SUBMARINE MASS FAILURE: WAVE GENERATION BY GRANULAR SLIDES

Frederic M. Evers, ETH Zurich, Laboratory of Hydraulics, Hydrology and Glaciology (VAW), evers@vaw.baug.ethz.ch
Helge Fuchs, ETH Zurich, Laboratory of Hydraulics, Hydrology and Glaciology (VAW), fuchs@vaw.baug.ethz.ch
David Vetsch, ETH Zurich, Laboratory of Hydraulics, Hydrology and Glaciology (VAW), vetsch@vaw.baug.ethz.ch
Robert M. Boes, ETH Zurich, Laboratory of Hydraulics, Hydrology and Glaciology (VAW), boes@vaw.baug.ethz.ch

INTRODUCTION

Submarine mass failures (SMF) are a potential source of hazardous tsunamis (Figure 1). While the link between seismic events and the magnitude of tsunami waves has been extensively studied and corresponding approaches are included in numerical tsunami warning models, the basic implementation of SMF generated waves is subject to ongoing research. In this context, laboratory experiments are essential for the validation of numerical schemes. Most experimental studies apply rigid slide models whereas only few include granular slides (e.g. Watts 1997, Ataie-Ashtiani & Najafi-Jilani 2008, Grilli et al. 2017). The objective of this study is to gain a better insight into the hydraulic processes related to wave generation by submarine granular slides based on experiments as well as establishing a comprehensive data set for the validation of numerical models.

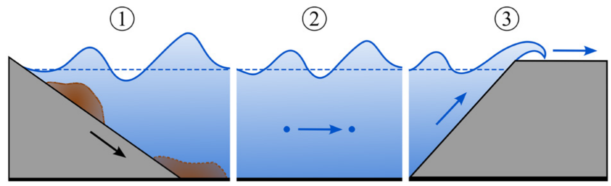

Figure 1 - SMF event with (1) wave generation, (2) wave propagation, and (3) wave runup and overland flow

EXPERIMENTAL SETUP

2D physical model tests were conducted in a rectangular wave tank with a length of 11 m, width of 0.5 m, and a depth of 1 m. The slides were released with a retracting metal sheet mounted perpendicularly to the inclined sliding plane. The varied parameters include the still water depth h = 0.56 … 0.87 m, the bank inclination angle α = 30° … 60°, the slide mass m_s = 5 … 20 kg, the grain diameter d_g = 2 … 8 mm, and the initial water cover above the slide centroid d_s = 0.11 … 0.31 m. The slide motion and the water surface deformation in the near field of the failure zone were captured with a side camera at 50 Hz. The outgoing wave train was tracked with six ultrasonic distance sensors (UDS).

RESULTS

Figure 2 shows two experiments at different bank angles α = 30° (A) and 60° (B). The initial water cover above the slide centroid d_s is approximately 0.13 m at a still water depth h = 0.70 m in both experiments. The vertical slide acceleration after the metal sheet has been retracted is substantially lower in test A due to its smaller bank inclination. The effect on the wave generation process is directly visible: while hardly any deformation of the still water surface may be observed for test A, a distinct wave trough resulting from the downward motion of the slide has formed in test B. Furthermore, despite some dispersion, slide B maintains its compact shape and slide A is subject to substantial elongation. At t = 2 s, some particles in test B are continuously entrained into the water column after most of the slide material is already deposited.

The first and the second wave crest amplitudes of the outgoing wave train as well as its first wave trough amplitude were extracted from the images and the six UDS. The governing parameters for the prediction of the maximum wave and trough amplitudes are the initial water cover above the slide centroid d_s, the slide mass m_s, and the bank inclination angle α. The grain diameter d_g had only a minor effect within the present parameter range.

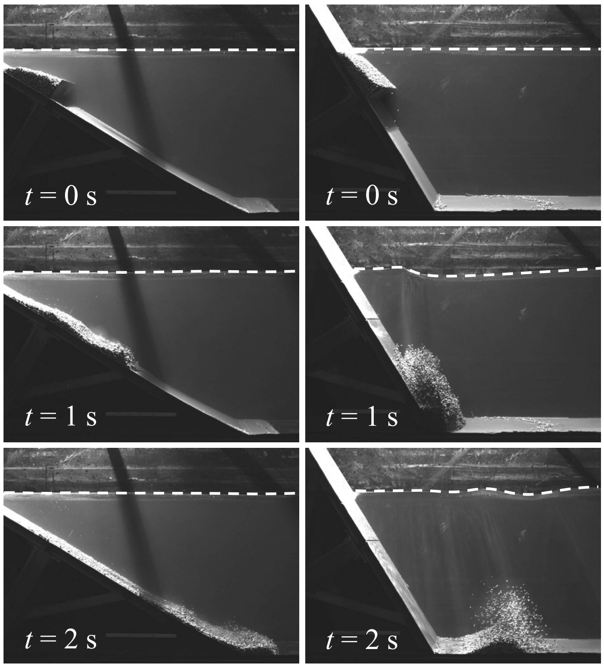

Figure 2 - SMF laboratory experiments at α = 30° (left) and 60° (right) with m_s = 10 kg, d_g = 8 mm, h = 0.7 m, $d_s \approx$ 0.13 m

CONCLUSIONS

The experiments provide insights into the wave generation processes related to SMF and allow for the quantification of the governing parameters. In addition, the measurement data are valuable for the development and validation of numerical models. While the physical properties of prototype SMF may only be inadequately reproduced in laboratory experiments, numerical models allow for the simulation of thin failure zones with very small thickness-to-area ratios as well as the integration of various failure mechanisms.

REFERENCES

Ataie-Ashtiani, Najafi-Jilani (2008): Laboratory investigations on impulsive waves caused by underwater landslide, *Coastal Engineering*, 55, 989-1004.

Grilli, Shelby, Kimmoun, Dupont, Nicolsky, Ma, Kirby, Shi (2017): Modeling coastal tsunami hazard from submarine mass failures: effect of slide rheology, experimental validation, and case studies off the US East Coast, *Natural Hazards*, 86(1), 353-391.

Watts, P. (1997): Water waves generated by underwater landslides, PhD thesis, Caltech, Pasadena.