ALTERNATE PROCEDURES FOR DETERMINING SOIL SUPPORT PARAMETERS
FOR SHALLOW FOUNDATIONS ON EXPANSIVE CLAY SOIL SITES
(Relating to the Post-Tensioning Institute Manual Design and Construction of Post-
Tensioned Slabs-on-Ground 2nd Edition)
By the Post-Tensioning Institute Slab-on-Ground Committee

1.0 Introduction

An alternate procedure for the determination of soil support parameters for shallow foundations on expansive clay soil sites has been developed by PTI's Slab-On-Ground Committee and others. This procedure provides rational means for evaluating the edge moisture variation distance $e_m$ and the differential soil movement $y_m$. The procedure provides the ability to model soil conditions more accurately by incorporating extensive databases and research from the USDA Soil Conservation Service and by allowing for more flexibility in evaluating vertical moisture barriers, planter areas and variable soil suction values controlling the suction conditions at the surface of the soil profile.

The support parameters in the document are equally applicable to all ribbed or uniform thickness slab foundations, whether reinforced with conventional reinforcing steel or post-tensioning, constructed on expansive soil sites. The procedures are not applicable to compressible or collapsing soils. The values of $e_m$ and $y_m$ determined by this procedure shall be used as a basis for structural design using the methods of Section 6.0 of the Post-Tensioning Institute manual Design and Construction of Post-Tensioned Slabs-On-Ground 2nd Edition. If this procedure is used for calculating soil support parameters, it is intended to partially replace Appendix A.3 of the manual.

Enhancements for calculating $e_m$ fundamentally involve the ability to use the Thornthwaite Moisture Index (TMI) in conjunction with estimates of the in-situ soil unsaturated diffusion coefficient calculated from simple soil properties. This value of the soil unsaturated diffusion coefficient is also modified by the soil fabric factor, ranging from 1 to 1.4, which takes into account the presence of horizontal flow discontinuities including roots, layers, fractures and joints. The procedure does not allow $e_m$ to exceed 9-feet for any case of center or edge lifts.

Enhancements for calculating $y_m$ involve the combination of current tables in Appendix A.3 of the 2nd edition of PTI's Design and Construction of Post-Tensioned Slabs-On-Ground manual (Ref. 4) into a single Table II using the concept of a Stress Change Factor (SCF). Further, in the absence of site specific soil suction information, the procedure allows for use of controlling suction at the surface to calculate movement based upon changes in soil suction from initial to final profile values. However, the procedure emphasizes that measures for estimating differential soil movements should most ideally be based
upon computer methods to generate the values of $e_m$ and $y_m$ for edge lift and center lift conditions (Ref. 5).

As with previous PTI soil parameter information, the new procedure for determining of $y_m$ found in Table II is limited to horizontal moisture flow (i.e., no moisture flow vertically) where the equilibrium soil suction is known at a given depth with the suction changing to either drier or wetter conditions from this depth “z” to the ground surface. Due to this limitation, Table II should be used to determine design values of $y_m$ assuming a typical trumpet-shape suction profile for ending conditions. Table II also assumes that $y_b$ (matrix suction compression index) is constant and further is limited to active soil depths up to 9-feet.

For active soil depths greater than 9-feet or to model post-equilibrium conditions using assumed or known soil suction profiles, the procedure requires the use of a two-dimensional analysis, which can be accomplished by using a computer solution.

1.1 Expansive Soil Sites

Sites for which this procedure is applicable should meet either of the following criteria:

- One foot or more of soil classified as CL or CH by the Unified Soil Classification System having a PI of 15 or greater within the upper 5 feet of the soil profile.

- An equivalent weighted PI computed by the methods found in Building Research Advisory Board Report #33 (Ref. 1) of 15 or greater.

If neither of these criteria is met, the foundation should be designed as a non-stiffened slab foundation, such as the BRAB Type II foundation, defined as one that is lightly reinforced with prestressed or non-prestressed reinforcing steel against shrinkage and temperature cracking.

2.0 Edge Moisture Variation Distance ($e_m$)

The edge moisture variation distance is the distance beneath the edge of a shallow foundation within which moisture will change due to wetting or drying influences around the perimeter. In an edge lift case, the moisture in the soil is higher at the edges than in the center. The center lift case is one in which the moisture is higher in the center than the edges. The major factor in determining the edge moisture variation distance is the unsaturated diffusion coefficient, $\alpha$. This, in turn, depends on the level of suction, the permeability, and the cracks in the soil. For the same diffusion coefficient, the $e_m$ value will be larger for the center lift case in which moisture is withdrawn from wetter soil around the center of the foundation. The $e_m$ value will be smaller for the edge lift case in which moisture is drawn beneath the building into drier soil. Roots, layers, fractures or joints in the soil will increase the diffusion coefficient and increase the $e_m$ value for both the edge lift and center lift conditions. Using representative values based on laboratory test results in each layer, the following values are required to determine edge moisture variation distance, $e_m$:

- Liquid Limit, LL
- Plastic Limit, PL
- Plasticity Index, PI
- Percentage of soil passing No. 200 sieve ($%_{#200}$)
- Percentage of soil finer than 2 microns ($%_{-2\mu}$) expressed as a percentage of the total sample.

For example: $45\% / 80\% = 0.56$, report as 56%.
2.1 Calculate $\gamma_h$

Calculate $\gamma_h$ for each significant soil layer to a minimum depth of 9-feet.

For swelling:

$$\gamma_h = (\gamma_o e^{\gamma_o}) \text{ (\%fc)}$$

For shrinkage:

$$\gamma_h = (\gamma_o e^{-\gamma_o}) \text{ (\%fc)}$$

Terms: $e$ is the base of natural logarithms

$\gamma_h$ is the correction of $\gamma_o$ for the actual \% of fine clay (\%fc).

$\gamma_o$ is the change of soil volume for a change in suction for 100\% fine clay content and is determined using the following steps:

**Step 1** Determine Mineral Classification Zone I, II, III, IV, V or VI from the Mineral Classification Chart, (See Figure 1). If the data does not fall within one of the six zones, use the nearest zone. No data should plot above the U-Line.

**Step 2** Proceed to the chart corresponding to the zone determined in Step 1 to determine $\gamma_o$. (See Figure 2,3,4,5,6,7)

The modified value of $\gamma_h$, $\gamma_{h \text{ mod}}$, is the average volume change coefficient of the soil supporting the slab. This should be calculated as a weighted average of the $\gamma_h$ values in each of the layers of soil to a depth of nine feet. Depths greater than nine feet may be used if justified by geotechnical analysis. The $\gamma_h$ values in the upper one-third have a weight of three, in the next third a weight of two, and in the bottom third a weight of one. The sum of the products of layer thickness (feet), $\gamma_h$ and weight for all layers should be used to obtain the weighted average as the modified value $\gamma_{h \text{ mod}}$.

Interpolate between $\gamma_o$ lines. Beyond extreme values of the contours, use the nearest values for $\gamma_o$. Figures 1, 2, 3, 4, 5, 6 and 7 were derived from data available from the National Soil Survey Center, USDA with analysis reported by Covar and Lytton (Ref. 2).

2.2 Calculate the unsaturated diffusion coefficient, $\alpha$

$$\alpha = 0.0029 \times 0.000162 (S) - 0.0122 (\gamma_{h \text{ mod}})$$

Where $S = -20.29 + 0.1555 (\text{LL\%}) - 0.117 (\text{PI\%})$ 
$+ 0.0684 (\%\#200)$

The resulting unsaturated diffusion coefficient, $\alpha$, for each significant layer should be converted to the modified unsaturated diffusion coefficient, $\alpha'$, using $F_f$. $\alpha' = \alpha F_f$, where $F_f$ is the soil fabric factor from Table 1.

Determine edge moisture variation distance, $e_m$ for both center lift and edge lift from the $e_m$ Selection Chart, Figure 8, using the larger value obtained from $I_m$ chart or $\alpha'$ chart.

3.0 Differential Soil Movement ($\gamma_m$)

Differential soil movement should be estimated using the change in soil surface elevation at two locations separated by a distance $e_m$ within which the differential movement will occur. An initial and a final suction profile should be used at each of the two locations to determine differential movement. For general analysis, the initial suction profile should be the same at both locations.

The final suction profile at each location should be determined from controlling suction conditions at the surface.
computer analysis of the layered profile
with measured or estimated suction profile
envelopes may be used to yield estimates of
movement for the purpose of design and
analysis, and to study the effects of trees,
edge barriers, flower beds, or lawn
watering.

In absence of local observations, controlling
soil suction values at the ground surface are
recommended as follows:

1. Wettest: 2.5 pF, if measured under
soaking conditions, which is typical of
poor drainage or excessive watering.

2. Driest 4.5 pF, if the surface suction is
controlled by vegetation or 6.0 pF, if the
surface suction is controlled by
evaporation from bare soil, or soil with
wilted vegetation.

Controlling soil suction values below the
soil surface occur at depths that are remote
from the surface (z) and are as follows:

1. High Water Table: 2.0 pF at the water
table unless there is a high osmotic
component, in which case, the measured
value of suction should be used.

2. Climate-Controlled Suction: This
suction may be determined by
measurement at a depth below which
the suction varies by less than 0.027 pF
per ft. This is also the z depth.

3. Tree Root Zone: 4.5 pF under driest
conditions, when the tree is near the
wilting point.

4. High Osmotic Suction or Cemented
Soil: These suction values must be
determined by measurement. Suction at
depths that are substantially different than
those estimated by the Soil Suction vs
Thornthwaite Moisture Index curve in
Figure A.3.6 of Ref. 4 indicates dissolved
salts in the pore water, and possible
formation from deposition in a marine
environment, or cementation.

A typical vertical suction profile is
computed by using the principles of steady
state unsaturated flow which links the
controlling suction values at the soil surface
to the controlling suction below the surface.
The principles of steady-state unsaturated
flow may be found in Ref. 3.

Differential soil movements may be
estimated using computer methods to
generate the design values of $y_m$ for edge
and center lift conditions.

In the absence of computer methods (see
Ref. 5), Table II may be used to estimate
approximate design values of $y_m$. This
method should only be attempted if a
typical trumpet-shape suction profile can be
assumed for the final suction profile and $\gamma_h$
is not highly variable. Otherwise, this
procedure may not be accurate or
conservative. In addition, the Table II
values assume the initial suction to be at
equilibrium from depth $z$ to the ground
surface, then either becoming wet or dry.
This limitation would not permit accurate or
conservative results in the case of a dry or
wet initial suction profile, followed by
significant wetting or drying, tree effects or
other moisture anomalies.

The estimated value of $y_m$ can be
determined from

$$y_m = \gamma_{h,mod} \times SCF \ (from \ Table \ II)$$

The modified value of $\gamma_h$, $\gamma_{h,mod}$, is the
average volume change coefficient of the
soil supporting the slab. This should be
calculated as a weighted average of the $\gamma_h$
values in each of the layers of soil to a
depth of nine feet. Depths greater than nine
feet may be used if justified by geotechnical
analysis. The $\gamma_h$ values in the upper one-
third have a weight of three, in the next
third a weight of two, and in the bottom
third a weight of one. The sum of the products of layer thickness (feet), γ₉ and weight for all layers should be used to obtain the weighted average as the modified value γ₉ mod, which is to be used to determine the yₘ value for edge lift (positive value) and center lift (negative value). The value of γ₉ mod calculated previously for swelling should be used with positive SCF and the γ₉ mod value for shrinkage should be used with negative SCF. If less than nine feet of active soil is present, or if significant variations occur in γ₉, use γ₉ for each layer to calculate yₘ.

4.0 Barriers

Vertical moisture barriers may be used to reduce the soil support parameters (eₘ and yₘ) provided the barriers are properly designed to virtually stop moisture migration to or from the under slab area on a permanent basis, around the entire perimeter.

The effect of a barrier on eₘ and yₘ may be estimated by the principles of un-saturated soil mechanics, most easily by the use of two-dimensional moisture flow analysis computer program, such as VOLFLO (Ref. 5).

A vertical barrier should extend at least 2.5 feet below adjacent ground surface to be considered as having any effect.

An approximation of the effect of a vertical barrier on eₘ can be obtained by using Table III.

The change of yₘ for various barrier depths requires analysis using a computer program, such as Ref. 5.

5.0 Conclusion

Three sample calculations for eₘ and yₘ are included (Appendix A, B, and C) to demonstrate the procedures specified in this document:

1. Using stress change factors from Table II (Appendix A)
2. Using VOLFLO for yₘ starting at equilibrium suction profile (Appendix B)
3. Using VOLFLO for yₘ starting at extreme wet and dry suction profiles (Appendix C).

6.0 References


5. VOLFLO Win 1.0. (2002). A computer program available through the Post-Tensioning Institute or Geostructural Tool Kit, Inc., Austin, Texas.
7.0 List of Symbols and Notations
(not defined in Ref. 4)

$\alpha$  Unsaturated diffusion coefficient, a measure of moisture movement in unsaturated soils.

$\alpha'$  Modified unsaturated diffusion coefficient. The modified unsaturated diffusion coefficient is calculated as: $\alpha' = \alpha (F_f)$

$e$  Base of the natural logarithm (approximated as 2.7183).

$\%fc$  Percent fine clay defined as percentage of soil passing the U.S. No. 200 sieve which is smaller than 2 microns (2$\mu$). The percent fine clay is calculated as shown below:

$$\%fc = \left( \frac{\% - 2\mu}{\% - \#200} \right) \text{ reported as a percentage.}$$

$\gamma_0$  Change of soil volume for a change in suction for 100% fine clay.

$\gamma_h$  Change of soil volume for a change in suction corrected for the actual % fine clay. Also referred to as the matrix suction compression index.

$\gamma_{h\,mod}$  Change of soil volume for a change in suction corrected for the actual % fine clay, weighted for layered soils.

$F_f$  Fabric factor. Factor used to modify the unsaturated diffusion coefficient ($\alpha$) for the presence of roots, layers, fractures and joints. See Table I.

$S$  Slope of the Suction versus Volumetric Water Content Curve. See Ref. 3.

SCF  Stress Change Factor. Factor used in the determination of $y_m$. See Table II.
Table I - Soil Fabric Factor

<table>
<thead>
<tr>
<th>Condition</th>
<th>$F_t$</th>
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<tr>
<td>Soil profiles contain <strong>few</strong> roots, layers, fractures or joints</td>
<td>1.0</td>
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<tr>
<td>(No more than 1 per vertical foot)</td>
<td></td>
</tr>
<tr>
<td>Soil profiles contain <strong>some</strong> roots, layers, fractures or joints</td>
<td>1.3</td>
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<td>(2 to 4 per vertical foot)</td>
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<tr>
<td>Soil profiles contain <strong>many</strong> roots, layers, fractures or joints</td>
<td>1.4</td>
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<tr>
<td>(5 or more per vertical foot)</td>
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Table II - Stress Change Factor (SCF) for Use in determining $y_m$

<table>
<thead>
<tr>
<th>Measured Suction (pF) at Depth z</th>
<th>Final Controlling Suction At Surface, pF</th>
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<td></td>
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Notes for Table 2: The positive sign indicates edge lift (swelling) and the negative sign indicates center lift (shrinkage). Measured suction at depth is the equilibrium suction. Z is the depth to constant suction.

Table III – Values of Reduced $e_m$ for Various Perimeter Vertical Barriers

<table>
<thead>
<tr>
<th>$e_m$ (feet) (Center or Edge)</th>
<th>Depth of Barrier (feet)</th>
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<th>5.0</th>
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<td></td>
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<td>4.9</td>
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</table>
Figure 1 - Mineral Classification Chart

[Diagram showing a chart with axes labeled 'Plasticity Index' and 'Liquid Limit', with lines indicating different mineral classifications.]
Figure 2 – Zone I Chart for Determining $\gamma_0$

Figure 3 – Zone II Chart for Determining $\gamma_0$
Figure 4 – Zone III Chart for Determining $\gamma_0$

Figure 5 – Zone IV Chart for Determining $\gamma_0$
Figure 6 – Zone V Chart for Determining $\gamma_0$

Figure 7 – Zone VI Chart for Determining $\gamma_0$
Figure 8 - $e_m$ Selection Chart

Thornthwaite Moisture Index ($I_m$)
see Post-Tensioning Institute Figure A.3.2

$e_m$ should not exceed 9 feet

$\alpha'$, Weighted Average of Modified Unsaturated Diffusion Coefficient
APPENDIX A

SAMPLE CALCULATION USING STRESS CHANGE FACTORS (TABLE II) with swelling and shrinking suction profile changes starting at the Equilibrium Profile (Post-Equilibrium Case)

**Laboratory Results and other Inputs**

- LL = 75
- PL = 24
- % passing 200 sieve (%-#200) = 88%
- % passing 2 micron (%-2μ) = 63%
- Fabric Factor (Table 1) from examination of sample = 1.0
- Location: Austin, Texas
- Soil Profile: Homogeneous
- Soil Unit Weight: Internal in procedure
- Ko: Drying and wetting internal in procedure

**Determine \( e_m \)**

1. Calculate the Plasticity Index (PI):
   
   Plasticity Index (PI) = LL – PL = 75 – 24 = 51

2. Calculate % fine clay (%fc):
   
   \( %fc = \% - 2\mu / \% - #200 = 63\% / 88\% = 0.716 \times 100 = 71.6\% \)

3. Determine Zone using the Mineral Classification Chart (Figure 1):
   
   The soil sample plots in Zone II (see attached)

4. Calculate the Activity Ratio (PI / %fc):
   
   \( PI / %fc = 51 / 71.6 = 0.71 \) (Note %fc is a percentage)

5. Calculate LL / %fc:
   
   \( LL / %fc = 75 / 71.6 = 1.05 \) (Note %fc is a percentage)

6. Determine \( \gamma_0 \) using the Zone II chart (Figure 3):
   
   \( \gamma_0 = 0.11 \) (see attached)

7. Calculate \( \gamma_h \):
   
   \( \gamma_{h\, swell} = \gamma_0 \times e^{\gamma_0 \times %fc / 100} = 0.11 \times e^{0.11 \times (71.6 / 100)} = 0.088 \)
   
   \( \gamma_{h\, shrink} = \gamma_0 \times e^{\gamma_0 \times %fc / 100} = 0.11 \times e^{-0.11 \times (71.6 / 100)} = 0.071 \)

8. Calculate S:
   
   \( S = -0.2299 + 0.1555 (LL) - 0.117 (PI) + 0.0684 (\% - #200) \)
   
   \( S = -0.2299 + 0.1555 (75) - 0.117 (51) + 0.0684 (88) \)
   
   \( S = -8.575 \)

9. Calculate Unsaturated Diffusion Coefficient (\( \alpha \)):
APPENDIX A

SAMPLE CALCULATION USING STRESS CHANGE FACTORS (TABLE II) with swelling and shrinking suction profile changes starting at the Equilibrium Profile (Post-Equilibrium Case)

\[ \alpha_{\text{swell}} = 0.0029 - 0.000162 \times (S) - 0.0122 \times (\gamma_h \text{ swell}) \]
\[ \alpha_{\text{swell}} = 0.0029 - 0.000162 \times (-8.575) - 0.0122 \times 0.088 \]
\[ \alpha_{\text{swell}} = 0.0032 = 3.2 \times 10^{-3} \]

\[ \alpha_{\text{shrink}} = 0.0029 - 0.000162 \times (S) - 0.0122 \times (\gamma_h \text{ shrink}) \]
\[ \alpha_{\text{shrink}} = 0.0029 - 0.000162 \times (-8.575) - 0.0122 \times 0.071 \]
\[ \alpha_{\text{shrink}} = 0.0034 = 3.4 \times 10^{-3} \]

10. Fabric Factor (Ff):

\[ Ff = 1.0 \]

11. Calculate Modified Unsaturated Diffusion Coefficient (\(\alpha'\)):

\[ \alpha'_{\text{swell}} = \alpha_{\text{swell}} \times (Ff) = 0.0032 \times 1.0 = 0.0032 = 3.2 \times 10^{-3} \]
\[ \alpha'_{\text{shrink}} = \alpha_{\text{shrink}} \times (Ff) = 0.0034 \times 1.0 = 0.0034 = 3.4 \times 10^{-3} \]

12. Determine Thornthwaite Moisture Index (\(I_m\)) from PTI Manual (1996) (Figure A.3.2 and A.3.3 a and b):

\[ I_m = -14 \]

13. Determine \(e_m\) based on \(I_m\) for center and edge lift (Figure 6):

\[ e_m \text{ center} (I_m) = 5.0 \text{ ft} \text{ (see attached)} \]
\[ e_m \text{ edge} (I_m) = 2.7 \text{ ft} \text{ (see attached)} \]

14. Determine \(e_m\) based on \(\alpha'\) for center and edge lift:

\[ e_m \text{ center} (\alpha'_{\text{shrink}}) = 6.1 \text{ ft} \text{ (see attached)} \]
\[ e_m \text{ edge} (\alpha'_{\text{swell}}) = 3.2 \text{ ft} \text{ (see attached)} \]

15. Use maximum values of \(e_m\):

\[ e_m \text{ center} = 6.1 \text{ ft} \]
\[ e_m \text{ edge} = 3.2 \text{ ft} \]
APPENDIX A

SAMPLE CALCULATION USING STRESS CHANGE FACTORS (TABLE II)
with swelling and shrinking suction profile changes starting at the Equilibrium Profile (Post-Equilibrium Case)

Determine $Y_m$

1. Determine Measured Suction at Depth:
   Using the PTI Manual (1996) Constant Soil Suction versus Thornthwaite Index Chart (Figure A.3.6) the Suction at Depth = 3.6 pF

2. Determine Dryest Suction:
   Dryest Suction = 4.5 pF

3. Determine Wettest Suction:
   Wettest Suction = 2.5 pF

4. Determine Stress Change Factors (SCF) for center and edge Lift (Table II):
   SCF – center = -15.8
   SCF – edge = +27.1 (see attached)

5. Calculate $y_m$ for center and edge lift:
   $y_m$ center = (SCF-center) $(Y_{h shrink}) = (-15.8) (0.071) = -1.12$ in (use +1.12 in for $y_m$ center)
   $y_m$ edge = (SCF-edge) $(Y_{h swell}) = 27.1 (0.088) = 2.38$ in

Soil Parameter Summary

$e_m$ center = 6.1 ft
$e_m$ edge = 3.2 ft
$y_m$ center = 1.12 in
$y_m$ edge = 2.38 in
Sample Calculation

Figure 1 - Mineral Classification Chart
$e_m$ Selection Chart

Thornthwaite Moisture Index ($I_m$)
see Post-Tensioning Institute Figure A.3.2

$e_m = 5.0$
$e_m = 2.7$
$e_m = 6.1$
$e_m = 3.2$

$\alpha'$, Weighted Average of Modified Unsaturated Diffusion Coefficient

$e_m$ should not exceed 9 feet

Use higher value of $e_m$ as found by $I_m$ and $\alpha'$. 
APPENDIX A

SAMPLE CALCULATION

<table>
<thead>
<tr>
<th>Measured suction (pF) at Depth z</th>
<th>2.5</th>
<th>2.7</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
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<td>+30.8</td>
<td>+20.7</td>
<td>+7.3</td>
<td>-1.3</td>
<td>-4.1</td>
<td>-9.4</td>
</tr>
<tr>
<td>4.2</td>
<td>+50.4</td>
<td>+42.1</td>
<td>+30.8</td>
<td>+14.8</td>
<td>+3.2</td>
<td>0</td>
<td>-4.1</td>
</tr>
<tr>
<td>4.5</td>
<td>+63.6</td>
<td>+54.7</td>
<td>+42.1</td>
<td>+23.9</td>
<td>+9.6</td>
<td>+5.1</td>
<td>0</td>
</tr>
</tbody>
</table>

SCF Edge = +27.1
SCF Center = -15.8
SAMPLE CALCULATION USING VOLFLO Win 1.0
with swelling and shrinking suction profile changes starting at the
Equilibrium Profile (Post-Equilibrium Case)

Laboratory Results and other Inputs

LL = 75
PL = 24
% passing 200 sieve (%-#200) = 88%
% passing 2 micron (%-2μ) = 63%
Fabric Factor (Table 1) from examination of sample = 1.0
Location: Austin, Texas
Soil Profile: Homogeneous
Soil Unit Weight: 120 PCF
Ko drying = 0.33
Ko wetting = 0.67

Soil Parameter Summary

e_m center = 6.1 feet
e_m edge = 3.2 feet
y_m center = 1.09 inches
y_m edge = 2.31 inches

Note: The differences in results are due to simplifying assumptions used to
generate the Stress Change Factors (Table II).
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Project Title: Sample Calculation - Post Equilibrium Case - Swelling
Project Engineer: Project Number:
Geotechnical Report: Project Date: June 30, 2002

SWELL CALCULATION

Ym Edge (Swell) = 2.31 inches (5.86 centimeters)
Em Edge = 3.20 feet (97.54 centimeters)

DISTANCE

0.0 ft 0.3 ft 0.6 ft 1.0 ft 1.3 ft 1.6 ft 1.9 ft 2.2 ft 2.6 ft 2.9 ft 3.2 ft
0 cm 10 cm 20 cm 29 cm 39 cm 49 cm 59 cm 68 cm 78 cm 88 cm 98 cm

0.0 in 1.0 in 2.0 in 3.0 in

Swell at Slab

Swell at distance X from edge of slab

Swell at

Edge

0.0 ft 0.3 ft 0.6 ft 1.0 ft 1.3 ft 1.6 ft 1.9 ft 2.2 ft 2.6 ft 2.9 ft 3.2 ft
0 cm 10 cm 20 cm 29 cm 39 cm 49 cm 59 cm 68 cm 78 cm 88 cm 98 cm

inches 2.31 2.00 1.71 1.44 1.18 0.93 0.70 0.50 0.31 0.14 0.00

cm 5.86 5.09 4.35 3.65 2.99 2.36 1.79 1.26 0.78 0.36 0.00

Page 1 of 5
APPENDIX B

**VOLFLO Win 1.0**
Geostructural Tool Kit, Inc.

Registered To: 
Serial Number: 200-100-000

Project Title: Sample Calculation - Post Equilibrium Case - Swelling
Project Engineer: 
Project Number: 
Project Date: June 30, 2002

Geotechnical Report: 
Report Date: 
Report Number: 

**SUMMARY OF INPUT DATA - Soil Properties**

**Layer Thickness and description**

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Layer Thickness</th>
<th>Depth to Bottom</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.0 ft</td>
<td>10.0 ft</td>
<td></td>
</tr>
</tbody>
</table>

**Layer Geotechnical Properties**

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>% Pass. #200</th>
<th>% Finer 2 mic.</th>
<th>Density (lb/ft³)</th>
<th>Gamma 100</th>
<th>Ko Drying</th>
<th>Ko Wetting</th>
<th>Fabric</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>24</td>
<td>88</td>
<td>63</td>
<td>120.0</td>
<td>0.12</td>
<td>0.33</td>
<td>0.67</td>
<td>1.0</td>
</tr>
</tbody>
</table>
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Registered To: 
Serial Number: 200-100-000

Project Title: Sample Calculation - Post Equilibrium Case - Swelling
Project Engineer: 
Project Number: 
Project Date: June 30, 2002
Geotechnical Report: 
Report Date: 
Report Number: 

SUMMARY OF INPUT DATA - Suction at Edge of Slab

Initial Suction Profile — Constant Suction Profile

Final Suction Profile — Default Wet Design Envelope
Suction value at surface 2.5 pF

Constant Suction
Constant suction 3.6 pF
Depth to constant suction 9.0 ft

Moisture Barriers
Vertical barrier depth: 
Apply vertical barrier to: Neither Profile
Horizontal barrier length: 0.0 ft
SUMMARY OF INPUT DATA - Em

Em Distance

User Input: Center Lift  Edge Lift

- 6.1 ft  3.2 ft

Suction Profile at Em — Constant Suction Profile
Sample Calculation - Post Equilibrium Case - Shrinking

Ym Center (Shrink) = -1.09 inches (2.77 centimeters)
Em Center = 6.10 feet (185.93 centimeters)

<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>0.0</th>
<th>0.6</th>
<th>1.2</th>
<th>1.8</th>
<th>2.4</th>
<th>3.1</th>
<th>3.7</th>
<th>4.3</th>
<th>4.9</th>
<th>5.5</th>
<th>6.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (cm)</td>
<td>0</td>
<td>19</td>
<td>37</td>
<td>56</td>
<td>74</td>
<td>93</td>
<td>112</td>
<td>130</td>
<td>149</td>
<td>167</td>
<td>186</td>
</tr>
<tr>
<td>Shrink at Slab Edge</td>
<td>-1.09</td>
<td>-0.96</td>
<td>-0.83</td>
<td>-0.70</td>
<td>-0.58</td>
<td>-0.47</td>
<td>-0.36</td>
<td>-0.26</td>
<td>-0.16</td>
<td>-0.08</td>
<td>0.00</td>
</tr>
<tr>
<td>Shrink at Slab Edge (cm)</td>
<td>-2.77</td>
<td>-2.43</td>
<td>-2.10</td>
<td>-1.78</td>
<td>-1.47</td>
<td>-1.18</td>
<td>-0.91</td>
<td>-0.65</td>
<td>-0.41</td>
<td>-0.20</td>
<td>0.00</td>
</tr>
</tbody>
</table>
SUCTION PROFILES

- Initial suction at edge of slab
- Final suction at edge of slab
- Constant Suction
**VOLFLO Win 1.0**
Geotechnical Tool Kit, Inc.

Registered To:  
Social Number: 200-100-986

**Project Title:** Sample Calculation - Post Equilibrium Case - Shrinking  
**Project Engineer:**  
**Project Number:**  
**Project Date:** June 30, 2002  
**Geotechnical Report:**  
**Report Date:**  
**Report Number:**

**SUMMARY OF INPUT DATA - Soil Properties**

**Layer Thickness and description**

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Layer Thickness</th>
<th>Depth to Bottom</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.0 ft</td>
<td>10.0 ft</td>
<td></td>
</tr>
</tbody>
</table>

**Layer Geotechnical Properties**

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>% Pass. #200</th>
<th>% Finer #2 mic.</th>
<th>Density (lb/ft³)</th>
<th>Gamma 100</th>
<th>Ko Drying</th>
<th>Ko Wetting</th>
<th>Fabric Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>24</td>
<td>88</td>
<td>63</td>
<td>120.0</td>
<td>0.10</td>
<td>0.33</td>
<td>0.67</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Page 3 of 5
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Project Title: Sample Calculation - Post Equilibrium Case - Shrinking
Project Engineer:
Geotechnical Report:

Project Number:
Project Date: June 30, 2002
Report Date:
Report Number:

SUMMARY OF INPUT DATA - Suction at Edge of Slab

Initial Suction Profile — Constant Suction Profile

Final Suction Profile — Default Dry Design Envelope
Suction Value at Surface: 4.5 pF

Constant Suction
Constant suction: 3.6 pF
Depth to constant suction: 9.0 ft

Moisture Barriers
Vertical barrier depth: 0.0 ft
Apply vertical barrier to: Neither Profile
Horizontal barrier length: 0.0 ft
SUMMARY OF INPUT DATA - Em

Em Distance

User Input:
Center Lift

| Edge Lift   | 6.1 ft |
|            | 3.2 ft |

Suction Profile at Em — Constant Suction Profile
APPENDIX C

SAMPLE CALCULATION USING VOLFLO Win 1.0
with swelling and shrinking suction profile changes starting at Extreme
Wet or Dry Profiles (Post-Construction Case)

Laboratory Results and other Inputs

LL = 75
PL = 24
% passing 200 sieve (%-#200) = 88%
% passing 2 micron (%-2μ) = 63%
Fabric Factor (Table 1) from examination of sample = 1.0
Location: Austin, Texas
Soil Profile: Homogeneous
Soil Unit Weight: 120 PCF
Ko drying = 0.33
Ko wetting = 0.67
Suction Profiles:

- Wetting - 4.5 pF to 2.9 pF
- Drying - 2.9 pF to 4.5 pF

Soil Parameter Summary

- $e_m$ center = 6.1 feet
- $e_m$ edge = 3.2 feet
- $y_m$ center = 2.25 inches
- $y_m$ edge = 3.81 inches

Note: The differences in results from the other sample calculations are in a major way due to using extreme suction profiles. This case could control if the soil surface is very dry or very wet at the time of construction. Interior equilibrium suction profiles may not be reached for several years.
SWELL CALCULATION

Ym Edge (Swell) = 3.81 inches (9.67 centimeters)
Em Edge = 3.20 feet (97.54 centimeters)

DISTANCE

<table>
<thead>
<tr>
<th>Distance (ft)</th>
<th>0.0</th>
<th>0.3</th>
<th>0.6</th>
<th>1.0</th>
<th>1.3</th>
<th>1.6</th>
<th>1.9</th>
<th>2.2</th>
<th>2.6</th>
<th>2.9</th>
<th>3.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (cm)</td>
<td>0 cm</td>
<td>10 cm</td>
<td>20 cm</td>
<td>29 cm</td>
<td>39 cm</td>
<td>49 cm</td>
<td>59 cm</td>
<td>68 cm</td>
<td>78 cm</td>
<td>88 cm</td>
<td>98 cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Swell at Slab Edge</th>
<th>0.0 ft</th>
<th>0.3 ft</th>
<th>0.6 ft</th>
<th>1.0 ft</th>
<th>1.3 ft</th>
<th>1.6 ft</th>
<th>1.9 ft</th>
<th>2.2 ft</th>
<th>2.6 ft</th>
<th>2.9 ft</th>
<th>3.2 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>inches</td>
<td>3.81</td>
<td>3.31</td>
<td>2.82</td>
<td>2.36</td>
<td>1.92</td>
<td>1.51</td>
<td>1.13</td>
<td>0.78</td>
<td>0.48</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td>cm</td>
<td>9.67</td>
<td>8.40</td>
<td>7.17</td>
<td>6.00</td>
<td>4.88</td>
<td>3.84</td>
<td>2.87</td>
<td>1.99</td>
<td>1.21</td>
<td>0.55</td>
<td>0.00</td>
</tr>
</tbody>
</table>
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Project Title: Sample Calculation - Extreme Post Construction Case - Swelling
Project Engineer:
Project Number:
Project Date: June 30, 2002
Geotechnical Report:
Report Date:
Report Number:

SUCTION PROFILES

Suction (pF)

Depth (feet)

- Initial suction at edge of slab
- Final suction at edge of slab
- Constant Suction

Page 2 of 5
### SUMMARY OF INPUT DATA - Soil Properties

#### Layer Thickness and description

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Layer Thickness</th>
<th>Depth to Bottom</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.0 ft</td>
<td>10.0 ft</td>
<td></td>
</tr>
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</table>

#### Layer Geotechnical Properties

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>% Pass. #200</th>
<th>% Pass. 2 mic.</th>
<th>Density (lb/ft³)</th>
<th>Gamma 100</th>
<th>Ko Drying</th>
<th>Ko Wetting</th>
<th>Fabric Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>24</td>
<td>88</td>
<td>63</td>
<td>120.0</td>
<td>0.12</td>
<td>0.33</td>
<td>0.67</td>
<td>1.0</td>
</tr>
</tbody>
</table>
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Project Title: Sample Calculation - Extreme Post Construction Case - Swelling
Project Engineer:
Geotechnical Report:

Project Number:
Project Date: June 30, 2002
Report Date:
Report Number:

SUMMARY OF INPUT DATA - Suction at Edge of Slab

Initial Suction Profile — Default Dry Design Envelope
Suction value at surface: 4.5 pF

Final Suction Profile — Default Wet Design Envelope
Suction value at surface: 2.9 pF

Constant Suction
Constant suction: 3.6 pF
Depth to constant suction: 9.0 ft

Moisture Barriers
Vertical barrier depth: 0.0 ft
Apply vertical barrier to: Neither Profile
Horizontal barrier length: 0.0 ft
### SUMMARY OF INPUT DATA - Em

<table>
<thead>
<tr>
<th>Em Distance</th>
<th>User Input</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Center Lift</td>
<td>6.1 ft</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Edge Lift</td>
<td>3.2 ft</td>
<td></td>
</tr>
</tbody>
</table>

*Suction Profile at Em* — Constant Suction Profile
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Registered To:  
Serial Number: 200-100-000

Project Title: Sample Calculation - Extreme Post Construction Case - Shrinking
Project Engineer:
Project Number:
Project Date: June 30, 2002
Geotechnical Report:
Report Date:
Report Number:

SHRINK CALCULATION

Ym Center (Shrink) = -2.25 inches  (-5.72 centimeters)
Em Center = 6.10 feet  (185.93 centimeters)

DISTANCE

<table>
<thead>
<tr>
<th>0.0 ft</th>
<th>0.6 ft</th>
<th>1.2 ft</th>
<th>1.8 ft</th>
<th>2.4 ft</th>
<th>3.1 ft</th>
<th>3.7 ft</th>
<th>4.3 ft</th>
<th>4.9 ft</th>
<th>5.5 ft</th>
<th>6.1 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 cm</td>
<td>19 cm</td>
<td>37 cm</td>
<td>56 cm</td>
<td>74 cm</td>
<td>93 cm</td>
<td>112 cm</td>
<td>130 cm</td>
<td>149 cm</td>
<td>167 cm</td>
<td>186 cm</td>
</tr>
</tbody>
</table>

Shrink at Slab
Shrink at distance X from edge of slab
Shrink at Edge

<table>
<thead>
<tr>
<th>0.0 ft</th>
<th>0.6 ft</th>
<th>1.2 ft</th>
<th>1.8 ft</th>
<th>2.4 ft</th>
<th>3.1 ft</th>
<th>3.7 ft</th>
<th>4.3 ft</th>
<th>4.9 ft</th>
<th>5.5 ft</th>
<th>6.1 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 cm</td>
<td>19 cm</td>
<td>37 cm</td>
<td>56 cm</td>
<td>74 cm</td>
<td>93 cm</td>
<td>112 cm</td>
<td>130 cm</td>
<td>149 cm</td>
<td>167 cm</td>
<td>186 cm</td>
</tr>
</tbody>
</table>

inches  -2.25  -1.97  -1.70  -1.43  -1.18  -0.94  -0.71  -0.50  -0.31  -0.14  0.00

cm     -5.72  -5.01  -4.31  -3.64  -3.00  -2.39  -1.81  -1.28  -0.79  -0.36  0.00
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Registered To: Sample Calculation - Extreme Post Construction Case - Shrinking
Project Engineer:
Geotechnical Report:

Project Number: Project Date: June 30, 2002
Report Date:
Report Number:

SUCTION PROFILES

Suction (pF)

0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5

Depth (feet)

5 10

10.0

- Initial suction at edge of slab
- Final suction at edge of slab
- Constant Suction

Page 2 of 5
APPENDIX C

VOLFLO Win 1.0
Geotechnical Tool Kit, Inc.

Registered To:  
Serial Number: 200-100-000

Project Title: Sample Calculation - Extreme Post Construction Case - Shrinking
Project Engineer:  
Project Number:  
Project Date: June 30, 2002
Geotechnical Report:  
Report Date:  
Report Number: 

SUMMARY OF INPUT DATA - Soil Properties

Layer Thickness and description

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Layer Thickness</th>
<th>Depth to Bottom</th>
<th>Layer Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10.0 ft</td>
<td>10.0 ft</td>
<td></td>
</tr>
</tbody>
</table>

**Layer Geotechnical Properties**

<table>
<thead>
<tr>
<th>Layer Number</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>% Pass. #200</th>
<th>% Finer 2 mic.</th>
<th>Density (lb/ft³)</th>
<th>Gamma</th>
<th>Ko Drying</th>
<th>Ko Wetting</th>
<th>Ko Fabric Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>75</td>
<td>24</td>
<td>88</td>
<td>63</td>
<td>120.0</td>
<td>0.10</td>
<td>0.33</td>
<td>0.67</td>
<td>1.0</td>
</tr>
</tbody>
</table>
SUMMARY OF INPUT DATA - Suction at Edge of Slab

**Initial Suction Profile** — Default Wet Design Envelope

- Suction value at surface: 2.9 pF

**Final Suction Profile** — Default Dry Design Envelope

- Suction Value at Surface: 4.5 pF

**Constant Suction**

- Constant suction: 3.6 pF
- Depth to constant suction: 9.0 ft

**Moisture Barriers**

- Vertical barrier depth: 0.0 ft
- Apply vertical barrier to: Neither Profile
- Horizontal barrier length: 0.0 ft
VOLFLO Win 1.0
Geostructural Tool Kit, Inc.

Project Title:  Sample Calculation - Extreme Post Construction Case - Shrinking
Project Engineer:  
Geotechnical Report:  

Project Number:  
Project Date:  June 30, 2002
Report Date:  
Report Number:  

SUMMARY OF INPUT DATA - Em

Em Distance

User Input:
Center Lift  6.1 ft
Edge Lift  3.2 ft

Suction Profile at Em — Constant Suction Profile