Simulation of the physical degradation of natural slopes of Jurassic marls when excavated and subjected to suctions changes

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ABSTRACT

Soft clayey rocks such as marls and argillites are very common in the Iberian Peninsula. Design provisions for engineering works such as slope excavation in these materials must consider their evolving behaviour. Evolution can be identified by physical degradation. In fact, volume changes, stiffness loss, and, quite often, loss of mass continuity due to the development of fissures can cause instability phenomena of finite volumes of rock (Alonso *et al.*, 2010).

Abadia marls from Arruda dos Vinhos, in Portugal, are an example of soft rocks exhibiting such type of evolving behaviour. These marls, Upper Jurassic in age, are characterized by relatively high *in situ* water content and low porosity. Clay minerals present are mainly chlorite, kaolinite and illite, which explain the relatively high plasticity of the material. Excavated slopes in this material exhibit strong degradation of its hydro-mechanical properties, as illustrated in Figure 1.a. Because this degradation is due to the exposition to atmospheric actions, the excavated slopes are often protected with a membrane. This was the procedure adopted in A10 Motorway slopes shown in Figure 1.b.

a)  b) 

Fig. 1. General view of Abadia marls: a) Weathered steep slope; b) Non weathered material (before being covered for protection) (Cardoso, 2009).

Physical degradation verified in this type of materials is explained by stress release and by the accumulation of swelling deformations. Because the recent excavated slopes are exposed to the atmos-

phere, water exchanges between the rock and atmosphere occur and therefore it is acceptable to study this degradation mechanism using concepts of unsaturated soil mechanics.

Abadia marls are been investigated in the past years with the purpose to full characterize their hydro-mechanical behaviour considering the degree of saturation. Experimental data available concerns their oedometric behaviour (Cardoso, 2009), isotropic compression, unconfined compression strength and shear strength (Caldeira *et al.*, 2011) considering different suctions applied. Saturated hydraulic conductivity and the water retention curve were also measured (Cardoso, 2009).

The degradation of individual fragments of these marls when wetted was studied by Cardoso and Alonso (2009), in which the numerical simulation of individual fragments of marl was performed for different situations. The development of patterns of tensile stress, shear stress and plastic deformation during wetting allowed the identification of degradation mechanisms of fragments of marl. Suction changes inside the fragment, developed during wetting, play a significant role. The resulting differential swelling deformations lead to tensile stress or shear stresses, and consequently to cracking.

Similar behaviour can be observed when simulating the excavation of slopes in marls followed by their exposition to atmospheric actions, which explains the physical degradation. The study performed is presented in this paper, in which a 60º slope with 5m high was modelled and suction changes including full saturation were applied in the recently excavated surface exposed to atmosphere. Program Code Bright (Olivella *et al.*, 1996) was used in the simulation. A hydro-mechanical coupled analysis was performed and Barcelona Basic model, BBM (Alonso *et al.*, 1990) was the constitutive model adopted for the marls. It is worth to note that the volumetric behaviour of the marls can be reproduced in a more realistic manner by using an elastoplastic constitutive model with a bonding parameter (Cardoso *et al.*, 2013). However, the model used in the numerical study of the degradation of a single fragment, BBM, is able to tackle the main features of the expansive behaviour of the marls only if it is intended to define a degradation mechanism. For this reason, and also because it is defined in Code Bright, BBM is the model adopted in the study presented in this paper.

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