Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering

doi:10.3233/978-1-61499-656-9-2433

Dry season problems created by volumetrically highly unstable marls and clays

Problèmes par temps sec relatifs aux argiles et marnes à grande instabilité de volume

A. Santos & V. Cuéllar
Laboratorio de Geotecnia, CEDEX (Spain)

ABSTRACT
Pathology induced in foundations by swelling soils and soft rocks has been widely recognized, and remedial measures have been put forward, with special emphasis placed upon determination of swelling pressures for restricted expansion and free expansion under saturation in oedometer. In arid areas, however, the dry season produces clay and marl shrinkage by loss of water content up to the shrinkage limit. During severe droughts, encompassing several successive years, ground shrinkage in marly and clayey terrains may extend to depths in excess of six meters, where loss of water content can be verified. When this occurs, sizeable settlements are unavoidable for any type of construction founded within the volumetrically unstable zone, and dry season pathologic trends are of large importance in materials broadly qualified as swelling or expansive. The shrinkage process introduces important cracking of the rigid ground, promoting new settlements and strength reductions of those soils and soft rocks at the beginning of a wet season. The paper considers this process, relating it to basic geotechnical parameters of the clayey and marly materials involved, and suggests remedial measures of such a varied nature that they may range from “in situ” ground improvement to vegetation control. Examples drawn from studies carried out in Spain by the Laboratorio de Geotecnia of CEDEX are shown, along with the main conclusions reached in those studies.

RÉSUMÉ
La pathologie liée aux sols et roches tendres qualifiés de gonflants est bien connue depuis longtemps et des mesures palliatives ont été mises au point, axées sur la mesure à l´oedomètre des pressions limites pour gonflement nul et du gonflement libre sur des échantillons saturés. Dans les pays à climat aride, cependant, les saisons sèches donnent lieu au retrait des argiles et des marnes par réduction de la teneur en eau jusqu´à la limite de retrait. Le phénomène peut atteindre des profondeurs qui dépassent les six mètres quand la sécheresse est grave et se prolonge à plusieurs années. Ceci donne lieu à des dégâts d´assises différentielles pour n´importe quelle construction établie à l´intervalle de sol instable volumétriquement, spécialement marqués dans le cas de sols qualifiés de gonflants. Le craquement du sol par perte de teneur en eau conduit, an début de la saison humide, à de nouvelles assises produites cette fois par l´infiltration de l´eau à travers les fissures qui conduit an ramollissement du sol. Cette étude décrit le phénomène et le rapporte aux paramètres géotechniques de base des sols instables tout en proposant des mesures de contrôle variées qui peuvent s´étendre de l´amélioration ou la substitution des sols sur site au contrôle de la végétation. Des exemples ont été tirés d´études, en Espagne, du Laboratorio de Geotecnia du CEDEX, et les conclusions principales de ces études sont montrées.

1 INTRODUCTION

The term swelling materials, when applied to marls and clays of medium to high plasticity may be misleading as it stresses basically the capacity of those materials for increasing their volume by incorporating water to their structure, developing medium to high pressures if the volume increase is completely restricted.

As a matter of fact in arid climates, many foundation problems may develop during dry cycles extending over several years, when substantial water losses occur in the subsoil at depths as high as 5 m below grade. To take account of those situations the term “volumetrically unstable materials” may be more appropriate to qualify the subsoil prone to shrink and to originate detrimental settlements in all kinds of constructions, with complete independence of their contact pressures on the ground.

In the early seventies, severe pathologies originate in suburbian areas of Southern Madrid (Spain), where architects, trying to protect their constructions from swelling episodes in the ground, introduced air ventilations of the space left below the structurally sustained lower floor of their buildings, with foundations established at 3,5 m below grade. Constructions that have been operating properly for years, soon after introducing the ventilation below the lower floor, started showing detrimental settlements by the end of the summer time. Those settlements showed specially at the Southern façades of the buildings, where the longer exposition to the sun had produced a more acute subsoil desiccation and shrinkage.

This study shows a number of characteristics of those materials that may explain their behaviour in drought, along with remedial measures that have been adopted to minimise the problems.

2 IDENTIFICATION PARAMETERS OF VOLUMETRICALLY UNSTABLE MATERIALS

Table 1 shows typical identification parameters for volumetrically unstable clayey soils studied by the Laboratorio de Geotecnia of CEDEX (2003; 2004) at the locations of Utrillas (Teruel) and Fuenteovejuna (Córdoba) in Spain.

A common feature to those clayey soils is a shrinkage limit generally quite smaller (5,9 to 11,9 difference) than the plastic limit, although locally the difference may be much less (1.1 to 2.4).

Table 1

Identification parameters of volumetrically unstable clayey soils					
Location	Depth interval (m)	% passing sieve #200 ASTM	Liquid limit W_L	Plastic limit W_P	Shrinkage limit W_S
Utrillas	0-1	92	52,5	27,3	19,8
Utrillas	1-2	95	57,1	25,6	19,1
Utrillas	2-3	89	31,8	16,5	15,4
Utrillas	3-4	96	37,0	17,8	16,0
Utrillas	4-5	96,2	49,0	25,3	17,6
Utrillas	5-6	99,9	55,7	23,4	14,1
Fuenteovejuna	0-1	66	36,1	17,8	15,4
Fuenteovejuna	1-2	83	52,7	26,2	14,3
Fuenteovejuna	2-3	71	45,5	23,2	17,1
Fuenteovejuna	3-4	62	63,3	28,5	21
Fuenteovejuna	4-5	93	44,5	22,5	16,6
Fuenteovejuna	5-6	99	46	27	18,8

3 WATER CONTENT VARIATIONS IN THE SUBSOIL AND CONSEQUENCES

The water content at 6 m depth is basically coincident or slightly above the plastic limit.

At shallower depths, the water content may change during the cycles of drought or regular precipitations (which occur usually in Autumn or end of Spring time). The “active” layer, where water content changes are predominant, ranges usually from 1.5 to 2.5 m thickness from the surface (although it may reach, in some localities, 6 m depth for lasting droughts).

There, in any case the water content during the year may vary from values intermediate to plastic and liquid limits (at the end of a humid period) to values close to and above the shrinkage limit (at the end of the dry summer period).

At the end of the summer, for a finishing dry cycle (elapsing some five to six years) values of water content below the shrinkage limit may be measured at depths close to 5 m, especially in the presence of trees at the vicinity of the houses (some 8 to 10 m from the façade). This feature is important to consider, because the sunny days call for having some spots of shade.

Figure 1 shows a typical swelling curve measured, at the Utrillas site, on a sample obtained, at the end of a dry cycle, at depths of 4,25 to 4,85 m. For this sample water content ranged from 14,6 at the top to 13% at the bottom. At the top of the sample the identification parameters were:

% passing sieve 200 ASTM = 99,8%
W_L = 47,5
W_P = 21,1
W_S = 15,5

At the bottom of the sample the following parameters were obtained:

% passing sieve 200 ASTM = 98,2%
W_L = 44,4
W_P = 21,4
W_S = 18

Some conclusions may be drawn from this information.

According to the yearly and cyclic variations of water content, detrimental settlements due to soil shrinkage, may be expected during dry periods. This affects not only foundations located within the depth of water content variations, but also buried pipes, unless they have special flexibility.

When shrinkage occurs, as water content falls below the plastic limit, the rigidity of the clay material promotes cracking that might be severe for the widest intervals between plastic and shrinkage limits.

At the end of an important dry cycle, the first infiltrations of water at the beginning of the humid period percolate through cracks, causing an important ground softening and subsequent settlements and even slope instabilities.

As it could be suspected on the basis of the typical swelling curve in fig. 1, the pathologies caused by swelling are of much less importance than those promoted by subsoil shrinkage. Usually only the lightest constructions, such as grade floors and pavements, or buried pipes, bearing directly on the ground without any previous precautions such as soil substitution and interception both of infiltrations and of capillary groundwater rise, are affected.

4 REMEDIAL MEASURES

As it has been already pointed out, the best approaches to the solution of problems involving volumetrically unstable formations, are either descending foundation levels to depths unaffected by cyclic water content variations (more than 6 m in our experience in Spain) or evitating, at shallower depths, those variations in water content. The latter condition may be satisfied by a combination of soil substitution and protection of both infiltrations and groundwater losses through capillary rise.

Fig. 2 shows a layout for protecting the foundations of a familiar one or two story house from infiltrations and desiccation in the vicinity of existing trees.

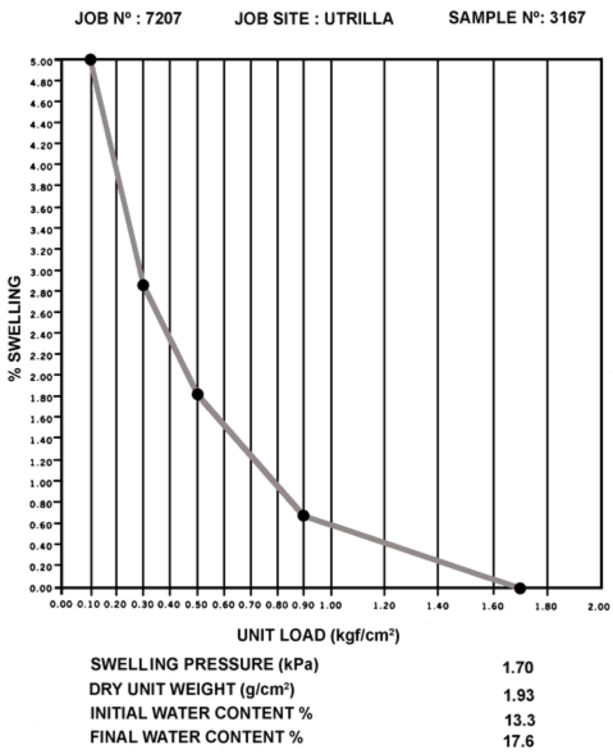

Figure 1. Typical swelling curve of Utrillas clay

5 CONCLUSIONS

The paper has described the mechanisms affecting foundation pathologies in volumetrically unstable soils (soil swelling is only one of the features of instability, not always detrimental if some soil heave may occur) during dry seasons.

In arid countries, soil shrinkage during cycles of drought may cause severe cracking in clayey soils showing sizeable

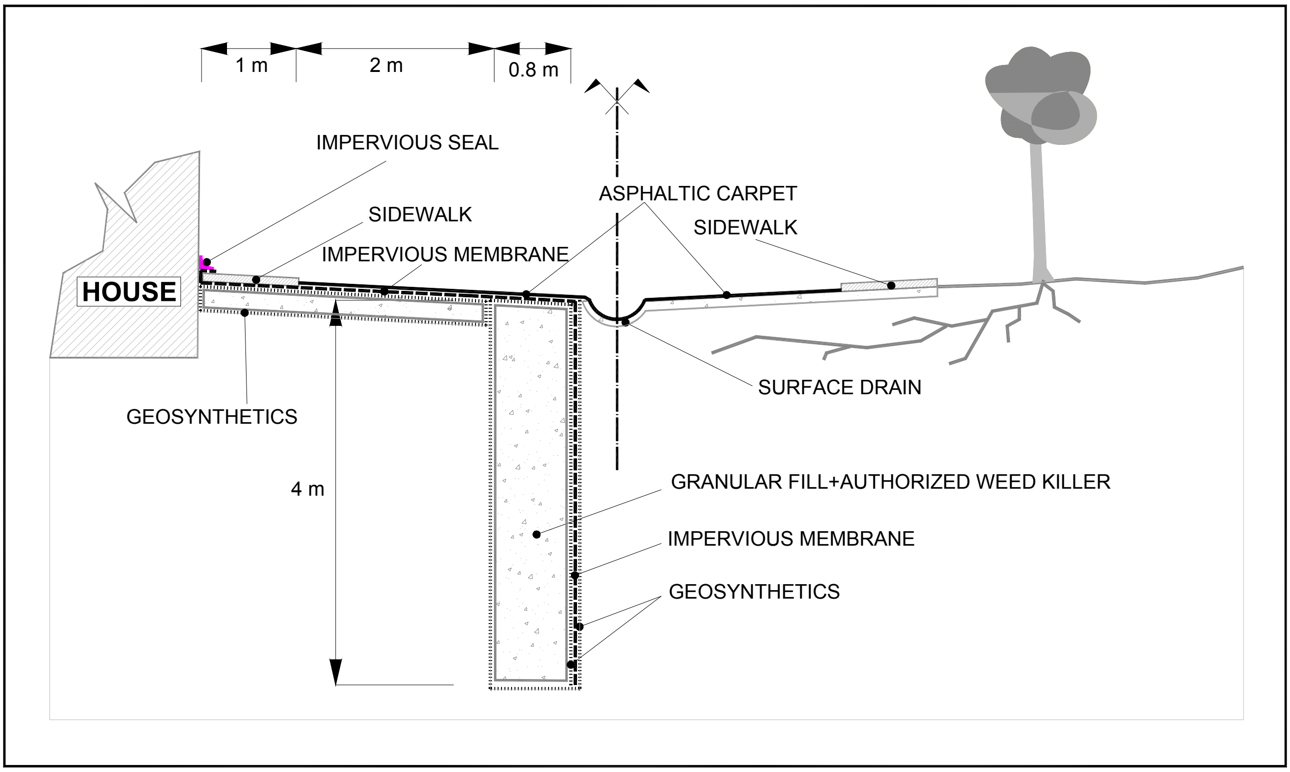

Figure 2. Schematic solution of foundation protection from changes in water content

differences between plastic and shrinkage limits. Soil integrity and strength is therefore affected, and the initial infiltrations at the beginning of the humid cycle may soften considerably the subsoil promoting foundation settlements and even slope instabilities.

The remedial measures point at evitating changes in water content of the foundation subsoil, either by adequate foundation depths or by proper soil substitution, and protection of infiltration and water losses.

REFERENCES

Laboratorio de Geotecnia of CEDEX (2003) “Technical Report nº 82-599-1-001”.

Laboratorio de Geotecnia of CEDEX (2004) “Technical Report nº 81-403-7-009”.