Slab-on-Ground Design

Using the PTI Method

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Biggest Single U.S. Market for Post-Tensioning Tendons

- Over 40% of all P/T tendons sold in the USA are for residential foundations.
- 58,000 tons of tendons installed in residential foundations in the year 2000 alone.
- Represents about 220,000 homes in one year.
History

- First used the late 1960’s in Texas and California
- Widest usage has been in
  - Texas (50%)
  - California (32%)
  - Nevada (7%)
  - Louisiana (5%)
- Usage increasing (4%) in
  - Arizona
  - Colorado
  - Florida
  - Georgia
Evolution of Design Methods

- Earliest methods (±1965) were semi-empirical
  - Based upon simplified mathematical models
    - Assumed loss of support (Spanability)
  - Confirmed by actual performance
- PTI Method (1980) based upon rigorous mathematical study of soil/structure interaction
  - Most comprehensive design method ever developed for behavior of concrete foundations on expansive soils
The PTI Design Method

- Based upon a finite element computer model of soil/structure interaction, with research sponsored by PTI and executed at Texas A & M University in late 1970’s
- Incorporated into model building codes (UBC 1997, IBC 2000)
- Used to design millions of existing foundations
PTI Publications

Design and Construction of Post-Tensioned Slabs-on-Ground

Construction and Maintenance Procedures Manual for Post-Tensioned Slabs-on-Ground
Two Slabs on Expansive Soils

1. Introduction

Post-tensioned slabs are widely used as foundations for light residential structures in areas of expansive soils. Common design methods for these slabs assume an as-united volume, which could result in severe settlement problems. Several design methods are available to calculate the settlements due to the expansive soil, but the design is not always accurate. This study was undertaken to evaluate the performance of post-tensioned slabs on expansive soils.

2. The Structural Function of Cracked Post-Tensioned Slabs

In the absence of any significant information about the actual stress distribution, the effectiveness of the design and the actual stress distribution in the slab, it is necessary to use a numerical method to analyze the behavior of the slab under tensioning. The plasticity theory is a good approach to analyze the behavior of the slab under tensioning.

3. Conclusions

The results of this study indicate that the post-tensioned slab system is adequate for the design of the slab on expansive soils. The design procedure is conservative and should provide a safe and economical solution to the problem of designing slabs on expansive soils.
Structural Function of P/T Foundation

- Acts as a buffer between the soil below and the superstructure above to prevent unacceptable deformations in superstructure.
- Foundation is designed to resist or span over moisture-induced deformations in the soil below, while still maintaining its top surface within permissible level tolerances.
Expansive Soil Swell Modes

- **Edge Lift**
  - Soils are wetter at slab edge than at any point inside slab edge.

- **Center Lift**
  - Soils are drier at slab edge than at any point inside slab edge.
Soil Model

Flexible Impervious Membrane

Datum Line

Uniform Clay Soil

Soil Moisture Content (%)
Edge Lift

Flexible Impervious Membrane

Rainfall

$e_m$

Uniform Clay Soil

$y_m$

Datum Line

Base

Soil Moisture Content (%)
Center Lift (Edge Drop)

Flexible Impervious Membrane

Evaporation/Transpiration

Uniform Clay Soil

Evaporation/Transpiration

Base

Soil Moisture Content (%)
Geotechnical Engineer Provides Critical Soil Design Parameters

- Edge Moisture Variation Distance $e_m$
  - Thornthwaite Moisture Index (climate)
  - Soil Permeability
  - Vegetation
- Unrestrained Differential Swell $y_m$
  - Properties (activity) of clay
  - Depth of clay (active zone)
  - Soil suction

- One set of $e_m$ & $y_m$ values established for each swell mode (edge and center lift)
- Design cannot be done without these parameters

<table>
<thead>
<tr>
<th></th>
<th>Edge Lift</th>
<th>Center Lift</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e_m$</td>
<td>2.0 ft</td>
<td>5.0 ft</td>
</tr>
<tr>
<td>$y_m$</td>
<td>0.75 in</td>
<td>3.0 in</td>
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</tbody>
</table>
New Method For Determining $e_m$ & $y_m$

- Under review by PTI Slab-on-Ground Committee.
- $e_m$ based upon soil properties:
  - Unsaturated diffusion coefficient $\alpha$
    - Soil suction.
    - Soil permeability.
    - Cracks and roots.
    - Soil Fabric Factor (roots, cracks, layers).
- Simplified method for determining $y_m$ based primarily on soil suction profiles.
- Considers effect of vertical barriers (cutoff walls).
Edge Lift

\[ \Delta \]

\[ \beta \]

All Structural Activity

\[ e_m \]

Wet to Dry

\[ y_m \]
Center Lift

\[ \beta \]

All Structural Activity

\[ e_m \]

\[ \Delta \]

\[ y_m \]

Dry to Wet
Ribbed and Uniform Thickness Foundations

- PTI Design Method based on “ribbed” foundation system
  - Slab thickness $t=4”$ minimum
  - Ribs=Grade Beams
    - $h=t+7”$ with $12”$ minimum depth.
    - $b=8-14”$
  - Rib spacing $S=6’$ minimum, $17’$ maximum.
- Can be converted to uniform (solid) thickness slab
Overlapping Rectangles

- Determine preliminary geometry and layout:
  - Rib spacing
  - Rib size
  - Slab thickness
- Divide slab into overlapping rectangles congruent with slab perimeter.
Rectangle A

24’ x 42’
Rectangle B

16’ x 36’
Design Equations

- For each swell mode (edge or center lift)
  - For each direction (Long or Short), use equations to determine:
    - Maximum Moment
    - Maximum Shear
    - Maximum Differential deflection
Design Based on Uncracked Section

- Effects of cracking studied in detail in original research and subsequent publications available through PTI.
- Effects of cracking generally inconsequential due to
  - Location of shrinkage cracks.
  - Increased soil support after flexural cracking.
Allowable Concrete Stresses

- **Flexural**
  - Tension $6\sqrt{f'_c}$
  - Compression $0.45f'_c$

- **Shear**
  - $v_c = 1.7\sqrt{f'_c} + 0.2f_p$

- **Differential deflection**
  - $L/C_\Delta$
    - $L=$ smaller of total slab length or $6\beta$.
    - $C_\Delta =$ coefficient based on superstructure material.
Typical Slab Layout
Typical Details
Ribbed Foundation
Uniform Thickness Foundation
Thank You!