Experimental study of scale effects on sand dike breaching due to overtopping

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Earthen embankments are usually constructed as stand-alone defense lines against river overflow or coastal storm surges to protect the downstream areas from flooding. However, these structures are facing an increasing risk of failure due to climate change that results in an increase of discharges and water levels leading to overtopping of embankments. One of the dominant failure modes of these structures following overtopping is the progressive development of a breach, starting from an initial weaker location in the embankment. This results in a continuous removal of sediments from the downstream side surface due to high flow shear stresses and in a progressive deepening and widening of the initial breached section, finally leading to the complete failure of the structure.

Therefore, designing more robust structures and better preparing the emergency response and flood risk management plans depend on producing reliable flood maps of the inundated area in the case of partial and complete failures. For that purpose, accurately predicting the breach outflow hydrograph becomes vital.

Many efforts have hence been dedicated to developing and validating numerical simulation tools by comparing the results with laboratory experiments that provide essential data to develop and calibrate physically-based models. Nevertheless, most of the laboratory tests are performed at a small-scale (embankment height < 0.5 m) and thus suffer from scale effects, especially since the sediments should be scaled down while keeping a same breaching behavior. Medium-scale tests considering embankments heights up to 1 m seem promising to bridge the knowledge gap between prototype and lab-scale experimental tests and investigate similarity laws. In addition, these tests may be used to calibrate existing numerical models.

To this end, small-scale sand-dike breaching tests already conducted at the Hydraulic Laboratory of UCLouvain were repeated at a larger scale while using the same sediment characteristics. The new tests were performed at the laboratory of the Direction des Recherches Hydrauliques of the Service Public de Wallonie with a 250 m^2 reservoir surface supplied with a 1 m^3/s rate. The dike was 1 m high and 4 m long. The discharge was adjusted to maintain the water level at 1 m during the breaching process and to simulate a pure overflow. The breach evolution was measured and reconstructed using photogrammetry and laser profilometry. Water levels were recorded with ultrasonic probes installed all over the floor and over the downstream dike slope. Particle Tracking Velocimetry was applied to measure the velocity field. The results are then compared to the small-scale tests results in order to highlight similarities and differences between the two scales, and discuss the influence of sediment scaling.