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Monitoring water saturation in earth levees with a customized resistivity system

D. Arosio[(1)], S. Munda[(1)], G. Tresoldi[(1)], L. Zanzi[(1)*], L. Longoni[(1)] and M. Papini[(1)]

[(1)] Politecnico di Milano, Milano, Italy
* luigi.zanzi@polimi.it

This work rests on the assumption that a resistivity meter can effectively monitor the level of water saturation in earth levees and can be used as a warning system when this level exceeds the expected seasonal maxima. The potential of this method to diagnose critical areas where seepage is exceeding a safe level and consequently the structural collapse risk is growing was preliminary validated at the startup of the project by performing time-lapse ERT tomographic measurements on a real site where a short segment of a levee affected by a well-known critical seepage was regularly controlled by the local authority managing the irrigation infrastructures.
Preliminary time-lapse measurements with a commercial resistivity meter were also performed on some other sections of the artificial water canal to evaluate the impact of temperature oscillations on resistivity maps and to select the most interesting site for the installation of a customized pre-commercial resistivity meter. Results show that temperature oscillations have no significant impact below one meter. Although the top meter of the levee is above the target depth, a temperature correction algorithm has been implemented based on resistivity-temperature relations reported in literature that seem consistent with our observations. For the installation of the permanent monitoring system, we selected a segment of the irrigation canal which, according to ERT maps, is apparently highly saturated during the irrigation season although the internal sides of the levees were grouted to protect the structure from erosion and excessive seepage. A further reason for monitoring this site consists of its location within a small village which would increase the impact of a structural collapse compared to other critical sites where flooding would affect only the agricultural fields.
The preliminary measurements with the commercial system were very useful to draft the specifications of the new monitoring equipment. Commercial resistivity meters have specifications, performances and costs that are largely beyond the needs and the affordable costs for this specific application on artificial canals. By customizing the equipment according to the required investigation depth, lower than 10m, and to the measured current and voltage ranges observed on these earth embankments, proper electrical components can be selected with remarkable savings.
The final arrangement of the pre-commercial system consists of a new resistivity meter piloting a spread of 48 stainless steel plate electrodes (20x20cm) that were buried in the middle of the levee cross-section by excavating a half-meter deep trench. Electrode spacing is 1m and the measurement configuration is Wenner. A dielectric rodent-resistant casing protects the cables.

A weather station equipped with air and soil temperature sensors, hygrometer, rain gauge, ultrasonic water level sensor and TDR (1m deep) was installed in order to analyze the correlation of apparent resistivity with temperature, rainfalls and water level seasonal variations and to calibrate a resistivity-moisture conversion curve.

Both weather station and resistivity meter use cellular modems to transmit data to the control room where a dedicated prototype software performs quality control, displays resistivity maps, compares time-lapse measurements, updates measurement parameters such as injection current, injection time, stack number, minimum voltage, measurement interval, etc..

After the deployment of the permanent prototype system, the commercial resistivity meter was still used several times to compare the measurements and to validate the new equipment. Considering the small difference in electrode depth, results from the two arrays are fairly consistent.