Rock mechanics of Callovo-Oxfordian claystones at the Meuse Haute Marne URL and consequences for the Cigéo repository design

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Clay formations in their natural state exhibit very favorable conditions for repository of radioactive waste, as they generally have a very low hydraulic conductivity, small molecular diffusion and significant retention capacity for radionuclide. Nevertheless, one concern regarding waste disposal is that, due to the necessary underground excavations and the associated disturbance and damage in the area close to these excavations, the favorable properties of such formations could change and the host rock could lose part of its barrier function and thus negatively influence the performance of a repository. That is why, in order to demonstrate feasibility of a radioactive waste repository in a claystone formation, the French national radioactive waste management agency (ANDRA) started in 2000 to build the Meuse/Haute-Marne underground research laboratory (URL) at Bure (at nearly 300 km East of Paris). The host formation consists of a claystone (Callovo-Oxfordian argillaceous rock) lying between 420 m and 550 m in depth, which is overlain and underlain by poorly permeable carbonate formations.

One of the main purposes for geomechanical experimental programme is to provide the data, with supporting evidence, required for the safety assessment of a repository: extension, features and hydraulic properties of excavation damaged zone (EDZ). The excavation worksite in the host layer is a scientific experimentation in itself to characterize the impacts of digging, to understand the hydro mechanical behaviour of the claystone and to study the EDZ. Furthermore, understanding the impact of support and excavation methods on the hydro-mechanical behavior of the drift at short and long term is necessary to optimize the design of the support for the CIGEO repository.

A huge program of experiments is planned to characterize the response of the rock to different shaft and drift construction methods. Numerous experiments and direct measurements were performed in the laboratory drifts starting in 2004 (drift at a depth of -445 m excavated from the main shaft) and in 2005 (drifts at a depth of -490 m excavated from an auxiliary shaft), and also during the excavation and construction of the main shaft between -445 m and -490 m. A set by step approach, started in 2006, is carrying on today based on comparison of HM behavior of parallel drifts excavated/supported by different construction methods. These various configurations give insight of the influence of construction method on the EDZ extend and evolution and on the loading of the support.

At the main level located at 490 m, the orientation of the scientific drifts has been determined according to the orientation of in situ stress field. Pneumatic hammer technique was first used for excavation. Bolts, sliding arches and 10 cm-thick layer of shotcrete were set in place immediately following a two-meter maximum progression. Other techniques have been and will be used, like road header (drift GET, GCS GCR), stiff and flexible support. A tunneling machine has been also tested (GRD drift) in 2013 to test segments emplacement technique with different gap filling materials. All the new experimental drifts are instrumented in order to measure the short and long term hydro mechanical behavior and the EDZ. When it is possible, measurements have been emplaced in field previously to excavation work to follow the HM impact of the digging.

For example, in order to understand the impact of different support's stiffness on the long term behavior of the rock mass, it was planned to compare hydro mechanical behavior around at least 60 m length drifts: one, called GCS drift, experiments allowing deformation supports, a second, called GCR drift excavated with the same method, but with a stiff support placed a few months after its excavation in order to stop deformations and a third with concrete segment emplaced under a shield during the excavation work. The comparison will enable to understand relationship between rock deformation in the EDZ and support loading. Those data gives insight to CIGEO drift design.

All those experiments also provide an important data-base which will be useful to check the ability and capacity of numerical models to reproduce and simulate the hydro mechanical behavior of the rock mass.