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High-resolution seismic measurements at loamy dikes for monitoring high-water influences

Katrin Jaksch and Rüdiger Giese
Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Germany (kawi@gfz-potsdam.de)

For the risk management of high-water events it is important to know how secure river dikes are. Even the structures of dikes are often unknown. Methods for the exploration of existing dikes and of their underground, for an evaluation of failure potential and strengthening requirements are needed. In the presented work, the potential of a high-resolution seismics to monitor the moisture penetration of dikes during flood periods was analyzed. To identify the extent of moisture penetration and to determine the structures of a loamy dike body would enable to determine the probability of a dike failure.

Dikes made of loam show a different behavior of moisture penetration under high-water influence. The distribution and penetration of water is moderate compared to sandy dikes and resist longer high-water events. The water expands slowly in the dike body in all directions known as fingering. It should be analyzed how the moisture penetration from a dike can be displayed with seismic methods. The aim was to identify on the basis of seismic measurements the areas of moisture penetration within a dike during a flood and out of it to determine the probability of collapse of the dike. For that purpose the structures in the dike body should be determined in reference to the materials and his soil parameters like water content and porosity.

A test facility was built for dikes including a regulation for the water level. This allowed the simulation of flood scenarios at dikes. Two dikes with different loam content were built in order to determine the failure mechanism of dikes. With a width of 8 meters at the basis they had nearly the dimension of river dikes. Seismic instrumentation was installed on both dike models. The seismic survey consists of three parallel receiver lines on the dike which recorded seismic signals emitted along the same lines, resulting in a 3D-seismic data set. The receivers were 3-component-geophones fixed in spikes, at the flooded side of the dike were taken water-proof geophones. In order to achieve a high resolution a magnetostricitve actuator was used as seismic source. The actuator generated sweeps within a frequency range from 100 up to 6100 Hz.

The measurements show a complex wave field, which is dominated by direct P-waves, surface waves as well as refracted waves at the boundaries of the model. The frequencies of the direct P-waves are up to 3000 Hz at small offsets and beyond it declines to about 700 to 900 Hz. Close to the source the entire sweep energy for all frequencies is transmitted in the dike. Surface waves show frequencies from 300 to 400 Hz. A comparison of seismic data at not flooded conditions and at high flood mark shows clearly that the seismic waves were attenuated due to strong moisture penetration of the dike, surface waves were not observed after flooding the dike. Also, travel times and wave field differ in their characteristics. With increasing moisture content in the dike body the P-wave velocity decreases continuously over 30 percent from 290 m/s at not flooded conditions to 200 m/s at the highest flood. The first breaks at longer distances of the measured data stem from refractions at the dike underground which is made of concrete. Calculated travel time tomography's of different saturation states of the dike show the water content in the dike body on the basis of a correlation with the P-wave velocity. Structural heterogeneities in the dike were also visualized by the travel time tomography's.