Foundations on problematic soils

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Pre Class Questions

- What are the types of problematic soils?
- How did problematic soils influence foundation stability
- Which areas in Malaysia can be identified as problematic soils area?
- When problematic soils becoming a major concern in foundation engineering?
- How we solve the foundation problems in problematic soils?

Types of problematic soils

- Expansive soils
- Collapsible soils

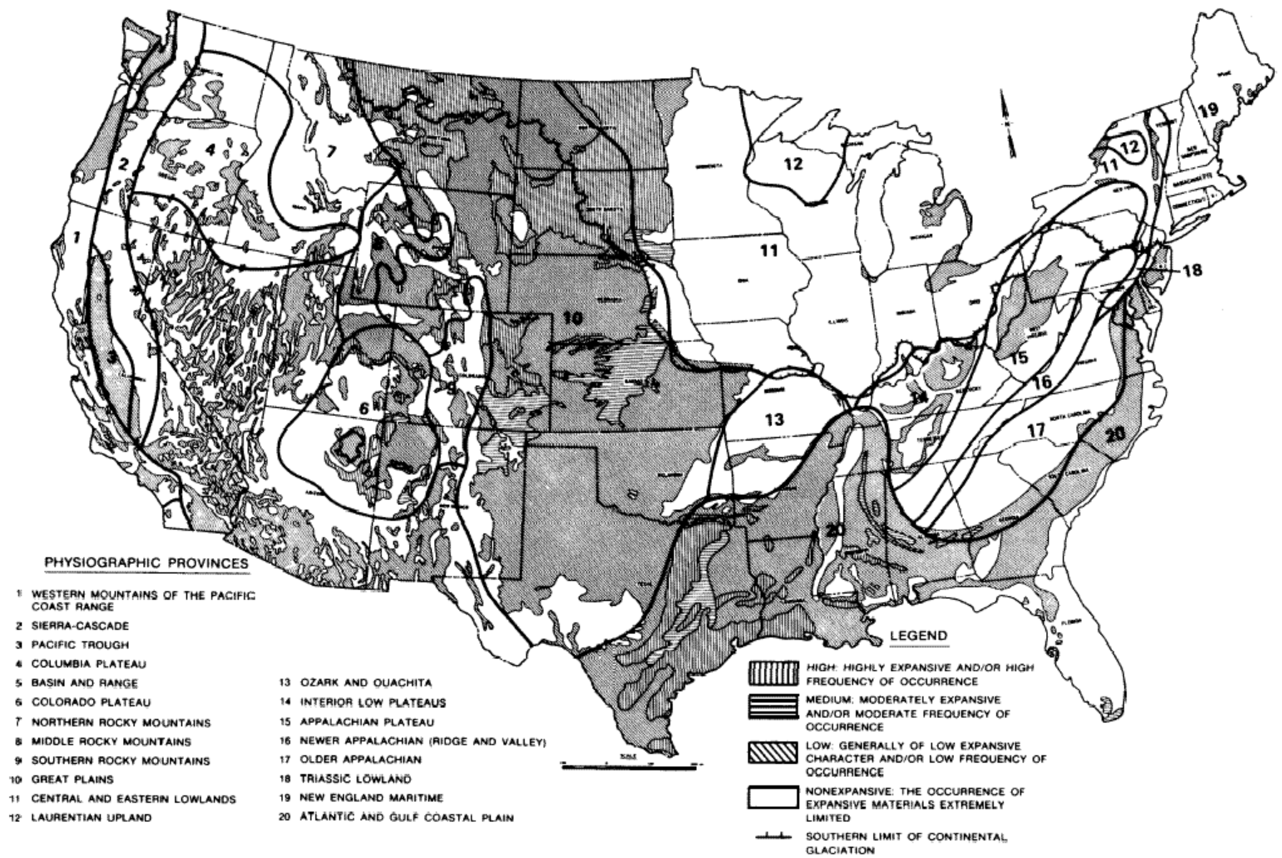

Expansive Soils

Credit to Sally Blackner
Re-edited Muhammad Azril

What are Expansive Soils?

- Vertisol Soils, or known as Shrink Swell Soils
- The Soil contracts due to its clay minerals and the structure of the clay allowing water to be imbedded in-between the clay layers
- Process is reversible, and causes contraction of the soil

Expansive Soils in the U.S



U. S. Army Corps of Engineers

Damage Done?

- 6 BILLION DOLLARS in the U.S alone

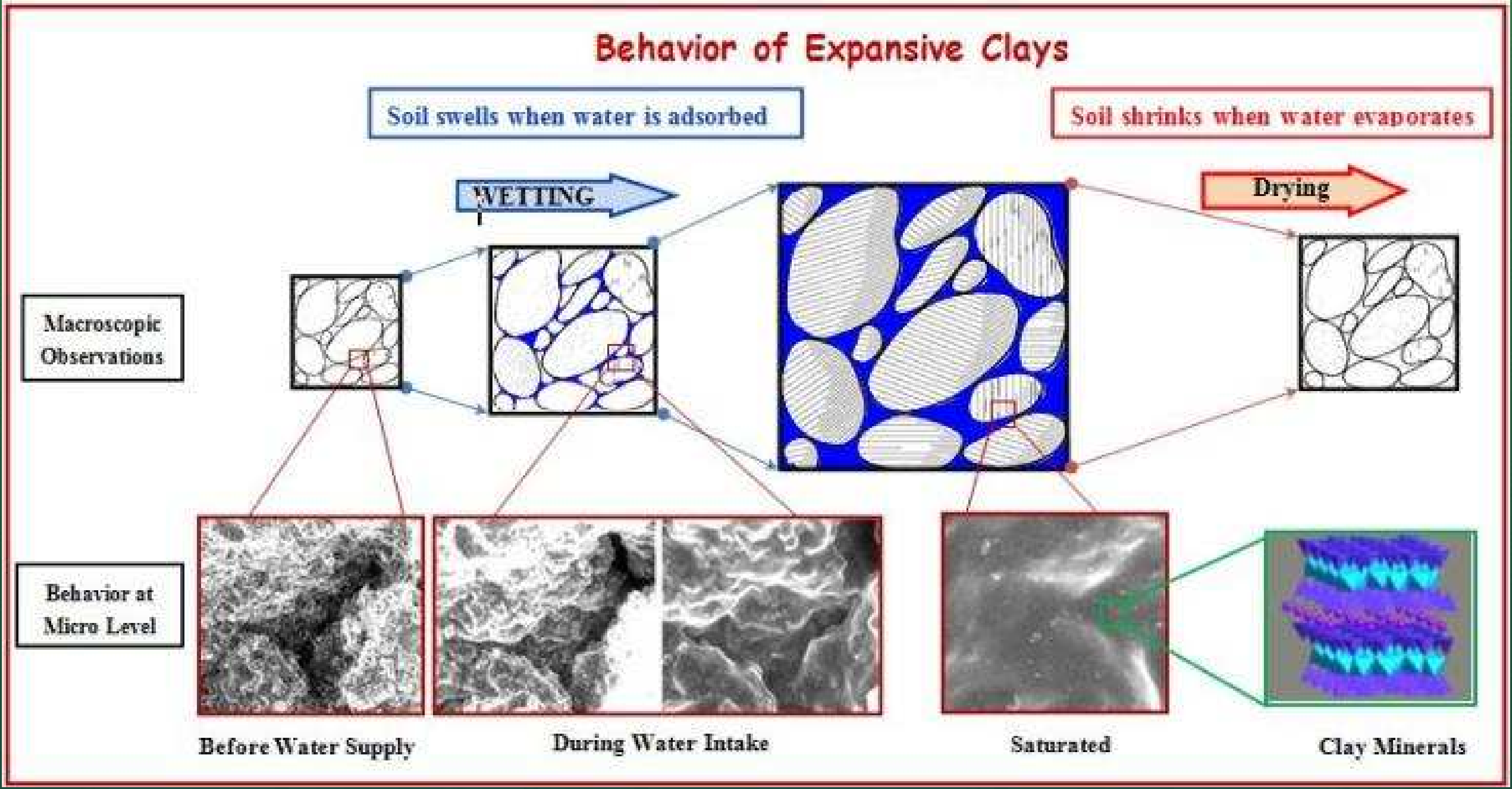
Mechanism of Expansive soil

- Expansive soils owe their characteristics to the presence of swelling clay minerals. As they get wet, the clay minerals absorb water molecules and expand; conversely, as they dry they shrink, leaving large voids in the soil. Swelling clays can control the behavior of virtually any type of soil if the percentage of clay is more than about 5 percent by weight. Soils with smectite clay minerals, such as montmorillonite, exhibit the most profound swelling properties.

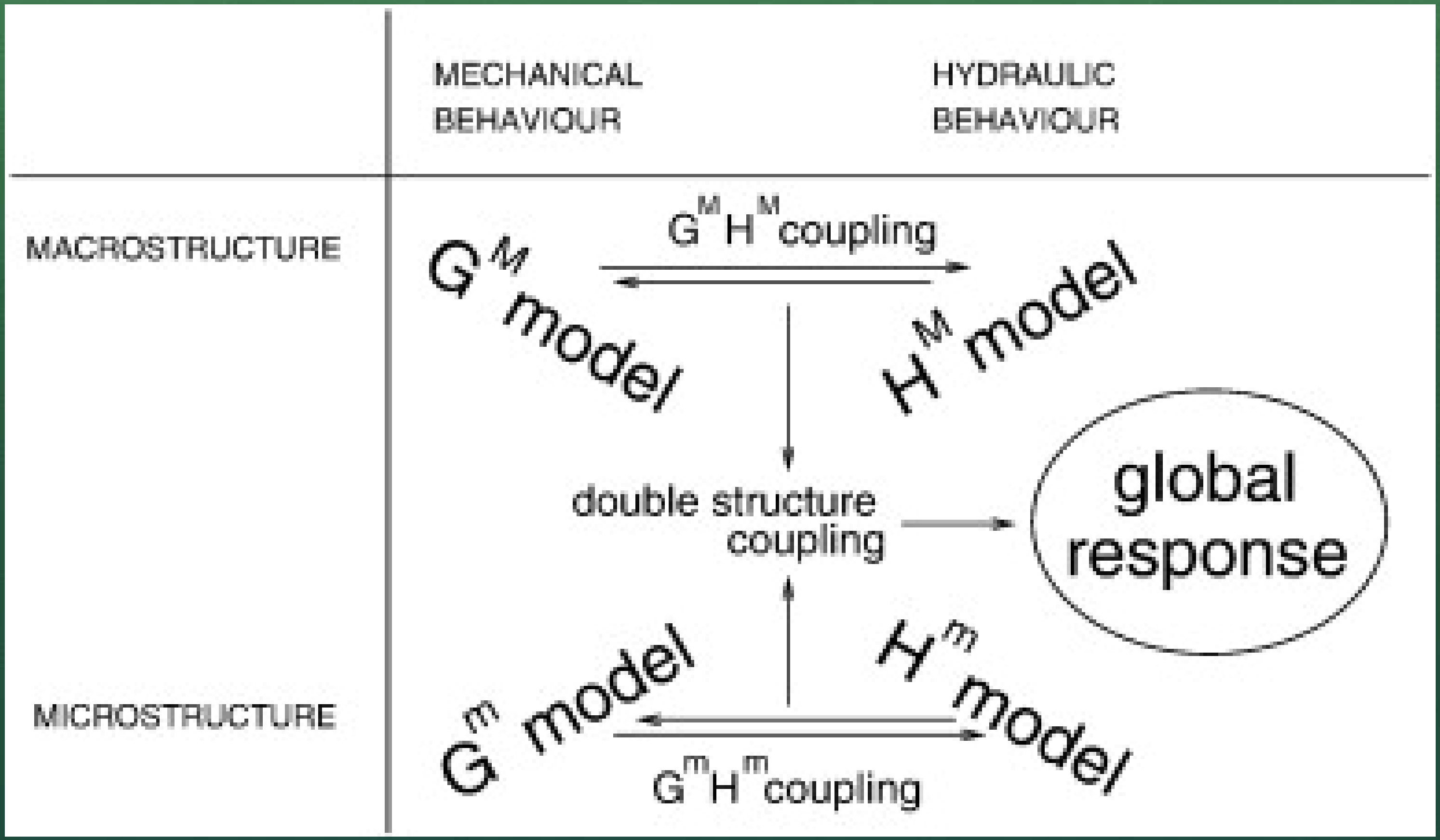
- Potentially expansive soils can typically be recognized in the lab by their plastic properties. Inorganic clays of high plasticity, generally those with liquid limits exceeding 50 percent and plasticity index over 30, usually have high inherent swelling capacity. Expansion of soils can also be measured in the lab directly, by immersing a remolded soil sample and measuring its volume change.

- In the field, expansive clay soils can be easily recognized in the dry season by the deep cracks, in roughly polygonal patterns, in the ground surface (see Fig. 1). The zone of seasonal moisture content fluctuation can extend from three to forty feet deep (see Fig. 2). This creates cyclic shrink/swell behavior in the upper portion of the soil column, and cracks can extend to much greater depths than imagined by most engineers.

Mechanism of Expanisive clay

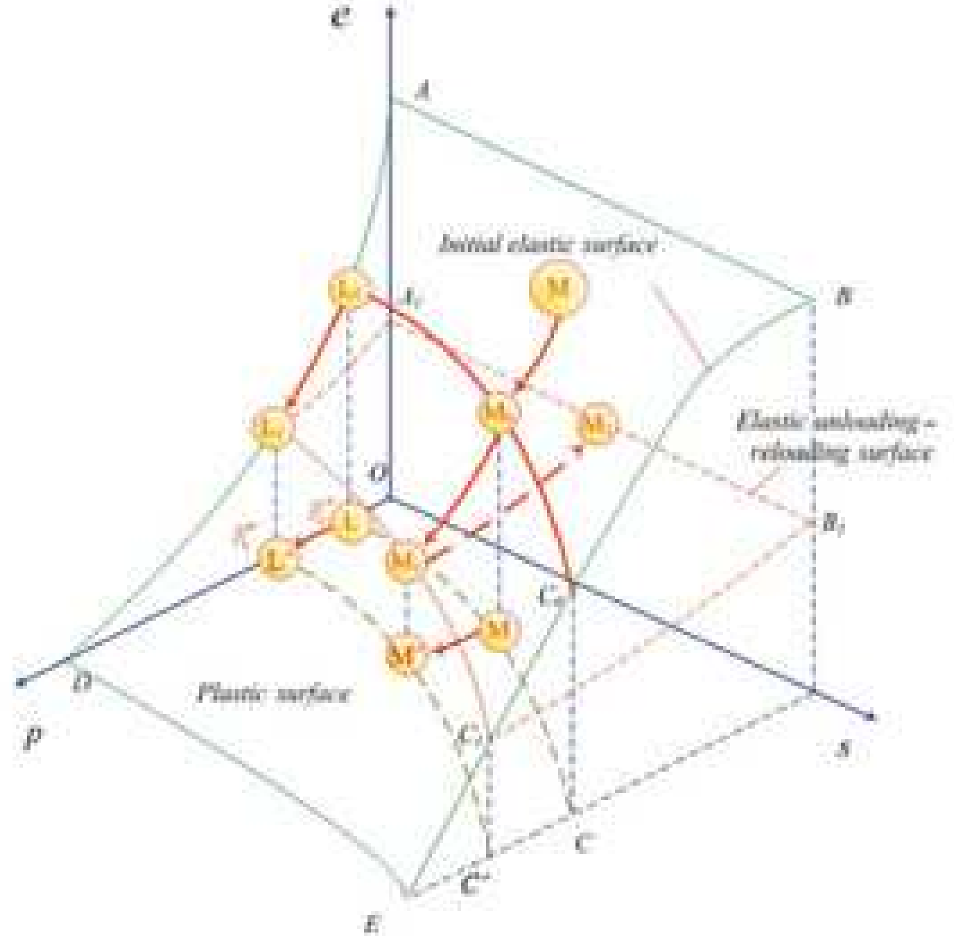


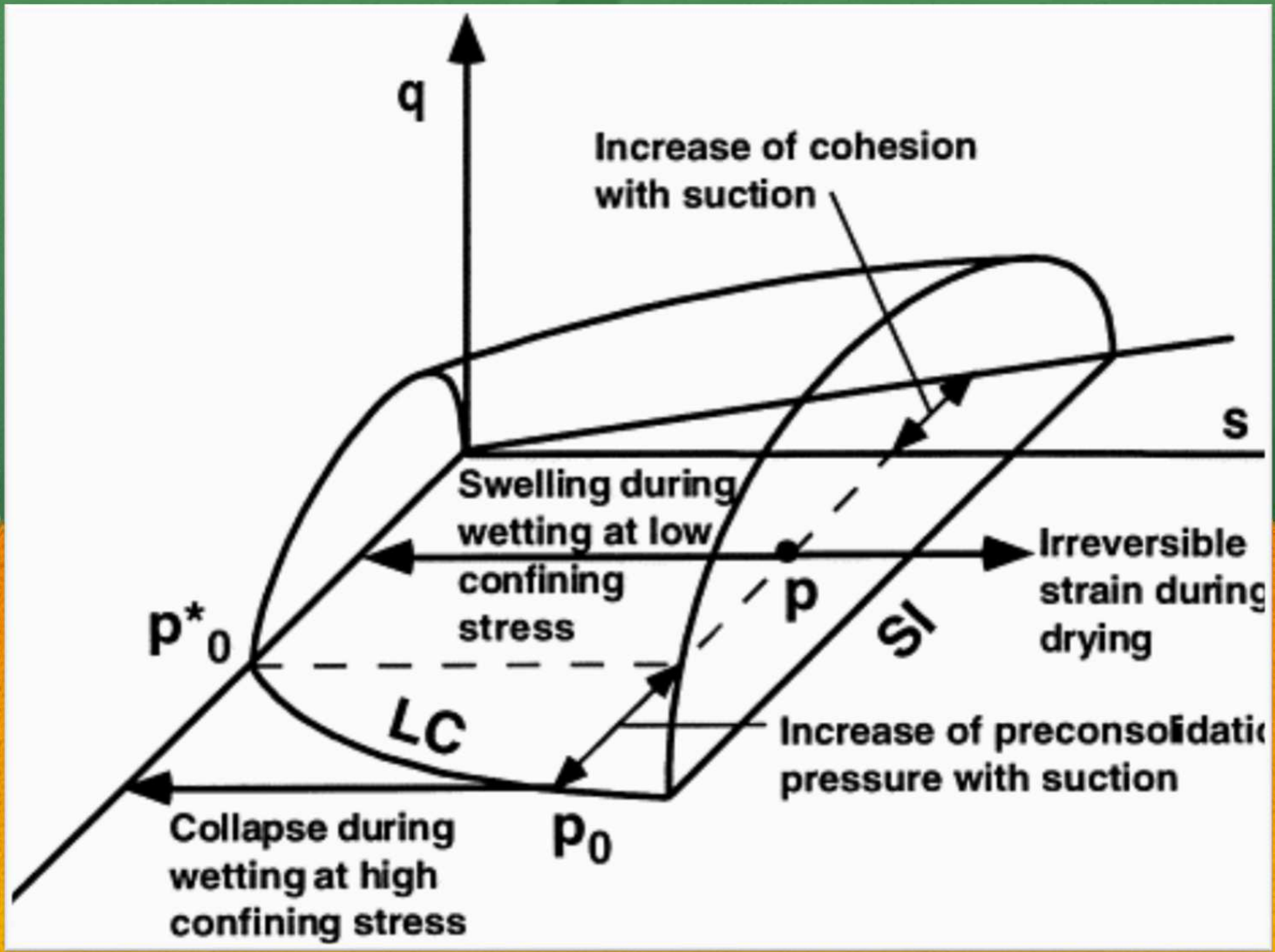
Constitutive modelling



Constitutive modelling

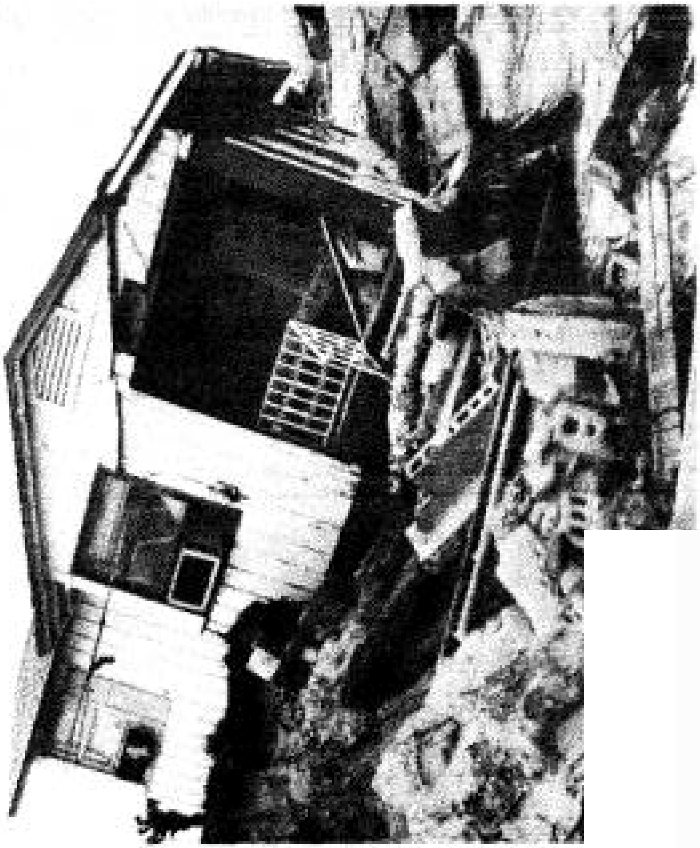
Fig. 1. Void-ratio constitutive surface in the MSSA.





Constitutive Modelling

Barcelona Basic Model



What can be done?

- Test soil before building
- If expansion is greater then 10 %, it is critical
- Remove soil
- Mix soil with material that does not expand
- Keep consistent soil moisture
- Have strong foundations in buildings that can handle the changes in volume.

Expansive soil

1. Expansive Soil Building Foundation Tips - Gutters And Site Drainage
2. Effects of Expansive soil
3. Stabilizing soil using foundation

Collapsible soil

- Collapsible soils are those that appear to be strong and stable in their natural (dry) state, but which rapidly consolidate under wetting, generating large and often unexpected settlements. This can yield disastrous consequences for structures unwittingly built on such deposits. Such soils are often termed “collapsible” or “metastable” and the process of their collapsing is often called any of “hydro-consolidation”, “hydrocompression”, or “hydro-collapse.”

- Collapsible soil deposits share two main features: (i) they are loose, cemented deposits; and (ii) they are naturally quite dry. Loess soils consist primarily of silt sized particles loosely arranged in a cemented honeycombed structure (Fig. 3). The loose structure is held together by small amounts of water softening or water soluble cementing agents such as clay minerals and $CaCO_3$. The introduction of water dissolves or softens the bonds between the silt particles and allows them to take a denser packing under any type of compressive loading.

- Since collapsible soil deposits are necessarily “loose”, they are generally created by deposition mechanisms that yield loose deposits. For example, alluvial (water deposited) and colluvial (gravity deposited) soils are usually deposited loosely and in a saturated state. As the water eventually drains from these soils, the last amounts of moisture are drawn by capillarity to the contact points between grains. As the water evaporates, minerals are left behind at the soil contact points, cementing them together.

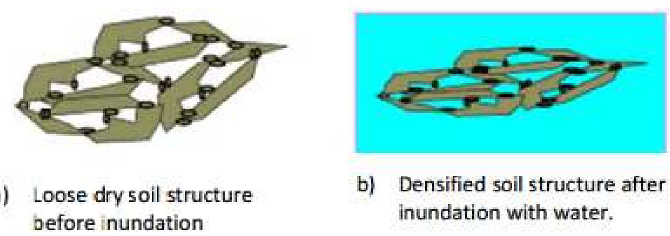


Fig. 3. Hydro-collapsible soil before (a) and after (b) inundation with water.

Testing & Identification

Tests are sometimes done to quantify the collapse potential of the soils. If lab tests are to be performed, "undisturbed" samples must be obtained using Shelby tubes. Once undisturbed samples are collected, two types of tests are generally performed: (a) double oedometer tests; and (b) single odeometer tests. The oedometer, as you recall, is the apparatus in which dry or wet stress-controlled confined compression or consolidation tests are performed on soil specimens

- Double Oedometer Test

- In this test, two "identical" soil specimens are placed in oedometers and subjected to confined compression tests. One of the specimens is tested at natural insitu water content, which is generally quite low. The other specimen is fully saturated before the test begins, and then subjected to an identical compression test. Two stress versus strain curves will be generated, one for the "dry" soil and one for the saturated soil. If the soil is strongly hydro collapsible, the stress-strain response for the saturated curve will be significantly different than that of the dry soil (Figure 4). For a given applied stress σ′n, the strain offset εw between the two curves is called the hydro-collapse strain for that stress level. Generally, for the dry specimen, there will be a critical stress σ′cr at which the loose structure breaks down and beyond which the two curves converge.

Testing & Identification

- b. Single Oedometer Test
- As the name implies, the single oedometer test uses only a single soil specimen. The procedure is as follows:
- 1) An undisturbed sample is placed in the oedometer at its natural (dry) moisture content.
- 2) A small seating load is applied to the specimen.
- 3) The soil is gradually loaded to the anticipated field loading conditions.
- 4) At this stress level, the sample is then inundated with water and allowed to saturate. The resulting hydro collapse is then observed.
- 5) Loading of the specimen is then continued with consolidation permitted. The characteristic stress versus strain curve

Double & Single Oedometer

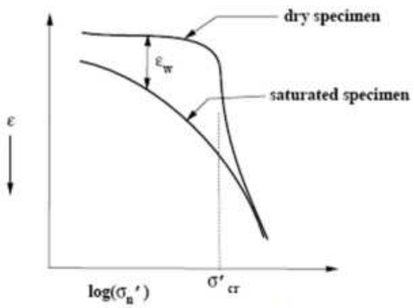


Fig. 4. Results of a double-oedometer test on a hydro-collapsible soil.

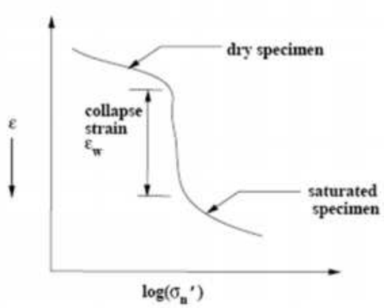


Fig. 5. Typical results from a single oedometer test on a hydro-collapsible soil specimen.

The characteristic stress versus strain curve generated from such a test is sketched in Fig. 5. Clearly, the larger the collapse strain εw observed, the more collapsible the soil is considered to be. Collapse strains on the order of 1% are considered to be mild, while those on the order of say 30% are considered to be very severe.

Wetting Processes

- The obvious problem with hydro collapsible soils is that they tend to have relatively low natural in-situ water contents. When development occurs on such soil deposits, the soil can be subjected to numerous sources of additional wetting that will lead to an increase of its water content.

- Among the common artificial sources of wetting associated with development are: (a) irrigation of landscaping and/or crops; (b) leakage from unlined canals, pipelines, swimming pools, storage tanks, etc; (c) septic systems; and (d) changes in surface drainage of rainwater. Minor artificial wetting is often confined only to the top few feet of soil.

- Sustained, long term leaks can lead to soil wetting deep below the surface which in extreme circumstances can be quite serious and lead to enormous settlements. As an example, a study was published by an investigator named Curtin in 1973 which involved large scale wetting collapse tests performed on collapsible soils located in California's San Joaquin Valley. After applying continuous wetting to a 75m deep collapsible soil deposit for 484 days, the wetting front advanced to a depth of 45m below the ground level. The resulting hydrocollapse settlement observed was 4.1m! 5.

Precautions

- When dealing with collapsible soils that will be subject to wetting depths of ≤ 2 meters, common measures are to:
- i. pre-wet the soil;
- ii. compact the soil using heavy rollers and heavy tamping.
- iii. treat the soil with sodium silicate and/or calcium chloride solutions to provide cementing that is not water soluble.
- When dealing with collapsible soils subject to large wetting depths, then deep foundations through the collapsible soils are commonly used.

EXAGGERATED EXAMPLE OF DAMAGE TO A HOME AS A RESULT OF SHRINKING OR SWELLING SOILS

Sources

- http://www.azgs.state.az.us/GEOHAZARDS/images/soils_popcorn_.jpg
- http://www.aegweb.org/images/Geologic%2520Hazards/expansive_map.gif&imgrefurl=http://www.aegweb.org/
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