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# Optimizing the construction method of a surface tunnel south of Vienna

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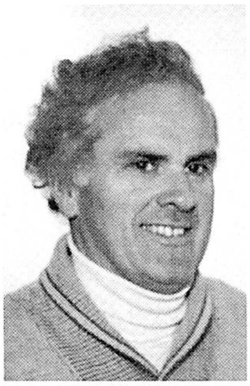

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**Summary**

Within the framework of planning a by-pass road in the south of Vienna a pass under will be required in order to traverse a built-up area. Since any re-settlement of the population concerned would be difficult to implement for political reasons, several economically, technologically and ecologically favourable variants were investigated in the context of an EU-wide planning competition and submitted to a comparative evaluation. The project refers to an approx. 2 km long route that would have to be executed near the surface and only in the immediate vicinity of buildings would mining constructions be necessary.
Three technologically different solutions were proposed both for the section to be realized in open construction and that requiring mining construction work.

## 1 Problem

A high-grade road link is needed on the south side of Vienna between the A 2 South motorway and the A 4 East motorway. The role of the road link is firstly to keep local traffic from the densely populated area of South Vienna out of the towns and villages, and secondly to link up the southern and eastern sectors of the city without putting a burden on the urban road network.

The traffic prognosis for this highway says that there will be between 30,000 and 60,000 vehicles per day in the year 2010, different in the various sections of the highway. The project involves a total of 14 kilometres of road. Five tunnels with a total length of about 4 km have to be built up as well as 5 surface tunnels, each with a length of 40 to 70 metres and about 20 bridges are included in this project.

As part of this planned road link, the Schwechattal has to be crossed in the vicinity of Rannersdorf. Surface solutions such as bridging the Schwechattal or a combined tunnel and bridge solution were discarded for town planning or environmental reasons.

In the General Project dating from 1994, the open tunnel method was therefore further pursued. This requires as shallow a depth below level as possible, while the mining construction tunnel requires as deep a position as possible because - according to the state of knowledge at the time - the intention was to cross the river bed in less permeable subsoil. In both cases, on completion of the motorway the Schwechttal is crossed by a tunnel approximately 2 km long. The open construction method involves relocating 22 houses, however.

In its wider setting, the planning area for the tunnel lies at the edge of the Vienna Basin, a typical trough created at the time of the Alpine rock formation. The basin linings are Neocene tea-green marls and sand in more or less parallel strata. During the 4 major ice ages, rubble with predominantly well-rounded components, loams and loess accumulated.

In the course of the preparatory work for the project, extensive subsoil investigations and hydrogeological investigations were carried out. These produced the following picture:

Under a thin layer of top soil or loess lies a thick layer of alluvial sediment, mainly sandy gravel. Below this is tertiary coarse clay and gravelly fine to medium sand. The upper edge of the sand stratum is encountered between 13 m and 22 m below the surface of land. Below the sand, at a depth of 20 - 29 m, come layers of clay and silt, in turn lying on top of layers of sand with clay or silt lentils embedded. Like the unhomogeneous geological structure of the planning area, the hydrogeological situation is also very unhomogeneous. The groundwater flows northwards through the quaternary gravel and tertiary sand strata more or less vertically to the proposed line of the tunnel. The groundwater table has a slight eastwards fall. The groundwater is very intensively used locally, including by one of the biggest breweries in the Vienna area.

Representatives of the local authorities and the State of Lower Austria vigorously championed the mining construction tunnel by the shield tunnelling method to keep disturbance to the local population to a minimum, particularly during the construction stage.

The estimated price difference at the time between an open construction tunnel and the mining construction tunnel was about ATS 370 million. The higher cost was felt to be quite disproportionate to the benefit that could be obtained with the mining construction method. The Federal Ministry of Economic Affairs therefore gave preference to the General Project with an open tunnel construction method.

In view of the controversy between the population affected and the construction sponsor over the method of tunnel construction, Österreichische Autobahnen- und Schnellstraßen Aktiengesellschaft decided to throw open a Europe-wide competition for ideas for alternative construction methods in order to tap the know-how of European specialists and thus find a cost-effective and environmentally compatible solution.

## 2 Competition

On the basis of the survey findings from the General Project, a Europe-wide search for potential tenderers was launched. Twenty-two candidates came forward with ideas for qualification in the first stage.

After a preliminary selection from the solutions submitted, 8 planning firms were invited to a hearing before a panel set up by Österreichische Autobahnen- und Schnellstraßen Aktiengesellschaft. The ideas were examined in detail by both the panel and representatives of Österreichische Autobahnen- und Schnellstraßen Aktiengesellschaft and 3 solutions were finally pronounced suitable for further development.

Accordingly, the engineering firms of

- Bösch & Gebauer - Munich Study A
- Stella & Stengel - Vienna Study B
- Strobl & Intergeo - Vienna/Salzburg Study C

were then asked to produce technical tunnel construction studies.

The terms of reference for the panel, formed of 2 university professors (Professor Jodl and Professor Semprich), a foundation engineering specialist (Sochatzy) and Mr Hörhan, were to evaluate the project from a technical point of view, identify imponderables, assess risks and work out technical advantages.

The planning firms were required to produce cost estimates to a preset comparable price level. These were examined in detail by the panel. Extras were allowed in cost estimating for geological method and cost risks associated with the projects.

## 3. Technical Solutions Proposed in the Studies

### 3.1 Study A

Study A comprises a combination of a single-shell open construction method with a mining construction tunnel building method at a shallow depth.

Open construction methods are used in the non-built up areas, which are mainly devoted to agriculture. The open construction tunnels can be backfilled and covered on completion to restore the site to its original state.

The way the open construction is done depends in particular on whether the routes pass above or through the groundwater. Accordingly, three different ways of making the excavations watertight were proposed. The open areas above the groundwater can be conventionally constructed with sloping cuttings. The slopes would penetrate the loess and gravel strata and were calculated at a 35° angle. Geotextile, sheeting or tried-and-tested shotcrete are proposed as temporary waterproofing of the slopes. The method suggested for open construction in the groundwater uses sheet piling to form a temporary water barrier. Because the rubble is expected to be densely packed, it is proposed to open up the ground by boring ahead of the sheet piling. The sheet piling will be put in place by the vibratory flushing method. Due to the relatively permeable sand layers in the integration area, tricky lengths of up to 25 m of sheet piling will be involved.

There is a relatively short section where open slope excavation is not possible. The excavations will therefore have to be secured by means of triple-anchored sheet piling in this area.

The actual tunnel structure will be constructed in the open area as a rectangular section with a centre partition and two lanes in either direction. At the point of transition to closed construction, 2 individual tubes will be constructed.

One advantage of using vibrated sheet piling as a barrier that was acknowledged during the evaluation is that it can be removed again once the construction work has been completed to minimise interference with the groundwater. Another point that has to be taken into account, however, is that sheet piling is not very flexible with respect to the changing depth. Relatively thick layers of sand are to be expected underneath the gravel stack.

The proposed method of tunnel construction in the built-up area is the New Austrian Tunnelling Method (NATM), which would be used to drive two individual tunnels protected by a watertight casing. As a rule, a subterraneous curtain with a 40 cm bulkhead width is used. In the section where the working area is too small, it is proposed to use the jet grouting method for the bulkheads. The two tubes of the tunnel will be driven in a protective vault from injection anchors. Inside the watertight casing, the groundwater table will be temporarily lowered to below the subsequent tunnel floor by means of vertical wells.

The panel judged Study A to be a feasible project with a manageable geotechnical risk. The proposed standard construction methods for both the open and the closed sections together with the recoverable bulkhead were regarded as advantages. A further point in its favour is the partial over and under flowing of the shallow tunnel structure in its final state. The single-shell construction in the fully overflowed area may lead to maintenance problems in the long term.

### 3.2 Study B

Study B comprises a combination of a twin-shell underground construction under top cover with mining construction tunnelling at a shallow depth.

As in the case of Study A, open construction is proposed in the non-built up area. In the section below the groundwater, the excavation would be sloped. In the parts where the tunnel cross-section penetrates the groundwater, it is protected by a narrow wall or curtain casing. The narrow walls are sunk from a preliminary level just above the groundwater table and tail into the groundwater bank. They are set back into the slope of the excavation so that when the excavations are carried out, the slopes will form the supports for the narrow walls. In the area of the subterraneous curtain casing, the tunnel is constructed under top cover with underground excavation. Inside the casing, the excavation is protected by an interior water barrier.

In the built-up area, both tunnels are constructed by the NATM using compressed air to control the rush of water. This requires preliminary sealing using cement bentonite via injection shafts from the surface. In addition to this shield, injection over the area of the cross-section is also proposed to stabilise the local face. The intention is to reduce pressure losses and permit roof driving. The maximum pressure head of 1 bar will be required while driving.

This Study was also acknowledged in principle by the panel as a feasible project with a manageable geotechnical risk. The tried and tested top cover construction method and the short duration of surface work, with less disturbance of surface structures and the population, was regarded as an advantage of this Study. Driving with compressed air is difficult and involves technical risks. On the other hand, the permanent levelling out of the groundwater using only drains is considered a drawback for the project as a whole from the point of view of maintenance.

### 3.3 Study C

In contrast to the other two studies, Study C involves a continuous single-shell construction at optimum shallow depth using guided caissons. This requires the construction area to be cleared along the whole length of the route, and hence resettlement of people living along the route.

The open tunnels are constructed separately with a distance between centres of 15.8 m. This leaves a body of earth 5.0 m wide between the tunnel wall exteriors. Construction involves sinking 15 m long prefabricated wall sections with a knife-shaped foot in pairs. During the sinking process the walls are held apart by 2 steel braces at the long ends and held in place and guided by a driver.

Temporary damming beams close the front of the excavations to prevent soil entering. Bentonite suspension can be introduced between the soil and the walls or between the soil and the damming beams to reduce the frictional forces during the driving process.

Following driving, the underwater concrete floor will be put in place. The walls of a section of tunnel will thus be fixed in position. After that, the assembly and sinking of the next pair of wall sections can start. A primary tubular seal will be fitted in the collapsed state in a recess on the front of the walls and cross-cutting between adjacent wall elements and cross-cutting. This is sealed by synthetic resin for chafing protection until the seal is inflated. Point sliding bearings are used to transmit the soil pressure from the caisson to be lowered to the adjacent sunk caisson.

The tunnel is roofed by 30 cm thick, 1 m wide prefabricated concrete panels. These serve as shuttering for the impermeable in-situ concrete roof.

Once the tunnel roof has been put in place and surcharged, full heave protection is guaranteed, and the tunnel can therefore be pumped completely free of groundwater.

To guard against any leaks in the primary seal, an additional compression seal is provided during the sinking process. Swallow-tail sealing sheets are to be fitted between the wall elements and the watertight floor. The joints between the individual wall plates and the sealing sheet are designed as pressure joints and sealed with swelling strips.

Injection tubes run parallel to all the sealing strips, allowing any leaky joints to be repaired if necessary. The project was evaluated by the panel as very innovative with a higher yet manageable technical risk. The construction risk is also high insofar as there are no comparable examples of implementation. In cost terms, at any rate, this is clearly the most favourable project, especially since in contrast to the other studies it involves a solution using wholly open construction.

## 4 Summing-up

The study has shown that it is entirely possible from a technical and economic point of view to construct a surface tunnel using mining construction methods. Combined solutions using open construction in open countryside and closed construction in built-up areas are also attractive from an economic point of view.

The cheapest method to emerge from the study is wholly open construction using caissons, with a total construction cost of approximately ATS 1.20 billion. This contrasts with combined methods costing around ATS 1.55 billion and the wholly mining construction tunnel at about 1.95 billions. The difference of ATS 370 million between open construction and mining construction mentioned at the beginning has increased to around ATS 770 million due to the technically highly innovative solution using caissons. From a technical point of view, the outcome can be judged very satisfactory, though local people could not be convinced of the appropriateness of an economic solution, even with the now even greater difference between the construction methods. On the basis of the study results, the price difference between combined solutions and open construction is still so great that the decision to use an environmentally compatible construction method has not yet been taken.

Having regard to the diverse range of solutions carefully and painstakingly worked out by the firms concerned, the competition should nevertheless be considered a success.

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