Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol II, 2013
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, ISSN-L 2285-6064

INFLUENCE OF CLIMATE AND VEGETATION ON STRUCTURES FOUNDED ON EXPANSIVE CLAYS

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Abstract

Shrinking and swelling behaviour of expansive clays in response to water content change is a worldwide problem. It is one of the most usually geotechnical behaviour that causes a lot of damages to buildings. Expansive soils have the property to modify their volume when moisture changes in relation with temperature, precipitation and vegetation. The paper aimed to determine the shrink-swell behaviour of three different types of expansive clays from Australia, UK and Romania related to the vertical ground movement.

***Keywords**: climatic conditions, expansive clay, ground movement, vegetation.*

INTRODUCTION

Expansive soils causes serious problem on civil engineering structures due to its tendency of swelling when it is in contact with water and shrinks when they dry out. In rainy seasons this soils imbibe water and swell, and in droughty seasons on evaporation of water, they shrink. This alternate swelling and shrinkage causes distress in many civil engineering structures like buildings, farms, deposits, etc.
Expansive soils contain the clay mineral montmorillonite with claystones, shales, sedimentary and residual soils. The expansive nature of the clay is less near the ground surface where the profile is subjected to seasonal and environment changes (Agrawal&Gupta, 2011).
An aspect in studying expansive and shrinkable clays is the establishing of certain criteria for the recognition of the soils capable of producing the degradation from this point of view. It was found that besides the specific nature of the soils, there must be fulfilled several conditions related to the existence and action of certain external factors as: vegetation and climatic conditions (Antonescu, 1959).
Semi-arid climates promote desiccation, while humid climates promote wet soil properties. A semi-arid climate can be described as a climate that has periods of rainfall followed by periods of no rainfall.
Vegetation depletes moisture from soil through transpiration and cause accumulation of moisture areas denuded of vegetation.

MATERIALS AND METHODS

In order to analyze the influence of climate and vegetation on structures founded on expansive clays, we used a number of experimental studies from the professional literature. These studies were analyzed according to Romanian standard in force NP 126/2012.
The analyzed studies track the variation of vertical ground movement for three expansive soils from Australia, UK and Romania.
The study achieved in Newcastle (Australia) by Fityus, Smith and Allman, indicates the vertical ground movement in relation with climatic prescriptions based on minimum and maximum daily temperature and total monthly rainfall over a period of 7 years (from Winter of 1993 to Summer of 2000).
Driscoll, Crilly and Chown studied the vertical ground movement for a plot in Chattenden (UK), in relation with existing vegetation and after the trees felling over a period of 12 years (from 1988 to 2000).
In Romania, the ground movement was studied by Antonescu, for a plot in Baleni, in relation

with prescriptions of rainfall over a period of 9 months (from January to September of 1952).

In this study cases were located landmarks on the ground surface and at several depths from the ground surface: 0.5 m, 1.0 m, 1.5 m, 2.0 m, 2.5 m, 3.0 m and 4.0 m.

RESULTS AND DISCUSSIONS

The characteristics and specific properties of the soils represent essential factors in establishing the possibilities of soils to produce degradations. Soils with important swelling and shrinkage behaviour are formed of montmorillonite clays with a rich content of fine particles, under 2µm (more than 50%).

Antonescu (1959) studied the characteristics of the vegetal soil layer at the surface of the ground. This study showed that the dangerous zone for foundations is limited to horizons A and B of the soil, rich both in organic material (hummus) and in very fine particles (especially horizon B).

In expansive soil areas, the soils are generally stiff, and the change of lightly loaded structures cracking due to settlement is more common. However, there are many cases where heavy cracks have appeared in the basement walls that were not caused by foundation heaving but by earth pressure exerted on the wall, generally compounded by seepage pressure. Diagonal cracks that develop below windows and above doors are a strong indication of swelling movement (Chen, 1975).

The most obvious identifications of damage to buildings are doors and windows that get jammed, uneven floors, cracked foundations, floors, masonry walls and ceilings. Moreover, different crack patterns mean different causes for different foundation materials. Oftentimes, cracks due to shrinkage and expansive clay usually run from corner towards adjacent opening and are uniform in width or v-shaped, wider at the top than the foundation wall (Lucian, 2008).

The weight of the structure has a significant impact in suppressing or levelling out the differential ground profile which result from the moisture changes in the soil alone. Swelling movements are often largely suppressed because the wet swelling soil has a relatively low stiffness. Cases of damage due to cyclic movements appear to be less common than those due to either swelling or shrinkage although there are some reports of extensive damage, such as roadway and ground movement due to seasonal climate changes, and severe cracks because of swelling during rainy periods and shrinkage during dry periods. Climatic conditions, wet seasons followed by warm and dry seasons are most favourable to cyclic movements. Foundation movements for different structures founded on expansive soils are reflected as cracks (Mansour, 2011).

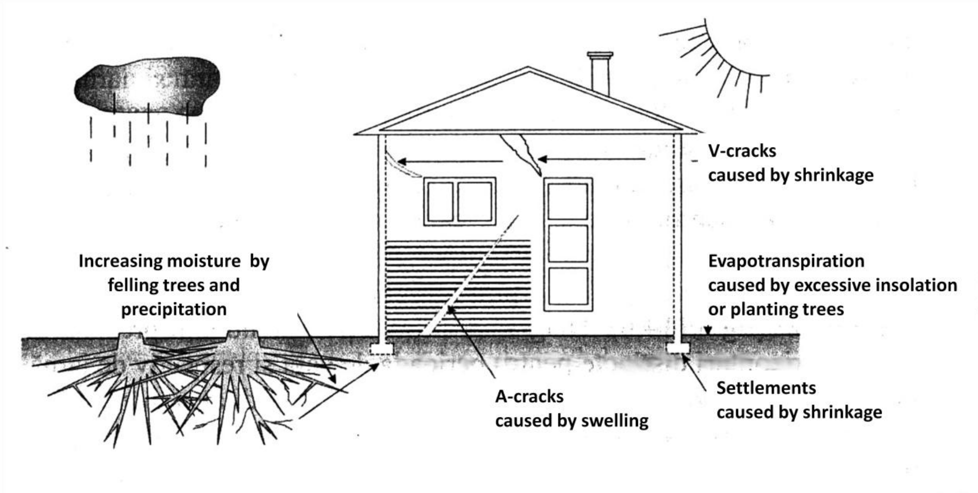

Figure 1. Effects of vegetation and insolation on buildings (NP 126 quoted by Ivasuc, 2012)

Andrei (1967) showed that the climate conditions from our country produce swelling and shrinkage to depths of 2 – 2.5 m. Because of this, are affected rural buildings; these buildings are founded at small depths of 1 -1.5 m and they transmit low pressures to foundation soil.

DAMAGE CAUSED BY VEGETATION

A common feature shared by homeowners in general is to plant trees and shrubs close to the foundation. Due to the highly expansive nature of the soil, the trees and shrubs have significantly affected the soil conditions around and under some houses resulting into differential swell of foundation and structural distress in a form of wall cracking, windows/door sticking and slab cracking (Lucian, 2008).
The vegetation existent in the zones with damaged constructions constitutes an important factor contributed to the releasing the damages; the most perceptible influence is that of evergreen shrubs which by abundant transpiration dries the soil and produces cracks. Around the trees which are planted close to the buildings water is absorbed; in general poplars, elms and oaks absorb the greatest quantities of water.
Damage to foundation in expansive soils commonly results from tree growth. This occurs in two principal ways – physical disturbance of the ground and shrinkage of the ground by removal of water. Physical disturbance of the ground caused by root growth is often seen as damage to pavements and broken walls. Vegetation induced changes to water profiles can also have a significant impact on other underground feature, including utilities – pipes (Jones&Jefferson, 2011).
Expansive soils problems typically occur due to water content changes in the upper few metres (2 – 5 m; the depth of the active zone could have important variation in correlation with climate conditions), with deep seated heave being rare. The water content in these upper layers is significantly influenced by climatic and environmental factors and is generally termed the zone of seasonal fluctuations or active zone as shown in Figure 2 (Nelson&Miller, 1992).

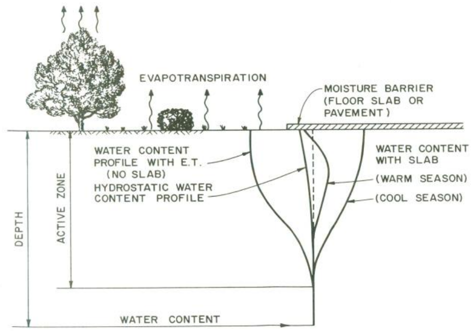

Figure 2. Water content profiles in the active zone (Nelson&Miller, 1992)

Tree roots will grow in the direction of least resistance and where they have the best access to water, air and nutrients. Trees will tend to maintain a compact root system. Paving of previously open areas of land, such as building of patios and driveways, can cause major disruption to the soil water system. If the paving cuts off infiltration, many trees will send their roots deeper into the ground or further from the trunk in order to source water. The movement of these tree roots will cause disturbance of the ground and will lead to the removal of water from a larger area around the tree. Problems occur when houses are situated within the zone of influence of a tree such in Figure 3 (Jones&Jefferson, 2011).

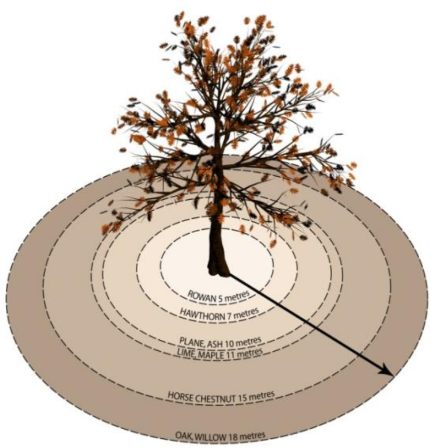

Figure 3. The zone of influence of some common UK trees (Jones&Jefferson, 2011)

Crilly and Driscoll (2000) and Driscoll and Chown (2001), based on an experimental study in Chattenden - UK, showed that ground movements are produced due seasonal fluctuation and vegetation (Figure 4).

If vegetation is involved, it produces a characteristic seasonal pattern of foundation movement: subsidence in the summer reaching a maximum usually in September, followed by upward recovery in the winter.

If it is occurring, there is no need to try to demonstrate shrinkable clay or desiccation as no other case produces a similar pattern – soil drying by vegetation must be involved (unless the foundations are less than 300 mm).

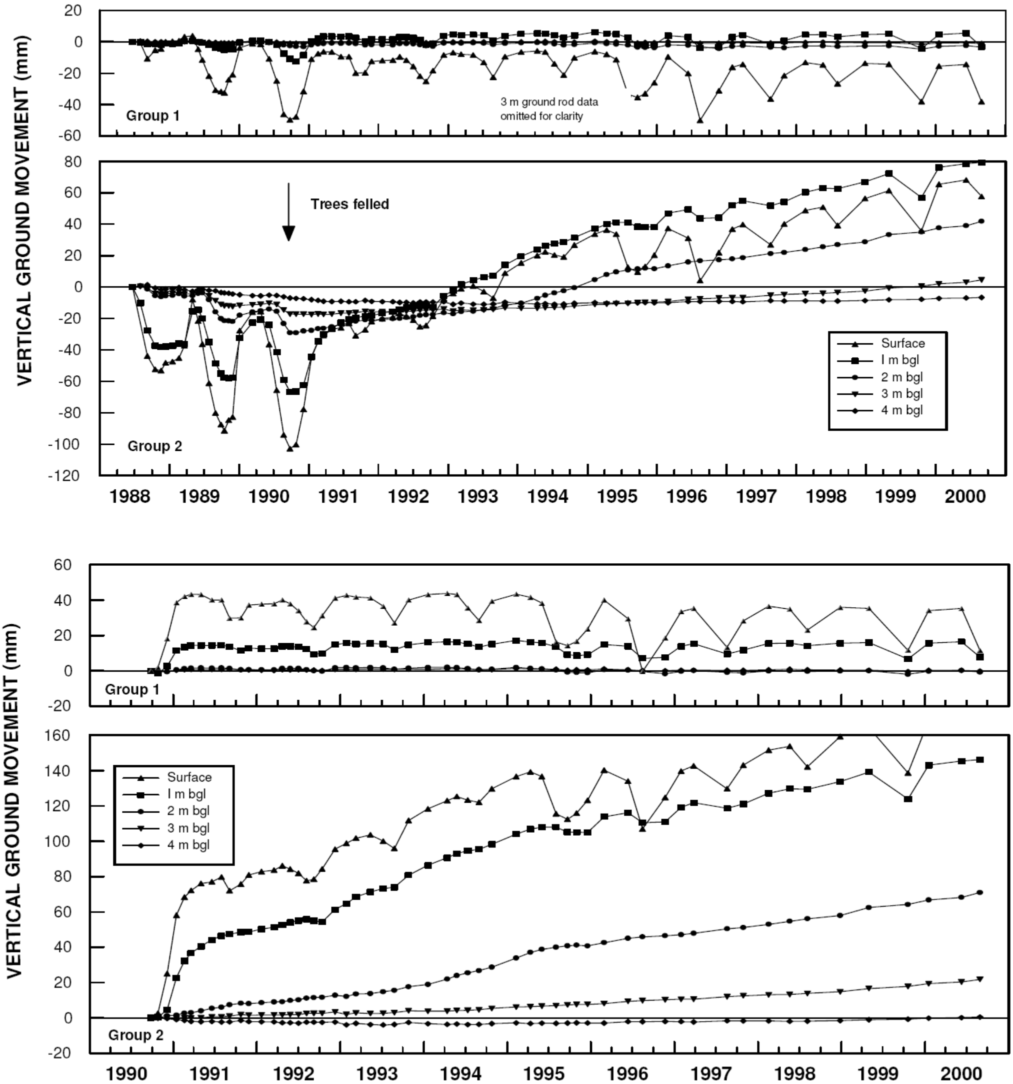

Figure 4. Examples of ground movements due seasonal fluctuation, Chattenden – UK. The upper plot shows results obtained since the first movements in June 1988. The lower plot shows an enlarged scale with results obtained since the trees were felled. Group 1 is remote from tree and group 2 near the trees (Crilly&Driscoll, 2000; Driscoll&Chown, 2001)

Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, ISSN-L 2285-6064

DAMAGE CAUSED BY CLIMATIC CONDITIONS

Important swellings and shrinkages are produced when the soil is submitted to an important moisture variation all over the year. The seasonal moisture variation decreases with the depth.

Antonescu (1959) showed that the maximum moisture range is about 20% at 0.4 m, 10% at 1.2 m and decreases under 5% from 1.8 m below.

Changing water content may be due to seasonal variation (often related to rainfall and the evapo-transpiration of vegetation), or brought about by local site changes such as leakage from water supply pipes or drains, changes to surface drainage and landscaping or following the planting, removal or severe pruning of trees or hedges, as man is unable to supply water to desiccated soil as efficiently as a tree extracted it through its root system. During a long dry period or drought a persistent water deficit may develop, causing the soil to dry out to a greater depth than normal, leading to long-term subsidence. This is why expansive problems are often found in arid and semi-arid environments (Jones&Jefferson, 2011).

In Romania, the depth to which the contraction cracks are developed is 1.5 – 2.0 m; and the climate is rather dry with precipitations of 500 – 700 mm/year, with mild winters and hot summers. Damages are reduced during the years with rainy summers.

Fityus, Smith and Allman (2004), based on an experimental study in Newcastle (Australia), showed important aspects of expansive soils sites including the magnitude and variability of changes in water content (produced by temperature and rainfall) and ground movement, at various depths (Figure 5).

A full assessment of climatic effects including rainfall, drainage, temperature and evapo-transpiration is beyond the scope of the experimental study made in Newcastle.

In Romania, Antonescu (1959) studied the ground movement behaviour in relation with precipitation (Figure 6). In this study were located landmarks at 0.5 m, 1.0 m, 1.5 m, 2.0 m and 2.5 m from the ground surface. Study was carried out from January to September; were recorded variations of vertical displacement for each depth and for each landmark.

It was noticed that ground movements decreases with depth, below 2.5 m are no longer significant displacement registered.

The influence of vertical ground movements related to precipitation receives a personal interpretation based on studies performed by Antonescu (1959), and it was materialized on diagrams in figure 6.

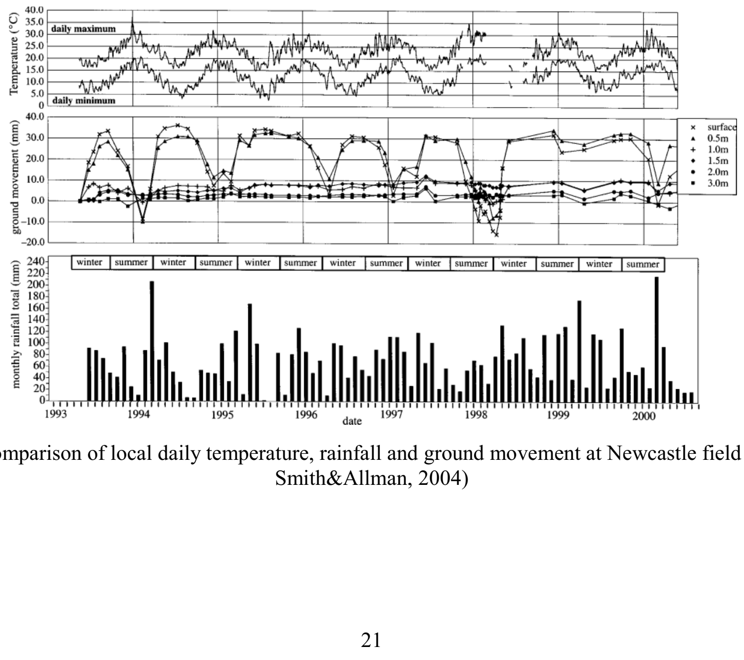

Figure 5. Comparison of local daily temperature, rainfall and ground movement at Newcastle field site (Fityus, Smith&Allman, 2004)

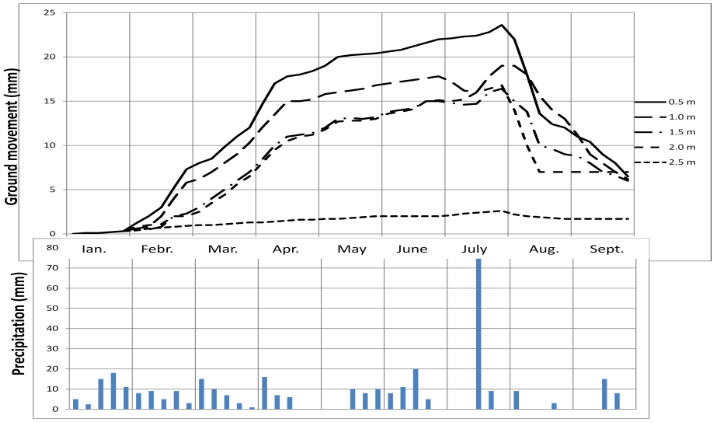

Figure 6. Ground movement in relation with precipitation at Baleni field site (personal interpretation after Antonescu, 1959)

CONCLUSIONS

Vertical soil movement is a function of soil depth, soil water content, rainfall, insolation and vegetation.

Rainfall appears to have an effect on short-term ground movement.

Many structural damages originate from insufficient foundation started by the swelling soils.

The slight, moderate and severe categories of damages are based on crack size and pattern.

Expansive soils are one of the most significant ground related hazards found globally.

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