Review of major revision to "Development of bridge failure model and fragility curves for infrastructure overturning and deck sliding due to lahars" by Dagá et al.

April 23, 2018

Summary and recommendation

This revised manuscript focuses on the development of fragility curves for *Chilean* bridges affected by lahars. The main damage mechanisms considered are pier/abutment overturning and deck sliding. Development of the fragility curves follows a process of developing a conceptual model and limit state functions, incorporating analytical models of scour and pressure and finally, Monte-Carlo simulation. These curves (for bridges without (C1) and with (C2) piers) are then parametrised and tested against bridge failure data. I believe this is a useful contribution, as while results are specifically for Chilean bridges (where the authors have data), the method and process is outlined well enough for it to be translated to other regions. Previous concerns highlighted by myself (Referee #2) and referee #1 have been addressed (see below for some smaller issues) and the language has greatly improved. The additional detail on methodology and validation, as requested, clarifies many of the previously highlighted issues. However, validation of the fragility curves (Section 6.2) is fatally flawed:

The number of empirical samples n_e in each test (Tables 3 and 4)is too small to draw any statistical conclusion. From n_a, x_a, n_e and x_e provided, the power of each Z test is around 0.05 (5%). That is, the probability of a Type II error (not rejecting the null hypothesis when it is actually false) is around 95%. Note this does not necessarily mean that the parametric curves (and failure model) are incorrect, but it indicates there is insufficient empirical data to provide a statistical validation of the model.

The lack of data is common in similar studies of fragility, and is not a problem which I expect the authors to solve. Rather, the bridge failure model should be well grounded in physical principles and critically evaluated against any sources of data. From my assessment, I believe the failure/limit state model is sufficiently comprehensive (keeping in mind the need for some level of simplicity) and the evaluation against empirical data in section 6.1 provides some

level of (qualitative) support. Therefore, I recommend the manuscript could be published, subject to the following critical changes:

- Section 6.2, and all references to the statistical validation (p. 1, lines 27-29; section 6.3 first paragraph; p. 22, line 16) should be removed completely.
- In section 6.3, the authors should additionally highlight the data-deficiency issue (possibly as a source of future work) and critically evaluate the success of the model in reference to Table 2. How representative is the empirical data of the range of conditions used to generate the analytical fragility curves? Are the main sources of force/vulnerability sufficiently explored with the empirical data and/or could qualitative 'bounds' on the reliability of these curves be determined?

Minor/typographic issues

- p.1 Line 29: "..that were reached..." change to "affected"
- p.2 Line 6: This implies a lower *hazard* only, not hazard intensity. Remove "intensity".
- p.3 Line 6: "...experimental design was elaborated..." not sure what this means here - possibly reword.
- p.6 Figure 1: What is F_t?
- p.9 Line 10: Change to "...a rectangular shape is assumed."
- p.10 Equation 14: Change to $Y_{w,found}$ (misspelt as *fuond*)
- Equations 13, 20, 21, 24 use the parameter L, which is bridge width. Introduce it at the first instance (Eq. 13) and I would suggest changing it to a less confusing variable (perhaps T for thickness).
- p.13 Table 1: Variable e_{super} is not listed on the table - what is its value?
- p.16 Line 20: This is a valid statement for your study, although I believe it may vary with type and depth of foundations (e.g. the use of piers).
- p.17 Line 29: Remove "...it was concluded that its..."