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Basel's New Motorway Link to France - Tunnel Construction Under Inner-City Conditions

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Summary

The Kanton of Basel Stadt is presently building a new expressway linking the Swiss motorway A2 with the French A35, closing the 3.2 km gap in the motorway system which has created heavy traffic on inner city roads for long time. Approximately 2.5 km of the total length of the link comprise tunnels under the city. Owing to the varying conditions along its length, the structural design principles and construction methods of the tunnel vary considerably from one section to the next. The paper discusses some of the most interesting aspects of the design and construction of these tunnels, concentrating on three different sections, each of which features different problems requiring specific solutions.

1. Introduction

The city of Basel, situated at the juncture of Switzerland, France and Germany has to this day been plagued by extremely dense and heavy traffic on its inner city roads. This is due to the lack of an expressway linking the Swiss and German highway systems to the French motorway A35. Both traffic to and from France and locally generated traffic at present pass through the city, adding to by traffic from the increasingly important regional airport Basel / Mulhouse / Freiburg. To improve this situation, and to honour a bilateral agreement between Switzerland and France dating back to 1963, the Kanton of Basel Stadt is now building the missing link between the Swiss A2 and the French A35.

The 3.2 km long four lane dual carriage way will branch off the A2 via a set of curved viaducts which lead into a 1090m long tunnel under the part of the city located on the right bank of the Rhine. The road will surface to cross the river on a new 260m long bridge and disappear again on the other side in a second stretch of tunnel, 1430m long, which will end only 240m before the Swiss-French border control post. A total of five connections to the city's road system will also make the new expressway attractive to local traffic. The new link represents a total investment of about 1.1 billion Swiss francs, spent over a period of 10 years and is due for completion in 2005.

Due to its complexity, and in order to spread the work involved with the planning, design and construction of the expressway to as many local companies as reasonably possible , the owner has decided to divide the project into four sub-projects, each of which is again divided into a number of contracts . While the typical problems arising from inner city construction are common to all sections each one is faced with different local conditions, requiring specific structural solutions and construction methods. Three different types of tunnel construction are presented below. Within the scope of this paper, only the more interesting aspects of each method will be discussed

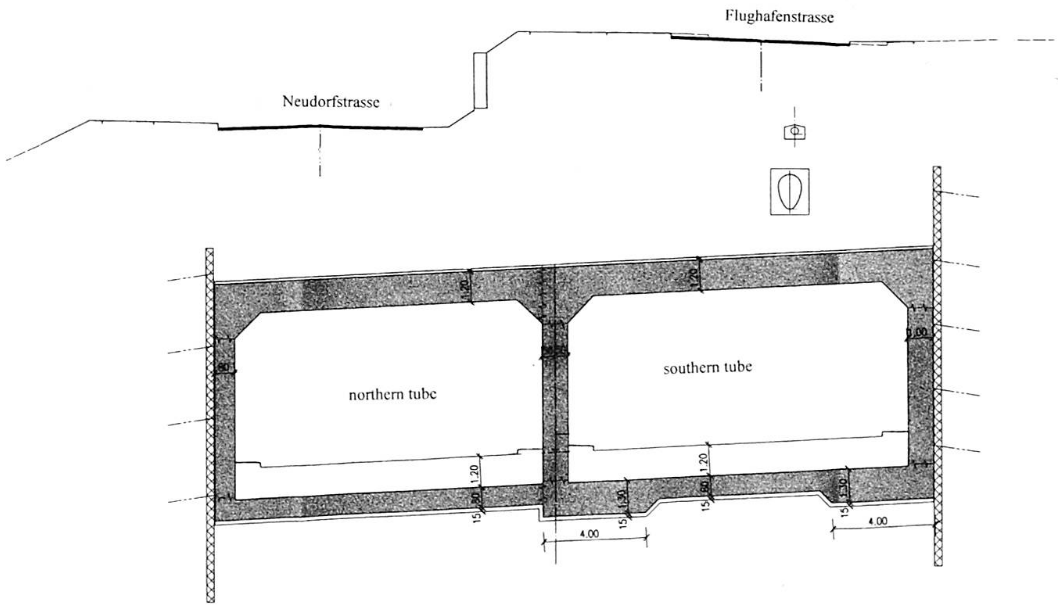
2.Tunnel 'Flughafenstrasse'

The author's direct involvement is limited to this 240 m long tunnel section under the two almost parallel roads leading to the airport and to the Swiss-French border control post. Since one of the two roads must be in operation at all times during tunnel construction, one tunnel tube has to be built ahead of the other. The finished tube is to be covered in order to rebuild the road above before excavation for the second tube can commence. Also, the overall construction program requires that the southern tube (inbound traffic) be in operation by the time work on the second tube of this section begins.

2.1 Structural Implications

Fig. 1a shows the typical cross section of the tunnel, Fig. 1b shows the cross section during the construction of the southern tube and Fig. 1c during the construction of the northern tube. During construction of the 10.5m wide second tube, the 14.5m wide inbound tube has to stand alone with an overburden of up to 9m, giving rise to very large bending moments in the frame corners and the middle wall. Also, shear forces are significant requiring shear reinforcement in the top slab.

To achieve full frame action during this governing construction load case, cut-and cover insitu concrete construction was chosen rather than top-down construction. The moment connections between the bored piles and the top slab would otherwise have been rather complex. Due to the proximity of the reconstructed road above the completed southern tube to the excavation for the second tube, the soil cover is secured using the principle of reinforced earth, allowing an almost vertical face (refer to Fig 1c). This causes the soil cover to exert a horizontal force on the tunnel roof slab, increasing the sectional moments and shear forces in the slab and middle wall. The ground anchors of the southern retaining wall are left in place fully stressed. This avoids significant unsymmetric lateral earthpressure which would further increase the frame moments and shears. The finally chosen cross section dimensions are indicated in Fig. 1a.



2.2 Partially Prestressed Roof Slab and Middle Wall

To limit the density of main reinforcement it was decided to partially prestress the roof slab and the middle wall of the tunnel using bonded prestressing tendons. Looped tendons are used for the wall, while the stressing anchorages of the slab tendons are placed in stressing pockets left in the top surface of the slab, alternate tendons being stressed from opposite sides. Fig. 2 shows the typical tendon layout. The reason for this layout is that the tunnel walls are directly cast against the anchored retaining walls of the excavation. The width of the excavation is limited by the proximity of the road and by property boundaries. It was not possible to leave a wide enough strip along the tunnel walls to allow the use of double breasted formwork.

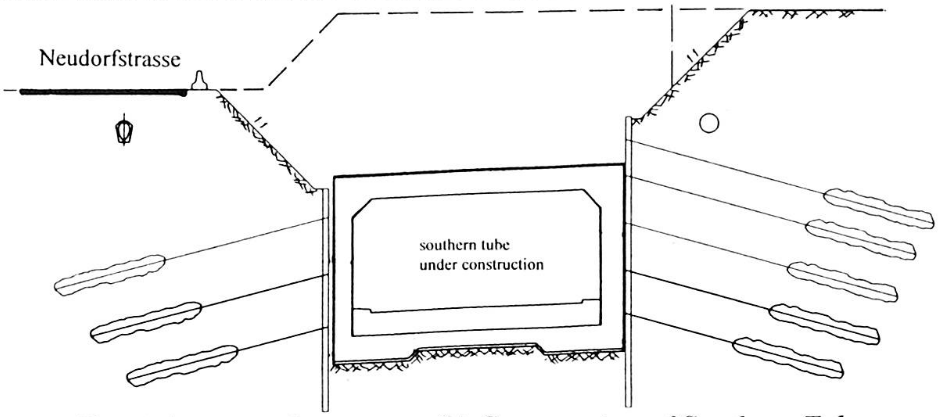


Fig. 1 (continued) *(b) Construction of Southern Tube*

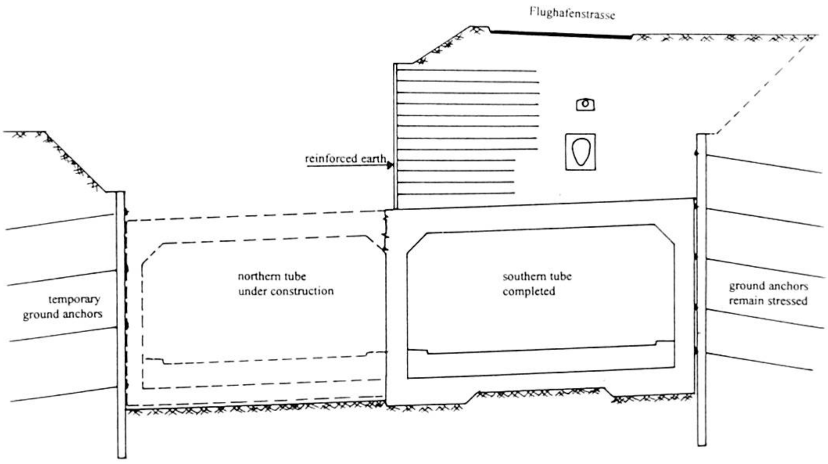


Fig. 1 (continued) *(c) Construction of Northern Tube*

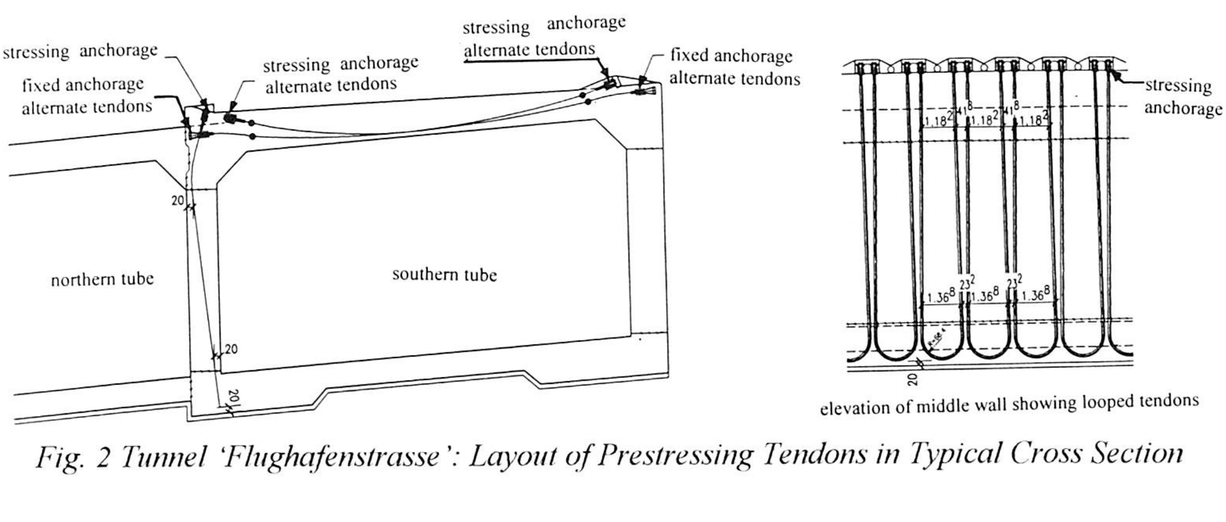


Fig. 2 Tunnel 'Flughafenstrasse': Layout of Prestressing Tendons in Typical Cross Section

3. Other Tunnel Sections

While the author is not directly involved, it is of interest to briefly present two more tunnel sections, where conditions completely different from those at the tunnel 'Flughafenstrasse' lead to quite different solutions. Both these tunnel sections are located on the right-hand side of the river and pass under densely built-up city quarters. The first, tunnel 'Horburg West' was designed by Aegerter & Bossardt, and the second, tunnel 'Horburg Mitte' by Walther Mory Maier. I would like to thank both these companies for making available the respective material.

3.1 Tunnel 'Horburg West'

This 363m long tunnel section under Horburgstrasse is characterised by the specific problems arising from the multitude of different underground services below street level, and from the rows of apartment blocks along either side of the street. Fig. 3 shows the typical cross section of the tunnel. The proximity of the foundations of the buildings to the outside walls of the projected tunnel requires underpinning measures before commencing any excavation work below foundation level. In some parts, the tunnel cuts up to 3.5m under the edge of the buildings. Two different methods of underpinning are employed: conventional section-by-section insitu concrete underpinning walls with temporary ground anchors, requiring relatively little disruption to the usage of the basements, and 15 to 25 cm ∅ micro piles installed from within the basements.

Major difficulties are caused by the various under ground services, which all have to remain fully operational during construction. These need to be temporarily diverted or fixed in place along the edges of the excavation. After completion they are rebuilt, and a services tunnel is constructed on top of the tunnel roof slab.

To minimise the duration of noise emission and disruption to traffic on this busy inner city street, the top-down construction method was chosen for this tunnel section. Three rows of ∅1.00m bored piles are installed, on top of which the top slab is constructed. This is carried out in two phases, as indicated in Fig. 4, to allow one half of the road to be operational at all times. After completion of the 1.20m thick top slab, the underside of which is at -5.0m below the road surface, the excavation is backfilled, replacing the underground services and building the new services tunnel. The tunnel is completed by excavating below the top slab to construct the insitu concrete base slab and the 30cm walls in front of the sheet pile walls. Since the ground water level is at approximately -8m, the ground water table only needs to be lowered by pumping during the construction phase below the tunnel top slab. After completion, a considerable part of the tunnel will be submerged in the ground water. A water-tight membrane is therefore placed around the entire tunnel cross section.

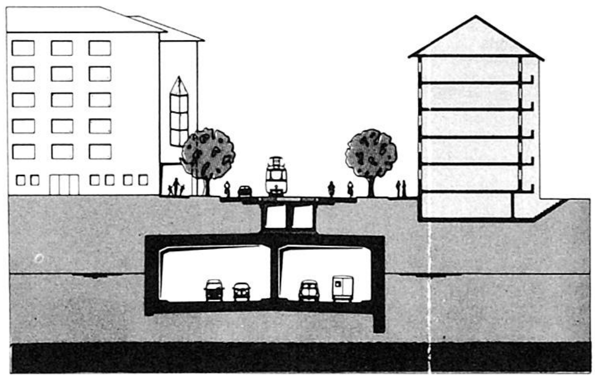


Fig. 3 Tunnel 'Horburg West': Typical Cross Section

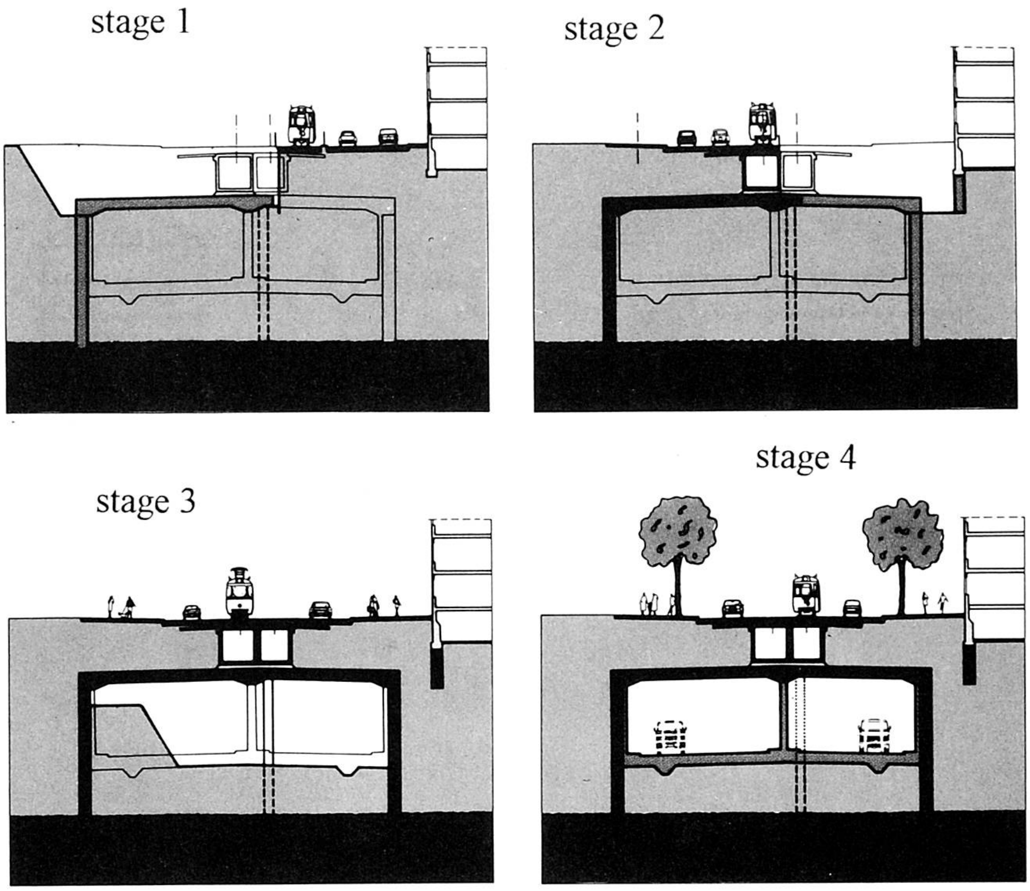
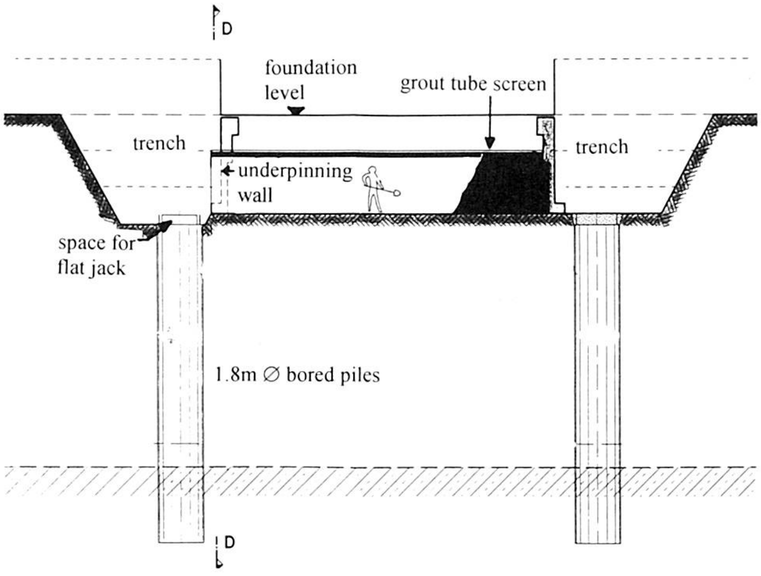


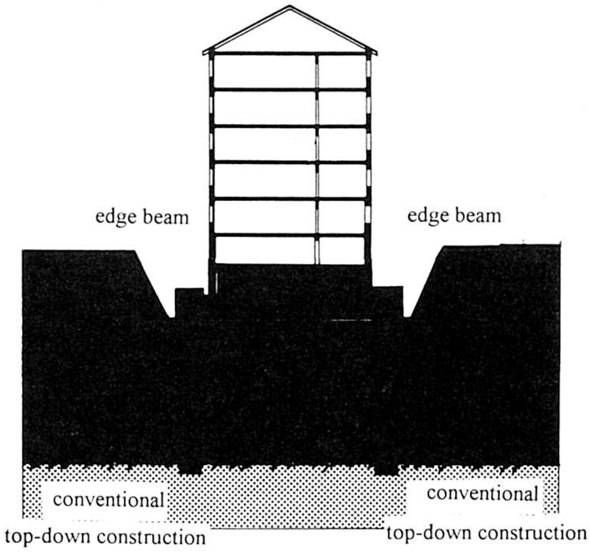
Fig.4 Construction Stages of Tunnel 'Horburg West'

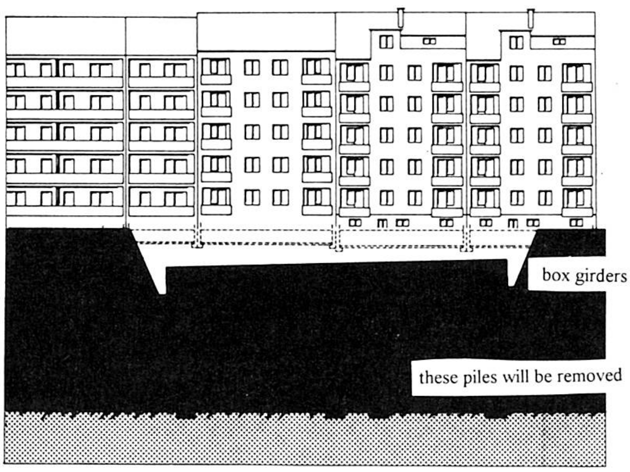
3.2 Tunnel 'Horburg Mitte'

This 247m long tunnel section is the continuation of the section 'Horburg West' and is of particular interest because it passes under a number of apartment blocks. Conventional tunnelling methods were not appropriate because the space between the top slab of the tunnel and the basement of the buildings is very small. The section 'Horburg Mitte' is also built using the top-down method of construction, hence the cross section is very similar to that of 'Horburg West'. And therefore only the specific problems of undermining the buildings shall be discussed.

Central to the selected solution is the construction of a transfer plate under the foundations. The principle is illustrated in the sequence of construction stages, Fig. 5. A trench is firstly excavated parallel to either edge of the basement (Fig. 5a). The foundations are underpinned in the process. These trenches serve two purposes: From one, injection tubes are driven horizontally under the basement to create a screen in the form of multiple cement grout arches. In addition, the soil between this screen and the basement is stabilised by cement grout injection. In the cover of the grout screen, 3.6m wide by 2.2m high tunnels are dug horizontally to build eight parallel partially prestressed concrete box girders which together form the transfer plate and the tunnel top slab (Fig. 5b). Shear keys and transverse prestressing serve to provide some load distribution between the individual box girders. After completion of the transfer plate, two partially prestressed edge beams, 2.8m high by 2.5m wide are built in the excavated trenches. These beams will later carry the load from the transfer plate to 1.8m ∅ bored reinforced concrete piles located on either side of the basement. Flat jacks are placed between the piles and the beams to transfer the load without undue settlements.







4. Conclusions

Three different sections of Basel's tunnelling project were presented, each characterised by very specific conditions and problems, leading to quite different structural solutions. At the time of writing this paper, the sections 'Horburg West' and 'Horburg Mitte' are well underway, while work on Tunnel Flughafenstrasse has commenced. So far, no major unforeseen problems have been encountered during construction.