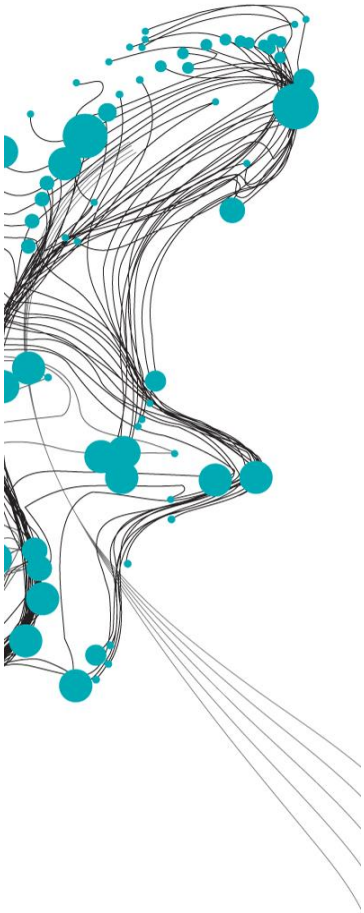
The impact of overtopping on the failure probability of slipped river dikes



Current Dutch WBI safety standards are strict and result in the investments of several billion euros in dike reinforcement projects until 2050. Present standards evaluate a single failure mechanism to determine dike failure. However, in the event of a slipped profile, follow-up mechanisms are often required before a dike will breach. Wave overtopping is one possible follow-up mechanism that results in dike failure. Within this study, a framework is constructed to quantify the residual dike strength for the follow-up mechanism of wave overtopping for slipped dikes, as shown in Figure 1 (a).

This framework was used to evaluate overtopping conditions that result in failure for a dike profile near Millingen aan de Rijn. Within this framework, failure erosion conditions for both the Hoffmans and Transition erosion model were evaluated by using the flow equations of Van Bergeijk et al. (2019). A method was developed for both erosion models to evaluate failure by overtopping for slipped profiles. By using the established framework, the failure probabilities for a regular dike profile and a slipped dike profile were obtained. These failure probabilities were compared by performing a Monte Carlo analysis at varying water levels resulting in fragility curves.

The results from the research framework revealed failure conditions at three locations of the dike. This showed that the slipped river dike profiles fail at a wave overtopping discharge of 3 l/m/s for both the Hoffmans and Transition model during a 6-hour storm. Moreover, the probabilistic assessment resulted in fragility curves as a description of the failure probability for a varying water level, as shown in Figure 1 (b). Conservative model runs approximating erosion by overtopping at a slipped profile indicated that a slipped dike is expected to increase the failure occurrence by overtopping by a factor 2–10 compared to a regular dike with erosion failure at the dike toe.

The developed approach indicates that a residual strength by overtopping is present after slipping. This residual strength can be included in more extensive probabilistic analyses for the assessment of safety standards after sliding. It is recommended to carry out overtopping experiments at slipped dikes to validate derived relationships. The resulting data can be used to test whether current erosion models can approximate the impact of a slipped profile at varying dike locations. Moreover, it is useful to examine the erosion process at a slipped profile more accurately using advanced RFEM shear and CFD overtopping models as extensive research will enable validation of findings and the usage of the residual strength within future WBI standards.

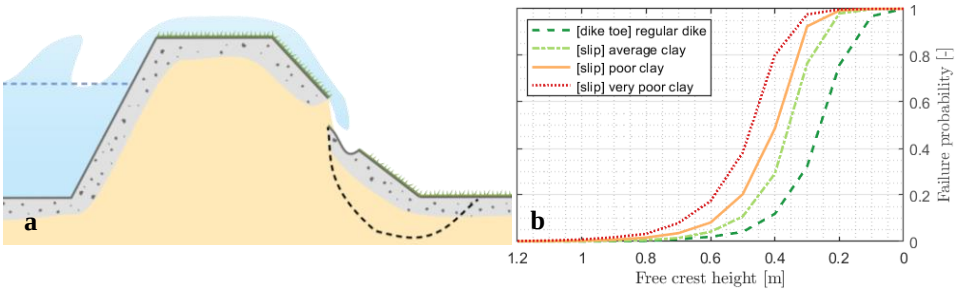


Figure 1: Failure by macro-stability with wave overtopping: (a.) erosion of the grass cover on the slipped dike (b.) fragility curve for a slipped dike profile compared to erosion at the dike toe following the Hoffmans model.

Vincent Verdonk

Graduation Date:
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Graduation committee:
University of Twente
Prof.dr. S.J.M.H. Hulscher
Dr. J.J. Warmink
V.M. van Bergeijk MSc.

References

Van Bergeijk, V. M., Warmink, J. J., van Gent, M. R. A., & Hulscher, S. J. M. H. (2019). An analytical model of wave overtopping flow velocities on dike crests and landward slopes. *Coastal Engineering*, *149*(March), 28–38. https://doi.org/10.1016/j.coastaleng.2019.03.001

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