Recommended Practice for the Design of Residential Foundations

Version 1

By the Texas Section
American Society of Civil Engineers

Forward to Version 1

The Texas Section of the American Society of Civil Engineers (ASCE) adopted Guidelines for residential foundation engineering on October 3, 2002, with an effective date of January 01, 2003. The Section began this work in 1999.

This effort grew out of the response of many Section members to the Policy Advisory issued by the Texas Board of Professional Engineers (TBPE) in 1998, which addressed residential foundation engineering. Many ASCE practitioners expressed the opinion that technical guidelines should more rightly be created by a technical society such as ASCE rather than by the TBPE. One goal of the guidelines has been to provide the TBPE with guidance in their evaluation of complaints brought against engineers practicing residential foundation engineering.

The committees were composed entirely of ASCE members who were licensed engineers. The dollar value of the professional services donated to the effort is conservatively estimated to exceed $1,000,000.

The Guidelines are not intended to be Standards, but are guidelines only, reflecting the engineering opinions and practices of the committee members. They in no way replace the basic need for good engineering judgment based on appropriate education, experience, wisdom, and ethics in any particular engineering application. Thus, they are primarily suited as an aid for and use by engineers.

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Table of Contents

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Section 1. INTRODUCTION

1.1 Objective

The function of a residential foundation is to support the structure. The majority of foundations constructed in Texas consist of shallow, stiffened and reinforced slab-on-ground foundations. Many are placed on expansive clays and/or fills. Foundations placed on expansive clays and/or fills have an increased potential for movement and resulting distress.

National building codes have general guidelines, which may not be sufficient for the soil conditions and construction methods in the State of Texas. The purpose of this document is to present recommended practice for the design of residential foundations to augment current building codes to help reduce foundation related problems. Where the recommendations in this document vary from published methods or codes, the differences represent the experience and judgment of the majority of the committee members.

On sites having expansive clay, fill, and/or other adverse conditions, residential foundations shall be designed by licensed engineers utilizing the provisions of this document. Expansive clay is defined as soil having a weighted plasticity index greater than 15 as defined by Building Research Advisory Board (BRAB) or a maximum potential volume change greater than 1 percent. This provision should also apply where local geology or experience indicates that active clay soils may be present. We propose that local and state governing bodies adopt this recommended practice.

1.2 Limitation

This recommended practice has been developed by experienced professional engineers and presents practices they commonly employ to help deal effectively with soil conditions that historically have created problems for residential foundations in Texas. This recommended practice presumes the existence of certain standard conditions when, in fact, the combination of variables associated with any given project always is unique. Experienced engineering judgment is required to develop and implement a scope of service best suited to the variables involved. For that reason, the developers of this document have made an effort to make the document flexible. Thus, successful application of this document requires experienced engineering judgment; merely following the guidelines may not achieve a satisfactory result. Unless adherence to this document is made mandatory through force of law or by contractual reference, adherence to it shall be deemed voluntary. This document does not, of itself, comprise the standard of care which engineers are required to uphold.

1.3 Adopted Changes

The Texas Section of the American Society of Civil Engineers (ASCE) has adopted procedures for changing the guidelines. In general, those interested in submitting changes for consideration by the Section should access the website at www.texasce.org, and follow the instructions for submitting changes. Changes may also be submitted in writing to the Texas Section - ASCE, 3501 Manor Road, Austin, 78723, phone 512.472.8905, fax 512.472.2934. Anonymous changes will not be considered. Those submitting changes should include contact information, state why a change is proposed, include applicable calculations if appropriate, and provide alternative language to incorporate the change. The appropriate committee will consider the changes, and from time to time the Texas Section may adopt the changes and issue revised Guidelines.

Readers should check with the Texas Section ASCE to make sure they are using the most recent version.

Section 2. DEFINITION OF "ENGINEERED FOUNDATION"

An engineered foundation is defined as one for which design is based on three phases:

a. geotechnical engineering information
b. the design of the foundation is performed by a licensed engineer
c. construction is observed with written documentation

These phases are described herein.

Section 3. DESIGN PROFESSIONALS' ROLES AND RESPONSIBILITIES

3.1 Geotechnical Services

Prior to foundation design, a geotechnical investigation and report shall be completed by a geotechnical engineer.

3.2 Design Services

The foundation design engineer shall prepare the plans and specifications for the foundation, and shall be the engineer of record. The foundation shall be built in accordance with the design. The engineer of record shall approve any design modifications. The geotechnical and foundation design engineering may be performed by the same individual.

3.3 Construction Phase Services

The engineer of record shall specify on the plans that construction phase observations shall be incorporated into the foundation construction. These activities shall be performed by: the engineer of record or a qualified delegate. The qualified delegate may be a staff member under his/her direct supervision, or outside agent approved by the engineer of record. The observation reports shall be provided to the engineer of record. The engineer of record shall issue a compliance letter as described in Section 6.3.

Section 4. GEOTECHNICAL INVESTIGATION

4.1 Minimum Field Investigation Program

The geotechnical engineer, in consultation with the engineer of record, if available, shall lay out the proposed exploration program. A minimum exploration program for subdivisions shall cover the geographic and topographic limits of the subdivision, and shall examine believed differences in geology in sufficient detail to provide information and guidance for secondary investigations, if any. The geotechnical exploration program should take into account site conditions, such as vegetation, depth of fill, drainage, seepage areas, slopes, fence lines, old roads or trails, man-made constructions, the time of year regarding seasonal weather cycles and other conditions that may affect foundation performance.

As a minimum for unknown but believed to be uniform subsurface conditions, borings shall be placed at maximum 300-foot centers across a subdivision. Non-uniform subsurface conditions may require additional borings. One soil boring may be sufficient for a single lot investigated in isolation for a simple residence under 2500 square feet. However, more borings may be required on sites having fill, having large footprints, or noticeably varying geological conditions such as steep slopes or locations near known fault zones or geological transitions.

Borings shall be a minimum of 20 feet in depth unless confirmed rock strata is encountered at a lesser depth. However, if the upper 10-ft of soils are found to be predominately cohesionless, then the boring depth may be reduced to 15 ft.. Borings shall extend through any known fill or potentially compressible materials even if greater depths are required.

All borings shall be sampled at a minimum interval of one per two feet of boring in the upper 10 feet and at 5-foot intervals below that. In clayey soil conditions, relatively undisturbed tube samples should be obtained. In granular soils, samples using Standard Penetration Tests should be obtained. Borings shall be sampled and logged in the field by a geotechnically-trained individual and all borings shall be sampled such that a geotechnical engineer may examine and confirm the driller's logs in the laboratory.

Exploration may either be by drill rig or by test pit provided the depth requirements are satisfied. Sites, which are obviously rock with outcrops showing or easily discoverable by shallow test pits, may be investigated and reported without resorting to drilled borings.

Field logs shall note inclusions, such as roots, organics, fill, calcareous nodules, gravel and man-made materials. If encountered, the depth to water shall be logged. If the geology or site conditions indicate, overnight water levels shall be recorded prior to backfilling boreholes. Additional measurements shall be taken at the direction of the geotechnical engineer.

4.2 Minimum Laboratory Testing Program

The geotechnical engineer, in consultation with the engineer of record, if available, shall develop the laboratory-testing program. Sufficient laboratory testing shall be performed to identify significant strata and soil properties found in the borings across the site. Such tests may include:

a. Dry Density
b. Moisture Content
c. Atterberg Limits
d. Pocket Penetrometer Estimates of Cohesive Strength
e. Torvane
f. Strength Tests
g. Swell and/or Shrinkage Tests
h. Hydrometer Testing
i. Sieve Size Percentage
j. Soil Suction
k. Consolidation

All laboratory testing shall be performed in general accordance with the American Society for Testing and Materials (ASTM) or other recognized standards.

4.3 Geotechnical Report

4.3.1 Report Contents

Geotechnical reports shall contain, as a minimum:

a. purpose and scope, authorization and limitations of services
b. project description, including design assumptions
c. investigative procedures
d. laboratory testing procedures
e. laboratory testing results
f. logs of borings and plan(s) showing boring locations
g. site characterization
h. foundation design information and recommendations
i. Professional Engineer's seal

4.3.2 Site Characterization

The geotechnical engineer shall characterize the site for design purposes. The report shall comment on site conditions which may affect the foundation design, such as:

a. topography including drainage features and slopes
b. trees and other vegetation
c. seeps
d. stock tanks
e. fence lines or other linear features

f. geologic conditions
g. surface faults, if applicable
h. subsurface water conditions
i. areas of fill detected at the time of the investigation
j. other man made features

4.3.3 Foundation Design Information and Recommendations

Reports shall contain the applicable design information and recommendations requested by the engineer of record for each lot in the project. If the engineer of record is not known at the time of the geotechnical report, the following design information should be presented, if applicable.

4.3.3.1 Soil movement potential as determined by the estimated depth of the active zone in combination with at least two of the following methods (identify each method used):

a. Potential Vertical Rise as determined by the Texas Department of Transportation Method 124-E, dry conditions
b. Swell tests
c. Suction and hydrometer tests
d. Linear Shrinkage tests
e. Any other method which can be documented and defended as good engineering practice in accordance with the principles of unsaturated soil mechanics

4.3.3.2 BRAB design information including:

a. Climatic Rating (C_w) of the site
b. Weighted Plasticity Index
c. Bearing capacity of the soil

4.3.3.3 Post-Tensioning Institute (PTI) parameters (using their most current design manual and technical notes) including:

a. e_m and y_m for edge lift and center lift modes (The e_m and y_m in the PTI design manual are based on average climate controlled soil movements and the design recommendations should take into account the added effect of trees and other environmental effects, as noted in the PTI design manual).
b. Bearing capacity of the soil.
c. If suction values are used to determine the depth and value of suction equilibrium or evaluate special conditions such as trees, the values shall be determined using laboratory suction tests. y_m determination shall be based on suction profile change and laboratory determined values of suction-compression index.
d. e_m and y_m shall be reported for design conditions for suction profile varying from equilibrium, and for probable extreme suction conditions.

4.3.3.4 Wire Reinforcing Institute (WRI) parameters including:

a. Climatic Rating (C_w) of the site
b. Weighted Plasticity Index
c. Slope Correction Coefficient (C_s)
d. Consolidation Correction Coefficient (C_o)

4.3.3.5 Deep Foundation (pier/pile) design information including:

a. Bearing capacity and skin friction along the pier length
b. Pier types and depths, and bearing strata
c. Uplift pressures on the pier and estimated depth of active zone (pier depth must be below the active zone and provide proper anchorage to resist the uplift pressures)
d. Down drag effects on the piers

4.3.3.6 Shallow foundations (including post and beam footings) design parameters.

a. Bearing capacity and footing depth
b. Minimum bearing dimension

4.3.3.7 Soil treatment method(s) to reduce the soil movement potential and the corresponding reduction in predicted movement.

4.3.3.8 Lateral pressures on any retaining structures or on piers undergoing lateral forces.

4.3.3.9 Trees and other site environment concerns that may affect the foundation design. Information useful for design and construction of residential foundations is presented in Appendix A.

4.3.3.10 Moisture control procedures to help reduce soil movement.

4.3.3.11 Surface drainage recommendations to help reduce soil movement.

4.3.3.12 Potential for load induced settlement.

4.3.3.13 On sloping sites, recommend whether a slope stability analysis is required due to possible downhill creep or other instability that may be present.

4.3.3.14 The presence and methods of dealing with existing and proposed fill. Fill criteria useful for design and construction of residential foundations is presented in Appendix B.

4.3.3.15 Geotechnical considerations related to construction.

Section 5. DESIGN OF FOUNDATIONS

5.1 Design Information

The foundation design engineer shall obtain sufficient information for the design of the foundation. This may include:

a. information gathered by a site visit
b. the subdivision plan, site plan or plat
c. the topography of the area including original and proposed final grades
d. the geotechnical report
e. special requirements of the project
f. the project budget
g. the architectural elevations and floor plans and sufficient additional architectural information to determine the magnitude, construction materials and location of structural loads on the foundation
h. exposed or architectural concrete schedule, if applicable

5.2 Design Procedures for Slab on Ground

5.2.1 The foundation engineer shall utilize one of the following methods, with the modifications presented in this section, as a minimum:

a. BRAB
b. Finite Element
c. PTI
d. WRI
e. other methods which can be documented and defended as good engineering practice

5.2.2 Input variables for residential slab-on-ground foundations shall be as follows:

5.2.2.1 BRAB:

a. Use the current design manual and technical notes, and the following design provisions:
   - a.1 Regardless of the actual beam length, the analysis length should be limited to a maximum of 50 ft; and
   - a.2 Use a maximum long-term creep factor as provided in ACI 318, Section 9.5.2.5.

5.2.2.2 Finite Element:

a. Use soil support parameters that can be documented and defended as good engineering practice in accordance with the principles of unsaturated soil mechanics;
b. Use a cracked moment of inertia for beams that exceed the cracking moment; and

c. Use a maximum design deflection ratio of 1 / 360 (deflection ratio is defined as the maximum deviation from a straight line between two points divided by the distance between the two points).

5.2.2.3 PTI:

a. Use the current design manual and technical notes, and the following design provisions.
b. Provide minimum residual average prestress of 100 psi.
c. Maintain the calculated prestress eccentricity within 5.0 inches. Bottom beam reinforcing should always be used.
d. If the computed concrete tensile stress at service loads, after accounting for prestress losses, exceeds $4\sqrt{f'_c}$, provide bonded additional reinforcement at the top or bottom of the beam as required by tensile forces equal to 0.0033 times the gross beam section. The transformed area of steel may be used to determine a new stiffness value for the beam.
e. The e_m and y_m in the PTI design manual are based on average climate controlled soil movements and the design analysis should take into account the added effect of trees and other environmental effects, as noted in the PTI design manual.

5.2.2.4 WRI:

a. Use the current design manual and technical notes, and the following design provisions.
b. Regardless of the actual beam length, the analysis length should be limited to a maximum of 50 ft; and
c. The minimum design length (L_c) shall be increased by a factor of 1.5 with a minimum increased length of 6 ft.

5.2.3 Design Considerations

The foundation design engineer should consider the following (deviation shall be based on generally accepted engineering practice)**:**

5.2.3.1 The latest ACI publications.

5.2.3.2 Exterior corners may require special stiffening. This can be accomplished with diagonal beams or parallel interior beams near the perimeter beams.

5.2.3.3 Provide continuous beams at reentrant corners. For post tensioned foundations, all exterior and interior beams should be continuous. For conventionally reinforced beams, interior beams may be discontinuous as long as the beam is continued a distance equal to at least twice the L_c distance.

5.2.3.4 Provide stiffening beams perpendicular to offsets (such as fireplaces or bay windows) in perimeter beams when the offset exceeds 18-inches.

5.2.3.5 Provide interior beams at concentrated loads such as fireplaces, columns and heavy interior line loads.

5.2.3.6 Sites with soil movement potential (see Section 4.3.3.1) exceeding 1.0 inch should have special design considerations such as strengthened sections, revised footprint, site soil treatment, or structurally suspended foundation if any of the following conditions is present:

a. a shape factor (SF) exceeding 20, (SF = perimeter squared divided by area)
b. extensions over 12 ft.

5.2.3.7 Slab-on-ground foundations with piers shall be designed as stiffened soil supported slabs for heave conditions and as structurally suspended foundations with the beams and slabs spanning between piers for shrinkage and settlement conditions. Piers shall not be attached to the slabs or grade beams unless the connections and foundation systems are designed to account for the uplift forces.

5.3 Design Procedures for Structurally Suspended Foundations

5.3.1 Structurally suspended floors supported by deep foundations shall be designed in accordance with applicable building codes.

5.4 Design Procedures for Footing Supported Foundations

5.4.1 Design in accordance with applicable building codes.

5.4.2 Shallow individual or continuous footing foundations should not be used on expansive soils, unless the superstructure is designed to account for the potential foundation movement.

5.5 Minimum Foundation Plan and Specification Information

5.5.1 Plans shall be signed and sealed by the engineer of record, and be specific for each site or lot location. Plans shall identify the client's name and engineer's name, address and telephone number; and the source and description of the geotechnical data.

5.5.2 The engineer's drawings shall contain as a minimum:

a. a plan view of the foundation locating all major structural components and reinforcement
b. sufficient information to show details of beams, piers, retaining walls, drainage details, etc., if such features are integral to the foundation
c. sufficient information for the proper construction and observation by field personnel
d. information or notes addressing minimum perimeter and lot drainage requirements

5.5.3 The engineer's specifications shall include as a minimum:

a. descriptions of the reinforcing or pre-stressing cables and hardware;
b. concrete specifications including compressive strengths;
c. site preparation requirements;
d. notes concerning nearby existing or future vegetation and the required design features to accommodate these conditions; and
e. the schedule of required construction observations and testing.

5.5.4 The engineer's plan shall address site fill:

a. The plans shall address fill existing at the time of the design or to be placed during construction of the foundation and shall require any fills which are to support the bearing elements of the foundation to be tested and approved by a geotechnical engineer assisted by a qualified laboratory (Bearing elements of a suitably designed slab-on-ground foundation are defined as the bottoms of exterior or interior stiffener beams.)
b. The plan shall require that a geotechnical engineer issue a summary report describing the methods, and results of investigation and testing that were used, and a statement that the existing or placed fills are suitable for support of a shallow soil-supported slab-on-ground, or that the foundation elements should penetrate the fill to undisturbed material. See Appendix B for more detailed information on fills.

Section 6. CONSTRUCTION PHASE OBSERVATIONS

6.1 Responsibility for Observations

Construction phase observations and testing shall be performed in accordance with this document.

6.2 Minimum Program of Observation and Testing

At a minimum, foundations should be observed and tested as applicable to determine whether:

a. exposed subgrade soils are prepared in accordance with the plans and specifications;
b. fill material and placement are in accordance with the plans and specifications;
c. pier placement, size and depth meet plans and specifications;
d. foundation elements, including reinforcement, meet plans and specifications immediately before concrete placement;
e. concrete properties and placement meet plans and specifications;
f. for post tension slabs, stressing meets the specified elongation and stressing load of each tendon; and.
g. specified site grading and drainage has been constructed.

6.3 Compliance Letter

6.3.1 At the satisfactory accomplishment of all the requirements of the plans and specifications, the engineer of record shall provide a letter to the client indicating, to the best of his knowledge (which may be based on observation reports by a qualified delegate as defined in Section 3.3), the construction of the foundation was in substantial conformance with:

a. the minimum standards of practice presented in this document; and
b. the engineer’s plans and specifications including any modifications or alterations authorized.

6.3.2 A non-compliance letter shall be issued if the construction of the foundation did not meet the requirements of Section 6.3.1.

APPENDIX A

IMPACT OF MOISTURE CHANGES ON EXPANSIVE SOILS

Most problems resulting from expansive soils involve swelling or shrinking as evidenced by upward or downward movement of the foundation producing distress to the structure. The difference between the water content at the time of construction and the equilibrium water content is an important consideration. Potential swell increases with lower initial moisture content, while potential shrinkage increases with higher initial moisture content. Moisture contents and shrink/swell movements may vary seasonally even after equilibrium is reached.

Precipitation and evapotranspiration control soil moisture and groundwater levels. A slab will greatly reduce the evapotranspiration rate beneath the slab and partially reduces the inflow due to precipitation or irrigation because of groundwater's ability to migrate laterally. Therefore, soils beneath a slab are frequently wetter than soils at the same depth away from the slab. However, a wet season may result in wetter conditions away from the slab than under the slab. With time and normal precipitation patterns, the soil moisture profile will return to its normal condition. Seasonal variations in soil moisture away from the slab will generally occur fairly quickly. Seasonal variations in soil moisture beneath the slab will be slower. In addition roots from trees and large vegetation will seasonally remove moisture from nearby soils.

Wetting of expansive soils beneath slabs can occur as a result of lateral migration or seepage of water from the outside. It can be aggravated by ponded water resulting from poor drainage around the slab or landscape watering. Leaking utility lines and excessive watering of soil adjacent to the structure can also result in foundation heave.

Foundations can experience downward movement as the result of the drying influence of nearby trees. As trees and large bushes grow, they withdraw greater amounts of water from the soil causing downward foundation movement. The area near trees removed shortly before construction may be drier and subject to localized heave.

Some construction and maintenance issues include the following:

a. In general, set top of concrete at least eight inches above final adjacent soil grade for damp proofing.
b. For adjacent ground exposed or vegetative areas, provide adequate drainage away from the foundation (minimum five percent slope in the first ten feet and minimum two percent slope elsewhere). The bottom of any drainage swale should not be located within four feet of the foundation. Pervious planting beds should slope away from the foundation at least two inches per foot. Planting bed edging shall allow water to drain out of the beds.
c. Gutters or extended roof eaves are recommended, especially under all roof valleys. For adjacent ground exposed or vegetative areas, all extended eaves or gutter down

spouts should extend at least two feet away from the foundation and past any adjacent planting beds.

d. Avoid placement of trees and large vegetation near foundations (taking into account the water demands of specific trees and vegetation).

APPENDIX B

IMPACT OF FILL ON FOUNDATIONS

B.1 Fill

Fill is frequently a factor in residential foundation construction. Fill may be placed on a site at various times. If the fill has been placed prior to the geotechnical investigation, the geotechnical engineer should note fill in the report. Fill may exist between borings or be undetected during the geotechnical investigation for a variety of reasons. The investigation becomes more accurate if the borings are more closely spaced. Occasionally, fill is placed after the geotechnical investigation is completed, and it may not be detected until foundation excavation is started.

If uncontrolled fill (see discussion below) is discovered later in the construction process, for instance, by the Inspector after the slab is completely set up and awaiting concrete, great expense may be incurred by having to remove reinforcing and forms to provide penetration through the fill. Therefore, it is important to identify such materials and develop a strategy for dealing with them early on in the construction process. Fill can generally be divided into three types: engineered fill, forming fill, and uncontrolled fill. These three types of fill are discussed below.

B.1.1 Engineered Fill

Engineered fill is that which has been designed by an engineer to act as a structural element of a constructed work and has been placed under engineering inspection, usually with density testing. Engineered fill may be of at least two types. One type is “embankment fill,” which is composed of the material randomly found on the site, or imported to no particular specification, other than that it be free of debris and trash. Embankment fill can be used for a number of situations if properly placed and compacted. “Select fill” is the second type of engineered fill. The term “select” simply means that the material meets some specification as to gradation and P.I., and possibly some other material specifications. Normally, it is placed under controlled compaction with engineer inspection. Examples of select fill could be crushed limestone, specified sand, or crusher fines, which meet the gradation requirements. Select underslab fill is frequently used under shallow foundations for purposes of providing additional support and stiffness to the foundation, and replacing a thickness of expansive soil. Engineered fill should meet specifications prepared by a qualified engineer for a specific project, and includes requirements for placement, geometry, material, compaction and quality control.

B.1.2 Forming Fill

Forming fill is that which is typically used under residential foundation slabs and is variously known as sandy loam, river loam or fill dirt. Forming fill is normally not expected to be heavily compacted, and a designer should not rely on this material for support. The only requirements are that this material be non-expansive, clean, and that it works easily and stands when cut. If forming fill happened to be properly compacted and inspected in accordance with an engineering specification it could be engineered fill.

B.1.3 Uncontrolled Fill

Uncontrolled fill is fill that has been determined to be unsuitable (or has not been proven suitable) to support a slab-on-ground foundation. Any fill that has not been approved by a qualified geotechnical engineer in writing shall be considered uncontrolled fill. Uncontrolled fill may contain undesirable materials and/or has not been placed under compaction control. Some problems resulting from uncontrolled fill include gradual settlement, sudden collapse, attraction of wood ants and termites, corrosion of metallic plumbing pipes, and in some rare cases, site contamination with toxic or hazardous wastes.

B.2 Building on Non-Engineered (Forming Or Uncontrolled) Fill

Foundations shall not be supported by non-engineered fill. To establish soil-supported foundations on non-engineered fill, the typical grid beam stiffened slab foundation is required to penetrate the non-engineered fill with the perimeter and interior beam bottoms forming footings. Penetration will take the load supporting elements of the foundation below the unreliable fill. Penetration could be accomplished by deepened beams, spread footings or piers depending on the depth and the economics of the situation. Generally, piers are most cost effective once the fill to be penetrated exceeds about three feet, but this depends on the foundation engineer’s judgment and local practice. Floor systems shall be designed to span between structurally supported foundation elements.

Pre-existing fill may be classified as engineered fill after investigation by the geotechnical engineer. The approval may depend on the fill thickness, existence of trash and debris, the age of the fill, and the results of testing and proof rolling. The geotechnical engineer must be able to expressly state after investigation that the fill is capable of supporting a residential slab-on-ground foundation.