Technical Note

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Long-Term Experiments for Demonstrating Durability of a Concrete Barrier and Gas Generation in a Low-and Intermediate-Level Waste Disposal Facility

Myunggoo Kang, Myunghwan Seo, Soo-Gin Kim, Ki-Jung Kwon, and Haeryong Jung*

Korea Radioactive Waste Agency, 19, Chunghyocheon-gil, Gyeongju-si, Gyeongsangbuk-do 38062, Republic of Korea

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Long-term experiments have been conducted on two important safety issues: long-term durability of a concrete barrier with the steel reinforcements and gas generation from low-and intermediate-level wastes in an underground research tunnel of a radioactive waste disposal facility. The gas generation and microbial communities were monitored from waste packages (200 L and 320 L) containing simulated dry active wastes. In the concrete experiment, corrosion sensors were installed on the steel reinforcements which were embedded 10 cm below the surface of concrete in a concrete mock-up, and groundwater was fed into the mock-up at a pressure of 2.1 bars to accelerate groundwater infiltration. No clear evidence was observed with respect to corrosion initiation of the steel reinforcement for 4 years of operation. This is attributed to the high integrity and low hydraulic conductivity of the concrete. In the gas generation experiment, significant levels of gas generation were not measured for 4 years. These experiments are expected to be conducted for a period of more than 10 years.

Keywords: LILW, A concrete barrier, Gas generation, An underground research tunnel

*Corresponding Author.
Haeryong Jung, Korea Radioactive Waste Agency, E-mail: nohul@korad.or.kr, Tel: +82-54-750-4340

ORCID

Myunggoo Kang	http://orcid.org/0000-0003-1561-2918	Myunghwan Seo	http://orcid.org/0000-0002-0774-2029
Soo-Gin Kim	http://orcid.org/0000-0003-4229-3799	Ki-Jung Kwon	http://orcid.org/0000-0002-4635-7906
Haeryong Jung	http://orcid.org/0000-0003-4869-5916		

Table 1. Composition of the concrete mock-up

W/(C+F) (%)	S/a (%)	Proportion (kg·m^{-3})							
		Water	Cement	Fly ash	3/4”	Coarser	Finer	WRA	AEA
40.0	38.4	206	412	103	961	357	241	2.3193	0.1287

1. Introduction

The first phase of the Wolsong Low-and Intermediate-level Waste Disposal Center located in Gyeongju, the Republic of Korea has been in operation since 2015. Six concrete silos were built to dispose of approximately 100,000 waste packages at the depth of 130 m below sea level [1].

An engineered barrier system of the first phase of the Wolsong Disposal Center consists of waste packages, disposal containers, concrete silos and backfill [1]. The silo concrete is considered to play an essential role in limiting water infiltration into the silo and mitigating radionuclide release to geosphere. However, it is expected that the concrete barrier degrades with time due to various mechanism and gradually lose its effectiveness as a barrier against groundwater infiltration and radionuclide release [2]. Corrosion of steel reinforcement in the concrete is evaluated to lead to formation of corrosion products with large volumes than the parent metal. The volumetric expansion would cause extensive degradation and cracking of the concrete [2].

Various gases are reported to be generated from a radioactive waste repository resulting from metal corrosion, the microbial degradation of organic matters and radiolosys [3]. The gas generation has been an important issue in terms of long-term safety of a radioactive waste repository because it could cause build-up of gas pressure. Therefore, it was required to demonstrate gas generation properties in a LILW disposal facility [3].

An underground research tunnel was built as a part of the first phase of the Wolsong Disposal Center in a view to demonstrating the long-term safety in terms of the gas generation and durability of an engineered barrier. Two different types of experiments, long-term gas generation from LILW and performance of silo concrete, have been undertaken since 2012. This technical note summarizes the preliminary results of the two experiments.

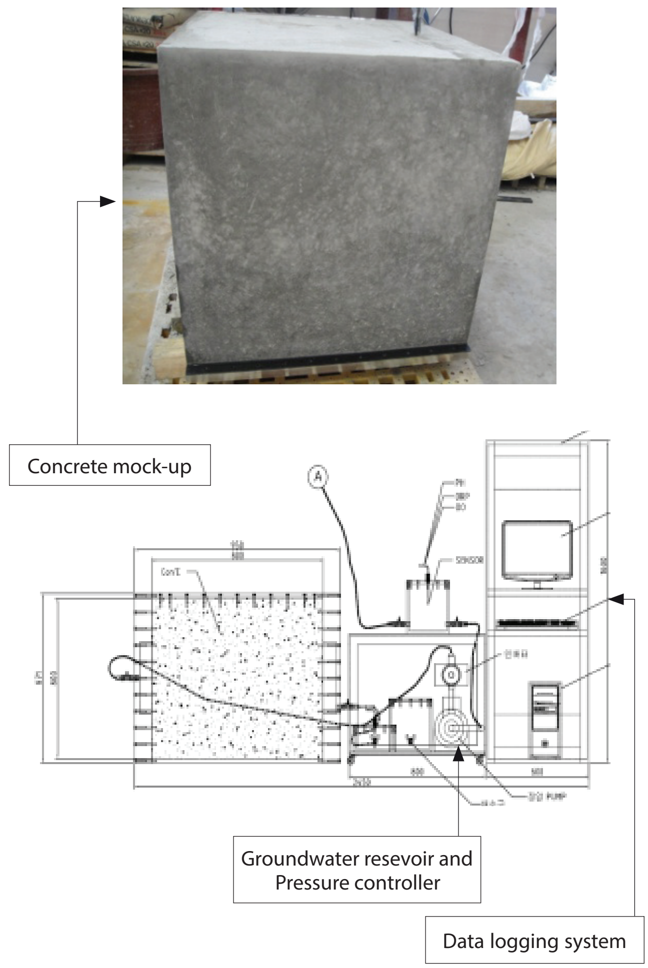

Fig. 1. Experimental setup for evaluation of long-term concrete durability.

2. Demonstration of Concrete Durability

A concrete mock-up was prepared with the same composition of the silo concrete with a length of 1 m, width of 1 m, and height of 0.8 m. Composition of the concrete mock-up is shown in Table 1. The steel reinforcements with a diameter of 42 mm was embedded in the concrete mock-up 10 cm below concrete surface.

As illustrated in Fig. 1, the experiment setup consists of groundwater reservoir and pressure controller for accelerating groundwater infiltration into the concrete mock-up, the concrete mock-up, and a data logging system. A separate groundwater well was installed into nearby host rock with a double packer system to feed uncontaminated groundwater into the concrete mock-up.

CorroWatch (PCTE) probes were installed at various depths under the concrete surface, to detect the corrosion initiation of the steel reinforcements in the concrete mock-up. The CorroWatch acts as a cell measuring the corrosion activity between anode and cathode on the surface of the steel reinforcements. Details and specifications of the CorroWatch is provided elsewhere (pcte.com.au/images/pdf/CorroWatch-Embedded-Corrosion-Front-Probes/Corrowatch.pdf).

3. Full-Scale Gas Generation Experiment

Two gas tight containers for concrete disposal containers packed with 16 waste packages (200 L) and 9 waste packages (320 L), respectively, were constructed for the gas generation experiment. Different types of simulated dry activated wastes were packed into the waste packages. Groundwater was injected into the gas tight container, and sampling lines for groundwater were installed inside the waste packages. Microbial and chemical analysis for the groundwater samples were carried out periodically. In addition, gas sampling ports were installed on the top of the gas tight containers. Details of the experiment are available elsewhere [4].

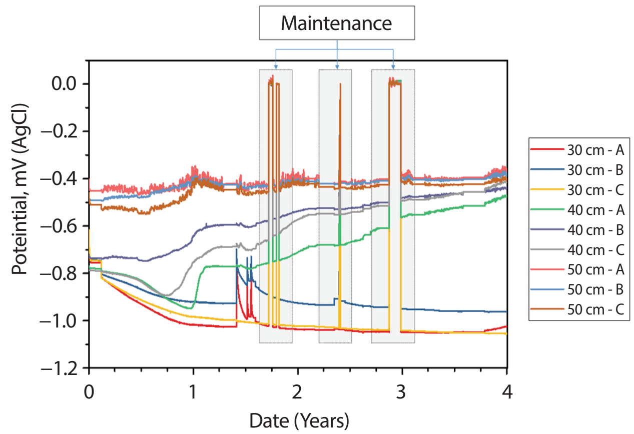

Fig. 2. Measurement of corrosion potential at various Depth of the concrete mock-up.

4. Results and Conclusions

Temperature and pH of input groundwater were in the range of 14.2–17.7°C and 6.0–8.2, respectively. The concentration of dissolved oxygen almost remained less than 1.0 $mg \cdot L^{-1}$.

The concrete experiment focused on the corrosion of the steel reinforcements because it was evaluated to be a main cause to degrade the silo concrete. Fig. 2 shows monitoring data of a corrosion sensor, the CorroWatch embedded in the concrete mock-up. Although groundwater input was pressurized at 2.1 bars to accelerate groundwater infiltration into the concrete, no evidence of corrosion initiation of the steel reinforcements has been observed for more than 4 years of initial operation. This appears to be caused by a high integrity and low hydraulic conductivity of the silo concrete measured to be 6.0×10^{-12} $m \cdot sec^{-1}$.

In the gas generation experiment, pH ranges from 6.8 to 8.6 in the gas tight containers, and dissolved oxygen (DO) concentration remains approximately less than 1.0 $mg \cdot L^{-1}$. Calcium dissolution from concrete disposal containers for 16 packs and 9 packs is not clearly observed. Dissolution of organic acids including Isosaccharinic acid reported to be generated from the degradation of cellulose at high pH conditions is not detected [5]. Ahn et al [4] reported that the bacterial communities in the containers have been influenced by indigenous microbes in input groundwater. It is worth mentioning that significant gas generation was not measured for initial 4 years.

Even though this technical note provides preliminary results from initial 4 years of operation, some meaningful findings are obtained in terms of the long-term safety of the Wolsong LILW Disposal Center: no signal for the corrosion of the steel reinforcements in the concrete silo under an aggressive condition and no detection of significant gas generation from the LILW. We plan to undertake the experiments for more than 10 years, and detailed information will be available in the near future.

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