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in Underground Hydrogen Storage**

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BENCHMARKING CONSTITUTIVE MODELS FOR SALT CAVERN DESIGN IN UNDERGROUND HYDROGEN STORAGE

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Abstract

The design of salt caverns for Underground Hydrogen Storage (UHS) requires reliable mechanical models that can capture the time-dependent, nonlinear behavior of rock salt under cyclic and thermodynamic loading. Although a variety of constitutive models are currently used across the industry, their applicability and comparative performance in the context of hydrogen storage remain an open question. This study presents the first phase of a collaborative benchmark involving multiple expert teams and modeling tools, each of which has already demonstrated robust performance in the rock mechanics design of salt caverns for underground natural gas storage (UGS). The initial objective is to present and compare the various design philosophies and modeling approaches used in industrial practice, identifying key parameters of interest when transitioning from methane to hydrogen storage – such as cycle frequency, pressure-temperature coupling, and hydrogen-specific constraints. The second part of the study focuses on a comparative numerical analysis using both finite elements (LOCAS) and finite difference (FLAC3D) simulations. A reference geometry and loading scenario representative of future UHS operations is defined. Each team implements its preferred constitutive model (e.g., Munson-Dawson, Lubby2 (or Lubby-CF including damage and healing), or creep-damage variants) and computes stress redistribution, creep convergence, subsidence, and the evolution of the damaged rock salt zone. The benchmark intended to foster a technical discussion on the sources of variation in model outputs, stemming from differences in model structure, parameter calibration, and numerical implementation. The results offer valuable insights into the current modeling landscape and contribute to building a common understanding of the safe and efficient deployment of UHS systems in salt formations.

Keywords: Rock mechanics, Thermodynamics, Gas operation, Constitutive models, Hydrogen