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Causes of Major Geotechnical Disasters

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ABSTRACT: Many disasters are related to geotechnical failure. Both for risk management and for future research it is important to know what new knowledge is needed to prevent these disasters. Therefore eleven geotechnical disasters or failing projects of the last ten years in modern countries are studied and compared in this paper. All examples show that the disasters or failing projects had nothing to do with a large spread of the strength or load in a foreseen failing mechanism. There was also not an unknown failure mechanism or a lack of existing scientifical knowledge. All cases show a lack of available knowledge (or incompetence) of the designing part of the construction management. The mistakes which were made were often of a level not higher than a BSc or MSc teaching level. In none of these cases these mistakes were tackled by an internal project auditing and in none of these cases these mistakes were tackled by an external project design control, for example for a building permit.

The biggest risk parameter in geotechnical design is therefore not the spread of load or strength parameters, but by far the existence and quality of the internal project auditing and the external project design control.

Keywords: Analyses, Collapsing Soil, Consulting, Failure, Risk Management

1 INTRODUCTION

For optimisation of the academic research it is important to know what new knowledge is needed to prevent problems, failures and even disasters. There are several causes for geotechnical failure:

1. There can be an exceptional large load, an exceptional low strength, or a combination of these two, in a foreseen failing mechanism.
2. There can be an unknown or unforeseen failing mechanism or other lack of scientifical knowledge.
3. There can be a calculation error from a well-qualified engineer.
4. There can also be a lack of available knowledge or willingness (incompetence) at the designing part of the construction management, for example when a lack of time, money, qualified people or qualified material tempt or lead managers to take unacceptable known or unknown risks.

The first cause of failure is very often the core of a risk analysis. The second cause of failure is mostly difficult to quantify and is very often regarded as very small or zero and disregarded. Also the third and fourth causes are both difficult to quantify. Normally internal project auditing should tackle these two causes of failure. And if an internal project audit does not, an external project design control, for example for a building permit, should tackle these two causes of failure.

The question is which of those four causes show mostly up during failures of geotechnical structures. Therefore several geotechnical failures of the last ten years in modern countries will be discussed here. This might help to find the best way to improve risk analysis in geotechnical engineering.

2 CASE STUDIES GEOTECHNICAL FAILURES

2.1 *Collapse water defense system of New Orleans*

Figure 1. Destroyed housing area Lower Ninth Ward.

The biggest geotechnical failure of the last ten years in modern countries is probably the disaster of New Orleans on August 29th, 2003. The water levels provoked by hurricane Katrina were not higher than their local design level and also not extreme for Dutch standards, nevertheless the water defenses could not withstand it, due to many mistakes in the design. The water defense system was too long by not using a secondary water system. Some of the dikes or gates were missing. Some of the dikes or I-walls were too light and were whipped away. Very often the height of the dikes or walls was insufficient and also very often the effect of piping was not taken into account for in the design.

Figure 2. Washed-in sand by piping.

Figure 3. Thickness of the washed-in sand layer.

In the city center there are two examples of this. In just the short moment of the passage of the hurricane, large quantities of sand of the shallow sand layers were washed underneath the water defenses into the housing areas. It is even for Geotechnical Engineers interesting to see that a housing area can be washed under a layer of sand of more than a meter in just a few hours.

Figure 4. Creation of a new dike.

It is also interesting to see how the Unites States Army Corps of Engineers think they can make new impermeable dikes after the disaster. Some dikes become therefore far too permeable.

2.2 *Singapore metro tunnel collapse*

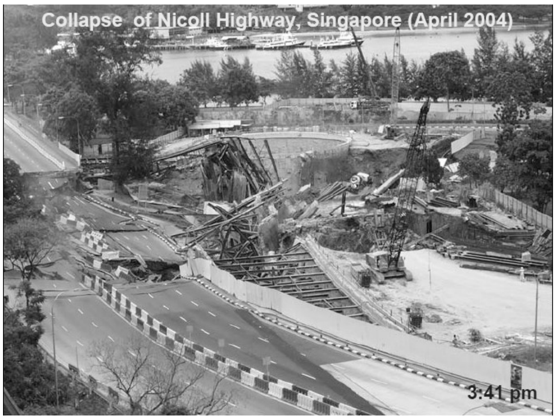

Figure 5. Collapse of the metro tunnel along Nicoll Highway, Singapore

In 2004 the building pit of a metro tunnel under construction in Singapore collapsed. Four people died. Many simple mistakes have been made in the design of the building pit and readings of instruments on site have indicated that things were not going as planned, but the warnings were not acted upon. The responsible manager was send to prison.

2.3 *Train station building pit collapse, Köln*

Figure 6. Collapse of a building pit of the North-South Line in Köln

The biggest construction disaster in Germany of the last few years is the collapse of a building pit of the North-South Line in Köln in 2009, leaving 2 people death and destroying one of the most important historical archives of the country. Workers had stolen up to 83% of the steel supports of the diaphragm walls and have sold this as old steel. And of course nobody, not even the inspectors, remember to have noticed anything.

2.4 *Subsidence along underground train station, Amsterdam*

During the construction of a building pit for a new underground station of the North-South Train Line in Amsterdam there were two identical incidents. Twice a diaphragm wall was leaking groundwater. This water washed sand particles away below the foundation piles of surrounding buildings, causing a subsidence of up to 23 cm of these old weaver houses. The only internal inspections of the diaphragm wall seemed to have been insufficient and there was no backup plan for this risk. There could have been a second line of defense for the most vulnerable areas like theses fragile houses. In the meantime the predicted costs have gone up from 1.5 to 3 billion euros and the project end shifted from 2011 to 2017.

Figure 7. Subsidence along an underground station of the North-South Train Line in Amsterdam

2.5 *Leaking tram tunnel, Den Hague*

In 1996 the city council in Den Hague, the Netherlands ordered to construct a Tram tunnel. In order to save some money, they had chosen not to use the common technique of a building pit with an underwater concrete floor retained by tension piles, but to use an experimental technique of deep arch-grouting. All contractors warned the municipality for the high risk of leakage with this technique, but that did not change the plans of the city council. Also the insurance companies warned the city council and decided not to ensure the project. The city council took the risk themselves.

Figure 8. Big Market tram tunnel in Den Hague

The predicted leaks appeared in 1998 causing the construction of the Tram tunnel to halt. The tunnel was for a long time under water, waiting for a new plan. This gave this tunnel its nick names: The Den Hague Swimtunnel and The Tramtanic. The tunnel was finished with a complex technique using high air pressure. In total 35.000 man-hours were worked under high air-pressure. The construction costs went up from 139 to 234 million euros and the opening was delayed from 1999 to 2004. In this way the construction of a 1250 m tunnel in Den Hague became more expensive than an 8 km long tunnel in Thüringen, built at the same time.

2.6 *Damage along garage building pit, Rotterdam*

Another example is the construction of the Museum Park Garage in Rotterdam, the Netherlands, which started in 2004. During construction the demolition of a large retention wall was needed, but the project organisation never thought of checking the effect of this on nearby buildings. Also excavating beyond a depth of NAP -4 m took place even though the geotechnical report had forbidden this. Therefore the construction of this so called “blunder-pit” caused damage to nearby buildings in 2005 and 2006. The municipality had to accept a delay of more than a year and an increase of the costs from 53 to 103 million euros.

Figure 9. Construction of the Museum Park Garage in Rotterdam

2.7 *Damage along garage building pit, Middelburg*

Figure 10. and Figure 11. Leakage and damage at the building pit of the new theater Middelburg

In 2004 in Middelburg, The Netherlands, the building of a new Theater with a large underground parking garage started. In 2005 a diaphragm wall started to leak and surrounding houses started to subside. To stop the disaster, the pit was filled with water and was nick-named the Biggest Swimming Pool. It remained this way until 2009 when new walls were placed in the pit and the pit was filled with 13,350 m^3 of concrete; a loss of almost half the volume of parking space. The remaining and very expensive parking is rather useless now, because the old theater has been renovated in the meantime.

2.8 *Peat dike failure, Wilnis*

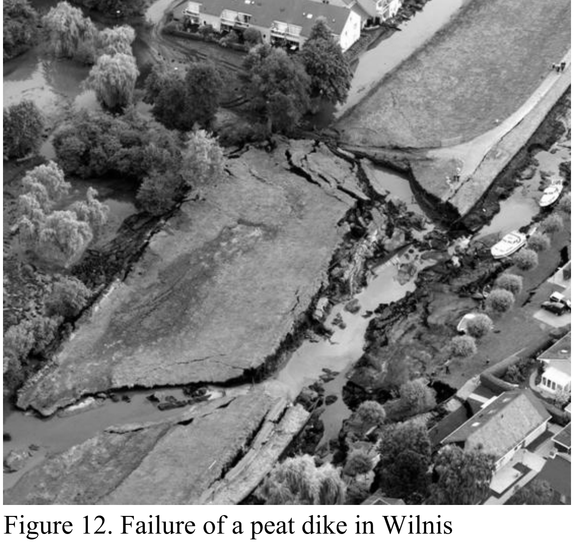

Figure 12. Failure of a peat dike in Wilnis

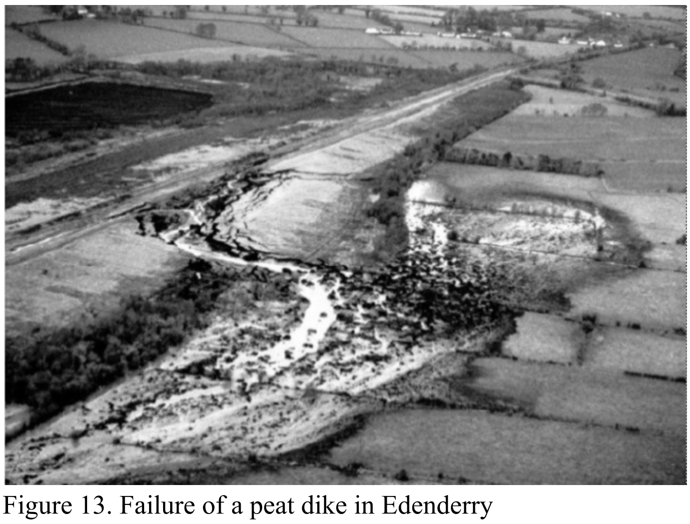

Figure 13. Failure of a peat dike in Edenderry

In the summer of 2003 a peat dike in the Netherlands failed in the village Wilnis near Mijdrecht. The dike was shifted horizontally by the water pressure in the canal. This type of failure is not uncommon.In the summer of 1947 a peat dyke in Zoetermeer, the Netherlands, failed in an identical way. And also in January 1989 in Edenderry, Ireland, a peat dike failed in a similar way. The failure of the dike in Wilnis came not as a surprise, because this dike, only made out of peat, was for 28 years disapproved, but the responsible waterboard never improved the dike in all those years. Both in smaller hand calculations and in finite element calculations, the effect of the drying out of the crest of the dike above the groundwater table and the failure of the dike can be simulated. Not the failing of the dike is a mystery, but the reason why the Waterboards accepted for so many years to do nothing about the many dikes which were disapproved.

2.9 *Large vibration and noise nuisance at construction underground parking, Eindhoven*

In 2009 and 2010 in Eindhoven a new underground parking garage was build next to the PSV football stadium. A large number of big precast foundation piles have been driven through very dense sand layers in 2009. Therefore a production of very strong ground vibrations for many months was obvious, which would exceed the allowed maximum of the Dutch standards. The corresponding high level of environmental vibration nuisance for the people living around the building pit should not have been ignored by the project organisation and also by the controlling municipality.


Figure 14. and Figure 15. Vibration and noise nuisance at precast pile driving in Eindhoven

Also the arguments used by them in court against the citizens, that using a vibration-free bore pile would lead to identical problems as in Amsterdam (here were no pile installation problems but problems with leaking diaphragm walls in combination with a high groundwater table) and Köln (also no pile problems but stolen steal supports) were clearly incorrect and not good for the respect of our science and of the court system. In court the judge declared this project illegal, but did not halt the project unfortunately.

2.10 *Failing retaining wall of building pit, Differdange*

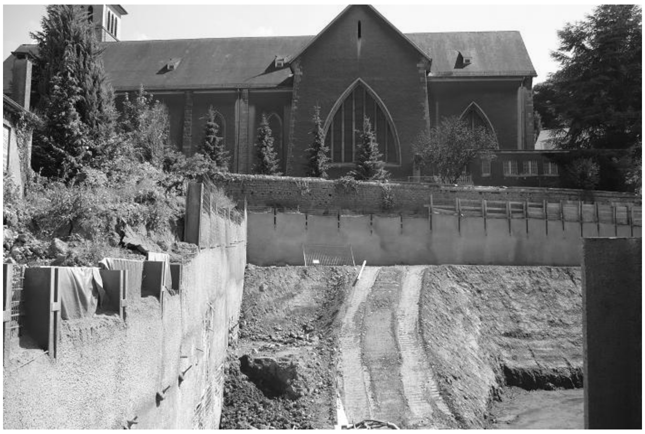

Figure 16. Failing retaining wall in Differdange

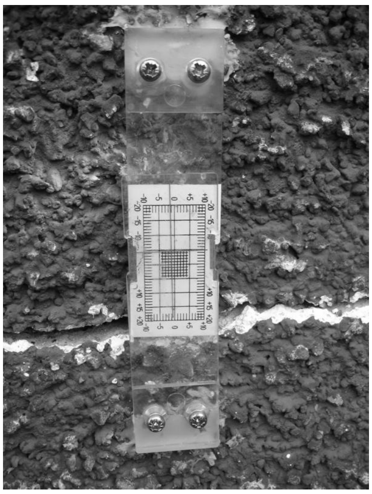


Figure 17. and Figure 18. Cracks in church Differdange

In 2010 in Differdange, Luxembourg, very close to the shallow foundation of the local church a building pit was made, in order to make a housing residence with a sub terrain parking garage. The project was halted when suddenly many cracks appeared in the church. Verification of the design calculations made clear that several major mistakes were made. Only an active earth pressure was used in the calculations, while in order to prevent horizontal deformations, a more neutral earth pressure had to be used. Also the water pressure behind the Berlin-wall was forgotten. The anchoring was made very close to and just below the fundament of the church. And a very high drained cohesion was used in the calculations, only based on undrained phicometer borehole field tests.

2.11 *Unsafe rock face, Clervaux*

In Clervaux, Luxembourg, a vertically-layered rock-face was inspected by a geological and geotechnical engineer. He warned for the danger of rock parts breaking off. Nevertheless the owner never secured the rock-face. A few years later a large part broke loose and crushed a parked car; luckily nobody was in the car. First then the authorities intervened and secured the wall on the expanses of the owner.

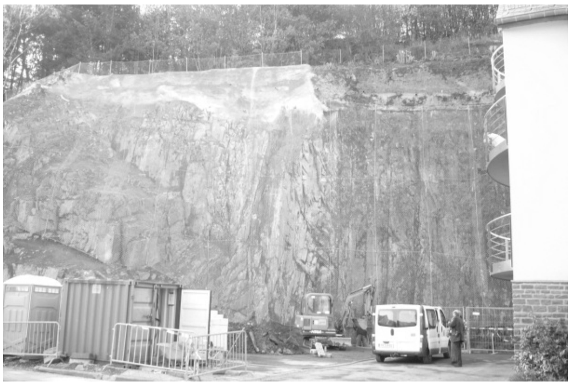

Figure 19. Rock face instability at Clervaux.

3 CONCLUSIONS

All examples show that the disasters or failing projects had nothing to do with the first three causes mentioned before: There were no exceptional large loads or low strengths in foreseen failing mechanisms. There was no lack of scientifical knowledge. There were also no calculation errors from well-qualified engineers. All cases show a lack of available knowledge (incompetence) at the designing part of the construction management. The mistakes which were made, were often of a level not higher than a BSc or MSc teaching level. In none of these cases the mistakes were tackled by an internal project auditing and in none of these cases these mistakes were tackled by an external project design control, for example for a building permit.

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