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Review and rebuttal of the paper

Admissible post-wave overtopping flow for persons on a horizontal surface

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Editor handling the paper: Bas Hofland

Reply to reviewers

Reviewer A:

I would like to thank the Authors for this interesting work. In recent years, more and more attention has been paid to redefining / improving the overtopping thresholds for the design of coastal defenses taking into account adequately the effect of individual overtopping flows on the safety of pedestrians and / or vehicles in the vicinity of coastal defense. In this sense, the present work adds very interesting analysis coming even from large-scale data, which contributes to a still poor literature on the stability of people under overtopping flows.

However, I see some aspects to clarify or expand on the part of the Authors. At some point, rather than a research paper, the work is written as a technical report, very concise and practical (I appreciate it, but not entirely in this context), but without further analysis or explanation.

Reply: we respectfully but strongly disagree with the reviewer's assertion that the paper is written as a technical report without further analysis or explanation. The tests in the Delta flume have been extensively analysed and every detail has been explained. The tests with a volunteer have been described in full detail and new analysis of overtopping flows reported in depth. Results have been compared to theoretical equations and finally - the only part in the style of practical guidance - a simple equation has been introduced that is not conservative, but has a wider application area than the theoretical equation.

Detailed comments can be found below, with the aim of improving the quality of the article before publication.

Lines 28-37.

The maximum individual volume is not necessarily associated to the most harmful conditions of flow depth (i.e. thickness) and velocity. Recently, Suzuki et al. (2020) by employing SWASH model have demonstrated that time dependent flow depth and flow velocity are better parameters to characterize risks on dikes more in details. Suzuki et al. (2020) have shown that the combination of stand-alone maximum values of flow depth and velocities can lead an overestimation of the hazard. I would suggest that the Authors review the most recent literature that analyses overtopping flow characteristics, including Suzuki et al. (2020).

Suzuki T, Altomare C, Yasuda T, Verwaest T. Characterization of Overtopping Waves on Sea Dikes with Gentle and Shallow Foreshores. Journal of Marine Science and Engineering. 2020; 8(10):752. https://doi.org/10.3390/jmse8100752

Reply: see response below next comment.

Line 38.

Literature review must be extended. For instance, recent works from Suzuki et al. (2020), Altomare et al. (2020), Arrighi et al. (2017, 2019) need to be mentioned. Altomare et al. (2020), performed experimental stuy at small scale to analysed flow velocity and depth on the crest of a coastal defense and showed that the combination of overtopping flow velocity and flow depth rather than single maximum values of one of these parameters is required to understand pedestrians hazard. Arrighi et al. (2017, 2019) conducted a numerical study on human's stability and highlighted the importance of relative submergence and Froude number to interpret the results. About Suzuki et la. (2020), see comment above.

Altomare C, Gironella X, Suzuki T, Viccione G, Saponieri A. Overtopping Metrics and Coastal Safety: A Case of Study from the Catalan Coast. Journal of Marine Science and Engineering. 2020; 8(8):556. https://doi.org/10.3390/jmse8080556

Arrighi, C.; Pregnolato, M.; Dawson, R.; Castelli, F. Preparedness against mobility disruption by floods. Sci. Total Environ. 2018, 654, 1010–1022.
Arrighi, C.; Oumeraci, H.; Castelli, F. Hydrodynamics of pedestrians' instability in floodwaters. Hydrol. Earth Syst. Sci. 2017, 21, 515–531.

Reply: The literature review was indeed short and that was done on purpose. With respect to the description of wave overtopping we consider EurOtop (2018) as the basis. With respect to tolerable wave overtopping for pedestrians we have taken Sandoval and Bruce (2017) as the basis. They give an extensive summary on data that is available and we did not simply want to repeat that. That is also stated in the paper.

The given references, also the two given by the editor, all contribute in one way or the other to description of how overtopping happens, by physical small scale modelling or numerical modelling and in some cases the results have been compared with theories. But none of these investigations had real people subjected to overtopping hazards. This was initially the reason not to mention such references, as they were not really directly underpinning the work of our paper.

But acknowledging the comments of editor and Reviewer A, we have added all references in the Introduction chapter, the first two pages. Also the limiting overtopping volume for pedestrians of 600 l/m in EurOtop (2018) has been explained and the way it was determined.

Lines 203-204

It is suggested to the authors to assess the uncertainty of measuring the front velocity with the drone images using the methodology they specify to overcome the front irregularities. A way might be to discretize the front in several segments (0.5m wide, for example) and to assess the velocity of each of them, so that an average value and standard deviation might be quantified and compared with the already proposed authors' estimation.

Reply: The problem is that front irregularities cannot be overcome, they are simply reality. If the test section had been wider or narrower, the irregularities would have been subsequently increased or decreased. The issue of the irregularity could have been avoided if we had chosen a line through the paddle wheels instead of looking at the full width. But the paddle wheels give the velocity only at one location and do not give any idea about the real variability over the width. To do more analysis on the changing velocity over the width does not really help to understand the paper. We have modified the section as follows:

The front of the overtopping wave was often irregular over the 4 m width of the test section and changed over distance, see Figure 10. A line was considered reached if about half of the front width had arrived at that line. The determination of the velocity by drone is a little subjective (when does the front really reach a line?), but it gives a fair average of the front velocity over the slope. The deviations over the width are in inherent aspect of wave overtopping in reality. The paddle wheel does not take into account any average over the width as it is based on a specific location in the test section. Front velocities were measured over 3 m.

Lines 247-253

By assuming similar shape of flow thickness and velocity over time, it means that the discharge is varying in time and it is not a constant, doesn't it? Are the authors saying that when the maximum of velocity is achieved in time, it corresponds to the maximum in thickness? Is that been seen during the test? Can we extend this assumption to real overtopping events? Authors are invited to provide further details on the performed caluclutions to help the readers to reconstruct and reproduce them.

Reply: we have the impression that the reviewer expects a constant discharge. There are two situations that may cause confusion. At one specific location a certain overtopping volume gives a record of flow velocity and flow thickness, changing over the flow time. Together they give an instantaneous flow discharge over time. Nothing is constant during such an event. We consider this event and assume that flow thickness over time has the same shape as flow velocity: starting and ending at the same time and having their maximum also at the same time.

This is different from a second situation: how does flow velocity and flow thickness vary over the slope? Of course if the flow would accelerate, the flow thickness should decrease (conservation of volume or discharge), but it does not have to be a fixed relationship because due to energy dissipation, the duration of the overtopping volume may increase. But overall, everywhere on the slope the same volume should pass. To enhance clarity distingishing situation 2 (conservation of discharge) with the local variation in flow velocity and thickness (situation 1), we have modified the section a little:

The record of flow velocity over time at a specific location has a correlation with the released overtopping wave volume. The flow thickness over time at the same location, multiplied with the flow velocity over time gives the instant discharge over time. The integration of this discharge over time, gives the overtopping wave volume. In our case we have the flow velocity, flow duration and the overtopping wave volume at specific locations. The missing variable is the flow thickness. By *assuming* that the shape of the flow velocity should be similar to the shape of the flow thickness over time at the same location, one can calculate this flow thickness over time. It also gives the maximum flow thickness at the same time as the maximum flow velocity. One should realise that this flow thickness is without any air entrainment, which may be up to 30-50%. All these assumptions apply to the same location. Over the slope the records over time may vary: the duration may increase, acceleration may give larger velocities and consequently smaller flow thicknesses, etc.

Lines 342-346

I am concerned about the distinction between "inexperienced" and "experienced" volunteers. If overtopping waves occur in reality, most probably the persons affected by them are not experienced or do not act immediately in the most adequate way to withstand overtopping flows. In other words, in those cases plotted in Figures 18 and 19 do the "safe results" refer to "experienced persons"? Maybe this aspect must be further clarified when the aforementioned figures are discussed.

Reply: in principle we agree and we had mentioned that at the end of the section. On the other hand, in the real situation people will probably be subjected to more than one overtopping wave if they decide to remain in the same area. They will then experience several small overtopping waves before a larger volume will hit them. So, what happened to the volunteer may also happen in reality. But we agree that guidelines should be safe and take this aspect into account. The volunteer did not become unstable (fell down), he stepped away a little. In that sense it may still be seen as stable and not as unstable. We have modified the section as follows:

It is clear that a position on a horizontal surface is more stable than on a slope. The tests also showed that an "inexperienced" person, who had not yet experienced becoming unstable in a certain way, moved earlier by an overtopping wave than on subsequent occasions, after he got this experience. On the crest the volunteer slipped away a little for the first time for an overtopping wave volume of 1250 l/m. When he bent his knees a little, he was better prepared for what was coming and survived the next volume of 1250 l/m. Something similar happened on the slope. The first overtopping wave volume of 600 l/m let him step down half a metre. But then he bent his knees again a little, was better prepared, and maintained stability even up to an overtopping discharge of 1000 l/m. With respect to guidance on admissible wave overtopping from these tests, one should take this into account, although it is well possible that a similar procedure will occur in reality.

Line 395

25%. How exactly this number is derived? Is it just an expert judgment based on the considerations above?

Reply: The rationale is added as follows:

Smaller overtopping wave volumes and smaller flow velocities have also less air entrainment than the 30-50% as mentioned in this paper for larger velocities. Therefore it is assumed that the air entrainment in all the observations by Sandoval and Bruce (2017) is 25% and the flow thickness observed has been reduced according to this percentage. In reality this percentage may of course vary with 5-10%.

Equation (2)

The proposed Eq. 2 is more conservative than Eq. 1, since unstable situations for velocities lower than 4.5 m/s are taken into account. Nevertheless, there is no further evidence that this equation is correct and expresses properly the instability under overtopping flows. The equation does not take into account the characteristics of the human body, neither the friction between person and dike crest and other features considered in previous studies. It is clear that as simple equation, is very useful and practical for a very first estimate of the instability, however there are many hypothesis and assumptions behind that makes this approach quite uncertain although conservative.

Reply: Eq. 2 is not more conservative than Eq. 1. Eq. 1 is not correct and unconservative for velocities smaller than 4.5 m/s. Although it is theoretically based, in practice we cannot straightforwardly apply that equation widely with current knowledge. Eq. 2 indeed is simple and indeed does not take into account various characteristics of people. But it is valid over the range 3-8 m/s and gives a good divide between all unstable and stable data points. Of course we would like that the theoretical curve would fit the data. But for smaller velocities is does simply not. We have modified the section as follows:

This gives a combination of 4 m/s flow velocity with a flow thickness of 0.2 m as well as 7 m/s flow velocity with a flow thickness of about 0.1 m. Eq. 2 does not represent a theory and does not deviate in type of person, but it is valid for most persons and from front velocities larger than 3 m/s. Eq. 1 as a theoretically sound equation is not valid, as non-conservative, for front velocities smaller than 4.5 m/s. In all cases the flow thickness is considered as having no air entrainment and a mass density connected to this situation (fresh or salt water).

Reviewer B: We thank reviewer B for their positive comments.