2ND REVIEW FOR THE PAPER ENTITLED "ASSESSING FRAGILITY OF A REINFORCED CONCRETE ELEMENT TO SNOW AVALANCHES USING A NON-LINEAR DYNAMIC MASS-SPRING MODEL" BY FAVIER ET AL.

REFEREE #4

In general the paper is much improved from the original version. I am thankful that the authors introduced in section 2 and in the conclusions more "snow avalanche dynamics".

The authors thank the referee for this positive comment regarding the first round of improvements we have done. Below is a detailed answer to all the remaining points and questions raised.

Line 5, Page 2: "Hence, in order to find a compromise between simplified but time-efficient models and refined but time consuming models, RC structures can be described using Single-Degree-of-Freedom (SDOF) models (Biggs, 1964) where the structure is modeled by an equivalent mass and an equivalent spring. This approach has been largely used and validated in the field of structures subjected to blast loads (Ngo et al., 2007; Jones et al., 2009; Carta and Stochino, 2013), but has still to be used for snow avalanches or any other mass flow."

I believe the traditional term for SDOF models is the Rayleigh's Method, at least in the United States. The goal is to reduce a complex structure to a single degree of freedom system. The method has been applied to snow avalanches, specifically snow avalanche blasts and forest destruction, see "Dynamic magnification factors for tree blow-down by posed snow avalanche air blasts" NHESS, Vol 18(3) by Bartelt et al. (2018).

The authors thank the referee for this comment. The text of the article has been changed in order to take into consideration the suggested reference. Indeed, in the referenced article a tree is reduced to a single degree of freedom system in order to evaluate its behavior towards powder snow avalanche air blasts, which is relevant. The paragraph of our article now writes as:

"Hence, in order to find a compromise between simplified but time-efficient models and refined but time consuming models, RC structures can be described using Single-Degree-of-Freedom (SDOF) models (Biggs, 1964) where the structure is modeled by an equivalent mass and an equivalent spring. This approach has been largely used and validated in the field of structures subjected to blast loads (Ngo et al., 2007; Jones et al., 2009; Carta and Stochino, 2013). On the contrary, in the field of snow avalanches such approaches are only emerging. A recent example is the application of a SDOF model to study the behavior of trees towards powder snow avalanche air blasts (Bartelt et al., 2018)."

Bartelt, P., Bebi, P., Feistl, T., Buser, O., & Caviezel, A. (2018). Dynamic magnification factors for tree blow-down by powder snow avalanche air blasts. *Natural Hazards and Earth System Sciences*, *18*(3), 759-764.

Line 11, Page 2, "civil engineering abacuses" is not clear to me.

Thank you for the comment. In order to clarify this part of the sentence, we changed the text to: "and simpler models based on civil engineering abacuses, that is to say, models that use structural sizing tables to calculate the resistance of standard structures."

Line 15, "ignor" – ignore.

Thank you, this has been corrected.

Line 15, The end of the this paragraph is not quite clear to me: is it really only "quasi-static"? Does not the "mass and spring" system mean that you account for the dynamic impulsive loads and therefore the method is "dynamic"? (I read on and you appear to solve the second order equation with Newmark's method – why to you insist to call the procedure "quasi-static").

From a mechanical/physical point of view, the resolution of the problem (via mass-spring system equivalence) accounts for potential inertial effects. Whatever the loading you apply onto the structure, the resolution is performed within structure dynamics framework. Three kinds of structural response can be expected function of the loading features. If the loading duration is very long and the loading rate is low, the structure will develop a quasi-static response. In the opposite case, if the loading is very very short, the structure will develop an impulse response. Finally, between those two regimes, the structure will develop a combination of both where inertial effect begins to be significant on the structure response.

Thus to clarify the text, the sentence has been rephrase from:

"However, it often operates under assumptions such as the response of the structure is quasi static which leads to ignore potential inertial effects due to the dynamic nature of the loading.";

to :

"However, simplified approaches often operates under questionable assumptions (e.g. *quasi*-static response of the structure, pressure field spatial distribution) and can leads to ignore potential inertial effects due to the dynamic nature of the loading.".

Section 2 "Avalanche dynamics and measured pressure signal". There are some misspellings in this section (e.g. avalance). Please check spelling. I found this section interesting, simply because the authors try to overview the present state of knowledge on impact pressures. I would be a little more critical with the avalanche community – they have measurements but are unable to identify underlying mechanisms, especially in the real scale field measurements. This is why there is such a large variation in the measurements. I would stress two things: 1) Measurements in the runout zone are rare (!) and therefore much is based on back-calculations, which is extremely difficult and 2) There are cases where the standard V^2 formula work extremely well, cases where it doesn't. Basically, it is a mystery. The loading rate of 0.1 kPa/s appears to me to be way too low, especially for the initial hit. I would suggest that impact loading rates of 2000 kPa/s are more appropriate – but this is all speculation, and not the problem of the paper. I would modify the text to express the uncertainty of the measurements, and the difficulties of gaining information from case studies (only one sentence is needed).

Thank you for your comment, we totally agree with your observation. The paragraph was spelt checked and we added a last sentence to emphasize the difficulties to catch the uncertainty of avalanche pressure measurements. Text has been changed to:

"Avalanches are defined as the release of a snow volume that propagates down a slope under the action of gravity. Snow avalanches are usually classified according to several criteria, e.g. snow type, release zone, weather conditions. Two main types of avalanches are distinguished: (i) powder snow avalanches composed of diluted dry snow, due to air incorporation, characterized by a mean flow velocity which can reach 100 $m.s^{-1}$ and having a density from 1 to 10 $kg.m^{-3}$, (ii) dense snow avalanches mostly composed of humid snow which can develop a mean flow velocity of hardly 30 $m.s^{-1}$ and a high density up to 500 $kg.m^{-3}$. The pressure field developed by an avalanche onto an obstacle depends on those latter features. Within the heart of the flow, high peak pressures can develop. For powder avalanches, important pressure values are related to high velocities of the flow and for dense snow avalanches to high snow densities. Up to now, measured peak pressures span from 6.6 kPa at the Lautaret experimental site (Berthet-Rambaud et al., 2008) and up to more than 1200 kPa at the Sionne site Sovilla et al. (2008). This last pressure was however measured very locally on the height of the avalanche front. The analysis of the signals data held by the authors suggests that the lowest recorded average loading rate is 6 $kPa.s^{-1}$ for a peak pressure of 21 kPa at the Lautaret experimental site (Thibert and Baroudi, 2010) and the highest is

400 kPa.s^{-1} for a peak pressure of 490 kPa at the Taconnaz site (Bellot et al., 2013). Those measurements were made with sensors placed at key positions within the flow, typically in the middle of the avalanche path, where high pressures and high loading rates can be recorded (see for instance Schaerer and Salway (1980), Berthet-Rambaud et al. (2008), Sovilla et al. (2008), Sovilla et al. (2013) or Thibert et al. (2015)).

It must however be stressed that such direct measurements, and related back calculations and numerical calculations of avalanches pressure impacts and loading rates, still suffer from large uncertainties and lack of information. In addition, dwellings and buildings are commonly located at the bottom of avalanche paths, in the so-called avalanche runout areas, where magnitudes of peak pressures and loading rates are lower than those recorded in the middle of avalanche paths, which adds further uncertainty to the analysis. This makes that engineering studies, as ours, cannot currently rely on very specific inputs to specify impact pressures and loading rate values. Hence, in most of what follows, because the RC wall is supposed to be located within the runout zone of the avalanche, a rough loading rate value of 0.1 kPa.s^{-1} has been assumed. This leads to load the RC wall under quasi-static conditions. However, a specific section (5.3.3) is dedicated to assess the effect of the avalanche loading rate on the fragility curve derivation. In many European countries, if a building is located in an avalanche prone area, civil engineering standards impose that the wall facing the avalanche flow has to support pressures of up to 30 kPa."

Section 3.1. The opening of section 3.1 I find somewhat awkward. Why don't you keep the geometry open and undefined. "We consider a simply support wall with length L, width b and thickness h". The method you develop is completely general. In the examples you state L=8m, somewhere. Merge section 3.1.1 into section 3.1.2.

Thank you for your comment. The beginning of section 3.1 was modified as you suggested. Sections 3.1.1 and 3.1.2 were merged to form a single section now entitled "3.1.1 Geometry, loading and material behavior laws".