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Discussion on "Procedure for assessing the liquefaction vulnerability of tailings dams"

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ABSTRACT

The stability of tailings dams has become a critical concern for mining industry due to the recent tailings dam failures. The authors have presented a good paper to investigate the failure of tailings dam due to static liquefaction using the commercial FE code Plaix2D. Three procedures that can trigger static liquefaction were investigated in the paper, including surface load, toe deformation, and rise in phreatic surface. However, this discussion presents several simple observations regarding the simulation of the static liquefaction and additional analysis on the Fundão tailings dam.

1. Introduction

This discussion is based on the original paper by Ledesma et al. (2022) (hereafter the authors or the original paper). The authors investigated three possible actions that can trigger the failure of tailings dams, including surface load, toe deformation, and rise in phreatic surface. This paper can provide insights into the design of tailings dams for practitioners, especially considering the several recent failures of tailings dams caused by static liquefaction. However, the original paper also raises several issues related to the trigger of static liquefaction under very small toe deformation as well as the additional analysis on the failure of Fundão Dam. The discusser believes that the further clarification of these issues can provide more insights for practitioners work in this area.

2. Issue 1

The discusser is particularly interested in the investigation of the liquefaction of mine tailings induced by the horizontal deformation at the toe. This mechanism has not only contributed to the failure of the Fundão tailings dam, but also the Cadia tailing dam. The latter was mainly caused by the horizontal movement of the underlying strain-softening clay foundation, followed by the static liquefaction of mine tailings due to the loss of support. However, the numerical results in the original paper show that only 0.02 m of horizontal displacement is needed to trigger the liquefaction under the intermediate configuration with the crest elevation at 885 m, and 0.2 m of horizontal displacement is required under the final configuration with the crest elevation at 900 m. The discusser believe that these two horizontal displacements are too small, which can be very easily attained during the upstream raise of a real tailings dam.

These small required horizontal displacements can be explained by the initial stress state of the tailings before adding the three selected actions. Fig. 11 in the original paper shows that Points D and E are very close to the instability line. Therefore, a minor displacement can cause the tailings to engage the instability line, followed by a sudden loss of the undrained shear strength. The same small horizontal displacements were also observed in the additional analysis for the Fundão tailings dam. A horizontal displacement of 3 cm was able to trigger the failure in the final configuration ((November 2015), while 8 cm was able to trigger the failure in the intermediate configuration (August 2014). These displacements are much smaller than that indicated in the report of Morgenstern et al. (2016), which shows a horizontal displacement of 600 mm is required to trigger liquefaction.

Although the authors have emphasized that the original paper was not a back analysis of the failure of the Fundão dam, the study will be more helpful and provide more insights into the design and analysis of a tailings dam for geotechnical engineers if a realistic horizontal displacement can be calcualted from the numerical modeling. This would not be hard to be achieved by adjusting the initial stress state at the end of the construction to be not too close to the instability line.

Additionally, the discusser is also curious to see the required horizontal displacement to trigger liquefaction if the action of adding the toe deformation is conducted with stored tailings under drained conditions. This drained condition is also commonly encountered as the tailings deposition in practice is usually controlled to attain a drained or at least

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partly drained condition. It is also the stress condition for the mine tailings in the back-analysis of the Fundão and Cadia tailings dams through laboratory tests and NorSand calculation (Morgenstern et al., 2016; Jefferies et al., 2019), as shown in Fig. 1. Under drained conditions, the underlying horizontal movement can lead to the decrease of the horizontal effective stress, while the vertical effective stress remains constant. This can in turn lead to the increase of the deviator stress and decrease of the mean effective stress, with the stress path approaching the instability line.

3. Issue 2

There is an obvious difference between the state parameter predicted from the numerical modeling and that reported by the Review panel report (Morgenstern et al., 2016). Fig. 11 in the original paper shows that the state parameter is 0.045 at a depth of 27 m below the tailings surface, which is higher than the value of 0.012 determined from the cone penetration tests (Morgenstern et al., 2016). While the discusser agrees with the authors that this could be caused by the inherent uncertainty in available screening methods (Been et al., 1987; Plewes et al., 1992; Torres-Cruz, 2021), this difference of state parameter could however lead to very different behaviors of mine tailings and performances of tailings dams after adding the three analyzed actions. This might also explain the very small horizontal displacement required to trigger liquefaction as discussed in Issue 1. This difference of state parameter could be minimized by considering the seed state parameter given in the reviewer panel report (Morgenstern et al., 2016). Through an iterative process, Morgenstern et al. (2016) has given a seed state parameter of −0.02 for mine tailings that leads to a good agreement of state parameter between the numerical modeling and field observations. If this seed state parameter could be considered in the numerical modeling, it might generate an initial stress state much closer to the real stress condition for the Fundão tailings. In this case, it would also appear to generate a more realistic and higher horizontal displacements required to trigger liquefaction in the additional analysis of the Fundão tailings dam.

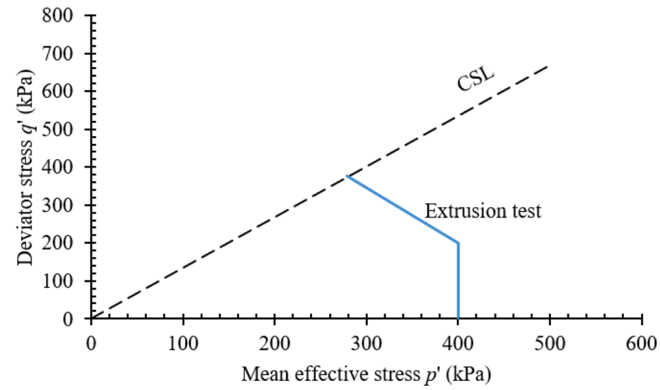

Fig. 1. Stress path for the extrusion collapse test conducted on Fundão tailings (adapted from Morgenstern et al., 2016).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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