

The logo for DATUM, featuring the word "DATUM" in a bold, white, sans-serif font with a slight shadow effect, set against a dark, gradient background that transitions from light to dark.

**DESIGNING
STRUCTURES IN
EXPANSIVE
CLAY**

*A GUIDE FOR
ARCHITECTS
AND
ENGINEERS*



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I. INTRODUCTION

Expansive clay soil common to many parts of Texas, as well as elsewhere, has caused significant structural damage to an alarming number of buildings. Soil swells of over 12" have been recorded in the Las Colinas area northwest of Dallas. The pressures generated by swelling clay can be devastating to a foundation if not managed correctly.

Despite all of the technical knowledge available to combat the problem, new construction continues to suffer damage. Structural distress caused by swelling clay even occurs in cases where the geotechnical engineer, structural engineer, architect, and contractor have utilized every conceivable state-of-the-art precaution known to prevent distress.

No simple solution exists. Each project is unique in its location, soil properties, stratigraphy, drainage, and structural requirements. The expansive potential of soil at any given site can vary dramatically from one season to the next, due to moisture content which is the driving force in the shrink/swell cycle, i.e.; a building constructed after a rainy period may experience fewer problems than one constructed at the end of a dry summer. To complicate matters, soil conditions are not uniform between test boring locations. A dip in the rock, an underground spring or a variation in a clay seam can, and often does, occur between reasonably spaced borings. So the destructive capacity of the soil may go undetected and only later defeat the most carefully applied efforts of the design team.

Compounding the problem, a circuitous and somewhat unreliable process exists for dealing with expansive clay. Geotechnical engineers apply different formulas and techniques, so their predictions of movement and recommendations are not always uniform. Architects and structural engineers implement various concepts in response to their perception of the geotechnical engineer's recommendations. Then, contractors and subcontractors implement the requirements of the architect's and engineer's drawings to varying degrees of compliance and understanding so that the final product might not be what is truly needed to protect against swelling clay. The landscape architect and civil engineer also play major roles in contributing, however inadvertently, to the buildings distress through their design concepts and details. For example; irrigation sprinklers can have a devastating effect when located next to a corner of the foundation or carton forms.

Since each project is unique it's difficult to modify standard specifications and details to properly address the problem. Rather, there is an optimum solution for each project which must be pursued in a concerted effort by the design team on a project-by-project basis. A successful solution depends on dedication to this principle and an understanding that applying standard details or construction techniques used on a previous building, however successful they may have been, will not suffice.

Nevertheless, there are many basic principles one should apply when confronted with expansive clay soil conditions. The purpose of this booklet is to discuss these principles and their proper application by architects, engineers, and contractors. The designer must determine which specific details apply to a particular project. But, in most cases, these principles simply represent sound construction practices for all buildings constructed in expansive soil.

II. COMMON FOUNDATION SYSTEMS

Two of the most common foundation systems used in commercial building construction in the north Texas market are:

Pier and grade beam foundation with a structurally suspended ground floor slab.

Pier and grade beam foundation with a slab-on-grade (soil supported) ground floor.

Other areas might use footings or piles to support the concrete grade beams, but the concepts are the same.

A third system, which is common in residential construction, is a floating waffle slab foundation cast directly on the ground. However, there are many potential problems with this system when constructed on expansive soil and similar care and concern should be used. This system is not commonly found in commercial construction and will not be addressed in this booklet.

III. DRILLED PIERS

The foundation systems which are most prevalent in expansive clay areas utilize drilled piers to support the loads of the superstructure. The most common pier systems are:

- A. **SKIN FRICTION PIERS:** Are straight shaft piers ranging in diameter from a minimum of 12" (used on small lightly loaded elements of a building like a porch), up to about 72" (used on high-rise structures). These shafts extend down through the expansive soils layers into a firm bearing strata of limestone or shale. They socket deep into the bedrock bearing stratum and depend on both the end bearing and skin friction along the sides of the shaft in contact with the bearing stratum to support the structures load.

With this system the drilled pier shaft comes in contact with the expansive soil materials above the bearing material, however, it's customary to not count on skin friction in the expansive clay to support the structural loads. The upper clays are required to laterally brace the pier shaft so that the pier can be designed as a continuously braced concrete section in compression, without regard to buckling. Since the upper shaft is in direct contact with the expansive clay, a key concern is that the expansive clay is capable of gripping the sides of the drilled pier shaft and pulling it entirely out of the bearing stratum socket, or even pulling it apart.

In the early 1960's a system came into use to eliminate the gripping force of the expansive soils on the pier shaft. It consisted of drilling an oversized pier hole and lining its perimeter with 6" thick bags of vermiculite. These bags were held in place with a smaller diameter Sonotube form, then concrete was placed inside the Sonotube. The concept being that the vermiculite bags would insulate the drilled piers from the clay, thereby preventing the gripping process. However, the layer of vermiculite around the pier created a space in which water could flow down to the pier and initiate even greater swelling problems than would have been experienced had the vermiculite bags not been used. Also, the pier was separated from the ground by the vermiculite bags leaving it laterally unbraced requiring it to be designed as a column, which increased the cost of the pier. This system was used only a few times before it was determined to be too costly, slow, and difficult to verify that the construction quality had conformed to the desired intent..

We recently proposed a similar system, except we substituted Bentonite grout for the vermiculite. We feel that Bentonite will prevent seepage of water down the side of the pier (which tends to expand clays) and, at the same time, separate the pier from the surrounding expansive clays (*See Exhibit A and B*).

This system is for unusually difficult sites with deep expansive weathered shale that has a history of extreme movement and structural damage due to the depth of expanding material. Typically, the method of reinforcing the pier against uplift is satisfactory for most sites.

In the case of typical drilled pier shafts poured directly against expansive soil

(as opposed to the vermiculite bag concept), the geotechnical engineer's soil report should include design values, to be used by the structural engineer, for the following:

1. Anticipated upward force on the piers due to expanding soil.
2. Depth of expansive soil which should be included in the structural calculations for uplift force. The effective depth of the force is related to the anticipated maximum depth of moisture fluctuations within the expansive soil.
3. Anchorage capacity or minimum socket depth in the bearing stratum to prevent the piers from pulling out of the bearing stratum.

The gripping principle makes it readily apparent that when dealing with straight shafts drilled in expansive soil the following rules apply:

1. The smaller the diameter of the pier the less surface area of the pier exists for expansive soils to grip and push on. Therefore, within economic reason the shaft should be the smallest practical size necessary to support the load of the structure.
2. It's desirable to spread the piers out as far as practical and to apply as much dead load on each pier as possible. The more dead load there is holding the pier down the less the possibility of upheaval. The goal is to have more dead load on the pier than the calculated upheaval force caused by the expansive soil material. However, this isn't always possible at lightly loaded areas (such as porches and other appendages) but, as a rule, it should be attempted.
3. Drilled piers must be reinforced with extra vertical reinforcing steel to prevent being pulled apart wherever expansive soil forces exceed the dead load. It's typical to reinforce drilled shafts even if calculations don't indicate the need for reinforcement. The structural engineer should design the reinforcement based on uplift forces predicted by a geotechnical engineer. It has been customary to rely on minimum reinforcing steel percentages, however, this approach isn't always reliable. In expansive clay the general rule-of-thumb is to use a minimum area of reinforcing steel equal to 1.0% of the area of concrete. However, more reinforcing may be required if expansive soil forces exert a tensile force on the pier greater than the resistance of the minimum steel requirements.
4. The bottom of the pier must be anchored into the bearing stratum a sufficient depth to prevent pull-out from expansive clay uplift forces. This anchorage depth should be designed by a structural engineer based on the negative skin friction value given by a geotechnical engineer.
5. Where reinforcing steel is required to resist uplift forces, lap splices in the steel should be long enough to develop the ultimate tensile strength of the

reinforcing. These splice lengths should be designed by the structural engineer.

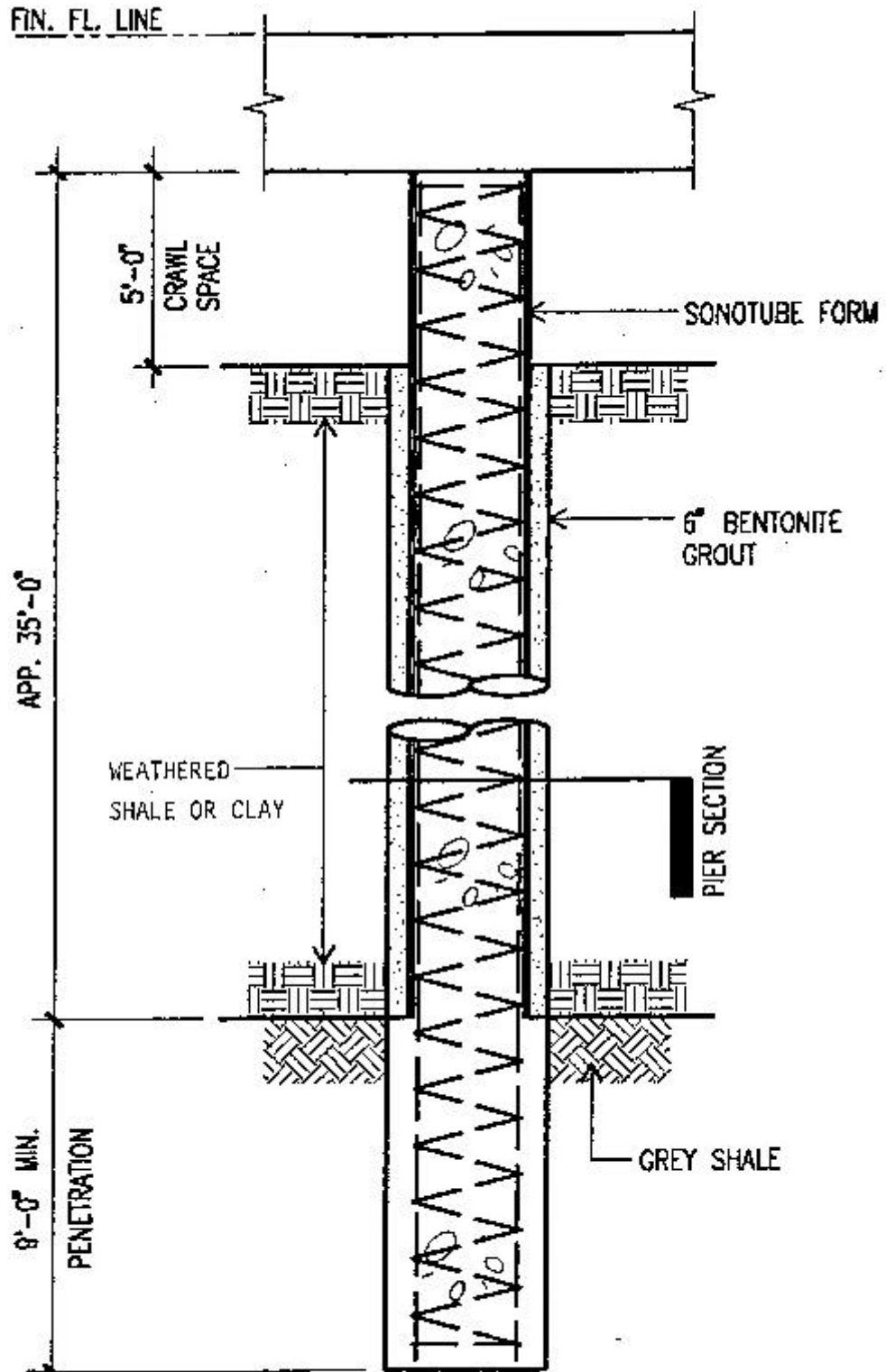
6. Connecting dowels, extending from the tops of the piers, should extend a sufficient distance above and below the connection to develop the ultimate strength of the reinforcing in tension. This is a prudent practice due to the possibility that swelling clay will exert uplift forces on the grade beam or wall supported by the pier, even if the beam or wall is detailed to be isolated from the soil.

There have been many cases of foundation beams pulling apart from piers in spite of having an isolating void space designed under the beam.

- B. BELLED PIERS: Have the same characteristics as skin friction piers, except that they depend only on end bearing. The bottom of the pier is "belled out" by underreaming to a diameter two to three times larger than the pier shaft, in order to provide additional bearing area on the bearing stratum. This system is most commonly used in areas where competent shale or limestone is uneconomically deep. An expansive soil layer might itself serve as the bearing stratum for a belled pier. Weathered shale, for example, is often quite expansive yet strong enough to support piers.

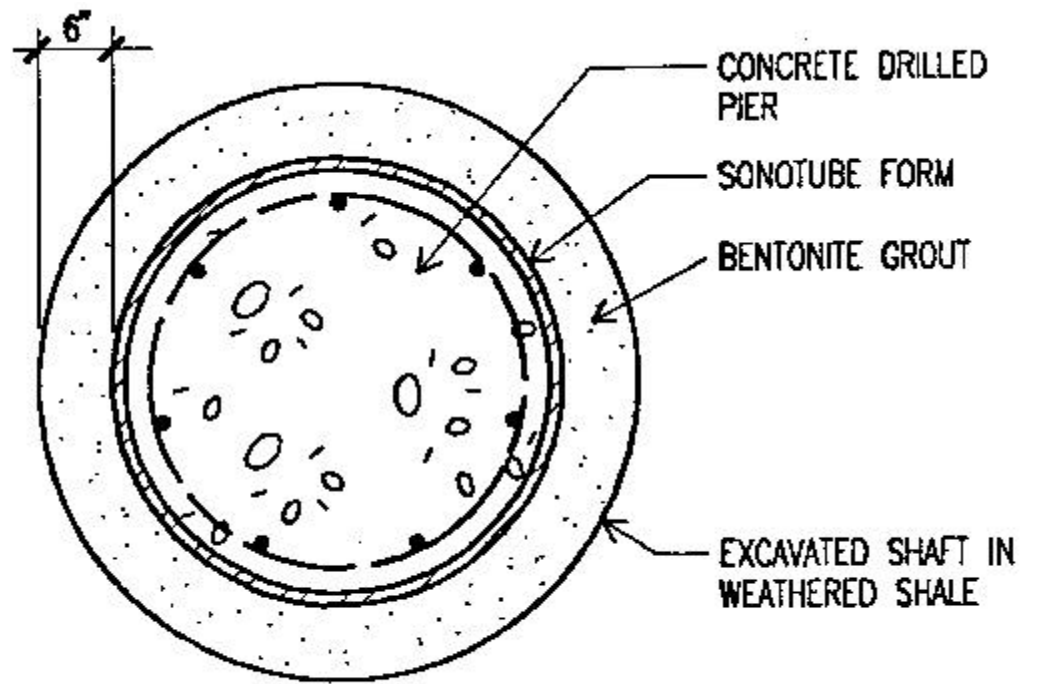
The major requirement here is to extend the bottom of the pier an adequate distance below the zone of seasonal moisture change to minimize its effect. Even so, settlements with this system are generally greater; especially where the bearing material is clay or sand.

It's not our intent to discuss all of the construction criteria necessary to construct belled pier foundation systems, but to point out that they are sometimes used and that all of the requirements listed previously for skin friction piers constructed in expansive soil also apply to belled piers. One additional requirement is that belled piers must be anchored into the soil below the zone of seasonal moisture change. Predictions for the depth of the seasonal moisture change and recommendations for the amount of anchorage must be obtained from the geotechnical engineer.



TYPICAL DRILLED PIER ELEVATION

EXHIBIT A



PIER SECTION

EXHIBIT B