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ER tomography for the validation of Muon Transmission Radiography (MTR) as a reliable technique to detect and characterise river levees' animal burrows

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Animal burrows in a river's earthen levee, are erosion tunnels that enlarge the structure macro-porosity. This leads to water piping phenomena causing structural damage that eventually leads to the embankment collapse during floods. Currently, the state of the art comprises case studies that deal with management and maintenance issues, while there are very few documented attempts at quantitatively assessing the biological damage in an earthen structure, i.e. quantify possible animal-induced failure mechanisms. For the latter, the detection and characterisation of the animal burrows within earth levees is crucial to the process of risk assessment. In literature Electrical Resistivity Tomography (ERT) and Ground Penetrating Radar (GPR) are the most employed geophysical techniques both for imaging the embankment internal structure and for detecting voids within it.

Between 2017 and 2018 our research group, a collaboration of physicists, geologists and geophysicists, has for the first time probed the possibility of exploiting the Muon Transmission Radiography (MTR) for verifying the internal conservation status of levees visibly damaged by animal activities. MTR is a non-invasive geophysical prospecting technique currently under development, based on the detection of the natural atmospheric radiation produced by cosmic rays in the upper layers of the Earth's atmosphere. It takes advantage of the enormous technological development that has taken place in the field of subnuclear physics in the last decades, which has allowed the creation of compact, rugged, and high precision particle detectors suitable for installations even in particularly inhospitable environments. By measuring the degree of transmission of the natural muon flux along different directions, this technique is capable of providing angular maps of the average density of layers of material present in front of the detector's position. Given the high penetration power of atmospheric muons, this technique is particularly suited for the study of thick material layers, up to tens of metres in depth. A relatively small apparatus (0.5 x 0.5 x 0.5 m3) can measure the structure of a rock wall of more than 10 metre thickness in just a few weeks.

Two MTR measurement campaigns were carried out, with a prototype instrument at two different sites in the Tuscany region (Italy), identified thanks to the support of the local authorities: the south bank of the Arno River in Mantignano (Florence) and the north bank of the Bure stream in Pontenuovo (Pistoia). While in the former case, only a short MTR test was performed before the demolition and reconstruction of the levee, in the latter case a longer measurement was completed successfully. In both test sites, the detector was placed beside the levee. This new survey methodology was compared to a 2D- and 3D-ERT measurement, performed with a pole-dipole and dipole-dipole configuration. Moreover, in the second test site, the actual burrows' distribution was mapped during the demolition works using Terrestrial Laser Scanner (TLS) measurements. These measurements validated and constrained the ERTs' results. The comparison between the ERTs and MTRs maps shows that MTR is a suitable and promising technique that could successfully complement a program of geological risk assessment.