

Micro-meso-macroscale correlation mechanism of red-bed soft rocks failure within static water based on energy analysis

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Abstract: The purpose of the present study is to fundamentally investigate the micro-meso-macroscale correlation mechanism of red-bed soft rocks failure within static water, based on energy analysis. Through a series of experimental studies, changes in the micro-meso-macroscale characteristics of the rocks were characterised by measuring ion concentrations in and pH of water, the pore structure and crack propagation. Based on the experimental measurements, theoretical modelling of micro-meso-macroscale energy conservation was carried out to determine the micro-meso-macroscale correlation mechanism of red-bed soft rocks failure. The results show that the microscale dominant effect of red-bed soft rocks is determined as chemical effects. The failure mechanism of red-bed soft rocks under static water saturation involves chemical, physical and mechanical dominant effects at the micro-meso-macroscale. It was demonstrated that the dominant chemical effect of clay minerals and water comprises a series of chemical energy changes in the microscale water–rock interface. This can induce the energy changes in both mesophysical and macromechanical levels. During the first month after the water saturation, there was a significant decrease in Na^+ and K^+ concentrations in aqueous solution, whereas there was little change in Ca^{2+} and Mg^{2+} concentrations. The scanning electron microscope (SEM) images indicated an obvious change in microstructure of the red-bed soft rocks after 3 months of water saturation. A decrease in pore number and increase in total pore surface area could be seen after 6 months of water saturation. Furthermore, the theoretical results suggest that chemical effects at the microscale dominate the softening process of the rocks. During the water–rock interaction, nearly 80% of the energy dissipation results from the microscale change, and the meso-macroscale change accounts for the remaining 20%. As a uniform measure of material evolution, energy can correlate the micro-meso-macro dominant effect of red-bed soft rocks softening appropriately.

Keywords: Energy conservation; Micro-meso-macroscale correlation; Pore structure; Red-bed soft rocks; Static water saturation; SEM imaging