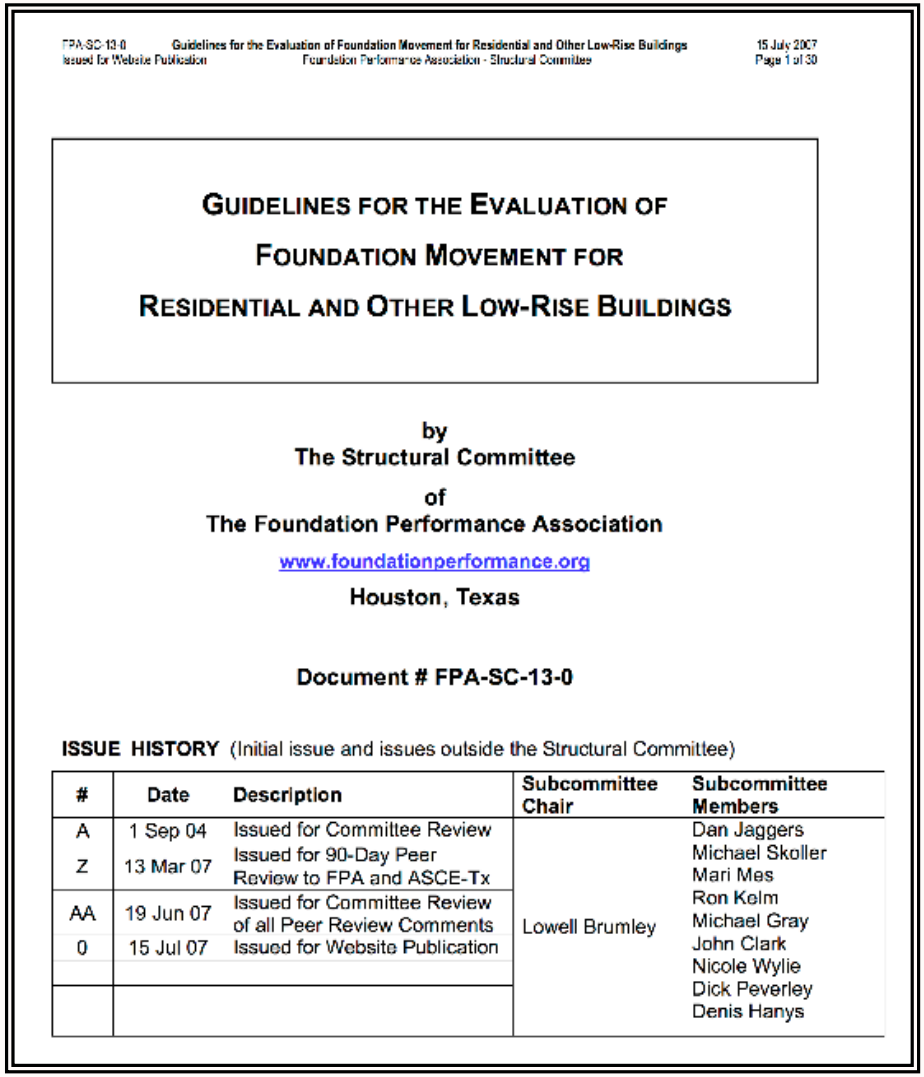
FOUNDATION PERFORMANCE ASSOCIATION

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

Document no:	**FPA-SC-13**
Developed by:	**FPA Structural Committee**
Committee chairs:	**Main Committee - Ron Kelm, P.E.** **Subcommittee - Lowell Brumley, P.E.**
Subcommittee:	**Dan Jaggers, Michael Skoller, Mari Mes, Michael Gray, John Clark, Nicole Wylie, Dick Peverley, Denis Hanys, Ron Kelm**
Presented by:	**Lowell Brumley, P.E., TSG Consultants Inc.**
Presented to :	**Foundation Performance Association**
Presented on:	**8 August 2007**

Why was it written?

…a brief history…



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Issued for Website Publication Foundation Performance Association - Structural Committee Page 1 of 30

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)

#	Date	Description	Subcommittee Chair	Subcommittee Members
A	1 Sep 04	Issued for Committee Review	Lowell Brumley	Dan Jaggers Michael Skoller Mari Mes Ron Kelm Michael Gray John Clark Nicole Wylie Dick Peverley Denis Hanys
Z	13 Mar 07	Issued for 90-Day Peer Review to FPA and ASCE-Tx		
AA	19 Jun 07	Issued for Committee Review of all Peer Review Comments		
0	15 Jul 07	Issued for Website Publication		

Who can use this document?

Document Summary

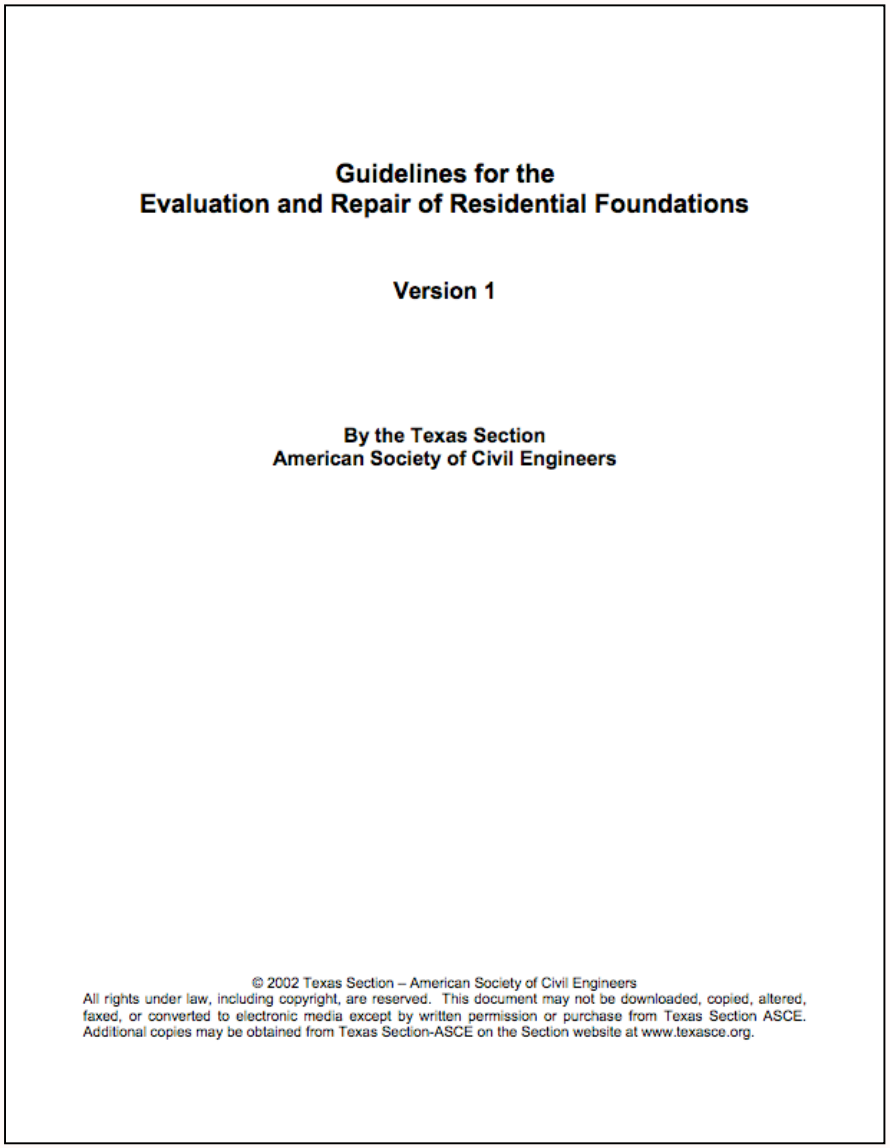
Levels of Investigation

- 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



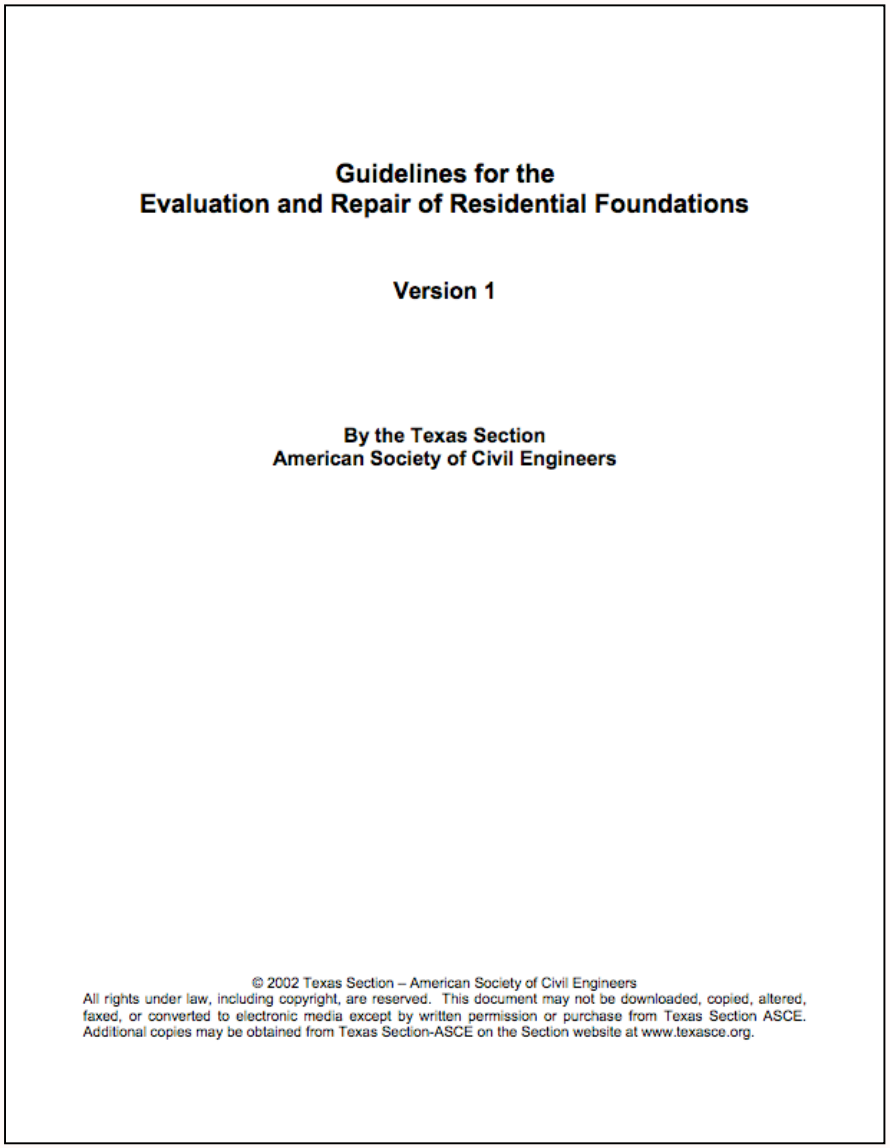
Guidelines for the
Evaluation and Repair of Residential Foundations

Version 1

By the Texas Section
American Society of Civil Engineers

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



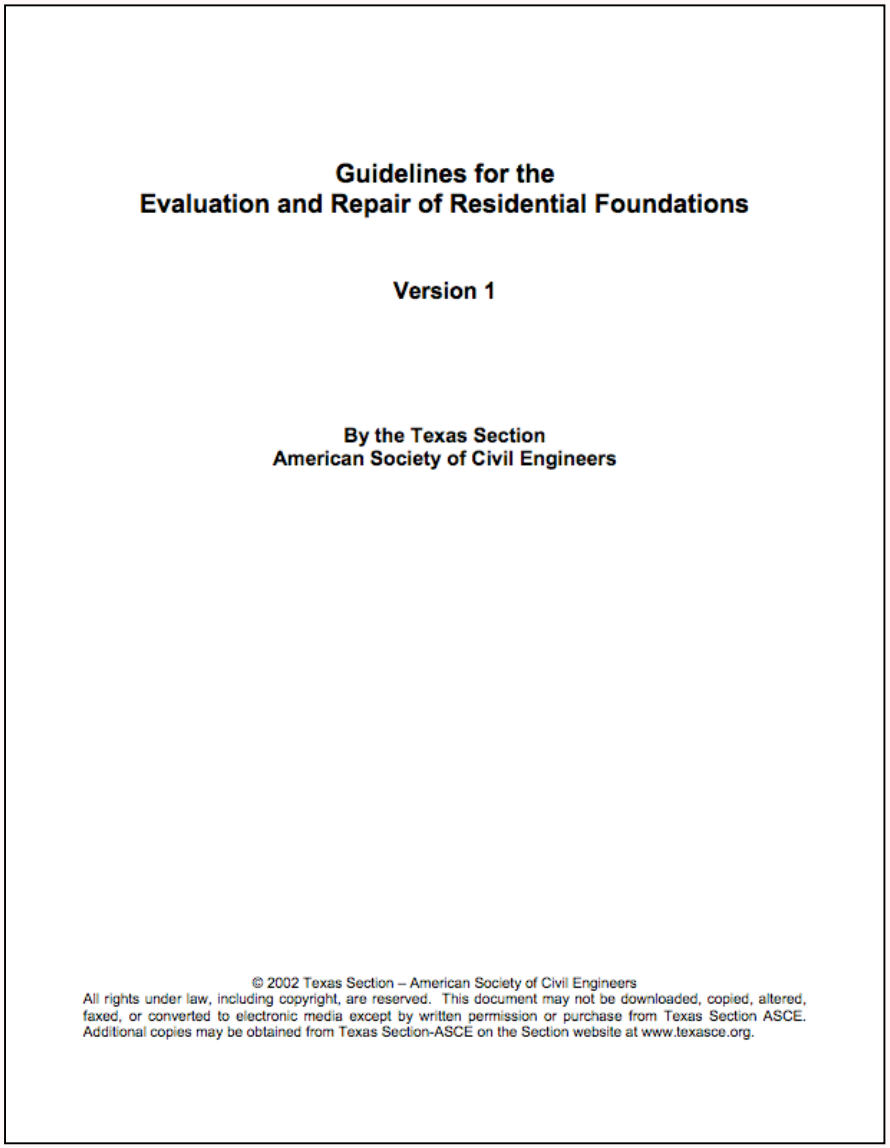
Guidelines for the
Evaluation and Repair of Residential Foundations

Version 1

By the Texas Section
American Society of Civil Engineers

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



Guidelines for the
Evaluation and Repair of Residential Foundations

Version 1

By the Texas Section
American Society of Civil Engineers

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.

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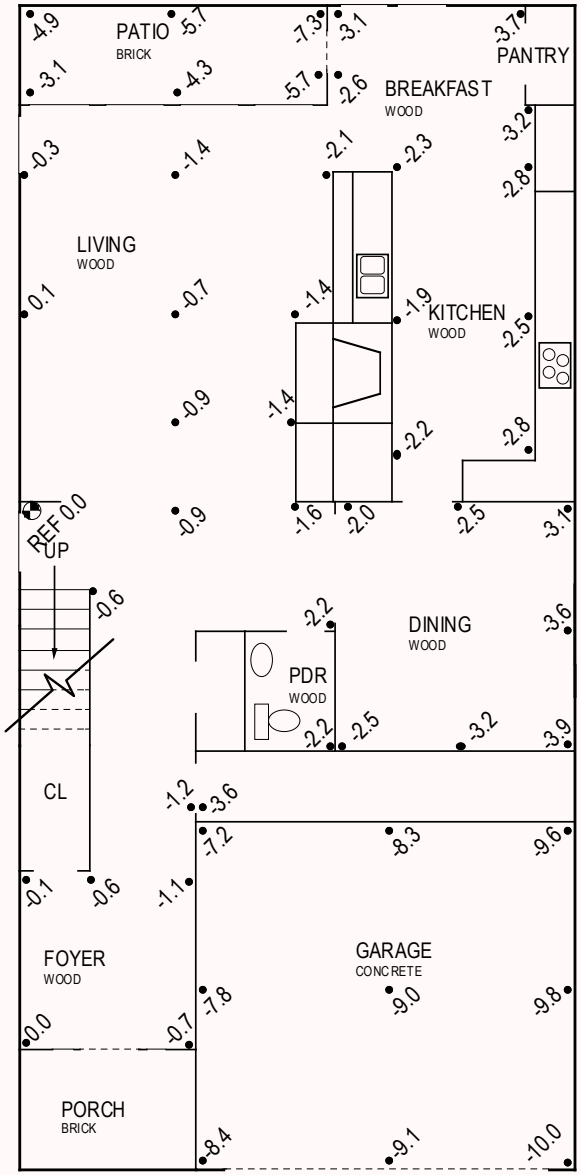
Data Evaluation

Allowable Criteria for Foundation Movement

Data Acquisition and Presentation



Zip Level

Digital Leveling Systems
Electronic Water Level

Document Summary

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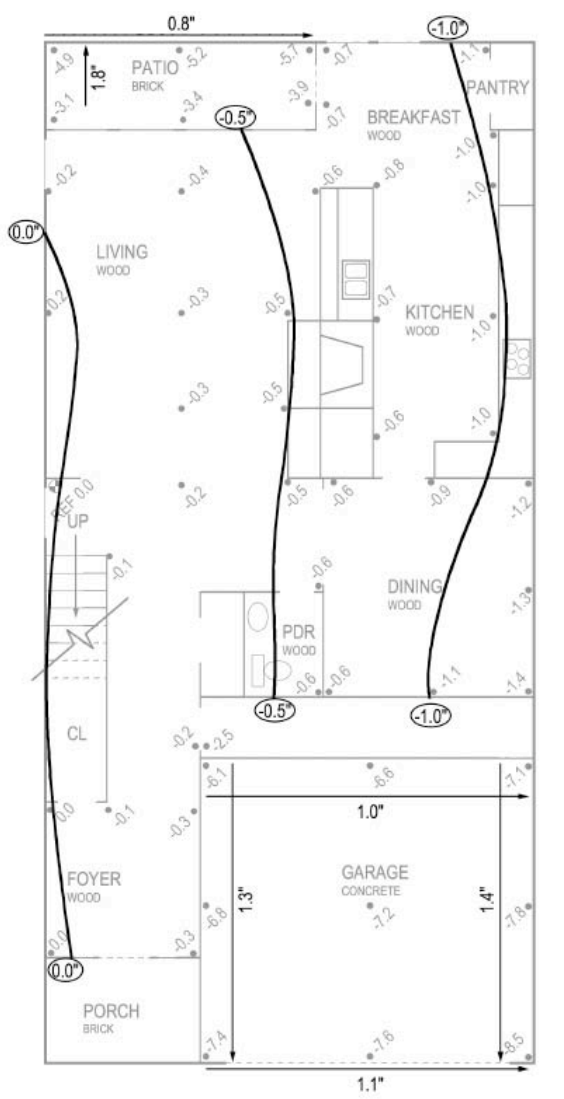
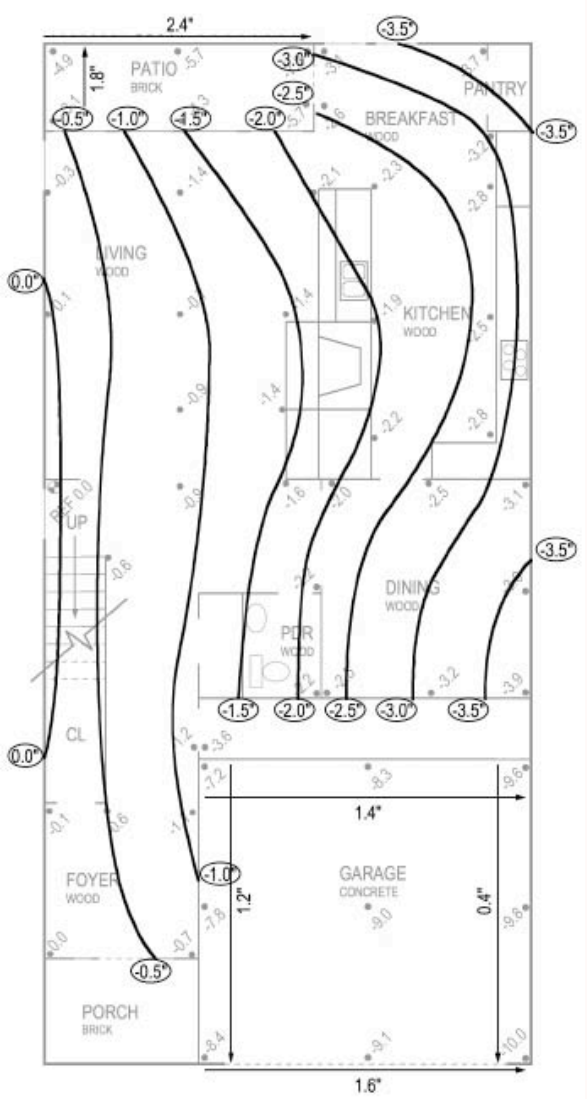
Data Evaluation

Allowable Criteria for Foundation Movement



Data Evaluation

Comparing elevations over a two-year period using Contours



Document Summary

Levels of Investigation

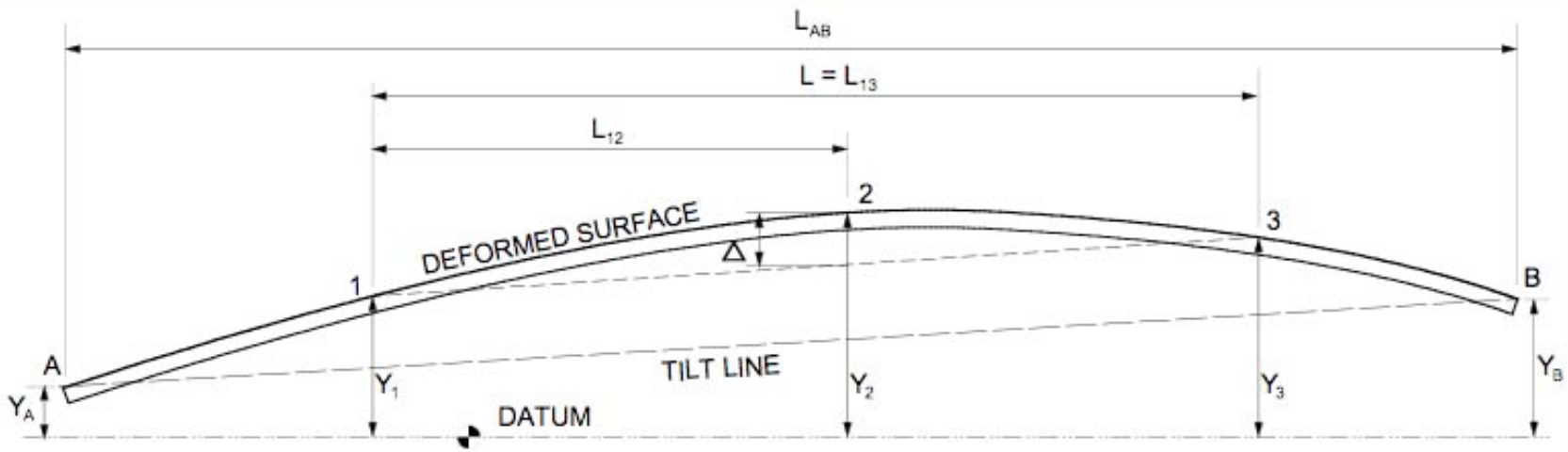
Data Acquisition & Presentation

Data Evaluation

Allowable Criteria for Foundation Movement

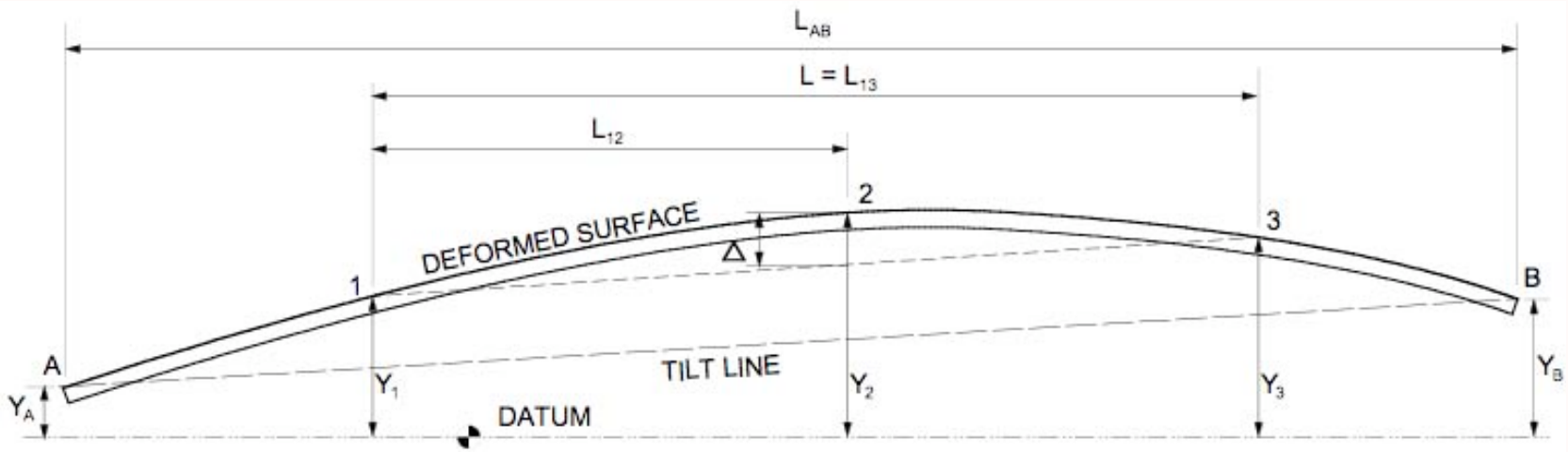
Important Definitions:

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.



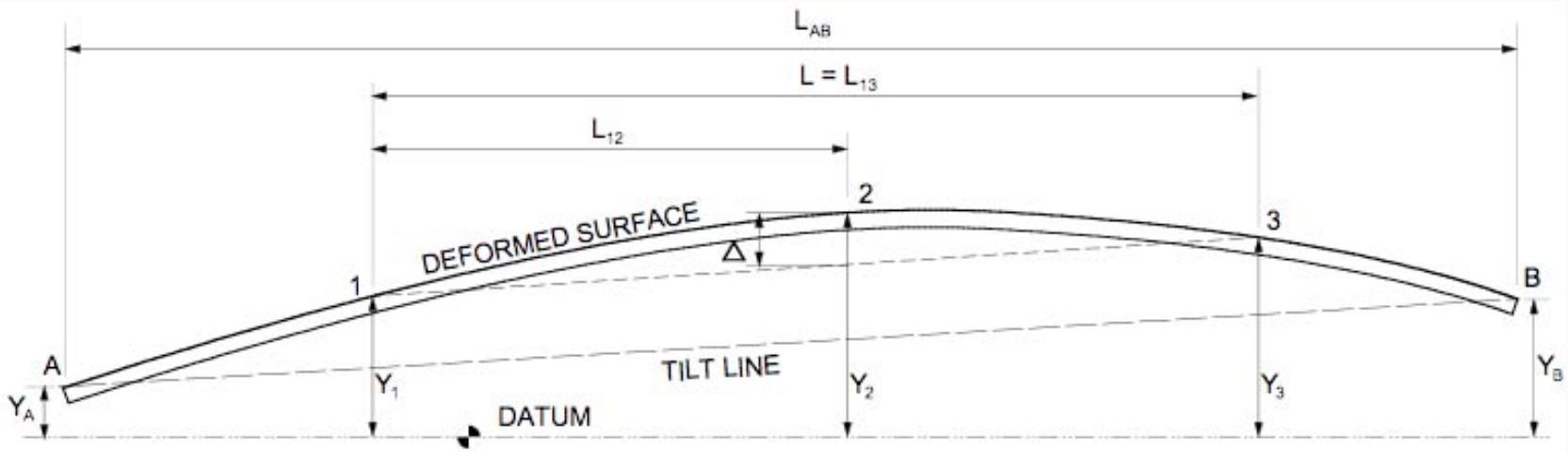
Important Definitions:

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.



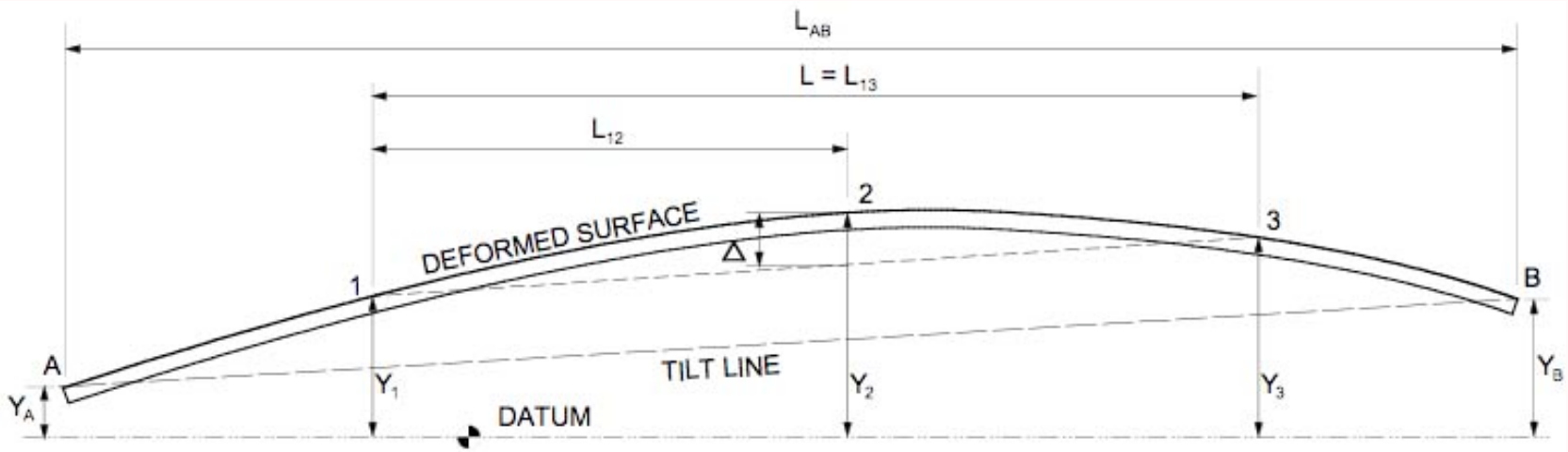
Important Definitions:

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.



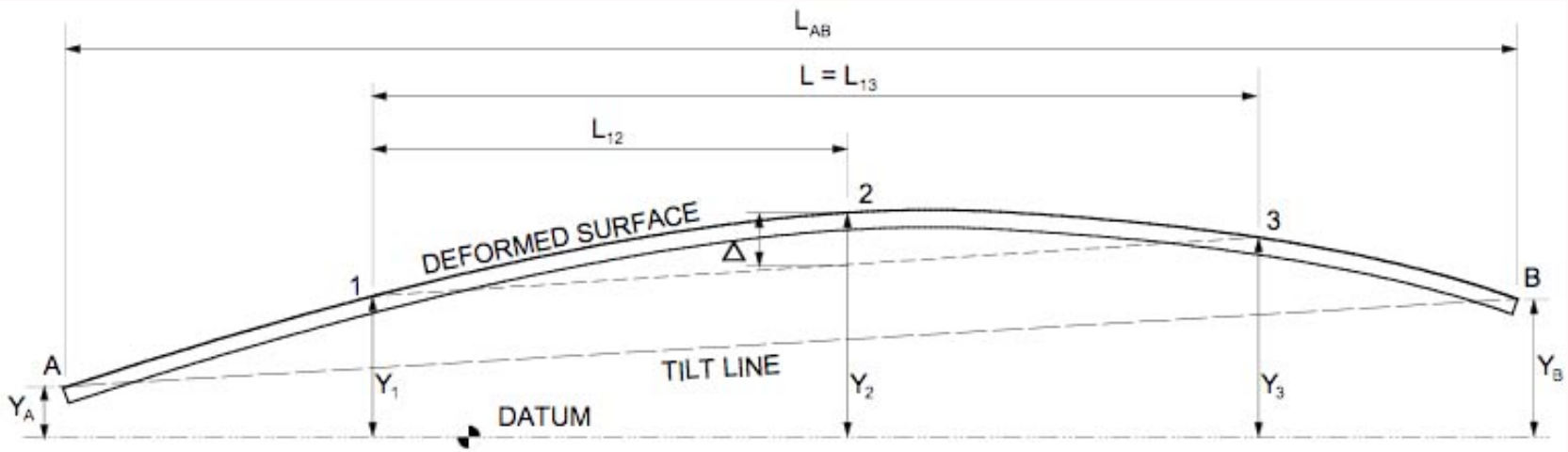
Important Definitions:

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



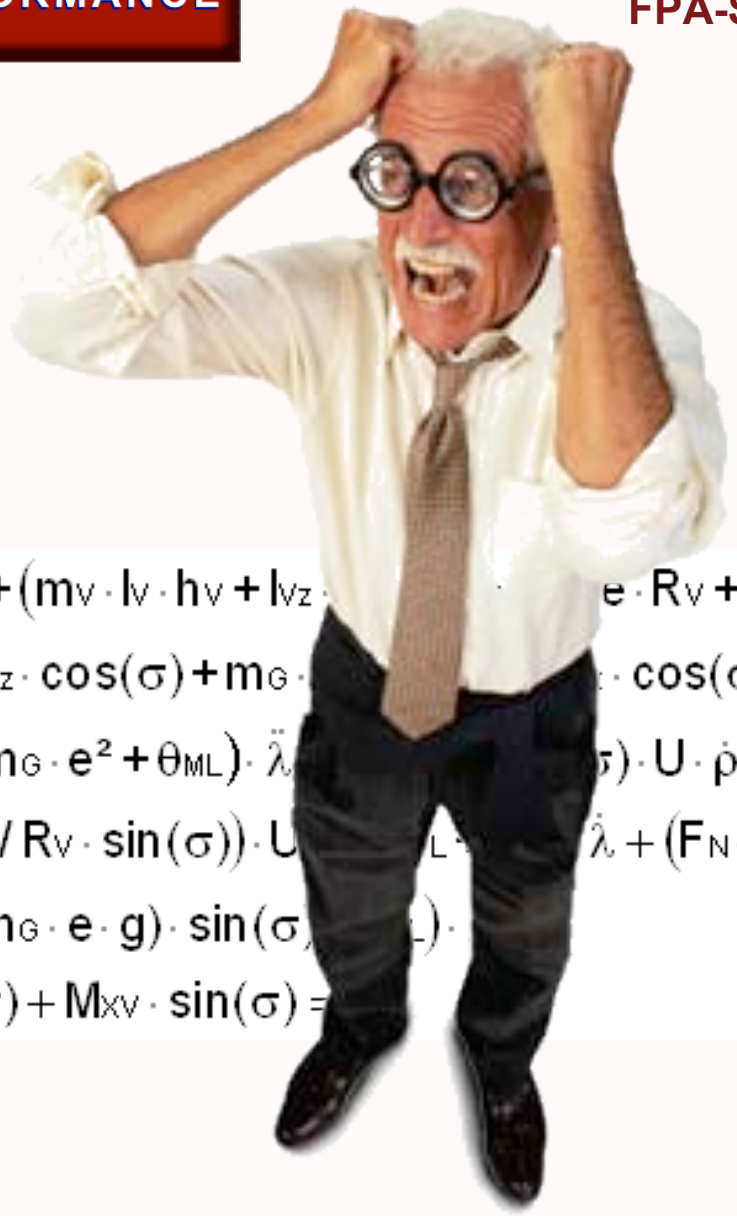
Important Definitions:

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:

$$(m_V \cdot l_V + m_G \cdot e) \cdot \ddot{V} + (m_V \cdot l_V \cdot h_V + I_{Vz} \cdot \sin(\sigma) + m_G \cdot e \cdot R_V + I_{Gz} \cdot \sin(\sigma)) \cdot \ddot{\rho} +$$
$$(m_V \cdot l_V \cdot (a_H - a_V) + I_{Vz} \cdot \cos(\sigma) + m_G \cdot e \cdot (a_N - N) + I_{Gz} \cdot \cos(\sigma) + \theta_\chi) \cdot \ddot{\gamma} +$$
$$(I_{Vz} + m_V \cdot l_V^2 + I_{Gz} + m_G \cdot e^2 + \theta_{ML}) \cdot \ddot{\lambda} - I_{Vy} / R_V \cdot \cos(\sigma) \cdot U \cdot \dot{\rho} +$$
$$(m_V \cdot l_V + m_G \cdot e + I_{Vy} / R_V \cdot \sin(\sigma)) \cdot U \cdot \dot{\gamma} + (r_L + r_{ML}) \cdot \dot{\lambda} + (F_N \cdot n - m_V \cdot l_V \cdot g - m_G \cdot e \cdot g) \cdot \rho +$$
$$((F_N \cdot n - m_V \cdot l_V \cdot g - m_G \cdot e \cdot g) \cdot \sin(\sigma) + k_{ML}) \cdot \lambda +$$
$$n \cdot F_{SV} + M_{ZV} \cdot \cos(\sigma) + M_{XV} \cdot \sin(\sigma) = 0$$



$$(m_V \cdot l_V + m_G \cdot e) \cdot \ddot{V} + (m_V \cdot l_V \cdot h_V + I_{Vz} \cdot \quad e \cdot R_V + I_{Gz} \cdot \sin(\sigma)) \cdot \ddot{\rho} +$$

$$(m_V \cdot l_V \cdot (a_H - a_V) + I_{Vz} \cdot \cos(\sigma) + m_G \cdot \quad \cdot \cos(\sigma) + \theta_\chi) \cdot \ddot{\gamma} +$$

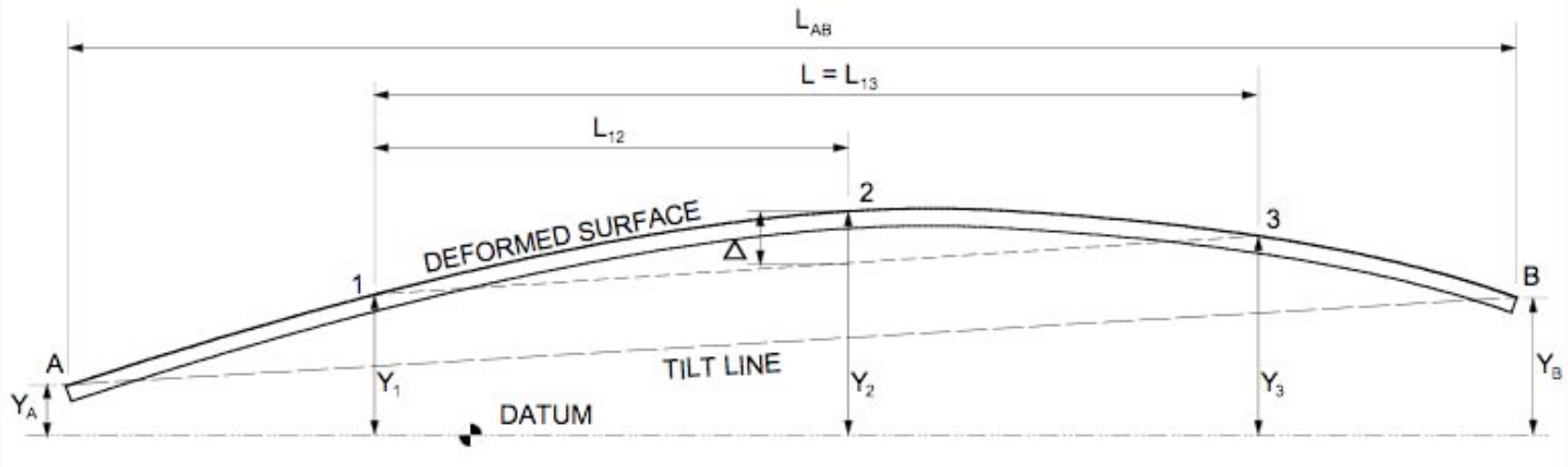
$$(I_{Vz} + m_V \cdot l_V^2 + I_{Gz} + m_G \cdot e^2 + \theta_{ML}) \cdot \ddot{\lambda} \quad \sigma) \cdot U \cdot \dot{\rho} +$$

$$(m_V \cdot l_V + m_G \cdot e + I_{Vy} / R_V \cdot \sin(\sigma)) \cdot U \quad \dot{\lambda} + (F_N \cdot n - m_V \cdot l_V \cdot g - m_G \cdot e \cdot g) \cdot \rho +$$

$$((F_N \cdot n - m_V \cdot l_V \cdot g - m_G \cdot e \cdot g) \cdot \sin(\sigma \quad) \cdot$$

$$n \cdot F_{SV} + M_{ZV} \cdot \cos(\sigma) + M_{XV} \cdot \sin(\sigma) =$$

The Real Equations



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

$$\text{Deflection Ratio} = \frac{L}{r} \quad \text{where } r = \frac{L_{\text{inches}}}{\Delta_{\text{inches}}}$$

$$\text{Tilt} = \frac{|Y_B - Y_A|}{L_{AB}} \text{ x } 100\%$$

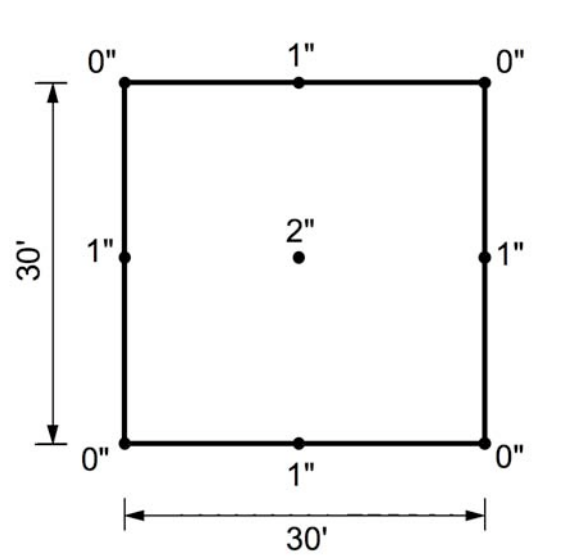
Allowable Criteria for Foundation Movement

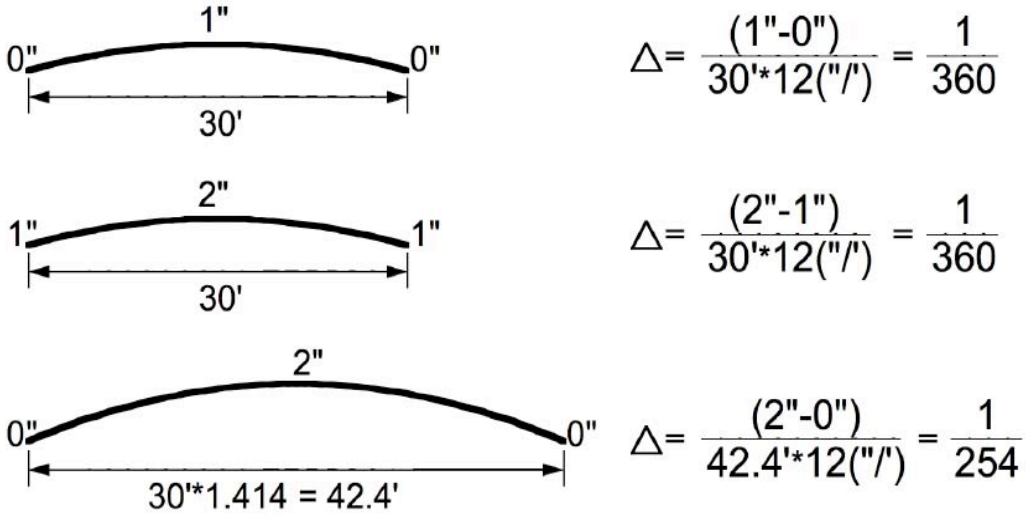
The "k" factor

$$k = \frac{\sqrt{length^2 + width^2}}{length}$$

Deflection Limit = kL / 360

The "k" factor





$$\Delta = \frac{(1"-0")}{30'*12("/')} = \frac{1}{360}$$

$$\Delta = \frac{(2"-1")}{30'*12("/')} = \frac{1}{360}$$

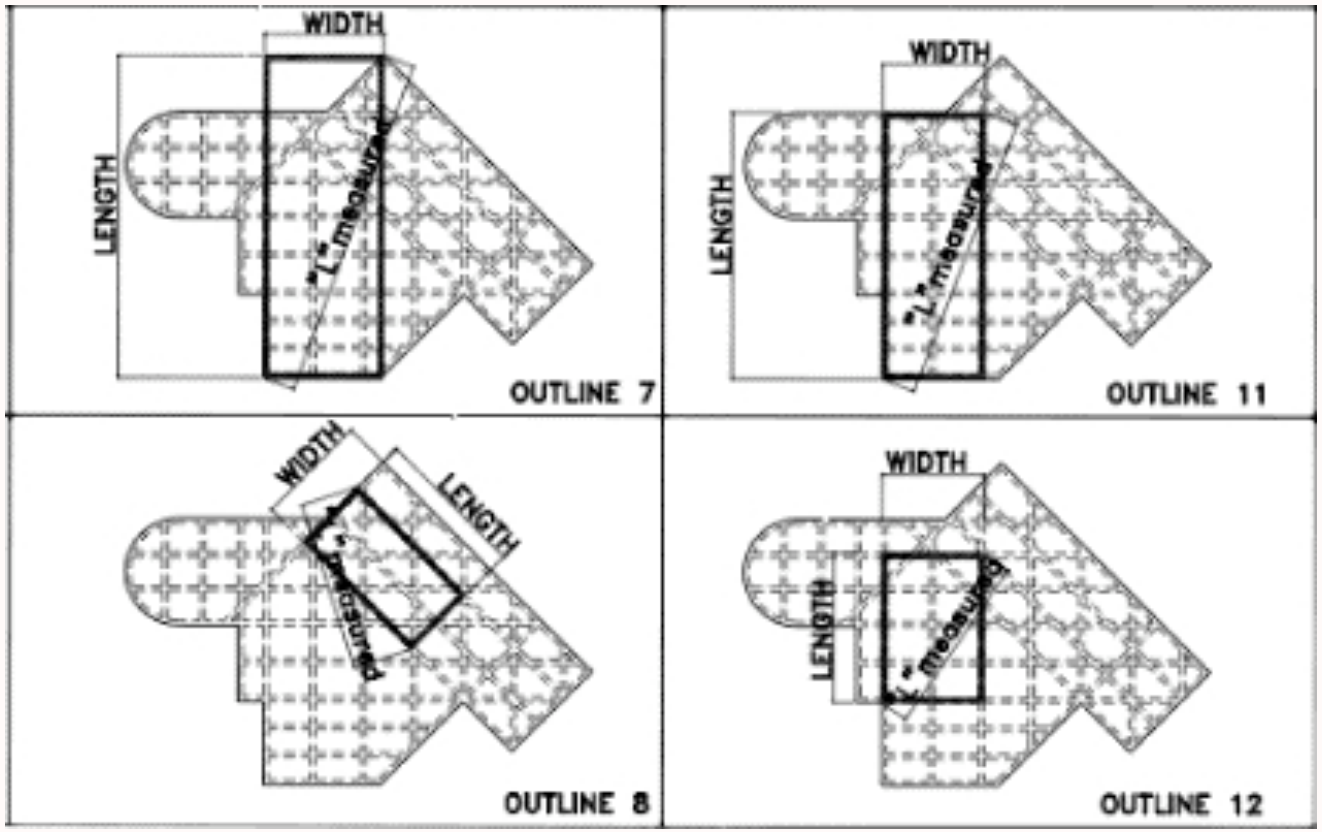
$$\Delta = \frac{(2"-0")}{42.4'*12("/')} = \frac{1}{254}$$

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

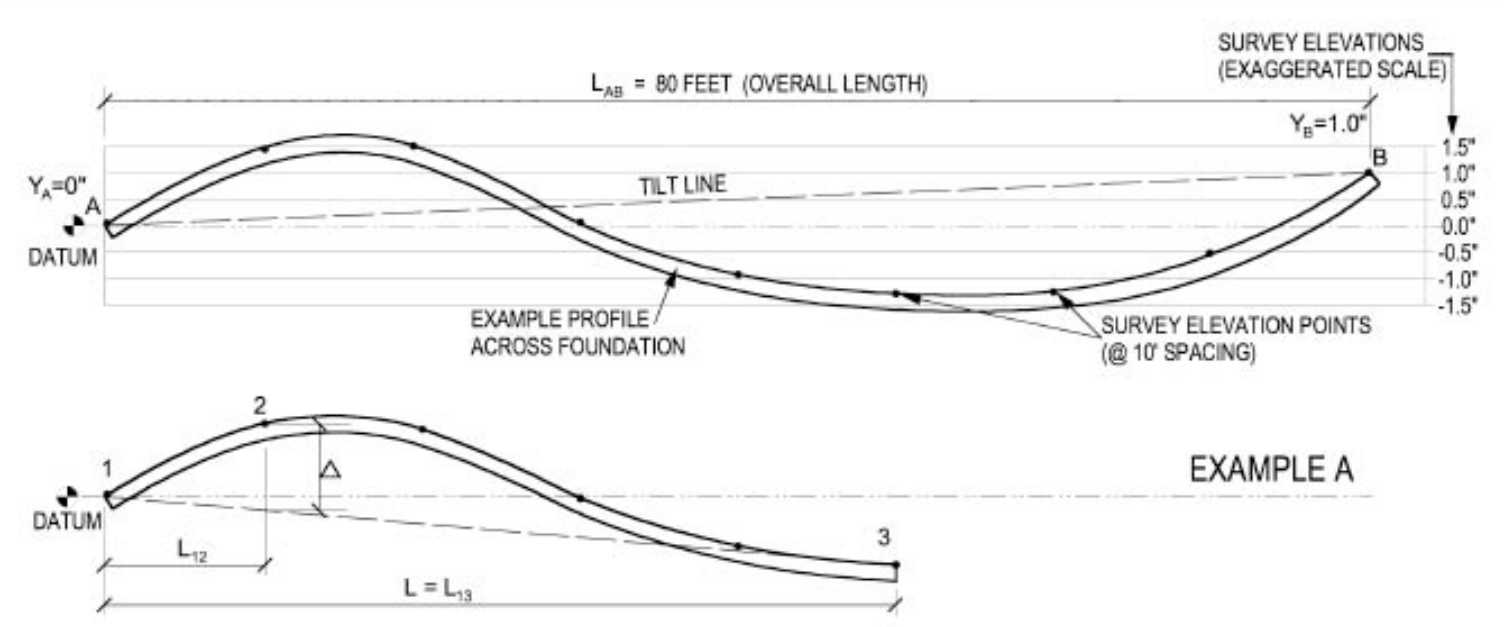
Deflection Limit = kL / 360

Allowable Criteria for Foundation Movement

Determining Principal Axis' Length and Width



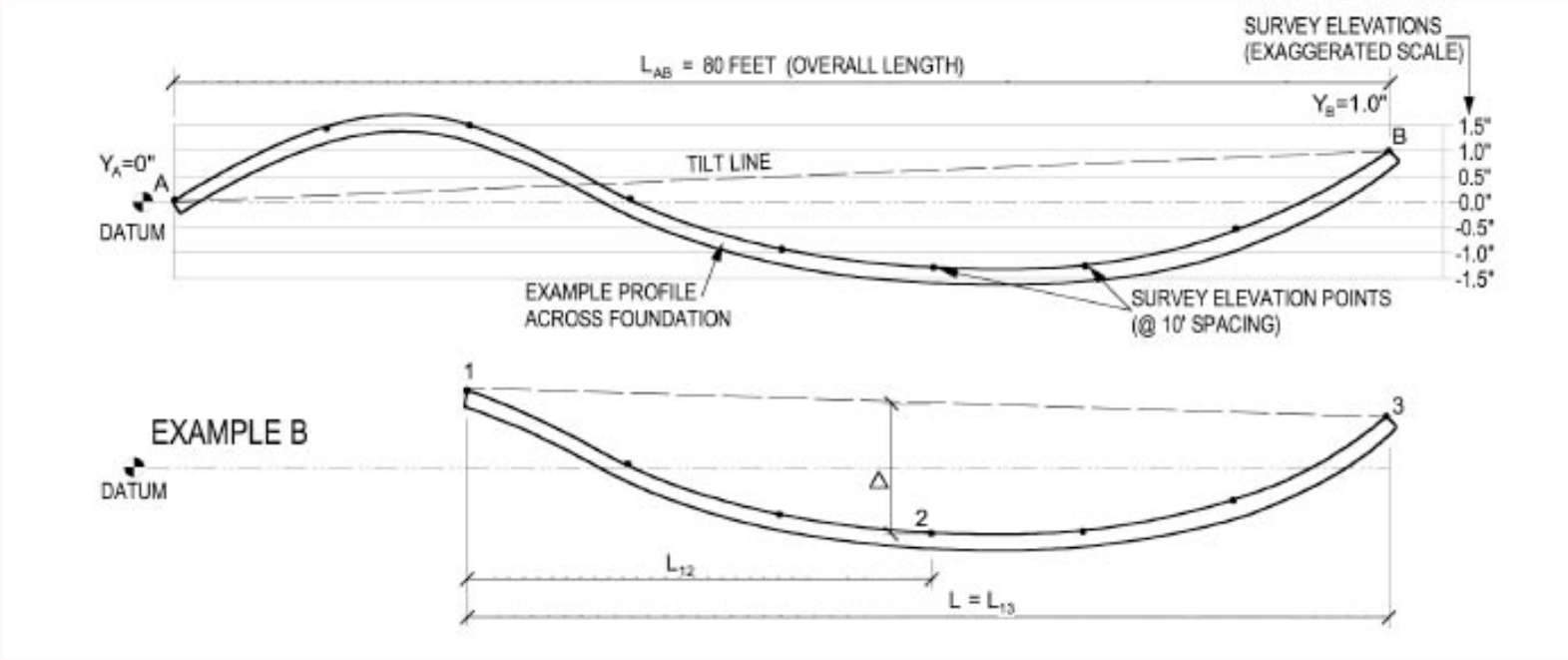
Example A



Ex.	L	L_{12}	Y_1	Y_2	Y_3	Δ (inches)	
A	50’	10’	0”	1.4”	-1.2”	1.64	L/366

$$\text{Deflection} = \Delta = Y_2 - [Y_1 + (\frac{L_{12}}{L})(Y_3 - Y_1)] = 1.4 - [0 + (\frac{10}{50})(-1.2 - 0)] = 1.64$$

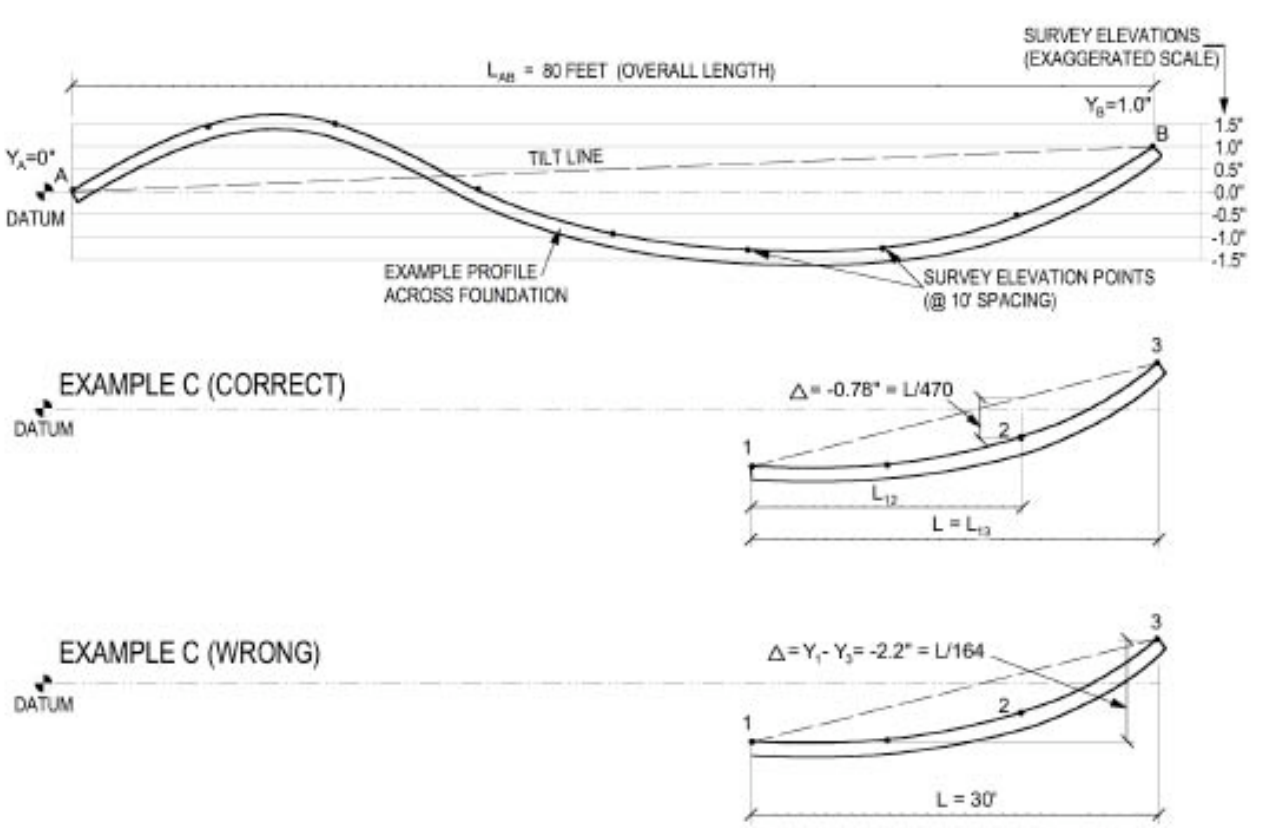
Example B



Ex.	L	L_{12}	Y_1	Y_2	Y_3	Δ (inches)	
B	60’	30’	1.4”	-1.2”	1.0”	-2.4	L/300

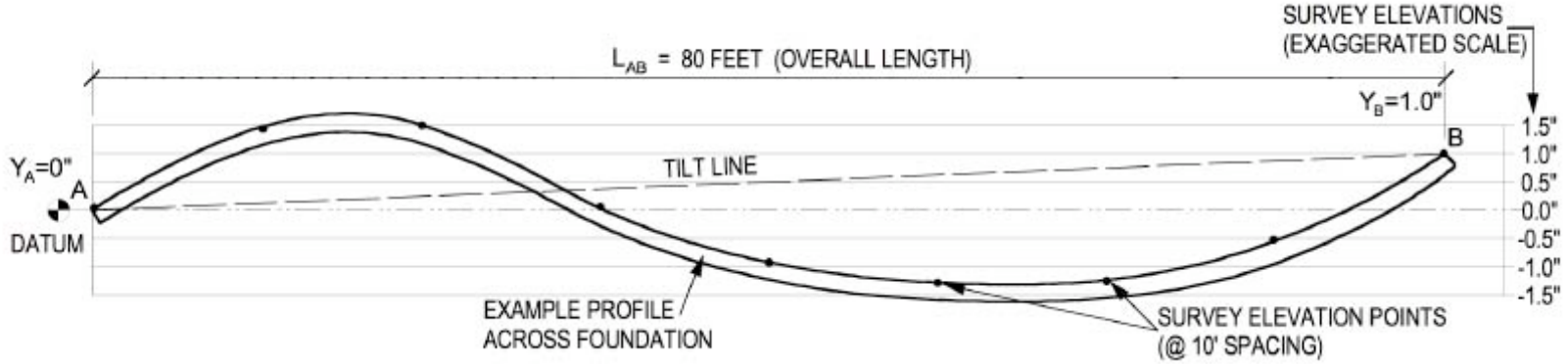
$$\text{Deflection} = \Delta = Y_2 - [Y_1 + (\frac{L_{12}}{L})(Y_3 - Y_1)] = -1.2 - [1.4 + (\frac{30}{60})(1.0 - 1.4)] = -2.4$$

Example C



Ex.	L	L_{12}	Y_1	Y_2	Y_3	Δ (inches)	
C	30’	20’	-1.2”	-0.5”	1.0”	-0.78	L/470

Tilt



$$\text{Tilt} = \frac{|Y_B - Y_A|}{L_{AB}} \times 100\% = \frac{|1.0" - 0"|}{80' \times 12 in/ft} \times 100\% = 0.10\% < 1.0\%,$$

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

Calculation Spreadsheet for FPA-SC-13-0 www.foundationperformance.org Rev. 15 Jul 07
Guidelines for the Evaluation of Foundation Movement for Residential and Other Low-Rise Buildings

Instructions to Compute Deflection Limit, Tilt and k-factored Deflection Limit:

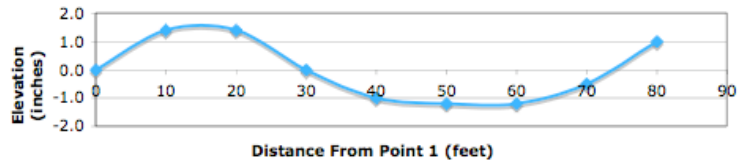
a) Input distances along profile into blue "L" cells from one edge of slab to the other.
(Spacing may be unequal, first L must be zero, each successive L greater than the previous)

b) Input elevations measured at each "L" into blue "Y" cells
(Start with Point 1; For less than 9 data sets, leave extra cells "empty", not zero)
* If Non-Principle Axis is used, enter Length and Width. Otherwise let Length=1, Width=0.01
** L/360 (Max. Allowable Deflection Limit) is used when L is along a principal axis. If Length L is not parallel to a principal axis, L is modified by the k-factor to adjust the Max. Allowable Deflection Limit to as much as L/255 for k-factors up to 1.414

PROFILE INPUT *Length 59.0 *Width 54.0 (ft)

	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	Point 9
L (ft)	0	10	20	30	40	50	60	70	80
Y (in)	0.0	1.4	1.4	0.0	-1.0	-1.2	-1.2	-0.5	1.0

Profile Input Plot



OUTPUT	ACTUAL	ALLOWABLES	PASS/FAIL
Deflection=	L / 253	L / 266	FAIL
Tilt =	0.10 %	1.00 %	PASS

User input is in the blue cells only and echoed in the Input Plot. Output is in the yellow cells.

Deflection between points 1 and 3: Deflection = Y2-[Y1+(L12/L)(Y3-Y1)]
Points 1 & 3 are end points of any intermediate span chosen by spreadsheet;
Point 2 is any point chosen by spreadsheet that falls in between 1 & 3

Edge-to-edge Tilt: Tilt = (100%) |Yb-Ya| / Lab

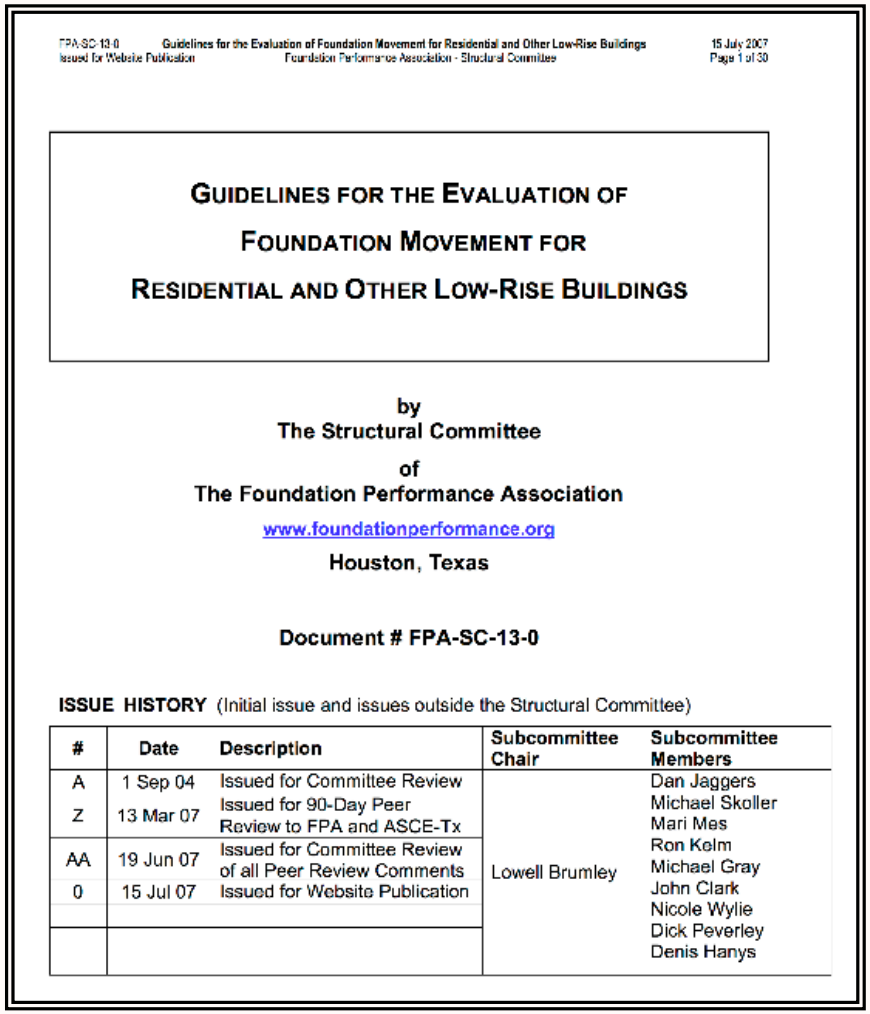
k-factor: k = SQRT(Length^2 + Width^2) / Length

This spreadsheet was used by the Foundation Performance Association to determine the appropriate deflection threshold, and is provided to FPA members as a courtesy and with no guarantee of its accuracy. Section 6 of FPA-SC-13-0 provides definitions and further information on the calculations performed.

In Summary…

Deflection Limit: kL / 360

Tilt: 1% maximum



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FOUNDATION PERFORMANCE ASSOCIATION

QUESTIONS?

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