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Expansive Soils

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Definition

Expansive Soils are soils that have the ability to shrink and/or swell, and thus change in volume, in relation to changes in their moisture content. They usually contain some form of expansive clay mineral, such as smectite or vermiculite, that are able to absorb water and swell, increasing in volume, when they get wet and shrink when they dry. The more water they absorb, the more their volume increases. For the most expansive soils volume changes of 10% are common (Chen 1988; Nelson and Miller 1992).

Introduction

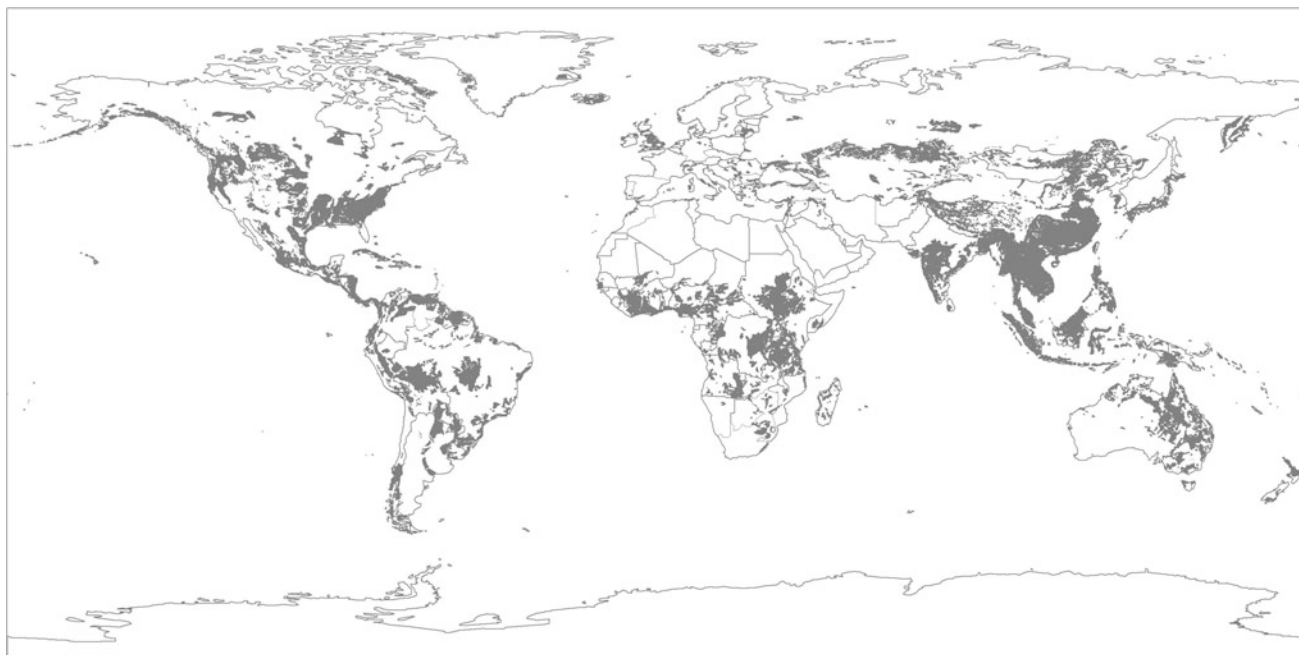
Many of the world's largest towns and cities, and therefore their arterial transport routes, services, and buildings, are founded on clay-rich soils and rocks. These expansive soils can prove to be a substantial hazard to engineering construction due to their ability to shrink or swell with seasonal changes in moisture content, 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. Houses and other low-rise buildings, pavements, pylons, pipelines, and other shallow services are especially vulnerable to damage because they are less able to suppress differential movements than heavier multi-story structures. Pavements are also highly susceptible to damage because of their relative light-weight nature extended over a relatively large area.

The amount by which the ground can shrink or swell is determined by the water content in the near-surface (active) zone; significant activity usually occurs to about 3 m depth, unless this zone is extended by the presence of tree roots (Driscoll 1983; Biddle 1998, 2001). During rainfall these soils can absorb large quantities of water becoming sticky and heavy and causing heave, or lifting, of structures, and during prolonged periods of drought they can become very hard, causing shrinkage of the ground and differential settlement. This hardening and softening is known as “shrink–swell” behavior and presents a significant geotechnical and structural challenge to anyone wishing to build on, or in, them. The main factors controlling this behavior are the clay content and mineralogy, the *in-situ* effective stresses, and the stiffness of the material. Aspects such as original geological environment, climate, topography, land-use, and weathering affect these factors, and hence shrink–swell susceptibility.

Where Are They Found?

Expansive soils are found throughout many regions of the world, particularly in arid and semiarid regions, as well as where wet conditions occur after prolonged periods of drought. Their distribution is dependent on geology, climate, hydrology, geomorphology, and vegetation. Countries where expansive soils occur and give rise to major construction costs include Ethiopia, Ghana, Kenya, Morocco, South Africa, and Zimbabwe in Africa; Burma, China, India, Iran, Israel, Japan, and Oman in Asia; Argentina, Canada, Cuba, Mexico, Trinidad, the USA, and Venezuela in the Americas; Cyprus, Germany, Greece, Norway, Romania, Spain, Sweden, Turkey, and UK in Europe; and Australia (Fig. 1).

In large areas of these countries, the evaporation rate is higher than the annual rainfall so there is usually a moisture



Expansive Soils, Fig. 1 Global distribution of shrink–swell soil where major construction costs occur (by region)

deficiency in the soil. When it rains, the ground swells and increases the potential for heave. In semiarid regions, a pattern of short periods of rainfall followed by periods of drought can develop, resulting in seasonal cycles of swelling and shrinkage; in humid climates, problems with expansive soils trend to be limited to those containing higher plasticity clays; and in arid climates, even moderately plastic soils can cause damage to residential property. The literature is full of studies, from all over the world, concerned with problems associated with expansive clays (Fredlund and Rahardjo 1993; Stavridakis 2006; Hyndman and Hyndman 2009).

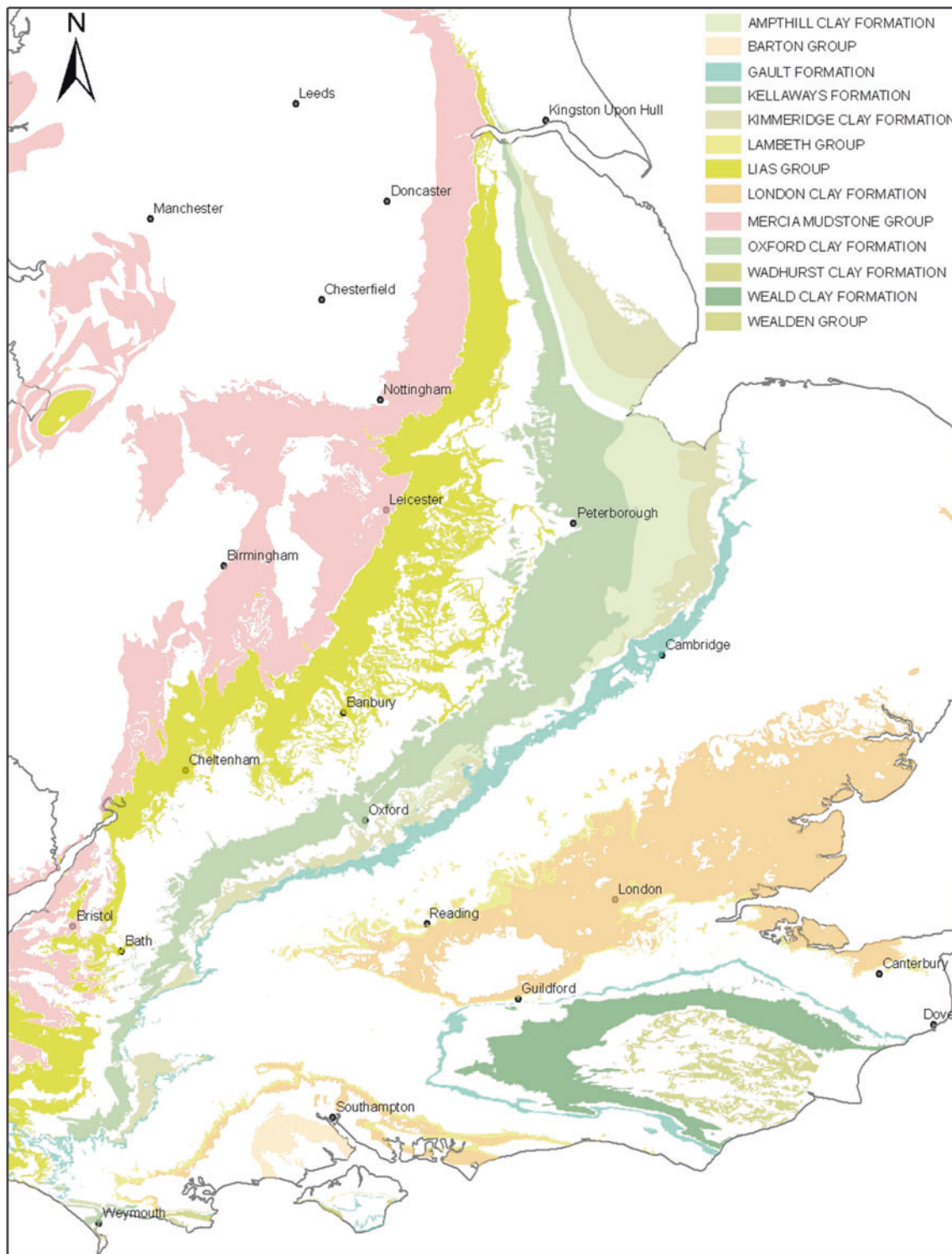
In the UK, towns and cities built on clay-rich soils most susceptible to shrink–swell behavior are found mainly in the south-east of the country, south of a line from Dorset to the North Yorkshire coast (Fig. 2). Here many of the “clay” formations are too young (Jurassic or younger) to have been changed into stronger “mudstones,” leaving them still able to absorb and lose moisture. These deposits are normally firm to very stiff clay or very weak mudstones that weather to firm to stiff clay near the surface. Clay rocks elsewhere in the country are older and have been hardened by processes resulting from deep burial; they are less prone to shrink–swell behavior because they contain less active clay minerals and are less able to absorb water. Some areas (e.g., around The Wash, northwest of Peterborough, and under the Lancashire Plain) are deeply buried beneath other (surficial) soils that are not susceptible to shrink–swell behavior. However, other surficial deposits such as alluvium, peat, and laminated clay can also be susceptible to soil subsidence and heave (e.g., in the Vale

of York, east of Leeds, and in the Cheshire Basin). In the UK, some Mesozoic and Tertiary clay soils and weak mudrocks are also susceptible to shrinkage and swelling as environmental conditions change (Harrison et al. 2012) (Based on section 3 of Jones and Jefferson 2012)

Whereas the distribution of UK clay soils is relatively well known in 2-D, for example, Loveland (1984), Jeans (Jeans 2006a, b), and Wilson et al. (1984), the 3-D distribution is less well known. A meaningful assessment of the shrink–swell potential of any soil requires a considerable amount of high-quality and well-distributed spatial data of a consistent standard (Jones and Jefferson 2012) and from this a Volume Change Potential (VCP) map can be constructed. However, looking at soils on a national scale (although giving a good indication of potential problem areas) does not tell the whole story; therefore it is better to look at them on a more regional scale. Jones and Terrington (2011) discuss a methodology for creating a 3D VCP interpolation of the London Clay, visualizing plasticity values at a variety of depths, relative to ground level, across the outcrop (Fig. 3).

What Is the Damage?

Expansive soils were first acknowledged, in the UK, as a major cause of foundation damage following the drought of 1947, since then insurance claims have dramatically increased. In 1991, claims peaked at over £500 million, and over the past 20 years, the Association of British Insurers has



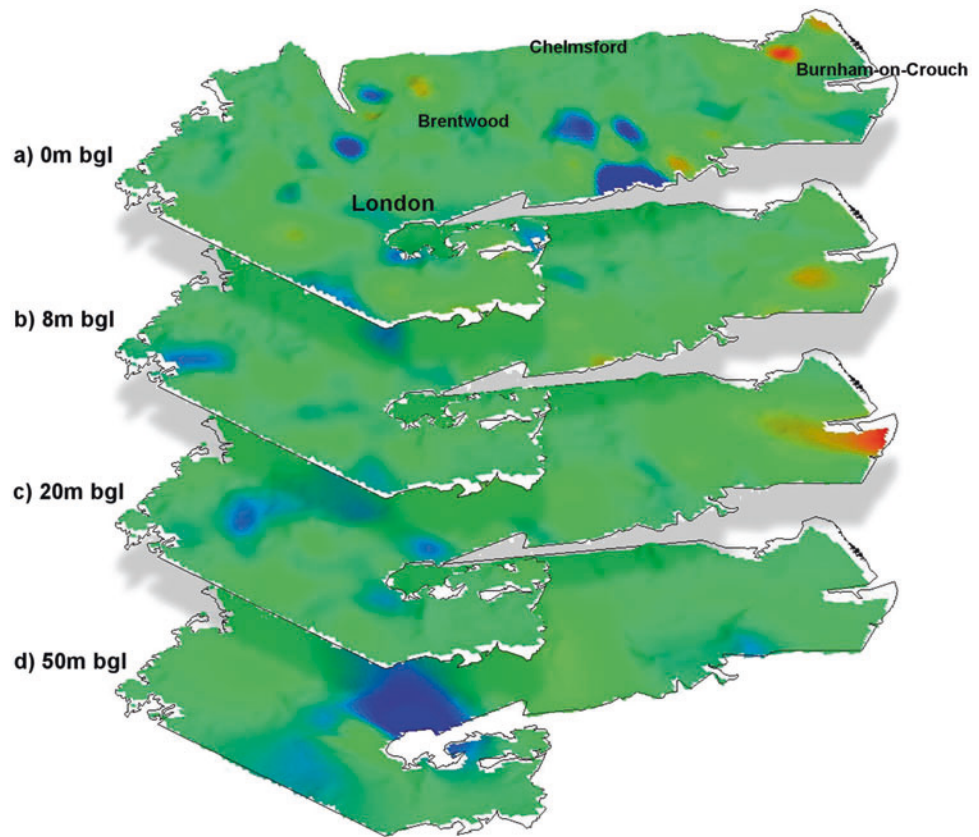
Expansive Soils, Fig. 2 Distribution of UK clay-rich soil formations (After Jones and Jefferson 2012)

estimated that damage caused by expansive soils has cost the insurance industry over £400 million a year (Driscoll and Crilly 2000), making it the most damaging geological hazard in the UK. In fact, one in five homes in England and Wales are

at risk from ground that swells when it gets wet and shrinks as it dries out (Jones 2004), although susceptible ground conditions are perhaps less severe under a temperate UK climate than in some other countries. The American Society of Civil

Expansive Soils,

Fig. 3 Interpolation of “Area 3” showing surfaces at 0 m, 8 m, 20 m, and 50 m below ground level. Note: blue: medium, green: high, red: very high (Jones and Terrington 2011)



Engineers has estimated that as many as one in four homes in the continental United States has some damage caused by expansive soils, with the annual cost of damage to buildings and infrastructure exceeding \$15 billion. In a typical year they cause a greater financial loss to property owners than earthquakes, floods, hurricanes, and tornadoes combined (Nelson and Miller 1992).

Expansive soils can cause heaving of structures when they swell and differential settlement when they shrink. Damage to a structure is possible when as little as 3% volume expansion takes place (Jones 2002), especially where these changes are distributed unevenly beneath the foundations. If the water content of a clay soil around the edge of a building changes, the swelling pressure will also change, whereas the water content of the soil beneath the centre of the building remains constant, causing a failure known as end lift (Fig. 4). Where the swelling is concentrated beneath the centre of the structure (or where shrinkage takes place under the edges) a failure known as centre lift takes place.

Another major contributing factor to ground shrinkage is tree growth, more specifically tree roots. Roots will grow in the direction of least resistance and where they have the best access to water, air, and nutrients (Roberts 1976). The actual pattern of root growth depends upon the type of tree, depth to

water table, and local ground conditions. Damage to foundations resulting from tree growth occurs in two principal ways:

- Physical disturbance of the ground – caused by root growth and often seen as damage to pavements and walls
- Shrinkage of the ground – caused by water removal and often leading to differential settlement of building foundations

Vegetation-induced changes to water profiles can also have a significant impact on other underground features, including utilities. Tree-induced movement has the potential to be a significant contributor to failure of old pipes located in clay soils near deciduous trees (Clayton et al. 2010).

Building, or paving, on previously open areas of land, such as the building of patios and driveways, can cause major disruption to the soil-water system. Sealing the ground in this way cuts off the infiltration of rain water and the trees that are dependent upon this water will have to send their roots deeper, or farther afield, in order to find water. The movement of these root systems will cause a major ground disturbance and will lead to the removal of water from a larger area around the tree (Jones and Jefferson 2012). Problems occur when structures are situated within the zone of influence of a tree



Expansive Soils, Fig. 4 Structural damage to house caused by “end lift” (© Peter Kelsey & Partners)

(Fig. 5). Pavements are also highly susceptible to damage because of their relative light-weight nature extended over a relatively large area.

Shrink–Swell Behavior

The shrink–swell potential of expansive soils is determined by its initial water content; void ratio; internal structure and vertical stresses; as well as the type and amount of clay minerals in the soil (Bell and Culshaw 2001). These minerals determine the natural expansiveness of the soil, and include smectite, montmorillonite, nontronite, vermiculite, illite, and chlorite. Generally, the larger the amounts of these minerals present in the soil, the greater the expansive potential.

Clay particles are very small and their shape is determined by the arrangement of the thin crystal lattice layers that they form. Taylor and Cripps (1984), Taylor and Smith (1986), and Driscoll (1983) provide useful reviews of the controls that clay mineralogy has on the drained compressibility/expansibility of geological materials and hence their susceptibility to large deformations from effective stress changes which lead to shrinkage and/or swelling. In expansive clay, the molecular structure and arrangement of these crystal layers has an affinity to attract and hold water molecules between them (and on their surfaces) in a strongly bonded “sandwich,” giving them a large shrink–swell potential. For further details of the mineralogy of clay minerals and their influence of engineering properties of soils see Mitchell and Soga (2005).

Potentially expansive soils are initially identified by undertaking particle size analyses to determine the percentage of fine particles in a sample. Clay sized particles are considered to be less than 2 μm (although this value varies slightly throughout the world) but the difference between clay and

silt is more to do with origin and particle shape. Silt particles (generally comprising quartz particles) are products of mechanical erosion whereas clay particles are products of chemical weathering and are characterized by their sheet structure and composition.

Soils with high shrink–swell potential will not usually cause problems as long as their water content remains relatively constant. This is controlled by the soil properties (mineralogy); suction and water conditions; water content variations; and geometry and stiffness of a structure founded on it (Houston et al. 2011). In a partially saturated soil, suction or water content changes increase the likelihood of damage occurring. In a fully saturated soil, the shrink–swell behavior is controlled by the clay mineralogy.

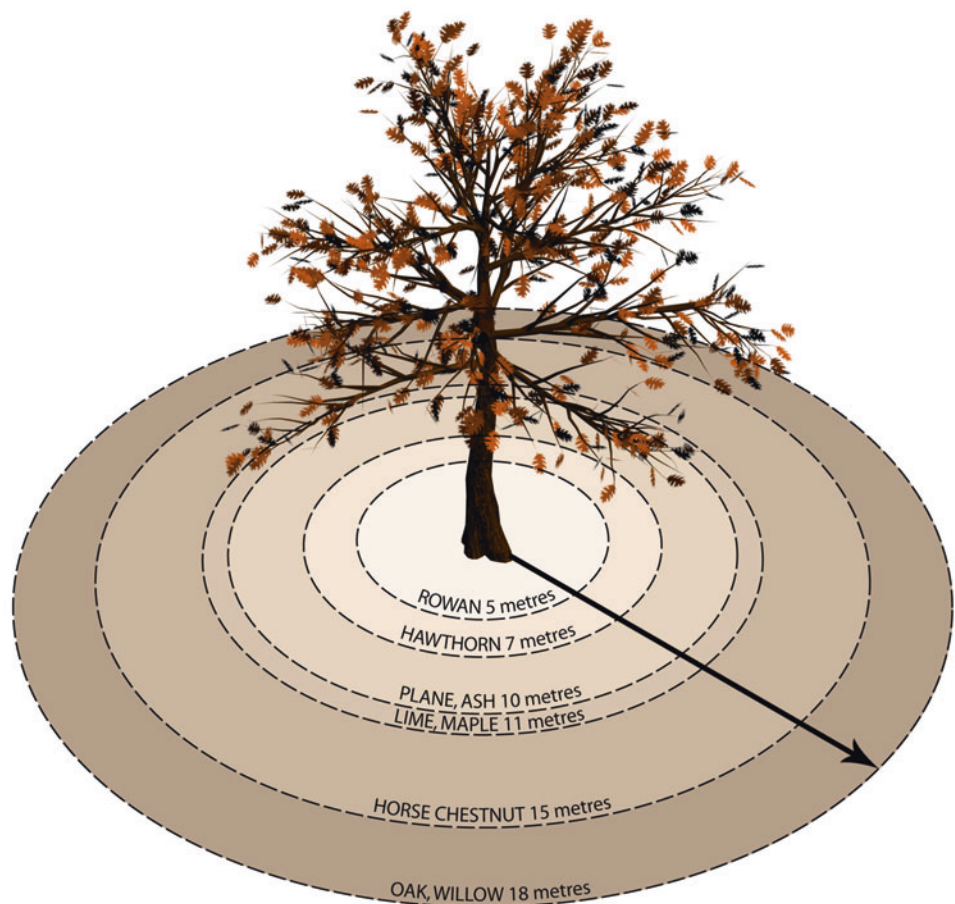
Expansive Soils in Construction

Potential shrinkage and/or swelling from these causes can usually be anticipated in most engineering circumstances. However, because of the differences between natural and tree-induced shrink–swell, and varying initial conditions, the relative susceptibility to volume change at any place may not necessarily always be the same for a given geological formation or soil type. Houses and other low-rise buildings, pavements, pylons, pipelines, and other shallow services are especially vulnerable to damage from shrink–swell clays because they are less able to suppress differential movements than heavier multistory structures.

Due to the global distribution of shrink–swell soils, many different ways to tackle the problem have been developed and these can vary considerably (Radevsky 2001). These methods depend not only on technical developments but the legal framework and regulations of a country, insurance policies, and the attitude of insurers, experience of the engineers, and other specialists dealing with the problem and, most importantly, the sensitivity of the owner of the property affected. A summary of these issues is provided by Radevsky (2001) in his review of how different countries deal with shrink–swell soil problems, and a detailed informative study from the United States has more recently been presented by Houston et al. (2011).

Shrink–swell soils require extensive site investigation in order to provide sufficient information. Normal investigations, relating to the structures most affected by shrink–swell soils, are often not adequate. These investigations may involve specialist test programs even for relatively light weight structures (Nelson and Miller 1992). Although there are a number of methods available to identify shrink–swell soils, each with their relative merits, there are no universally reliable methods available (Jones and Jefferson 2012), and they are rarely employed in the course of routine site investigations in the UK. This means that few data are available for data-basing the directly measured shrink–swell properties of the major clay

Expansive Soils, Fig. 5 The zone of influence of some common UK trees (Jones et al. 2006)



formations, and reliance has to be placed on estimates based on index parameters, such as liquid limit, plasticity index, and density (Reeve et al. 1980; Holtz and Kovacs 1981; Oloo et al. 1987). No consideration has been given to the saturation state of the soil and therefore to the effective stress or pore pressures within it. For further details on the strategies for dealing with the engineering issues and management of expansive soils see Jones and Jefferson (2012).

Summary

Expansive soils are found throughout many regions of the world and the subsidence and heave problems associated with them causes billions of pounds of damage annually, making them one of the most costly and widespread geological hazards to domestic properties and other low-rise structures. In arid/semiarid regions, their ability to take up large quantities of water can cause major damage to structures, whereas in more humid regions, such as the UK, problems mainly occur in the more highly plastic soils, especially after prolonged periods of drought. Either way, expansive soils have the potential to demonstrate significant volume change in direct

response to changes in water content, induced through water ingress, modification to local water conditions, or via the action of external influence such as trees and shrubs.

The shrink–swell hazard is controlled by a number of factors, primarily, the geology and mineralogy and the climate. Shrinkage and swelling usually occurs in the near-surface to depths of about 3 m; water content in this upper layer is significantly influenced by climatic and environmental factors and is generally termed the active zone. The shrink–swell potential of expansive soils is determined by its initial water content; void ratio; internal structure and vertical stresses; as well as the type and amount of clay minerals in the soil.

To understand and hence engineer expansive soils in an effective way, it is necessary to understand soil properties, suction/water conditions, temporal and spatial water content variations, and the geometry/stiffness of foundations and associated structures.

Cross-References

- [Casagrande Test](#)
- [Classification of Soils](#)

- Clay
- Cohesive Soils
- Collapsible Soils
- Hydrocompaction
- Noncohesive Soils
- Organic Soils and Peats
- Residual Soils
- Saline Soils
- Soil Field Tests
- Soil Properties

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Exposure Logging

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Synonyms

Exposure mapping; Trench logging; Trench mapping

Definition

The making of a geological map of vertical (or near-vertical) face(s), whether natural or man-made.

The U.S. Bureau of Reclamation (USBR 1998) describes standards for the following types of exposure logging: Dozer [bulldozer] Trench Mapping, Backhoe Trench Mapping, Large Excavation Mapping, and Steep Slope Mapping (Fig. 1).

Prior to logging, the exposure must be cleaned well enough to expose the features of interest (structures, stratigraphy, and soil horizons). This requires removing vegetation and any thin regolith cover (on natural exposures) or material smeared on the excavated face by excavating machinery (on excavated exposures). The detail shown in the log is



Exposure Logging, Fig. 1 Multibench trench excavated during an active fault study, USA. Each vertical wall is ~1.2 m high and horizontal benches are the same width. Walls have been cleaned enough to differentiate the major deposits. All spoil from wall cleaning was removed from bench surfaces so contacts can be traced across benches, allowing 3D mapping

dependent on how well cleaning was done; insufficient cleaning will obscure subtle structures and contacts that may be critical for interpretation.

In logging, one first defines mappable units (depending on the purpose of logging), and then draws or transfer their boundaries to some type of scaled drawing or image of the face that faithfully reproduces them. The lithologic units on an excavated face are normally unconsolidated (Quaternary) sediments, and are differentiated as discrete deposits characterized by a consistent texture, sorting, bedding, fabric, or color (McCalpin 2009). Soil horizons, in contrast, are post-depositional weathering zones that may be developed on a single lithologic unit, or may be developed across multiple lithologic units. Defining units on trench walls is facilitated if visual contrast is enhanced. For example, contacts in dry sediments may appear sharper if walls are sprayed/misted with a portable water sprayer. Slight differences in deposit cohesion are accentuated if the trench wall is left to “weather” for several days or weeks. Similar relief can be created by brushing the face with brooms or paintbrushes.

Contacts identified visually are then marked on the face before logging, e.g., by scribing a line with a sharp tool (in finer sediments). In coarser sediments, one marks contacts with nails and attached colored flagging, or with spray paint, using unique colors for soil horizons, depositional contacts, erosional contacts, faults, etc. In the corresponding trench log, lines depicting target features of the highest importance for the particular study (e.g., faults, tension cracks, liquefaction features, landslide shear planes, sinkhole collapse zones, angular unconformities) are rendered by the thickest lines; lithologic contacts by thinner lines; and soil horizon

boundaries or facies boundaries within major (genetic) depositional units by very thin or dashed lines.

If deducing the time history of an exposure is important to the project, *soil horizons* should be identified and logged separately from deposits, because they indicate the location of past ground surfaces in the stratigraphic sequence, and their degree of development may indicate the length of time that surface was stabilized. The interaction of soil profiles with lithologic units and structures is often critical to understanding the sequence of depositional events versus deformation events and their relative timing (Shlemon 1985). To accurately identify and map soil horizons separately from lithologic units on an exposed face requires some formal training in pedology, something that many engineering geologists lack. Techniques for recognizing and delineating soil horizon contacts are beyond the scope of this article; see Shlemon (1985), Birkeland (1999), and Borchardt (2010) for applications of pedology to fault trenching.

Exposure Logging Philosophies

There are many reasons to map an exposure in engineering geology, so map units should be defined in a way that best achieves the goal. Two end-member philosophies are subjective versus objective logging. In *subjective logging*, the logger first observes the trench wall and makes a visual/mental interpretation of the structural and stratigraphic relations exposed in the wall. The log is then made to illustrate the salient geologic features. The rock or soil matrix is added in secondary importance; small features that do not bear on the major interpreted structures or strata may not be logged at all. The log is thus planimetrically accurate but schematic. The subjective approach developed during nuclear power plant investigations in the 1960s when the log was meant to answer specific regulatory questions, such as “Is a fault present?” and, if so, “Is the age of faulting older than some predefined regulatory criterion?” Subjective logs can be made rapidly and are easy to interpret with respect to regulatory criteria, because all extraneous features that do not bear on the major interpretation have been omitted. The disadvantage of subjective logs is that it is difficult to advance alternative interpretations of the log, because the interpretation was integral to drafting the log, and thus many details (which might conflict with the interpretation) have been omitted.

In contrast, *objective logging* depicts all physical features on the trench face in an impartial manner without regard to perceived importance. The approach documents only what the trench wall looked like, so is similar to an unannotated photograph of the trench wall. The advantage of an objective trench log is that multiple interpretations can be proposed/tested against the relationships portrayed on the log. The log is also an unbiased archival record of how the trench wall

appeared, which has archival value. The disadvantage of strictly objective logs is they may not be readily interpretable because the log is not annotated to support an interpretation. In practice, most trench logs combine subjective and objective aspects, with the former dominating the twentieth century and the latter dominating the twenty-first century.

Exposure Logging Techniques

Over the past 40 years, trench logging techniques have evolved from simple sketching on graph paper, to increasingly sophisticated digital techniques. Nevertheless, all engineering geologists should still be able to make a trench log using the manual method (McCalpin 2009). As of 2018, the 2D photomosaic logging method is arguably most widely used, especially in the consulting sector, but 3D digital methods will probably replace it within the next decade.

The two-dimensional photomosaic method became the standard for research-grade studies around the year 2000. Normally, the wall would be cleaned, horizontal and vertical reference marks attached to the face, and all contacts marked before taking the wall photographs. Each photograph would then be rotated, rescaled, stretched, contrast-enhanced, and trimmed as needed, before being added to the mosaic, with the assistance of the reference marks on the wall. After the mosaic was complete, the author would annotate the photomosaic with vector graphics software to illustrate the interpretation (Fig. 2).

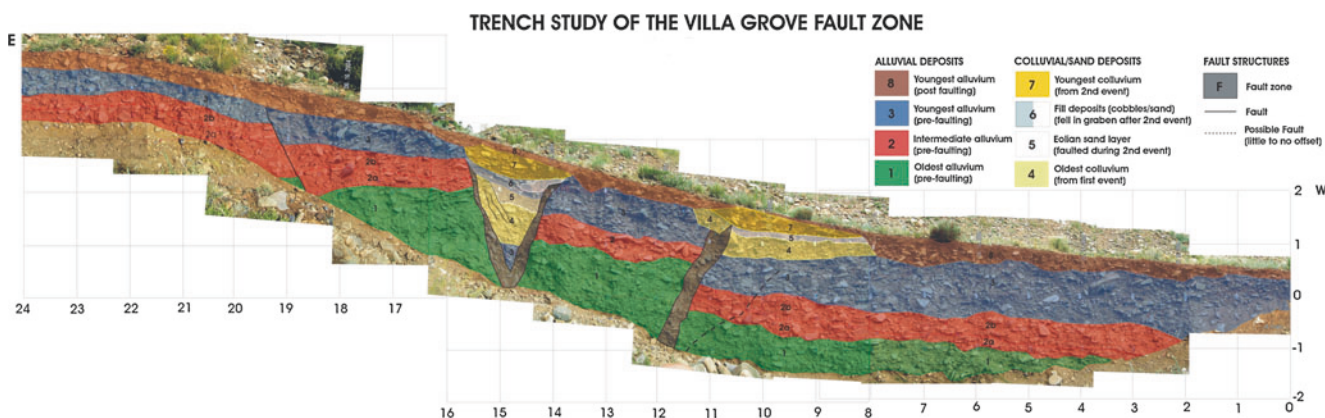
In the mid2000s, computer software became available for creating three-dimensional images of man-made and natural exposures. This was done by terrestrial lidar surveying or by photogrammetry software. The earliest software used digital photographs aimed at pit-wall mapping in large mines where access to highwalls and benches was difficult (e.g., Sirovision; JointMetrix; see Haneberg et al. 2006). The software emphasized identifying faults and joint sets in bedrock in 3D by

measuring their strikes-and-dips interactively from the 3D model. The data were then input into stereographic plots to define stability domains for slope stability calculations. Different rock types or structural domains could also be mapped as overlays on the 3D model. In 2010, Russian developers released a user-friendly software package (Agisoft PhotoScan) based on the Structure-from-Motion algorithms, which created a 3D model from numerous overlapping photographs. The photographs could be taken from the air looking down to the surface, or from the surface looking at cliffs, outcrops, or trench walls. The latest version of mapping natural outcrops and cliffs is termed Digital Outcrop Models (e.g., Wilkinson et al. 2016). Because the techniques are based on photographs, one should mark all possible contacts on the trench walls before taking the photos. Photogrammetric logging has advantages in the objective sense [it uses a high-resolution, georeferenced 3D model of the wall(s)] and in the subjective sense (by adding the third dimensions, strata and structures can be seen in their true 3D shape/orientation, rather than just in a 2D section, and this may change the interpretation). Within the next 10 years, 3D logging (e.g., Reitman et al. 2015) may replace 2D logging as the standard of practice.

Applications of Trenching in Engineering Geology

Trenching in engineering geology usually has one of two targets: (1) to expose and characterize structures (fault and joints, shear zones, landslide planes), in order to assess past movement history and/or future hazard [*structural targets*], or (2) to expose a Quaternary deposit in section, in order to assess its stratigraphy, sedimentology, geotechnical parameters, or to collect samples for dating the deposit [*stratigraphic targets*].

To date, most structural targets have been active faults studied as part of a seismic hazard assessment (McCalpin and Shlemon 1996). Since 1970, the field of paleoseismology



Exposure Logging, Fig. 2 Two-dimensional photomosaic of a trench wall in coarse-grained alluvial fan deposits, with overlaid semitransparent colored polygons depicting geologic units and structures. This

combines the objective qualities of the photomosaic with the subjective qualities of interpreted trench contacts (lines and polygons)

has grown considerably, due to government regulations requiring fault trenching studies for critical structures (dams, power plants, pipelines, etc.). Since 1990, trenching has been expanded to characterize deformation caused by strong ground shaking (e.g., liquefaction, sand blows, clastic dikes, earthquake-triggered landslides). Recently, trenching been applied to landslide studies, to supplement the more traditional methods of obtaining subsurface information (drilling and geophysics). As pointed out by Cotton (1999), the structures that define the head, flanks, and toe of a landslide are structural targets essentially identical to the normal, strike-slip, and reverse faults (respectively). In the past few years, landslide workers such as Gutiérrez et al. (2010) have demonstrated the advantages of trenching for answering questions about past landslide movement patterns, that were previously unanswerable. Similar results have come from trenching deep-seated gravitational slope deformations (DSGSD) and sinkholes.

Trenching for stratigraphic targets includes: (1) test pits to determine gross lithology, soil classification, and geotechnical parameters of shallow deposits; (2) trenching floodplain deposits to estimate flood depths and ages; (3) trenching alluvial fans to expose the number of debris flow deposits at various parts of the fan, their average thickness (proxy for flow depth), and to date their recurrence interval.

Summary

Logging of exposures in trenches, excavations, and steep slopes is undertaken to determine physical features, lithologies, soil classification, and geotechnical parameters. It involves cleaning the exposure and, sometimes, cutting benches to identify 3D relationships. The task is commonly undertaken using photomosaics but is becoming increasingly digital. Exposure logging is also undertaken to detect palaeoseismic features to identify potentially active faults, structures of large landslides, and relationships and recurrence intervals of debris flows in alluvial fans.

Cross-References

- Deformation
- Engineering Geological Maps
- Excavation
- Faults
- Geohazards
- Lidar
- Peels
- Photogrammetry
- Site Investigation

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Extensometer

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Synonyms

Extensometer

Definition

The extensometer is an instrument designed to measure the distance separating two fixed points by determining extension or contraction of a connecting element under stress which is temporarily or permanently attached to the fixed points.

Characteristics

The first such instrument was designed to measure deformation of iron rods during fatigue testing (Huston 1879). There are other instruments allowing determination of distance between fixed points by direct distance measurements (e.g., precision tape; laser distance meters; electronic distance meters) without using connecting element under tension.

Repeated readings are required to detect changes of the connecting element length which indicates relative displacement of the fixed points with respect to each other. Determination of their movement vector or total displacement requires additional information which cannot be provided by the extensometric measurements alone but is largely affected by the monitoring setting (e.g., placement of the fixed points with respect to geological and engineering structures, Corominas et al. 2000) which requires at least one point (i.e., reference point) to be stable or to move at much slower rates compared to the other fixed points.

Typical use of extensometers represents, but is not limited to, measurements of deformations across cracks on buildings and rocks, closure of underground constructions, convergence of building structures, slope deformations, and ground settlement. The specific application and monitoring setting determines the design of the extensometers among which number of types can be distinguished based on operational mode (portable/fixed; analogue/digital measurement readings; surface/borehole; single/series of interconnected extensometers), which often requires remote access and data downloading; type of connecting element (tape; cable; rod); and measurement technology (e.g., potentiometers measuring electric resistance; vibrating-wire transducers measuring frequency response; linear variable differential transformer measuring induction).

Accuracy of the measurements depends on the instrument design, in particular the deformation properties of the connecting element (e.g., steel tape; lead cable) and mechanism of conversion of the mechanical change (distance) into

recordable readings. The latter may involve number of different electronic sensors, the performance of which may be adversely affected by harsh environmental conditions (e.g., temperature; humidity; corrosion; electric surge) under which extensometers often operate (Lin and Tang 2005). Temperature-induced deformations of the connecting element also have to be carefully considered during data processing. A possible source of errors, common to all types of extensometers, concerns the stability of the fixed points which may deteriorate through time disrupting the time series of the measurements.

Cross-References

- [Deformation](#)
- [Dilatancy](#)
- [Instrumentation](#)
- [Landslide](#)
- [Mining Hazards](#)
- [Monitoring](#)
- [Site Investigation](#)
- [Strain](#)
- [Stress](#)
- [Surface Rupture](#)
- [Surveying](#)
- [Tension Cracks](#)

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