Tunnelling in the Europaviertel Frankfurt

Dr.-Ing. Jürgen Schmitt, Dipl.-Ing. Heiner Fromm
CDM Consult GmbH, Alsbach

Prof. Dr.-Ing. Wolfgang Krajewski
Expert Geotechnique / Tunnelling, University of Applied Sciences Darmstadt

1 Introduction

With the relocation of the main goods station and its patch bay (fig. 1) this gave the city of Frankfurt/Main the chance to provide a large inner-city area with new urban use and to improve links to the surrounding quarters (fig. 2). By the direct neighbourhood to Frankfurt fairgrounds is offered in addition the possibility, which location in the city of the fair in required measure to extend (Frankfurt/Main Town Planning Office 2010).

Located to the west the Frankfurt city centre the area is situated between the quarters of Bockenheim and Gallus. The three development plans, which cover the future Europaviertel and the entire fairground area, occupy an area of altogether approx. 145 hectare. Approx. 100 hectare are void of it to those formerly for course purposes used surfaces.

In the Europaviertel, approximately 32,000 jobs and 3,800 dwellings are to be developed. Likewise, it is a purpose of placing to the fair Frankfurt at their location in the city extension surfaces for the order. Additionally, the recovery function in the adjacent quarters and in the city-spatial networking can be improved by the planning of abundant green areas in the western part.

Fig. 1 Aerial photograph of the whole of Europaviertel (Frankfurt/Main Town Planning Office 2010)

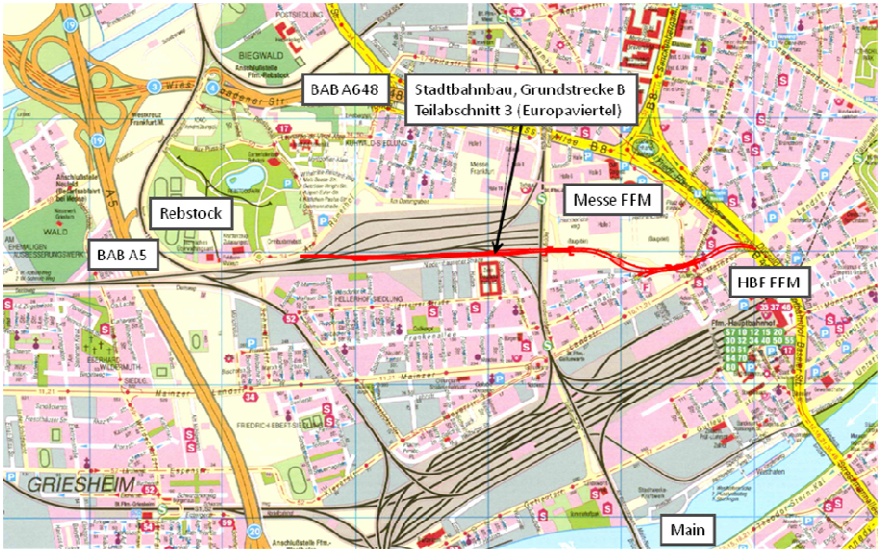

Fig. 2 Overview of project area

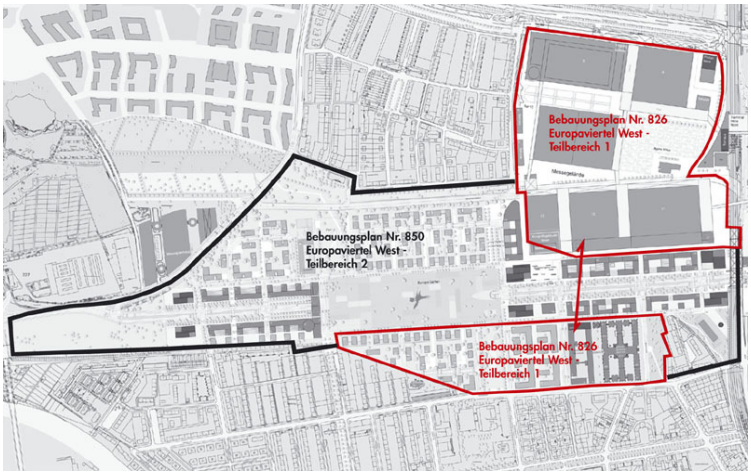

Fig. 3 Areas of application of the development plans (Frankfurt/Main Town Planning Office 2010)

Since the start of planning of the Europaviertel quarters, approximately 10 years before the project area became available, three development plans were chosen (fig. 3). Development plan No. 556: "Messeviertel / Hemmerichsweg" for the eastern part of the Europaviertel has been legally binding since May 2001. The development plan No. 826 "Europaviertel West - subarea 1", the surfaces already exempted from the use as course surface over-planned, has been obligatory since February 2008. The third development plan No. 850 "Europaviertel West - subarea 2" over-plans the areas, those at present to be back-built and to 13.07.2010 into force stepped. These development plans form the basis of an outline plan concerning the town's construction, which has been continuously updated since its first edition in the 2000 (Frankfurt/Main Town Planning Office 2010).

In order to link up Europaviertel to the underground system of the city of Frankfurt/Main, an extension to the B-line (U5) is planned as branch of the existing line U4 through to the Bockenheimer Warte (D-line). The planned underground line leads from the Platz der Republik (connection to the existing line) over the Güterplatz to the Lia-Wöhr-Platz at the road junction of the Kölner Straße into the Frankenallee. From the Lia-Wöhr-Platz the underground route heads northwest into the southern part of the former goods station. The underground route runs under the Emser Bridge and parallel to the Niedernhausener Straße in the southern part of the former marshalling yard to the west, up to the final flag stop at height of the western Wohnpark development at Rebstock (fig. 4).

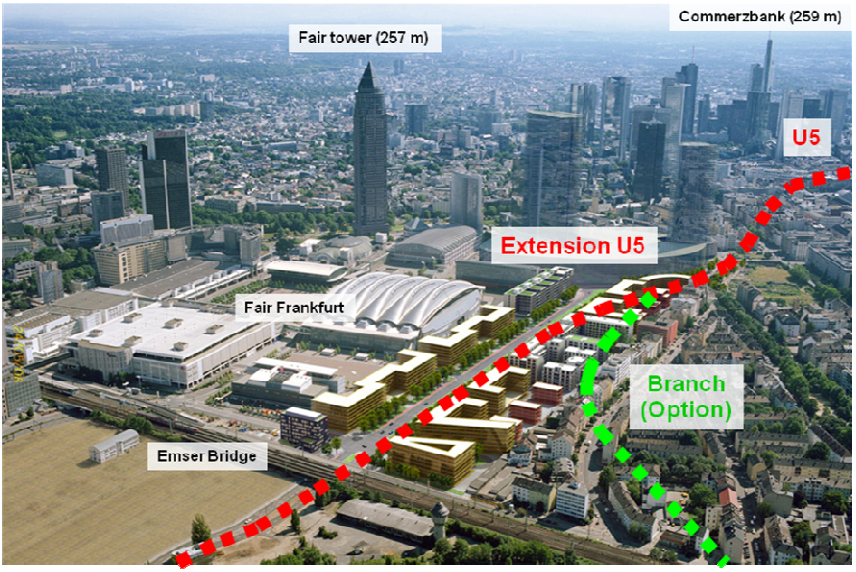

Fig. 4 Europaviertel Frankfurt: Europa-Allee - visualisation of the buildings and architecture - Skyline Plaza: preliminary study (after VIVICO 2010)

2 Buildings

The extension of the line has an overall length of approx. 2.6 km (fig. 5) starting from the existing building at the Platz der Republik. The planned route runs completely underground for four stations, with the work titles “Güterplatz”, “Emser Bridge”, “Europagarten” and “Wohnpark” up to the end of the route at the top of the western Wohnpark development.

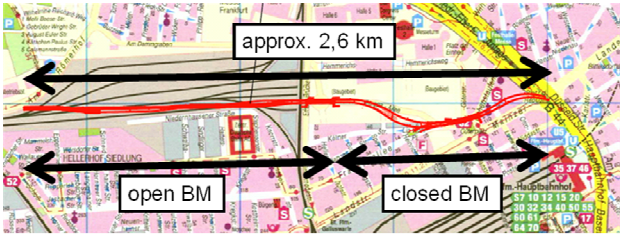

Fig. 5 Overview of the construction method

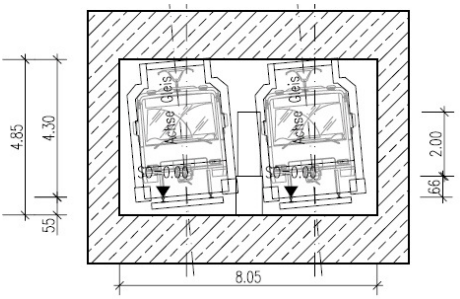

Fig. 6 Cross section of open cut tunnelling

The 1.6 km long section west of Emser Bridge is to be established in the open building method. Here the tunnel is to be built as a single-cell reinforced concrete frames with an inside diameter of approx. 8 m and headroom of approx. 5 m (fig. 6). The overburden amounts to approx. 4 m to 7 m.

At the stations the width of construction for approx. 20 m becomes larger (fig. 7).

The approx. 1.0 km long eastern distance section up to the Emser Bridge is to be driven by underground means. The subway railway tunnel is to receive here two single tube lines (north and south track).

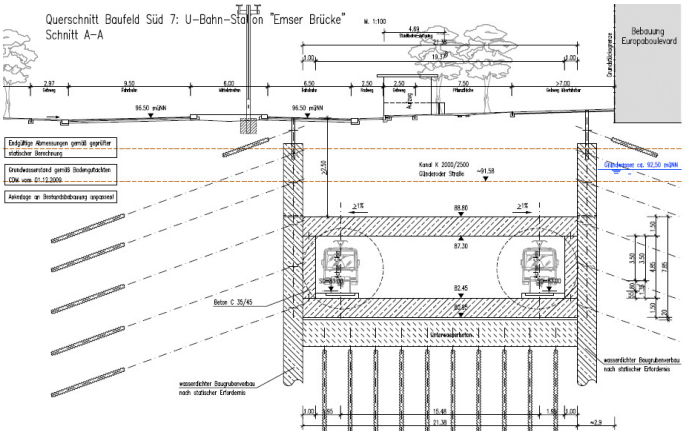

Fig. 7 Cross section of the open building method station Emser Bridge

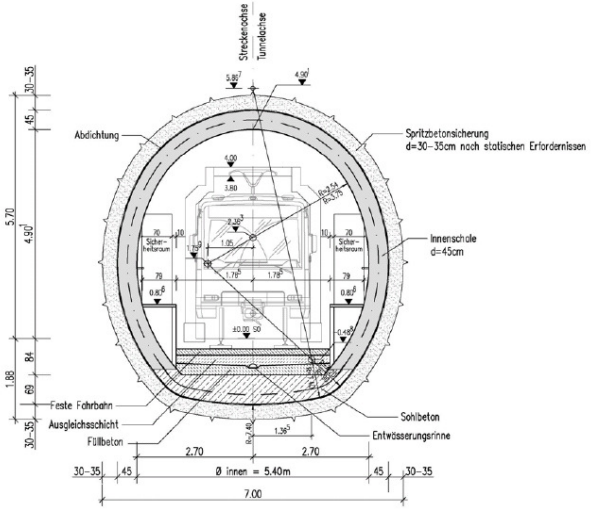

Fig. 8 Cross section - shotcreting method

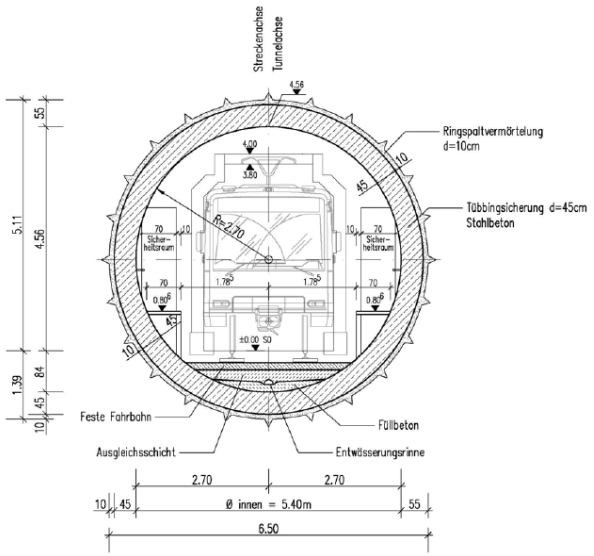

Fig. 9 Cross section - shield driven method

The single tube lines are connected by two cross cuts. These are arranged between the Platz der Republik and the station “Güterplatz” and between the “Güterplatz” and the “Emser Bridge” stations. The overburden is ranges from approx. 7 m to a maximum of 17 m. The tunnel ranges driven by underground means is in the shotcrete construction way to be manufactured (fig. 8). Alternatively, at the preliminary design stage a shield driving was also examined (fig. 9), which was ruled out, however, due economic reasons.

3 Geological overview and boundary conditions for the tunnel construction

In the project area, quaternary surface layers are expected between approximately 5 m and 10 m. Here cohesive soils such as loess, loam and silt, are underlain by sands and gravels of the Main and the Niddaterrassen. As a result of earlier anthropogenic activities, parts of the quaternary soils were cleared away and replaced by back-fill.

In the footwall follow tertiary measures into large depth. The uppermost tertiary layer is formed in the western route section of Pliocene sands, into which subordinated gravel, silt, clay and wood remains are switched on. In the eastern route section, the Hydrobien-layers of the Miocene form the uppermost tertiary period layer. These are formed by clay and silt, underlain by limestone, dolomite and algal limestone. This layer sequence is generally called “Frankfurter clay”. Between the two ranges lies landsnail marl lie, on top of the Prososthenien-layers over the Hydrobien-layers (both from the Miocene).

The range, which is driven by underground methods, can be described concerning the layer sequence by two characteristic geological profiles (see fig. 10). In the section Platz der Republik to “Güterplatz“station the planned tube tunnel runs completely through the Miocene layer (“Frankfurter clay”) (fig. 10a). In the section of the “Güterplatz” to “Emser Bridge” station, different geotechnical conditions arise. In individual sections the tunnel tubes lie completely in the Miocene layer. In other sections the roof breaks through the Pliocene sands, which are enough locally into the outbreak cross section inside (fig. 10b) and up to the tunnel bottom lead in parts (fig. 11). In the extent of the open building method the tunnel lies on the Pliocene sands and gravels.

The groundwater level lies approx. to 3 to 5 m below ground, so the tunnel is completely submerged in the groundwater.

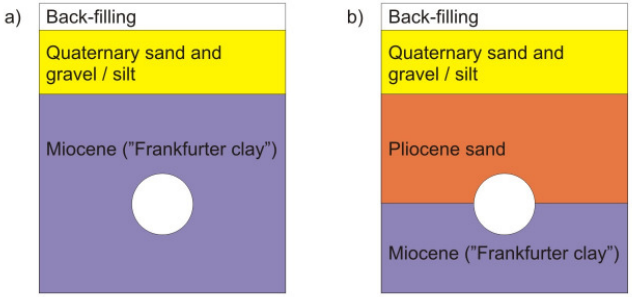

Fig. 10 Schematic structure of the layers with the tunnel cross section

Both for the open and the driven by tunnelling methods, the choice of the building procedure and the choice of the tunnel support depends on the geological boundary conditions.

For the driven by underground means in “Frankfurter clay” extensive experience from the earlier construction of the underground is present. The ground can generally be solved with a tunnel excavator. The irregularly occurring rock banks in the ground structure may require chisel work and loosening breakup. For the control of the groundwater, generally a hurrying ahead sinking is implemented by means of force of gravity wells. Alternatively, compressed air tunnelling is possible, whereby the experience from appropriate sites in the east of Frankfurt have shown that due to anthropogenic influences and due to the comparison-wise small roof cover with the compressed air tunnelling problems arise regarding any blowout. Altogether it can be stated however that with a crown drivage of the tunnels in the Miocene layers in proven way can be driven.

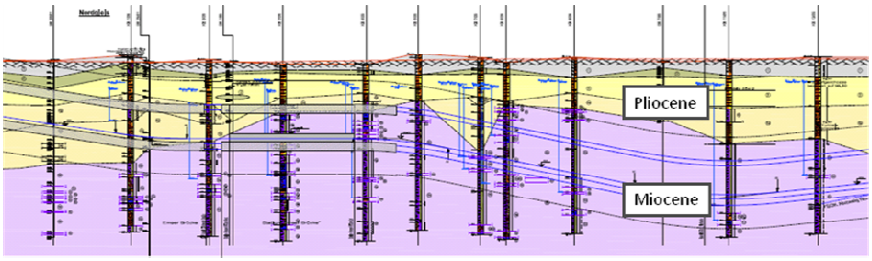

Fig. 11 Geological cut within the range of the closed building method

The driven by underground means with the entering the Pliocene sand strata becomes comparatively difficult. These layers are permeable to highly permeable, so that a groundwater lowering is not feasible both either an ecological or economic viewpoint. Furthermore, it should be considered that due to the comparatively small shear strength of the cohesionless ground and influences from earlier and current land development, the ground bearing ring necessary in the shotcrete construction way adjusts itself only conditionally. For the reasons specified previously compressed air tunnelling will become necessary, whereby to avoid of blowouts and to strengthen the ground bearing ring supplementary special measures are necessary.

In continuation of these considerations for the execution of the distance section which can be realized in open building method, waterproof excavations have been conceived. The constructions merge in the Pliocene sands. The natural seals horizon is clearly under the base of the excavation, and can be achieved by an economically conceived building pit sheeting only in individual places. Accordingly the excavation is artificially sealed to the lying (e.g. underwater concrete sole or sealing the base by jet grouting). For the building pit, sheeting tied and/or braced sheeting with bored piles or diaphragm walls, with comparatively small excavation depths are also possible with sheet pile walls.

5 Outlook

After the conclusion of the next planning phase line up to the preliminary design with the investigation of different planning options. Work is due start in 2012.

References

Stadtplanungsamt Frankfurt am Main (2010)
Europaviertel - Städtebaulicher Entwurf, Büro, Gewerbe, Wohnen, URL: http://www.stadtplanungsamt-franfurt.de/europaviertel_5196.html?psid= 9e3c679 3b9dc40be7b22df0c30f386f7N, Last accessed: 11.12.2010

VIVICO (2010)
Das Europaviertel - mitten in Frankfurt, mitten im Leben, URL: http://www.vivico.de, Last accessed: 11.12.2010

Frankfurter Rundschau (2010)

Nächster Halt Europaviertel, Frankfurter Rundschau, 09.02.2010

Frankfurter Neue Presse (2010)
Vorplanung für neue U-Bahn abgeschlossen, Frankfurter Neue Presse, 09.12.2010