Application of Mazars Damage Model to KURT Rock Under Thermo-Hydro-Mechanical Coupled Conditions

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1. Introduction

The coupled thermo-hydro-mechanical (THM) behaviors in a geological formation is one of the key issues from the perspective of a nuclear waste disposal. The damage evolution and its evaluation are prominent with regard to the long-term performance assessment.

While, most of damage models have been developed based on the experiments, primarily carried out in dry and room temperature conditions. These are far away from the in-situ real condition of a waste disposal.

The objective of this study is, therefore, to apply the damage model (Mazars) to KURT (KAERI Underground Research Tunnel) rock under THM (Thermo-Hydro-Mechanical) coupled conditions to investigate the time-dependent deformation and failure process of rock. This information will be used as a primary input parameter in the development of coupled THMD (Thermo-Hydro-Mechanical Damage) model in KAERI.

2. Approach & Experiments

Mazars' damage model is described by two different evolution laws under tension and compression.

$$D = \alpha_t * D_t + \alpha_c * D_c \quad (1)$$

$$D_t = 1 - \frac{(1-A_t)\varepsilon_{d0}}{\varepsilon_{eq}} - A_t e^{B_t(\varepsilon_{eq}-\varepsilon_{d0})} \quad (2)$$

$$D_c = 1 - \frac{(1-A_c)\varepsilon_{d0}}{\varepsilon_{eq}} - A_c e^{B_c(\varepsilon_{eq}-\varepsilon_{d0})} \quad (3)$$

Where D is the total damage, D_t and D_c indicate tensile and compressive damages. A_t, B_t, ε_{d0}, A_c, and B_c are material parameters which can be determined by experiments.

With regard to determination of constants in Mazars damage model, the uniaxial compression and indirect tensile tests were performed under a simulated THM coupled condition (Fig. 1). Simultaneously, acoustic emission (AE) was also monitored during the test to compare the degree-of-damages predicted from the damage model and physically measured from AE detection.

Fig. 1. Experimental apparatus and DAQ system.

Target temperature were 15, 21, 45, and 75 ◦C which were determined from the numerical study (the maximum temperature at the interface between buffer and rock mass was predicted as 70 ℃).

Table 1. Test conditions and sample numbers in use

Tests		Notations	Temp.	Cond.	Sample no.	AE meas.	Strain meas.
Material Properties		UCS, E, ν, n, γ	21℃	Dry	27	X	X
Uniaxial compression test	M test	Mc-AE	21℃	Dry	3	O	O
	TM test	TMc(L)-AE	15℃	Dry	3	O	O
		TMc(M)-AE	45℃	Dry	3	O	O
		TMc(H)-AE	75℃	Dry	3	O	O
	HM test	HMc-AE	21℃	Sat.	3	O	O
	THM test	THMc(L)-AE	15℃	Sat.	3	O	O
		THMc(M)-AE	45℃	Sat.	3	O	O
		THMc(H)-AE	75℃	Sat.	3	O	O
Indirect tensile test	M test	Mt-AE	21℃	Dry	3	O	O
	TM test	TMt(L)-AE	15℃	Dry	3	O	O
		TMt(M)-AE	45℃	Dry	3	O	O
		TMt(H)-AE	75℃	Dry	3	O	O
	HM test	HMt-AE	21℃	Sat.	3	O	O
	THM test	THMt(L)-AE	15℃	Sat.	3	O	O
		THMt(M)-AE	45℃	Sat.	3	O	O
		THMt(H)-AE	75℃	Sat.	3	O	O

* c: compression test, t: tensile test, T: thermal test, H: hydraulic test, M: mechanical test, L: at 15℃, M: at 45℃, H: at 75℃

3. Main Results

From the HM test at a room temperature, the initial damage threshold (ε_{d0}) was determined within the range of 85~140 με. The tensile parameters A_t and B_t showed the values of 0.20~0.25 and 1996~3156 respectively. Compressive material parameters A_c and B_c showed a distribution of 19~23, and 1962~2789 respectively.

In case of THM(H) test, ε_{d0} was determined within a range of 90~125 με. A_t and B_t were 0.20~1.30 and 3268~5883 and A_c and B_c were 8~14 and 1475~1992.

Among the various test results, the representative stress-strain relations measured for THM test at 15∘C test is presented in Fig. 2.

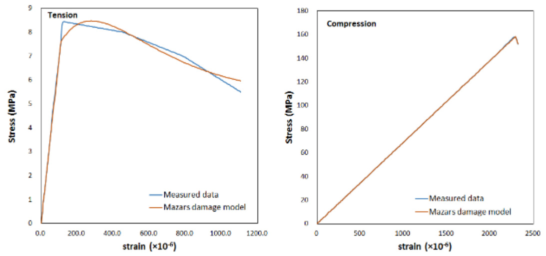

Fig. 2. Predicted and measured stress-strain relation for THM(L) test.

Table 2. Mazars damage model parameters under coupled test conditions

Test Name		Specimen ID	ε_{d0} (με)	Tension A_t	Tension B_t	Compression A_c	Compression B_c
M test		M-3	170	0.55	2349	12	1242
TM test	15℃	TM(L)-3	210	0.35	2346	8	1011
	45℃	TM(M)-3	155	0.37	2729	18	1555
	75℃	TM(H)-3	155	0.45	2885	7	1206
HM test		HM-3	85	0.25	3156	23	1962
THM test	15℃	THM(L)-3	110	0.30	3595	25	2065
	45℃	THM(M)-3	115	0.25	3342	28	2133
	75℃	THM(H)-3	110	0.20	3268	14	1992

4. Conclusion

Mazars damage model was successfully obtained under the simulated THM condition of a geological waste disposal. The development of damage evolution model can contribute to the better prediction of in-situ rock behaviors in a nuclear waste repository.

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