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Investigate the softening properties of weak interlayers in slope failure process using nanoindentation test and simulation

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This work proposed an available approach to analyze the property evolution of weak interlayers during immersion softening at micro and macro scales, which combining the advantages of nanoindentation tests and numerical modelling. The weak interlayers has significant impact on the failure process of natural slopes, however, their properties are difficult to be obtained using traditional triaxial compression tests. Because these weak interlayers are consist of clay and rock fragments which leads to the difficult to prepare intact samples. Additionally, the softening properties of these weak interlayers are strongly related to their fillings at micro scale. In this work, the weak interlayers is investigated using nano-scale micromechanical tests and upscaling methodologies, so only small rock fragments are required (see Fig.1).
In northwestern Hubei China, the mountains often developed several layers of weak interlayers with major lithology as shale which is sedimentary rock with low strength and dense clay particles. We investigated these shale fragments in weak interlayers, which is prone to decrease in strength induced by precipitation erosion. The Gaussian mixture model was used to analyze a large amount of data obtained by statistical grid nanoindentation method. Then the Mori-Tanaka scheme was used to homogenize the elastic properties of the samples and upscale the nanoindentation data to the macroscale. The hardness values which obtain by Berkovich and Cube corner indenter were able to assess the cohesion and friction angle of shale. Finally, these achieved parameters were applied in numerical model, in order to analyze the slope failure caused by the softening of weak interlayers (see Fig. 2).
The results show that: (1) the chlorite and muscovite minerals, which are major proportion of shale, soften or dissolve with the increasing saturation time. The fine mineral particles are gradually stripped from micro structure. As a result, at microscale the compact shale samples sale became loose. The strength of these shale samples are also decrease because water seeped through pores and micro cracks. (2) After water immersion, the friction angle is almost constant, while the elastic modulus and cohesion decrease significantly with increasing saturation time. (3) The shear strength decrease so that the shearing creep occurs along the weak interlayers surface, then bottom sliding surface is cut, which leads to landslide.