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Solid Earth
Discussions
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Interactive comment on "Geomechanical modelling of sinkhole development using Distinct Elements: Model verification for a single void space and application to the Dead Sea area" *by* Djamil Al-Halbouni et al.

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This manuscript presents a numerical study of Discrete Element Models set to simulate the formation of sinkholes in different types of rocks, and compare the observed craters with those observed at the Ghor al-Haditha sinkhole site, close to the Dead Sea. The shape of the craters formed in series of simulations, with different types of rocks, depth and size of the underground cavity responsible for the sinkhole formation, is compared with Digital Elevation Models reconstructed by Stereophotogrammetry from field data. The study is well introduced and well presented. The data is solid, both for the nu-

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merical part and for the field study. The exploration of the parameters is systematically performed, with a good number of simulations performed, and a systematic discussion of the effect of the diffenrent parameters.

The study is of relevance to the readership of this journal, and the study is well explained and well conducted. Hence, I support its publication in Solid Earth.

I only have a few minor remarks that I would propose the authors to consider :

1. In general, what should be the effect of chosing a stepwise removal versus the reality, where a progressive dissolution happens ? i.e., what would be the effect of memory (linked to friction and nonelastic effects) and path dependent stress state? How can the authors estimate this, and justify that their stepwise removal appoximation is a good one to model the mechanical state ? The authors mention that they consider either a stepwise removal, or a progressive removal, but it would be interesting to document in what they differ. Also, is there a convergence towards a given stress state for a sufficiently small step in the shrinking of the cavity ? What is this limit step ?

2. The effect of pore pressure, at least being hydrostatic in the saturated regions without significant flow, does not seem to be integrated in the current study. PResumably, for sinkhole formation, where the waterbed is close to the surface, and to the sinkhole bottom, this can affect the effective stress, and modify the resulting solid stress. For example, a paper taking this into account for soil liquefaction is : Clément, C., Toussaint, R., Stojanova, M., & Aharonov, E. (2018). Sinking during earthquakes: Critical acceleration criteria control drained soil liquefaction. Physical Review E, 97(2), 022905.

Can the authors state if they take this buoyancy effect on the stress state into account, how, and if not, how it can modify the results, and where in their system ?

3. If there are in addition dynamic effects, and pore pressure affected by flow and the fluid viscosity, this can also modify the pressure - see e.g. : Zeev, S. B., Goren, L., Parez, S., Toussaint, R., Clement, C., & Aharonov, E. (2017). The Combined Effect of

Buoyancy and Excess Pore Pressure in Facilitating Soil Liquefaction. In Poromechanics VI (pp. 107-116). Or Niebling, M. J., Toussaint, R., Flekkøy, E. G., & Måløy, K. J. (2012). Dynamic aerofracture of dense granular packings. Physical Review E, 86(6), 061315.

Could it be possible to evaluate the characteristic flux of underground flow present in the soils in the deadsea banks, the associated momentum exchange with the solid matrix, and justify when they can be neglected, or when they have to be incorporated ?

A small list of typos or very minor remarks follows :

Fig 1 : precise in the caption that De/Di symbol on the figure refers to depth/diameter ratio

P3, line 12 : " and " missing between Fig 2 Fig3

Please indicate the coordinates of the field site studied.

P4, line 2 : missing comma between Figure 1 and Figure 3

P4, line 3 : metres should become meters

P5, line 17 : some more examples of applications of DEM in the geomechanics literature could be given. For example - non exhaustively, many other examples exist in the literature - About the mechanical effect of a cavity formation : Pierce, M, Weatherley, DK & Kojovic, T 2010, 'A hybrid methodology for secondary fragmentation prediction in cave mines', in Y Potvin (ed.), Proceedings of the Second International Symposium on Block and Sublevel Caving, Australian Centre for Geomechanics, Perth, pp. 567-581. And/or, About the propagation of fractures due to overpressure : Ghani, I., Koehn, D., Toussaint, R., & Passchier, C. W. (2013). Dynamic development of hydrofracture. Pure and Applied Geophysics, 170(11), 1685-1703.

P11, line 13 and line 19 : missing references (" Error " appears in the text)

P12, line 21 : "A Hoek-Brown approach can yields UCS/T ratios of 5-6." : can yield

p14, line 6 : typo (missing reference)

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