Study of Failure Mechanisms of Multi-functional Flood Defenses

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In order to ensure the robustness and adaptability of infrastructure it is essential to consider the main different possible failure mechanisms that may occur during the structure service period. Failure mechanisms are one of the main concerns of designers and managers as these are the ones that may compromise the stability and functionality of the structure. To estimate the occurrence of each failure mechanism, limit state functions have been derived for the general embankment cases.

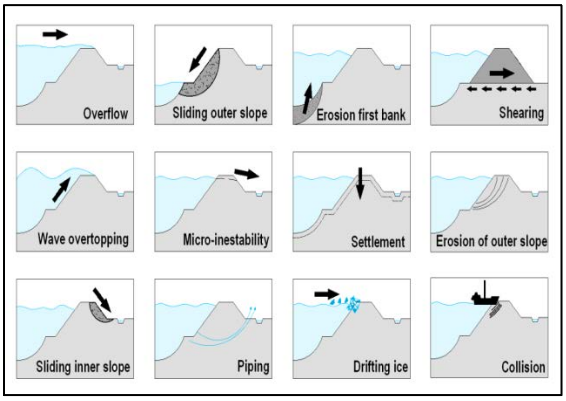

***Fig. 1** Failure mechanisms of embankments (TAW 1998)*

For the design of flood defenses based on Dutch regulation, each of the main failure mechanism has a predefined reliability function that is accepted by the Dutch national authorities (TAW 1998) as it can be found in the "Leidraad voor het ontwerpen van rivierdijken". In the year 2007, the project FLOODsite in the report 4 (Allsop W. 2007) developed an even larger inventory containing limit state descriptions for 80 of the case specific possible failure mechanisms and their reliability equations with the aim to improve the tools for safety assessment of the most common flood defence structures in Europe (Morris 2008). Most common methodologies (Software) for flood defence safety assessment such as PC-ring, ProDeich and Rasp are supported on this kind of reliability equations in order estimate the joint failure probability. However for security matters, flood defenses where not conceived as structures that could have additional functions besides water retaining purposes. In reality, cases like dikes with roads on top and houses embedded in their talus (**Fig. 2**) are frequently observed in the average Dutch landscapes.

***Fig. 2** Multiple functions in a dike()*

If new additional functions are included in the safety quantification of the flood defenses, the probabilities of the structure to fail given a certain mechanism might change in unknown ways. The parameters used as input for stochastic calculations might be correlated to a certain level which can increase the probability of failure (Šimić 2003). During a dike overtopping experiment performed by Infram and Local Authorities Millingen aan de Rijnte near Nijmegen, the research hypothesis was validated by the fact that the scouring rate of the dike revetment is accelerated in the transition zone between the road and the embankment (**Fig. 3**) compared to the rest of the dike revetment area. This can be taken as evidence that the existence of an additional function might increase the total probability of overtopping failure estimated for the defense.

Objective

The main objective of this research is to establish a methodology that allows to estimate the failure probability of a river flood defense with additional functions, by analyzing the possible correlations of their main design parameters such as geometry, construction materials and external loads.

Methodology

The physical understanding of the embankment behavior for most of the main failure mechanisms is explained by reliability functions derived from soil mechanics and porous media flow theory. The parameters used to evaluate this expressions might be correlated to a certain degree with the ones used for the risk analysis of the additional functions (*e.g. road stability, house deformation*).
Once the degree of correlation of these parameters is estimated, the limit state equations have to be re-written and re-validated based on common state variables. This means that all limit state functions that are going to be used for risk quantification, should be expressed in common terms for each failure mechanism. In order to find the common parameters, it’s necessary to build numerical models capable of recreating the main classical failure mechanisms (**Fig. 1**). This models can be used for stochastic simulation techniques in order to generate large sampling data sets once they are built and calibrated.

Most of the models for simulating hydrodynamics and geotechnical stability analysis are quite advanced right now but this also means they are highly time consuming and so surrogate modeling techniques (Bichon, McFarland et al. 2011). are going to be used in order to generate large data samples. Finally when the reliability equations are re-validated the failure estimation considering additional failure mechanisms can be done by the analysis of the new limit state equations for simple general cases.

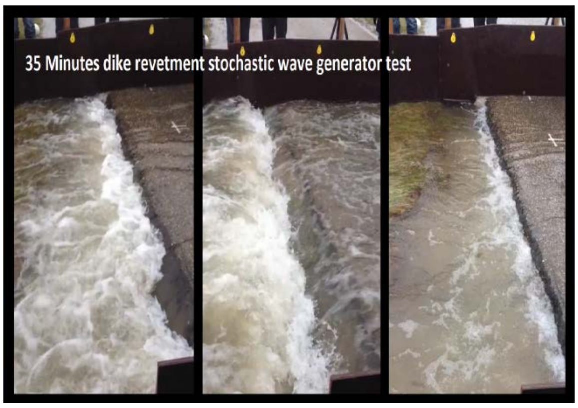

Fig. 3 *Wave generator experiment, Millingen aan de Rijn–Nijmegen*

Expected results

At the final stage of the study it is intended to produce a methodology, so that designers and managers can be able quantify the risk of adding a function to a river flood defense embankment.

References

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