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Does a Staggered Scheme Pay Off on Large-scale Hydraulic-mechanical Simulations?

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From previous studies it is evident that decoupled simulations lack the ability to capture certain coupled effects, such as the Noordbergum effect or the Mandel-Cryer effect in a hydraulic-mechanical context. Thus, for detailed simulations of geotechnical or geological system, coupled simulations are usually chosen. For example, thermal-hydraulic-mechanical (THM) coupled systems, and even chemical and biological couplings (THMCB), are considered in simulations used to assess barrier integrity over long time spans in the context of geological waste disposal.

This paper is restricted to coupled hydraulic-mechanical (HM) systems. A monolithic approach is both stable and accurate for strongly coupled systems. However, as site-scale models of geological disposal facilities are also large in spatial dimensions, it is worth to investigate how staggered methods may cut down the computational costs. The fixed-stress split appears to be a promising approach for staggered schemes in terms of stability, consistency, accuracy, and efficiency.

While adding another iteration level in comparison to monolithic schemes, staggered schemes allow for lower-order approximation spaces, whereas monolithic schemes require Taylor-Hood elements resulting in a larger number of degrees of freedom per element. Both coupling schemes are implemented in the the open-source finite-element (FE) software OpenGeoSys and used to simulate a large-scale model, which is oriented towards a real site in planning in Russia. Simulation results are compared in terms of accuracy, coupling effects and performance.