Use of the mixture of clay and crushed rock as a backfill material for low and intermediate level radioactive waste repository

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Background

At the time of the CRP, a repository for low and intermediate level radioactive wastes arising from nuclear power plant operation and radioisotope application in the Republic of Korea was to be constructed in the bedrock below ground surface. As the intermediate level waste cavern would contain the major part of radionuclide inventory in the cavern, the radionuclide release from the intermediate level waste cavern was therefore important from the viewpoint of disposal facility performance. The then current design concept suggested that the intermediate level waste would be emplaced into the compartment made of reinforced concrete, and the space between the concrete wall and cavern surface would be backfilled with a clay-based material.

As compacted clay-based materials have a low hydraulic conductivity and the hydraulic gradient in a disposal cavern was expected to be relatively low, molecular diffusion was considered to be the principal mechanism by which radionuclides would migrate through the backfill. The mixture of calcium bentonite and crushed rock was being suggested as a candidate backfill material.

This appendix summarises the KAERI research activities on the evaluation of hydraulic conductivity, radionuclide diffusion coefficient, and mechanical properties of the candidate clay-based backfill material for the intermediate level waste cavern.

Experimental

1. Materials

The clay being considered for the backfill material was a calcium bentonite from Younil, Kyungsangbukdo, the Republic of Korea, and it contains approximately 53.2% SiO_2, 22.1% Al_2O_3, 8.4% F_2O_3, 2.6% CaO, 2.0% MgO, 1.4% Na_2O, and some minor elements. Only clay portion that passed a No. 200 size sieve (with opening of width 0.074 mm) was used. The rock aggregate was crushed granite from Daeduk, Taejon. The maximum and minimum particle sizes of rock aggregates were set at No.4 sieve size (with the opening of width 4.70 mm), and No.200 sieve size, respectively.

2. Hydraulic conductivities

To measure the hydraulic conductivities of clay and crushed rock mixture, distilled water was used for the sample preparation and subsequent testing. The apparatus used to determine the hydraulic conductivity was designed to supply water into the sample at the hydraulic pressure of 1.3 kg/cm^2. The cylindrical chamber was 5 cm in diameter, and 5 cm in height, and the distilled water flows from the bottom to the top of the sample chamber at room temperature. The penetrated water volumes were measured by weighing.

3. Diffusion coefficients

The clay was saturated with a synthetic groundwater solution (SGW) with a pH of 7.0 and the following composition (in ppm): Na, 8.3; K, 3.5; Mg, 3.9; Ca, 13; Cl, 5.0; SO_4, 8.6; NO_3, 0.62; F, 0.19; HCO_3, not detectable. Both "in-diffusion" and "through-diffusion" methods were used to measure diffusion coefficients in compacted saturated clay. The clay was compacted to a dry density of 1.4 Mg/m^3, and the SGW was spiked with ^{90}Sr, ^{137}Cs, ^{60}Co, and ^{125}I.

4. Mechanical Properties

For the mechanical properties, Atturberg limits, the compaction property, the compressive strength, and the consolidation property were measured.

Conclusions

The hydraulic conductivities of clay/crushed rock mixtures decreased with increasing clay content. When the clay content increased to 50 wt%, the hydraulic conductivities of mixtures maintained the lower values, about 3×10^{-10} m/s, even at the dry density of 1500 kg/m^3. When the dry density increased to 2000 kg/m^3, the hydraulic conductivities decreased considerably, and were below 1×10^{-10} m/s, at the clay content of wt% so that the principal mechanism of radionuclide transport through the proposed backfill material would be molecular diffusion.

The diffusion coefficients of ^{137}Cs, ^{90}Sr, ^{60}Co, and ^{125}I in the clay with dry density of 1400 kg/m^3 were similar to those for Na-bentonite. The apparent diffusion coefficients in the clay with dry densities of 1000, 1200, 1400 and 1700 kg/m^3 decreased with increasing clay dry density, and the values were in the range of 3.80×10^{-11} to 7.12×10^{-11} m^2/s for ^{125}I, and of 1.21×10^{-12} to 1.43×10^{-12} m^2/s for ^{90}Sr. The values of apparent diffusion coefficients were not sensitive to the clay dry density, and varied by less than a factor of two.

Atturberg limits increased with increasing clay content and the clay/crushed rock mixture showed considerably good volume change potential. The unconfined compressive strengths of the clay/crushed rock mixture were in the range of 195 kN/m^2 to 269 kN/m^2 at the clay content of 20 wt% to 40 wt%. The consolidation coefficient at the consolidation pressure of 80 kN/m^2 to 320 kN/m^2 were 0.77 m^2/y to 1.65 m^2/y for clay content of 20 wt%, 0.88 m^2/y to 1.15 m^2/y for clay content of 30 wt%, and 0.18 m^2/y to 0.36 m^2/y for clay content of 40 wt%.