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A2 Maastricht Tunnel: Geotechnical Risk Analysis

Summary

This article summarizes the conclusions of the MSc thesis of the author, based on research done under supervision of the A2 Projectbureau.
The A2 Maastricht Project's goal is the design and construction of a tunnel for the busy A2 motorway, which runs right through the city of Maastricht.
The A2 tunnel shall greatly reduce current daily traffic problems which negatively impact Maastricht's living conditions.

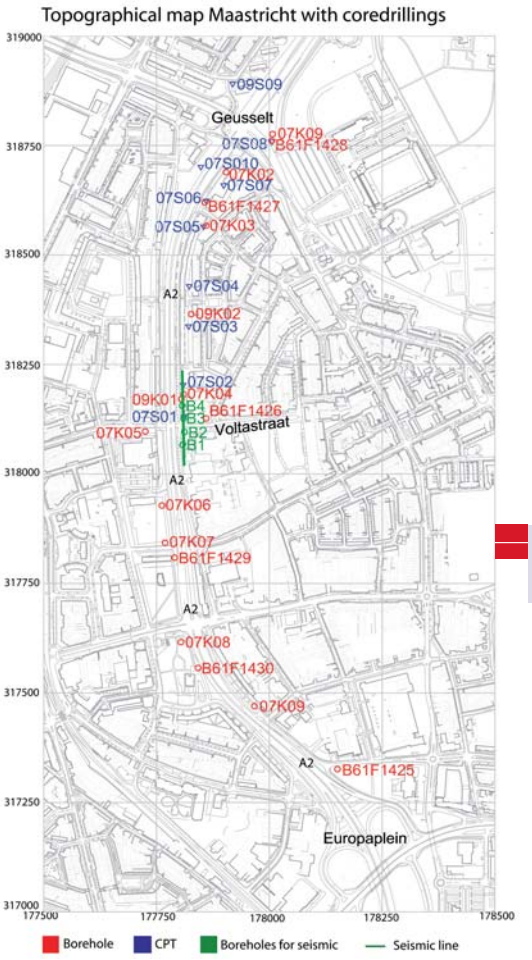

Figure 1 *Overview of the project location. The site investigation locations are indicated.*

The A2 Maastricht project is a challenging project indeed, as this tunnel will be constructed using cut-and-cover techniques in a deep building pit, to be dug in a subsurface very unusual in the Netherlands. The tunnel will be built on 2 levels, with on each level 2x2 traffic lanes, separated by a safety tunnel. Total length of the tunnel is to be about 2300 m, roughly between junctions Geusselt and Europaplein *(see figure 1)*.
The main goal of the research and subject of this article has been to get a better insight in geotechnical risks involved, by linking geology to different physical properties of the local limestone; which were obtained by geological, geotechnical and geophysical surveys.

The surface level along the planned tunnel varies between 46 and 50 m +NAP, and the groundwater table is about 3 m below surface. The subsurface consist of a top soil of about 3 m of sand and clay, and a 10 m thick gravel layer on top of limestone from the Formations of Maastricht and Gulpen, containing flint and hardground layers.
The Formation of Maastricht here consists of six members, the material properties of which are presented in *Table 1*.
These members are distinguishable, based on characteristic horizons, hardgrounds and flint content. Vertical displacement of these members between adjacent boreholes revealed the existence of faults. On one location (intersection Voltastraat) a fault was found with a displacement of about 15 m *(see figure 2)*. The chemistry of the groundwater confirmed a connection between the gravel and deep limestone layers.
Site investigation data were used for Risk Determination. Descriptions and laboratory tests (UCS and pocket penetrometer tests) of seventeen 'undisturbed' cores along the tunnel alignment were available, as were data from some in-situ tests (Menard and Lugeon tests).

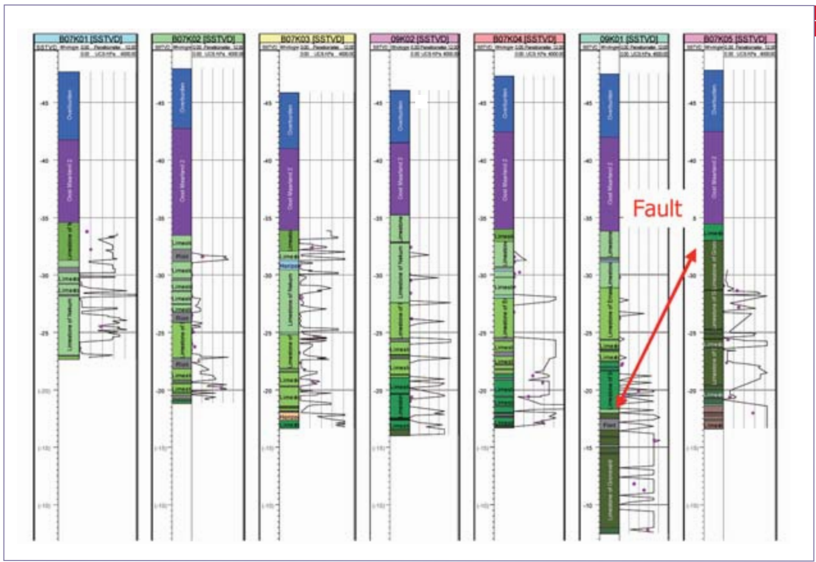

Figure 2 *Adjacent boreholes. Blue represents the top soil, purple the gravel layer, the green colours the different members of the Formation of Maastricht and brown the Formation of Gulpen. The black line indicates the pocket penetrometer readings.*

Geophysical Techniques

To get a better understanding of the (existence of the) fault and to find more information on the local subsurface in general, different downhole geophysical techniques were tested in the fault area. Most of the techniques (gamma ray, sonic logging, electric conductivity logging, borehole penetration radar, crosshole tomography) were alas unsuccessful, due to high groundwater conductivity and/or formation damage due to drilling.
Seismic reflection with a low energy airsound source was found to be very useful to develop an adequate image of the shallow subsurface. This revealed the presence of a complex fault zone, rather than a single fault under the Voltastraat *(see figure 3)*. Based on knowledge of normal faults in the neighborhood, it is assumed that the strike of this fault zone will be between 110 - 140°. To the south of this fault younger members (Meerssen, Nekum and Emael) have been eroded.

Fault Zone Risks

The fault zone in question is characterised by very low strength material (carbonate sand, or limestone which degrades easily into sands under mechanical loading). Beside this, they are also expected to have high permeability. Where faults and younger members are encountered, ground improvement techniques (jet grouting columns and grout injection) may have to be used, to limit water ingress into the building pit, to increase the ground bearing capacity and to provide adequate passive resistance to the planned sheet pile walls of the building pit. These techniques themselves have been associated with several risks, and therefore might require an alternative design (like underwater concrete with tension piles) if proven to be inadequate. For example, it is difficult to guarantee adequate quality, shape and overlap of jet grouting columns, since intercalations of hard and weak materials are found. As for the grout injection, it is difficult to control which discontinuities will be sealed.

Slurry filled trenches will be used to install the sheetpile walls through the gravel. The high permeability of the gravels and possibly of the fault zones themselves may cause loss of the bentonite slurry during trench construction, and consequently trench instability might occur. This risk can be reduced by thickening the slurry. The presence of large boulders or other obstacles (thick vertical flint layers, sliding blocks in fractured limestone) may also divert and increase locally the groundwater flow and thus cause instabilities. Moreover, there always remains the possibility of local problems emerging during trench and building pit excavation, even when the flint logs derived from the borehole logs do give a reliable estimation of the flint content expected along the tunnel's planned alignment.

Reducing Risks

To minimize these risks, the A2 Maastricht Project decided on a number of interventions and new research projects. It was recommended to perform a large scale pumping test, aimed at determining the permeability of the limestone and gravel. Also, to perform extensive seismic reflection along the total tunnel alignment, in combination with the creation of additional boreholes.

Furthermore, more research into the ground improvement methods is needed. There also is a great need for a method to effectively detect discontinuities. It is also recommended to reconsider the length of each of the planned construction compartments, since smaller compartments can greatly reduce construction risks in zones with a high risk profile, as found along the new A2 Maastricht Tunnel. ■

Member	*Meerssen*	*Nekum*	*Emael*	*Schiepers-berg*	*Gronsveld*	*Valken-burg*
UCS (MPa)						
Average	0.78	0.4	0.48	1.53	1.73	1.71
Standard deviation	0.21	0.52	0.79	0.77	1.06	1.16
Minimum	0.56	0.03	0	0.23	0.03	0.53
Maximum	0.97	1.55	2.7	2.32	3.74	2.86
Number of tests	3	32	18	6	33	3
E50 (MPa)						
Average	173	104	109	460	387	499
Minimum	100	2.2	1.9	39	2.2	58
Maximum	250	480	640	760	1570	750
Number of tests	3	25	17	6	31	3
Dry density (mg/m³)						
Average	1.25	1.37	1.31	1.4	1.46	1.6
Standard deviation	0.04	0.08	0.05	0.03	0.1	0.11
Minimum	1.18	1.18	1.24	1.36	1.31	1.39
Maximum	1.29	1.5	1.43	1.46	1.67	1.73
Number of tests	5	48	17	10	41	7
Flint content (%)	0.1	2.2	4.3	4.6	6.7	4.2

	Permeality [Darcy]	*Hydraulic conductivity [m/day]*
Primary	0.001 - 10	0.001 - 10
Secondary	0.8 - 1.8	0.7 - 1.4

Table 1 Material properties of the members of the Formation of Maastricht

Primary permeability is material permeability.
Secondary permeability is the mass permeability (including discontinuities).

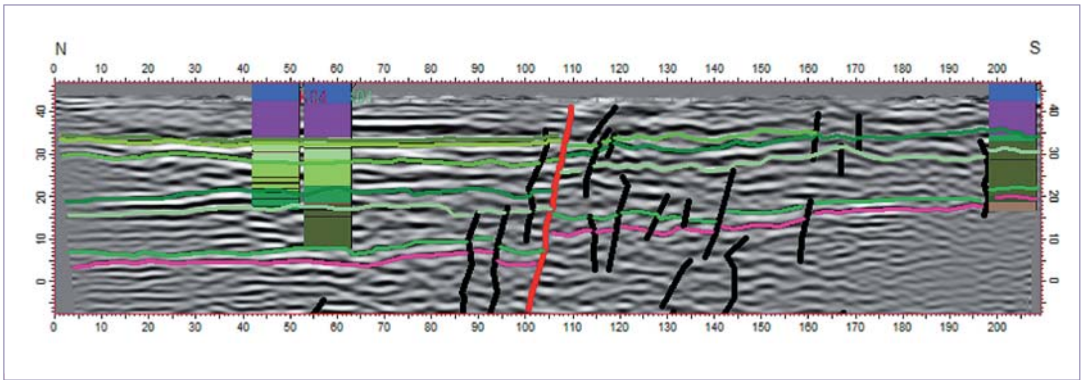

Figure 3 *Seismic reflection profile underneath the Voltastraat. Reflections highlighted in green represent the top of the members of the Formation of Maastricht. The pink line indicates the top of the formation of Gulpen. The red line is the fault with the largest vertical displacement (about 8 m) and the black lines indicate smaller faults.*

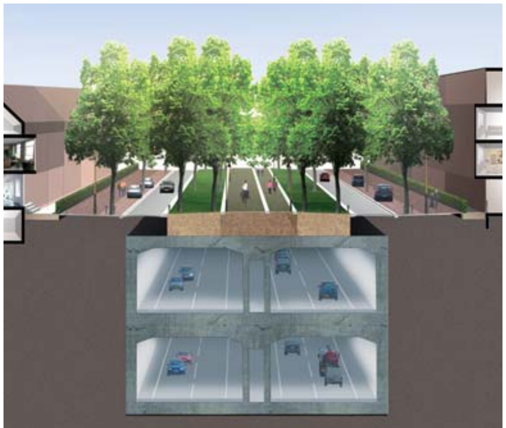

Figure 4 *Dubble stacked tunnel A2 Maastricht.* Source: Avenue2.