GFZ POTSDAM
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High-resolution seismic measurements at loamy dikes

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Project partners & aims of the project

Within the BMBF Project "Failure of dikes and dams at and with loamy zones", investigations at dike models took place. The aim of the project is to determine the mechanisms of dike failure. The behaviour of loamy zones in dikes under hydraulic influence was to be investigated in terms of moisture penetration and erosion. Methods for the evaluation of existing dikes and of their underground, of failure potential and strengthening requirements should be developed. In addition, geotechnical stabilisation methods for existing and for new dikes are to be developed.

The geophysical part of the project analyses the potential of seismic high-resolution measurements to monitor the moisture penetration of dikes during flood periods. An aim of the project is to identify the extent of

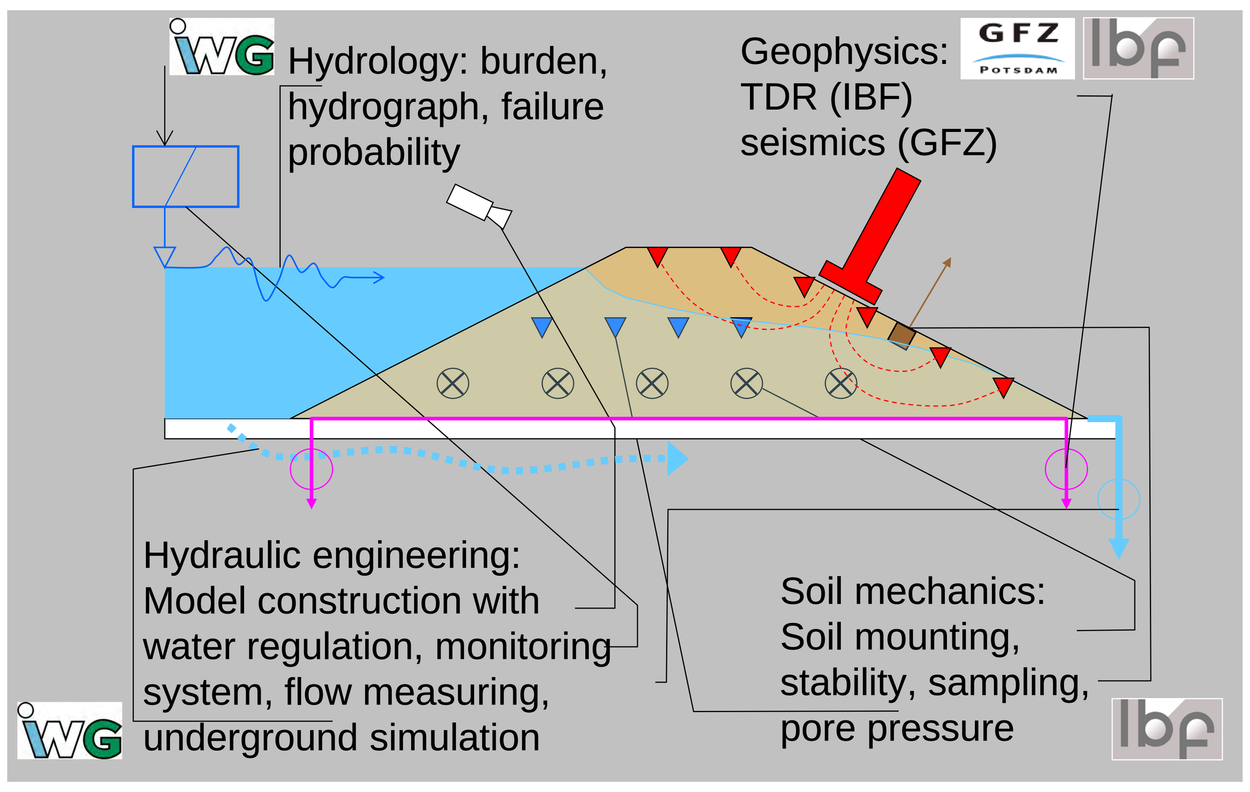


Fig. 1: Project partners and investigation methods at the model dike

moisture penetration using seismic measurements. This would enable to determine the probability of a dike failure.

Aims of the geophysical approach:

Development and application of nondestructive measuring methods for:

- Determination of structures in dike body and underground
- Analysis of the process of moisture penetration and its effects on soil mechanical properties

The purpose of the seismic measurements is to determine the structural setting of the dike body and define its composition and soil parameters such as water content and porosity.

Seismic measurements at the model dike

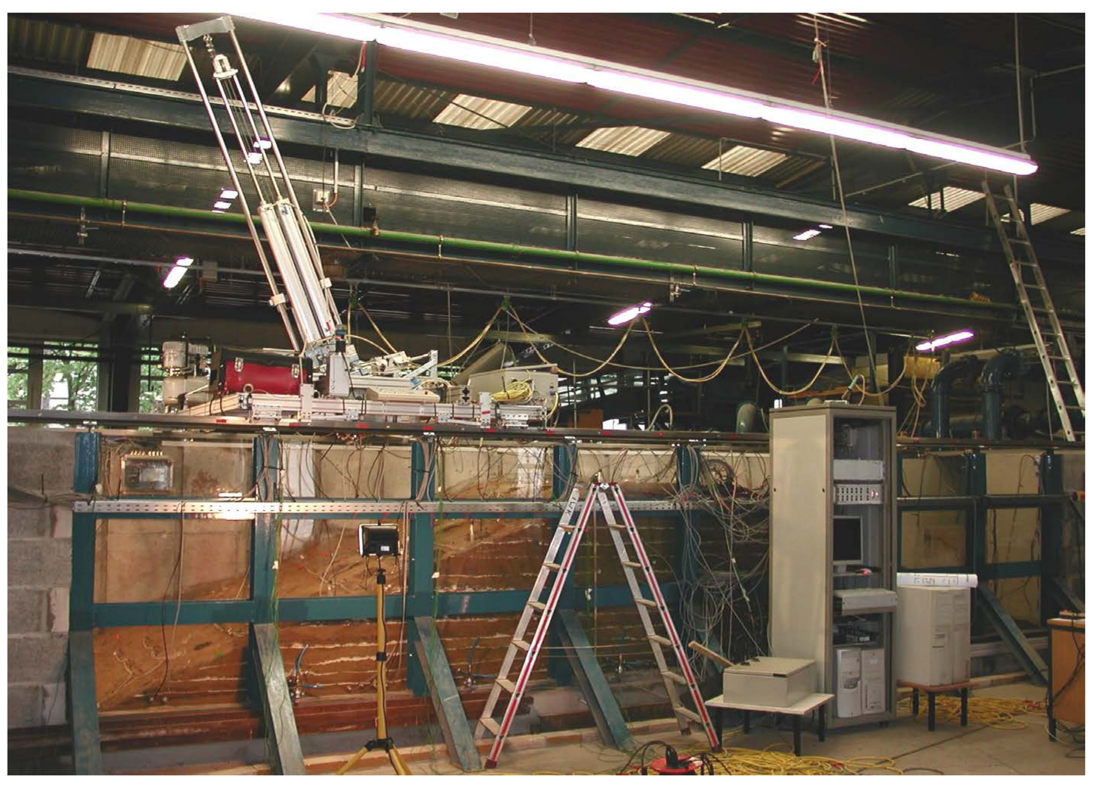


Fig. 2: Test facility at the Theodor-Rehbock-Laboratory, with model dikes according to a proportion of 1:3 to 1:4 of real dikes

Model data

Dimensions of experimental rig for 2 model dikes

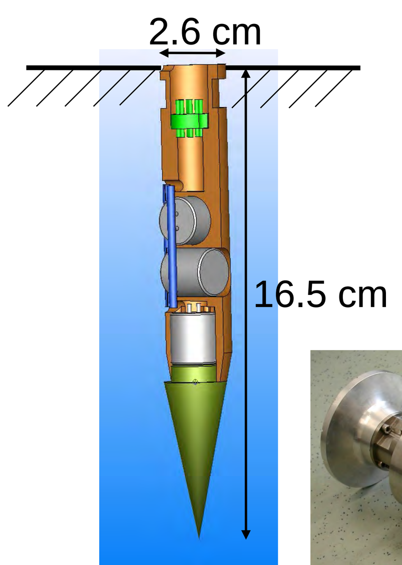
• Maximum width of dike	8 m
• Height of dike	1,4 m
• Length of dike	2,3 m

Technical equipment

- Water level control, measurement of leachate
- Camera monitoring
- Spatial TDR, seismics, geoelectric, GPR
- Tensiometer, pressure transduce, sensor for strength

At the Theodor-Rehbock-Laboratory of the IWG a test facility for dikes including water level regulation was built. This allows the simulation of flood scenarios at dikes. Two dikes with a different loam content were built in order to determine the failure mechanism of dikes.

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.



Technical parameters of vibrator:

Maximum weight:	15 kg
Frequency range:	10 Hz - 15 kHz
Maximum power:	22 kN
Power input:	3 kW
Surface pressure:	1 t

Fig. 3: Design of 3-component geophone spikes (left), magneto-strictive vibrator alone (center) and implemented in the measuring system (right)

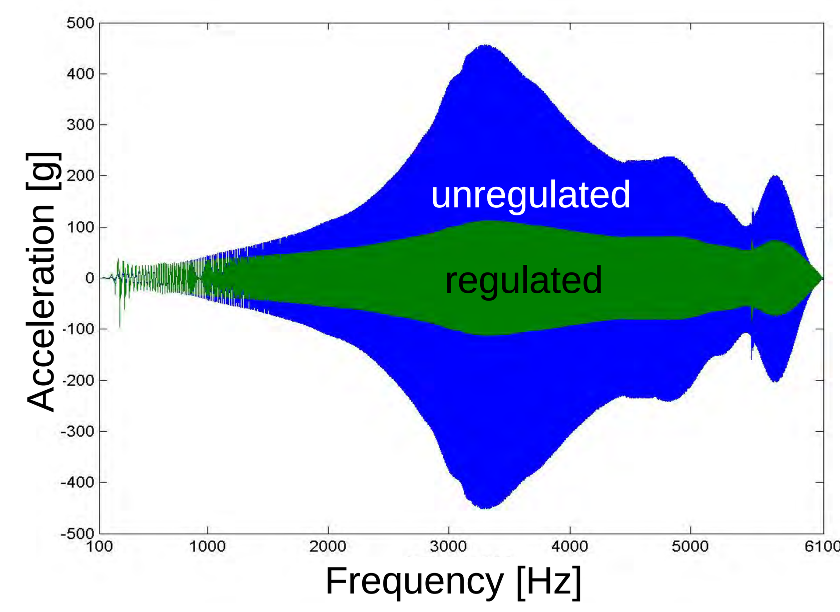


Fig. 4: Application of the real-time control system at the linear sweep (here 100-6100 Hz) leads to the regulated sweep signal (green graph). All frequencies were stimulated nearly with the same amplitudes, whereas at the unregulated sweep (blue graph) the resonant frequencies are clearly seen.

The receivers were 3-component-geophones fixed in spikes which were pressed into the dike. On the flooded side of the dike, water-proof geophones were used. In order to achieve a high resolution seismic signal, a magnetostrictive vibrator was used as a seismic source. The vibrator is able to generate sweeps in a frequency range of 100 to 7000 Hz. The quality of the sweep signal is improved by a real-time control system (see figure 4). This control system uses the acceleration signal measured at the vibrator´s head in order to adjust the amplitude of the sweep.

Data interpretation

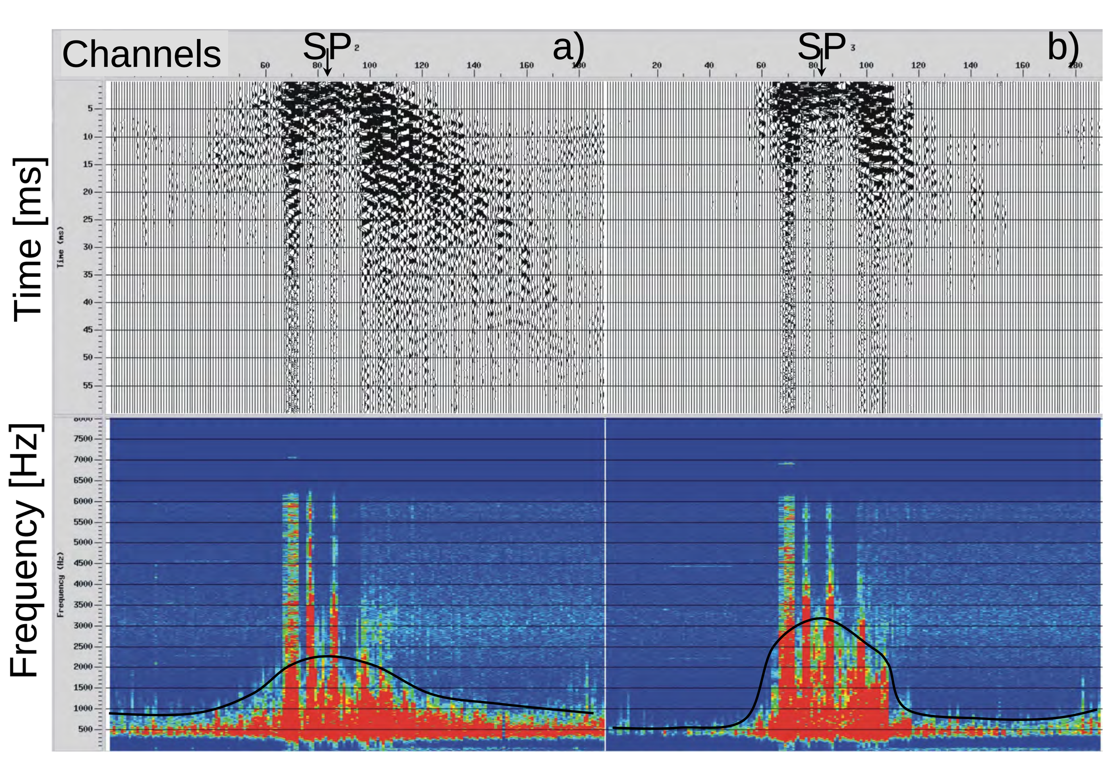


Fig. 5: Seismic data and frequency spectrum for all 189 used geophone channels at a) dry conditions and b) at a dike with a high flood mark, SP source point

In figure 5 the comparison of seismic data with a source point (SP) at the top of the dike at dry conditions and at high flood mark shows these results:

- Attenuation of seismic waves due to strong moisture penetration of the dike
- Near the source the entire sweep energy for all frequencies is transmitted in the dike
- Enhancement of transmitted energy due to moisture penetration near the source point

The measurements show a complex wave field, which is dominated by direct P- and S-waves, surface waves, as well as waves reflected and refracted at the boundaries of the model.

A finite difference mathematical model for the dike was created at the University Kiel in order to study the wave field properties. In figure 6 a comparison of measured and synthetic data at a measuring line with a source point (SP) at the land side of the dike shows that the travel times do not strongly differ in their characteristics. The first breaks at longer distances of the measured data stem from a refraction at the dike underground which is made of concrete.

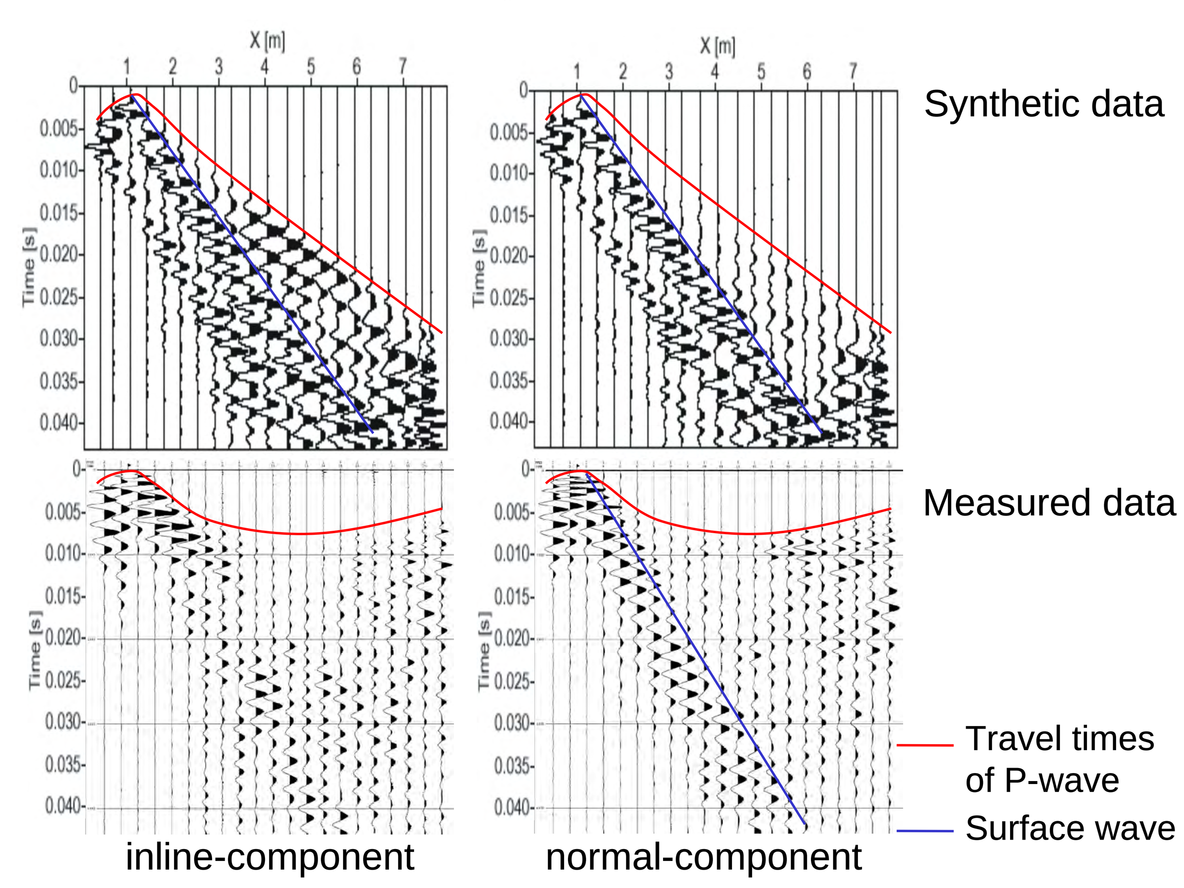


Fig. 6: Comparison of synthetic and measured data in inline- and normal-component of all 21 channels along a measuring line (synthetic data from D. Köhn, Th. Bohlen (University Kiel))

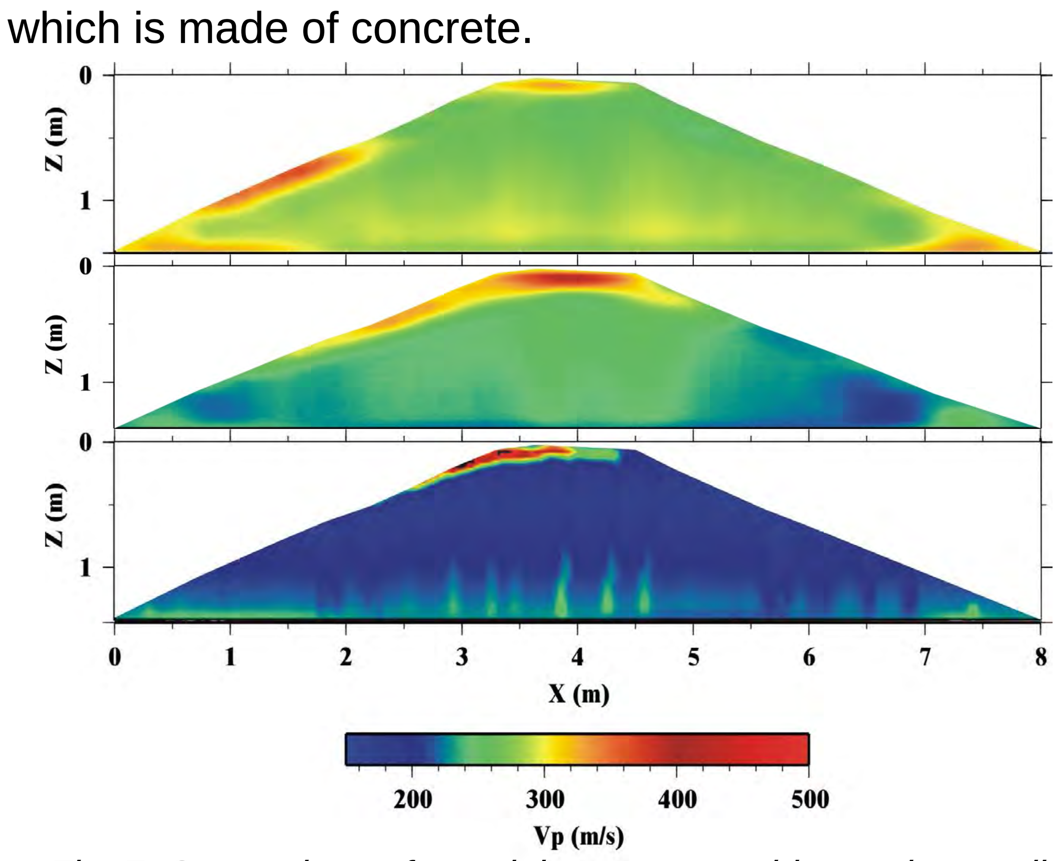


Fig. 7: Comparison of travel time tomographies at dry conditions (above), after five days at the flood mark 0.5 m (middle) and at a dike with the highest flood mark 1.25 m (below)

A comparison of the travel time tomographies at dry conditions and the highest flood mark of the middle measuring line of the dike shows a decrease of the velocities about 80 m/s with an increasing moisture content. The decrease of P-wave velocity with an increasing moisture content is also seen in the data by longer traveltimes. At dry conditions the tomography shows heterogeneties in the dike in spite of an homogenic soil mounting.