PROBLEMS DUE TO EXPANSIVE SOILS AND THEIR REMEDIES

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ABSTRACT

Expansive soil, also called shrink-swell soil, is a very common cause of foundation problems. Depending upon the supply of moisture in the ground, shrink-swell soils will experiences changes in volume of up to thirty percent or more. Foundation soils which are expansive will "heave" and can cause lifting of a building or other structure during periods of high moisture. Conversely during periods of falling soil moisture, expansive soil will "collapse" and can result in building settlement. Either way, damage can be extensive. Expansive soil will also exert pressure on the vertical face of a foundation, basement or retaining wall resulting in lateral movement. Shrink-swell soils which have expanded due to high ground moisture experience a loss of soil strength or "capacity" and the resulting instability can result in various forms of foundation problems and slope failure. Expansive soil should always be a suspect when there is evidence of active foundation movement. In order for expansive soil to cause foundation problems, there must be fluctuations in the amount of moisture contained in the foundation soils. If the moisture content of the foundation soils can be stabilized, foundation problems can often be avoided. This paper discusses different types of expansive soils and problems associated with them and remedies during and after construction.

DOI Number: 10.14704/NQ.2022.20.12.NQ77264 **NeuroQuantology2022;20(12): 2707-2712**

1.0 INTRODUCTION

Foundation materials that exhibit volume change from change in soil moisture are referred to as expansive or swelling clay soils. Characteristic expansive or swelling materials are highly plastic clays and clay shales that often contain colloidal clay minerals such as the montmorillonite. Soils that exhibit greatest volume changes from dry to wet state usually possess a considerable percentage of montmorillonite. Since expansive soils have a tendency to change their volume to a large extent, they cause heavy distress to engineering constructions. The lightweight structures are severely affected due to high swelling pressure exerted by these soils. Such type of large scale distress, due to expansive shrinking nature of expansive soil, can be prevented by either obstructing the soil movement and reducing the swelling pressure of soil or making the structure sufficiently resistant to damage from soil movement. The main objective of this study is to focus on the characteristics and the behaviour of swelling-shrinkage properties of expansive soils on foundation. The engineering properties, problems and solution need to be considered when constructing a foundation on expansive soils. The foundation types to be applied on expansive soils will also be elaborated.

1.1 Expansive Soils

The swelling and shrinkage of soil depending on the amount of water present. In other words, expansive soils are soils that expand when water is added, and shrink when they dry out. Expansive soil expands due to the clay content.

Soil with little clay content will expand only a little bit, while soil with a greater amount of clay content will expand more. Most soil expansion is triggered by water, but some expansion can be triggered by changes in temperature. These soils often expand by 10 percent or more during a rainfall. When the soils dry out, they shrink back to the original size. This continuous change in soil volume may cause homes built on this soil to move unevenly and crack. The formation of expansive soils is shown to occur, in general, under similar geological, geomorphological and climatic conditions. This is problematic at building basements and foundations, as high levels of expansive soils can require costly designs and repairs.

1.2 Identifying Expansive Soils

Soils containing expansive clays become very sticky when wet and usually are characterized by surface cracks or a "popcorn" texture when dry. Therefore, the presence of surface cracks is usually an indication of an expansive soil. The swelling behavior of a soil would also depend largely on the type of clay minerals that are present in these soils and the proportion in which they are present. The commonly used methods are the differential thermal analysis (DTA), X-ray diffraction method and electron microscopy.

1.3 Characteristics of expansive soils

The expansion potential of expansive soil on a foundation is determined by the amount of clay and type of particular clay in the soil. Expansive soils form mainly by the alteration of other minerals through the action of chemical weathering (Mclean and Gribble 2005). The type of soil formed depends on the composition of the parent material that has undergone weathering and the climatic conditions where weathering took place (Mclean and Gribble 2005). The engineering properties of expansive soils depend on the grain size, mineralogy and water content, all of which are inter-related (Waltham 2002).

Chemical weathering of parent rock in high rainfall climatic conditions mainly form primary minerals. The primary minerals altered through chemical weathering processes into secondary minerals. For example, the hydrothermal alteration of primary ferromagnesian minerals can result in secondary chlorite (Mclean and Gribble 2005). Chemical decomposition of primary minerals of the rock are altered to secondary minerals such as the smectite group, mainly montmorillonite which is a 1:2 clay type mineral which further weathers to kaolinite, which is a 1:1 clay mineral as moisture content of the soil increase (Brink 1983).

Expansive soils have swelling tendencies which are quantified by the swell potential and swelling pressure parameters (Al-Rawas and Goosen 2006). Al-Rawas and Goosen (2006) defined swelling pressure and swell potential “The swell pressure of a soil is the external pressure that needs to be placed over a swelling soil to prevent volume increase, while the swell potential of an expansive soil is the magnitude of heave of a soil for a given final moisture content and loading condition. There are different ways to recognise expansive soils in the field before constructing a foundation. Field recognition of expansive soils (Waltham 2002): Stick when wet, polished glaze on cut dry surfaces, Dry lump dropped in water expands so fast that it breaks up explosively.

2.0 Foundation Problems Due to Expansive Soils

Expansive soil shrinks and cracks when it dries out. When it rains, soils with high clay and silt content don’t allow water to pass through the soil. Instead, water is absorbed and held in the soil, significantly increasing its volume. Some of the foundation problems due to expansive soils are swelling of soil, cracking and buckling of walls, Foundation Movement, Failure under External, Loads and Support Structure Deflection.

2.1 Swelling of soil

- The most obvious way in which expansive soils can damage foundations is by uplift as they swell with moisture increases. Swelling soils lift up and crack lightly-loaded, continuous strip footings, and frequently cause distress in floor slabs.
- Because of the different building loads on different portions of a structure's foundation, the resultant uplift will vary in different areas.
- The exterior corners of a uniformly-loaded rectangular slab foundation will only exert about one-fourth of the normal pressure on a swelling soil of that exerted at the central portion of the slab.
- As a result, the corners tend to be lifted up relative to the central portion. This phenomenon can be exacerbated by moisture differentials within soils at the edge of the slab. Such differential movement of the foundation can also cause distress to the framing of a structure.

2.2 Foundation Movement

Foundation Movement normally results in stepped cracking often emanating from the corners of windows and doors. Such cracks are normally widest at the top. In a building constructed on a flat block, founded on uniform soil and with no gardens close by, this swelling would lift the outside foundations uniformly and only have a tendency to crack inner walls. This is because the moisture regime under the house would tend to stay the same while the perimeter would be affected by the usual seasonal variations. In normal circumstances however the ground moisture and soil parameters vary around the house and cracking can occur in any number of locations.

2.3 Cracking and Buckling of walls

- Cracked and buckled walls probably occur more frequently due to expansive soils than other foundation problems.
- During a dry spell, clay-rich soil is likely to pull away from a foundation wall, creating a gap that can fill with stone, gravel, loose soil and other debris. Some homeowners even deliberately fill in this shrinkage gap.
- Nothing bad happens until there’s a long, soaking rain. Then the extra material in the crack increases pressure on the foundation wall as the soil expands.
- Since there’s not a balancing volume of expansive soil against the inside of the wall, this one-sided pressure can push the wall inward, causing it to crack and bow in sections.
- Occasionally the foundation wall will resist cracking or bowing, but the damage will take the form of tilting. The top of the wall will be pushed in by the expansive soil, creating a foundation that tilts inward.

2.4 Damage to home supported on shallow piers

- At the beginning of the rainy season, the piers are still supported by friction with the soil. When it begins to rain, water enters deep into the soil through the cracks.
- After 5 to 10 large storms, the soil swells, lifting the house and piers. In the dry season, the groundwater table falls and the soil dries and contracts.
- Tension cracks grow around the pier, the skin friction is reduced and the effective stress of the soil increases (due to drying). When the building load exceeds the remaining skin friction, or the effective stress of the soil increases to an all-time

high, adhesion is broken by this straining, and the pier sinks.

- The soil below will exert swelling pressure both upwards and laterally. As a result, the floor slab is lifted up, typically in an irregular dome shaped or corners-down pattern, leading to the cracking of floor.
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- The footing walls are pushed outward, leading to cracking of the end walls of the structure. Since there is restriction of movement at the junctions between the walls and the floor as well as between the walls and the roof slab, structural distress is apparent at these locations.
- Cracking is also normally evident at the corners of window and door openings. These usually assume the form of diagonal cracks - a consequence of differential settlement in the wall.
- Often, utilities buried in the soil such as the water pipes and sewage lines get damaged due to displacement in the soil in which they are buried. The ensuring leakage of their contents would result in a further wetting of the soil and enhances the swelling.

3.0 SOLUTIONS

3.1 Reduction of soil compaction and compacting wet of OMC (Pre-wetting)

One technique for stabilization of expansive soils that can be effective under light structures such as residential houses is to flood the area prior to construction. As in natural expansive soils extensive network of fissures and cracks present initially, ponding process is easily facilitated, Because of pre-wetting the water content will be closer to be attained after construction, hence volume changes will be small subsequently. Reduction of compaction density could reduce the total swell magnitude. This is done by compacting the soil wet of optimum and by pre-wetting. The resulting lowered soil density will reduce the rebound swell magnitude in such the same way that a coiled spring will rebound less if the pre-compression is reduced.

3.2 Chemical treatment (quicklime, Portland cement or other stabilizing agents)

The liquid Limit and the Plasticity Index of expansive soils stabilized with quicklime abruptly decreases which also indicates that the swell potential is significantly reduced. The quicklime chemically reacts with the soils and reduces the activity of the soil as well as providing bonding of the soil particles as to reduce the swell potential. Stabilization by quicklime also increased the overall strength of the stabilized soil. Other chemical stabilizing agents are also available that could act on the expansive soils but these should be tested in the laboratory before being used in the problem.

3.3 Footings with special cushions

In this method the excavation is carried out up to a depth of greater than depth of foundation and freely draining soil such as a mixture of sand and gravel, is filled up and compacted up to base level of the foundation. Reinforced concrete footing is constructed at this level and over this brick wall may be constructed. Mixture of sand and gravel is filled up loosely over the footing. A cushion of granular soil below the foundation absorbs the effect of swelling and so its effect on foundation will considerably reduce.

3.4 CNS – MSM Technologies

CNS Technology

In this technology we intercept Cohesive Non-Swelling soil layer below the shallow foundations on expansive soils. Thus CNS concept is based on self-equilibrating phenomenon with a difference that clay minerals present in CNS are non-expanding such as kaonite, chlorite etc., The thickness of CNS needed to prevent transmission of swelling pressure and heave to the foundation. Thickness depends upon swelling pressure, heave, index properties, density, and compression index of under laying expansive soil and also on the index properties, density, and compression index of CNS material. CNS can be obtained as a natural material or can be made produced by blending two or more materials.

MSM Technology

In this technology we intercept the layer of Mechanically Stabilized Mix over CNS intercepting layer, to improve the bearing capacity of the system. Normally MSM consists of graded aggregate, sand and fines with more plasticity, similar to that allowed in water bond macadam mix if possible better compaction may be adopted.

4.0 Suggested remedies for swelling soil

1. Provide CNS layer

Some percentage of clay, sand and the existing swelling soil may be used as CNS material. Katti (1978) has developed a technique where by removal of about 1.0m of expansive soil and replacement by cohesive non-swelling soils (CNS) layer beneath foundations has yielded satisfactory results. Katti has successfully adopted it for prevention of heave and resultant cracking of canal beds and linings and recommends it for use in foundations of residential buildings also. Cohesive forces of significant magnitude are developed with depth in an expansive soil system during saturation which is responsible for reducing heave and counteracting swelling pressure. Moorum is a typical example of CNS material. The cohesive bonds develop around the particles at a faster rate than the ingress of water molecules into the interlayer of the expanding lattices of montmorillinite, thereby reducing heave. The heave of expansive soil underlying a CNS layer reduces exponentially with increase in thickness of the CNS layer and attains a value of no heave around a depth of 1.0m.The shear strength of the underlying expansive soil at the interface and below increases with the thickness of CNS layer.

2. Provide under-reamed pile foundation. Provide slotted footing so that this may reduce the swelling pressure.
3. Addition of gypsum will reduce the swelling pressure.
4. Limit the foundation depth if swelling soil is at some depth so that distance between foundation and swelling soil will be more and as the distance is more there are less chances of cracks in building. Take effective measures to maintain moisture equilibrium in foundation soil. Add dune sand in the existing swelling soil.

5.0 Conclusion

Expansive soils are very problematic during the construction of foundations. Foundation on expansive soils is affected by the behaviour of soil under different moisture content. The swelling tendency of expansive soils on foundation can be quantified by the swell potential and swelling pressure parameters. The major engineering problem of expansive soils on foundation is shrink-swelling characteristics of the soil. Engineering problems and solutions need to be defined to assess a type of foundation to be constructed. Foundation types that can be utilized on expansive soils are pile, raft, shallow and caissons foundation.

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