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Riverbank stability analysis considering the limited longitudinal extent of mass failures

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Existing riverbank stability analyses treat the bank stability as a two-dimensional problem. When driving forces exceed resisting forces, the bank is assumed to fail over an infinite length in a uniform bank. In contrast, failure blocks clearly exhibit a limited longitudinal extent and a three-dimensional geometry in the field. A bank geometry monitoring of high spatial and temporal resolution was conducted at the Drau River, Austria, to investigate the geometries of single failure blocks and the overall bank evolution. The monitoring results revealed the average longitudinal extent often to be smaller than the bank height. Moreover, the continuous observance with a time-lapse camera allowed detecting series of adjacent failures of small longitudinal extent. The pronounced three-dimensionality of the failure blocks suggests a significant influence of the shearing resistance at the ends of the failure block on the bank stability.

To investigate the effect of the three-dimensionality on bank stability, an analysis was developed which accounts for the limited longitudinal extent of the failure block and for the shearing resistance along its sides. The analysis uses an idealized bank geometry according to an existing two-dimensional bank stability analysis, which considers tension cracks and simulates fluvial erosion as a horizontal erosion at the bank toe. The block sides are represented as vertical planes perpendicular to the bank edge, where the shearing resistance results from cohesion and from friction induced by the earth pressure. The bank stability varies with the lateral erosion at the bank toe, tension crack depth, number of vertical block sides attached to the bank (0, 1 or 2), and the longitudinal extent of the failure block.

The calculated factors of safety showed to be significantly higher than the results obtained from corresponding two-dimensional analyses. Analyses of parallel bank retreat scenarios revealed that more sediment is fluvially eroded while mass failures deliver less sediment into the channel per unit bank length. For uniform scouring along the bank due to fluvial erosion, the bank stability decreases with the length of the failure block and for a given lateral erosion distance at the bank toe the maximum possible longitudinal extent can be defined. For non-uniform scouring, a longitudinal extent with the minimum factor of safety can be calculated. A parameter characterizing the three-dimensionality of observed failure blocks helps estimating its effects on the bank stability. By defining an average longitudinal extent of failure blocks observed in the field, at least an average effect of the limited longitudinal extent of failure blocks on the bank stability can be accounted for in conventional two-dimensional analyses to still easily couple them with hydrodynamic-numerical models.