## *Answers to comments of reviewer no. 2.*

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 approximation 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?

*The idea of a more progressive, rather than step-like, removal of material was tested with cavity generation method M4 (see appendix B.1), in which particle radii were reduced by an extremely small amount in each step (5 % of the radii, cf. p.45 l. 10). Such a particle reduction was applied to the outer particles of cavity at the inset of each growth increment and allowed to run until the particle masses became negligible. The gradual particle reduction procedure was then repeated for each subsequent increment of the cavity growth. As shown in Figure 19 in Appendix B.1, this more progressive material removal procedure yielded similar results in terms of the surface displacements profile, but with an order of magnitude higher computation time.*

*One must be careful to differentiate the model calculation timestep and the material removal increment. The absolute length of each model calculation timestep is automatically calculated in PFC2D based on consideration of model mass and stiffness (see Appendix A.1). We can thus vary the size of the material removed in each increment and the number of timesteps the model calculates for in that increment.*

*Dynamic effects, such as dynamic fracturing or triggering of collapse, may occur if the chosen increments of cavity growth are too large for the number of timesteps in which they take place. Therefore we took conservative values of depletion(16 m², compare p.54 l.3) amount to avoid this, based on the experience of Holohan et al 2011 where such a convergence testing was undertaken (though not reported in detail). Essentially, the 'step limit' in this sense depends on the initial size of the void, and here it was chosen so that in each increment of material removal only a couple of particles are deleted. In addition, for each increment of material removal, the models were allowed to calculate until a conservative ratio (Solve Ratio, SR) between the "out-of-balance" forces to the overall forces was met. Usually the SR was $1^{-5}$ or lower. Only after the SR was achieved was the next increment of material removal undertaken. These points are noted in appendices A.1, A.2 and B.1. We have not explicitly tested for convergence toward a given stress state with varying timestep, although the similarity of the differing cavity generation approaches under elastic conditions, as noted above and detailed in Appendix B.1, suggests such a convergence has occurred. Overall these procedures safeguard against an insufficiently long calculation time for each removal increment and thus against dynamic effects.*

2. and 3. 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?

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.

*It is correct that the buoyancy effect related to saturated subsurface has not been considered in this study. There is a paragraph in the discussion (p. 31 l. 20) dedicated to future work which will consider the inclusion of 1) hydrostatic effects and 2) dynamic pore pressure effects which are indeed of high relevance for sinkhole formation. Changes in pore pressure, as mentioned also in the above-suggested publications, may lead to an effectively weaker soil because of changes in the effective stress. It is possible to do such inclusion in PFC (see reference Yoon et al. 2015 in the manuscript p. 31 l. 20) but a combination of FDM (e.g. FLAC3D) with DEM is preferable for this purpose. For now, the simulations are considering only the mechanical nature of the system and stand for a simplified approach to simulate sinkhole formation. Any more complex phenomena related to fluids should and will be studied later. As noted above, we were also cconscious of possible dynamic effects created by a too fast void space growth, and we therefore decided for a quite slow growth rate (higher in terms of computation time) aiming to replicate sinkhole generation more realisticly.*

4) 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 solidmatrix, and justify when they can be neglected, or when they have to be incorporated?

*Also this is important, yes, and possibly realisable in case a combination of DEM + FEM? with simulated drag forces of fluid flow is incorporated, or pore pressure effects are taken into account. This is, however, is out of the scope of this study, which deals with the verification, benchmarking and pure mechanical modelling of the soil/rock system for the sinkhole phenomena. For future work, this is of clear relevance.*

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

*Done, also adjusted in Fig.2.*

P3, line 12: "and" missing between Fig 2 Fig3 Please indicate the coordinates of the field site studied.

*Added coordinates and corrected.*

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

*Done*

P4, line 3: metres should become meters

*Correction is made.*

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.

*The suggestion has been added to the paragraph in P. 31 line 20.*

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

*Corrected.*

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

*Ok.*

p14, line 6: typo (missing reference)

*Corrected.*

*Additional changes:*

*Section 3 has been moved to section 2.3.*

*In Appendix B.5 pp 52 l 29 the term annealing has been added to describe the bond installation procedure for mud material.*

*Some minor word rephrasing (yellow paragraphs) and figure adjustments (Using differential stress in Figs. 6 and 23, stress/strain labels)*