COCONS: A numerical tool for Thermo-Hydro-Mecanical dimensioning of a deep geological repository High Level Waste area

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For a deep geological disposal in clay, the most important point for the structural dimensioning of a High Level Waste (HLW) area is spacing between the cells containing the canisters and the gallery length. Indeed, HLW containers are placed inside a series of parallel horizontal cells linked to an access gallery (Figure 1, for Andra's concept). In order to reduce the disposal footprint in the host geological layer, spacing between these HLW cells must be optimized to respect thermal and mechanical criteria. The first one is the maximum temperature near the containers. This temperature depends on the residual power of the waste containers and of the number of containers in each cell. The second one is a Thermo-Hydro-Mechanical (THM) criterion which needs to be met in order to prevent fracture initiation in the geological layer between two cells. This criterion derives from the mechanical consequences of thermal overpressure within the geological layer: due to heating and expansion of water, pore pressure will rise and could generate potential damage. The long term safety relies on the properties and integrity of this geological layer.
Numerical models are required to check both criteria for different repository architectures. The first criteria on temperature is checked by estimating temperatures with a 3D modelling representing packages, cavities between packages, the cell and the geological domain in detail (Figure 2). The thermal software SYRTHES [1] developed at EDF is commonly used for these kind of studies, using a model including conduction, convection and radiation.
The second criteria i.e. the THM criteria which is a Terzaghi stress, is verified by using a porous model in EDF's software code_Aster [2]. The model used here is a classical saturated Thermo-Hydro-Mechanical one, with an elastic mechanical law.
Considering the array of horizontal cells to be "infinite", only half a cell and a part of gallery with symmetrical conditions are modelled (Figure 2). For reasons of computational time, three-dimensional calculations are only performed for the thermal modelling. Temperatures at different time steps are then projected on a 2D mesh dedicated to the mechanical computations (Figure 3). This methodology is well suited since, on one hand, the HydroMechanical behaviour of the host rock doesn't influence its own temperature and, on the other hand, a 2D modelling is sufficient to capture HM behaviours between two cells. This well-known methodology has been tested several times and applied for example on the *in situ* experiment LUCOEX (full scale cell subjected to thermal loading [4]).

Based on the approach described above, an automated tool, COCONS (Cost, Optimisation and CONception of diSposal) has been developed to manage parametric studies allowing to find an optimum configuration of a deep geological disposal. COCONS is a SYRTHES-Code_Aster chaining. Based on Python's libraries, it allows to define sets of geometric and physical parameters (packages number, distance between cells, waste residual power, …). The procedure is the following: a thermal computation is first performed with SYRTHES based on a specific 3D Salome meshing [3], then results are transferred to Code_Aster THM solver for a complete calculation. Numerous configurations can be quickly evaluated and analyzed with COCONS and thus provide the optimized configuration of an underground geological disposal.
In the future, the current version of the COCONS tool is thought to be further improved (enrichment of material libraries, configurations, etc.)

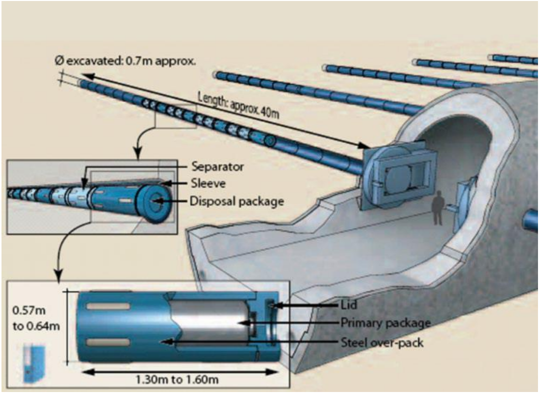

Figure 1: zoom of HLW area (ref. Andra).

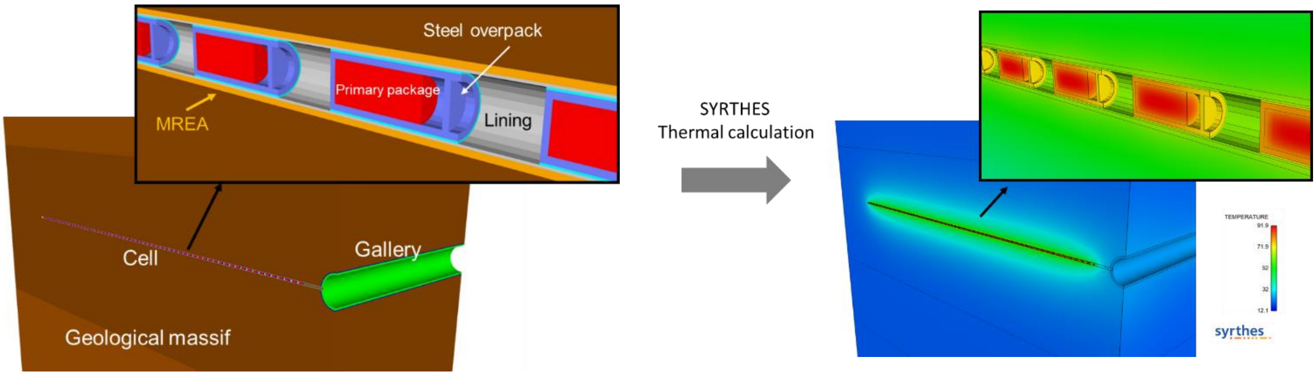

Figure 2: 3D modeling for the SYRTHES thermal calculation (left) and example of a thermal field (right).

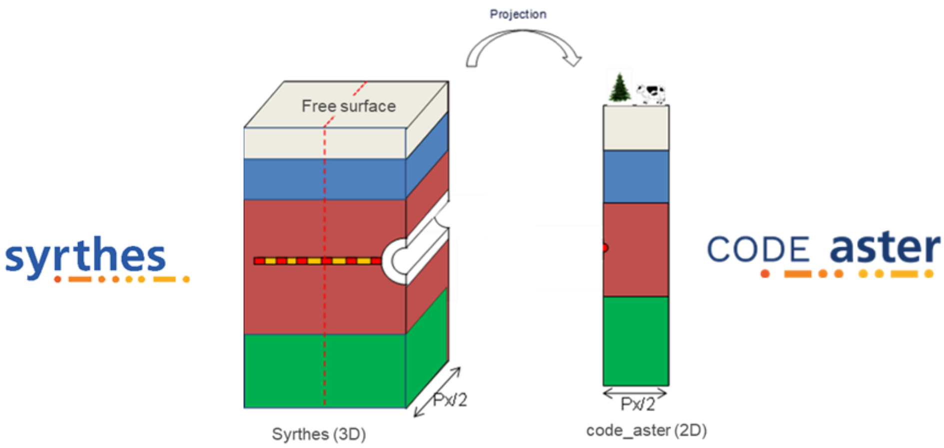

Figure 3: Schematic principle of COCONS - Extraction of a 2D plane with interpolated thermal field from SYTHES, for a subsequent Code_ASTER THM calculation

References

[1] https://ww.edf.fr/recherche/code-syrthes, last accessed on 2024
[2] http://www.code_aster.org, last accessed on 2024
[3] http://www.salome-platform.org, last accessed on 2024
[4] LUCOEX (Large Underground Concept Experiments), https://igdtp.eu/activity/lucoex-large-underground-concept-experiments, last accessed on 2024