UTILISATION OF GEOTHERMAL ENERGY FROM TUNNELS WITH A FOCUS ON THE NOVÉ DVORY METRO D STATION

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ABSTRACT: The possibility of obtaining geothermal energy offers a new use for tunnels, which primarily serve only for transport purposes. This not only increases the economic value of these structures, but also, in the case of tunnels in urban areas, their acceptability among residents. The tunnel is then perceived less as a necessary burden and more as a valuable energy source for its surroundings.

Given that this is an emission-free and geopolitically independent source of energy, major investors in transport infrastructure in the Czech Republic are also beginning to take an interest in the possibility of obtaining geothermal energy from tunnels. The authors of the article have so far produced two studies on this topic: a study on the use of geothermal energy from tunnels and stations on the new metro line D in Prague and a study on the use of geothermal energy for planned road and motorway tunnels by the Czech Road and Motorway Directorate (ŘSD - Ředitelství silnic a dálnic).

The first study was commissioned by the Prague Public Transport Company (DPP - Dopravní podnik hl. m. Prahy) with the aim of examining the possibilities of obtaining geothermal energy on the future Metro line D. The study examined metro stations and inter-station track tunnels. Technical solutions for capturing geothermal energy were proposed for individual types of structures and the possible energy gain was calculated. The results of the study were presented and positively received by the Prague City Council. Based on these results, the single-hall Nové Dvory station was selected for the pilot installation of the geothermal system.

The reason for this decision was the favourable situation in this location, with the presence of three municipal companies that meet the conditions of the provider, processor and consumer of geothermal energy. The source will be provided by DPP, heat and cooling will be supplied by Pražská plynárenská, or rather its subsidiary Teplo pro Prahu, and the developer of the new urban district above the station will be Pražská developerská společnost.

From a technical point of view, the single-hall Nové Dvory station is one of the most complex on line D in terms of geothermal system integration. It is expected that the main aisle of the station, the technological tunnels, the sidings and the segmental lining of the adjacent track tunnels will be used for energy purposes. The requirement to install a geothermal system will be part of the tender documentation for the construction of the station as a pilot project for the first use of this technology in the Czech Republic.

1. GEOTHERMAL ENERGY FROM UNDERGROUND STRUCTURES

The use of geothermal energy for heating and cooling buildings using ground-water heat pumps has been successfully applied for several decades, both in small-scale projects – family houses and villas – and in larger buildings and complexes – office buildings, apartment buildings, schools, etc. This technology is finding increasing application, especially in larger buildings with combined heating and cooling requirements. The use of geothermal energy is less common in tunnel construction, but there are dozens of applications abroad where this technology has already been used and is operating successfully. However, this technology has not yet been used in tunnels in the Czech Republic, even though it offers a number of advantages. Its deployment is supported by efforts to use renewable resources, climate change and the current geopolitical situation.

1.1 ADVANTAGES OF GEOTHERMAL ENERGY

The technology of extracting geothermal energy from tunnels, or more generally from building structures in contact with rock massif, can significantly reduce the cost of constructing geothermal facilities. Thermally activated structures, which in the case of underground structures include the lining of excavated tunnels, foundation slabs and underground walls of excavated track sections and stations, or bored piles for the purpose of ensuring the stability of construction pits or deep foundations, are necessary for structural reasons and can also be used as structures for extracting geothermal energy or storing residual heat generated by air conditioning buildings in the summer months. In this way, it is possible to create incomparably larger areas for energy extraction and storage at a relatively low cost compared to expensive geothermal drilling.

Compared to other renewable energy sources, such as solar and wind energy, geothermal energy is not dependent on weather or season and can therefore complement these sources well. Underground structures are usually located so deep below the surface that their temperature influence on surface conditions is practically negligible.

The development of current European legislation, which is reflected in the legislative requirements of the Czech Republic, clearly points in the direction of decarbonisation – i.e. the continuous reduction of emissions produced by the operation of buildings. The new Energy Performance of Buildings Directive (EPBD IV) even stipulates the requirement for zero emissions in all new buildings from 2028 (public sector) and 2030 (all others). From this perspective, it is a "trendy" source that is also geopolitically independent, sustainable for many decades and capable of supplying stable energy despite the interests of hostile powers and fluctuations in energy prices.

Other advantages of this technology include:

- architectural "invisibility"; the primary source is literally hidden in the structure, subsoil, boreholes, etc., unlike photovoltaic or wind farms and systems, which are often not viewed very positively by the public
- the primary source does not produce any noise, light, infrasound, etc., again unlike the above-mentioned renewable energy sources
- the primary source is used for both heating and cooling and can also be connected to a so-called cold network, i.e. an energy sharing system
- The service life of this source is in the order of 100+ years, similar to the tunnel lining structure itself.
- The system is mechanically very simple, with low maintenance and operating costs.

Last but not least, the installation of geothermal equipment in underground structures can improve their media image and positively influence public opinion, which is usually negative towards the construction of transport structures. Municipalities in the overburden of the tunnel can obtain a stable source of clean energy that is relatively independent of fluctuations in electricity or gas prices and thus benefit from the existence of the tunnel in the long term.

Given the advantages described above, major transport infrastructure investors in the Czech Republic are also beginning to take an interest in the use of geothermal energy from underground structures. Specifically, these include the Road and Motorway Directorate (ŘSD - Ředitelství silnic a dálnic), which commissioned a technical and economic study on the use of geothermal energy from the ŘSD's road and motorway tunnels, and the Prague Public Transport Company (DPP - Dopravní podnik hl. m. Prahy), which commissioned a study on the use of geothermal energy from the tunnels and stations of the new metro line D. These studies are described in the following chapters. (Chapters 2-3)

1.2 PRIMARY CIRCUIT OF THE HEAT PUMP IN THE TUNNEL

The primary circuit in the tunnel consists of a system of pipes for conducting the medium integrated directly into the building structures that are in contact with the surrounding rock massif and a system of distributors and collectors that ensures the hydraulic connection of the individual circuits to the backbone piping and the circulation of the medium in the system. Its significance lies in the thermal activation of the structure and the rock mass with which it is in contact, which allows the capture of low-potential energy. Within the entire geothermal system, the primary circuit functions as a heat exchanger, where the circulating heat transfer fluid (water or antifreeze mixture) extracts heat from the ground in winter or stores it there in summer. In this way, the thermodynamic inertia of underground structures and rock mass can be used to create a "ground accumulator" and effectively heat or cool buildings above the tunnel or technological facilities used to operate the tunnel.

The construction and location of the primary circuit varies depending on the tunnelling method used. Geothermal energy can be obtained from cyclically or continuously excavated tunnels, as well as from excavated cut and cover sections of tunnels or stations. The technical solution must be adapted to the specific tunnelling method and construction procedure. It is necessary to take into account the method of ensuring the watertightness of the structure. If watertight lining with sealing of the working joints between the concrete blocks is used in conventionally excavated tunnels, then the pipes can be fixed to the primary lining. When using a waterproofing membrane, the pipes must usually be placed in the secondary lining. The design of the geothermal system should ensure that the primary circuit does not pass through the waterproofing membrane, which would increase the risk of leaks at the penetration points. Although it is technically and systemically possible to resolve penetrations of the waterproofing membrane, this would significantly complicate and increase the cost of the entire installation.

At the same time, it is necessary to take into account that the installation of geothermal system components should have as little impact as possible on the construction schedule and the complexity of the tunnel itself. The extension of the construction period should be minimal. Therefore, in other countries, tunnels without waterproofing membranes often use so-called energy absorbers with pipes fixed to geotextiles, which allow for quick surface installation with the absorber fixed directly to the primary lining.

The individual absorption loops of the primary circuit are always connected to distributors and collectors, which regulate the flow of the heat transfer fluid. These components can be located in niches directly in the tunnel lining or led out to system shafts or technological spaces outside the main tunnel tube, which greatly facilitates maintenance and inspection of the system. From these locations, the fluid is then fed through the backbone piping to the heat pump itself using circulation pumps.

2. GEOTHERMAL ENERGY FROM ROAD AND MOTORWAY TUNNELS IN THE CZECH REPUBLIC

As part of a technical and economic study on the use of geothermal energy from tunnels managed by the Czech Road and Motorway Directorate (ŘSD) , the possibilities of installing the primary circuit in the lining or other structures of cut-and-cover or bored tunnels were investigated. The aim was to use two specific examples, the Suchdol cut-and-cover tunnel on section 518 Ruzyně – Suchdol on the Prague ring road and the Luka bored motorway tunnel on the D3 motorway, to demonstrate the possibilities of a technical solution for the primary circuit and energy utilisation, including an economic assessment.

The Suchdol Tunnel, with a length of 1,970 m, is designed as a directionally divided, twin-tube tunnel with three lanes and a hard shoulder in each tunnel tube with a clear width of 17 m. Between the tunnel tubes is a central tunnel serving as a ventilation duct, collector and space for sewerage. The total width of the ceiling slab is 43.55 m, making it the widest tunnel in the Czech Republic. The tunnel passes through the area between the built-up areas of Starý Suchdol and Nový Suchdol, and due to its proximity to the surrounding buildings in the overburden, it can be considered an urban tunnel. The supporting structure of the tunnel includes large-diameter piles, which form the shoring of the construction pit and, together with the concrete side wall of the tunnel, ensure the static function of the tunnel structure. For geothermal activation of the lining, a foundation slab under the tunnel tubes, large-diameter piles and a ceiling slab are being considered. The pipes for conducting the medium are not concreted into the supporting structures. Similarly, the shafts for the distribution/collection manifolds do not interfere with the tunnel structures, so the geothermal system does not restrict the operation of the tunnel in any way and minimises the negative impact on the construction schedule. When the tunnel structures with a length of approx. 1,800 m are activated, the absorbers located in large-diameter piles can be expected to supply approx. 1,900 MWh of heat and 1,200 MWh of cooling per year. The calculated theoretical annual gain from the foundation slab is approximately 2,200 MWh of heat and 1,400 MWh of cooling. When activating the ceiling slab lying relatively shallow below the ground, a conservative energy yield value of 13 W/m^{2}and a possible supply of 3,000 MWh of heat per year were considered. A prerequisite for the use of geothermal energy from the Suchdol tunnel for buildings above ground is the construction of the relevant infrastructure, which, compared to the permanent use of geothermal energy, is largely a one-off initial investment.

The Luka Tunnel is designed as a dual-tube, directionally divided tunnel with a length of 1,843 m and a width category of T 9.5/100 on the D3 Jílové - Hostěradice motorway section. Over a length of 1,500 m, the tunnel is bored in an igneous rock environment with overburden of up to 50 m using NATM, while the portal sections are cut and covered. The tunnel is located outside the built-up area. Apart from the operational and technological building, there are no other buildings in its vicinity where the geothermal energy obtained could be used. The tunnel's waterproofing system is designed as an umbrella system with gravity drainage of groundwater to the portals. For the purposes of the model example, it was proposed to use both the cut-and-cover and bored sections of the tunnel near the portals, with the energy obtained being used only for the operation of the tunnel.

The first section is a cut-and-cover tunnel at the Prague portal, where the pipes will be attached to the outside of the vault lining and covered with backfill. The geothermal system pipes are connected from individual circuits to distribution and collection manifolds in system shafts and backbone pipes to the heat pump. The excavated section of the tunnel at the Prague portal is 370 m long. Due to the greater cooling of the areas near the portal, the first approx. 25 to 30 m will not be used for energy. Before backfilling, the geothermal system piping will be fixed to the back of the excavated tunnel lining, covered with a protective layer and backfilled as part of the backfilling of the excavated sections of the tunnels. The maximum length of a single hydraulic circuit of the primary exchanger is expected to be up to 200 m. The hydraulic connection and connection of individual circuits to distributors/collectors will be carried out in shafts equipped with fittings for closing, regulating, filling and venting. For the purposes of geothermal energy utilisation, the activation of both tunnel tubes with a length of approx. 90 m is being considered. The section will be divided into ten circuits. The calculation was based on a safe conservative output of approx. 13 W/m^2. The proposed system can be expected to deliver approximately 100 MWh/year of heat and 60 MWh/year of cooling. Given that this is a cut-and-cover section of tunnel with the groundwater level below the tunnel floor, there will be no significant groundwater flow in the backfill material. It is therefore possible to view the geothermal system and rock mass as an energy accumulator, into which residual heat from cooling is stored during the summer months and from which it is drawn during the winter months.

The second section is in the excavated part of the tunnel near the portal towards the town of Tábor. The pipes of the individual hydraulic circuits are expected to be attached directly to the primary lining of the tunnel. The distributors and collectors will be routed under the drainage pipes and through the concrete footing of the secondary lining to prevent penetration of the waterproofing membrane. The distributors and collectors will be located in the tunnel on the side of the lining in cabinets, or, in order to reduce the risk of damage in the event of a vehicle colliding with the lining in a traffic accident, they can be placed in specially created niches in the secondary lining. Whether placed on the lining or in niches, the distributors/collectors should be covered with a stainless steel cover to meet fire safety requirements and to prevent unauthorised tampering with the hydraulic system valves. The backbone piping is again routed through the secondary lining from the distributors and collectors. It is encased in concrete, so plastic piping can be used. The backbone piping is always routed through a tunnel to the portal, then routed below ground level at a frost-free depth to the heat pumps.

2.1 USE OF GEOTHERMAL ENERGY

The energy obtained is used primarily to save operating costs associated with heating or cooling operational technology buildings (PTO), where it can be used to heat and cool rooms with sensitive electronics for the tunnel control system and substations. Another important possibility is the temperature control of permanently water-filled fire water pipes, which are commonly located under tunnel pavements and require heating to prevent them from freezing. By heating fire water using a heat pump, it is possible to reduce the cost of heating it to approximately a quarter.

In addition to the tunnel's internal needs, energy can also be supplied to external consumers in the vicinity, such as schools, government offices, or new development projects. A modern and advantageous concept is the creation of so-called cold energy networks (5GDHC), which operate at low temperatures and enable decentralised energy sharing between buildings. In portal sections or on connecting bridges, geothermal energy can also be used to heat road surfaces, which increases traffic safety by eliminating black ice.

2.2 CONCLUSIONS OF THE STUDY

The results of the technical and economic study show that the use of geothermal energy for operational and technological buildings (PTO) is advantageous compared to heat pumps that draw thermal energy from the air, if a longer investment horizon is considered. The simple payback period for a geothermal system is around 15 years. Although the initial investment costs for a ground-water heat pump system are approximately six times higher than for an air-to-air system, the high seasonal heating factor (SCOP up to 5.0) means that subsequent operating costs are more than 60% lower. This saving is a key factor that justifies the higher initial investment in the long term.

3. GEOTHERMAL ENERGY FROM THE D NOVÉ DVORY UNDERGROUND STATION

3.1 STUDY

The first step for the geothermal project at the Nové Dvory station was a study on the use of geothermal energy in Metro I. D commissioned by the Prague City Council. The motivation was the Prague Climate Plan until 2030, one of the key pillars of which is the use of highly efficient heat pumps to replace conventional combustion heat sources or fossil fuel-dependent systems. The implementation of these energy systems in the metro is also in line with the requirements of the EU Taxonomy, as these devices are capable of producing useful energy with specific CO2 emissions of less than 100 kg per 1 MWh. This ecological approach also responds to the growing demands for ESG standards, which are now a priority for institutional investors in the construction of new non-residential buildings.

From an economic efficiency perspective, the main impetus was the fact that the metro completely eliminates the need for costly drilling or excavation work to install the primary heat pump circuit. In addition, extensive above-ground development is planned in the vicinity of the future D metro stations, which could use energy from the metro, so it was appropriate to examine how significant a source of energy the metro line could be.

The main subject of the study is to assess the energy potential of part of the Prague Metro I.D route, specifically the section from Olbrachtova station to Depo Písnice, for the purpose of capturing low-potential geothermal energy using heat pumps. The study was prepared on the basis of expert estimates using available literature and existing project documentation from 2014 and 2019, as previous geotechnical surveys did not focus on parameters for geothermal energy extraction. Choice of location for

3.2 GEOTHERMAL ENERGY CAPTURE

The study considered the thermal activation of a wide range of structural elements that are in direct contact with the rock mass or soil. These elements included: the lining of bored tunnels, cut-and-cover tunnels and stations, the foundation slabs of cut-and-cover stations and piles used for temporary securing of construction pits. In addition to these structures, the study also mentions the possibility of using residual heat from exhaust air in ventilation shafts (exhaust vents).

The energy potential for individual stations and inter-station sections of the metro was calculated. With a uniform expected gain of 20 W/m^2 determined on the basis of empirical experience from other buildings, the total theoretical output for the entire route under consideration is approximately 5.5 MW.

After the study was completed, a discussion was held on the possibilities of using geothermal energy for future above-ground development (residential buildings, office buildings, schools). Finally, the Nové

Dvory station geothermal facility was selected for construction . The reason for this was that the planned construction in the vicinity of the station is to be carried out by the municipal company PDS (Pražská Developerská Společnost), so it would be easier to reach agreement on a suitable form of cooperation. More than 100,000 $m^2$of space is to be built in several buildings in the area of interest.

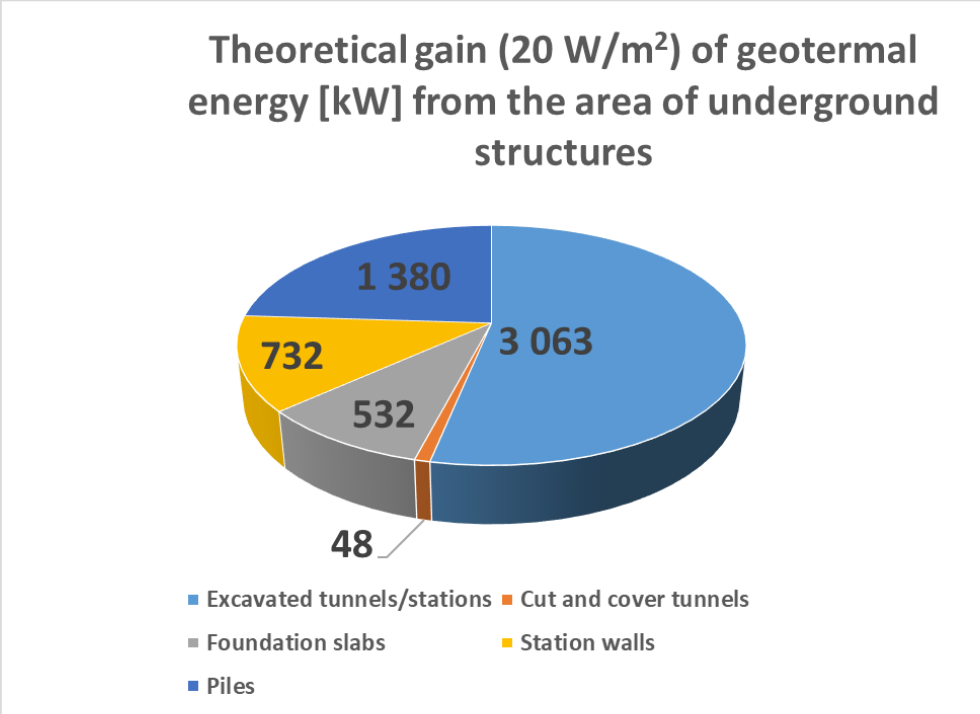

Figure1: Distribution of theoretical geothermal energy gain for a value of 20 W/m2 on the I.D. metro section

The Nové Dvory station is a major technical challenge. It is a single-hall underground station with an escalator entering the centre of the hall, making it one of the most complex underground structures in the Czech Republic. To give you an idea: the height of the vault at the intersection with the escalator tunnel is approximately 24 m. Due to the complexity of the station's construction, the construction of the geothermal facility is also complicated. If an cut-and-cover station had been chosen for the geothermal application, technologies commonly used in ground structures, such as energy-activated underground walls or energy-activated piles, could have been used for the construction of the primary circuit. However, the synergy between three Prague companies, namely the Prague Public Transport Company (DPP), the Prague Development Company (PDS) and Teplo pro Prahu, proved to be decisive in the choice of location.

As the owner of the metro infrastructure, the Prague Public Transport Company (DPP) enables the direct integration of energy absorbers into the construction of future tunnels and stations. The Prague Development Company (PDS) is preparing extensive above-ground construction in the vicinity of the station, which will be the main consumer of the heat and cold obtained. Early coordination with the geothermal facility construction plan allows buildings to be designed from the study phase onwards to be ideally suited for low-temperature heating and cooling using heat pumps.

The energy distribution company Teplo pro Prahu will probably be the administrator of the geothermal system in Nové Dvory. The role of the administrator includes:

- Operation and maintenance: The administrator is responsible for the operation of heat pumps and regular inspection of the primary circuit, including distributors and collectors.
- Energy distribution: The administrator is responsible for energy distribution in the above-ground part of the geothermal system. They sell energy to end consumers in above-ground buildings and manage contractual relationships.
- Optimisation: The administrator must monitor the energy balance of the system (the ratio between heat consumption in winter and heat storage during cooling in summer) to prevent thermal depletion or "freezing" of the rock mass.

Because all these entities are controlled by the City of Prague, it is much easier to reach agreement on technical solutions and property rights.

3.3 DESIGN IN THE TENDER DOCUMENTATION PHASE

3.3.1 Technical challenges

The project faced a number of challenges from the outset. One problem was that the geothermal project was included in the design of the I.D. metro construction later on, which caused coordination difficulties. The location of the absorbers, backbone piping, distributors and collectors had to be resolved retrospectively.

In addition to this underground coordination, it was also necessary to coordinate with the above-ground section. The key was to find a space through which to route the backbone pipeline from underground while satisfying the requirements for above-ground construction. Finally, the connection point to the above-ground part was located in a utility shaft adjacent to the Southern vestibule building. The backbone pipeline will be temporarily terminated there until the above-ground buildings are constructed and the above-ground part of the geothermal system is connected.

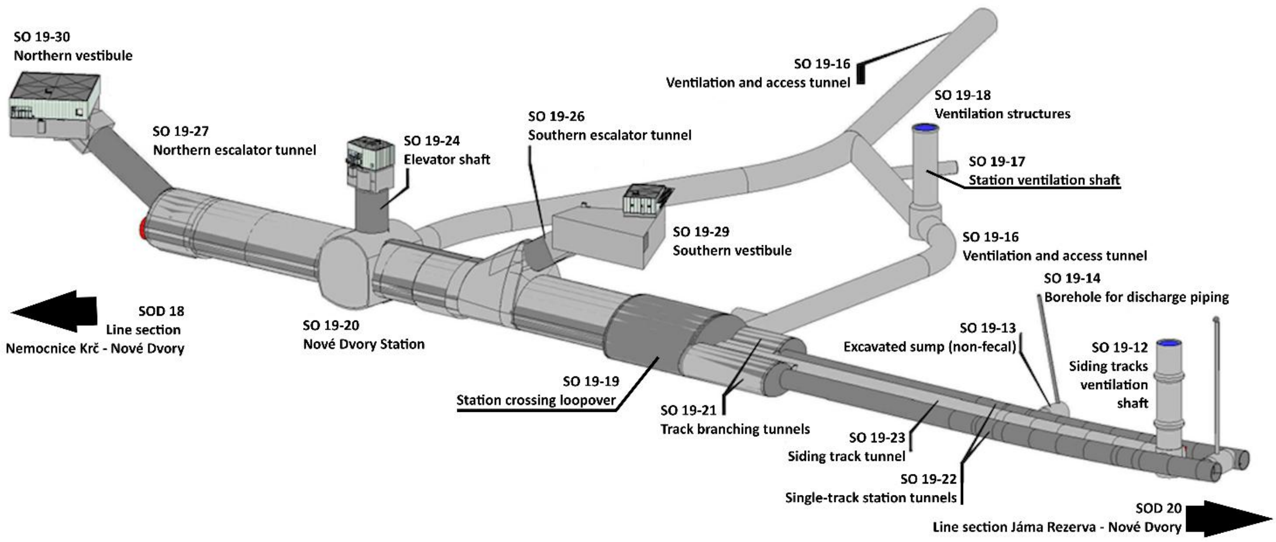

Figure2: Diagram of the Nové Dvory metro stationobjects

Another problem was the location of the collection pipes (heat exchangers) in the lining in the NATM excavated section. The station's waterproofing system, which is of the "submarine" type and provides full pressure insulation around the entire perimeter of the tunnel, poses a fundamental technical problem with pipe penetrations through the waterproofing membrane. For this reason, it was ultimately decided to attach the collection pipes directly to the secondary lining reinforcement. This solution is considered the most suitable because it does not compromise the integrity of the waterproofing and does not require any intervention in the membrane. The pipes are installed to the external distribution reinforcement on the back of the lining, thus remaining safely inside the waterproof envelope.

Although this location in the concrete is not in direct contact with the groundwater behind the membrane and is slightly less advantageous in terms of heat transfer, it completely eliminates the technologically demanding and risky details of penetrations. Although installation on the reinforcement may be more laborious due to the need to weave the pipe between the reinforcement frames, it provides a safe solution against leaks below the groundwater level.

At the same time, the 20 mm diameter collection pipe occupies a negligible area in the concrete cross-section of the secondary lining and therefore does not need to be taken into account in the static calculation. There were doubts about compliance with the cover layer requirement. However, it should be noted that the pipes are spaced approximately 300 mm apart and only cause localised disruption to the reinforcement cover layer. In addition, a more detailed analysis revealed that the cover layer in the station is designed with a reserve, and therefore the location of the pipes will not cause any disruption to the cover layer, even locally.

Another challenge was to find space for the manifolds and collectors, where the individual pipe circuits converge. The collectors and manifolds are located in the station in niches in the secondary lining hidden behind the station cladding and in the intermediate tunnel in the concrete base between the rails. The standard niches will measure 1000 × 1000 × min. depth 120 mm. The niches will then be covered with perforated stainless steel sheet with a minimum thickness of 0.7 mm, which will serve as protection against unauthorised access to the distributors and collectors and tampering with this equipment.

Last but not least, due to the nature of the metro, high demands are placed on the system in terms of fire safety. While the primary circuit encased in concrete in the lining does not pose a risk, visible elements such as distributors must be made of non-combustible materials (stainless steel, brass) or be fitted with fire covers with the prescribed resistance. An advantage is that the backbone piping is routed directly in the lining structure, where it is protected from direct fire and can be made of common plastics, reducing investment costs compared to stainless steel distribution systems.

3.3.2 Technical solution

The technical solution for the primary circuit for geothermal energy collection involves the installation of pipe absorbers directly into the concrete structures of the underground. The system is designed as a closed circuit in which a heat transfer medium (demineralised water) circulates, which is heated or cooled as it flows through the lining. PEXa pipes with dimensions of ⌀20 x 2.0 mm, are used to create the collection exchangers, with an expected service life comparable to that of the station's waterproofing membrane. The pipes are laid in loops with an axial spacing of approximately 300 mm in the structures. The individual circuits are connected to system distributors and collectors, either directly via compression fittings or using stainless steel bellows. These distributors and collectors enable automatic flow control for each loop.

The collection pipe is located in the secondary lining of NATM-excavated station structures and in the connecting sections of TBM-excavated track tunnels.

In sections excavated using the conventional NATM method, the collection pipe is installed directly into the secondary monolithic lining in the upper and lower vaults. It is located both in the main station hall and in other structures such as the station crossing loop and ventilation tunnel. Unsuitable locations in the lining for pipe placement are omitted due to their complexity (front walls, intersections of structures).

In track tunnels constructed using TBMs, the collection pipes are integrated into the prefabricated segmental lining, with one ring forming a single complete collection circuit. Absorbers are inserted into these segments during their manufacture, where they are point-fixed to the main load-bearing reinforcement on the outer face so that the concrete cover layer is preserved. For subsequent pipe connection, the segments are equipped with special connecting niches located on the inner face of the lining. After the segments are installed in the tunnel, the pipes in these niches are connected to each other and led out at the bottom of the lining towards the distributor and collector through the track concrete. The entire technological process is completed in the final phase of construction by filling the connecting niches with concrete screed.

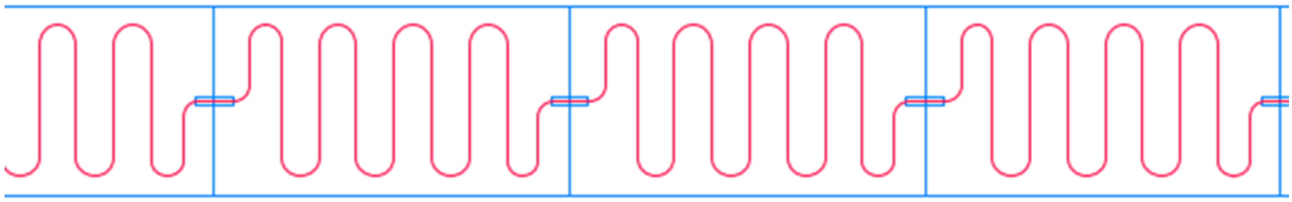

Figure 3: Diagram of the absorbing pipe on the unrolled ring of segmental lining

3.4 OUTLOOK FOR THE FUTURE

At the time of writing, the project to construct a geothermal facility at the Nové Dvory metro station has not been contractually secured with the contractor. The plan is to add it to the metro construction contract as an addendum, which means that the geothermal facility construction project itself will not go through a public tender.

Due to ongoing legal disputes, it is not known when construction of the geothermal facility or the Nové Dvory station itself will begin.

After completion of the underground part of the geothermal system, a cold energy network will be created, to which other energy sources will also be connected. New above-ground buildings will be gradually connected to the cold network. It is expected that geothermal energy from the underground will supply approximately 0.45 MW of source power. The operation will also include monitoring, in particular temperature monitoring, which will set the optimal operation of the geothermal system and prevent undesirable conditions such as condensation of air humidity on the surface of the lining or "freezing" of the rock massif. The specific and realistic energy coverage of this source will therefore only be possible to evaluate after the first few years of operation. However, there is already international experience with the operation of these systems, and it is very positive.

4. CONCLUSION

The pilot project at the Nové Dvory station on the new D metro line confirmed that even in the most technically demanding conditions of bored underground works, it is possible to successfully integrate collection systems into monolithic lining or prefabricated tubigs without compromising the integrity of the waterproofing, reducing fire safety or requiring disproportionate additional measures that would increase the cost of the construction itself. The decisive factor for the project was the synergy between the Prague municipal companies DPP, PDS and Teplo pro Prahu, which enables effective coordination between the underground energy source and future above-ground development.

The authors believe in continuing the project through its implementation and subsequent operation. If this happens, it will not only be the first application of geothermal energy from tunnels in the Czech Republic, but also a unique project in terms of its scope and complexity. The successful implementation of this project will pave the way for the wider use of geothermal energy in other planned road, motorway and railway underground constructions throughout the Czech Republic.

Geothermal energy will find particular application in urban tunnels, from which geothermal energy can be supplied to surrounding buildings, fully utilising the tunnel's potential energy gain. This is an innovative solution for heating and cooling buildings, which contributes to the fulfilment of climate goals and geopolitical independence from foreign energy sources. At the same time, the use of geothermal energy can increase the acceptability of tunnel structures among the general public. As a study prepared for the Road and Motorway Directorate of the Czech Republic (ŘSD) has shown, further use of energy can be found in the tunnels themselves, which can lead to savings in tunnel operating costs.

In order to introduce this new technology in the Czech Republic, it will be necessary not only to overcome all the technical challenges, but also to overcome the natural distrust of anything new, which is no less important and natural for most people, and to find enough enthusiasts in the field who will be willing to devote their energy and time to promoting this idea.

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