Numerical Analysis of Thermo-Hydro-Mechanical Coupled Behavior in Multi-level HLW Repository Concept

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1. Introduction

High-level radioactive waste disposal facility based on Korean Reference HLW disposal System (KRS) will be constructed at depth of 500 m underground and the estimated total area of the facilities is approximately 8 km^2 [1]. This would be a constraint for site selection of repository. Therefore, it is necessary to consider multi-layer disposal concept in order to lessen the area of disposal facility. In this study, numerical modeling was conducted to investigate thermo-hydro-mechanical coupled behavior in multi-layer concept base on the KRS.

2. Numerical model

Numerical analysis was performed to investigate THM coupled processes in the multi-layer HLW repository concept using TOUGH2-MP/FLAC3D. Modeling cases are listed in Table 1. The first case is numerical modeling for double layer disposal system where is located at depth of 400 m and 500 m. And the second case is numerical modeling for triple layer disposal system where is located at depth of 400 m, 500 m, and 600 m. Tunnel spacing and disposal holes interval are listed in the Table. 1. Temperature criterion is 100℃ for all modeling cases.

Table 1. Modeling cases

Modeling case	Depth	Tunnel spacing and disposal holes interval
1	400 m & 500 m	40 m & 8 m
2	400 m, 500 m, 600 m	40 m & 10 m

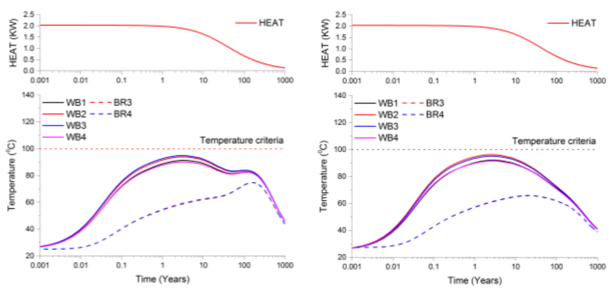
The used input parameters, function of decay heat, initial and boundary conditions are presented in the [1]. And monitoring points at each level (400 m, 500 m, 600 m) are same as that is presented in Lee et al. [2]. The excavation sequence was simulated for 10 years, and then the waste canister, bentonite buffer, and backfill are installed instantaneously and the post closure simulation can start for all modeling cases.

3. Results

3.1 Thermo-hydraulic analysis

Maximum temperature is calculated below 100℃ for the two modeling cases. Temperature evolutions are analogous to that is described in Lee et al. [2]. But, temperature evolution is slightly different at depth of 500 m in triple layer disposal system (modeling case 2) as shown in Fig. 1. In the triple layer disposal system, the temperature generated at depth of 500 m (middle level disposal system) could be difficult to escape, because temperature of upper and lower disposal system act as thermal boundaries. Therefore, a secondary peak temperature due to superposition phenomenon is shown after about 1.5 hundred years.

According to Lee et al. [2], fluid pressure is slowly increased until several years, after then, the pressure is rapidly increased and becomes hydrostatic pressure after decades. However, fluid pressure is rapidly increased after ten years and becomes hydrostatic pressure after one hundred years for the modeling case 1 and 2. And the liquid saturation evolutions in the buffer are analogous to that presented in Lee et al. [2]. Degree of saturation decreases to a minimum of about 0.2 after a few years, after then saturation starts to increase and finally reaches 1.0.



(a) Temperature evolution at depth of 500 m

(b) Temperature evolution at depth of 600 m

Fig. 1. Temperature evolution for modeling case 2.

3.2 Mechanical analysis

Thermal stress, sum of swelling stress and fluid pressure can influence the stress filed at BR1 and BR2 where is described in the Lee et al. [2] as shown in Fig. 2. Therefore, stress path at BR1 and BR2 was calculated to investigate the potential rock failure using Mohr-Coulomb criterion [3] is used to investigate the evolution of the stress field and potential for rock failure.

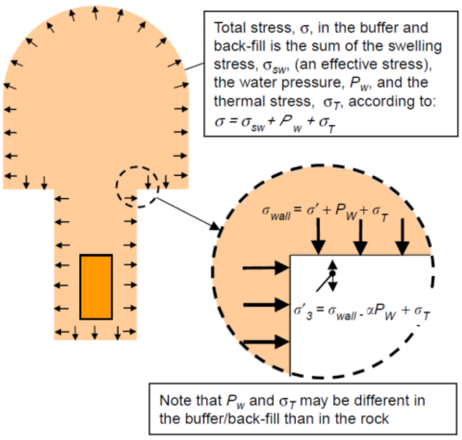
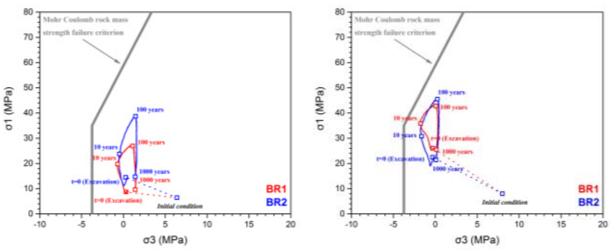


Fig. 2. Illustration of the effect of compressive stress, σ, in the backfill on minimum compressive principal effective stress, σ'_3, in the floor of the drift [4].

Fig. 3 and Fig. 4 show the evolutions of minimum and maximum principal effective stresses at BR1 and BR2 with the Mohr-Coulomb failure envelopes. The stress path in multi-layer disposal system is analogous to that presented in the Lee et al. [2]. The stress state of rockmass stays below that required for failure, however, stress state at depth of 500 m is relatively close to the failure envelope in the double layer disposal system (Fig. 3). In case of triple layer disposal system, stress state at depth of 500 m is relatively higher after 1,000 years (Fig. 4), because temperature is higher than others.



(a) Stress path at depth of 400 m

(b) Stress path at depth of 500 m

Fig. 3. Principal stress path in relation to Mohr-Coulomb failure criterion in double layer disposal system.

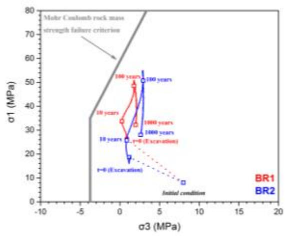


Fig. 4. Principal stress path at 500 m in modeling case 2.

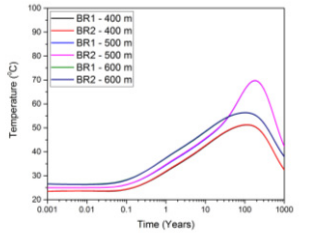


Fig. 5. Temperature evolution in modeling case 2.

4. Conclusions

Numerical modeling was performed to investigate influence of THM processes on multi-layer disposal system based on KRS during 1,000 years after operation. The maximum temperature can satisfy temperature criteria of 100 ℃ and stress state of rockmass stays below the failure criterion for all measuring points in multi-layer concept. However, it is necessary to investigate the stress state is below the spalling criterion as presented in Lee et al. [2].

Acknowledgements

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