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# Slope stability in slightly fissured claystones and marls

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## Extended Summary

Tertiary basins of the Iberian Peninsula are filled with deep deposits of clayey soft rocks horizontally layered. A characteristic case is the very large Ebro basin. At the basin borders tectonic activity folded the strata and introduced often additional sets of discontinuities. On the other hand, some characteristic geological periods (the Keuper period, within the Triassic; the Weald, at the Jurassic-Cretacic transition; the Garum facies which marked the beginning of the Tertiary era) saw the deposition of clay deposits of variable plasticity. These formations are more thoroughly tectonized than the Tertiary deposits mentioned. Reference will be made in the lecture to some of these soft clayey rocks. The discussion will be organized around the following aspects:

a) The intact material and its brittle behaviour

b) The weathering action of atmospheric events

c) The persistent discontinuities and scale effects and

d) The modification of strength after failure

In all cases instability phenomena will be addressed.

a) The intact material

These are brittle materials, densely packed, not necessarily cemented. “In situ” horizontal stresses are seldom reported despite their profound effect on the triggering of slope stability. Elastoplastic bonding models have been proposed to describe their behaviour. A recent case of first time failure, induced by a rapid excavation will be discussed.

b) Weathering

Degradation by the accumulation of atmospheric cycles but also by the loss of confining stresses leads to a systematic increase in water content and a reduction of dry density. A recent long term laboratory investigation on the nature of degradation has been performed by imposing Relative Humidity cycles in specially designed triaxial cells. The amplitude of RH cycles, its number and the effect of confining stress were varied in an effort to get a comprehensive picture of the nature of degradation. Microscopic observations stressed the role of micro fissuring, which develops at the interfaces between hard particles (quartz, dolomite) and the clay paste. Macroscopic variables such as stiffness and tensile strength have been found to be uniquely predicted by a degradation

law in terms of the accumulated plastic deformations. This is a convenient result for the purposes of constitutive modeling (Fig. 1).

Weather-induced fissuring leads to a loss of continuity of the rock mass, which may present a blocky nature. Results of an analysis of the effect of RH changes on small blocks explain how the developed tensile strains contribute to a further division of the matrix. The confining stress is also a fundamental aspect of this process. Loss of confining stress accelerates the degradation rate.

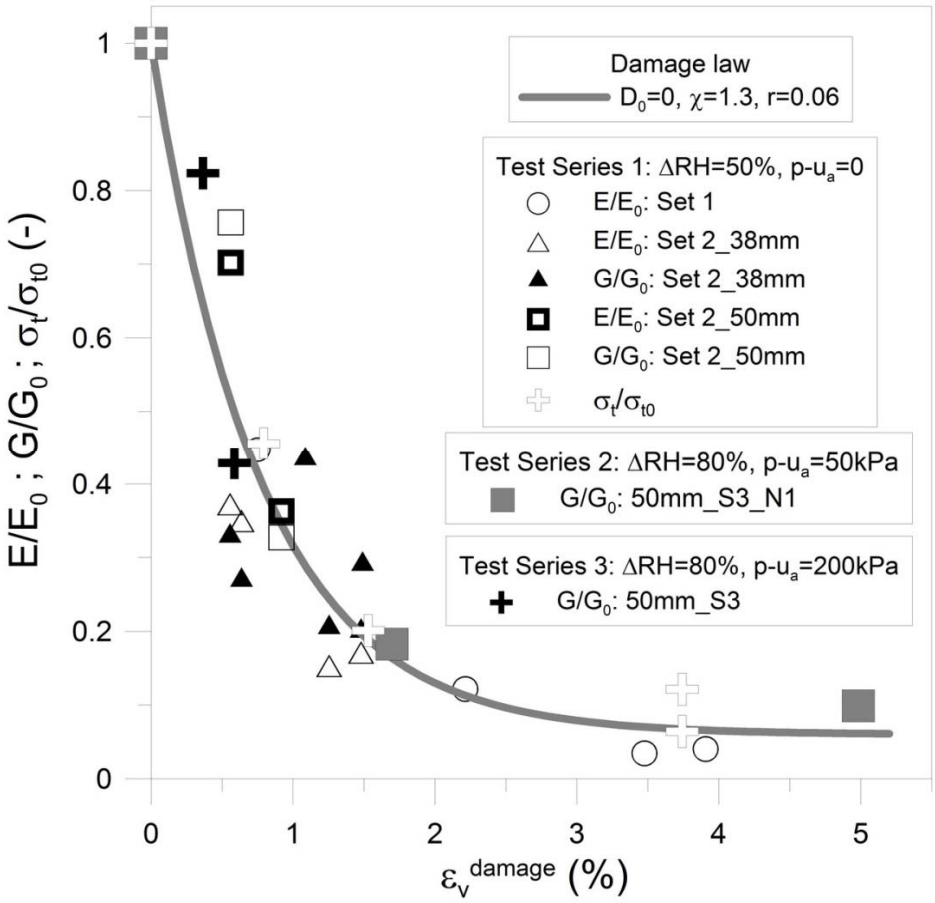


Figure 1. Degradation law for Lilla claystone: Decay of stiffness and strength parameters with accumulated plastic volumetric strain.

Field observations of the relevance of weathering and, also, on the rate of weathering, will be given for a Weald claystone. Shallow instabilities in a sloping ground take place in the weathered material. There are two main contributing factors favouring instability: The loss of strength and the distribution of permeability within the weathered profile. Field observations emphasize the importance of sharp transitions between weathered and intact (or slightly weathered) levels. These transitions define also a marked change in permeability which controls the development of rain induced pore water pressures.

c) Discontinuities

Persistent discontinuities and, in particular, sedimentation planes, play a dominant role to explain slope failures not related to the shallow failures usually associated with weathered

profiles. Determining the operating strength on these pre-existent discontinuities is a major task. The case of an investigation of the relevant strength of sedimentation planes in a Weald formation will be given. Observed medium sized failures and the stability of a gravity dam were controlled by the strength of claystone-claystone or claystone-sandstone contacts. The strength of these discontinuities was investigated by means of tests performed at two scales: relatively large samples tested in a 30x30 cm shear box and larger "in situ" samples (80x80 cm). One of the most disturbing findings was the difficulty to interpret and evaluate the effect of scale. This aspect, which is critical to decide the "in situ" strength, will be discussed. Figure 2 shows the aspect of a critical discontinuity in Weald claystone.

Figure 2. A sedimentation surface in Weald claystone

d) Changes in strength after failure

Strength is typically assumed to evolve towards a residual state after failure. Residual strength has been extensively investigated and reported in the geotechnical literature. The reactivation of landslides is then a simple conceptual problem. All that is needed is to measure the residual strength of the sliding surface in order to estimate the stability conditions. In addition, since residual strength is a ductile property, progressive failure is not of special concern.

However, the real situation may be more complex. Two phenomena will be highlighted. The evolution in time of residual strength induced by chemical actions, including the effect of groundwater flow and the healing effects which transform the ductile response into a strain softening behaviour, bringing back the question of progressive failure.