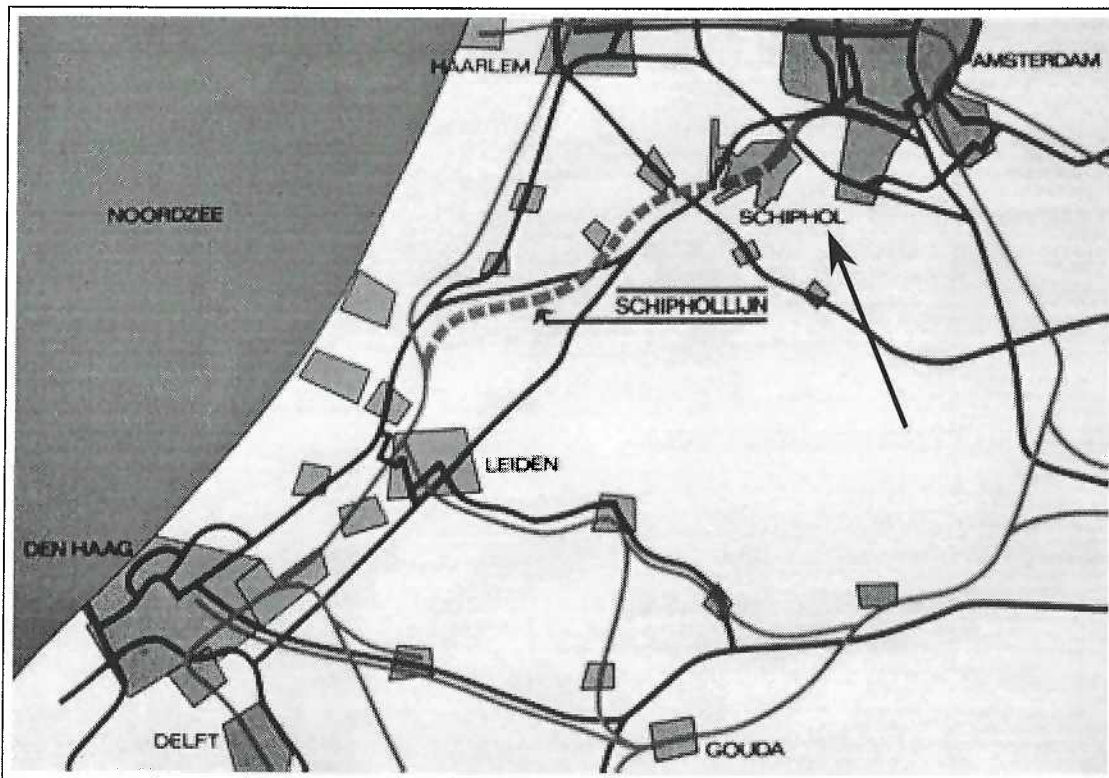


THE SCHIPHOL RAILWAY TUNNEL

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1. Introduction

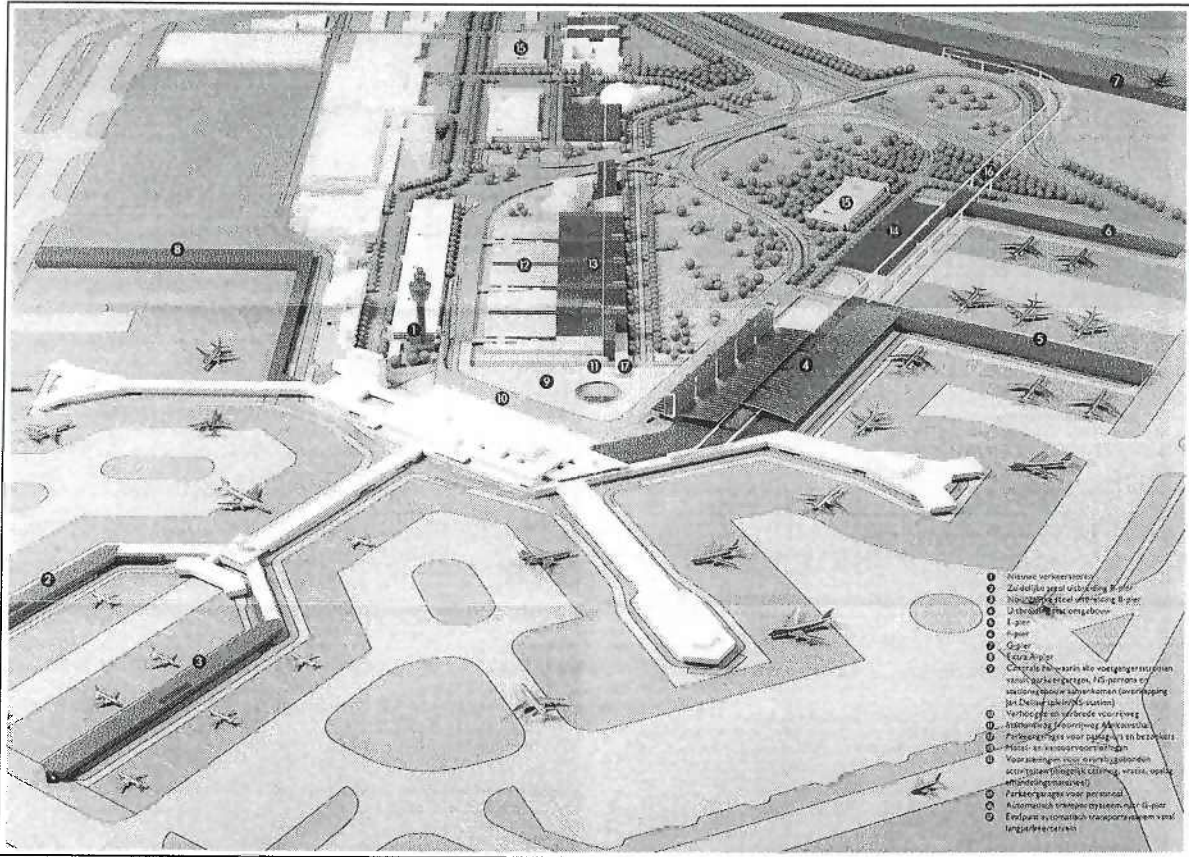
Schiphol, the most important airport in Holland, is situated in the Haarlemmermeerpolder near Amsterdam.



"Location of the airport"

This airport wishes to grow into one of the five largest airports in Europe, with the status of a main entry port into the continent. That means that the number of annual passengers is planned to increase from 16 million in 1990 to 34 million passengers by the year 2005.

In connection with this planned growth Schiphol airport had developed their ambitious Master Plan 2003, which provided for an expansion of the airport with the provision of new car parks, hotels, offices, roads, fly-overs and a new terminal.

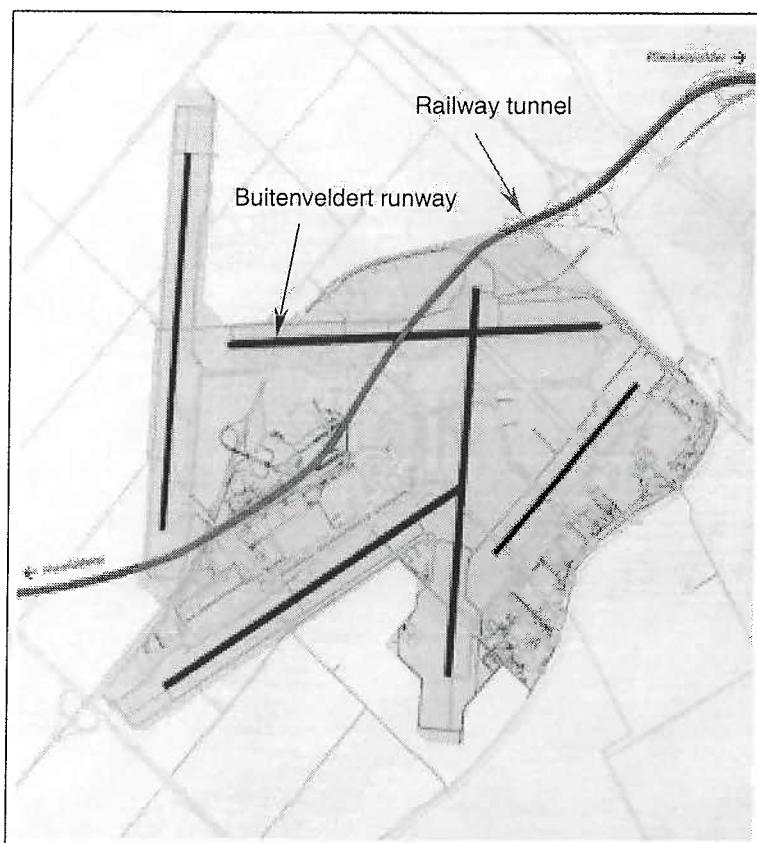


"Master Plan 2003"

The Dutch railway company NS was first informed by the airport authorities about their plans in 1988.

Circumstances

There has been a 5.5 km long double-track railway tunnel under Schiphol Airport since the 1970's. As the airport was aiming at doubling its capacity as part of the Master Plan 2003 and Dutch Railways wanted to increase the number of tracks for the line to four as part of its Rail 21 plan, a major project to double the size of the railway tunnel under Schiphol was instigated in 1989.



"Railway tunnel beneath Schiphol"

The conditions which had to be met here were that all air traffic and rail activities had to be able to continue unimpeded, and that passengers should be inconvenienced as little as possible. A clear and detailed agreement between all parties in respect of the activities to be carried out was therefore needed, with preparation and planning assuming a very important role.

Doubling the width of a 5.5 km long tunnel in such a busy airport presented a major challenge. 800 metres of the new tunnel had to be integrated within the existing tunnel for the station-part and 4700 metres had to be built directly alongside the existing tunnel. The preparation time for the job was very short.

For that reason NS decided to appoint a building consortium made up of two major contractors to try and meet this challenge. Only three months after the formation of the consortium, the first sheet piles for this project were driven in April 1989.

2. Soil conditions along the tunnel route.

As said before the tunnel was located in a polder four metres below sea level.

The first soil layer occurring at ground level along the tunnel route consists of 1.5 metres of sand fill, formerly brought in from elsewhere. The second layer, from -5.5m to -10.5m NAP¹ consists of a mixture of in-situ sand and clay.

Below these layers, at a level from -10.5m to -11.0m NAP, a consolidated peat layer was found, which forms a barrier between the atmospheric groundwater surface at -4.8m NAP, and the brackish and slightly pressurised water trapped below, which has a pressure head of -4.50m NAP. Below the peat layer is dense Pleistocene sand with a high compressive resistance.

For the construction of the tunnel the cut-and-cover method was chosen. The chosen construction sequence was as follows:

1. Driving compressive and tension piles from ground level.
2. In order to excavate the construction pit in the dry down to a level of -6.50m NAP and fix a layer of struts and wailing's, the natural groundwater was lowered by pumping within the sheet pile cofferdam to -7.0m NAP. To prevent the bottom of the pit from bursting up because of the unbalanced water pressure, the pit was subsequently refilled with water to a level of -4.50m NAP. The remainder of the excavation was then carried out under

¹ NAP = reference level [Nieuw Amsterdams Peil]

water. The video that you will see during my presentation will make the procedure clearer.

3. When the pit was deep enough, tremie concrete was poured underwater to form a temporary watertight barrier in the bottom of the excavation. After hardening of this concrete the pit could be pumped completely dry.
4. Construction of the concrete tunnel with standard reusable formwork.

Pile systems used

So-called VIBROCOMBINATION piles were selected as the most suitable type of pile for this situation; they consist of a steel tube with a closed foot, which is first driven into the ground; then a pre-stressed prefab concrete pile (core) is placed in the tube. The space between the core and the steel tube is filled up with grout and the steel casing, forming two possible pile types; either a tension pile (pile always carrying a tensile load) where the prefab core has a ribbed head; or a bearing pile (pile only has a compression load in the final phase) where there is no need for a special head.

What are known as TUBEX GROUT INJECTION piles were also used at places where the working height was not sufficient for the equipment needed for the Vibro-combi piles. This is a vibration-free pile system in which a steel casing fitted with a special point is driven into the ground in segments. Grout is injected at the same time.

Water management of the pit

The water that was pumped *into* the pit was freshwater from the nearby canals. The water that was pumped *out* of the pits was however brackish and therefore had to be piped to specially constructed holding basins located elsewhere within the airport area. After reducing the chloride content of the brackish water with more fresh water or rain water, it could then be safely pumped into the canals of the polder without causing any environmental harm. In some cases, the brackish water was injected directly back into the deeper ground layers.



"Water Storage at the airport area"

Site conditions

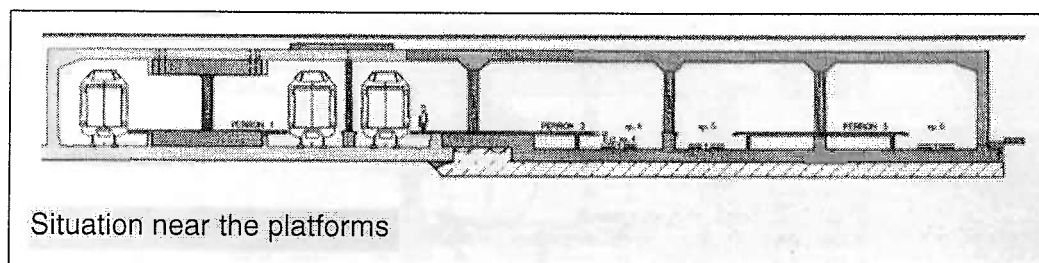
NS had specified that the construction of the new tunnel should cause no vertical settlement of the existing tunnel at all; and that any horizontal movement of the existing tunnel had to be limited to 4mm. The sequence of construction for the new tunnel had also to be worked out in close consultation with the airport to fit in with their own program for upgrading of the airport facilities. The airport authority would not accept any settlement of the runways.

The project is divided into a number of segments, most of which had their own specific design and/or constructional problems. This paper describes two particularly challenging sections of this interesting work:

1. Where the new tunnel had to be integrated with the existing one.
2. A 500m length of tunnel, which had to pass under a runway; here the immersed tube method was used to meet the tight time schedule.

Ad 1. Connecting the new tunnel to the existing one

A long section of the new tunnel had to be structurally linked to the existing one.



"Example of integrationIntegrate"

The architect demanded a completely open area where the platforms are located, which made it necessary to remove the existing tunnel wall. The existing tunnel had been designed and reinforced as a closed tube, and was therefore not easy to partly demolish and extend. However, by connecting the floor and deck of the new tunnel to the existing tunnel with pinned connections it proved possible to replace the dividing wall with a row of columns.

To this end, individual bases were built under the platform, and holes bored for pins from these bases to project through the existing wall. The pins were glued into the wall, which then formed a moment free connection to the floor.

The new roof was also fixed to the existing tunnel by means of pins which had been drilled into the existing roof, extra anchorage being used to withstand the fixed-end moment in the roof slab.

The load transfer of the existing roof changed from a continuous support to a number of concentrated supports because the existing wall had been replaced by a row of columns. Since the existing tunnel roof contained no shear reinforcement, short prestressed bars were introduced to ensure that the increased shear forces would be resisted.

The existing wall was demolished after these measures had been implemented, completing the connection of old and new tunnel cross-section. All modifications to the tunnel section were hidden under the platforms or the false ceilings, so that nothing more can be seen of these provisions.



"One of the pits near the connection part"



"The connection near the station"

Ad 2. The immersed tube tunnel

The route of the tunnel had also to cross the "Buitenveldert" runway (See figure at page 3) and two taxiways over a length of 500 metres. In July 1993 this runway and the taxiways were planned to be out of service until June 1994, for necessary maintenance and refurbishment. After this date the runways/taxiways had to be operational again for aircraft traffic. This allowed a window of opportunity for the construction of the tunnel under the "Buitenveldert" runway, but the actual time available was limited to only 7 ½ months.

After studying a few alternative methods of execution in terms of time, cost and risks, an immersed tube tunnel was chosen as the solution.

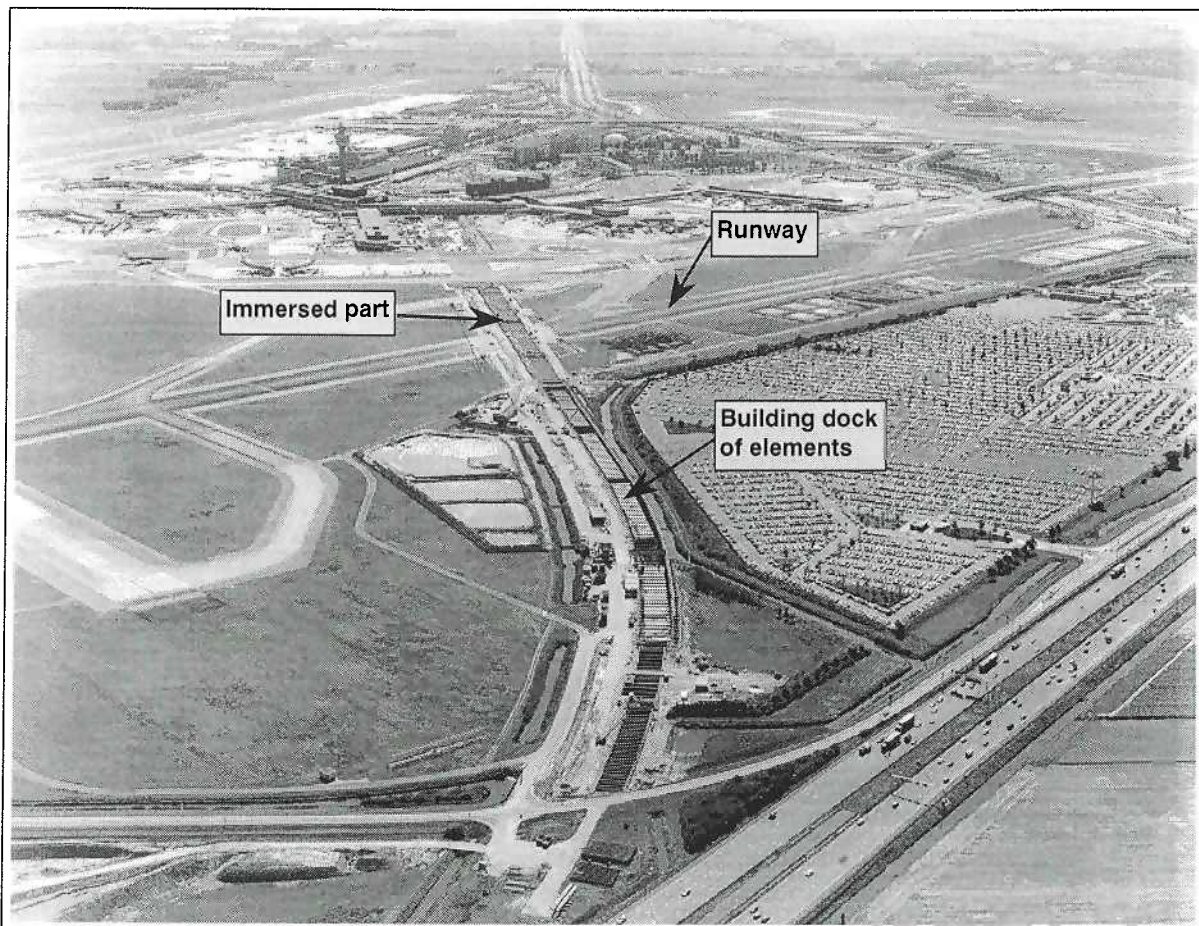
Because an adjacent part of the tunnel had to be built at a later stage, this adjacent tunnel pit could also form a suitable building dock for the immersed tube segments.

In this dock with a length of 540m, four tunnel elements each 125m long were assembled. After crossing the runways with a line of braced sheet pile walls and having dredged the pit until the required depth has been reached, the floating tunnel elements were transported into position and immersed.

The tube elements were flexibly connected against each other by means of a rubber joint, after which a sandlayer was pumped beneath the tunnel.

After loading these elements with a layer of soil, the ballast tanks in the tunnel could be removed and the joints completed.

Using this method the whole 500m length was constructed within the maintenance period of the runway.



"View of the dock and the runway crossing"



“View inside the dock after transport of the immersed elements”

3. Conclusion

Only a few aspects of this very interesting work have been discussed here; a full description would require a whole book!

The new railway tunnel is now in full operation in 1999, about 10 years after the flying start in 1989.