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Volume change behaviour of a swelling soil compacted at different initial states

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ABSTRACT

This paper presents a simple approach to model the hydro-mechanical behaviour of swelling soils at different initial states during successive wetting and drying cycles. This model was developed based on the experimental results obtained for an expansive bentonite/silt mixture compacted at three different initial dry densities representing loose, intermediate and dense states.

The parameters of the simplified model were initially fitted based on the results obtained for the loose and dense samples and then used to estimate the hydraulic and mechanical behaviour of the intermediate samples. Generally, the model prediction produced a satisfactory correspondence with the experimental results.

1. Introduction

The exposure of clay soils to varying climatic conditions can induce soil settlements that affect the structures built on these soils: shallow foundations, drainage channels, and buffers of radioactive waste disposal. The complex hydro-mechanical behaviour of clay materials essentially results from their fabric (Pusch, 1982; Alonso et al., 1987, 1999; Gens and Alonso, 1992), which has been the main subject of several studies on the micro- and macrostructures of soils (Wan et al., 1995; Pusch et al., 1999; Cui et al., 2002a; Lloret et al., 2003; Pusch and Yong, 2003; Cuisinier and Masrouri, 2005; Hoffmann et al., 2007; Nowamooz, 2007).

The swelling behaviour of unsaturated, expansive clays has often been described through relatively simple empirical laws that relate the material response to suction changes and applied stresses. There are relatively few formulas that integrate the main aspects of coupled hydro-mechanical behaviour in a unified framework. To address this issue, the model proposed by Gens and Alonso (1992), Alonso et al. (1999) (BExM, Barcelona Expansive Model) can be used as a reference to analyse the behaviour of unsaturated, expansive materials. The model takes into account the accumulation of strains during wetting and drying cycles in soil, as well as the asymptotic elastic state, called the equilibrium stage, that is present at the end of the wetting–drying cycles (Chen, 1965; Chu and Mou, 1973; Dif and Bluemel, 1991; Day, 1994; Al-Homoud et al., 1995; Basma et al., 1996; Alonso et al., 2005).

Nowamooz and Masrouri (2008, 2009) studied the mechanical behaviour of loosely and densely compacted bentonite and silt mixtures after a single cycle of decreased suction under oedometric conditions. The compression curves under different suctions converged toward the normally consolidated curve (NCC) for higher applied stresses (Figure 1-a). In other words, at sufficiently high stresses, the compression behaviour of the soil is independent of suction. The stress obtained at the intersection of the normally consolidated curve (NCC) and the compression curve is called the saturation stress P_{sat}. Nowamooz and Masrouri defined the loading collapse curve (LC, representing the variation of the preconsolidation stress $P_0(s)$ with suction) and the saturation curve (SC, representing the variation of the saturation stress (P_{sat}) with suction) in the plane (vertical net stress-suction). For the loose samples, the two curves were completely separated before the application of the wetting and drying cycles (Figure 1-b). For the dense samples, the LC and SC yield curves were superimposed before the application of the suction cycles (Figure 1-c).

Nowamooz and Masrouri (2010a) showed that the cyclic wetting and drying process promotes a net accumulation of swelling strains on densely compacted specimens and a net accumulation of shrinking strains on loosely compacted specimens. Eventually, the final asymptotic strain is unique for a given compacted soil and is independent from the as-compacted density. They concluded that a critical dry density may be defined as a reference asymptotic state for a given compacted soil (Figure 2).

Moreover, the mechanical behaviour of these compacted loose and dense samples at the end of several wetting and drying cycles was studied at different suctions (Nowamooz and Masrouri, 2010b). At the end of the suction cycles, the samples exhibited the same mechanical behaviour (compression curves and yield surface) under the same suction conditions (Figure 3 a–b).

As in most geotechnical fields, cyclic hydraulic variations in clayey soils induce significant structural damage, so it is important to predict the long-term behaviour of expansive soils after being submitted to

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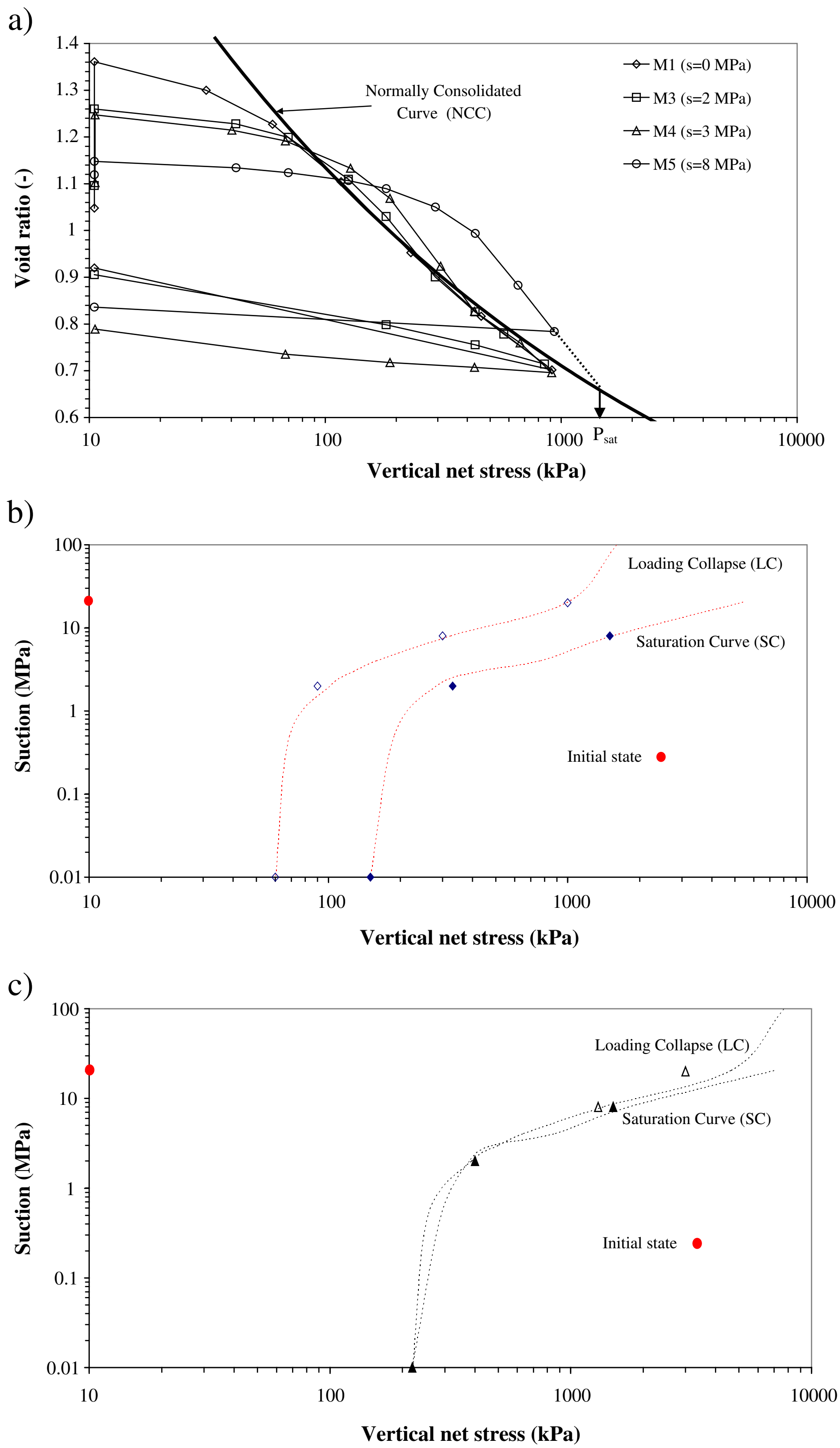

Fig. 1. a) Compression curve at different suctions for the loose samples; yield curves for the b) loosely and c) densely compacted bentonite and silt mixtures (Nowamooz and Masrouri, 2008, 2009).

several wetting and drying cycles. Based on the above-mentioned experimental results, this paper presents a simple approach to model the mechanical behaviour of swelling soils, at different initial states, that are submitted to wetting and drying cycles.

2. Analytical approach

The hydro-mechanical behaviour of unsaturated, expansive soils has been studied by several authors (e.g., Alonso et al., 1990; Fredlund and