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Preliminary Test of Alternative Backfill Materials for Closure of Radioactive Waste Disposal Facility

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1. Introduction

Closure of a radioactive waste disposal facility requires the development of proper backfill and closure concepts to limit the release of radionuclides from the disposal facility. The partial closure of the Wolsong disposal center is expected to start after the first operational stage. Preliminary tests of crushed rock and cement mortar as alternative backfill materials were performed to investigate basic properties and hydraulic data and to be used in the Wolsong disposal center.

2. Material and Method

The sizes of crushed rocks used in the test were 5 mm, 25 mm and 40mm. The crushed rocks are granite gneiss from the Gyeongju area. A 5mm crushed core sample from on-site, which is grano-diorite, was used for comparison. The composition of cement mortars are shown in Table 1.

Table 1. Composition of cement mortars

Material	Composition
cement:fly ash:water:sand	1:0.25:0.56:2.585 (used in domestic nuclear facility)
cement: water: sand	1:1.13:4 (used in Swedish disposal facility [1])
cement: water: sand	1:0.5:0.5 (bubbled cement mortar)

The hydraulic conductivity of crushed rock and cement mortar were measured with the constant head permeability test (KS F 2322)[2] and the Triaxial Compression Permeability Test (ASTM D 5084)[3], respectively. Figure 1 illustrates test apparatus for cement mortar. The hydraulic conductivity for crushed rock was calculated with the following equation:

$$k = \frac{L}{h} \cdot \frac{Q}{A(t_2 - t_1)}$$

where k : hydraulic conductivity (m/s), L, A : length(m) and cross-sectional area(㎡) of specimen, h : hydraulic head(m), Q : water flow (㎥), t_2-t_1 : measurement time(s).

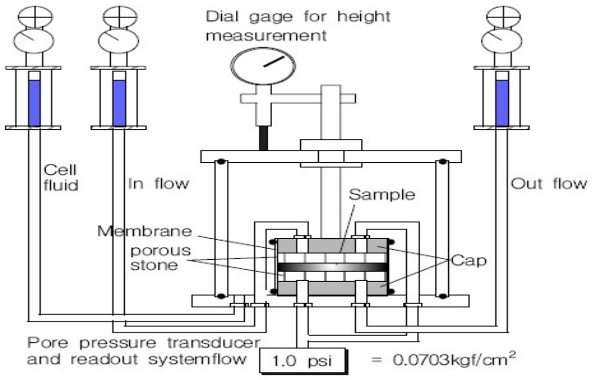

Figure 1. Test of hydraulic conductivity of cement mortar

The hydraulic conductivity for cement mortar was calculated with the following equation:

$$k = \frac{Qlm}{AP}$$

where k : hydraulic conductivity (m/s), Q : flux per unit time(㎥/s), A:cross-sectional area of specimen(㎡), P : water pressure(kg/㎡), l : thickness of specimen (m), m : unit mass of water (kg/㎥).

The gas flow rate, Q, through the specimens(100mm diameter and 30mm height) was measured with the apparatus as shown in Figure 2. The gas permeability of cement mortar was determined according to Darcy's law:

$$K = \frac{2P_2 h\gamma}{P_1^2 - P_2^2}\frac{Q}{A}$$

where K : gas conductivity (m/s), P_1 : inlet pressure(kg/㎡), P_2 : atmospheric pressure(kg/㎡), h: thickness of specimen (m), Q : gas flow rate(㎥/s), A : Area(㎡), γ : gas unit mass /volume(kg/㎥).

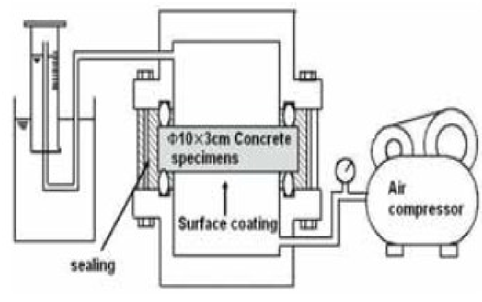

Figure 2. Schematic diagram of test apparatus for gas permeability

The gas permeability has the following relationship with the gas conductivity :

$$k = \frac{\eta K}{\gamma g}$$

where k: gas permeability (m^2), K: gas conductivity(m/s), η: air viscosity(cP), g: acceleration of gravity(m/s^2).

3. Results and Discussion

The bulk density of crushed rocks ranged from 1556 to 1820 kg/m^3 with diameters from 5 to 40 mm. The porosity and hydraulic conductivity ranged from 0.31 to 0.42 and from 8.5×10^{-5} to 1.3×10^{-4} m/s, respectively. The hydraulic conductivity decreased as the sizes of crushed rocks decreased. In the same size of crushed rock, the crushed rock from the Gyeongju area showed smaller hydraulic conductivity than that from onsite. Figure 3 presents the hydraulic conductivity of crushed rock.

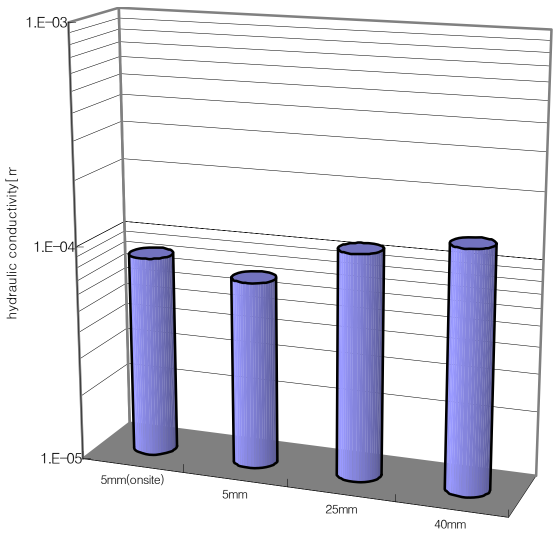

Figure 3. Hydraulic conductivity of crushed rock onsite and from Gyeongju area

Figure 4 shows the hydraulic conductivity of the three kinds of cement mortar. The density, porosity and hydraulic conductivity of cement mortar prepared according to the mixing conditions applied to the domestic nuclear facilities were 1871 kg/m^3, 0.07 and 6.7×10^{-12}m/s, respectively. The density, porosity and hydraulic conductivity of cement mortar prepared according to the mixing conditions of the Swedish disposal facility were 1923 kg/m^3, 0.275 and 2.7×10^{-11}m/s, respectively. Thus, cement mortar prepared according to the mixing conditions of domestic nuclear facilities is expected to give better performance than cement mortar prepared for the Swedish disposal facility.

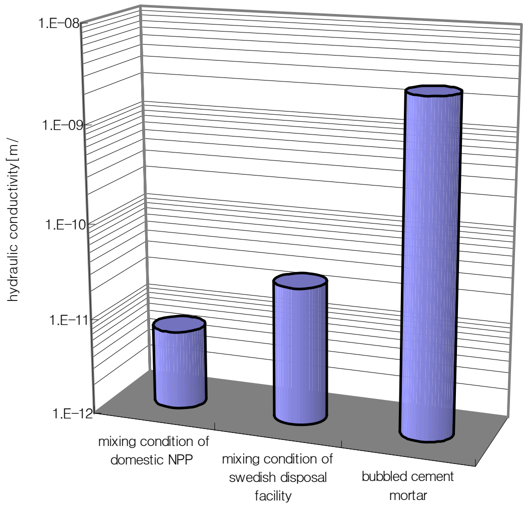

Figure 4. Hydraulic conductivity of various mixing conditions of cement mortar

The density, porosity and hydraulic conductivity of bubbled cement mortar were 802 kg/m^3, 0.247, and 2.69×10^{-9}m/s, respectively. Bubbled cement mortar allows greater infiltration of groundwater into silo, but has gas permeability of 1.8E-14 m^2, which is higher than gas permeabilities on the other cement mortars (1.42E-16 m^2 ~ 7.1E-16 m^2) used in this test.

4. Conclusion

The proper use of backfill materials enhances the closure safety of a disposal facility. Different backfill materials offer wide ranges of potential performance benefits depending on their chemical, hydrological, and physical properties. An optimized closure plan and detailed backfill design will be developed in consideration of long-term safety as well as constructional and economic aspects. The research and development of the closure technology will be continued during the operation period of the disposal facility.

REFERENCES

[1] L. O. Hőglund, "Modelling of long-term concrete degradation processes in the Swedish SFR repository", Project SAFE, SKB R-01-08, 2001.

[2] KS F2322, "Test methods for permeability of saturated soils",2000.

[3] ASTM D5084, "Standard test methods for measurement of hydraulic conductivity of saturated porous materials using a flexible wall permeameter",2003.