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# TWO FAILURES WITH CUT-OFF WALLS

Ir. T.K. HUIZINGA
Director of the Laboratory of Soil Mechanics, Delft, Holland.

In structures built to withstand water pressures sheet piling is often used to increase the path of percolation of water through the soil and thus to prevent erosion or other inconveniences downstream from the structure. Because this sheet piling is situated underground and has only a sealing function, it is customary to leave out any calculation. However, an excessive deflection, when the sheet piling is standing in a cohaesive material, may have detrimental results. Lately two accidents have occurred in this context and it seems useful to invite attention to them.

For the construction of the lock and the pumping station for the North East Polder at Urk (Fig. 1), carried out within a dewatered area of the IJsselmeer, enclosed by an earth dam drainage by well points was applied to maintain the groundwater level in the thus formed site at about 9,50 m - N.A.P. By the beginning of September 1945 the groundwork was almost completed. With a view to put in operation the mechanical installations, namely the filling of the cooling water system and the boilers, it was decided to fill the harbour basin ahead of the pumping station carefully from the IJsselmeer and to convey the required amount of water thence to the pumphouse through the pressure pipes. Some days after the actual filling and no signs of alarm having been noticed, suddenly, directly West of the pumphouse a spring started, ejecting with considerable force water containing lumps of clay, peat and sand. The water level of the filled harbour basin subsided quickly, showing a vortex motion at the mouth of the pressure pipes. In addition some slides occurred, a fairly large one at the South bank of the basin covering the stone revetment of the bottom and by doing so throttling the flow so much that in the end, after the water table in the basin had dropped about 1 meter, the flow was checked (foto 1). Subsequently, by way of precaution, the harbour basin was emptied. During the next few days the ground at some places under the pressure pipes collapsed, resulting in two craters, one to each side.

PHOT. 1

At the time of the accident the hydrostatic head at the spot was about 8 meters, this being much larger than the maximum head to be expected in future, with the polder water level at 5,70 - N.A.P.

Evidently piping has developed from the entrance of the water at the vortex on the revetment of the bottom of the basin, to the outlet at the boil at the West front of the pumphouse. The path of it is not known.

Now the foundation floor of the pressure pipes lies above the original floor of the dam area. To make up for the difference, a bank of clay was deposited both under and aside of the pipes; moreover, 3 sheet-piled cut-offs were driven under the pipes, reaching more than one meter into the original dam floor.

It seems unlikely that the water has flowed through the clay fill, nor is it probable that the path of piping would lie anywhere in the undisturbed foundation soil. It can only lie somewhere in the boundary areas, either under or above the clay fill, going downwards and upwards again at each cut-off wall. The cut-offs themselves are carefully driven and the connection to the foundation floor was sound, so that any possibility of leakage here can be precluded.

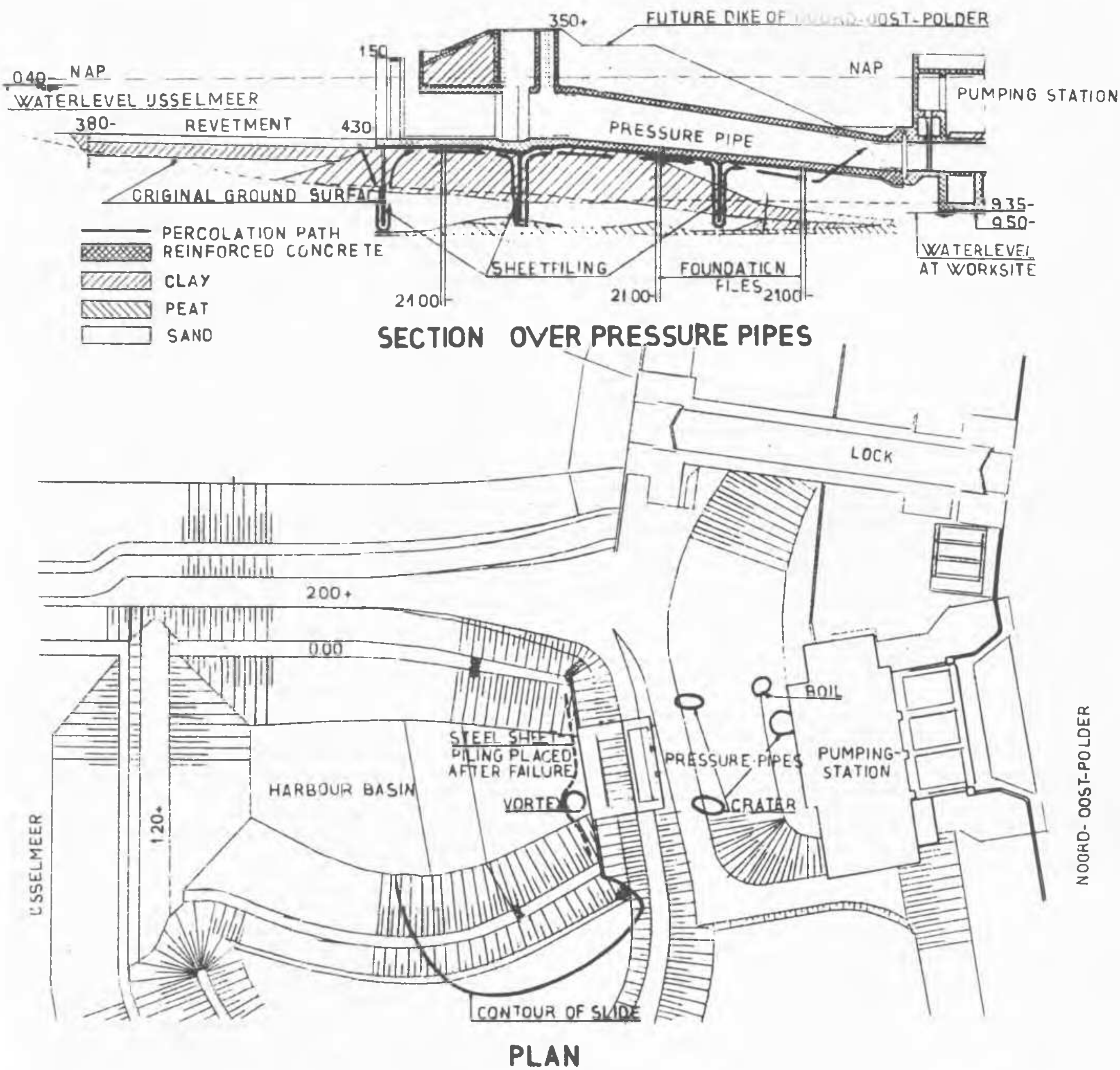
Afterwards inspection holes have been made in the foundation floor of the pressure pipes, and only in one instance it was found that the clay fill did not adjoin the floor any more.

A tentaive explanation may be given as follows:

Free water from the harbour basin can have reached the first cut-off through the revetment, causing a considerable hydrostatic pressure on the sheet piling which must deflect against the soft clay. As a result the joint between the sheet piles and the adjacent clay mass on the upstream side opens up and the water pressure in the sand mass at the toe of the piles rises. In this sand mass the passage of water is impeded by the presence of the underlying peat layer.

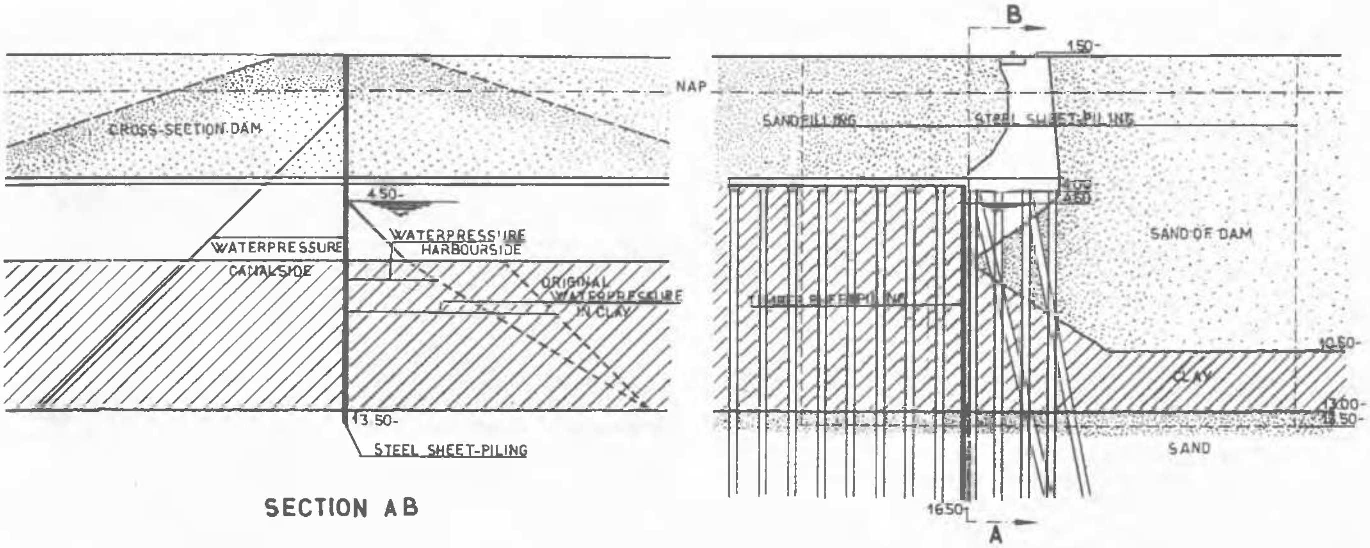
Also at the back of the first cut-off now the hydrostatic pressure rises. The result is that the piles bend backwards somewhat. In doing so, erosion in the sand mass at the back can develop and the water can reach the foundation floor of the pressure pipes. Intimate contact of the clay with the foundation floor cannot be assumed, because the deposited clay , especially at the sides may have settled under the weight of the body of the dike. Therefore after a short time the hydrostatic pressure under the pressure pipes between first and secon cut-off will rise and the same phenomena will happen at the second cut-off. After repeating itself once more at the third cut-off, "boiling" may be produced beyond, owing to insufficient overburden. Ultimately retrogressive internal erosion will cause a continuous stream of water, leading to failure.

If the well point drainage had not been in operation, the difference of the hydrostatic pressures at the two sides of the cut-off walls would have been appreciable smaller, causing less deflection, and the internal ero-




Failure Dam Urk

FIG. 1




SECTION AB

CROSS-SECTION QUAY WALL
AT JUNCTION WITH DAM

Failure Dam Coenhaven

FIG.2

sion round the toes of the sheet piling would probably not have materialized. Altogether it seems that the cause of the failure must be found in the deflection of the sheet piling after the filling of the harbour basin at a time of low hydrostatic pressure in the deep sand layer.

Repairs consisted mainly in the driving of a cut-off wall of ample length at the front round the vortex pool and the extension beyond it of the reinforced concrete foundation floor of the pressure pipes.

A second accident with possibly similar causes happened shortly at the reconstruction of the Coen Harbour at Amsterdam. The design and construction of the existing quay walls may be found in fig. 2. Planning the repairs of these war-damaged structures it was decided to lower the water level to just below the continuous reinforced concrete floor in order to be able to inspect the front piles below the face and to work above water level when repairing the superstructure. To this end an earth dam was designed in the entrance channel to the harbour basin, connected to the quay wall at both ends. In order to avoid slides in the body of the dam the slopes were laid flat and at the low water side drainage was laid at water level. Where the dam joined the existing quay wall, a 20 meter long wall of steel sheet piling was provided parallel to the axis of the dam, cutting 10 m into the earth dam and 10 m into the quay walls.

After the construction of the dam was almost completed - only a clay cover had still to be laid in order to forestall failure brought about by the entrance of excessive rainwater - the water within the harbour basin was slowly pumped out. When the required level had been reached after a fortnight and successfully maintained during almost 3 days, failure of the dam occurred at the Western connection to the quay wall. Various failure theories were considered and judged in the light of the situation after the accident but none seemed acceptable in view of the observed facts. In the end it was thought that here too it was a case of percolation and erosion under the sheet piling.

It is to be noted that the water on the high water side is in free communication with the one side of the steel sheet piling by way of the empty space under the face of the quay wall i.e. in front of the auxiliary timber sheet piling. At the low water side, where the same free communication is possible, the hydrostatic pressure is thereby lowered with the water level of the harbour area. Therefore a considerable water pressure is acting on the steel sheet piling.

When under construction, the quay wall was built on the originally existing surface. Subsequently the harbour basin was dredged and the area behind the wall was filled up. The remaining clay under the face of the wall must have been washed away in the course of time. In this case as well as in the first case mentioned the steel sheet piles will deflect and an open joint will result. And here too the hydrostatic pressure at the toe of the piles will correspond to the water level at the high water side.

In order to be able to drive the steel sheet cut-off piling through the quay wall, the by explosive action damaged reinforced concrete floor was forcibly split over the full width by driving a steel beam through it and thus pushing the reinforcing bars apart. By this action the auxiliary timber sheet piling must also have been split or pushed aside. The steel sheet piling has been driven straight through this gap. It seems probable that through this gap the first discharge of water from the deep sandlayer has taken place. More and more soil particles will have been washed out, causing ultimate failure by retrogressive erosion.

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