Physics and Chemistry of the Earth 65 (2013) 98–110

Contents lists available at SciVerse ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Evaluating hydro-mechanical interactions of adjacent clay-based sealing materials

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ARTICLE INFO

Article history:
Available online 31 May 2013

Keywords:
Deep geologic disposal
Clay-based sealing materials
EMDD (Effective Montmorillonite Dry Density)
Water uptake
Deformation

ABSTRACT

Canada's Nuclear Waste Management Organization (NWMO) is investigating various geological isolation concepts for Canada's used reactor fuel (NWMO, 2005). These options are all based on the concept of multiple barriers that include Highly Compacted Bentonite (HCB), Dense Backfill (DBF), Light Backfill (LBF), and Gap Fill (GF). The hydraulic, mechanical, and other characteristics of these clay-based sealing materials have been examined previously, but typically in relative isolation (e.g., Dixon, 1999; Blatz, 2000; Siemens, 2006; Stroes-Gascoyne et al., 2006; Baumgartner et al., 2007). Information on how these clay-based sealing materials interact with each other is needed to understand the evolution and performance of the overall sealing system.

A total of twenty-three (23) tests that examine the physical interaction of physically dissimilar clay-based sealing materials were installed and monitored at Atomic Energy of Canada Limited's (AECL) geotechnical laboratory. This paper describes the process of water uptake, interaction between the components installed, and the role of groundwater salinity on water uptake as interpreted from these tests.

1. Introduction

Canada's Nuclear Waste Management Organization (NWMO) is examining a range of geological and geometric options for isolation of Canada's used reactor fuel within a deep geological environment (NWMO, 2005). These concepts include, amongst others, the Infloor Borehole (IFB), Horizontal Borehole (HB), and Horizontal Tunnel Placement (HTP) geometries (Maak and Simmons, 2005) as shown in Fig. 1. Fig. 2 shows some of the details of the IFB concept considered by NWMO, which requires the drilling of smooth-walled boreholes in the floor of rooms or tunnels excavated deep below the surface in a geologically suitable medium. In each borehole, appropriate sealing materials would be installed and then a corrosion-resistant container would be placed in the borehole such that it was fully encapsulated by the surrounding sealing materials.

Despite differences in placement geometry and dimensions, the options being considered are all based on the concept of multiple barriers to contaminant release and migration and propose using many of the same materials in their construction. The sealing system for the placement methods for a Canadian Deep Geological Repository (DGR) includes four clay-based components (Highly Compacted Bentonite (HCB), Dense Backfill (DBF), Light Backfill (LBF), and Gap Fill (GF)). The hydraulic, mechanical, and other characteristics of these clay-based sealing materials have been examined previously, but typically in relative isolation (e.g., Dixon, 1999; Blatz, 2000; Siemens, 2006; Stroes-Gascoyne et al., 2006; Baumgartner et al., 2007).

In many of the initial repository performance assessments it was assumed that the backfill would completely homogenize with respect to density and that the backfill in the tunnel would behave based on the average backfill density. This situation is not however considered to be representative of a system where very different materials are used in the backfilling of the tunnel. The tests undertaken in this study are part of a process of physically testing the actual evolution of the backfill system and therefore will provide a robust basis for compliance models used to predict long-term evolution of the system.

One means of determining how sealing system components interact physically is to install cylinders of dissimilar clay-based sealing materials in contact with each other in a constant volume system. These materials are then allowed access to a fluid of known composition at the face where groundwater would be expected to enter sealing materials in a repository. As hydration proceeds and strains induced by swelling pressure occur, it is important to determine at what rate such strains occur and how the adjacent materials will evolve, hence a series of duplicate tests were installed and are being dismantled at preselected intervals.

A total of twenty-three (23) tests have been commissioned at the Atomic Energy of Canada Limited (AECL) geotechnical laboratory located at the Underground Research Laboratory (URL). These tests consist of three combinations of clay-based sealing materials

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http://dx.doi.org/10.1016/j.pce.2013.05.004

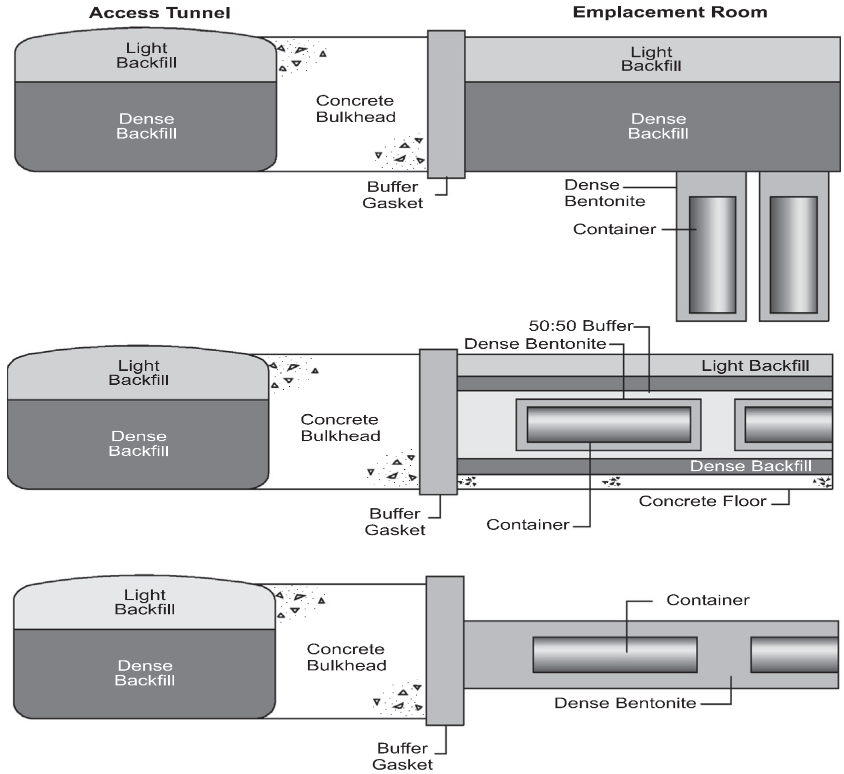

Fig. 1. Examples of container placement concepts being considered by NWMO (note figure is for illustration only and is not to scale).

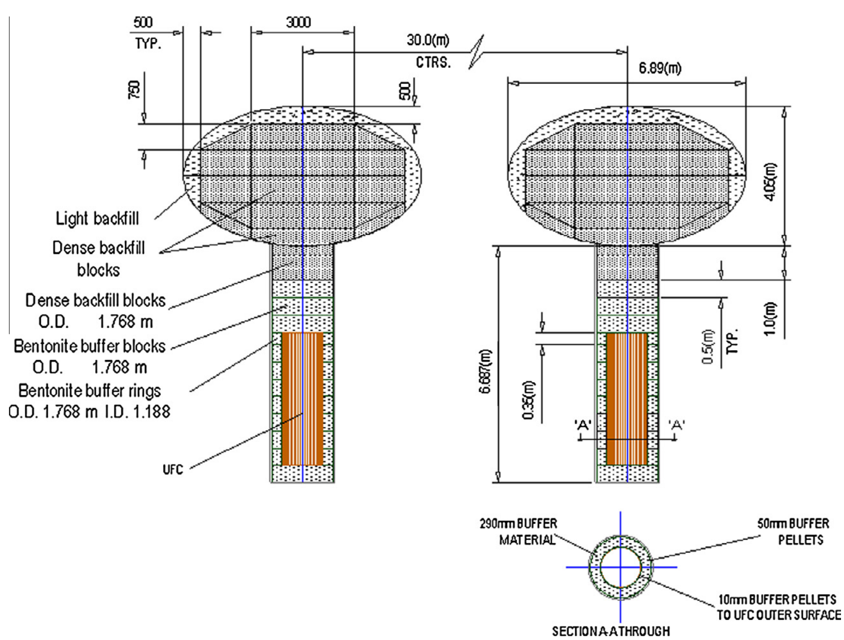

Fig. 2. NWMO IFB placement concept showing nominal component dimensions (NUKEM 2003).

(LBF–DBF, DBF–HCB, and GF–HCB) and two types of fluid (deionised water and 250 g/L $CaCl_2$ solution). A total of eight tests were decommissioned in two campaigns (2007 and 2009) to provide data for 1.5, 2 and 3.5 years of material interaction. Fifteen (15) tests are still operating and being monitored. These tests will be dismantled when they have been operating for 5 and 10 years with associated measurement of gravimetric water content and volume changes of the components installed. At the end of this testing program, data will be available on the evolution over a 10-year period of the internal gravimetric water content and density. This information will be useful input into compliance models used to predict long-term evolution of the system, to optimize clay-based material compositions and placement methods, and to develop numerical simulations to describe sealing system evolution.