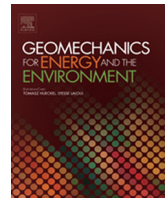




ELSEVIER

Contents lists available at ScienceDirect

Geomechanics for Energy and the Environment

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

Effect of the clay–water interaction in the hydration of compacted bentonite used in engineered barriers

Abel Carlos Jacinto^{a,*}, Alberto Ledesma^b, Agustín Demagistri^a^a National University of Tucumán (UNT), Av. Pellegrini 1800, (4000) San Miguel de Tucumán, Argentina^b Technical University of Catalonia (UPC), Mòdul D2, C. Jordi Girona 1-3, (08034) Barcelona, Spain

HIGHLIGHTS

- Using a variable water density degrees of saturation lower than one are obtained.
- Using the proposed methodology experimental results were well captured.
- Because of clay–water interaction, more time and water is needed to saturate a barrier.

ARTICLE INFO

Article history:

Received 11 September 2015

Received in revised form 11 October 2016

Accepted 13 October 2016

Available online xxxx

Keywords:

Engineered barrier

Energy

Bentonite

Coupled processes

ABSTRACT

Compacted expansive clays are considered in the design of barriers for different engineering applications. The expansion and sealing capacity of those clays when hydrated is the main engineering property in that particular context. Numerical models used to analyse and predict the behaviour of these barriers need, among other constitutive laws, the soil water retention curve. In general, numerical codes used in those calculations are formulated considering the degree of saturation as the variable to indicate the water content within the porous medium. Because of that, it is common to express the water retention capacity as a relation between the suction and the degree of saturation. Surprisingly, degrees of saturation larger than one are systematically obtained in the laboratory at low suction values in the case of samples of expansive clay tested at constant volume. This effect is attributed to the density assigned to the water within the pores, which is assumed equal to that of the bulk water. In a previous work a method which defines the density of water in samples of expansive clays as a function of the suction was developed. Using this relation, water retention curves where the degrees of saturation are lower than one are obtained. This work compares experimental results of the hydration processes of a compacted sample of expansive clay with those obtained in numerical models where different laws for the water density were considered. Conclusions with respect to the hydration time as well as to the quantity of water needed to saturate the sample are obtained.

© 2016 Elsevier Ltd. All rights reserved.

* Correspondence to: National University of Tucumán (UNT), Av. Independencia 1800, (4000) San Miguel de Tucumán, Argentina.

E-mail addresses: ajacinto@herrera.unt.edu.ar (A.C. Jacinto), alberto.ledesma@upc.edu (A. Ledesma), ademagistri@facet.unt.edu.ar (A. Demagistri).

<http://dx.doi.org/10.1016/j.gete.2016.10.002>

2352-3808/© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

Engineered clay barriers have been used for several decades as technically suitable, cost-effective solutions for containing water, wastewater, landfill leachate and gas. Bentonites are used in linear and cap systems for minimizing migration of contaminants of chemical species from industrial and municipal waste disposal facilities to the general groundwater system. They are also used as engineered barriers for the deep underground storage of nuclear waste¹ and as liners for remediation of contaminated soils and ponds.^{2,3} In some cases, soils present in the site project are unsuitable to make barriers and it would be necessary to import the full volume of clay from other place. In that case, it can be more economical to import bentonite which has the ability to swell significantly when wetted, to fill large pore spaces in sandy or other well-graded soils and thus reduce permeability to a required level.

In general, numerical codes used to analyse and predict the behaviour of these barriers are formulated considering the degree of saturation as the variable to indicate the water content within the porous medium. Because of that, it is common to express the water retention capacity as a relation between the suction and the degree of saturation. However, in the case of compacted samples of expansive clay tested at constant volume⁴⁻⁶ degrees of saturation larger than one are systematically obtained in the laboratory at low suction values. This effect is attributed to the fact that the water confined in small pores or in the proximity of the clay layers of expansive materials presents properties that differ from those of free water, including variations in its density.⁷⁻¹⁰ In a previous work a method which defines the density of water in samples of expansive clays as a function of the suction was developed.¹¹ Using that procedure, a relationship between the density of the water present within the pores of a compacted bentonite sample and the suction level could be deduced. As a consequence water retention curves where the degrees of saturation are lower than one were obtained. This work analyses the influence of the clay-water interaction in the hydration processes of a compacted bentonite sample and compares analyses of hydration assuming the conventional value of 1.0 Mg/m³ for water density with the proposed approach involving a variable density depending on suction. Conclusions with respect to the hydration time as well as to the water needed to saturate the sample are obtained.

2. Clay-water interaction in expansive clays

Experimental analysis on bentonite samples compacted at different dry densities show that in their fabric it is possible to consider a double structure defined by the clay aggregates and the pores between them.¹² Fig. 1 presents a sketch of the fabric of a compacted bentonite sample where the different structures can be identified.

An aggregate includes several particles and each particle is formed by several silicate sheets (also called unit layers or clay layers). The microporosity or intra-aggregate porosity (porosity inside an aggregate) is not

homogeneous, but includes the pores inside each particle (ranging between 0.2 and 2.0 nm) constituting the intra-particle (or interlayer) porosity and the pores between particles or inter-particle porosity. It is commonly assumed that the porosity inside the aggregates is not affected by compaction when the water content is not too close to saturation.¹³⁻¹⁵ Consequently, the microporosity distribution is initially independent of the dry density of the compacted sample.¹⁶ The macropores (pores between the aggregates) define the inter-aggregate porosity or macroporosity.

During the hydration of montmorillonite from the dry state, the exchangeable cations located in the interlayers are initially hydrated according to their hydration energy. Subsequently, the spaces between particles are filled with free water. These mechanisms produce changes in the microstructure of the material associated with variations in the basal distance (distance between clay layers) and specific surface area. At low and moderate relative humidity, the swelling develops at particle level and occurs without any significant global volume change. On the other hand, in the range of high relative humidity the changes of volume are appreciable in the case of samples hydrated under free volume conditions.^{17,18} For confined samples, macroscopic swelling is prevented and porosity redistribution occurs, which results in microporosity invading macroporosity.^{14,15,19-21}

The sorption of water into the interlayer space of smectites depends on the size and charge of the exchangeable cations, and the value and localization of the layer charge of the silicate sheet.²²⁻²⁷ Many experimental results suggest that the water confined in small pores or in the proximity of the clay layers of expansive materials presents properties that differ from those of free water.^{7-10, among others}

From a macroscopic point of view, Villar & Lloret⁶ showed that the average density of the water in saturated samples of compacted bentonite depends on the specimen density and gravimetric water content, and values higher than 1.05 Mg/m³ and up to 1.22 Mg/m³ were obtained for bentonite dry densities between 1.3 and 1.8 Mg/m³.

Taking into account the hydration mechanism of a montmorillonite powder²⁸ and the measurements at microscopic level, Jacinto et al.¹¹ assumed that the water adsorbed on the external surface and the water in the macropores have both a density of 1.0 Mg/m³, but the water in the interlayer space has a greater density. This change in the conventional value of water density is assumed to be responsible of the degrees of saturation greater than one found by several authors.

3. Water density in compacted samples of expansive clays

In the following the main ideas of the method proposed to determine the water density in compacted samples of bentonite are indicated. A more detailed explanation can be found in 11. The methodology considers that the total water content w in a sample of expansive soil is given by

$$w = w_i + w_e + w_f \quad (1)$$

Download English Version:

<https://daneshyari.com/en/article/4921546>

Download Persian Version:

<https://daneshyari.com/article/4921546>

[Daneshyari.com](https://daneshyari.com)