Physics and Chemistry of the Earth 33 (2008) S499–S503

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

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

Humidity-induced water absorption and swelling of highly compacted bentonite in the project KBS-3H

A. Dueck *, L. Börgesson, R. Goudarzi, M. Lönnqvist, M. Åkesson

Clay Technology AB, IDEON Research Centre, SE-223 70 Lund, Sweden

ARTICLE INFO

Article history:
Available online 14 October 2008

Keywords:
Bentonite
Swelling
Water absorption
Modelling
Relative humidity

ABSTRACT

In the KBS-3H concept for disposal of nuclear waste, the canisters and bentonite blocks are placed in horizontal boreholes in the bedrock. In this concept, large perforated supercontainers, containing the copper canisters and buffer materials, are separated by a number of distance blocks of highly compacted bentonite. One of the critical design issues for the distance blocks is the humidity-induced swelling, absorption and cracking when the blocks are exposed to high relative humidity.

The objectives of the laboratory tests were to determine the water absorption rate, swelling rate and cracking of the bentonite with respect to time at different conditions when a bentonite block is placed above a free water surface separated by an air gap. The main variables are the gap width, the initial water content of the bentonite, the initial density, the temperature and the sample size. The material is a commercially available sodium bentonite with the quality symbol MX-80 (Wyoming bentonite from American Colloid Co.).

It was here demonstrated that a lower initial water content yields higher rates of absorption and swelling. It was also shown that a smaller size of the gap between the water surface and the sample yields higher absorption rate and swelling rate. Some of the tests were theoretically modelled with a FEM code. The influence of the initial water content and the size of the air gap on water absorption was well captured by the models.

1. Background

In the KBS-3H concept for disposal of nuclear waste, the canisters and bentonite blocks are placed in horizontal boreholes in the bedrock. The concept is described in detail by Thorsager and Lindgren (2004). In this concept, large perforated supercontainers of steel, containing the copper canisters and buffer material, are separated by a number of distance blocks of highly compacted bentonite installed in horizontal tunnels with a diameter of 1.85 m (Fig. 1). One of the critical design issues for the distance blocks is the humidity-induced swelling, absorption and cracking when the blocks are exposed to the high relative humidity in the tunnels.

The process of humidity-induced swelling is of general interest for the understanding of water transport mechanism in buffer and backfill materials. It is especially important for the early behaviour of some concepts where the tunnel is supposed to be drained during the installation and no water should come in contact with the blocks. The hydration process may cause cracking and subsequent loss of bentonite debris that could fall to the floor and also swelling of blocks that could then come in contact with the rock wall. Both these effects could cause problems before closure of the tunnel, such as hindering of the free flow of water along the floor or erosion and transport of bentonite material out of the tunnel. The present paper is part of a project previously reported by Sandén et al. (2008).

2. Objective

The objectives of the laboratory tests were to determine the water absorption rate, swelling rate and cracking of the bentonite with respect to time under different conditions. The main variables are the gap width between the water interface and distance blocks, the initial water content of the bentonite, the initial density, the temperature and the sample size. Absorption by vapour diffusion through air from a free water surface was considered unfavourable for the distance blocks, and consequently this condition was focused on. The results from the laboratory study have been compared to theoretical models based on vapour diffusion in air.

3. Experimental set-up

Two scales were used for the tests. Fig. 2 shows the small-scale equipment where each sample was placed in a vessel or jar made of acrylic plastic with a tight lid. The bottom of the vessel was filled with water. The sample was covered with a rubber seal only

* Corresponding author. Tel.: +46 46 286 25 80; fax: +46 46 13 42 30.
E-mail address: ad@claytech.se (A. Dueck).

1474-7065/$ - see front matter © 2008 Elsevier Ltd. All rights reserved.
doi:10.1016/j.pce.2008.10.026

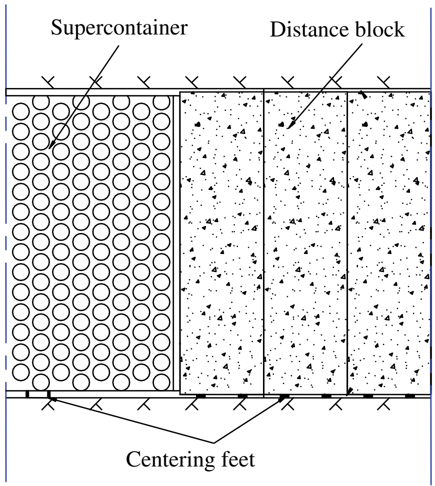

Fig. 1. Schematic illustration of the KBS-3H layout with the supercontainer and distance blocks of bentonite placed in horizontal boreholes in the bedrock. The present study concerns the transport of humidity between the wet rock surface and the bentonite blocks.

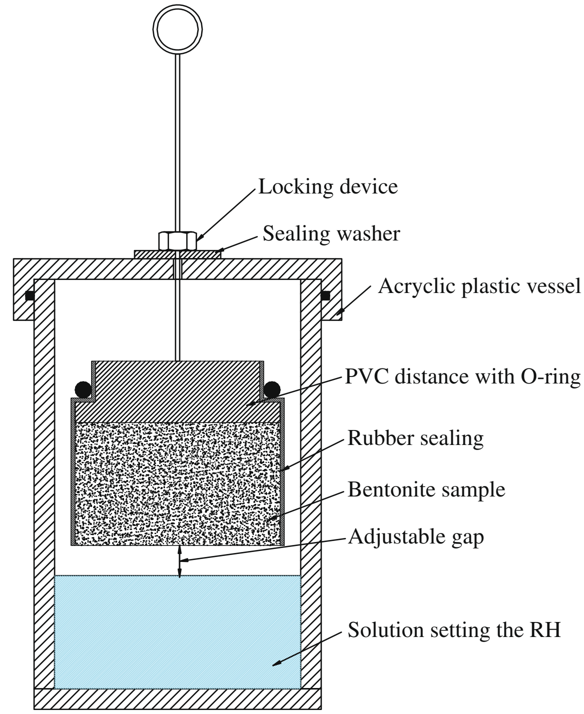

Fig. 2. Schematic view of the test equipment for the small-scale tests. The samples had an initial diameter of 50 mm and an initial height of 30 mm.

exposing one end to the water surface and the humid air above the water surface. The sample was hung in a rod which was led through the lid to be able to weigh the sample during the absorption without taking the sample out of the vessel. The weighing was made below a balance. The distance between the exposed bentonite surface and the water surface was held constant during the test period by adjusting the level of the water surface. The samples had an initial diameter of 50 mm and an initial height of 30 mm. A number of double samples were also used for studying the swelling. These samples were taken out of the jars to be measured with a slide calliper at prescribed intervals.

The medium-scale equipment is shown in Fig. 3. Cylindrical blocks with a diameter of 280 mm and a height of 100 mm were installed in steel cans. The inner wall of each steel can was covered with a filter which was kept wet by circulating water through four inlets and two outlets. The outer surface of the blocks was exposed to water vapour from the filter via an air filled slot or gap. The water content w (%) is defined as the ratio of the mass of water to the dry mass of the sample. The dry mass is obtained from drying the wet sample at 105 °C for 24 h.

4. Bentonite material

The material is a commercially available sodium bentonite with the quality symbol MX-80 (Wyoming bentonite from American Colloid Co.). The powder is delivered with a water content of 10%. Higher water contents were produced by adding water during mixing. After powder preparation, the bentonite was compacted to samples at different compaction pressures. Different initial densities and initial water contents were used. The dry density was varied between 1600 and 1900 kg/m^3, and the water content was varied between 10 and 25%.

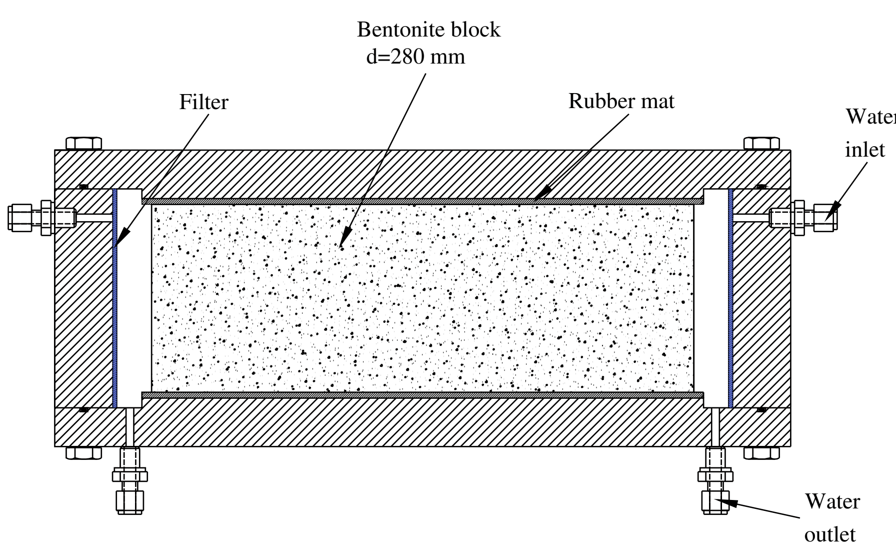

Fig. 3. Schematic view of the test equipment for the medium-scale tests. The samples were ring shaped with an outer initial diameter of 280 mm and a height of 100 mm.