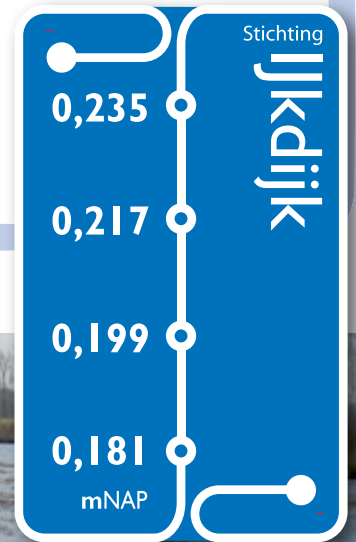


IJkdijk

macro-stability experiment



In the coming years, The Netherlands will be making substantial investments to keep our feet dry. Climate changes are not only leading to a rise in sea levels, but are also resulting in larger peak flows in catchment basins. Increasing extremes mean that these may occur within a shorter time frame. It is uncertain whether the set-up of current water drainage systems are sufficient to cope. The chance of extreme drought will also increase. When combined with other factors such as land subsidence (due to gas- or salt extraction or settlement in peat areas), and the increasing wealth that is being invested behind the levees, this represents an enormous challenge for maintaining the sustainable safety of our delta.

The adjustments that are needed to prepare the water system for such changes are well underway. Water storage areas are being created, space is being given over to the rivers, and water-retaining structures and sea defences are being raised and strengthened. In view of the high costs of these adjustments (coupled with management and maintenance issues), water authorities have a growing need to determine the up-to-the minute strength of water-retaining structures or systems, and to use new methods for measuring, monitoring or managing various real-time parameters in and around water-retaining structures in a more permanent and objective way.

What is more, social acceptance of the problems caused by high water has fallen. There is also the realisation that not only can potential flooding risks be prevented by stronger levees, but also by using advanced prediction systems in a preventative way to manage and combat disasters.

The aim and experiments of the IJkdijk Foundation fit within this framework.

Objectives of the IJkdijk Foundation

The scientific aims of the IJkdijk Foundation are two-fold: firstly to stimulate the development and validation of state-of-the-art multi-sensor networks and IT tools, and secondly to increase knowledge about failure mechanisms for water-retaining structures.

The IJkdijk Foundation was established by Deltares, IDL Sensor Solutions, NV NOM, STOWA and TNO. Deltares and TNO are institutes that focus on the development and transfer of knowledge in the field of delta technology and sensor technology. The IJkdijk Foundation aims to develop smart levees. IDL promotes the application of sensors. STOWA emphasises coordination with daily water management practice, and the NOM focuses on the realisation of economic undertakings.

Experiments are carried out with the following objectives:

- To test whether the state-of-the-art multi-sensor networks and IT-tools can supplement standard visual inspections by levee patrollers and managers. With the help of these techniques, an up-to-date picture of the strength of the levee can be formed. If deviations are found, water authorities are then able to implement timely (emergency) measures as part of the daily management programme and when the circumstances are relevant.

- To test whether the state-of-the-art multi-sensor networks and IT-tools can supplement existing water management systems and control rooms when determining the current safety of stretches of the levee or levee systems during high-water threats and during extreme drought. Decisions-makers and emergency services can draw on the information that has been acquired in the event of (threatening) calamities.
- To obtain knowledge about failure mechanisms and to carry out model validation. Greater understanding about the actual levee strength is derived from knowledge built up during the tests. The Netherlands has approximately 3,700 km of primary levees and some 14,000 km of other or secondary levees. It is not always known whether these structures meet safety standards, and whether they are high or strong enough to continue defying the water. Filling in these knowledge gaps means that measures needed to keep The Netherlands safe can then actually be implemented. The knowledge is used within two programmes that are being carried out over several years. The first is known as SBW (Strength Loading of Levees) carried out by the Ministry of Transport, Public Works and Water Management, the second is VIW (Improving Levee Inspections) from the Ministry of Transport, Public Works and Water Management, and STOWA.

Macro-stability experiment

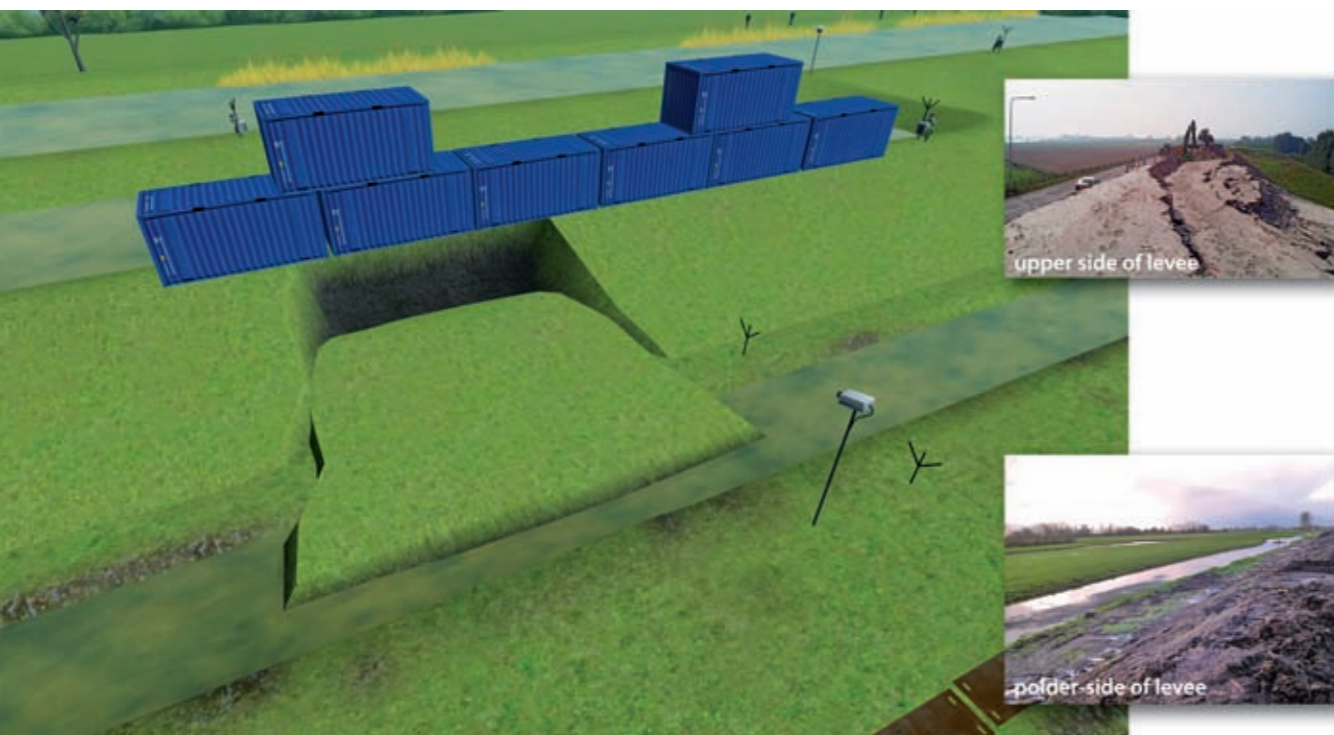
The failure of levees can be caused by a variety of mechanisms. The type of mechanism that occurs is in particular dependent on the height and duration of the water level (load), the type of water-retaining structure, and the structure of the sub-soil (strength). A number of failure mechanisms are being studied within the IJkdijk project. One of these failure mechanisms is the macro-stability failure mechanism, as shown in the figure below. The macro-stability failure mechanism involves a large-scale stability problem. This not only means failure of the levee body, but also the soil layers underneath the levee. The section of soil that moves during macro-instability can then be simplified as a circular section of soil. A deep fissure forms on the top of the levee.

The top collapses on the polder-side of this crack. At the same time, deformation will be observed on the lower side. If a berm ditch is present on the polder-side of the levee, it will often be pushed closed, or the ditch bottom will move upwards. If there is no berm ditch then the ground surface will be pushed upwards. This test is specifically concerned with the inwards stability. The test represents a situation where there is high water in the river and where there is shearing on the polder side of the levee, as shown.

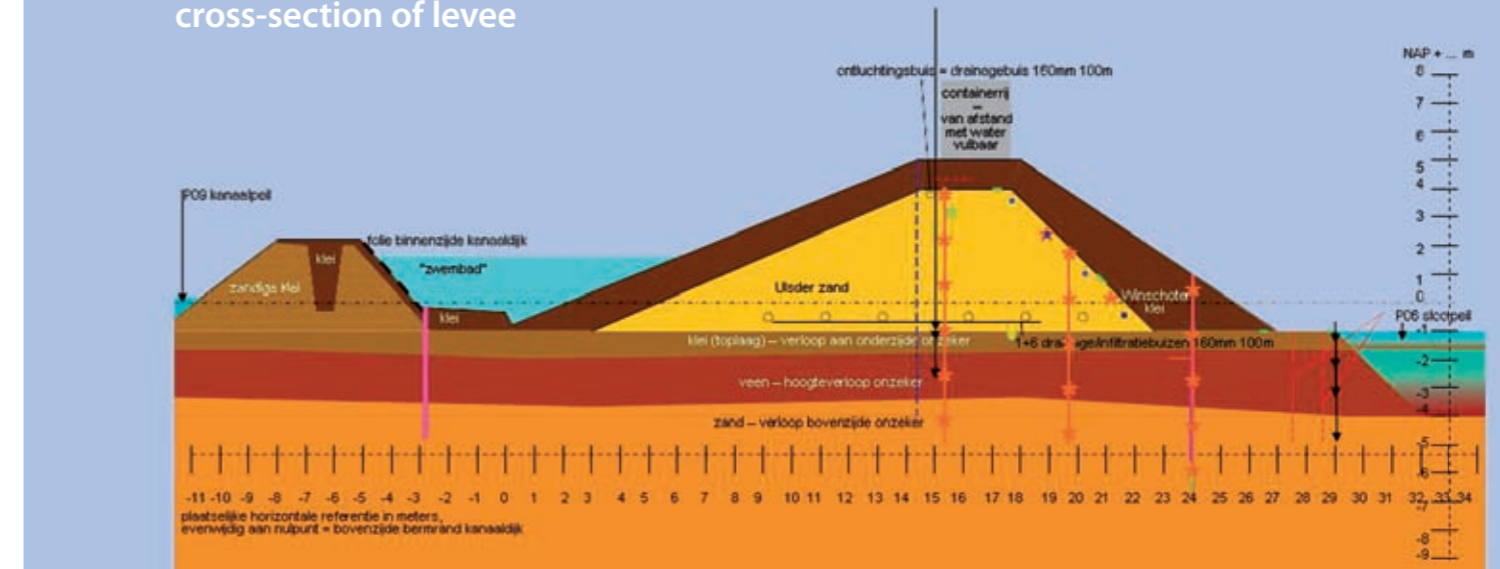
Test objective

- The aim of the test is to investigate the extent to which modern measurement- and sensor techniques in multi-sensor networks can detect the inwards macro-stability failure mechanism in advance. The pre-condition in this case is that the test levee fails inwards in accordance with the macro-stability failure mechanism.
- During a successful test, shearing occurs along a sliding surface that runs through the levee body as well as through the subsoil. The macro-stability failure mechanism does not occur if the sliding surface that is present only exists within the levee body, and the test is therefore not successful
- The extent of the deformation that occurs during shearing determines the success of the test. If there is a small degree of deformation, it cannot be stated that the levee body has failed. It can be stated that macro-instability has occurred during the test if deformation along the desired sliding surface is a minimum of 20 cm.

Based on the above, it can be concluded that the test is successful if a sliding surface occurs after loading that travels through the levee body as well as through the subsoil, and where deformation along the sliding surface measures a minimum of 20 cm. When designing instrumentation, the possibility of larger deformations (a metre or more) are taken into account.



cross-section of levee



Dimensions of the levee macro-stability experiment

- Height of top +6.00 m from surface
- Height of sand core +5.00m from surface
- Inner slope 1:1.5
- Outer slope 1:2.5
- Inner slope of sand core 46.1° (1:0.96)
- Outer slope of sand core 29.2° (1:1.79)
- Berm width 1 m
- Slope of ditch 1:1.5
- Width of top 3.7 m
- Total ditch depth approx. -2 to -3 m from surface (up until sand layer)
- Length of water-retaining structure approx. 100 m.

Logbook of macro-stability experiment

Construction of the levee takes place during August and September, together with the instrumentation. The experiment is carried out during mid-September.

Construction began in August 2008. A brief impression is given below.

The following general phased plan is used while carrying out the test:

- filling the compartment on the outer (canal) side of the test levee with water
- excavating the first metre of the ditch
- completing excavation of ditch (until the top of the sand layer)
- filling 2/3's of the sand core
- draining ditch
- filling containers
- complete filling of sand core.

The duration of the experiment is a maximal of seven 24-hour periods.





The participants used the following instruments for the macro-stability experiment:

- GeoBead (Alert Solutions);
- thermographic cameras (Intech);
- movement and vibration measurements (DikeSurveys);
- moisture level, temperature, and conductivity sensors (Deltares/IBM/TNO in the FloodControl 2015 programme);
- hybrid-glass fibres, an OTS4OP measurement system and temperature probes (GTC Kappelmeyer);
- probes met sensors (Koenders);
- listening conduit (Landindustrie/TNO/Volker Wessels);
- airborne thermographic cameras (Miramap);
- slope measurement tubes, bat probes and inverted pendulums (RPS BCC/IFCO);
- geo-textile strips fitted with optical glass fibres (Ten Cate/Inventec).

In addition to the above measurements, Deltares also carries out reference measurements using proven equipment in order to calibrate the new instruments.

The macro-stability experiment has been made possible in cooperation with the Ministry of Transport, Public Works and Water Management and by the support of SNN (the North Netherlands Collaboration), the Ministry of Economic Affairs, the Forestry Commission, and the Hunze en Aa's Water Authority.

