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Dutch Dike Breach, Wilnis 2003

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DUTCH DIKE BREACH, WILNIS 2003

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ABSTRACT

In August 2003, after a very dry and warm summer, one of the dikes along a canal in The Netherlands failed at night. Because of this dike breach, the water in the canal started to run into a housing quarter of the village Wilnis, which is about 30 km Southeast of Amsterdam. A local contractor immediately started to close off the canal. By the time this was finished, 600 houses were already half a meter under water. The 2000 residents were evacuated in the early morning. Almost all residents could return to their homes the same evening after the water was pumped out of this area.
Like many other small dikes in The Netherlands, the complete dike consists of peat. Since peat has a relatively low specific weight, a peat dike has a higher risk of being pushed aside by water pressure than sand or clay dikes. This horizontal sliding is a rare type of failure mechanism. Though, when the stability of this dike is checked with a simple one page computation, it becomes clear that the failure of the dike after a dry period was a realistic threat.
For many years it was known that this part of dike was at risk. This was reported to the minister of Public Works in 1993, but the two involved provincial authorities, the provincial government and the water board, did not take steps until after the dike failure.

INTRODUCTION

In The Netherlands there is more than 17.000 km of dikes. The Dutch are all familiar with the huge flood disaster of February 1953, at the islands of the province Zeeland (Sea land), in the Southwest of The Netherlands, in which 1836 Dutch people died. The sea dikes failed during a combination of high tide and a heavy storm. Also the problems of the river dikes during the high water situations in March 1988, December 1993, and January-February 1995 are not yet forgotten. So, the Dutch people expect a higher risk of dike failure during storm, high tide or after a long rain period sometimes combined with melting water from the glaciers in the Alps.

Fig. 1. Canal (left) and dike(right)

Therefore the Dutch were very much surprised at August 26th 2003, after the warmest and driest summer in fifty years, that a dike along a canal failed.
Figure 1. shows the empty canal on the left and the dike on the right. Figure 2. shows the dike after failure. About 50 meter of dike was shifted towards the north (left of the picture), leaving two breaches through which the water from the canal streamed into a lower quarter of the village Wilnis, 30 km Southeast of Amsterdam.

Fig. 2. Shifted part of a canal dike

PRIMARY AND SECONDARY DIKES IN THE NETHERLANDS

The Netherlands is a country crossed by rivers and surrounded in the North and West by sea. More than 50% of the country is below the high water level of the rivers or sea. To prevent these areas from flooding, dikes are build along the rivers and seas, with a total length of about 3200 km. These dikes are called the primary dikes.
A large part of these areas are even below average sea level. Most of these areas are in the province Holland, which is in the West of the country. For example the area "Haarlemmer meer" (Harlem's Lake) was until 1852 the largest inner lake and is pumped dry in order to create new land, up to 4.5 meters below sea level. In this former lake, at 2 m below sea level, the Amsterdam National Airport Schiphol is situated. Nowadays about 100.000 people live in this former lake.
The precipitation of the lower areas of the country drains into the many ditches crossing these flat lands. From the ditches the water is pumped up into canals with water levels sometimes several meters higher than the land. From these canals the water is pumped up into the rivers, or in some rare occasions into the sea. The water in the canals is stopped from flooding the land by canal dikes, which are called the secondary dikes. There is about 14000 km secondary dike in The Netherlands.
The main differences between the primary and the secondary dikes are:

- Primary dikes only seldom have a maximum load (water level to the head of the dike), secondary dikes have a constant maximum load.
- The water level of the primary dikes are driven by nature (sea dikes: tide, storm and wind direction; river dikes: precipitation and melting glaciers of the Alps), the water level of the secondary dikes are controlled by man.
- The water level of the primary dikes are in most cases much higher than of the secondary dikes. This results in a higher damage at failure of primary dikes.
- The primary dike are controlled by the state government, the secondary by both a democratically elected provincial water board and a democratically elected provincial government.
- Per year € 10.000 per km primary dike is spend on maintenance and € 2000 per km secondary dike.

SITUATION WILNIS

The village Wilnis is part of the community "Ronde Venen" (Round Peats). It is about 30 km Southeast of Amsterdam. There is a ring canal which goes from the lake near Vinkeveen, through Wilnis, towards the city Mijdrecht (Figure 3). The old part of Wilnis is South of the ring canal. The new housing quarter, named "Veenzijde" (Peat-side) is the square of land North of the ring canal.

Fig. 3. Wilnis connected with the lake

Most of the soil in these areas are peat layers. In some areas the peat has been excavated for heating houses. This peat extracting took place from the middle ages up to one century ago when coal was found in the Southwest of the country, but mostly in the 17th and 18th century.

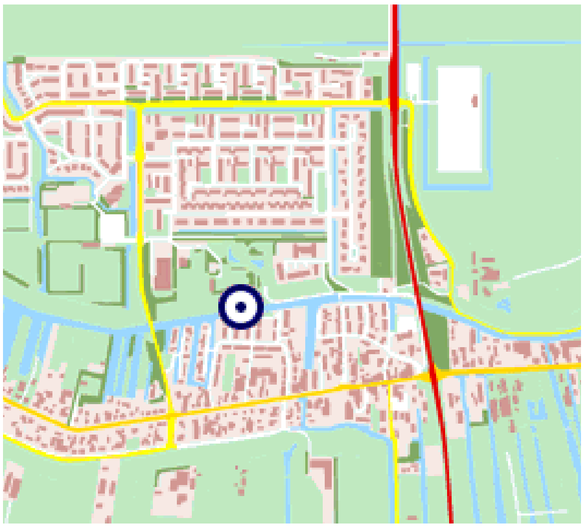

Fig. 4. Wilnis along the ring canal

In figure 4, a dot marks the location of the dike failure. The new housing area Veenzijde is North of this dot and is one of these excavated peat areas. The secondary ring dike between Veenzijde and the canal is not like most of the Dutch dikes man-made, but is a left-over from the peat-excavation. The area south of the ring canal is not excavated and is therefore as high as the

failing ring dike on the other side. The ring dike is the only barrier between 10 square km of water of the "Vinkeveense plassen" (Finch-Peat's Lakes).
The complete dike consists of rather homogeneous forest-peat. Below this forest-peat there is a layer of swamp-peat, full of reed, leaves and roots. Below this layer there is a thin fat-clay layer, which lays on a very thick sand layer. Because of the soft subsoil, the houses in the South are founded on wooden piles, the new houses in the North on prefab concrete piles.

DIKE BREACH WILNIS

Fig. 5. Shifted part north-dike

In the night of Monday on Tuesday August 26th, at 1:30 h, about 50 m of the secondary dike along the ring canal near Wilnis was translated sideways over 15 m. Because of this, the water in the canal started to run, along both ends of the shifted dike part, into the new housing quarter Veenzijde.

Fig. 6. Circular slip surface failure of the south-quay

Fortunately, a local contractor immediately started to close off both ends of the ring canal in the East and the West and a side canal in the South. By the time the ring canal was closed off with clay, which was immediately brought by other contractors, the 600 houses in Veenzijde were already half a meter under water. The 2000 residents were evacuated in the early morning. Almost all residents could return to their homes the same evening after the water was pumped out of this area. Because of the failure of the north-dike, the water level in the canal dropped instantly. Because of this the supporting horizontal water pressure on the south-quay disappeared, creating this quay to fail by a circular slip surface, see figure 6.

FAILURE MECHANISM

The failure mechanism of the dike is a horizontal pushing aside of the dike. The forces reacting on the dike and sizes are more or less as shown in figure 5. The stability of this dike can be checked easily with a simple one page computation.
The specific weight of wet peat is rather low. Because of the large amount of water (up to 80% or 90%!) and organic mater (lighter than water!) the specific weight is not more than γ_{wet} = 10 kN/m^3. When peat dries out in a dry summer, the specific weight can drop easily to γ_{dry} = 6 kN/m^3, or even lower.

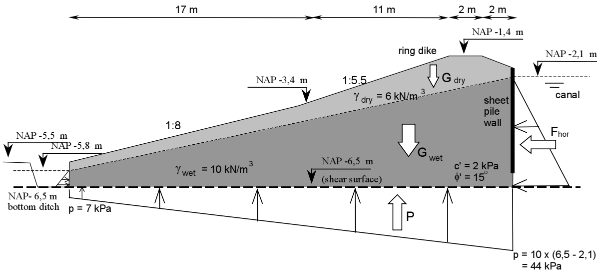

Fig. 7. Cross section and failure mechanism

In figure 7, the total cross section of the dike above the horizontal slip surface is $I_{tot} = 99,85 \text{ m}^2$. The cross section of the peat below the diagonal freatic line is $I_{wet} = 81,6 \text{ m}^2$, so the part of peat which is able to dry out is: $I_{dry} = I_{tot} - I_{wet} = 99.85 - 81,6 = 18,25 \text{ m}^2$. The vertical uplifting water pressure P is identical to the weight of the wet part of the dike G_{wet}, since in this case the specific weight of peat is the same as the specific weight of water.
The driving horizontal force of the water pressure is:

$$F_{hor} = \tfrac{1}{2} \times 10 \times \left[(6,5 - 2,1)^2 - 0.7^2 \right] = 94,35 \text{ kN/m} .$$

In the Dutch Standard for soil mechanics (code: NEN 6740, table 1) lower representative soil parameters are given in case no soil investigation has been carried out. For unloaded or non-pre-stressed peat a specific weight of γ_{wet} = 10 kN/m^3 is given and a angle of internal friction of $\phi' = 15°$ and a cohesion of c' = 2 kPa. (Since the reed and leave parts lay flat (horizontally) in the peat, the shear resistance is minimal in horizontal direction.)
Suppose the dike is completely wet, which means also the part above the freatic line (γ = 10 kN/m^3). In this case the maximum resistance force of the dike against horizontal shear failure is:

$$F_{max} = c'A + \tan(\phi') I_{dry}\gamma_{wet}$$
$$= 2\times 32 + 0.268\times 18.25\times 10$$
$$= 112.90 \text{ kN/m}$$

This results in a stability factor during wet times of:

$f = 112,9/94,35 = 1.20$

However when the peat of the upper part has dried out after a long hot summer, an average specific weight of the top layer of 6 kN/m^3 or lower is possible, so:

$$F_{max} = c'A + \tan(\phi') I_{dry}\gamma_{dry}$$
$$= 2\times 32 + 0.268\times 18.25\times 6$$
$$= 93,35 \text{ kN/m}$$

This results in a stability factor after a dry and hot period of:

$f = 93.35/94,35 = 0.99$

which explains the failure of the dike of Wilnis.

Interesting is that in this case about 2/3 of the maximum shear resistance is obtained from cohesion ($c'A = 2\times 32 = 64$ kN/m) and not from friction. This makes the dike in fact less sensible to mass reduction caused by drying out. So, the drying out was more like the last straw that broke the camels back. The safety of the dike was already rather low.

Another interesting question is why the dryness did not decrease the pore pressure and as a result increase the effective stresses and strength near the slip surface? There may be several reasons for this:

1) The slip surface is to deep for being influenced by the dryness.
2) The horizontal permeability of the forest-peat is much higher than the vertical.
3) The permeability of the swamp-peat (near slip surface) is higher then the forest-peat.
4) A combination of these three.

This question is still part of research.

RESPONSIBILITIES

Flooding can lead to huge financial damage in The Netherlands. In order to prevent insurance companies from getting bankrupted after a hug flood, the Dutch government has accepted a law which forbids insurance companies from insuring any damage caused by flooding or dike failure. Another law has been accepted which gives the state the option to pay a part of the occurred damage, but this does not mean that the victims have any rights to claim for money after a flood disaster. In most cases, however, the government pays a part of the damage. The only way for the victims to get all the damage paid is to prove that some party has been negligible in doing its duties. Therefore knowing who is responsible, and for what part, is very important for the victims.

In The Netherlands the primary dikes are the responsibility of the state government by the ministry of public works, who is in most cases also the owner of the dike. The responsibility of the secondary dikes is more complex. First of all the owner (private person, company, city or province) is not responsible for dike failure. The water boards should maintain the dikes such that they remain in good shape. Upgrading of the dikes to a higher safety level is, according to the water board, more than maintenance so the water board will only do this if provincial rules prove this is necessary. The provinces are responsible for making rules to which the dikes should satisfy, but they haven't made any rules yet. This has led to a stalemate situation. Since the provinces and water boards are both directly elected, this situation can not easily be solved by state regulations.

The state government is not allowed to intervene in this provincial matter. One time however, the state government has made an exception. In January 1960 a canal dike failed near Amsterdam, leaving many houses of a village flooded. Because of this the governmental Technical Advisory board for Water barriers (TAW) was erected in 1965 with the task to determine which primary and secondary dikes were unsafe. They reported to the minister of public works firstly about the primary dikes and in 1993 finally about the secondary dikes, saying:

"1730 km secondary dikes of the most important 200 polders have been surveyed. 323 km of dike was unsafe. 167 km of dike has been improved already, 156 km of dike is still unsafe (date: January 1st, 1993)".

The dike of Wilnis was among these unsafe dikes. The water board for Wilnis, named after three important small rivers in this area "Amstel, Gooi and Vecht", knows about this report but never decided to carry out a stability analysis. In fact there are no provincial rules which force the water board to do this. Although the minister and the governmental TAW are not allowed to have an opinion about this provincial situation, the minister has asked in 1993 the provinces and water boards to improve the unsafe dikes.

Therefore only the provincial government and the water board can be held responsible for the dike failure of Wilnis. The questions whether and which of these two authorities are responsible are not easy to answer. At least one point is clear. The dike failure is not a geotechnical problem but a governmental management problem.

REFERENCES

NEN 6740 [1990]. *Geotechniek TGB 1990 Basiseisen en belastingen*, NNI (Nedelands Normalisatie-Instituut) Delft, ISBN 90-5254-074-8

STOWA [2002]. (Stichting Toegepast Onderzoek Waterbeheer), *Quick-scan niet-primaire waterkeringen, tussen zwemvliezen en droge voeten; over het grote belang van kleine keringen*, STOWA Utrecht, ISBN 90.5773.189.4

TAW [1993] (Technische Adviescommissie voor de Waterkeringen), *Systematisch Kade-onderzoek: de resultaten*, Delft