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Construction and Operational Experiences of Engineered Barrier Test Facility for Near Surface Disposal of LILW

중·저준위 방사성폐기물의 천층처분을 위한 인공방벽 실증시험시설의 건설 및 운전 경험

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Abstract

To validate the previous conceptual design of cover system, construction of the engineered barrier test facility is completed and the performance tests of the disposal cover system are conducted. The disposal test facility is composed of the multi-purpose working space, the six test cells and the disposal information space for the PR center. The dedicated detection system measures the water content, the temperature, the matric potential of each cover layer and the accumulated water volume of lateral drainage. Short-term experiments on the disposal cover layer using the artificial rainfall system are implemented. The sand drainage layer shows the satisfactory performance as intended in the design stage. The artificial rainfall does not affect the temperature of cover layers. It is investigated that high water infiltration of the artificial rainfall changes the matric potential in each cover layer. This facility is expected to increase the public information about the national radioactive waste disposal program and the effort for the safety of the planned disposal facility.

Key words : Engineered barrier system, multi-layered cover, water content, matric potential

I. Introduction

A former simple trench type of a near surface disposal facility showed many problems in the aspect of radiological safety. To resolve the safety problems of disposal facility, multiple layered landfill cover system which limits surface water infiltration into a radioactive waste package was suggested and included in regulatory requirement from 1980's.

Specifically designed landfill cover systems are adopted for near surface radioactive disposal facility at several nations such as England, France and Spain. These cover systems are designed to reflect the domestic environmental conditions of each nation. In Korea, the concepts of an engineered barrier cover system for the near surface disposal facility was proposed [1-4].

To validate the previous conceptual design of cover system, construction of the engineered barrier test facility is recently completed. Then, performance tests of the disposal cover system are being actively conducted. The work scope of this engineered barrier test facility can be summarized as: (1) detailed design and construction of the facility, (2) analysis of the cover system performance by computer simulation and (3) long- and short-term validation experiments of the cover system [5].

In this paper, construction and operational experiences of the engineered barrier test facility for the near surface disposal of low- and intermediate-level radioactive waste (LILW) are discussed.

II. Conceptual Design of Near Surface Disposal Facility

The conceptual design of the vault type disposal facility was conducted at Nuclear Environment Technology Institute (NETEC) from 1998 to 2000 along with a preliminary safety assessment of the near surface disposal facility. Fig. 1 shows the conceptual design of the multi-layer disposal cover for the LILW disposal facility.

The cover material and functions of each layer in the conceptual repository design are as follows:

(1) The top soil layer is considered to support the growth of vegetation and thereby to promote evapo- transpiration, to prevent soil erosion, and to temporarily intercept and store moisture for later removal by evapo-transpiration.

(2) The protective layer 1 is a gravelly sand layer designed to function as the top soil layer, but it acts as a filter to prevent migration of the top soil into a underlying gravel layer.

(3) The protective layer 2 is made of a pea gravel. Its function is to protect an underlying layer from degradation through repeated freeze/thaw cycle, repeated excessive wetting/drying, and plant roots or animal intrusion.

(4) The drainage layers, 1 and 2 are designed to facilitate the lateral drainage and to prevent head build up over the underlying asphalt and a geosynthetic membrane.

(5) The asphalt and geosynthetic membrane layer are designed to act as an artificial barrier to minimize water infiltration into the underlying materials. Material of the geomembrane is high density polyethylene (HDPE).

(6) Finally, the barrier layer is consisted of 20%-bentonite and 80%-sand mixture which would limit the water infiltration flux.

This design was configured based on the computer simulation of four disposal cover

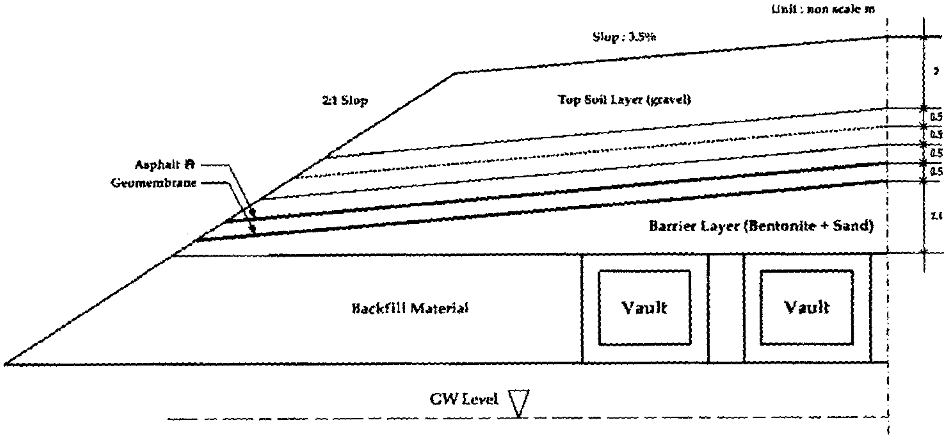

Figure 1. Conceptual Design of Multi-layered Disposal Cover System

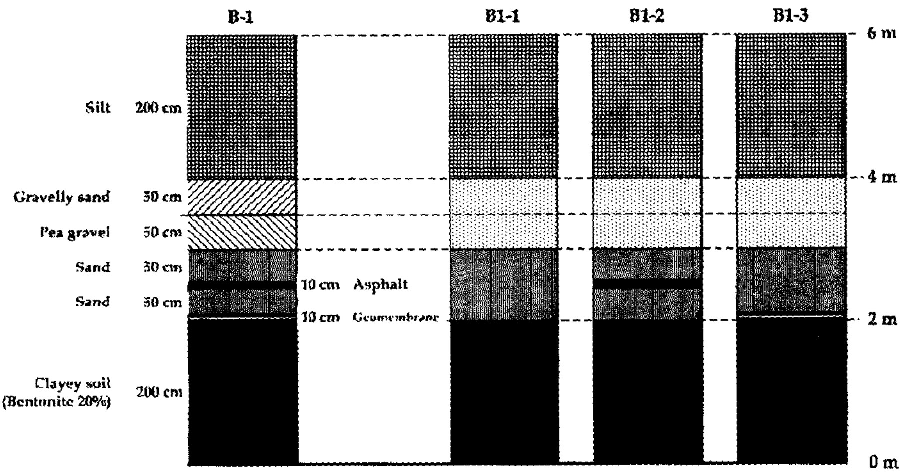

Figure 2. Disposal Cover System Design Alternatives

design alternatives. These different design alternatives are depicted in Fig. 2. The simulation with these four design alternative was conducted with HELP (Hydrologic Evaluation of Landfill Performance) computer code [6].

As for domestic rainfall conditions, predicted domestic rainfalls during 100 year are used in computer simulations. The first simulation is based on 100 years average domestic rainfall, which is predicted through weather generation subroutine of HELP code [6]. Second one is based on 100 years maximum domestic rainfall. The result of these two simulations about four design alternatives of the cover system are shown in Tables 1 and 2, respectively. Comparing with percolation through the clayey soil in Tables 1 and 2,

Table 1. Results From the Cover System Design Alternatives - 100 years average

Component \ Type	B-1		B1-1		B1-2		B1-3	
	mm	%	mm	%	mm	%	mm	%
Precipitation	1373.6	100	1373.6	100	1373.6	100	1373.6	100
Runoff	161.3	11.7	161.3	11.7	161.3	11.7	161.3	11.7
Evapotranspiration	691.19	50.32	691.19	50.32	691.19	50.32	691.19	50.32
Lateral Drainage (Upper Layer)	431.98	31.45	485.51	35.35	431.98	31.46	519.14	37.79
Percolation through Asphalt	89.09				89.09			
Lateral Drainage (Lower Layer)	88.80	6.46			56.23	4.09		
Percolationthrough clayeysoil	**0.507**	**0.02**	**34.68**	**2.52**	**32.75**	**2.38**	**1.42**	**0.08**
Water storage	0.12	0.01	0.91	0.07	0.13	0.01	0.91	0.07

Table 2. Results From the Cover System Design Alternatives - 100 year maximum

Type \ Component	B-1		B1-1		B1-2		B1-3	
	mm	%	mm	%	mm	%	mm	%
Precipitation	1916.16	100	1916.16	100	1916.16	100	1916.16	100
Runoff	333.39	17.39	333.39	17.39	333.39	17.39	333.39	17.39
Evapotranspiration	754.67	39.38	754.67	39.38	754.67	39.38	754.67	39.38
Lateral Drainage (Upper Layer)	698.9	36.47	757.49	39.52	698.9	36.47	790.82	41.26
Percolation through Asphalt	94.02				94.02			
Lateral Drainage (Lower Layer)	94.38	4.92			61.96	3.23		
Percolationthrough clayeysoil	**0.52**	**0.03**	**35.18**	**1.84**	**32.88**	**1.72**	**1.2**	**0.06**
Water storage	35.75	1.81	35.88	1.87	34.82	1.82	36.54	1.91

results show that the cover system which is equipped with two artificial barrier layers such as the asphalt and the geomembrane (B-1) is the most favorable system to limit the water infiltration into the waste package.

III. Construction Experiences of the Near Surface Disposal Test Facility

1.Disposal Test Facility

Layout of the disposal test facility is depicted in Fig. 3. The disposal test facility has two floors. There are the multi-purpose working space and the six test cells are located in the upper floor and the disposal information space for PR center is located in the lower floor.

Two types of test cells called as Type 1 (T1) and Type 2 (T2), respectively, are installed to simulate the degradation of the asphalt and geomembrane based on the result of computer simulation. Type 1 (T1) test cell has the layer of the asphalt and the geomembrane and Type 2 (T2) does not have these artificial barrier layers such as the asphalt and the geomembrane. Detailed configurations of Type 1 (Tl) and Type 2 (T2) cells are shown in Fig. 4.

Fig. 3 shows the symmetrical allocation of Tl (Tlw and Tln) with destructive sampling cell (denoted as Ds) in left hand side and T2 (T2w and T2n) cell with in-situ test cell (denoted as Is) in right hand side. This division is to test abnormal and normal rainfall situation for each test cell. Abnormal rainfall test, in short-term experiment, is simulated with the artificial rainfall system which is installed with motor driven pump and water storage tanks.

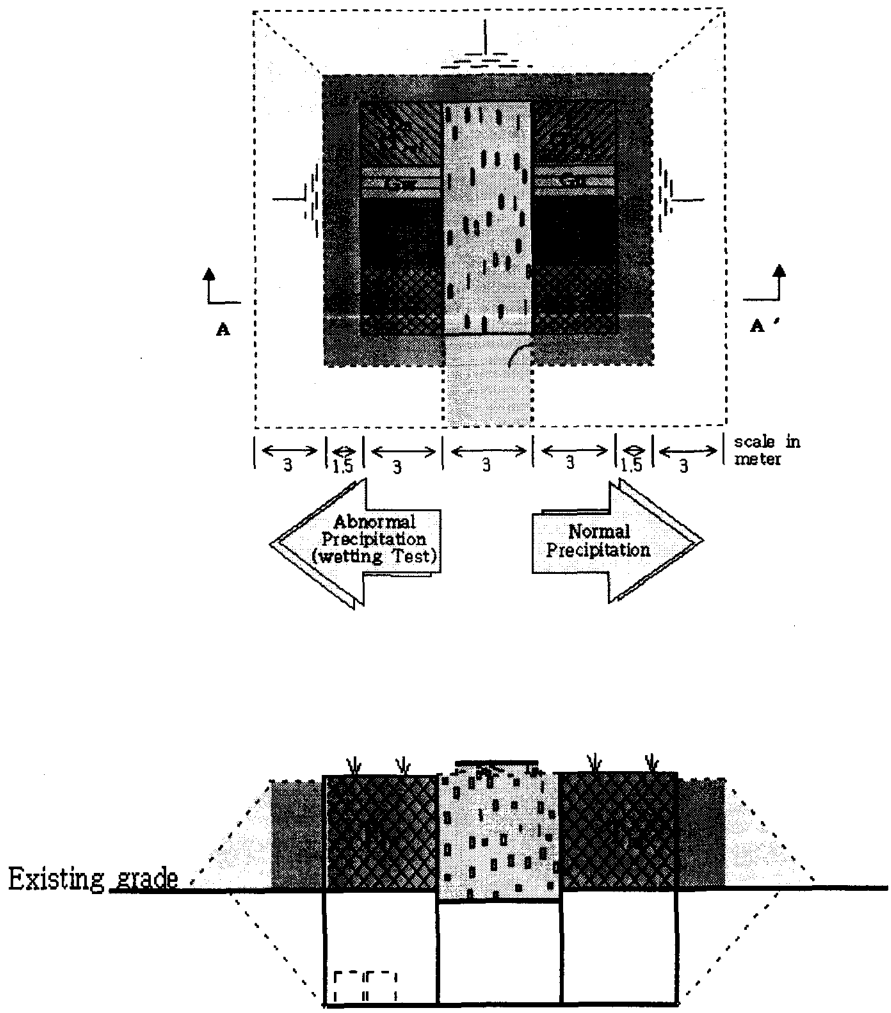

Figure 3. Layout of the Disposal Test Facility

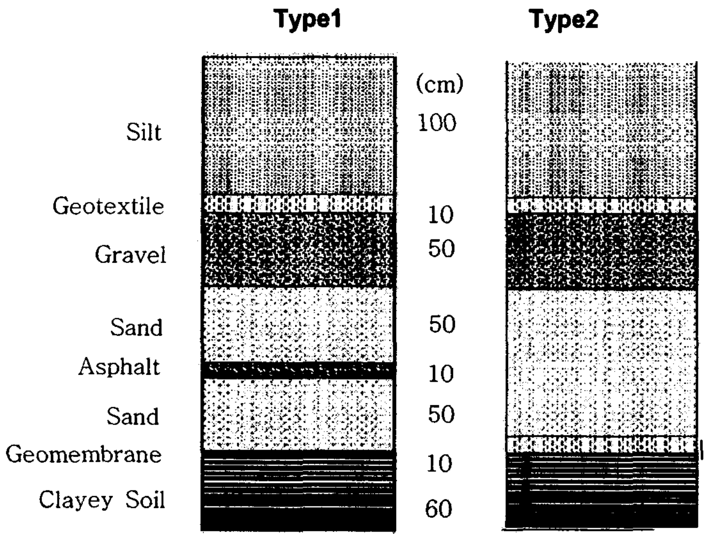

Figure 4. Cross Sections of Type 1 (T1) and Type 2 (T2) Test Cells

2. Detection System

The water contents and the temperature of each cover layer are measured with Time Domain Reflectometry (TDR). Total 108 numbers of TDR sensors are installed and 72 tensiometers measure the matric potential of each cover layer. All TDRs and tensiometers are connected to the multiplexer for collecting the detected data. The configuration of detection system is depicted in Fig. 5 and the position of instruments (TDR and Tensiometer) are listed in Table 3. The datalogger system of CR10X, which is the measurement and control system, is installed in wiring panel and is connected to personal computer.

Ⅳ. Operational Experiences of the Near Surface Disposal Test Facility

1.Disposal Test Facility

The construction of a disposal test facility took nine months since Nov. 2002 to July 2003. Fig. 6 shows the external view of the disposal facility from main gate. Fig. 7 shows the internal view of experimental facilities such as the lateral drainage piping and the instrument multiplexer systems.

2.Short-term Artificial Rainfall Test

Short-term experiments on the disposal cover layer using the artificial rainfall system are implemented from 21 Oct. 2003. Total 1,800 liters of water that is poured through the artificial rainfall nozzles into the T2w cell for five hours. Fig. 8 shows the daily water content in a T2w test cell from the artificial rainfall experiment. The temperature and matric potential of different cover layers are measured in Fig. 9 and Fig. 10, respectively.

The initial water content in the top soil layer is measured about 47% and 48% at two different levels of 290 and 310 cm, respectively. After the artificial rainfall system start to operate, the peak value of water contents reaches rapidly to 66 % and 62% at two different levels of 290 and 310 cm within a day as illustrated in Fig. 8, and then water content profiles decrease slowly.

The initial water content of the upper sand layer at 150 cm indicates 37%. After the artificial rainfall, the water content at 150 cm starts to increase to the maximum value (43%) and then decreases more slowly. By contrary to the upper sand drainage layer, the low sand drainage layer shows higher water content about 70%, initially. This is due to the clay barrier layer beneath the low sand drainage layer whose water content is close to the full-saturation value about 90%. The low sand drainage profile shows a small peak

Table 3. Installed Instrument Positions of TDRs/Tensiometers in a Test Cell

Instruments	Position(EA)	Depth(cm)	Test cell
TDR/Thermistor	3 (Near, Middle, Far)	30,90,150,260,290,310	T1n,T1w,Ds
TDR/Thermistor	3 (Near, Middle, Far)	30,90,150,260,290,310	T2n,T2w,Is
TDR/Thermistor	2	-50,-100,-150	Is backfill zone
Tensiometer	2 (Near, Far)	30,90,150,260,290,310	T1n,T1w,Ds
Tensiometer	2 (Near, Far)	30,90,150,260,290,310	T2n,T2w,Is
Tensiometer	2 (Near, Far)	-50,-100,-150	Is backfill zone
Tracer test tube	2	50,80,250,310	T1n,T2n,Is

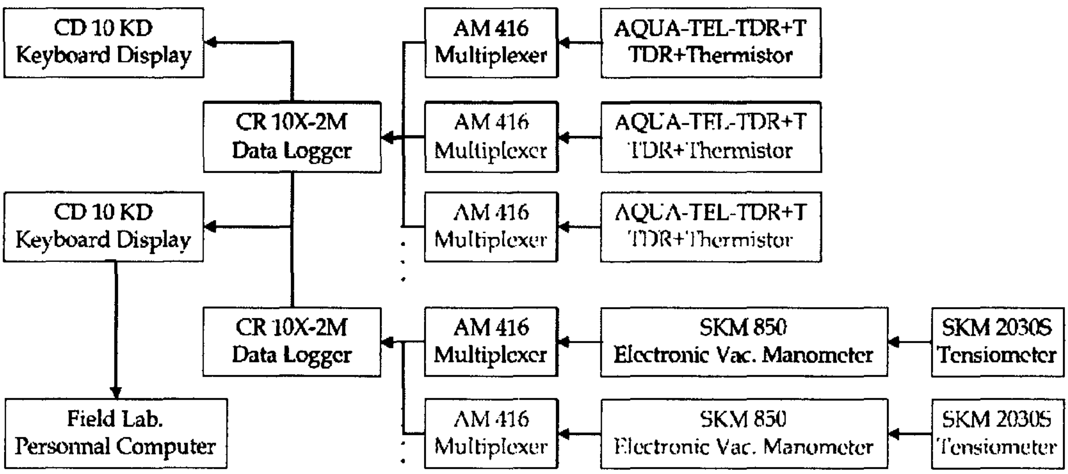

Figure 5. Configuration of Data Detection System in a Test Cell

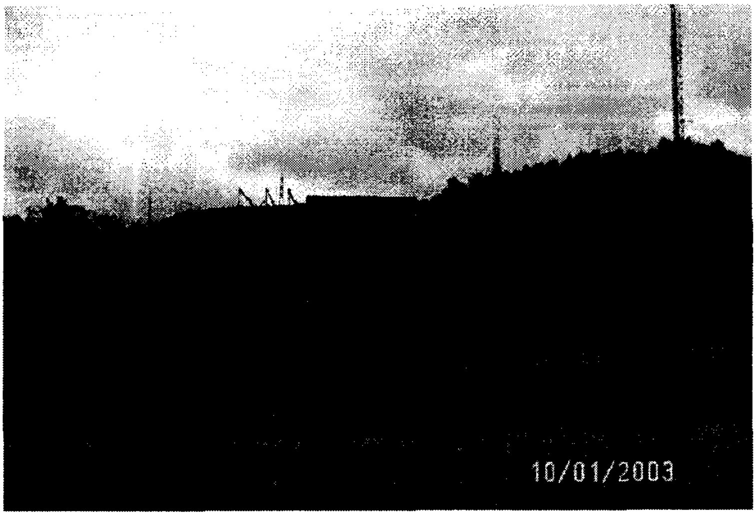

Figure 6. External View of the Disposal Test Facility- Front View

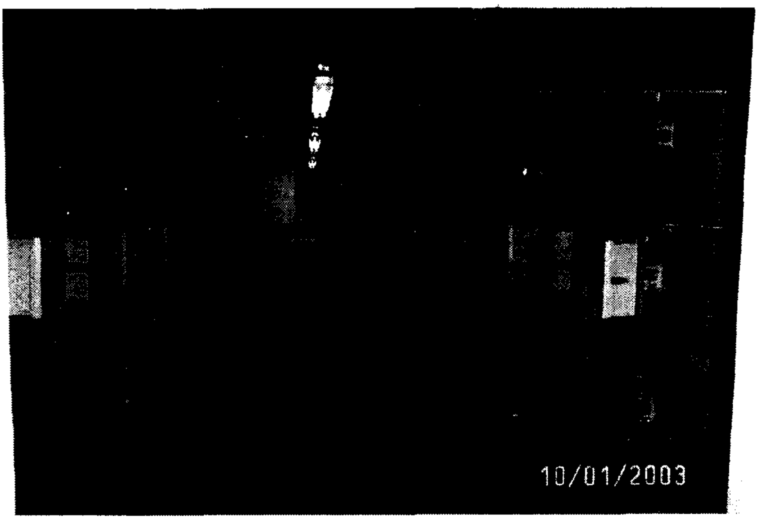

Figure 7. Internal View of the Test Facility- Lateral Drainage and Detection System

of water content and then return to the previous value within several hours. The sand drainage layer shows the satisfactory performance as intended in the design stage from the artificial rainfall test. It is investigated in Fig. 8 that no increase of water content in the clay barrier layer.

Fig. 9 shows the temperature variation in cover layers. Fig. 9 shows that the artificial rainfall does not affect the temperature of cover layers at the test facility. In Fig. 10, the variation of a matric potential is depicted. It is investigated that high water infiltration of the artificial rainfall changes the matric potential in each cover layer.

Table 4 shows the accumulation of

lateral drainage from the upper and the low sand drainage layers. Table 4 indicates the prompt initial increase of the lateral water drainage and then the accumulated water volume reaches to its plateau. This means that, from the Table 4, a half of artificial rainfall water flows to the lateral water drainage system and another half of rainfall water increases the water content of the top soil material mainly. The volume of the top soil is more than 1400 liters (1.2m x 1.2m x 1.0m(H)). The small portion of rainfall water is supposed to stay in the sand drainage layer.

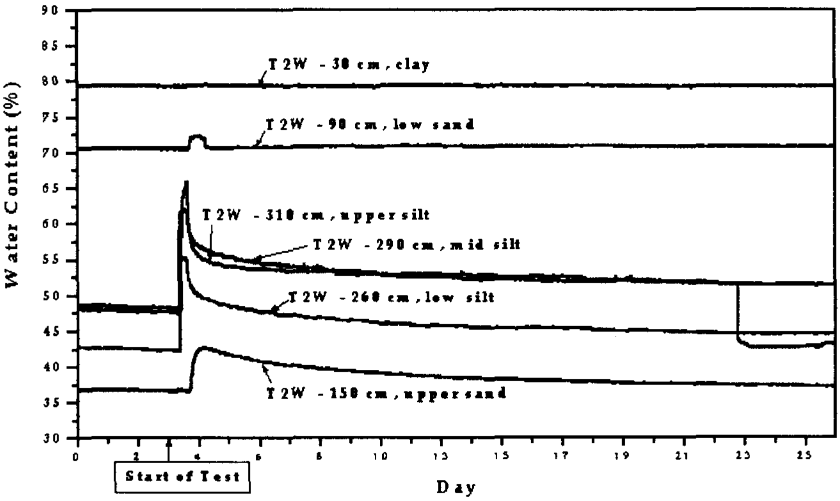

Figure 8. Daily Water Content in the T2W Test Cell from an Artificial Rainfall Experiment

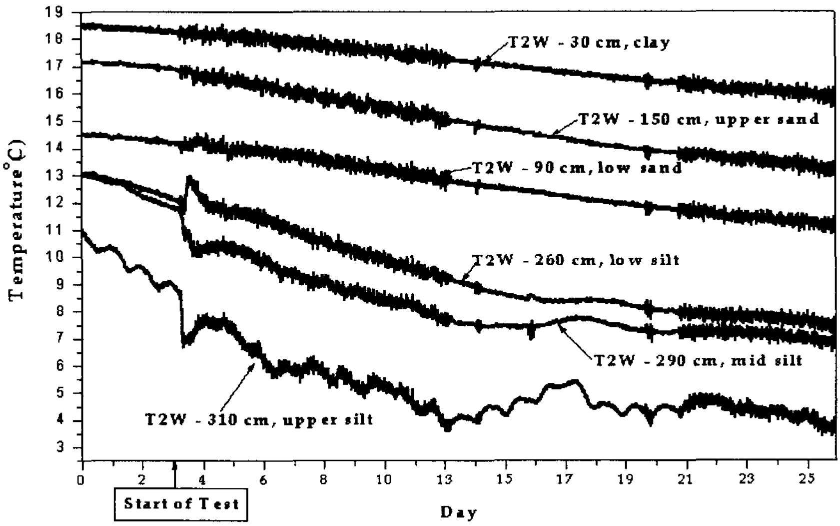

Figure 9. Daily Temperature in the T2W Test Cell from an Artificial Rainfall Experiment

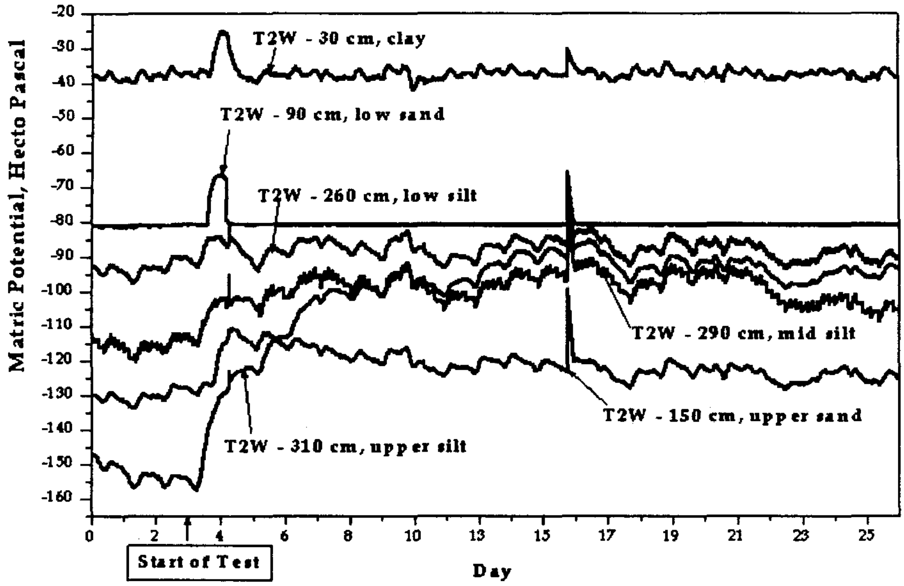

Figure 10. Daily Matric Potenrial in the T2W Test Cell from an Artificial Rainfall Experiment

Table 4. An Accumulated Lateral Drainage Water Volume in the T2W Test cell

Measurement time	Accumulated volume of lateral drainage (liters)	Ratio (%)
03-10-22 (11:30)	238	28.4
03-10-23 (16:00)	511	36.0
03-10-25 (10:00)	648	40.0
03-10-26 (17:00)	720	41.8
03-10-27 (15:00)	753	44.1
03-10-28 (17:30)	793	45.1
03-10-29 (15:30)	811	46.2
03-10-30 (18:00)	832	47.5
03-10-31 (17:00)	855	48.2
03-11-01 (17:00)	867	48.8
03-11-02 (13:00)	879	49.6
03-11-03 (09:00)	893	49.8
03-11-04 (09:00)	897	50.4
03-11-05 (14:00)	907	50.7
03-11-06 (09:00)	913	51.7
03-11-07 (09:00)	930	52.4
03-11-08 (09:00)	943	53.1
03-11-09 (09:00)	955	53.6
03-11-10 (09:00)	965	-

3. PR Center for Near Surface Disposal

The lower floor of the disposal test facility is used as the PR center to the public. Information panels of the test facility show the external and internal views of the test facility, functions of each cover layer, computer simulation results, the structure of instrumentation systems. General processes of the radwaste disposal from a nuclear power plant to the final disposal of low- and intermediate-level radioactive waste is also illustrated.

The illustrated systematic drainage system of the planned national disposal facility during the operational phase is displayed and can give the detailed inspection plan of water infiltration into the planned LILW disposal facility to the public.

The cross sectional view of the Type 1 (T1) cell is prepared in the form of a 30% reduced size to show the actual composition of the T1 cover layers. Fig. 11 is the internal view of the PR center for near surface disposal at the lower floor of facility.

V. Conclusions

To validate the previous conceptual design of cover system, construction of the engineered barrier test facility is recently completed and the performance tests of the disposal cover system are being actively conducted.

This conceptual design was analyzed based on the HELP simulation of four disposal cover design alternatives. When comparing with percolation through the clayey soil, results show that the cover system which is equipped with two artificial barrier layers such as the asphalt and the geomembrane is the most favorable system to limit the water infiltration into the waste package.

The disposal test facility is composed of the multi-purpose working space and the

Figure 11. The PR Center for Near Surface Disposal at the Lower Floor of Test Facility

temperature and the matric potential of each cover layer.

Short-term experiments on the disposal cover layer using the artificial rainfall system are implemented from 21 Oct. 2003. From the results of the artificial rainfall test, it is founded that:

After the artificial rainfall system start to operate, the peak value of water contents reaches rapidly to 66 % and 62% at two different levels of 290 and 310 cm within a day and then water content profiles decrease slowly,

The sand drainage layer shows the satisfactory performance as intended in the design stage,

There is no increase of water content in the clay barrier layer from the artificial rainfall test,

The artificial rainfall does not affect the temperature of cover layers at the test facility. It is investigated that high water infiltration of the artificial rainfall changes the matric potential in each cover layer,

A half of artificial rainfall water flows to the lateral water drainage system and another half of rainfall water increases the water content of the top soil material mainly. The small portion of rainfall water is supposed to stay in the sand drainage layers.

The low floor of the test facility is used as the PR center for a near surface disposal to the public. This facility is expected to increase the public information about the national radioactive waste disposal program and the effort for the safety of the planned disposal facility.

Ⅵ. Acknowledgements

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