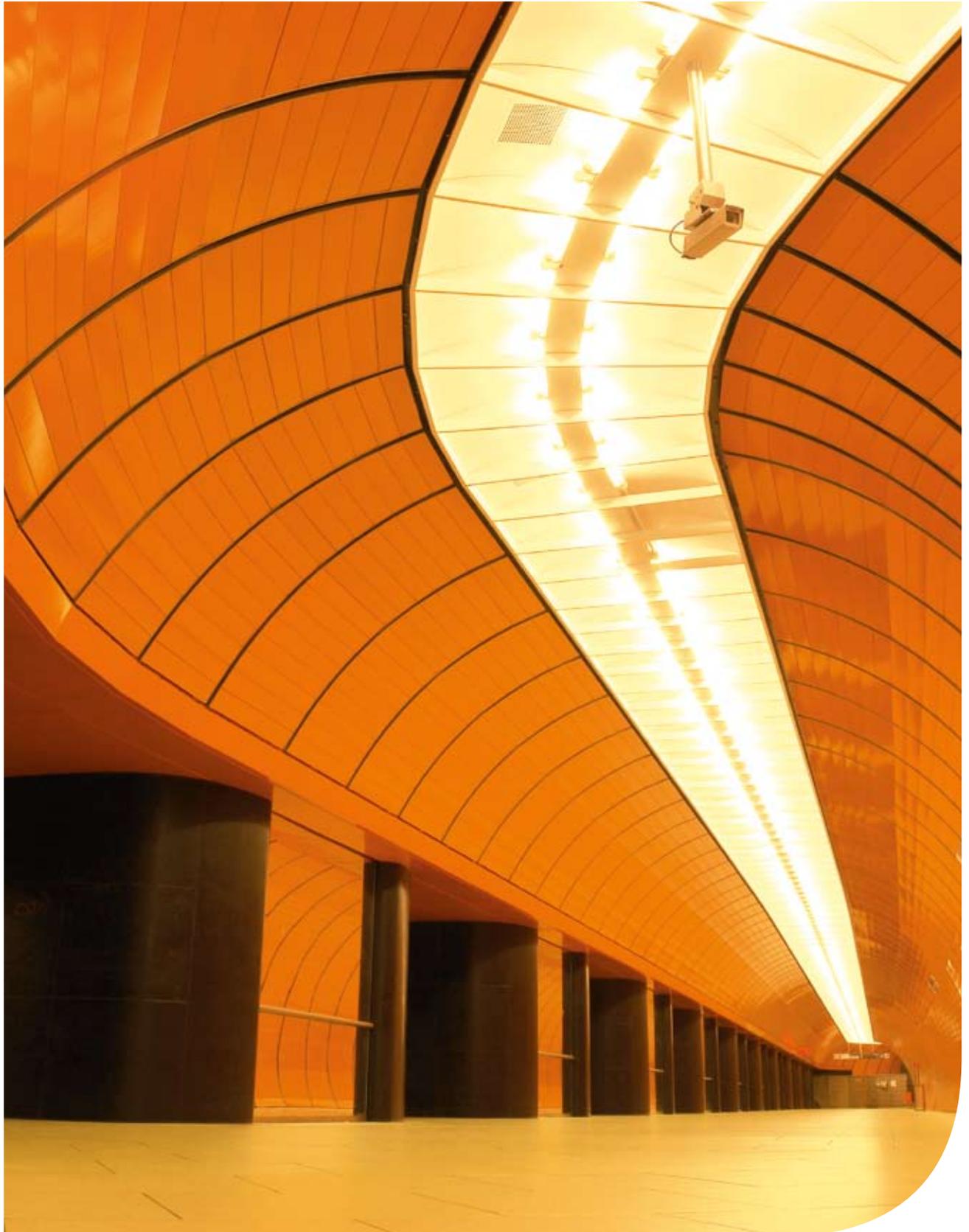
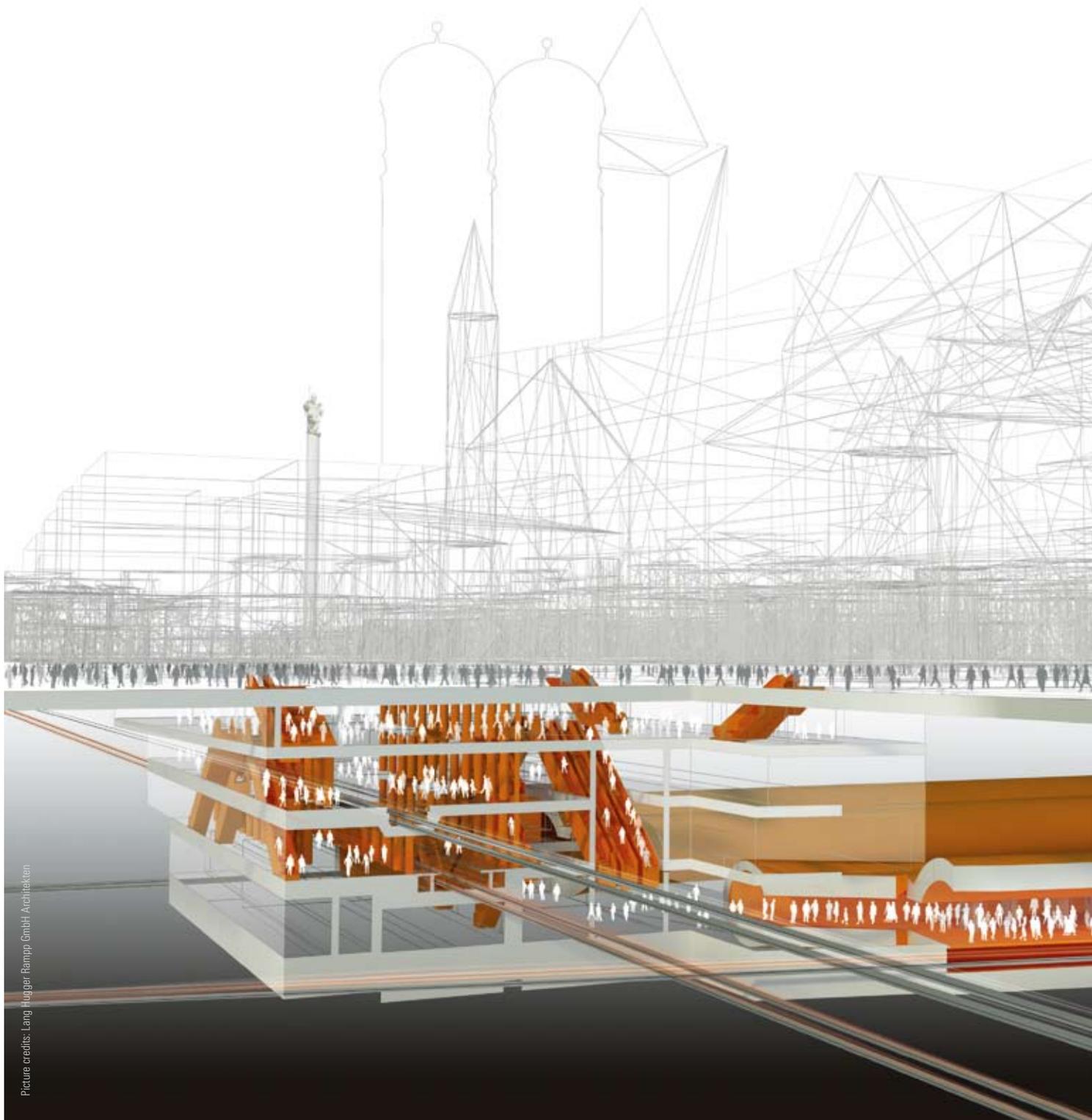
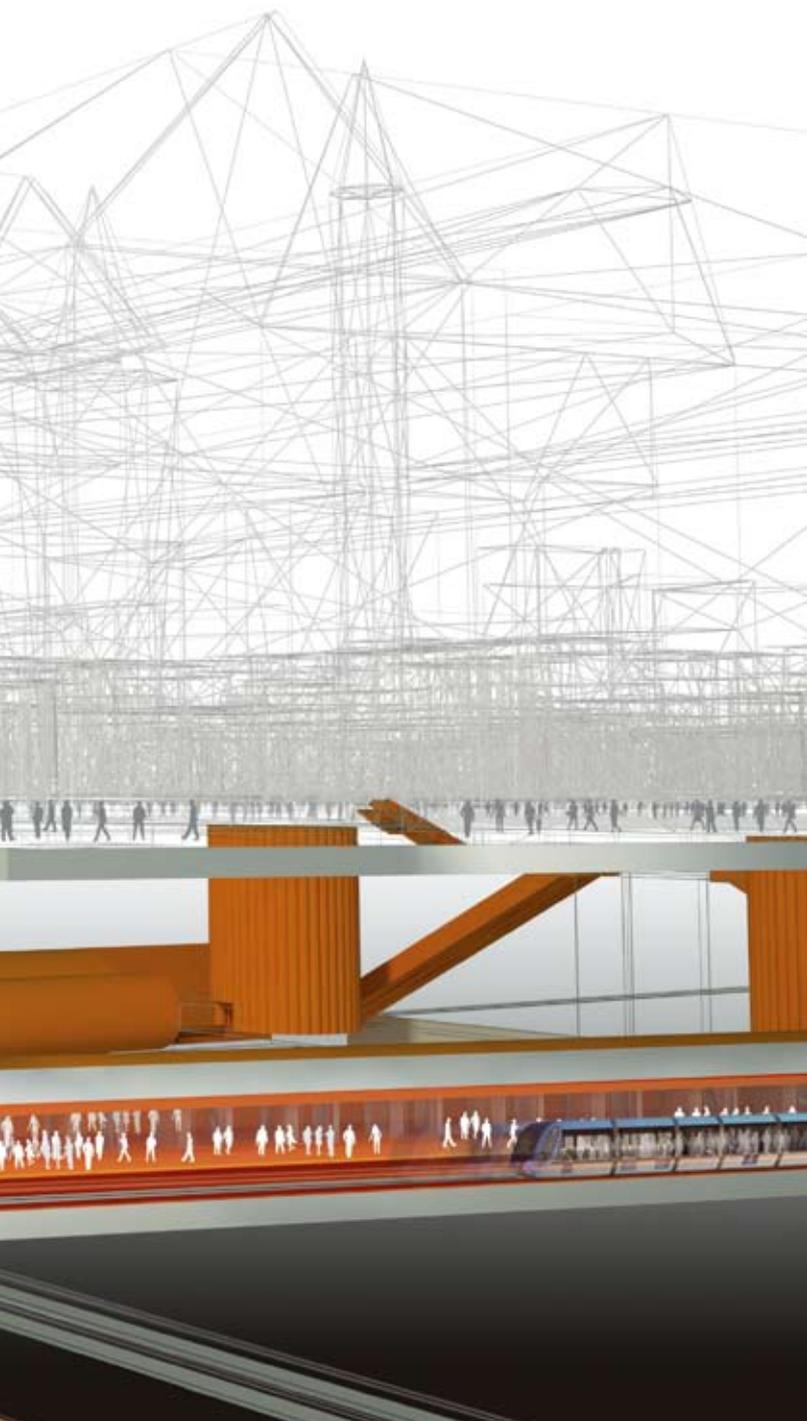


Marienplatz Underground Station, Munich
Tunnelling method by using soil freezing



Underground station Marienplatz – visualisation





Marienplatz

The underground station Marienplatz is by far the most frequented traffic intersection of the Munich regional train and underground transport system. The possibility to change from underground lines U3/U6 to the regional train lines as well as its location in the heart of Munich provoke huge numbers of passengers. After the decision in 2001 to build a new football stadium in Fröttmaning just outside Munich linked to the town centre by underground line U6, it was certain: In time for the Football World Cup 2006 in Germany, the station Marienplatz, since long time at its capacity limit, had to be significantly enlarged.

The aim was to efficiently ease the passenger flow. The examination of different concepts resulted in a solution that envisaged two tunnels running parallel to the platforms and connected to them by eleven gallery-like cross-cuts, thus, nearly doubling the platforms' surface.

The construction comprised interference into the ground only ten metres underneath the Munich City Hall. The very sensitive historic building was not be harmed under no circumstances by settlement intolerances. That is why a tunnel drilling method was chosen that used partial soil freezing expected to cause the least possible interference in the ground and to offer huge advantages in terms of risk consideration.

SSF Ingenieure was responsible for the whole final design of this variant proposal and was awarded in 2005 the engineering price of the Bavarian Chamber of Civil Engineers for enlargement of the platforms of underground station Marienplatz.

Ground

On top, the ground consists of sandy fine and coarse gravel. A huge closed groundwater horizon is missing; only singular quaternary water due to infiltrating rainwater had to be expected. In the underlying clays and silt are very thick (7.5 to 12 meters) layers of fine and medium dense sands that stow the ground water. They carry groundwater that is in parts highly pressurized (confined groundwater). It was difficult to handle the relicts of the first underground construction of the years 1966 to 1970. Several filter wells and groundwater levels were not rebuilt according to the current state-of-the-art and could not be clearly located.

Construction process

Behind the City Hall two oval starting pits were built. For each shaft two superimposed bored piles with 1.2 m diameter up to 30 metres deep were erected and equipped with additional reinforced concrete rings at the height of the tunnel starting point to protect it from earth pressure. Next, two pilot shafts for soil freezing were excavated. The approximately 100 metre long pilot shafts had an inner diameter of two metres and were constructed by using reinforced concrete rings that were pushed into the ground one after the other from the starting pit. The working chamber for the mining machine at the working head was put under overpressure in order to keep the groundwater away which occurred in the sand layers with a thickness of 2 to 5 meters.

Soil freezing

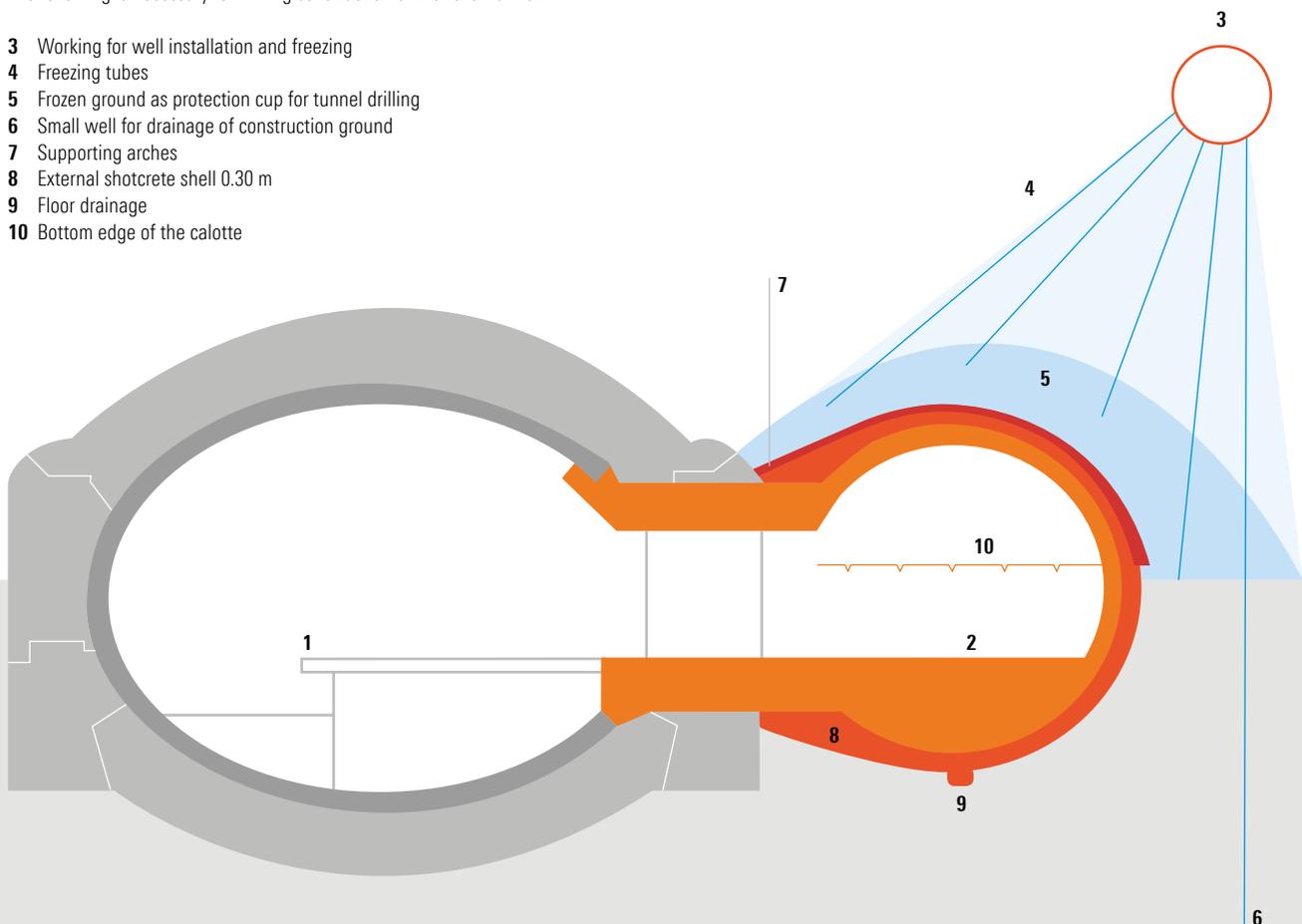
Initially the extension of the underground station was envisaged by utilizing conventional tunnel mining technique with lowering of the groundwater level. There, the construction ground would have been drained by numerous horizontal wells. The then occurring settlements of the ground would have been equalised by compensation grouting. The tunnelling method by using soil freezing elaborated by SSF Ingenieure in cooperation with the construction company and presented as alternative to the method in the tender was awarded the contract because it comprised economic and technical improvements. By freezing the soil, the horizontal wells could be relinquished. At the same time the ground's stability was amplified, thus simplifying the later on

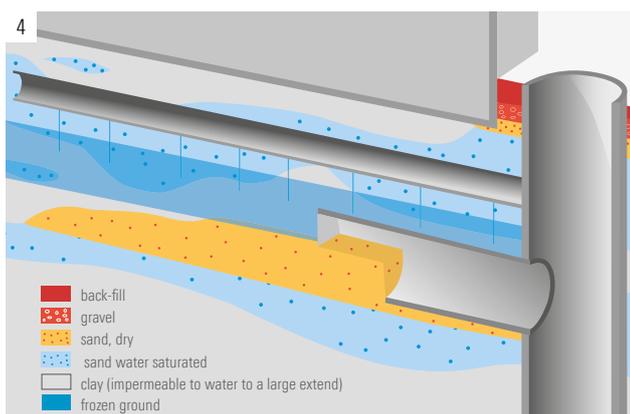
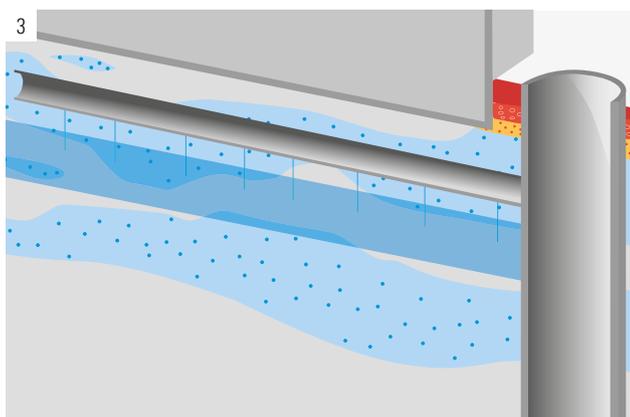
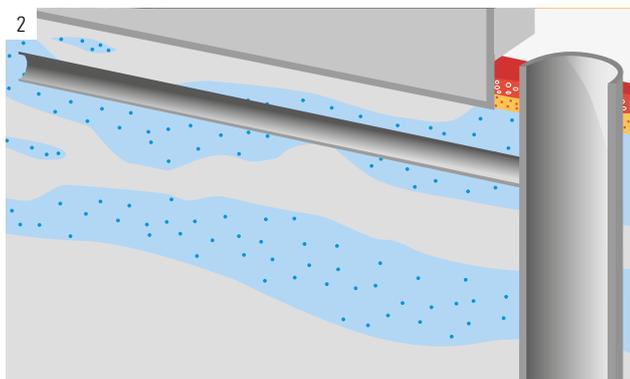
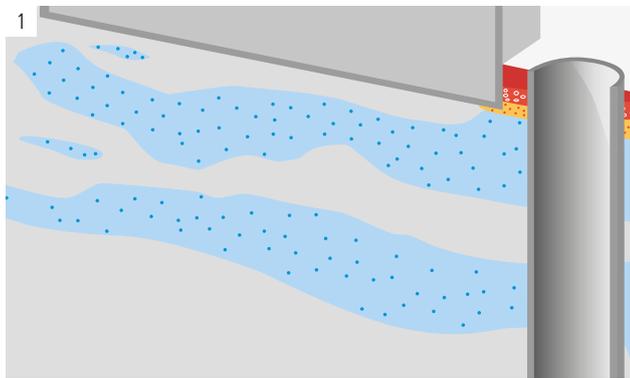
Cross-section platform lines U3/U6, direction south

- 1 Existing platform
- 2 New platform in the relief tunnel

The following is necessary for mining construction of the relief tunnel:

- 3 Working for well installation and freezing
- 4 Freezing tubes
- 5 Frozen ground as protection cup for tunnel drilling
- 6 Small well for drainage of construction ground
- 7 Supporting arches
- 8 External shotcrete shell 0.30 m
- 9 Floor drainage
- 10 Bottom edge of the calotte





- back-fill
- gravel
- sand, dry
- sand water saturated
- clay (impermeable to water to a large extent)
- frozen ground

drilling of the galleries and increasing security for the historic City Hall building. Departing from the pilot shaft, 654 freezing drillings with a diameter of 88.9 millimetres and a total length of 4,000 metres were executed in fan-like order. The ground was frozen at minus 38 degrees Celsius, intermittently adapted to the actual state of the drilling. This measure was permanently controlled by 180 temperature probes which enabled temperature control so as to avoid large lifting through frost as water expands up to nine percent when frozen.

The new tunnels

Underneath the ice caps, both new tunnel galleries were constructed by mining technique with shotcrete. The drilling speed was at about two metres in 24 hours with a uniform breakthrough cross-section of 50 square metres. A particularity was the tangent position to the existing platforms. In order to connect old and new structures, the old remaining steel sheeting elements were removed. Then, 15 centimetres of the outer concrete shell were demolished. Special dowels ensured the connection of the new reinforcement to the existing construction. Eleven openings link the new tunnels to the platforms. At the southern head front, two openings were built cutting through the 2.5 metres thick reinforced concrete shells of the existing tunnels with a diamond wire saw. Under static considerations these cut-throughs were done in several steps. The sawn-out concrete blocks weighted about 40 tonnes. They were pulled into the new tunnel by special hydraulic devices, cut up and disposed of via the starting shaft.

- 1 **Construction** of both launching shafts
- 2 **Drilling** of pilot shafts
- 3 **Ground freezing**, decompression of groundwater
- 4 **Tunnel boring**

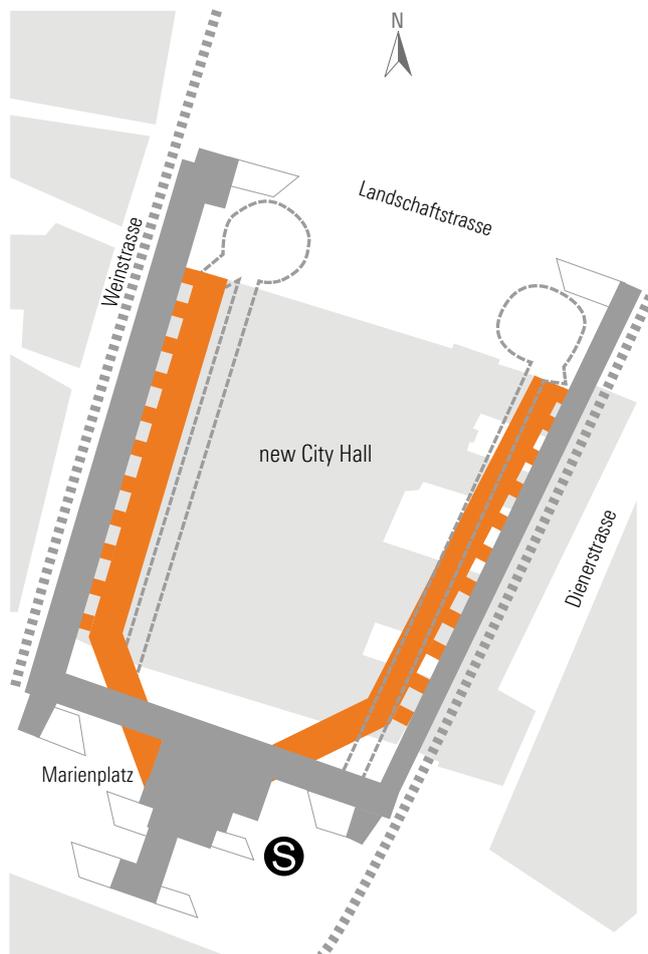
Water tight connections and inner shell

As the platforms lie within groundwater, the connection between the new and the existing structures were made watertight. The outer shotcrete shell was complemented by a 50 centimetres thick water-tight inner shell made of reinforced concrete.

All construction measures were accomplished whilst underground operation was maintained. There was nearly no inconvenience caused to the passengers throughout the whole construction period of the new tunnels. Only during breaking-through the openings to the platforms, passengers had to put up with narrowing of the platforms and of the connecting gaits.

Facts Marienplatz

Client	City of Munich, department for underground construction
Tunnel length	103 m / 95 m
breakthrough cross-section	50 m ²
Construction period	2003 – 2006
Construction	Mined tunnel with cross-cuts to the existing structure, construction with pilot shafts, soil freezing and groundwater decompression
SSF Ingenieure	variant proposal, final design



Whilst the ground plan remained unaltered, the following modifications arose in the course of the European-wide invitation to tender, as a result of a variant proposal put forward by SSF Ingenieure:

- oval starting shafts
- additional pilot tunnels for targeted freezing of the subsoil above each of the tunnel roofs
- subsoil freezing, and extraction of the second pocket of ground water

planned relief tunnel 

existing platforms and ways to the regional trains and the surface 

track lines U3/U6 

launching shaft with working pits for tunnel boring 

connection to the regional train system 

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Consulting Engineers

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Berlin
Halle
Augsburg
Cologne

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