

TECHNICAL NOTE NO. 2.1.5

Requirements for Expansive Soils

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The design of Geopier elements in expansive soils and related moisture conditioned soils require special attention. This Technical Note provides guidance for the design of Rammed Aggregate Pier (RAP) elements in expansive soils and related moisture conditioned soils. An overview, general design protocol, and requirements are presented herein.

EXPANSIVE SOIL OVERVIEW

Expansive soils include a fine-grained material that has the potential to volumetrically expand from the addition of water. Soil expansion can cause significant foundation issues for structures (e.g., cracking and differential settlement). The mineral composition, size, and shape influence the rate and magnitude of volume change. Local experience, minerology (i.e., geology), and laboratory tests (e.g., Atterberg Limits – ASTM D4318, Wetting-Induced Swell – ASTM D4546) help aid the geotechnical engineer to better assess the potential for expansive properties.

The Atterberg Limits, specifically the Plastic Limit (PL) and Liquid Limit (LL), are required to estimate the degree of plasticity of fine-grained soil. The Plasticity Index (PI) is the difference between the Liquid Limit and Plastic Limit. The degree of plasticity of a fine-grained soil is directly related to the value of PI, as shown in Table 1.

Table 1. Degree of Plasticity of Fine-Grained Soils

Degree of Plasticity	Plasticity Index (PI)
None or Slight	0 to 4
Low	4 to 20
Medium	20 to 30
High	30 to 40
Very High	>40

The degree of plasticity, as shown by Table 1 (Seed et al. 1962), can be paired with the Plasticity Chart, as shown in Figure 1, to assess the expansion potential of a fine-grained soil by classifying the sample as fat (H) or lean (L) and as clay (C) or silt (M). Fat soils generally have higher plasticity than lean soils. The Plasticity Chart illustrates the fat and lean delineation by a vertical line at a Liquid Limit of 50. A soil sample's relation to the "A-line" is an empirical method to distinguish if the soil is clay or silt; clays and silts fall above and below the A-line, respectively. The A-line is represented by: $PI = 0.73*(LL-20)$.

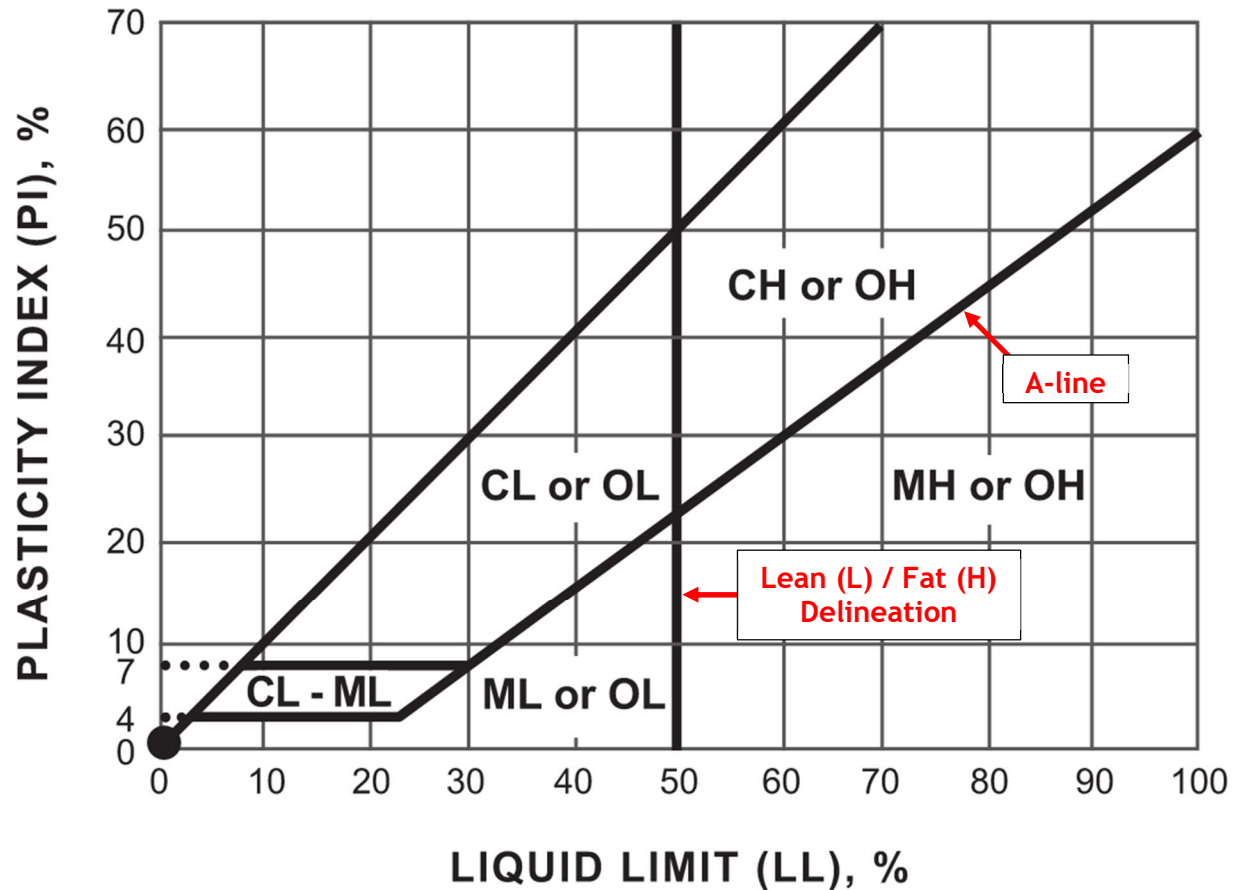


Figure 1. Plasticity Chart.

Skempton (1953) introduced *Activity* (A) as a relatively simple means to measure the colloidal behavior of a clay (i.e., tendency to attract or repel electrical charge). Colloidal Activity is defined as the ratio of PI to the percentage by weight of particles finer than 2 microns. Mineralogy has a significant effect on the degree of colloidal activity. Skempton defined *inactive clay* with $A < 0.75$, *normal clay* with A between 0.75 to 1.25, and *active clay* with $A > 1.25$. Clay minerals kaolinite, illite, and montmorillonite, have low to very high expansive potential, respectively, as shown in Table 2.

Table 2. Typical Clay Minerals, Activity, and Expansive Potentials

Mineral	Liquid Limit	Plasticity Index	Activity / Expansive Potential
Kaolinite	35 – 55	10 – 20	0.33 – 0.45 / LOW
Illite	100 – 120	50 – 70	0.9 / MEDIUM
Montmorillonite	500 – 700	425 – 650	1.5 – 7.2 / VERY HIGH

The project geotechnical engineer often estimates the magnitude of volume change in inches and typically define this value as the Potential Vertical Rise (PVR). PVR is estimated by empirically derived charts that relate plasticity index and structure load to percent volume strain (see TxDOT Tex-124-E). Direct measurement tests on soil specimens can also be performed, including one-dimensional swell test (ASTM D4546) and centrifuge test methods presented by University of Texas.

Structurally, expansive soils present the greatest risk to floor slabs, which have a relatively low contact pressure that is unable to overcome the expansive pressure. Expansive soils also present risk to footings, however the risk is less because footings often have a much higher contact pressure that is in some cases able to compensate and/or exceed the expansive pressure.

GENERAL DESIGN PROTOCOL AND REQUIREMENTS

Geotechnical engineers may recommend one or more moisture conditioning treatment options to limit the PVR magnitude of an expansive soil. Moisture conditioning options are presented with a PVR magnitude estimate and corresponding remediation depth (i.e., moisture condition zone) that generally ranges between 3 ft to 10 ft below finished grade. Standard Geopier design procedures apply for cases when footings are embedded below the MC zone in the native soils.

There are three primary moisture conditioning methods:

- 1) Removal and replacement of expansive soils with structural fill utilizing a moisture content above optimum. We expect fine-grained structural fill to have a stiff to very stiff consistency if compacted in accordance with typical geotechnical specifications.
- 2) Chemical injection with a chemical stabilizer, such as lime slurry, that causes a chemical reaction within the soil matrix to reduce the expansive potential of native soils. We expect stiff to very stiff consistencies from chemical injection.
- 3) Water injection to initiate soil expansion prior to construction. We estimate soft soils or isolated soft zones to result from the water injection process.

Standard Geopier protocol is to rely on the project geotechnical engineer of record to identify expansive potential and the proper remediation method. If we identify an expansive potential based on the PI of the soil as discussed previously that was not identified by the geotechnical engineer, we should specify that in the design review and clearly state that Geopier elements do not mitigate expansive potential. However, no special design considerations are required.

When the project geotechnical engineer of record identifies expansive potential but does not provide a mitigation method, we should indicate the geotechnical engineer's conclusion regarding expansive potential in the design review and clearly state that Geopier elements do not mitigate expansive potential. However, no special design considerations are required.

When the project geotechnical engineer of record identifies expansive potential and provides a mitigation method, the Geopier design approach will vary depending on the mitigation method and building loading conditions. It is important to confirm footing embedment depths and moisture conditioned (MC) zone depths as footings are typically embedded within MC zone. In this case, Geopier elements require special design protocol as outlined below:

- 1) MC method 3 requires full depth cement treated aggregate (CTA) within the MC zone. This need is governed by the risk and uncertainty of soil non-homogeneity resulting from water injection.
- 2) MC methods 1, 2, and 3 require full depth cement treated aggregate (CTA) within the MC zone for footing loads exceeding 500 kips.
- 3) MC methods 1 and 2 may utilize untreated aggregate provided protocol #2 does not apply. This option requires a low permeability cap (see special considerations below). Design parameters in accordance with 7-9 bl/ft fine-grained soils are expected.

Please note the following special considerations:

- CTA must extend at least 2 ft below the moisture conditioned zone as shown in Figure 2. Untreated aggregate may be used beneath the CTA zone to develop geotechnical capacity in end bearing and skin friction.
- Cement treated sand (CTS) may be used as a 1:1 replacement to CTA provided the use of sand backfill is applicable (i.e., see TN 13.2.4 for guidance).
- A low permeability cap is required for protocol #3 (untreated aggregate). There are several options that function as a low permeability cap, which are provided below. Note that all cap options require a 1-ft thick compacted lift of untreated aggregate between the footing bottom and top of cap.
 - 6 inches of moisture conditioned drill spoil;
 - 3 inches to 6 inches of bentonite chips;
 - 6 inches of non-expansive on-site fill;
 - Or a 6" CTA/CTS cap.

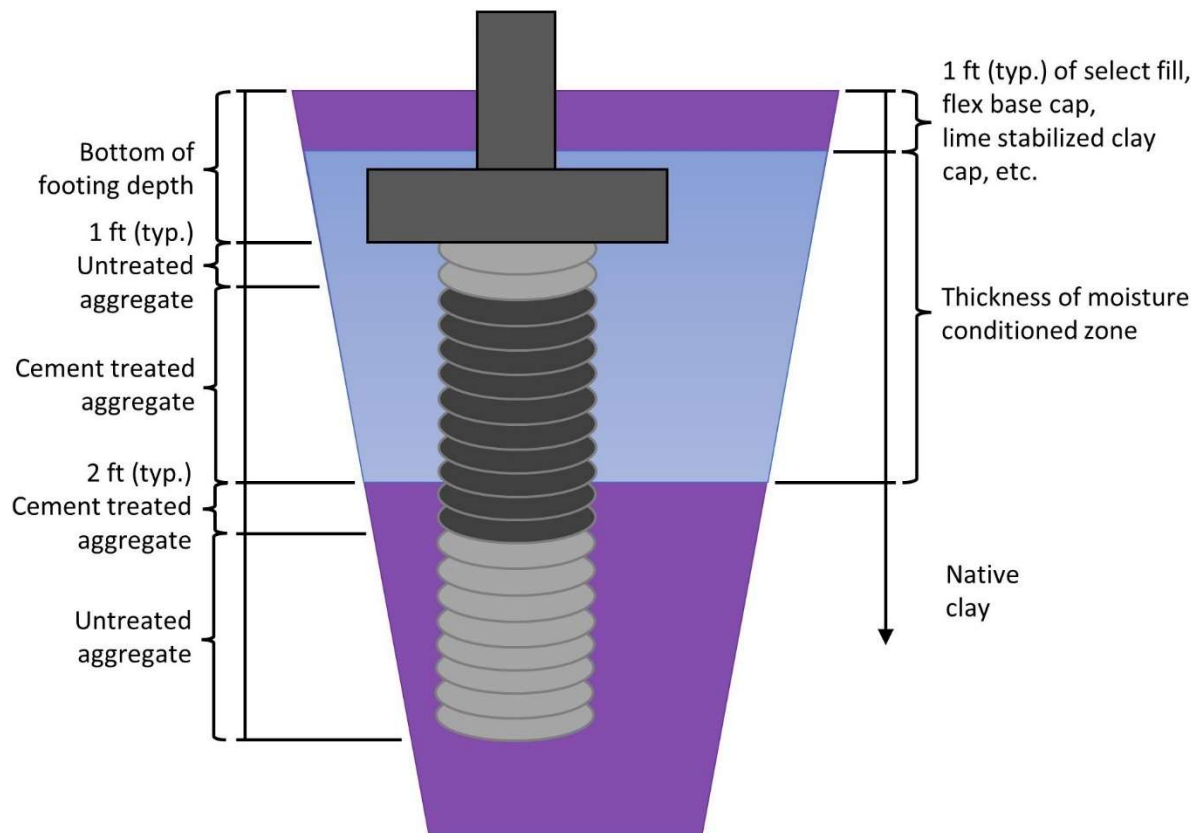


Figure 2. Typical moisture conditioned profile with cement treated aggregate pier.

References

Seed, H.B., R.J. Woodward, Jr., and R. Lundgren (1962). "Prediction of swelling potential for compacted clays," *ASCE J. Soil Mech.*, **88**, No. SM3, pp. 53-87.