Review of manuscript NHESS-2022-173

Sensitivity analysis of a built environment exposed to debris flow impacts with 3-D numerical simulations.

Overview

In the manuscript, the authors analysed how the surrounding buildings modify the maximum debris-flow impact force on a target building. The purpose was to identify how some geometrical features of the buildings affect the impact force. The authors used the three-dimensional commercial code FLOW-3D to investigate numerically them. Firstly, they validated the code with a flume experiment, and then 160 simulations were performed and used for metamodel modelling. This approach allowed defining a ranking among the geometrical feature involved. Finally, additional simulation was performed and analysed to understand if and how the surrounding building modifies the debris-flow impact force.

Observations and critical points

In the following, I list my main observations and critical points about the manuscript.

1. Debris flow is a word commonly used to describe the flow of a mixture composed of water and a high concentration of sediment. Depending on the type and quantity of finer sediment grains, debris flow can be dived into two main classes: stony debris flow where the percentage of cohesive material (usually clay and the finer classes of silt) is negligible and mudflow where the percentage of cohesive sediment is important. This division is necessary since the rheological properties of the two are quite different: in the mudflow, the solid particles are essentially suspended inside fluid and the division between solid and fluid are difficult. This means that a monophase approach can be used and the mixture presents a non-Newtonian behaviour where yield stress is present (e.g., Bingham fluid). On the other hand, in the stony debris flow the two phases are easily identified and divided. This implies that a two-phase approach is necessary where the fluid behaviour is usually Newtonian, while the solid phase presents a collisional regime. See e.g., Iverson 1997, Takahashi 2007, Armanini 2013. The authors have to clarify which type of debris flow are dealing with: it seems, from the validation test that a stony debris flow is the target, however, in all the other sections it seems that a mudflow is analysed.
2. The authors use the FLOW-3D code to simulate debris flow. Which are the equations used? These are crucial when you describe the parameters used. Without the equations, the parameters described by the author can be not present in the model. Moreover, looking at other papers dealing with FLOW-3D, also other parameters are needed: these are not listed in the manuscript.
3. A peculiarity of stony debris flow is the rapid formation of large scour and deposition. Deposition rapidly occurs when the mixture flow decreases the velocity, while scour usually happens when the flow is accelerated. Both decreasing and increasing velocities are present when the flow impacts the building. From the literature, I found that the model FLOW-3D can describe scouring and deposition for river and coastal morphodynamics, so when the morphological variation presents a longer time scale than the hydrodynamic one. In debris flow, the variation is of the same time scale. How did the authors consider this bed variation in the FLOW-3D modelling?
4. How are the impact forces evaluated? The authors write “the General Moving Objects (GMO) model of FLOW-3D was applied to obtain the overall impact forces on the building, in which a rigid body motion was introduced for the fluid-rigid interaction behaviour (Postacchin, 2019; Isobe, 2021)”. Is it correct that the object where the forces are evaluated must be in motion? How is it possible to use this when dealing with a fixed and non-deformable target building as the one described in the manuscript?

Moreover, the citations proposed are not relevant: Postacchini 2019 deals with experimental apparatus where a movable reference system is used (they move the building in a static pool of water), while Isobe 2021 deals with movable and deformable steel frame buildings but with another kind of models, not the FLOW-3D.

5. In the validation section, the authors reproduce one laboratory experiment. The particular stony debris flow experiments can be reproduced well also with a monophase approach since the bed is rigid and all the material remains quite well mixed during all the experiment (only some separation between solid and fluid phase is visible in figure 2(c)). However, I think that it is not correct to say "FLOW-3D reproduces the debris flow impact process in the flume test very well" basing the statement mainly on the peak impact pressure. It is important also the time history of the pressure: arrival time of the flow, the timing of the peak, duration of the peak, etc. Moreover, it is missing some parameters used in the model (e.g., the roughness) and it is not clear the dimension of the cell: is it composed of cubes of 0.02 m side? If yes, since the first load cell position is 0.015 m from the bottom of the flume, how do the authors evaluate the pressure at that height that is neither on the centre nor the border of the cube? Additionally, on line 105 the authors highlight that the data is averaged over 10 points (it means cells?) how is it possible to do this in the flume experiment? Is it horizontally averaged? Finally, for better validation, I suggest using the calibrated parameter to reproduce a second flume experiment and discuss it.
6. In the numerical modelling, the authors used a fixed discharge of 500 m^3/s for a very short time (10 s). If the peak of discharge could be of some interest for very large debris flow, however, the duration and the constant value are not realistic and leads to unrealistic values of impact force. A more realistic debris flow inflow can be a triangular one where the overall duration is about 15 minutes with a peak discharge that occurs after 5 minutes (some examples of real and simplified hydrographs with can be found in Berger & al. 2011, Marchi & al. 2021). This modification in the inflow is essential for a truthful analysis of forces since, one of the main features of a debris flow just described previously, is the great deposition that occurs when the flow is slowed down. The direct consequence of the deposition is the time increase of the pressure due to this saturated terrain at rest.
7. Some perplexity will arise also by looking at some of the parameters used: roughness and viscosity. For the surface roughness, the authors used 0.05 m which represents "the equivalent grain roughness (or absolute height in meters)". This means that on all the surfaces of the computational domain (that also includes the buildings) the roughness is generated by grains of 5 centimetres. This kind of roughness can be representative of a natural environment (e.g., riverbed, grassland, wood) but in an urban environment, where usually the surfaces are paved or made of gravel, is too big. For the viscosity, the authors used 1 Pas. This value is at least one order of magnitude higher compared to the ones described by Iverson 1997 (the fluid viscosity ranges from 0.001 Pas to 0.1 Pas) or also the ones measured by Song & al. 2021 (laboratory experiment with fluid viscosity ranging from 0.001 up to 0.1). Also, the authors use a value of 0.1 Pas to validate the FLOW-3D model (based on one of the experiments of Song & al. 2021). Why this choice? If you validate the model with 0.1 Pas, also the other simulations should be performed with similar viscosity.
8. The target building has walls with a thickness of 0.35 m (line 156), while the cell (cube?) has a 0.25 m side (line 158). How is possible to simulate a wall that has a dimension that is not a multiple of a cell? Why not use a wall thickness equal to the cell side?
9. The force is a vector, so it has an orientation. In the paper, I suppose, the authors report only its module. This aspect gives rise to two main questions. The first one is how the impact force is evaluated: is it evaluated also considering the tangential stresses on the walls? The second question is about where the force is evaluated: it is all over the surfaces of the building (inside and outside walls)? If the answer is yes, is it simply a sum of the force exerted by the mixture over all the walls? In this specific case, if there is flow inside the building, is the force on one wall the net force evaluated between inside and outside or is it the sum of the two? Moreover, is it considered also the roof?

10. When the azimuth angle A decreases and approaches 0, it has to be specified that the two surrounding buildings become a single building. Regarding this aspect, is the metamodel able to consider this? Otherwise, the authors have to be neglected, from the metamodel simulations, all the cases when the surrounding buildings are merged.
11. Regarding the metamodel simulation, what are the ranges of variation of the four input variables?
12. I think that the duration of the simulation, which, from figures 17 and 21 it is set to 10 s (as the discharge duration), is too short since it for some tests the maximum value of the impact force is registered at the end of the simulation when a positive trend is also visible. I suggest increasing the simulation duration until the mixture is fully stopped or is flowed away from the target building.

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