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The role of post-failure brittleness of soft rocks in the assessment of stability of intact masses: FDEM technique applications to ideal problems

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Strain-softening under low confinement stress, i.e. the drop of strength that occurs in the post-failure stage, represents a key factor of the stress-strain behavior of rocks. However, this feature of the rock behavior is generally underestimated or even neglected in the assessment of boundary value problems of intact soft rock masses. This is typically the case when the stability of intact rock masses is treated by means of limit equilibrium or finite element analyses, for which rigid-plastic or elastic perfectly-plastic constitutive models, generally implementing peak strength conditions of the rock, are respectively used. In fact, the aforementioned numerical techniques are characterized by intrinsic limitations that do not allow to account for material brittleness, either for the method assumptions or due to numerical stability problems, as for the case of the finite element method, unless sophisticated regularization techniques are implemented. However, for those problems that concern the stability of intact soft rock masses at low stress levels, as for example the stability of shallow underground caves or that of rock slopes, the brittle stress-strain response of rock in the post-failure stage cannot be disregarded due to the risk of overestimation of the stability factor.
This work is aimed at highlighting the role of post-peak brittleness of soft rocks in the analysis of specific ideal problems by means of the use of a hybrid finite-discrete element technique (FDEM) that allows for the simulation of the rock stress-strain brittle behavior in a proper way. In particular, the stability of two ideal cases, represented by a shallow underground rectangular cave and a vertical cliff, has been analyzed by implementing a post-peak brittle behavior of the rock and the comparison with a non-brittle response of the rock mass is also explored. To this purpose, the mechanical behavior of a soft calcarenite belonging to the Calcarenite di Gravina formation, extensively outcropping in Puglia (Southern Italy), and the corresponding features of the post-peak behavior as measured in the laboratory, have been used as a reference in this work, as well as the typical geometrical features of underground cavities and rock cliffs, as observed in Southern Italy, have been adopted for the simulations. The numerical results indicate the strong impact for the assessment of stability when rock post-peak brittleness is accounted for, if compared with perfectly plastic assumptions, and the need for adopting numerical techniques, as the FDEM approach, to take properly into account this important aspect of the rock behavior is highlighted.