Determination of Water Content in Compacted Bentonite Using a Hygrometer

Jae Owan Lee and Won Jin Cho
Korea Atomic Energy Research Institute, 1045 Daedeok-daero Yuseong-gu, Daejeon 305-353, Korea
jolee@kaeri.re.kr

1. Introduction

The Korean reference disposal system (KRS) for high-level wastes which was developed in 2002 considers use of compacted bentonite as the buffer of a repository [1]. The Korea Atomic Energy Research Institute (KAERI) has carried out a mock-up KENTEX to investigate the coupled thermal-hydro-mechanical (T-H-M) behavior in the buffer of the reference disposal system [2]. The water content of compacted bentonite, which is one of input parameters for a coupled T-H-M model, is of importance in interpreting the resaturation of the buffer and thereby its thermal and mechanical behavior. The measurement techniques of the water content are broadly divided into two manners: a direct method by manual core-sampling and then gravimetric weighing, and an indirect one using sensors for automatic data acquisition. The KENTEX employed the latter with a capacitive hygrometer sensor. First the relative humidity (RH) of compacted bentonite is acquired from the hygrometer sensor, and then it is converted into the water content, which is determined from a relationship among the water content, RH, and temperature. This study deals with the characteristic curve of RH and its dependency on water content and temperature, in the measurement using a hygrometer sensor. From a linear multi-regression analysis based on the measurement results, a relationship among the water content, RH and temperature is derived and, using this relationship, the water content distribution in the compacted bentonite of the KENTEX is determined and the resaturation behavior is also interpreted.

2. Methods and Results

The bentonite was taken from Kyeongju, Kyeongsangbuk-do. It contains montmorillonite (70%), feldspar (29%), and small amounts of quartz (~1%). The adjustment of the water content was done by drying the at 110 ℃ for 24 hours and then adding de-mineralized water by pre-weighed amounts using a sprayer. The water contents in the measurements were 3%, 7%, 12%, 17%, and 22%. The bentonite after its adjustment of water content was compacted in a cylindrical cell (0.05 m in inner diameter and 0.05 m in height) to the dry density of 1.5 Mg/m^3 using a hydraulic press; a hole was drilled in it to allow a capacitive hygrometer sensor(Vaisala HMT #334) to be installed inside; then it was left in a desiccator for more than 3 days for its water content equilibrium. In the measurements, the temperature is stepwise changed to 25 ℃, 35 ℃, 45 ℃, 55 ℃, 70 ℃, 90 ℃ every 3 days to guarantee the equilibrium of the relative humidity.

The RH in the characteristic curve of the measured relative humidity reached steady state in a couple of hours. This indicates that a measurement time of 3 days is enough to guarantee the equilibrium RH at each temperature. Table 1 summarizes experimental results when the dry density of compacted bentonite is 1.5 Mg/m^3. The effect of temperature on the RH with respect to different water contents is shown in Figure 1. Against our expectation, the RH increased a little with increasing the temperature. It appears that the water and/or its vapor in the pores of compacted bentonite, when it is heated up, moves to the sensor for equilibrium, which results in an increase of the relative humidity. Figure 2 shows that the relative humidity increases with the increasing water content at each temperature. From a linear multi-regression analysis, the following relationship was obtained:

$$\omega = 0.200\ RH - 0.021\ T + 0.851 \qquad (1)$$

where ω is the water content [%], RH the relative humidity [%], and T the temperature [℃]. Using the above relationship, the water content distribution in the compacted bentonite of the KENTEX was as shown in Figure 3. The water content was in the range of 0 % to 28 %, and it increased sharply during an initial hydration and then it decreased followed by a gradual increase as time passed.

3. Conclusions

The RH characteristic curve showed that the relative humidity of compacted bentonite reached equilibrium in a couple of hours. The equilibrium RH was strongly dependent on the water content, while not on the temperature. A linear multi-regression analysis led to the following relationship among the water content, RH, and temperature: w = 0.200 RH - 0.021 T + 0.851. Based upon this relationship, it was observed that the water content in the compacted bentonite of the KENTEX increased sharply during an initial hydration and then it decreased followed by a gradual increase as time passed.

References

[1] C.H. Kang et al., "High-level Radwaste Disposal Technology Development/ Geological Disposal System Development," KAERI/RR-2336/2002, Korea Atomic Energy Research Institute (2002).

[2] Jae Owan Lee and Won Jin Cho, "Thermal-Hydro-Mechanical Behaviors in the Engineered Barrier of a HLW Repository: Engineering-scale Validation Test," Tunnel & Underground Space, Vol. 17, No. 6, pp. 464-474 (2007).

RUN	Dry density (Mg/m3)	Water content (%)	Temperature (oC)	Relative humidity (%) A	B	Average
1	1.5	3	25	10.01	10.82	10.4
2	-	-	35	10.82	11.71	11.3
3	-	-	45	11.65	12.59	12.1
4	-	-	55	12.46	13.49	13.0
5	-	-	70	13.76	14.89	14.3
6	-	-	90	15.62	16.8	16.2
7	-	7	25	31.49	32.26	31.9
8	-	-	35	32.42	33.1	32.8
9	-	-	45	33.98	34.63	34.3
10	-	-	55	35.37	36	35.7
11	-	-	70	37.35	37.99	37.7
12	-	-	90	39.72	40.31	40.0
13	-	12	25	72.62	77.29	72.6
14	-	-	35	73.96	78.24	74.0
15	-	-	45	75.13	79.04	75.1
16	-	-	55	76.09	79.69	76.1
17	-	-	70	77.42	80.42	77.4
18	-	-	90	81.23	83.75	81.2
25	-	17	25	86.42	87.64	87.0
26	-	-	35	87.29	88.24	87.8
27	-	-	45	87.88	88.61	88.2
28	-	-	55	88.53	89.08	88.8
29	-	-	70	89.7	89.98	89.8
30	-	-	90	94.28	95.15	94.7
31	-	22	25	96.17	97.51	96.8
32	-	-	35	95.78	97.38	96.6
33	-	-	45	95.59	97.53	96.6
34	-	-	55	95.44	97.41	96.4
35	-	-	70	95.92	97.91	96.9
36	-	-	90	100.49	102.79	101.6

Table 1 Experimental Results for the RH and water content.

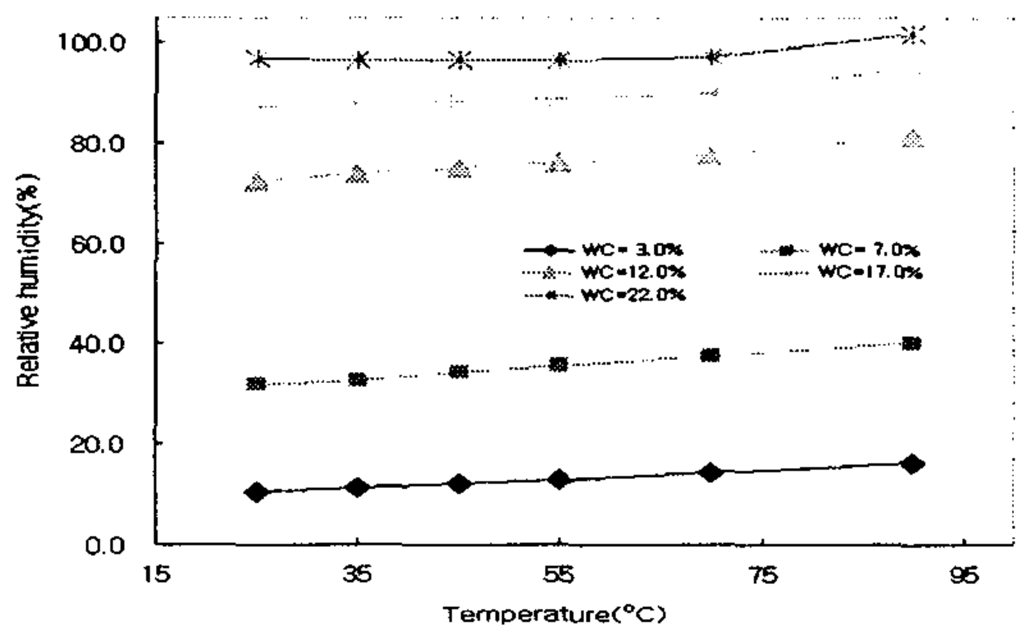

Figure 1 Effect of temp. on the RH.

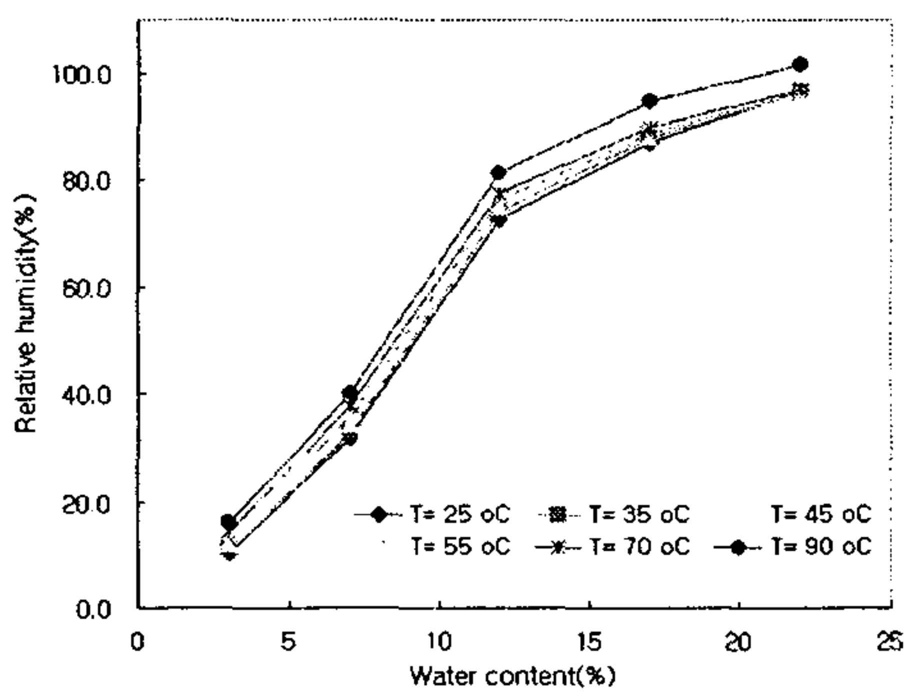

Figure 2 Relationship between the water content and RH at each temp.

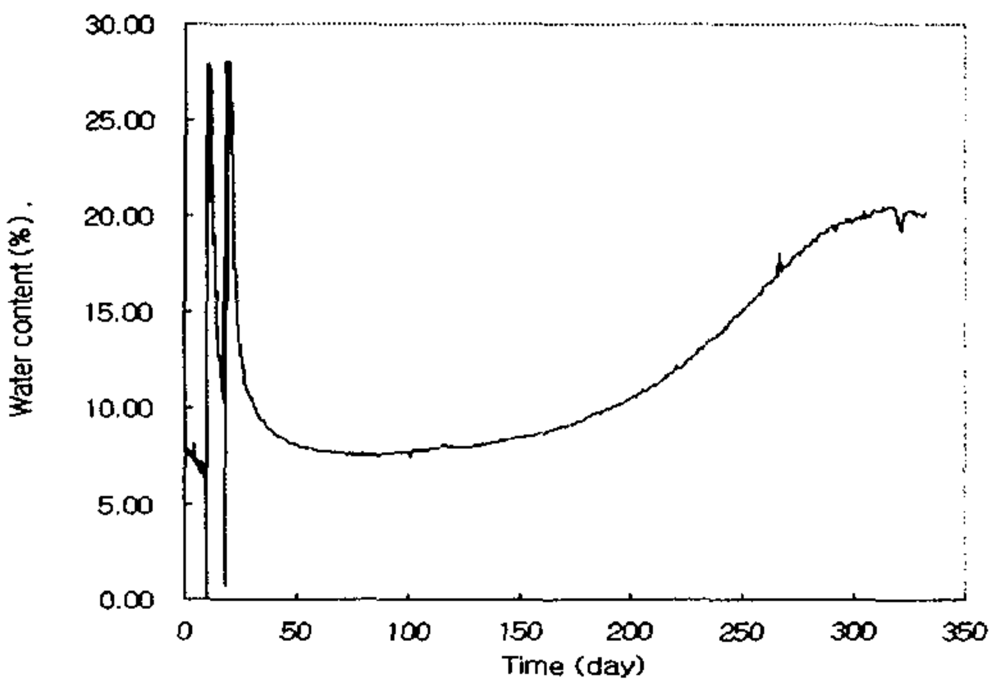

Figure 3 Water content distribution in the compacted bentonite of the KENTEX.