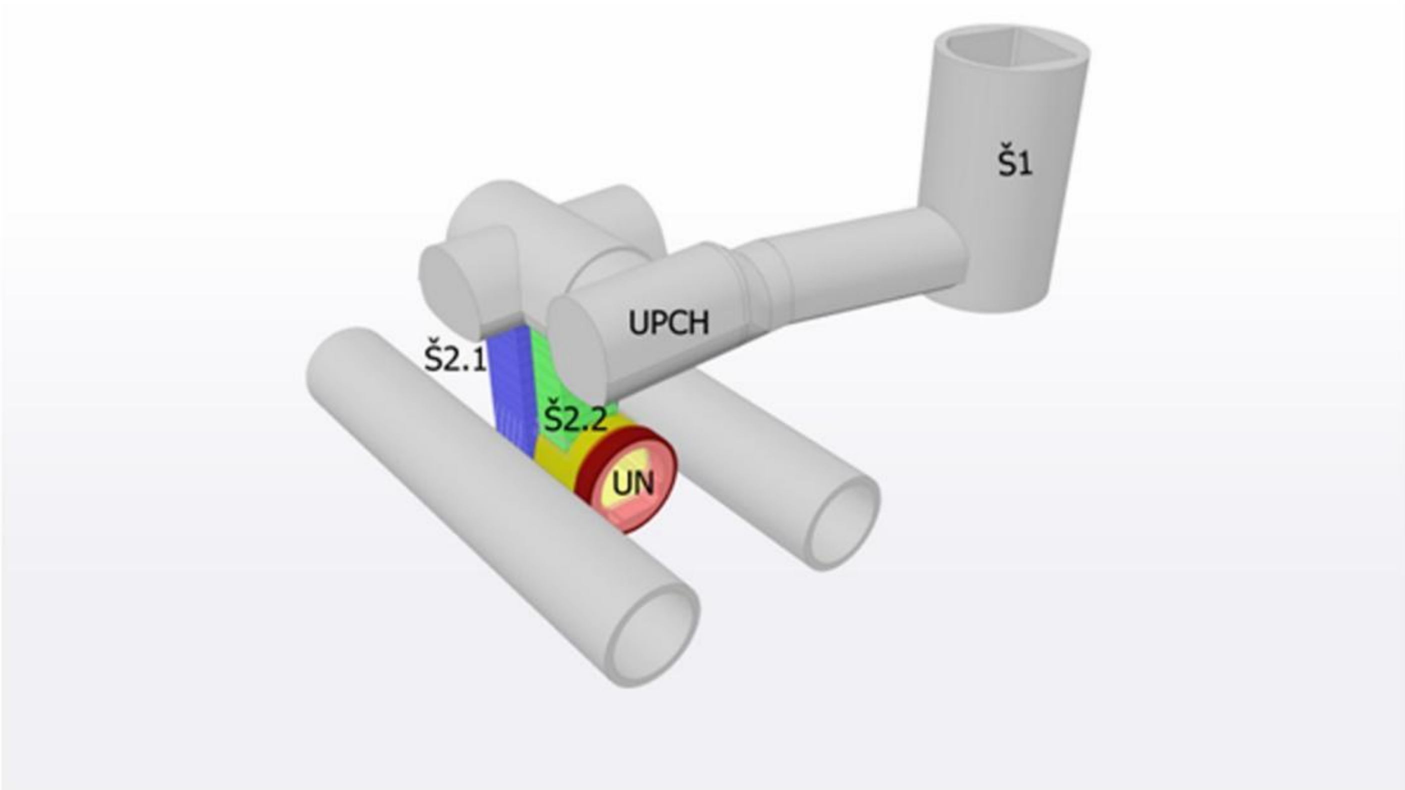

Figure 1: 3D model of the excavated part of barrier-free access

The initial part is an open construction pit for the subsurface entrance structure with a connecting circular excavated shaft Š1. This vertical shaft is followed by a horizontal transfer corridor UPCH, which connects the first stage of the structure with a pair of deeply laid shafts Š2.1 and Š2.2. These shafts overcome the height difference between the UPCH transfer corridor and the station platform level. A horizontal passageway UN is excavated from the larger staircase shaft Š2.1, which connects the entire newly constructed structure to the existing central platform of the metro station.

5. GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS

The geological conditions of the area are characterised by folded rocks of the north-eastern part of the Ordovician Barrandian syncline, mainly Letná shales with varying degrees of weathering and local inserts of quartz sandstones. The rock massif is significantly tectonically disturbed, with local fault zones filled with clayey material.

During construction, a supplementary geotechnical survey confirmed zones of increased disruption of the rock mass, particularly in the sensitive area between the metro station tubes and near the church building. This situation had a direct impact on the design of the primary lining of individual excavations and on the choice of technological procedures and measures during excavation.

The hydrogeological conditions were described relatively favourable, with no significant groundwater inflows. Nevertheless, it was necessary to take into account the predicted local waterlogging of the fissure system. The drainage effect of the existing underground metro structures probably had a positive impact, as their gradient allows groundwater to migrate along their route, thus significantly draining the area of interest.

6. CONSTRUCTION OF THE EXCAVATED PARTS OF THE PROJECT

The excavated parts of the barrier-free access were implemented using the NATM. The excavation procedure, the length of individual cuts, the securing of the excavation and the method of rock breaking continuously responded to the geological conditions encountered and to the proximity of surrounding above-ground and underground structures, in particular the operational metro tunnels and the church building.

The rock was broken up mainly mechanicaly by using hydraulic excavators with rock buckets and jackhammers. Due to the characteristics of the area, the use of blasting was limited to the minimum and was under strict seismic limits. These limiting factors were most important for the speed of the work. The rock was delivered to the surface using a wheeled crane and 6 m^3 containers, and in the lower part of the structure using an electric crane and a smaller container.

Figure 2: Extraction of rubble using a crane and a container

This method of extraction and other transport was used throughout the entire excavation period. The loaded containers were immediately transported from the surface to the final dump site without the need to set up an intermediate storage, which significantly improved the clean of public areas and reduced dust levels. The primary lining was carried out by wet shotcrete spraying.

The dynamic effects of the excavation were continuously monitored, and the measured values remained below the specified limits throughout the construction period, confirming the correctness of their design.

6.1 EXCAVATED PARTS OF THE STRUCTURE

The construction pit was constructed in two levels with a total depth of 13.9 m below ground level. The design was a combination of sheet piling and temporary anchors, at three levels. From its bottom, a circular excavated shaft Š1 with a diameter of 12.58 m and a depth of 21.66 m continued, which was excavated using a combination of mechanical rock breaking and blasting. The shaft and other subsequent parts of the structure were secured using welded steel mesh, truss frames, shotcrete and radial bolts.

The UPCH transfer corridor was excavated from shaft Š1, connecting shaft Š1 with a pair of deeper rectangular shafts Š2.1 and Š2.2. The total length of the transfer corridor, including cross-cuts, was 72.45 m, with the area of the cross-sections ranging from 45.6 m^2 to 63.3 m^2. The corridor was routed with a 90° right-hand bend before connecting to shafts Š2.1 and Š2.2. Horizontal excavation was carried out using a similar technology to that used for the excavation of shaft Š1, i.e. a combination of mechanical rock breaking and blasting, which, however, was only permitted in predefined sections of the work – primarily in order to prevent any possible impact on the existing metro tunnel structures (secured by segmental lining).

The pair of shafts Š2.1 and Š2.2 served to overcome the 21.6 m height difference between the transfer corridor and the station platform level. First, the larger stairwell Š2.1 with a profile of 58.6 m^2 was excavated, followed by the excavation of the lift shaft Š2.2 with a profile of 24.9 m^2.

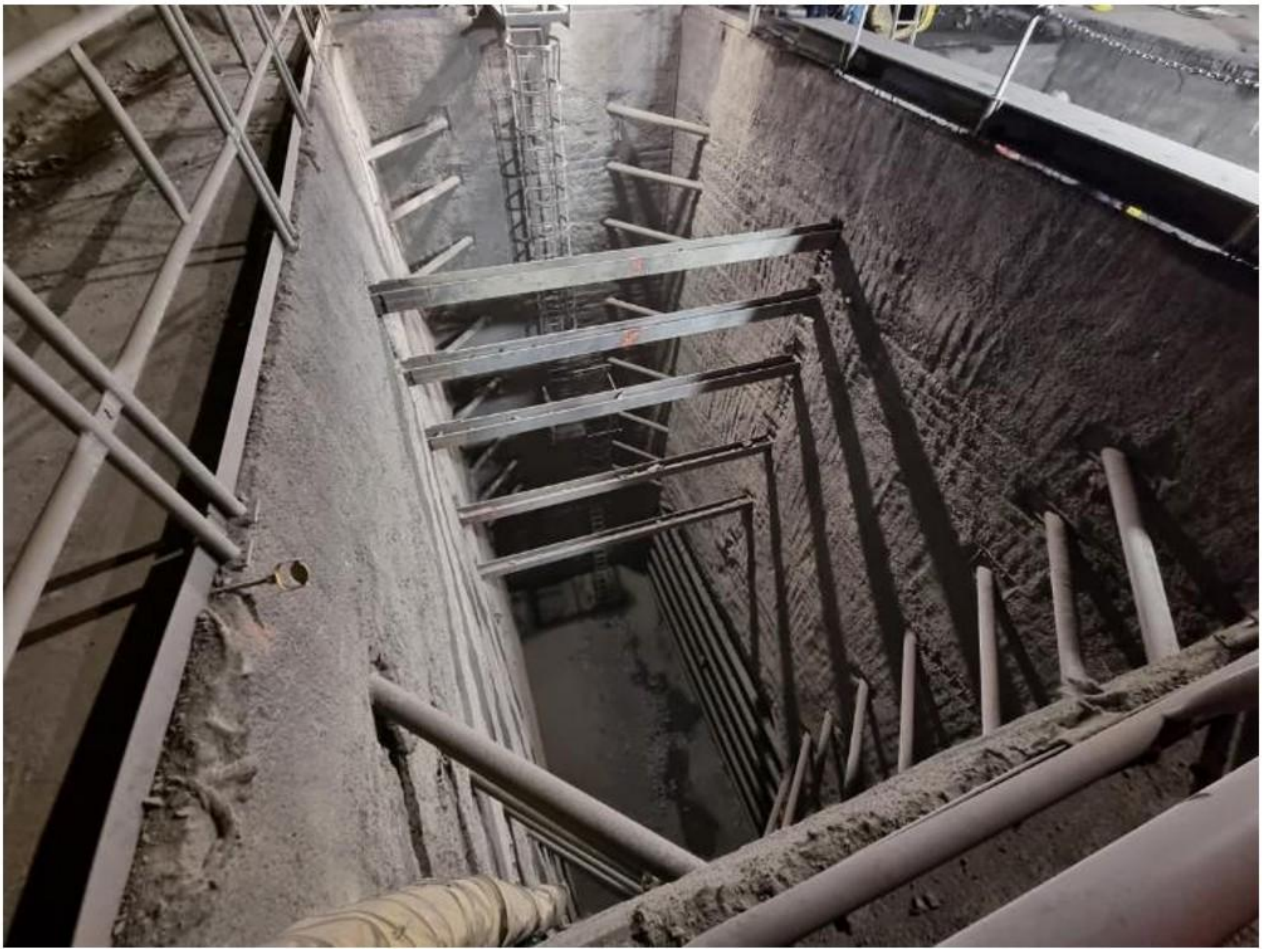

Figure 3: Lift shaft Š2.2

Due to the limited load capacity of the electric wheel crane located in the transfer corridor, a pit frame was first installed in both shafts and the smaller shaft was temporarily covered with a steel structure. Excavation was first carried out in the larger shaft.

Before the final phase of excavation, which connected the shaft area with the central existing platform of the station via the UN corridor, rock grouting was carried out from the station area in order to reinforce the entire area of the future breakthrough. This procedure was chosen based on the results of a supplementary geotechnical survey, which included core drilling from the planned breakthrough area on the station side. In the last section of the excavation, due to the limited load capacity of the crane located above shafts Š2.1 and Š2.2, smaller machinery was used, which significantly slowed down the progress of the work.

The actual connection to the central platform of the station did not consist of a classic hard breakthrough of the rock mass, but rather the sensitive demolition of a massive reinforced concrete wall that originally terminated the central station tunnel. In view of the requirement for the most gentle removal of this structure, especially given its connection to the existing tunel lining, a technology was chosen that combined partialy core drilling, subsequent cutting of the structure with a diamond wire and removal of the concrete blocks.

Figure 4: Cutting the reinforced concrete front wall with a diamond wire

7. MODIFICATIONS TO THE DESIGN BASED ON ADDITIONAL GEOLOGICAL SURVEYS

During the project performance, additional geotechnical surveys were carried out, particularly in the area between the metro station tubes and then in the immediate closenesst of the church. These surveys confirmed the existence of tectonically disturbed zones with worse RQD parameters than originally considered in the design. Based on these findings, Metroprojekt Praha a.s., the author of the design, had to propose modifications of geotechnical parameters in the calculation models and propose higher reinforce ratio of the primary lining in selected sections, especially in the area of the UPCH transfer corridor, shafts Š2.1 and Š2.2, and also of the connection to the central platform in UN. The design of the massive steel frames in the lower part of both shafts and their transition to the UN vertical corridor was also changed.

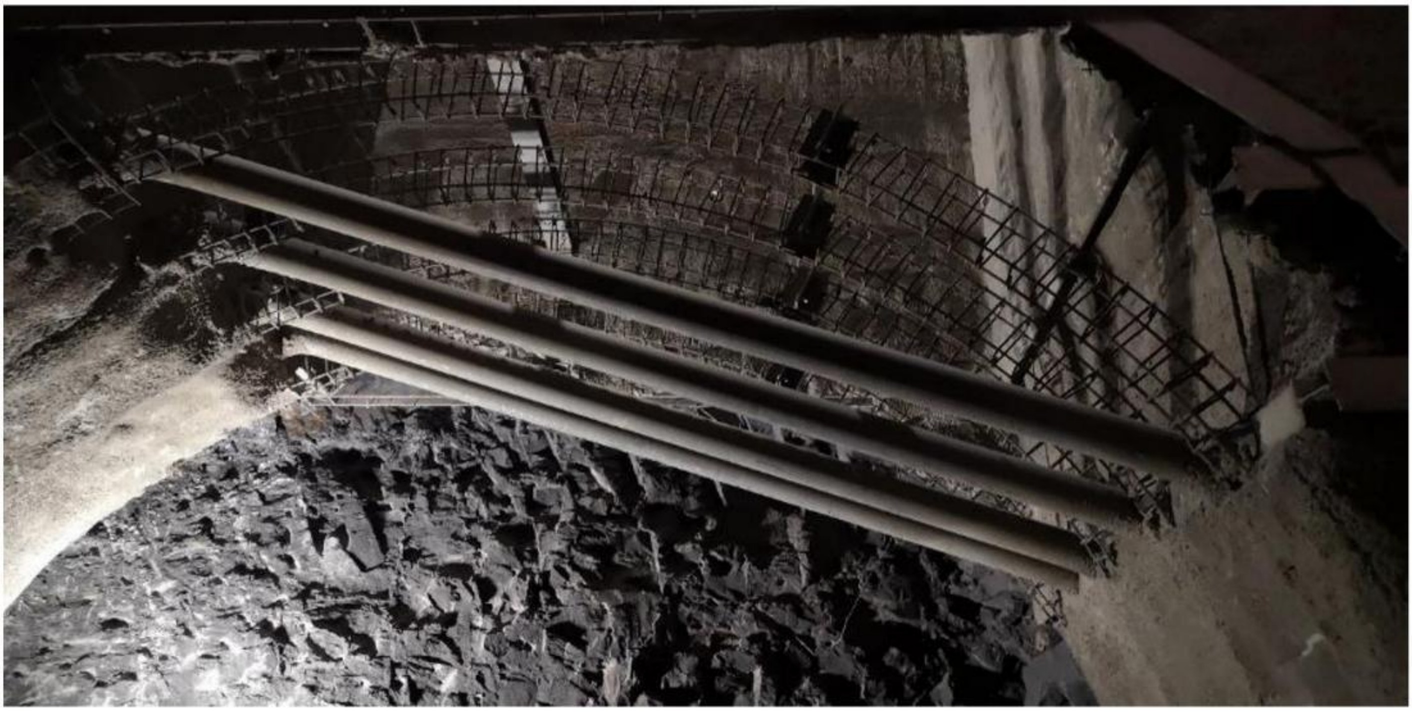

Figure 5: Spacers in the lower part of the shafts at platform level, transition to the vertical corridor

8. WATERPROOFING AND FINAL LINING

The design of the final lining together with the waterproofing system was a crucial phase of the project, in which the contractor had to plan in detail the individual steps, their sequence and technical implementation. Above all, it had to cope with the considerable complexity of the shape and layout of the work, i.e. the large number of different cross-sections and their interconnection, as well as the vertical division of the work into two levels (UPCH and UN). As with the excavation work, it was necessary to plan in detail the transport of individual materials to the site, especially vertical transport. Transport of materials within the existing metro route was not used. Especially for work positions in the lower parts of the structure, this involved a set of technical and logistical challenges associated with specific requirements for mechanisation and high demands for worker safety. For example, special lifting equipment was used to operate shafts Š2.1 and Š2.2, which were suitable for the size of the UPCH space and met the required load capacities.

Figure 6: Special lifting equipment for operating the shafts

Support structures and scaffolding for worker movement were implemented for the individual steps of waterproofing layer installation and concrete works. Due to the number of profiles, these were mostly unique support structures without repeated use.

8.1 WATERPROOFING SYSTEM

The barrier-free access structure was designed as a double-shell structure with an intermediate waterproofing layer located between the primary and secondary lining. A 3mm thick softened PVC membrane was used as the waterproofing layer, laid on a protective and separating geotextile (800 g/m^2). In places where the waterproofing was applied to the bottom of the profile, the foil was additionally protected from above by geotextile (500 g/m^2) and covered with a 100mm thick protective layer of C16/20 concrete. The waterproofing system was supplemented with a safety system of injection hoses, allowing for additional remediation of leaks if necessary.

Figure 7: Waterproofing system of the bottom with a protective layer of concrete

Special attention was given to the design and execution of details in areas of technological penetrations, expansion joints, connections between individual structural units and in the area of the pressure seal, where there was an increased risk of damage to the waterproofing layer. Given the complexity of the reinforcement and formwork, it was crucial to protect the waterproofing layer from mechanical damage during the installation of the reinforcement and formwork.

8.2 FINAL LINING

Close behind the application of waterproofing, the installation of steel reinforcement, formwork and concreting of the secondary lining took place, with the entire work divided into 31 concreting steps/parts progressing from the bottom of the station through the transfer corridor towards the surface.

The secondary lining was made of C30/37 concrete, with a designed reinforcement cover of 50 mm on both sides. Injection pipes with a diameter of 50-80 mm were installed in the vault of the transfer corridor for additional grouting possibility.

Working joints were designed both transverse and longitudinal, with or without continuous reinforcement. Expansion joints in the structure were designed with a thickness of 20 mm and fitted with an external joint strip with injection hoses.

Figure 8: External joint strip with injection hoses

Passive protection against stray currents was designed and implemented throughout the structure.

A 3.6-tonne pressure seal iron door was concreted in the transfer corridor, which will be used in the event of civil or military emergencies.

Figure 9: Preparation for concreting the pressure seal

This large steel panel had to be transported to the concreting site in one piece (frame + door) and concreted into the partition wall in the closed position to maintain perfect flatness and seating of all its parts. This is the only way to guarantee the flawless functionality and tightness of this important element of metro protection. This wall was also equiped by a battery of protective iron cabel tubes.

8.3 FORMWORK AND ITS IMPLEMENTATION

Due to the variable geometry of the individual parts of the structure, it was not possible to use a uniform formwork system. The contractor therefore combined standard system formwork elements with atypical formwork structures custom-made for individual profiles.

The formwork design was influenced not only by the required shape of the final lining, but also by the limited handling space and the requirements for the execution (working and expansion joints).

The implementation of formwork in a spatially limited structure, at considerable depths and with limited transport routes using "rope" transport, placed extraordinary demands on logistics and safety.

1. FINAL WORKS AND TECHNOLOGICAL EQUIPMENT

After the final lining, the next stage was to fit out the new spaces. This construction work included the installation of reinforced concrete fixtures, the assembly of prefabricated staircase arms fitted into the shafts using specially designed lifting equipment, the installation of partitions, the fitting of fire-resistant doors, the assembly of all visible structures for subsequent suspended ceilings, and the finishing of floors and walls.

Figure 10: Formwork elements for secondary lining

While work on the secondary lining was still in progress, the installation of internal staircase structures began from the bottom of the structure. The original design of monolithic staircase arms was changed, following a proposal by the contractor and assessment by the designer, to prefabricated components, which allowed for better coordination of work and reduced labour compared to reinforcing and formwork for the arms on site. This also increased the accuracy of the components. The installation of the arms was quite complicated, especially in the lower shaft (Š2). For this purpose, a special steel frame structure was made above the shaft, with the help of which the arms were lowered into the shaft continuously, taking into account the progress of concreting of the stair landing. After the installation of the arms was completed, the steel structure was dismantled and only then was the concreting of the secondary lining completed. After the individual arms were installed, the steel pressure door, which could not be transported and installed earlier for logistical reasons, was concreted in. Parallel to the installation of the staircase arms and the concreting of the landings, the internal structure – the lift shaft, which is surrounded by an escape staircase – was concreted in shaft Š1. This staircase was also constructed from prefabricated arms with monolithic landings made on site. Below ground level, a single-storey underground facility with technical facilities was concreted in the final phase, which opens to the surface through an escape staircase covered by a hydraulically operated hatch and a lift kiosk, as the upper station at street level for a pair of lifts.

Figure 11: Escape hatch after installation

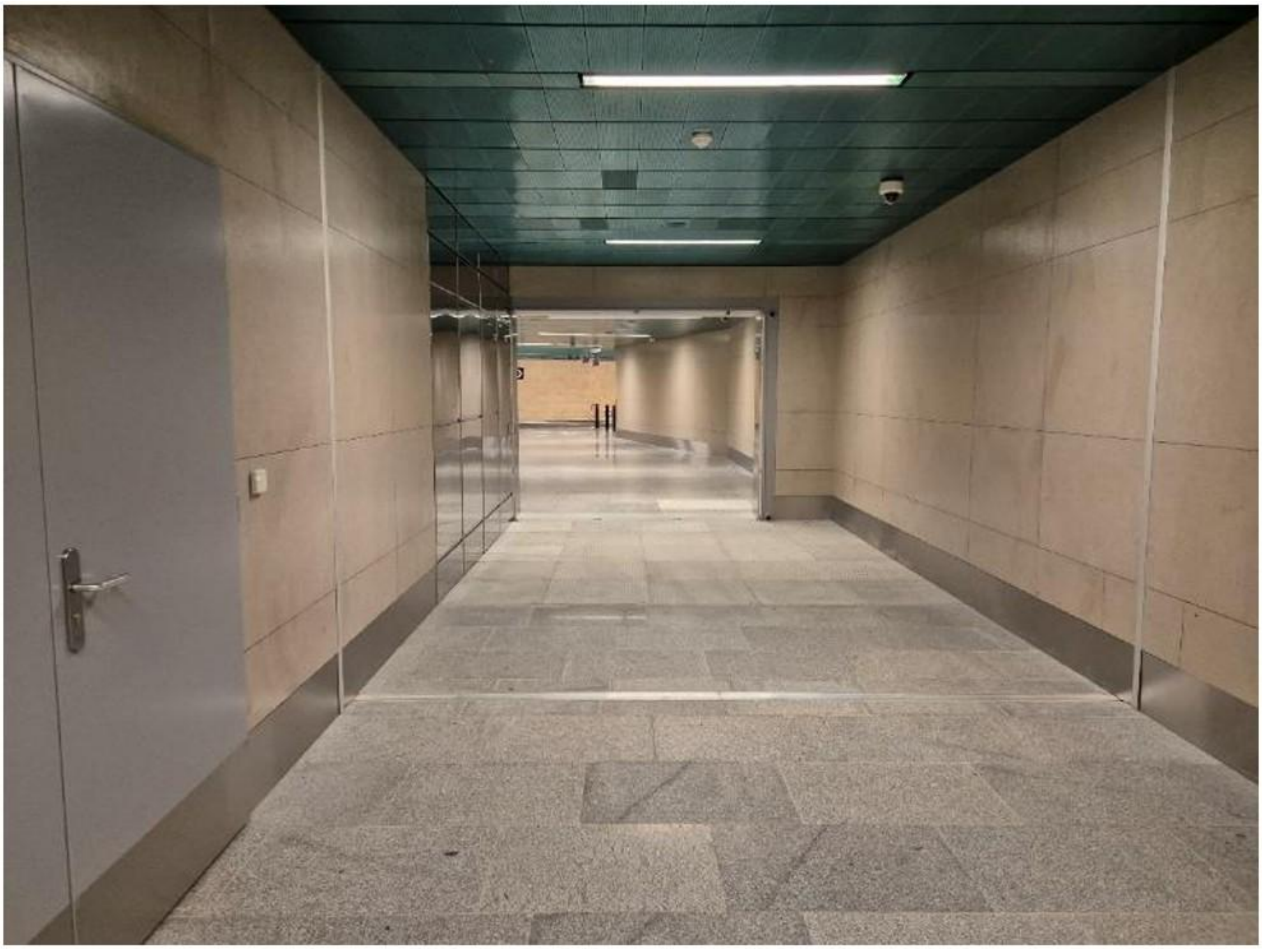

Figure 12: View of the completed barrier-free transfer corridor

The entire barrier-free access area was then completed with brick partitions, doors and supporting structures for visible elements. At the same time, cable routes and technological elements were installed, which are hidden under the final visible cladding.

This stage also included the installation of technological equipment, including high-voltage and low-voltage distribution systems, lighting systems, ventilation, dry water pipes, electronic fire alarms and security devices. Four lifts were also an important technological element of the work.

2. EXCAVATION OF THE SEWER

As part of the completion of the project, a sewer connection was constructed to drain the area in front of the lift kiosk, to collect rainwater from the perimeter of the escape hatch and to drain the underground structure under the kiosk. The sewer connection was constructed as a separate excavated tunnel connected to the main sewer running under Vinohradská Street with an underpass of the tram tracks. The excavated tunnel was 22.04 m long with an excavation area of 4.1 m^2 and was excavated from a 6.25 m deep working shaft secured with K21 steel mining reinforcement frames in combination with Union system driven shoring.

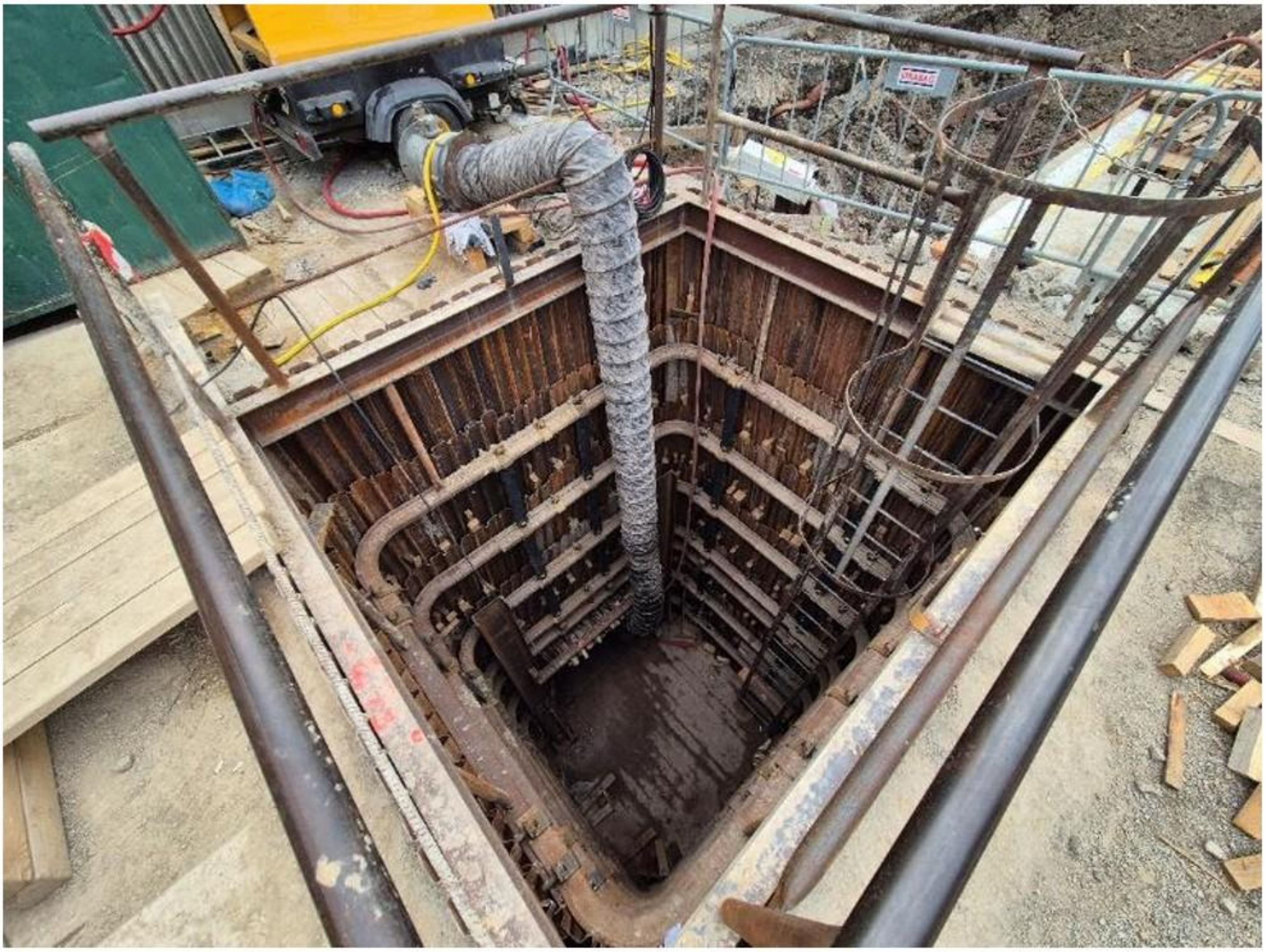

Figure 13: View into the shaft of the excavated sewer connection

The excavation took place in a downpipe with a 1.5% slope towards the main sewer, which allows for gravity drainage of the connected areas.

The primary securing of the tunnel was carried out using K21 steel frames, supplemented by Union driven piling and transverse thresholds made of U160 rolled steel profiles. After reaching the main sewer on the other side of Vinohradská Street, the new connection was connected to the existing brick sewer by installing a connecting insert. The excavated tunnel was then equipped with DN200 stoneware pipes.

The shaft was lined with prefabricated DN1000 reinforced concrete rings and fitted with a cast iron cover of the appropriate load class. After completion of the lining, the shaft and the excavated tunnel were filled with C16/20 concrete, thereby achieving definitive stabilisation of the structure and protection of the pipes.

3. CONCLUSION

The construction of barrier-free access to the Jiřího z Poděbrad metro station was an exceptionally demanding underground construction project carried out in the centre of the capital city. From the contractor's point of view, the biggest challenges were the limited space, the proximity of buildings and the need to carry out excavation work in close proximity to the operating transport infrastructure. The design of the technology for excavating individual profiles and the final lining required the use of specific techniques and construction methods. Another key area was the design of the logistics for the transport of materials, machinery and huge components, and the subsequent implementation of the technological part of the work. The contractor had to have a careful attention to these issues during the preparation and implementation of the project. Thanks to its inventiveness and close cooperation with the designer and client, the contractor successfully completed the project, the results of which will serve the public for many years to come.

Ing. Jan Panuška
Transport Engineering, TB Directorate
jan.panuska@strabag.com

Ing. Petr Velička
Transport Engineering, TB Directorate
petr.velicka@strabag.com

LITERATURE:

Underground Structures Prague 2023: Czech Tunnelling Association ITA-AITES, 2023 - BARRIER-FREE ACCESS TO THE JIŘÍHO Z PODĚBRAD STATION – EXPERIENCES FROM THE IMPLEMENTATION OF THE DRIVEN PART OF THE WORK, I. Gaja & J. Panuška, STRABAG a.s., Prague, Czech Republic, J. Korejčík, METROPROJEKT Praha a.s., Prague, Czech Republic

Silnice a Železnice 3/2024, Jiřího z Poděbrad Station has barrier-free access, Ing. Jan Panuška, Technical Manager, STRABAG a.s.

Tunnel Magazine, 34th year – No. 3/2025 – REVITALISATION OF THE JIŘÍHO Z PODĚBRAD METRO STATION AND CONSTRUCTION OF BARRIER-FREE ACCESS – CONTRACTOR'S EXPERIENCE, Petr Velička, Jan Panuška

Tunnel Magazine, 32nd year – No. 2/2023 – PROJECT FOR BARRIER-FREE ACCESS TO THE JIŘÍHO Z PODĚBRAD METRO STATION, Jan Korejčík, Zděnek Žižka, Michal Kolevski

Tunnel Magazine, 33rd year – No. 4/2024 – GEOTECHNICAL MONITORING DURING THE CONSTRUCTION OF BARRIER-FREE ACCESS TO THE JIŘÍHO Z PODĚBRAD METRO STATION, Martin Čermák, Barbora Pavelková, Radek Morávek