Work on the railway

The railway zone is a marvellous ‘test lab’ for Delft researchers.

We look at the work underground and some of the projects, from distinctive station designs to a study of the way the city ‘breathes’.

Tomas van Dijk

The Markt, with the Stadhuis and the Nieuwe Kerk, is not the true heart of Delft, says Willemijn Wilms Floet, of the faculty of Architecture’s building typology research group. “Geographically, the railway zone is the city centre. Once the railway line has been moved underground, this will be an extremely interesting district,” she contends, “but only if it can be structured as a dynamic hub that increases the vitality of the city.”

Wilms Floet has been studying the railway zone for eight years and supervises relevant Bachelor’s and Master’s projects. She has written several books about the district and knows its history inside out.

“For years, Delft has been pressing for the above-ground railway line, laid in 1968, to be relocated,” she states. “It is a bottleneck which blocks the addition of a fourth overtaking track. The intercity trains cannot get up enough speed because of the bend or ‘dogleg’ in the route. Moreover, an above-ground railway line running through the city creates unacceptable noise and an unattractive area. A railway tunnel will solve all these problems.”

Greater cohesion

The tunnel will also create greater spatial cohesion between the historic city centre and the more recent expansion areas. Westlandseweg, for example, the road which connects the city centre with Delft-Zuid (a district which most people currently regard as a suburb, says Wilms Floet) will be transformed into a tree-lined city boulevard. Phoenixstraat will also become a boulevard, with the Nieuwe Singelgracht canal, filled in since the late 1960s, largely restored.

Above the 2-kilometre railway tunnel will be a long, narrow park. There will also be space for 1,500 homes and 50,000 square metres of offices and shops. There will be very little construction immediately above the tunnel itself, however, because it would be too expensive to insure against collapse should there be a disaster.

Alongside the existing station is to be an imposing futuristic building, designed by Mecanoo architects, combining the new station and the local council offices. The area development plan has been produced by the Spanish urban planning specialist, Joan Busquets. “In terms of construction, the development plan remains quite flexible,” says Wilms Floet, “although rules have been devised for the various blocks. There must be plenty of variety, just as in the existing city centre. And the blocks must all have semi-public courtyard gardens.”

In the graduation phase of the Master’s programme in hybrid building, students use Busquets’ design as their starting point. It forms a framework against which they can assess their own design solutions. Recent graduate, Luuk Stoltenborg, thought that the area around the new station had been given too modest a role within Busquets’ plan. “An almost invisible transport interchange,” was his verdict. He therefore designed two separate buildings, one on each side of the existing station, with one entirely dedicated to the council offices. The open area between the three buildings would extend under part of the station itself. This is possible because his design for the new station is ‘stacked’ on several levels, with the platforms underground, below the station forecourt. Luuk has incorporated three further levels above that, with hotels, restaurants and conference facilities. Huge light-wells ensure that the lower levels enjoy adequate daylight.

Stoltenborg’s design won the 2007 Zuid-Holland Design Award, the incentive prize which acknowledges the best designs by students in the province of Zuid-Holland. In 2008, the competition focused on ideas for Delft’s railway zone. The winner of the public award was Carien Akkermans, who treated the new station as a means of restoring an important historic element of the city. She suggested that the station exit should run through a sort of transparent plinth to emerge at the Bolwerk, which until the mid-nineteenth century was the site of Delft’s main city gate. So there is no shortage of good ideas. “It’s just a pity that the city authority doesn’t always listen to us carefully enough,” says Wilms Floet with a smile.

Dr Stefan van der Spek of the faculty of Architecture is also using the railway development zone as a gigantic laboratory. He wishes to study, “how the city centre..."
functions today, and how it functions once the entire programme is complete.” He sees pedestrians as the lifeblood of the city. By equipping dozens of volunteers with GPS receivers, he will map the routes they use most frequently. Van der Spek’s experiment began in April. He intends repeating his observations every season during the construction process, continuing after its completion. “At present, the railway zone is a sort of no-go area,” he says. I want to see how that changes.”

Subsidence
If any of the houses in and around the railway zone begin to show small cracks in ten or twenty years’ time, remote sensing expert, Professor Ramon Hanssen, of the faculty of Aerospace Engineering, will be able to determine whether this is due to the tunnelling work. Ever since 1992, his research group has been monitoring ground movements in Delft using data from radar satellites. “We analyse the land and the buildings on it from two positions in space,” he explains. “For the past year, we have done so using data from the TerraSar-X satellite. We receive the data every four or five days: one measurement when the satellite travels from the South Pole to the North Pole, and hence over Delft, and one when it goes from the North Pole to the South Pole. Due to the Earth’s rotation, the satellite once again passes above Delft - ed.]. Until 2009, we relied on a satellite which passed over the city only once every 35 days.” Each satellite photo covers an area of 30 kilometres by 60 and has 200 million pixels. A small group of students and PhD students analyse each and every pixel – using software, of course. They are looking for any deviations over and above the ‘natural breathing of the city’.

“In the summer, the land dries out, whereupon the soil settles and the city subsides very slightly,” Hanssen explains. “In the winter, the level is restored. Buildings, on the other hand, expand in the heat of the summer, sometimes by as much as several centimetres, depending on the height of the building. We term these movements the ‘breathing of the city’. Any deviation over and above this natural process can cause excess tension within the structure of buildings. Although minor, this tension could lead to cracking at a later date, even after the construction work has finished. If you want to establish a causal link, it is important that you know all the ground movements that have taken place over a long timeframe.”

Risks
It is almost impossible to preclude slight subsidence due to the construction work on the tunnel. But what about major landslips, such as that seen in 2009 near the new Vijzelgracht metro station in Amsterdam? The construction of the double-bore underground railway tunnel in Delft is certainly no simple task. Peter Gossink, director of the consortium Crommelijn, is clear about that. The City of Delft and Prorail, the company responsible for the Netherlands’ rail infrastructure, have commissioned Crommelijn to build the tunnel, which will take several years to complete.

“This tunnel project is by far the most ambitious that I have been involved in to date,” Gossink said earlier this year during the ‘Delft – build on your future’ symposium. But Gossink sees the main challenge as a logistical one. Over a 10-year period, various sections of the railway zone will be dug up in succession, but during this time trains, buses, trams, cars, cyclists and tour boats must be able to pass along this major city artery as smoothly as possible. Gossink is not afraid of major subsidence, such as that seen
in Amsterdam. “There, they are digging to a depth of 32 metres. We are only going down 12 metres. That makes it very much less hazardous. Moreover, the subsoil here is very different.”

But JanGeert van der Post, TU Delft alumnus and one of the project managers for the City of Delft, reminds us that it is not as simple as it sounds. “One of the tunnels will be just three metres away from the houses on Phoenixstraat. That is very close. To excavate the tunnel directly from the surface here would be too risky, so we shall use the ‘diaphragm wall’ method instead.”

This means that contractors will dig narrow trenches to a depth of 24 metres, which is where the first sand layer is found. While they are digging, they will keep the trench filled with bentonite, a sort of clay suspended in water, which prevents the trench collapsing in on itself. Once the trench is to the required depth, steel reinforcement meshes are installed and concrete is poured in. The concrete takes the place of the bentonite and the diaphragm wall takes shape.

“During this work, the houses are likely to shift by a couple of millimetres,” reports Van der Post, “but this movement will be very gradual.” To keep subsidence to an absolute minimum, the sections of diaphragm wall, each of which is several metres in length, must not be built directly adjacent to each other but with spaces in between. Once a series of the walls has been completed and the soil has completely stabilised, further walls are then installed to fill the gaps. Once all the tunnel walls are in place, a concrete roof is added. Contractors can then proceed to excavate the earth from within. The first tunnel is due to be completed in 2013. All trains will then pass through this tunnel and the above-ground railway can be removed to allow contractors to start on the second tunnel, which will be completed in 2016. After that, work on the parks and buildings will begin.

**Leaks**

There are various mishaps that can occur on a project like this. The joints between the diaphragm walls are sealed with a sort of rubber flap. But what if there is nevertheless a leak? This problem was also seen at the Vijzelgracht station project in Amsterdam. Water flooded into the excavation site, bringing with it sand from the sand layer on which the foundations of several adjacent houses were standing.

Luuk Stoltenberg’s design consists of different layers.

“**In Delft, there can be no erosion of the sand layer like this,**” states Van der Post. “Above the sand layer on which the diaphragm wall rests, and on which the houses’ foundations also stand, is nothing but clay and peat. They will not wash away.”

Even so, Van der Post regards the Het Bolwerk section as a challenge. At this point, contractors will not use the diaphragm wall method but the more traditional ‘box culvert’ on pilings. “What makes this location so difficult is that there was once a small river, the Gaag, running through it,” Van der Post explains. “The subsoil is therefore very different. The sand layer is much nearer the surface and any leakage would create a far more hazardous situation. Another factor is that there is a slight bend in the railway line at this point. The pilings supporting the railway are not vertical, but have been driven at an angle to counteract the sideways force exerted by the trains as they negotiate the bend. This makes the work more difficult, since the slanting piles leave less room to manoeuvre.”

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**Railway tunnel for Delft**

Delft’s railway viaduct carries 350 trains a day and is one of the busiest train routes in the Netherlands. A new 2300-metre railway tunnel is to replace this two-track viaduct, which dates from 1965.

**Diaphragm wall method**

The diaphragm wall method will be used for large parts of the tunnel. The advantages of this technique are that relatively little space is required and surface works are kept to a minimum. Other locations will use sheet piling and traditional open excavation.

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**Delft railway remains two-track**

In Phoenixstraat the first phase (2009 - 2012) will involve constructing the east tunnel. In the curve just before the station, the piles of the railway viaduct lie partly in the planned route of the west tunnel, so the west tunnel can be built only after the viaduct has been removed – which can only be done once trains can be routed through the east tunnel. The two tracks in the east tunnel are planned to be ready for use in 2013. The west tunnel, with space for another two tracks, will be delivered empty in 2016. The west tunnel will not immediately be fitted out for train transport, so even with the new tunnel Delft will remain a two-track route for the time being.

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**Diaphragm Wall Construction**

- **A** Guide walls are placed
  - The guide walls ensure that the excavator bucket falls in a perfectly vertical line. Even a small deviation by the excavator can cause a serious slant in the diaphragm wall.

- **B** The trench is excavated
  - Diaphragm wall digging machines dig trenches up to 24m deep. The trench is immediately filled with bentonite, a special mixture of water and clay, which protects the trench from collapse.

- **C** Rebar is positioned
  - A crane lowers the steel rebar construction into the trench.

- **D** Concrete is poured
  - Concrete is piped into the bottom of the trench. The displaced bentonite is pumped off for reuse.

- **E** The next panel is excavated
  - The diaphragm wall panels are constructed consecutively. Once a panel has dried and set, the adjoining section is excavated, with the existing concrete panel serving as a guide for the bucket. In Phoenixstraat, two diaphragm wall construction units are in use.

- **F** The roof is poured
  - When all the tunnel’s diaphragm walls are ready, a concrete roof for it is poured.

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**Demolition of railway viaduct 2013**

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**Tunnelblend**

- **Tunnel width**
  - **90 cm**

- **Tunnel depth**
  - **24 m**

- **Tunnel thickness**
  - **1 m**

**Diaphragm wall**

- **Depth of sand layer**
  - **25 - 8 m**

**Habitat**

- **Habitat protection**
  - **20 m**
Excavating the tunnel under the roof
The tunnel is then excavated through openings in the roof, and the material transported away by lorry.

The floor poured and walls constructed
After the tunnel is excavated, the floor and interior walls are constructed. The central wall divides the tunnel into two fireproof halves.

Narrow diaphragm walls
A number of nearby buildings – the Hoogheemraadschap (water board), the Nusantara Museum and the Delft Studenten Corps (student society) – do not have pile foundations, and run the greatest risk of subsidence as a result of tunnel construction. The building closest to the tunnel wall is that of the Corps, with a distance of just three metres.

Moving stock
The diaphragm wall method involves a succession of building activities. Works will begin at the Binnenwatersloot crossing and will gradually move towards the Roos windmill.

Deep sand layer
Broadly speaking, the ground under Delft is made up of three layers. The topmost is a thin layer of sand and rubble. The second is a thick layer of compressed peat and clay. The third and lowest (at 24m) is a sandy layer that is capable of bearing weight. The diaphragm walls and foundation piles of the tunnel have to stand on this deep sand layer.

Historic monuments above the tunnel
The Molen de Roos windmill and the Bagijnetoren fortified tower, both national historic monuments, lie above the tunnel route. Both monuments will be given new foundation piles resting on the tunnel roof. Because the fortified tower stands directly above the planned route of a tunnel wall, the tower will be temporarily moved 20 m. The east tunnel wall will be constructed in a bend around the windmill.

Underground car park
In Spoorsingel a two-storey underground car park, with about 650 vehicle spaces, will be built next to the tunnel.

Tunnel length
2300m (including approaches)

Total investment
500 million euros
(100 million euros inclusive real estate)

Client
NS ProRail

Works contractor
Combinatie CrommeLijn

Diaphragm wall height
24 m

Depth of tunnel floor below surface
-8.9 m NAP

Sand cover above tunnel
About 90 cm

Tunnel width
External dimensions 25.8 m