Ground Movement – Heave and Subsidence

Prepared by:
Joseph McPherson
Geotechnical Engineer
Intrax Consulting Engineers

Introduction

Ground movement in the form of heave and subsidence is the major cause of distress to residential dwellings and light weight structures in the Melbourne area. Melbourne's geology is highly susceptible to ground movement given the highly reactive Basaltic clays to the West of Melbourne, which has been a major growth area for residential construction, over the last decade.

Ground movement which influences residential structures is predominately caused by the expansion and contraction of the soil mass due to changes in soil moisture content. A soil's propensity to change volume with changes in moisture content is referred to as its reactivity (or shrink/swell behaviour). AS2870-2011 Residential slabs and footings expresses the reactivity of a soil in the site classification (A, S, M, H1, H2, and E).

Soil Particle Interaction

To understand the cause of ground movement we will look at a small sample of soil and examine its structure, refer figure 1. The traditional model separates soil into three components; solids, water and air. The percentage of each component in the sample mass defines many of the soils properties. The water and air combined is referred to as the void space, which can be filled entirely with air, water or any combination of both. The solids within the soil are assumed to be of constant volume, while the void space can vary depending on the moisture content of the soil.

The moisture content at which the entire void is filled with water is known as the shrinkage limit. As the moisture content increases beyond the shrinkage limit the individual soil particles are separated by water molecules causing the entire sample volume to increase. This occurs because water is an incompressible fluid. The phenomenon of increasing a soil volume by increasing the moisture content is referred to as swelling and effects only fined grained soil.

Soil swelling occurs only in fined grained soil, such as clay, because the small particle size and correlating high specific surface area of the particles result in a net negative surface charge and creates a high suction potential. Fine grained particles with a diameter less than 0.002mm are referred to as clay particles, given their small size, they are packed closely together with very small gaps between each particle. The small gaps create a capillary suction or negative pressure within the clay that draws water into the voids. The negative surface charge of a clay particle attracts dipolar water molecules to the surface of each particle. The attraction between the clay particles and water molecules combined with capillary effect of the tiny void spaces draws moisture around and between the individual clay particles. As the moisture content increases the clay particles are forced apart by the water molecules, thus increasing the total volume of the soil mass.

Coarse soil particles can create suction through a capillary action however they do not exhibit a negative surface charge, and therefore water molecules do not form a tight bond around

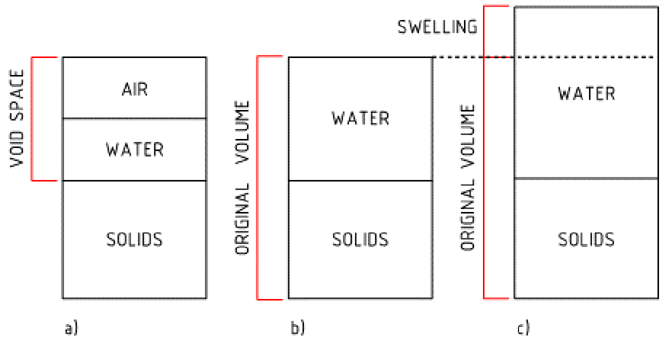

Figure 1: ***a)*** *Idealised soil structure* ***b)*** *Shrinkage limit: water fills the void space, total volume unchanged* ***c)*** *Swelling: water molecules bonded around soil particles separate the particles, increasing total volume*

each particle. As such water flows more freely through the soil mass and will not cause the volume changes experienced by clay.

If the moisture content is further increased in a clay soil, the water molecules will cause significant separation between the clay particles such that the soil mass behaves like a liquid, the moisture content at this point is referred to as the liquid limit. It is rare for this to occur naturally, however when it does there can be severe consequences.

Conversely to swelling, as the moisture content is decreased clay soils will contract in volume, this is referred to as shrinkage. Shrinkage occurs in the reverse manner to swelling with soil reaching its minimum volume at the shrinkage limit.

Ground Movement

To this point the swelling and shrinkage of a small sample of clay has been discussed, however to understand the implications of this movement on residential structures we will now consider wide and deep layers of clay.

As the small samples of clay each shrink or swell they interact with surrounding samples. At a shallow depth as a fully swelled clay dries, cracks are observed in the surface, this occurs as certain bonds within the clay remain stronger than others causing the sections of the soil to separate. The depth to which a surface crack can extend is referred to in AS2870-2011 as the crack zone, in the cracked zone soil movement occurs both horizontally and vertically as long as the cracks exist within the soil. However, once swelling has filled the cracks, the soil can no longer expand laterally as the horizontal force of one section of soil is reacted in the opposite direction by another section of soil resulting in a net zero horizontal force. Given that expansion still occurs, and provided that a significant vertical surcharge load is not applied, the swelling will be directed vertically, resulting in the ground movement observed below residential structures. Below the cracked zone soil expansion will also be directed vertically upwards. The process of raising the ground level via increased soil moisture is known as heave, while the opposite movement is known as subsidence.

Tree Influence

One of the causes of subsidence effecting residential structures is the presence of trees near the footings. A tree requires moisture, drawn from the soil via its root system to grow and survive, and as such reduces the moisture content in soil around it. The volume of water a tree draws from the soil varies greatly depending on the species of tree, height, canopy width, leaf surface area, and many more factors. These factors are often simplified down to assess the influence of a tree upon a structure based on the tree height and proximity to the footing.

AS2870-2011 Appendix H provides one theory to engineers in order to design for the influence of trees, based upon the site classification, mature tree height, and number of trees present. This allows the engineer to estimate the influence this tree will have on the expected ground movement of the site, and the area which will be influenced.

It defines the influence zone of a single tree as one times the height of the tree or two times the height of the largest tree in a group of four or more trees. This means that for a group of four native gum trees, each capable of growing in excess of 20m in high, the influence could extend up to 40m away from the trees in any direction.

The influence of trees on soil moisture can cause both subsidence and heave, depending on if the tree is being removed or planted. A new tree will grow in height increasing its demand for water over time and therefore begin desiccating the soil further away from the trunk. This will ultimately result in the shrinkage of a clay soil, subsequently leading to subsidence of the surface level. However, removing an existing tree which has already created a dry desiccated soil mass around its roots, will leave the soil with a low moisture content and therefore a high potential to heave. Therefore removing an existing tree can often be as damaging as planting a new one, and as such AS2870 classifies any site with trees or recently removed trees as class P.

Distress Caused by Heave and Subsidence

Heave and subsidence both result in the vertical movement of soil often in excess of the engineered tolerance of the footing founded on top of it. This ground movement can directly morph the shape of a flexible footing, which therefore propagates this movement into the frame of the structure. A brick veneer dwelling has rigid walls, even when properly articulated, which will crack under excessive ground movements. The most extreme distress will occur in buildings which are effected by localised areas of both heave and subsidence, as the maximum deflection point between downward and upward slab flex can greatly exceed the allowable deflection of the footing slab and walls.

Combating Heave and Subsidence

Subsidence caused by the growth a tree in close proximity to a

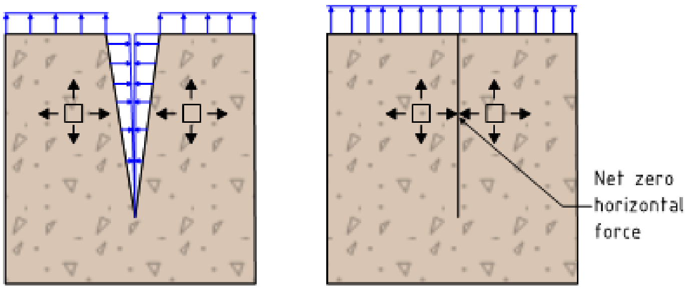

Figure 2:* *a) *Soil swelling within the cracked zone, fills the cracks horizontally and causes vertical ground movement* ***b)*** *Cracked is closed (or below cracked zone) ground movement is only in the vertical direction.*

tree will result in lower floor levels in the dwelling. As such it is important to design for anticipated levels of ground movement in both directions prior to construction. If this can be achieved through comprehensive information collection on soil conditions, tree locations, tree identification and structural requirements; a residential footing can be designed in a cost effective manner. Unfortunately knowledge of past, future or present trees and their influences is difficult to identify which ultimately means that many footing designs will be effected by heave and subsidence issues.

Engineers have been developing solutions to protect residential dwellings from ground movement for decades, nevertheless it is still a difficult task to complete in a cost effective manner.

Stiffened slabs and slabs suspended on piers are widely accepted methods to combat the abnormal moisture conditions, however abnormal moisture conditions are difficult to predict as they will often occur from sources outside the property boundary or may not be present at the time of design, therefore they are often not accounted for in the foundation design.

Therefore, dwellings across Melbourne, particularly through the residential growth corridor in the West are suffering from issues relating to heave or subsidence.

The Geotechnical team at Intrax encounter the challenges presented by ground movement on a regular basis. As such, our team has the technical knowledge and breadth of experience to find the best possible solution. The collaborative element of our Engineering departments mean that we find solutions that mitigate risk and achieve project objectives. Intrax continues to develop engineering solutions that protect against ground movement.

Joseph McPherson
Geotechnical Engineer

Head Office – 35 Bank Street, South Melbourne, VIC 3205
P: 03 8371 0100 , F: 03 8371 0199
info@intrax.com.au www.intrax.com.au

Date of Publish: 29 June 2016
Revision 3.0

Intrax
Engineering Confidence