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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Model development for simulating mudslide and the case study of the failure of the gypsum tailings dam in East Texas in 1966" *by* Tso-Ren Wu et al.

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Response to referee #2 comments We sincerely thank you for all of your questions, suggestions, and comments. They are really useful for us to improve our manuscript. According to your comments and a long discussion with co-authors, we decide to change the title, the abstract, as well as the main conclusions. The writing of the entire article has been largely improved to satisfy the standard of NHESS.

The validations of the numerical framework and rheological models in Sec. 3 do not include the MBM, leaving aside the comparison with the proposed ideal model for mudflows. Moreover, the numerical modifications and assumptions for adapting the model

from 3D into a 2D representation are not discussed nor evident. Answer: Thanks for the comments. The validation framework is: We validate the accuracy of the Bingham model (BM) by two cases. After the validations, the BM and the conventional Bi-viscous model (CBM) are used to simulated the event of FGT66. The sensitive analysis shows that the results of BM and CBM are nearly identical when the yield strain rate is small. In the end, a large viscosity of plug zone is proposed in the modified Bi-viscosity model (MBM) as the suggestion of Assier Rzadkiewicz et al., 1997; Taibi and Messelmi, 2018; Yu et al., 2020 to describe the sturdy behavior in the un-yield region. The only difference between CBM and MBM is the material parameters. The numerical code is kept the same. Therefore, the code validation for MBM could be referred to as the CBM. The numerical code remains the same for a 2D and 3D problem. 2D problem is one special case of the 3D problem as the free-slip boundary conditions are applied to the lateral boundaries.

It is unclear, why the authors choose to simulate the 1966 East Texas event. If the authors interest is to highlight how the model can be used for tailing hazard assessment, then a detailed description of the event and the mobilized materials is needed. Moreover, given the frequency of tailing failures, it is tempting to see the model being validated with more cases. Answer: The purpose of this study is to give a flexibility for illustrating the sturdy un-yield behavior numerically in the mudflow by migrating BM to CBM, and from CBM to MBM. Because of the clear setup and simplicity in geometry and topography, the event of FGT66 is chosen and discussed.

However, if the authors motivation with the 1966 event is to prove how the MBM rheology reproduce a more accurately a mudflow, the selection of a field event of limited information makes it difficult to assess the advantages of the rheological model. Then, the selection of a benchmark case as a dam-break model seems more suitable for this purpose. Answer: Thanks for your comments. We agree that choosing a benchmark case as a dam-break model will be a better choice. However, in our limited knowledge, no experiments have been done for MBM. For the FGT66, the geometry, and fundamental material parameters were reported in Jeyapalan et al., (1983); Pastor et al., (2002); Chen and Peng, (2006).

I got the impression that the comparisons between the three rheological models on the 1966 event are not supported by direct measurements of the material parameters of each particular model. Also, it is not clear how these parameters are obtained and calibrated. These missing information makes a critical assessment of each model difficult and leaves the reader with a qualitative similitude. Answer: Thanks for the comments. The material parameters are obtained from the publications such as Jeyapalan et al., (1983); Pastor et al., (2002); Chen and Peng, (2006). More information is added to the manuscript: Based on the parameters reported by Jeyapalan et al., 1983, Pastor et al., (2002), and Chen and Peng, (2006), the yield stress of the tailings is τ_y=ãĂŰ10ãĂŮˆ3 Pa, the viscosity of the liquefied zone is μ_B=50 Pa s, and the density is =1400 kg m-3. The viscosity of the plug zone is suggested to be infinite (e.g. μ_A=ãĂŰ10ãĂŮˆ10 Pa s) by Assier Rzadkiewicz et al., (1997); Taibi and Messelmi, (2018); Yu et al., (2020). In this model, the yield stress τ_y and yield viscosity μ_B of the tailings material are exponentially dependent on material concentration (Julien, 2010). The detailed descriptions are added to Section 5.2. To present the un-yield behavior in the plug zone, μ_A is chosen to be infinite based on the suggestions of Assier Rzadkiewicz et al., (1997); Taibi and Messelmi, (2018); Yu et al., (2020). In this paper, the infinite number of viscosity μ_A=ãĂŰ10ãĂŮˆ10 Pa s is chosen by a sensitivity analysis. The values of yield strain rate γ ÌĞ_y are also discussed in Section 5.2. By sensitivity analysis, γ ÌĞ_y=0.2 s-1 is adopted to illustrate the deformation in MBM.

The manuscript goal differs slightly between line 72 and line 293. I understand that the authors explore the formation of a plug and a sheared region within the mudflow, but disagree in referring to them as solid and liquid phases, respectively. Answer: Thanks for the comments. The solid phase has been changed to the un-yield phase, and the liquefied phase has been changed to the yield phase.

It is not clear the difference between the volume fraction r and the solid concentration

Cv introduced at the end of Sec. 5. A discussion on how this parameter evolves and controls the stratification process might strengthen the authors message. Answer: The concentration Cv is used to determine the yield stress τ_0 and the yield viscosity μ_B of the mud material (Julien, 2010). The volume fraction of mud, F (has been changed from r), in the VOF equation is used to track the mud free-surface. The detailed algorithm of the VOF method can be found in the paper, we recently published (Chu et al., 2020).

The authors claim in line 305 that the initiation and slip surface of the mudflow is described in their model. However, I do not find information that supports this claim, as the event simulation assumes the sudden release of the tailing material. Therefore, the conditions leading to the tailing failure are not accounted for in their model nor studied. Answer: Thanks for the comments. This part has been improved as: Error! Reference source not found. illustrates the strain rate profile of the initiation process of the tailing flow. The strain rate profiles in BM results show a smooth and continuous feature (Error! Reference source not found. (a)). A large amount of tailing material deforms and slides down (Error! Reference source not found. a)). On the other hands, in MBM results, the yield strain rate γ ÌĞ_y=0.2 s-1 is introduced as the indicator to identify the plug and sheared zone. Because the un-yield viscosity μ_A=ãĂŰ10ãĂŮˆ10 Pa s is much greater than τ_y/γ ÌĞ_y, a discontinuity pattern of the strain rate can be observed in Error! Reference source not found. (b). The yield strain rate γ ÌĞ_y=0.2 s-1 keeps the plug zone rigid. The initiation process of mudslide in MBM results is different from the ones in BM results. A high strain rate appears not only near the toe of the breach but also in the gate area, which causes the sliding process and forms a slip surface. The slip surface is the interface between the un-yield and yield parts. In the bank of homogeneous mud, the slip surface of failure can be determined from the empirical method, which follows the arc of a circle that usually intersects the toe of the bank (Sun et al., 2008; Fredlund et al., 2012). However, the slip surface is developed automatically by MBM. It is worth a more profound study in the future. Error! Reference source not found. shows the strain rate profiles of BM and MBM. The slip surface (Error! Reference source not found. (b) at t = 10 s), as well as the interface between the plug/sheared zones (Fig 10 (b) and Fig 13 (b) at t = 40 s), can be identified in the results of MBM. From the comparisons of Fig 13 (a) and (b) at t = 10 s, and also Fig (a) and (b) at t = 10 s, we can see that the slip surface is relatively sharp in the MBM results than the ones in MB.

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Please also note the supplement to this comment:
https://nhess.copernicus.org/preprints/nhess-2020-126/nhess-2020-126-AC2-supplement.pdf

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