

Review of “Multi-hazard fragility analysis for fluvial earthen dikes in earthquake and flood prone areas” by Tyagunov et al.

1 General comments

The Authors have studied fluvial dikes along the river Rhine nearby Cologne (Germany) under combined seismic and
5 flooding loads. The manuscript contains: multi-hazard fragility analysis and damage risk (failure probability) analysis. It represents an interesting interdisciplinary research, which perfectly fits in with the scope of NHESS. The topic is timely and innovative.

Although the text is generally very well written (it is virtually word-perfect), the style is slightly verbose. There is room for considerably shortening the manuscript by focusing more strictly on the key messages and avoiding redundancy. For
10 instance, the text on P7 (comments of Figs. 3; 4 and 5) is unnecessary long, ...

The literature review is comprehensive.

It seems that the Authors focus solely on “liquefaction” of the dike (based on Seed and Idriss, 1971), while worldwide dike overtopping is by far the most frequent mode of dike failure. A discussion is needed in this regard.

Wording “damage risk” sounds a bit odd. If I understand well, the authors use the word “risk” for “probability”, since they
15 mean actually the “probability that some damage occurs” (elsewhere, they use “damage probability”, e.g. in Sect. 3, in title of Sect. 4 ...). In science and engineering, risk is a broader concept than just “probability”. It would be wiser to consistently use the wording “failure probability” throughout the manuscript, instead of “damage risk”.

Clarifications are necessary regarding the derivation and characteristics of the fragility surface displayed in Fig. 3. Why does the failure probability not reach 1 for the highest values of water level (e.g. overtopping or nearly overtopping conditions)
20 when PGA is low or zero? The same applies for Fig. 4. The reason relates probably to the liquefaction mechanism which is considered by the Authors; but still the results seem a bit puzzling.

2 Specific comments

- In the Introduction, mention the different failure mechanisms of dikes (incl. overtopping, seepage ...) and briefly discuss their relative importance.
- Make clear which are the differences between *embankments* (frontal / normal to the flow direction) and *dikes* (parallel to the flow direction), and which are the consequences in for risk analysis (different designs, presence of a core ...)?
- Explain the complementarity between “large scale” studies such as the present one and more detailed small-scale studies (e.g. Rifai et al. 2017, WRR). While the latter are interested in the fine details of the failure mechanisms,

studies such as the present one provide valuable insights on the effects on dike failure at a much broader spatial level (regional).

- Define “hazard curve”.
- Is the wording “impoundment of the dike” standard in the field? It sounds a bit odd compared to more standard terminology such as “overtopping” or “overflowing” of the dike ...
- Explain shortly “overburden stresses”, as the readership of NHESS is multidisciplinary.
- Is “phreatic surface” a standard terminology in English? Does it stand for “water table”?
- Table 1: explain “N-values”, “blows/foot”.
- Acronym PGA must be clearly defined when it is first used.
- P6 L28: is the word “proportional” (i.e. a purely linear relationship) appropriate?
- Fig. 3 and Fig. 4 seem redundant ... They display the same information, don’t they?
- P8 L9: why disregard more frequent floods than the 100-year flood?
- P8 L15: explain briefly “S-wave velocity” for the multidisciplinary readership of NHESS.
- P8 L33: is the word “risk” appropriate there?
- P9 L13: replace “term of the equation” by “factor in the integral”.
- P9 L17-19: remove this paragraph as it sounds trivial.
- P10 L17: “at” instead of “it”
- P10 L23: “uppermost” instead of “most upper”
- Fig. 6 : the caption must explain that each curve corresponds to a different dike section. Using a grey scale (or colors) for the different curves would make the graph more informative by suggesting which curves correspond to more upstream (resp. downstream) dike sections.
- Conclusion: please shorten. There are some repetitions, particularly in the second half of the Conclusion.

3 Formal issues, typos ...

- P5 L9: “there are different methods exist” ... Rephrase.
- P5 L11: remove “engineering”
- P5 L25: remove “to be”
- P6 L20: “in three-dimensional form”, instead of “in the three-dimensional form”

4 Conclusion

I strongly recommend that the Authors are invited to submit a revised version of the manuscript for publication in NHES. I believe that substantially shortening the text, by focusing on the main points, would enhance the potential impact of the paper. If necessary, I am available to review the revised manuscript.