



EGUsphere, author comment AC1
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Reply on RC1

Fatemeh Jalayer et al.

Author comment on "Empirical tsunami fragility modelling for hierarchical damage levels" by Fatemeh Jalayer et al., EGU Sphere, <https://doi.org/10.5194/egusphere-2022-206-AC1>, 2022

We thank the reviewer (R1, <https://doi.org/10.5194/egusphere-2022-206-RC1>) for the very constructive comments that contribute to enriching our paper. Please find below a point-by-point response to the comments.

R1: This manuscript presents their newly developed tsunami fragility functions using previously published survey data. I appreciate the author`s attempt in applying advanced statistical methods but still lack of advertising (or being distracted by too detailed explanations on other parts) benefit of the proposed model. In addition, I strongly feel that it will be more useful if the authors add another data set to compare results when using the proposed method. For example, building damage data from the 2018 Sulawesi tsunami can be accessed from this article.

Characteristics of Tsunami Fragility Functions Developed Using Different Sources of Damage Data from the 2018 Sulawesi Earthquake and Tsunami, *Pure and Applied Geophysics*, 177, 2437-2455.

Reply: This is a very good point. In response to reviewer's point, we are planning to include in the revised version of the paper fragility functions developed for another class of buildings "Residential Buildings in Timber" based on the Reese et al. 2011 dataset for 2009 Southern Pacific Tsunami (results are attached as a PDF). This class is distinguished by having a significantly lower number of data points (see Table 1 in the next page for details). Moreover, the fragility functions obtained by fitting the curves separately to different damage levels do intersect for this class. Therefore, this class is more challenging for fragility assessment and better highlights the strength and benefits of the proposed methodology. Moreover, following reviewer's suggestion, we have derived fragility curves for three different classes of buildings for Sulawesi 2018 Tsunami: "unreinforced masonry with clay brick, 1 storey", "unreinforced masonry with clay brick, 2 storeys", "non-engineered light timber" (the results are attached as PDF). As a matter of fact, through applying the methodology to these different cases, the stability and robustness of the proposed methodology becomes more evident. We used the field survey results by (Paulik et al. 2019, supplementary material):

Paulik, R., Gusman, A., Williams, J. H., Pratama, G. M., Lin, S. L., Prawirabhakti, A., ... & Suwarni, N. W. I. (2019). Tsunami hazard and built environment damage observations from Palu City after the September 28 2018 Sulawesi earthquake and tsunami. *Pure and Applied Geophysics*, 177, 2437-2455.

Applied Geophysics, 176(8), 3305-3321.

We going to add these fragility curves to the revised paper (**please see the attached PDF for the fragility curves and the model class selection results**). Table 1 in the next page reports the characteristics of these additional fragility curves. We are also going to revise the paper title (to also indicate application to Sulawesi Tsunami) and the final discussions based on the additional results and fragility functions.

R1: Please find below for some suggestions.

Abstract: Please add some major findings also in the abstract. Currently, your abstract only explains introduction and method.

We are going to modify the abstract to add the major findings of the paper.

Section 1: Tsunami fragility functions were actually developed following earthquake fragility functions. I believe that it would be good to also briefly review to explain if the proposed method (in your study) had been used in developing earthquake fragility functions.

It is true that the development of tsunami fragility functions follows that of earthquakes. However, in the specific case of hierarchical fragility functions, we did not find significant applications to seismic fragility assessment in the literature. As far as it regards the methodology presented in this paper, it is the first time we are presenting it. In fact, we can imagine interesting applications to seismic fragility assessment. We are going to specify this point in the revised manuscript.

Lines 72-80: I feel that these sentences are more suitable for discussion part. Instead, the authors shall state clearly their research objectives and framework at the end of this section.

We are going to move this part to the discussions and instead state the objectives of the work.

Section 2: I would suggest adding small explanations on limitations of the classical linear regression method at the beginning of this section.

We are going to add sentences that are going to describe more clearly why the generalized regression models are more suitable (compared to classical linear regression) for empirical fragility assessment.

Table 1: Although this is not your own data, I wonder how such detailed statistical analysis model works with data with small sample size. I also feel that the damage level description between D1 and D2 is not so clear "non-structural damage" vs "significant non-structural damage". Did they use 50% more or less to classify? Similar concern for D2 and D3. I wonder how large the bias the damage classification at the site during field survey. Such misinterpreted damage definition might largely affect when the sample size is very small.

Table below summarizes the total number of data points available for the derivation of tsunami fragility curves for each class of buildings and the number of damage levels for which we could derive the curves. The table also reports the total number damage levels defined in the adopted damage scale.

Building Class	Tsunami Event	Total Number of Data Points	Number of Damage Levels/total number of damage levels defined, N_{DS}
Brick masonry residential, 1 storey	South Pacific 2009	120	5/5
Timber residential	South Pacific 2009	23	3/5
Non engineered masonry, un reinforced with clay brick, 1 storey	Sulawesi (Palu) 2018	279	2/3
Non engineered masonry, un reinforced with clay brick, 2 storey	Sulawesi (Palu) 2018	37	2/3
Non engineered light timber	Sulawesi (Palu) 2018	14	2/3

Table 1: The characteristics of the additional fragility functions derived and reported in the revised manuscript.

Therefore, in the revised version of the manuscript, we are also going to show applications based on significantly smaller number of data points.

As far as the distinction between various damage levels, Table 4 of Reese et al. (2011) distinguished DS1 and DS2 based on both the degree of non-structural damage (as the reviewer notes), but more notably on the presence of some structural damage (DS2) vs. no structural damage (DS1).

Section 3: I think the word "flow depth" or "inundation depth" is more suitable than the currently used "water height" as I guess that the authors mean that is water height above ground level. Which model is comparable or the same as those used in Reese et al. (2011)? I would suggest discuss clearer on how the accuracy has been improved by this new work. From a general look, all results in

Figures2-4 show similar results with no-cross and width of error bands.

Yes, this should be "flow depth". We have fixed it in the revised manuscript. With the addition of the fragility curves for additional classes of buildings, we encounter cases where the fragility curves would cross if the fragility curves were fitted one at a time to each building class. We have discussed these cases in the revised manuscript.

In general, the major improvement offered by this method is in providing a tool that can fit fragility curves to a set of hierarchical damage levels in an ensemble manner. This method, which starts from prescribed fragility models and explicitly ensures the hierarchical relation between the damage levels, is very robust to cases where few data points are available. This tool provides confidence bands for the fragility curves and performs model selection among a set of viable link functions for generalized regression. To our knowledge, a tool with these specific features is not present in the literature. We are going to add this discussion to the revised manuscript.

Please also note the supplement to this comment:

<https://egusphere.copernicus.org/preprints/2022/egusphere-2022-206/egusphere-2022-206-AC1-supplement.pdf>