

1977/23. A review of the literature on expansive soils.

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RECOGNITION OF EXPANSIVE SOILS

INDEX METHODS (I)

<i>Swelling potential</i>	<i>Plasticity index</i>
Low	0-16
Medium	10-35
High	20-55
Very high	>35

Not all soils with high PI will have high swelling potential.

Shrinkage limit. Does not show good correlation with expansion.

Free swell. Soils with values over 100 may cause difficulties. From Chen (1975); $S = Be^{A(PI)}$.

Where S = swelling potential [Proctor optimum density. Load 6.894 kPa (1 p.s.i.)]
 $A = 0.838$
 $B = 0.2558$

DIRECT MEASUREMENT

Swelling potential and swelling pressure are important measurements. Usually these tests should be conducted on undisturbed samples at natural moisture content, or on remoulded soils which have been compacted at Proctor optimum density. The usual surcharge load is 6.894 kPa (1 p.s.i.) but Chen (1975) considers 68.94 kPa (10 p.s.i.) to be more suitable.

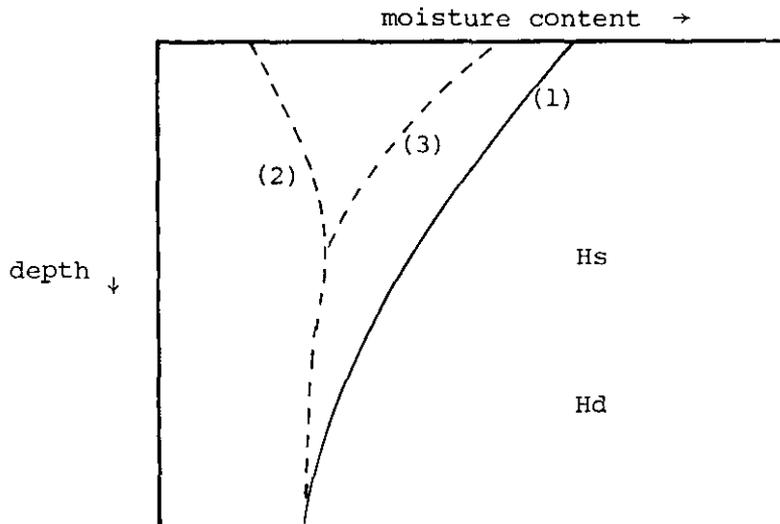
MECHANICS OF SWELLING

Expansion takes place with increase of moisture content, but it can be restrained by sufficient pressure.

Moisture migration beneath a house. There is a long term increase in the moisture content of soils beneath a house. This can be due to:

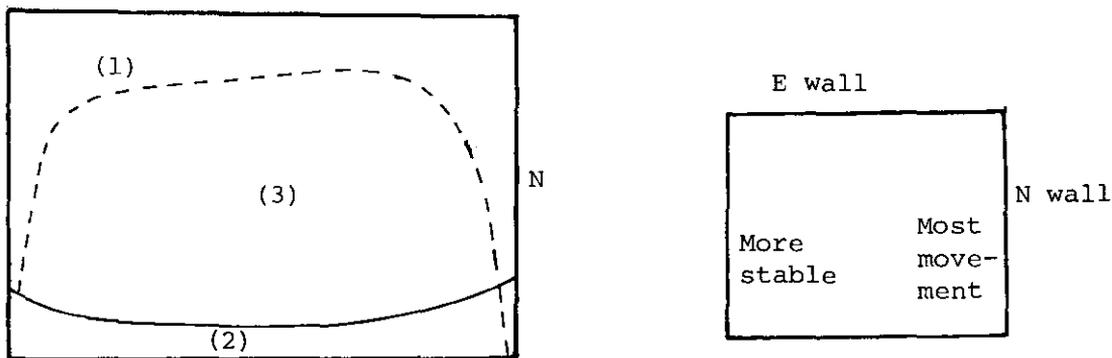
- (1) Capillary rise of moisture from the water table, with no evaporation possible.
- (2) Moisture migration under thermal gradient, as moisture will migrate to cooler areas. This is particularly efficient near the plastic limit.
- (3) Specific moisture problems.
 - (a) Poorly compacted back fill.
 - (b) Subsurface spring.
 - (c) Poor surface drainage for stormwater etc.
 - (d) Broken plumbing.

From personal observation, long term increase in moisture content does not occur under a house with footing foundations.



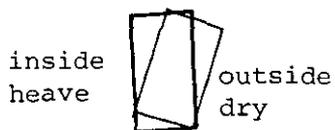
- (1) Equilibrium moisture content, reached after many years beneath a covered surface.
- (2) Desiccated moisture content in uncovered area.
- (3) Wet season moisture content in covered area.

Hs depth of seasonal change.
 Hd depth of desiccation.



- (1) Maximum seasonal change of M.C.
- (2) Smaller seasonal change.
- (3) Heave zone.

If shrinkage is important the outer walls will splay.



DAMAGE TO STRUCTURES

Total heave, differential heave, shrinkage and ground movements beneath a building on expansive clay are due to:

- (1) General long term heave (see moisture migration beneath a house).
- (2) Seasonal movements in the outer walls.
- (3) Localised movements due to tree transpiration, broken services etc.

For (1), Chen (1975) considers that the effect is always one of heave, yet considers that when slab is placed in wet weather long term settlement will occur, quoting a case of 3-inch heave or 1-inch settlement. Settlement may occur as a loading effect, rather than as a drying effect. Percentage saturation will always increase.

For (2), Chen (1975) considers this effect to be insignificant, whereas Yeates (1972) considers it to be important. If this effect is noticeable, the effects should be seen mostly at the north, west and east walls.

SWELLING PRESSURE AND SWELLING POTENTIAL

Swelling pressure (S.Pr) is the pressure needed to prevent soil expansion when it is wetted (Chen, 1975, p.57).

Swelling potential is the potential volume expansion of a soil due to wetting.

Swelling pressure

- (1) Swelling pressure of a clay is independent of surcharge pressure, the initial moisture content, the degree of saturation or the thickness of the strata.
- (2) Swelling pressure increases with the increase of initial dry density in a log-log relationship (Chen, 1975, p.58).
- (3) For undisturbed soil S.Pr is the pressure required to keep the volume of a soil at its natural dry density constant (when wetted).
- (4) For remoulded soils S.Pr is the pressure required to keep the volume of soil at its maximum Proctor density.
- (5) S.Pr can be used as a yardstick for swelling soils. It reflects only the swelling characteristics of the soil and will not be changed by placement or environmental conditions.

Swelling potential

- (1) Swelling potential is dependent on surcharge pressure in a log-linear relationship (Chen, 1975, p.45).
- (2) Swelling potential has a direct linear relationship to the degree of saturation at the end of the test (Chen, 1975, p.48).
- (3) Swelling potential has a direct linear relationship to the initial moisture content (constant initial density). Before further wetting the high moisture soils compressed under load.
- (4) Volume change is proportional to sample thickness.
- (5) S.P. has a direct relationship to initial dry density.

TOTAL HEAVE

Total heave is dependent on:

- (1) The thickness of expansive soils above the water table.
- (2) Their initial moisture content; when the water table is near surface there is seldom any difficulty as the soils beneath the structure are rapidly saturated.
- (3) Surface drainage.

Predicting total heave is complex. A method is outlined by Chen (1975, p.41).

Differential heave may be of equal magnitude to total heave.

GENERAL SITE TREATMENTS

Moisture control

Polythene membrane may be placed around buildings to control seasonal fluctuations at the building edge. As the membranes are easily holed the soil beneath will soon saturate. Chen (1975) does not recommend the method.

Concrete aprons may control seasonal effects at the edge of the building. If carefully constructed they can also help to direct surface drainage away. There must be an effective seal between the building and the apron, but it should not be tied into the building. The apron needs constant maintenance, but is cheap.

Back-fill, when properly constructed, serves as a vertical moisture barrier which slows down the wetting process, and helps to make it more even. When poorly constructed, back-fill allows surface water to seep freely into the foundation soils. Soil should be compacted in 100 mm layers to 85% Proctor density to be an effective moisture barrier.

Subsurface drainage. Intersecting drains can be used to intersect free water or perched water. The drains should extend 600 mm below the base of the foundations and lead to a suitable outlet.

Peripheral drains, either immediately inside or outside the foundation wall, can be used to prevent free-flow and also lateral capillary transfer. They should be back-filled with gravel graded at 20 mm to 50 mm and less than 5% fines.

Surface drainage is important and can be done by grading of the surface and piping away storm drainage etc. Shrubs next to the foundation need to be watered so that excess water gets into foundation materials.

Large bushes and trees cause differential drying and should be at least 3 m from the structure.

Interior plumbing should be carefully checked for leakage.

Pre-wetting

This aims at achieving maximum heave before construction. The method usually involves excavation and flooding for 1-5 months.

Difficulties include uneven moisture content as the water travels through fissures, length of time required, insufficient depth of penetration and weakening of materials to a value less than 992×10^3 kPa (1000 p.s.f.).

The method is cheap and may be useful for slab construction but probably not for footings.

Compaction and loosening

When a building is underlain by swelling soils at a low density, both swelling pressure and swelling potential is reduced. This is only suitable for light structures and needs compaction control which is designed on the basis of swell tests on soils of varying density (Chen, 1975, p.165). Between 0.6 m and one metre of such material is most often used.

Soil replacement

The excavation and replacement of expansive soils by non-expansive fill, usually to a depth of 1-2 m. Preferably all expansive soil above the water table can be replaced. When there is more expansive soil below the replacement material total heave will be partially reduced, but differential heave can be reduced by 60-70%. This method is often used with a rigid raft foundation.

Fill should extend well beyond the building line. It should be compacted to 90% Proctor density for slab and 95% for supporting footings.

It is important that the excessive wetting of the natural soils is not allowed to happen whilst the fill is laid. Replacement fill must be non-expansive, and preferably impermeable also, so that a percolation path is not provided. Lime stabilisation is expensive.

FOUNDATIONS

Shallow raft and slab on ground

Without considerable reinforcing, these types of foundation are subject to damage. They may be usable when combined with pre-wetting, aprons and stiffening.

Stiff raft foundations may be used when a series of internal and edge beams are cast in the slab. The reinforcement is related to the expected distortions and keeping them in prescribed limits. This method is cheaper than deep piers.

Footing foundations

These can be successfully used if:

- (1) Sufficient dead load pressure is exerted.
- (2) The structure is ridged enough so that differential heave will not cause cracking.

Residential houses normally exert a pressure of 496×10^3 kPa (500 p.s.i.) to 992×10^3 kPa (1000 p.s.f.) for spread footings. This load can be increased by using very narrow footings, or placing the foundation wall directly on the soil. It is essential that there are no soft pockets where settlement could occur, that there is sufficient reinforcement of the footing wall to ensure rigidity and that the walls are restrained against earth pressure.

Footings can be used when the soil has a relatively high bearing capacity, and moderately swelling pressure, and where the layer of expansive soil is too deep to make piers economic (Chen, 1975, p.103).

Box construction. When there is no discontinuity in the structure heavy reinforcing can be used in the foundation or cellar walls as a base for the building. Reinforced concrete walls in a rectangle can support considerable differential heave. Masonry or bricks cannot be used for this job.

Drilled pier and beam footings

These can be used where the rock is shallow, or where a zone of constant moisture is shallow, or where soils are very expansive and other methods are not feasible (e.g. when over 75 mm of expansion can be expected). It is essential to isolate the substructure from the soil, and this increases structural costs.

Pier uplift can be caused when wall friction in the zone of seasonal moisture change is greater than the load, and the friction in the stable zone, or it can be caused by groundwater rising. Settlement can also be a problem. Engineering design is necessary.

REFERENCES

CHEN, F.H. 1975. *Foundations on swelling soils.* Elsevier : Amsterdam.

YEATES, J.A. 1972. *Foundations and road construction on swelling clay.* in *Symposium on physical aspects of swelling soils.* University of New England : Armidale.

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