GUIDELINES FOR THE EVALUATION OF FOUNDATION MOVEMENT FOR RESIDENTIAL AND OTHER LOW-RISE BUILDINGS

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Presented to: Foundation Performance Association
Presented on: 8 August 2007
Why was it written?

...a brief history...

GUIDELINES FOR THE EVALUATION OF FOUNDATION MOVEMENT FOR RESIDENTIAL AND OTHER LOW-RISE BUILDINGS

by

The Structural Committee
of
The Foundation Performance Association

www.foundationperformance.org

Houston, Texas

Document # FPA-SC-13-0

ISSUE HISTORY (Initial issue and issues outside the Structural Committee)

<table>
<thead>
<tr>
<th>#</th>
<th>Date</th>
<th>Description</th>
<th>Subcommittee Chair</th>
<th>Subcommittee Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 Sep 04</td>
<td>Issued for Committee Review</td>
<td>Dan Jaggers</td>
<td>Dan Jaggers, Merri Keitel, Ron Kalm</td>
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<tr>
<td>Z</td>
<td>13 Mar 07</td>
<td>Issued for Committee Review of 90-Day Peer Review of FPA and ASCE-Tx</td>
<td>Michael Gray</td>
<td>Michael Gray, John Clark, Nicole Wylde</td>
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<tr>
<td>AA</td>
<td>19 Jun 07</td>
<td>Issued for Committee Review of all Peer Review Comments</td>
<td>Lowell Brumley</td>
<td>Lowell Brumley, Dick Pesky, Denis Harys</td>
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<tr>
<td>0</td>
<td>15 Jul 07</td>
<td>Issued for Website Publication</td>
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Who can use this document?
Document Summary

Levels of Investigation

- Per ASCE Texas Section’s Guidelines for the Evaluation and Repair of Residential Foundations
- Levels A, B and C

Data Acquisition & Presentation

Data Evaluation

Allowable Criteria for Foundation Movement
Level A Investigation

- Interview the occupant/owner/client for history of property and performance of structure
- Review client supplied documents
- Make visual observations during walk-through
- Observe factors influencing the performance of the foundation
- Provide written report, if requested by client
Level B Investigation

- All of Level A, with written report
- Determine relative foundation elevations in sufficient detail to represent the shape of the foundation adequately
- Include drawing showing relative elevations
Level C Investigation

- All of Levels A and B
- Additional services, testing and related reports deemed appropriate by the Engineer. May include soil test, plumbing test, material test, etc.
- More detailed written report, which may include scaled drawings, tree survey, photos, distress survey.
Document Summary

Levels of Investigation

Data Acquisition & Presentation

Data Evaluation

Allowable Criteria for Foundation Movement
Data Acquisition and Presentation

Zip Level

Digital Leveling Systems
Electronic Water Level

Lowell Brumley, TSG Consultants Inc.
Document Summary

Levels of Investigation

Data Acquisition & Presentation

Data Evaluation

Allowable Criteria for Foundation Movement
Data Evaluation
Comparing elevations over a two-year period using Contours
Document Summary

Levels of Investigation

Data Acquisition & Presentation

Data Evaluation

Allowable Criteria for Foundation Movement
Important Definitions:

*Deflection* is the distorted shape of a structural element due to bending. As shown below, Deflection is the vertical distance between any point 2 on the surface and a line $L_{13}$ that connects two end points 1 and 3 on that surface.
Important Definitions:

Deflection Ratio is defined as the Deflection divided by the horizontal distance over which the Deflection occurs, and is used as criteria of acceptance when evaluating Foundation Movement.
Important Definitions:

Deflection Limit is defined as the Effective Length divided by a number, and is used as criteria of acceptance when evaluating Foundation Movement. Deflection Limit is the length times the maximum Deflection Ratio.
Important Definitions:

*Tilt* is defined as a planar rotation, measured over the length or width of the Foundation.
Important Definitions:

**Effective Length** is the length of a straight line (L) drawn along a minimum of three points in the plan view for which the Elevations are known, multiplied by the "k" factor (i.e., kL).
Deflection calcs are easy… just solve the following equation:

\[
\begin{align*}
(m_v \cdot l_v + m_g \cdot e) \cdot \ddot{V} + & (m_v \cdot l_v \cdot h_v + l_{vz} \cdot \sin(\sigma) + m_g \cdot e \cdot R_v + l_{gz} \cdot \sin(\sigma)) \cdot \ddot{\rho} + \\
(m_v \cdot l_v \cdot (a_h - a_v) + l_{vz} \cdot \cos(\sigma) + m_g \cdot e \cdot (a_n - N) + l_{gz} \cdot \cos(\sigma) + \theta_x) \cdot \dot{\rho} + \\
(l_{vz} + m_v \cdot l_v^2 + l_{gz} + m_g \cdot e^2 + \theta_{ml}) \cdot \dot{\lambda} - & l_{vy} / R_v \cdot \cos(\sigma) \cdot U \cdot \dot{\rho} + \\
(m_v \cdot l_v + m_g \cdot e + l_{vy} / R_v \cdot \sin(\sigma)) \cdot U \cdot \dot{\lambda} + (r_l + r_{ml}) \cdot \dot{\lambda} + (F_n \cdot n - m_v \cdot l_v \cdot g - m_g \cdot e \cdot g) \cdot \rho + \\
((F_n \cdot n - m_v \cdot l_v \cdot g - m_g \cdot e \cdot g) \cdot \sin(\sigma) + k_{ml}) \cdot \lambda + \\
n \cdot F_{sv} + M_{sv} \cdot \cos(\sigma) + M_{xv} \cdot \sin(\sigma) &= 0
\end{align*}
\]
\[ (m + m_G \cdot e) \cdot V + \left( m \cdot V \cdot h + l_{vz} \right) \cdot \ddot{V} + e \cdot R_v + l_{gz} \cdot \sin(\sigma) \right) \cdot \ddot{p} + \\
\left( m \cdot (a_H - a_v) + l_{vz} \cdot \cos(\sigma) + m_G \cdot e + l_{g} \cdot \cos(\sigma) + \theta_m \right) \cdot \dot{q} + \\
\left( l_{vz} + m \cdot v^2 + l_{g} + m_G \cdot e^2 + \theta_m \right) \cdot \lambda + \lambda \cdot U \cdot \dot{p} + \\
\left( m \cdot v + m_G \cdot e + l_{vy} \right) \cdot R_v \cdot \sin(\sigma) \cdot \dot{p} + \\
\left( \left( F_N \cdot n - m \cdot V \cdot g - m_G \cdot e \cdot g \right) \cdot \rho + \\
\left( \left( F_N \cdot n - m \cdot V \cdot g - m_G \cdot e \cdot g \right) \cdot \sin(\sigma) \cdot \dot{p} + \\
n \cdot F_{sv} + M_{sv} \cdot \cos(\sigma) + M_{sv} \cdot \sin(\sigma) = 0 \right)
The Real Equations

Deflection = \( \Delta = Y_2 - [Y_1 + \left( \frac{L_{12}}{L} \right)(Y_3 - Y_1)] \)

Deflection Ratio = \( \frac{L}{r} \) where \( r = \frac{R\text{ inches}}{\Delta\text{ inches}} \)

Tilt = \( \frac{|Y_B - Y_A|}{L_{AB}} \times 100\% \)
Allowable Criteria for Foundation Movement

The “k” factor

\[ k = \frac{\sqrt{\text{length}^2 + \text{width}^2}}{\text{length}} \]

Deflection Limit = \( kL / 360 \)
The “k” factor

\[ k = \frac{\sqrt{\text{length}^2 + \text{width}^2}}{\text{length}} \]

Deflection Limit = \( \frac{kL}{360} \)
Allowable Criteria for Foundation Movement

Determining Principal Axis’ Length and Width
Example A

<table>
<thead>
<tr>
<th>Ex.</th>
<th>L</th>
<th>L12</th>
<th>Y1</th>
<th>Y2</th>
<th>Y3</th>
<th>Δ (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50’</td>
<td>10’</td>
<td>0’</td>
<td>1.4”</td>
<td>-1.2”</td>
<td>1.64</td>
</tr>
</tbody>
</table>

Deflection = Δ = Y2 − [Y1 + \( \frac{L_{12}}{L} (Y_3 - Y_1) \)] = 1.4 − [0 + \( \frac{10}{50} \)(-1.2 − 0)] = 1.64
Example B

<table>
<thead>
<tr>
<th>Ex.</th>
<th>L</th>
<th>L_{12}</th>
<th>Y_1</th>
<th>Y_2</th>
<th>Y_3</th>
<th>Δ (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>60’</td>
<td>30’</td>
<td>1.4”</td>
<td>-1.2”</td>
<td>1.0”</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

Deflection = Δ = Y_2 - [Y_1 + \left(\frac{L_{12}}{L}\right)(Y_3 - Y_1)] = -1.2 - [1.4 + \left(\frac{30}{60}\right)(1.0 - 1.4)] = -2.4
Example C

<table>
<thead>
<tr>
<th>Ex.</th>
<th>L</th>
<th>L_{12}</th>
<th>Y_1</th>
<th>Y_2</th>
<th>Y_3</th>
<th>\Delta (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>30’</td>
<td>20’</td>
<td>-1.2”</td>
<td>-0.5”</td>
<td>1.0”</td>
<td>-0.78</td>
</tr>
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Tilt

\[
\text{Tilt} = \frac{Y_B - Y_A}{L_{AB}} \times 100\% = \frac{|1.0" - 0"|}{80' \times 12 \text{in/ft}} \times 100\% = 0.10\% < 1.0\%,
\]
Allowable Criteria for Foundation Movement

Deflection Limit:
- L / 240?
- L / 360?
- L / 480?

Why did we choose L/360?
Determining Allowable Criteria for Foundation Movement

Calculation Spreadsheet
In Summary...

Deflection Limit: $kL / 360$

Tilt: 1% maximum
QUESTIONS?

Download “Guidelines for the Evaluation of Foundation Movement for Residential and Other Low-Rise Buildings” at:
http://www.foundationperformance.org/committee_papers.cfm