GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Range: 6"

Serial Number: 18673

Mfg. Number: 01-752

Customer: Loadtest Inc.

Temperature: 24.2 °C

Cust. I.D. #: n/a

Cal. Std. Control #(s): 124, 213, 506, 524, 529

Job Number: 17473

Date of Calibration: July 20, 2001

Technician: MLC

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2411	2409	2410		-0.26
1.200	3674	3675	3675	1265	0.10
2.400	4924	4921	4923	1248	0.20
3.600	6162	6161	6162	1239	0.15
4.800	7395	7394	7395	1233	0.00
6.000	8626	8623	8625	1230	-0.19

Calibration Factor (C): 0.0009661 (Inches/Digit)

Regression Zero: 2426

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B":* 5606

or

Position "F":*

Date: August 16, 2001

Temperature: 24.3 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

The above instrument was found to be in tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Range: 6"

Serial Number: 18674

Mfg. Number: 01-753

Customer: Loadtest Inc.

Temperature: 23.8 °C

Cust. I.D. #: n/a

Cal. Std. Control #(s): 124, 213, 506, 524, 529

Job Number: 17473

Date of Calibration: July 23, 2001

Technician: MLC

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2428	2426	2427		-0.26
1.200	3700	3699	3700	1273	0.11
2.400	4952	4951	4952	1252	0.16
3.600	6202	6202	6202	1251	0.19
4.800	7439	7438	7439	1237	-0.02
6.000	8676	8677	8677	1238	-0.19

Calibration Factor (C): 0.0009607 (Inches/Digit)

Regression Zero: 2443

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B":* 5622

or

Position "F":* ______

Date: August 16, 2001

Temperature: 24.4 °C

Wiring Code: Red and Black: Gage White and Green: Thermistor

The above instrument was found to be in tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 21344

Customer: Loadtest Inc.

Job Number: 17473

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.5 °C

Calibration Date: August 20, 2001

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 85 ft.

Factory Zero Reading: 6847

Regression Zero: 6865

Technician: MLC

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6917	6921	6919		
1,500	7585	7588	7587	668	-0.30
3,000	8326	8328	8327	741	0.05
4,500	9061	9061	9061	734	0.18
6,000	9783	9785	9784	723	-0.07
100	6921				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor:

0.347 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 per cent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 21345

Customer: Loadtest Inc.

Job Number: 17473

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.4 °C

Calibration Date: August 20, 2001

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 85 ft.

Factory Zero Reading: 6741

Regression Zero: 6742

Technician: MLC

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6800	6800	6800		
1,500	7460	7461	7461	661	-0.31
3,000	8191	8193	8192	732	-0.17
4,500	8925	8927	8926	734	0.06
6,000	9654	9657	9656	730	0.13
100	6800				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor:

0.348 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 per cent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 21346

Customer: Loadtest Inc.

Job Number: 17473

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.2 °C

Calibration Date: August 20, 2001

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 75 ft.

Factory Zero Reading: 6816

Regression Zero: 6827

Technician: MLC

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6890	6888	6889		
1,500	7536	7534	7535	646	-0.41
3,000	8259	8257	8258	723	-0.30
4,500	8990	8987	8989	731	0.07
6,000	9714	9711	9713	724	0.22
100	6888				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor:

0.350 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 per cent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 21347

Customer: Loadtest Inc.

Job Number: 17473

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.3 °C

Calibration Date: August 20, 2001

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 75 ft.

Factory Zero Reading: 6932

Regression Zero: 6934

Technician: MLC

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6985	6989	6987		
1,500	7650	7653	7652	665	-0.16
3,000	8378	8380	8379	728	0.02
4,500	9101	9106	9104	725	0.09
6,000	9820	9828	9824	721	0.03
100	6989				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor:

0.349 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 per cent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number :	4911-4	Calibration Date:	August 20, 2001
Serial Number:	21348	Cal. Std. Control Numbers:	85888-1, 398
Customer:	Loadtest Inc.	Cable Length:	65 ft.
Job Number:	17473	Factory Zero Reading:	6935
Cust. I.D. #:	n/a	Regression Zero:	6947
Prestress:	35,000 psi		
Temperature:	23.1 °C	Technician:	MLC

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7001	6994	6998		
1,500	7659	7660	7660	662	-0.21
3,000	8386	8384	8385	726	0.03
4,500	9107	9113	9110	725	0.25
6,000	9820	9814	9817	707	-0.15
100	6994				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor:

0.351 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 per cent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

GEOKON 48 Spencer St. Lebanon, N.H. 03766 USA

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 21349

Customer: Loadtest Inc.

Job Number: 17473

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.3 °C

Calibration Date: August 20, 2001

Cal. Std. Control Numbers: 85888-1, 398

Cable Length: 65 ft.

Factory Zero Reading: 6846

Regression Zero: 6873

Technician: MLC

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6929	6913	6921		
1,500	7603	7599	7601	680	0.01
3,000	8333	8326	8330	729	0.04
4,500	9065	9056	9061	731	0.16
6,000	9785	9777	9781	721	-0.09
100	6914				

For conversion factor, load to strain, refer to table C-2 of the Installation Manual.

Gage Factor:

0.348 Microstrain/Digit (GK-401 Pos."B")

Calculated Strain = Gage Factor(Current Reading - Zero Reading)

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 per cent

The above instrument was found to be In Tolerance in all operating ranges.

The above named instrument has been calibrated by comparison with standards traceable to the NIST, in compliance with ANSI Z540-1.

TEST CERTIFICATION

Trident Supply Company of Ocala, Inc.
5760 SW 25th Street
Ocala, Florida 34474

Phone: (352) 873-6300
Fax: (352) 873-0335
Email: sales@tridentsupply.com

Customer: LOADTEST

This test document certifies that Trident Supply has successfully completed a Hydrostatic Proof Pressure Test (150% of rated working pressure) on enclosed hose assembly(ies).

Aeroquip Hose No. GH781-08   Customer Hose ID: 1/2"   Assembly Length: 90'

Aeroquip Coupling No. 1AA8FR8   Number of Assemblies Tested: 2

Date Tested: 8/14/01   Working Pressure: 4250   Test Pressure: 6375

Pressure Tested By: Don Roberson
Employee name

Couplings Attached By: [illegible]
Employee name

Customer PO#: 8810   Trident Sales Order#: 1036796   Certificate Number: 0003

APPENDIX C

CONSTRUCTION OF EQUIVALENT TOP-LOAD CURVE

CONSTRUCTION OF THE EQUIVALENT TOP-LOADED LOAD-SETTLEMENT CURVE FROM THE RESULTS OF AN O-CELL™ TEST (August, 2000)

Introduction: Some engineers find it useful to see the results of an O-cell™ load test in the form of a curve showing the load versus settlement of a top-loaded driven or bored pile (drilled shaft). We believe that an O-cell™ test can provide a good estimate of this curve when using the method described herein.

Assumptions: We make the following assumptions, which we consider both reasonable and usually conservative:

1. The end bearing load-movement curve in a top-loaded shaft has the same loads for a given movement as the net (subtract buoyant weight of pile above O-cell™) end bearing load-movement curve developed by the bottom of the O-cell™ when placed at or near the bottom of the shaft.

2. The side shear load-movement curve in a top-loaded shaft has the same net shear, multiplied by an adjustment factor 'F', for a given downward movement as occurred in the O-cell™ test for that same movement at the top of the cell in the upward direction. The same applies to the upward movement in a top-loaded tension test. Unless noted otherwise, we use the following adjustment factors: (a) F = 1.00 in all rock sockets and for primarily cohesive soils in compression (b) F = 0.95 in primarily cohesionless soils (c) F = 0.80 for all soils in top load tension tests.

3. We initially assume the pile behaves as a rigid body, but include the elastic compressions that are part of the movement data obtained from an O-cell™ test (OLT). Using this assumption, we construct an equivalent top-load test (TLT) movement curve by the method described below in Procedure Part I. We then use the following Procedure Part II to correct for the effects of the additional elastic compressions in a TLT.

4. Consider the case with the O-cell™, or the bottom O-cell™ of more than one level of cells, placed some distance above the bottom of the shaft. We assume the part of the shaft below the cell, now top-loaded, has the same load-movement behavior as when top-loading the entire shaft. For this case the subsequent "end bearing movement curve" refers to the movement of the entire length of shaft below the cell

Procedure Part I: Please refer to the attached Figure A showing O-cell™ test results and to Figure B, the constructed equivalent top loaded settlement curve. Note that each of the curves shown has points numbered from 1 to 12 such that the same point number on each curve has the same magnitude of movement. For example, point 4 has an upward and downward movement of 0.40 inches in Figure A and the same 0.40 inches downward in Figure B.

Note: This report shows the O-cell movement data in a Figure similar to Fig. A, but uses the gross loads as obtained in the field. Fig. A uses net loads to make it easier for the reader to convert Fig. A into Fig. B without the complication of the first converting gross to net loads. For our conservative reconstruction of the top loaded settlement curve we first convert both of the O-cell components to net load.

Using the above assumptions, construct the equivalent curve as follows: Select an arbitrary movement such as the 0.40 inches to give point 4 on the shaft side shear load movement curve in Figure A and record the 2,090 ton load in shear at that movement. Because we have initially assumed a rigid pile, the top of pile moves downward the same as the bottom. Therefore, find point 4 with 0.40 inches of upward movement on the end bearing load movement curve and record the corresponding load of 1,060 tons. Adding these two loads will give the total load of 3,150 tons due to side shear plus end bearing at the same movement and thus gives point 4 on the Figure B load settlement curve for an equivalent top-loaded test.

One can use the above procedure to obtain all the points in Figure B up to the component that moved the least at the end of the test, in this case point 5 in side shear. To take advantage of the fact that the test produced end bearing movement data up to point 12, we need to make an extrapolation of the side shear curve. We usually use a convenient and suitable hyperbolic curve fitting technique for this extrapolation. Deciding on the maximum number of data points to provide a good fit (a high r^2 correlation coefficient) requires some judgment. In this case we omitted point 1 to give an $r^2 = 0.999$ (including point 1 gave an $r^2 = 0.966$) with the result shown as points 6 to 12 on the dotted extension of the measured side shear curve. Using the same movement matching procedure described earlier we can then extend the equivalent curve to points 6 to 12. The results, shown in Figure B as a dashed line, signify that this part of the equivalent curve depends partly on extrapolated data.

Sometimes, if the data warrants, we will use extrapolations of both side shear and end bearing to extend the equivalent curve to a greater movement than the maximum measured (point 12). An appendix in this report gives the details of the extrapolation(s) used with the present O-cell™ test and shows the fit with the actual data.

Procedure Part II: The elastic compression in the equivalent top load test always exceeds that in the O-cell™ test. It not only produces more top movement, but also additional side shear movement, which then generates more side shear, which produces more compression, etc . . . An exact solution of this load transfer problem requires knowing the side shear vs. vertical movement (t-y) curves for a large number of pile length increments and solving the resulting set of simultaneous equations or using finite element or finite difference simulations to obtain an approximate solution for these equations. We usually do not have the data to obtain the many accurate t-y curves required. Fortunately, the approximate solution described below usually suffices.

The attached analysis p. 6 gives the equations for the elastic compressions that occur in the OLT with one or two levels of O-cells™. Analysis p. 7 gives the equations for the elastic compressions that occur in the equivalent TLT. Both sets of equations do not include the elastic compression below the O-cell™ because the same compression takes place in both the OLT and the TLT. This is equivalent to taking $l_3 = 0$. Subtracting the OLT from the TLT compression gives the desired additional elastic compression at the top of the TLT. We then add the additional elastic compression to the 'rigid' equivalent curve obtained from Part I to obtain the final, corrected equivalent load-settlement curve for the TLT on the same pile as the actual OLT.

Note that the above pp. 6 and 7 give equations for each of three assumed patterns of developed side shear stress along the pile. The pattern shown in the center of the three applies to any approximately determined side shear distribution. Experience has shown the initial solution for the additional elastic compression, as described above, gives an adequate and slightly conservative (high) estimate of the additional compression versus more sophisticated load-transfer analyses as described in the first paragraph of this Part II.

The analysis p. 8 provides an example of calculated results in English units on a hypothetical 1-stage, single level OLT using the simplified method in Part II with the centriod of the side shear distribution 44.1% above the base of the O-cell™. Figure C compares the corrected with the rigid curve of Figure B. Page 9 contains an example equivalent to that above in SI units.

The final analysis p. 10 provides an example of calculated results in English units on a hypothetical 3-stage, multi level OLT using the simplified method in Part II with the centriod of the combined upper and middle side shear distribution 44.1% above the base of the bottom O-cell™. The individual centroids of the upper and middle side shear distributions lie 39.6% and 57.9% above and below the middle O-cell™, respectively. Figure E compares the corrected with the rigid curve. Page 11 contains an example equivalent to that above in SI units.

Other Tests: The example illustrated in Figure A has the maximum component movement in end bearing. The procedures remain the same if the maximum test movement occurred in side shear. Then we would have extrapolated end bearing to produce the dashed-line part of the reconstructed top-load settlement curve.

The example illustrated also assumes a pile top-loaded in compression. For a pile top-loaded in tension we would, based on Assumptions 2. and 3., use the upward side shear load curve in Figure A, multiplied by the F = 0.80 noted in Assumption 2., for the equivalent top-loaded displacement curve.

Expected Accuracy: We know of only five series of tests that provide the data needed to make a direct comparison between actual, full scale, top-loaded pile movement behavior and the equivalent behavior obtained from an O-cell™ test by the method described herein. These involve three sites in Japan and one in Singapore, in a variety of soils, with three compression tests on bored piles (drilled shafts), one compression test on a driven pile and one tension test on a bored pile. The largest bored pile had a 1.2 m diameter and a 37 m length. The driven pile had a 1-m increment modular construction and a 9 m length. The largest top loading = 28 MN (3,150 tons).

The following references detail the aforementioned Japanese tests and the results therefrom:

Kishida H. et al., 1992, "Pile Loading Tests at Osaka Amenity Park Project," Paper by Mitsubishi Co., also briefly described in Schmertmann (1993, see bibliography). Compares one drilled shaft in tension and another in compression.

Ogura, H. et al., 1995, "Application of Pile Toe Load Test to Cast-in-place Concrete Pile and Precast Pile," special volume 'Tsuchi-to-Kiso' on Pile Loading Test, Japanese Geotechnical Society, Vol. 3, No. 5, Ser. No. 448. Original in Japanese. Translated by M. B. Karkee, GEOTOP Corporation. Compares one drilled shaft and one driven pile, both in compression.

We compared the predicted equivalent and measured top load at three top movements in each of the above four Japanese comparisons. The top movements ranged from ¼ inch (6 mm) to 40 mm, depending on the data available. The (equiv./meas.) ratios of the top load averaged 1.03 in the 15 comparisons with a coefficient of variation of less than 10%. We believe that these available comparisons help support the practical validity of the equivalent top load method described herein.

L. S. Peng, A. M. Koon, R. Page and C. W. Lee report the results of a class-A prediction by others of the TLT curve from an Osterberg cell test on a 1.2 m diameter, 37.2 m long bored pile in Singapore, compared to an adjacent pile with the same dimensions actually top-loaded by kentledge. They report about a 4% difference in ultimate capacity and less than 8% difference in settlements over the 1.0 to 1.5 times working load range -- comparable to the accuracy noted above. Their paper has the title "OSTERBERG CELL TESTING OF PILES", and was published in March 1999 in the Proceedings of the International Conference on Rail Transit, held in Singapore and published by the Association of Consulting Engineers Singapore.

B. H. Fellenius has made several finite element method (FEM) studies of an OLT in which he adjusted the parameters to produce good load-deflection matches with the OLT up and down load-deflection curves. He then used the same parameters to predict the TLT deflection curve. We compared the FEM-predicted curve with the equivalent load-deflection predicted by the previously described Part I and II procedures, with the results again comparable to the accuracy noted above. The ASCE has published a paper by Fellenius et. al. titled "O-Cell Testing and FE Analysis of 28-m-Deep Barrette in Manila, Philippines" in the Journal of Geotechnical and Geoenvironmental Engineering, Vol. 125, No. 7, July 1999, p. 566. It details one of his comparison studies.

Limitations: The engineer using these results should judge the conservatism, or lack thereof, of the aforementioned assumptions and extrapolation(s) before utilizing the results for design purposes. For example, brittle failure behavior may produce movement curves with abrupt changes in curvature (not hyperbolic). However, we believe the hyperbolic fit method and our assumptions used usually produce reasonable equivalent top load settlement curves.

August, 2000

Example of the Construction of an Equivalent Top-Loaded Settlement Curve (Figure B) From Osterberg Cell Test Results (Figure A)

Figure A

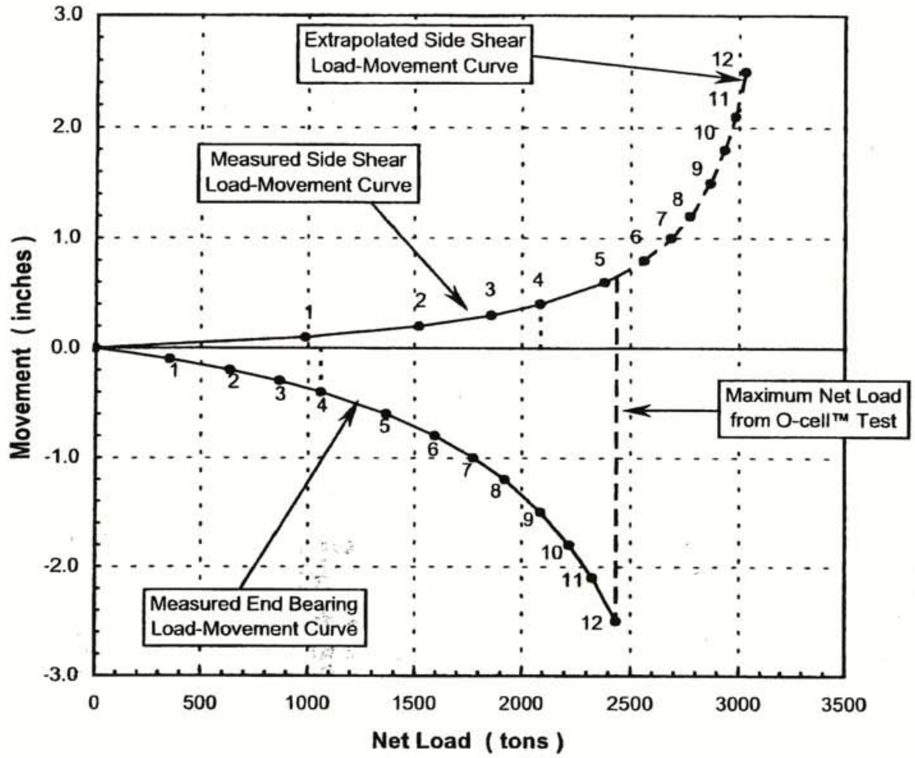
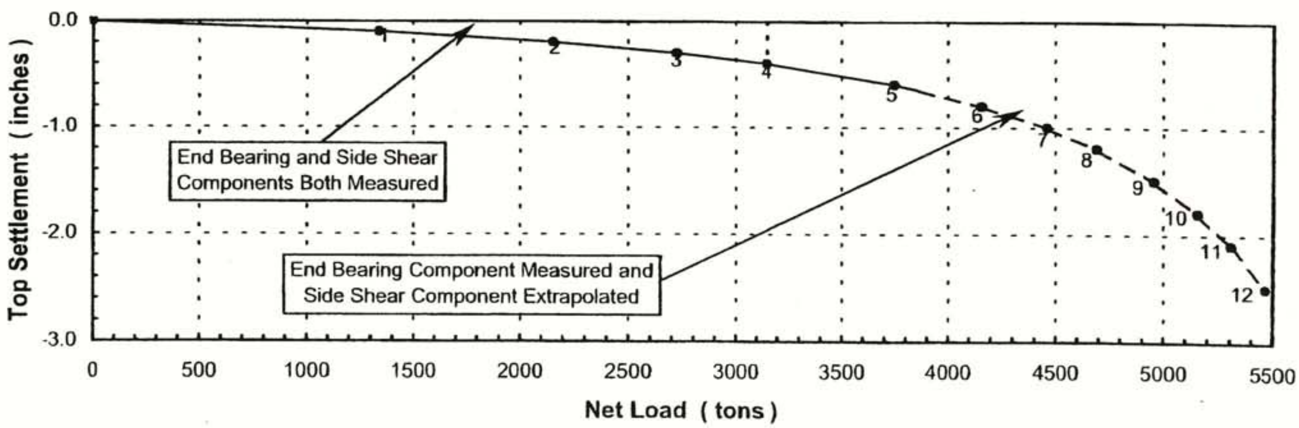
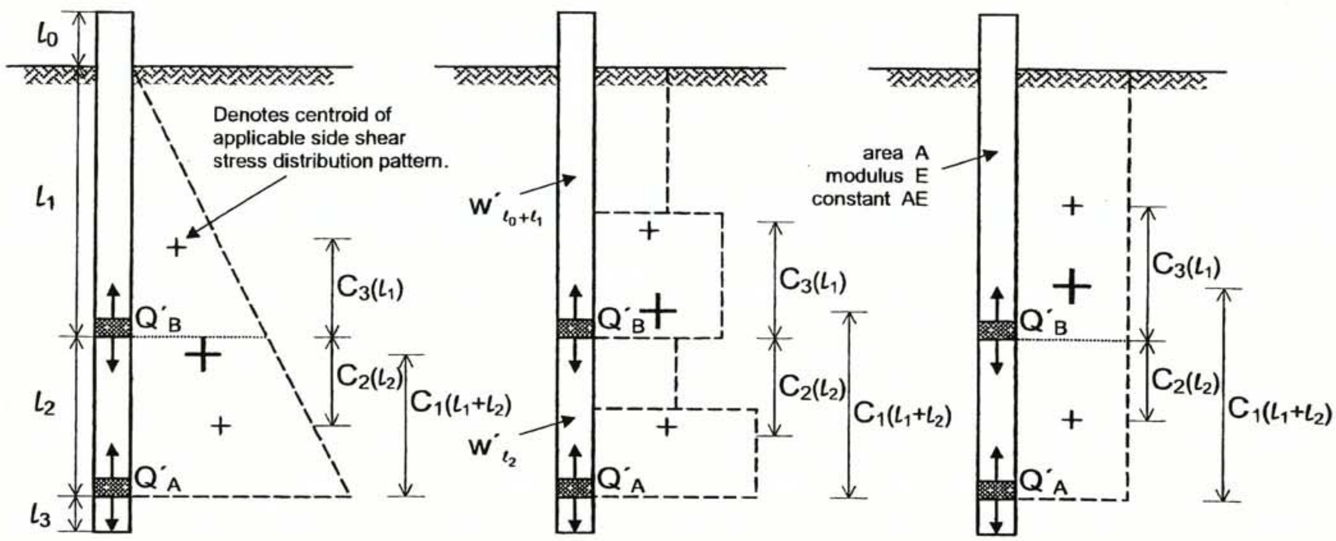


Figure B



Theoretical Elastic Compression in O-cell™ Test Based on Pattern of Developed Side Shear Stress



1-Stage Single Level Test (Q´A only): $\delta_{OLT} = \delta_{\uparrow(\ell_1+\ell_2)}$

$C_1 = \frac{1}{3}$	$\text{Centroid Factor} = C_1$	$C_1 = \frac{1}{2}$
$\delta_{\uparrow(\ell_1+\ell_2)} = \frac{1}{3}\frac{Q'_{\uparrow A}(\ell_1+\ell_2)}{AE}$	$\delta_{\uparrow(\ell_1+\ell_2)} = C_1\frac{Q'_{\uparrow A}(\ell_1+\ell_2)}{AE}$	$\delta_{\uparrow(\ell_1+\ell_2)} = \frac{1}{2}\frac{Q'_{\uparrow A}(\ell_1+\ell_2)}{AE}$

3-Stage Multi Level Test (Q´A and Q´B): $\delta_{OLT} = \delta_{\uparrow\ell_1} + \delta_{\downarrow\ell_2}$

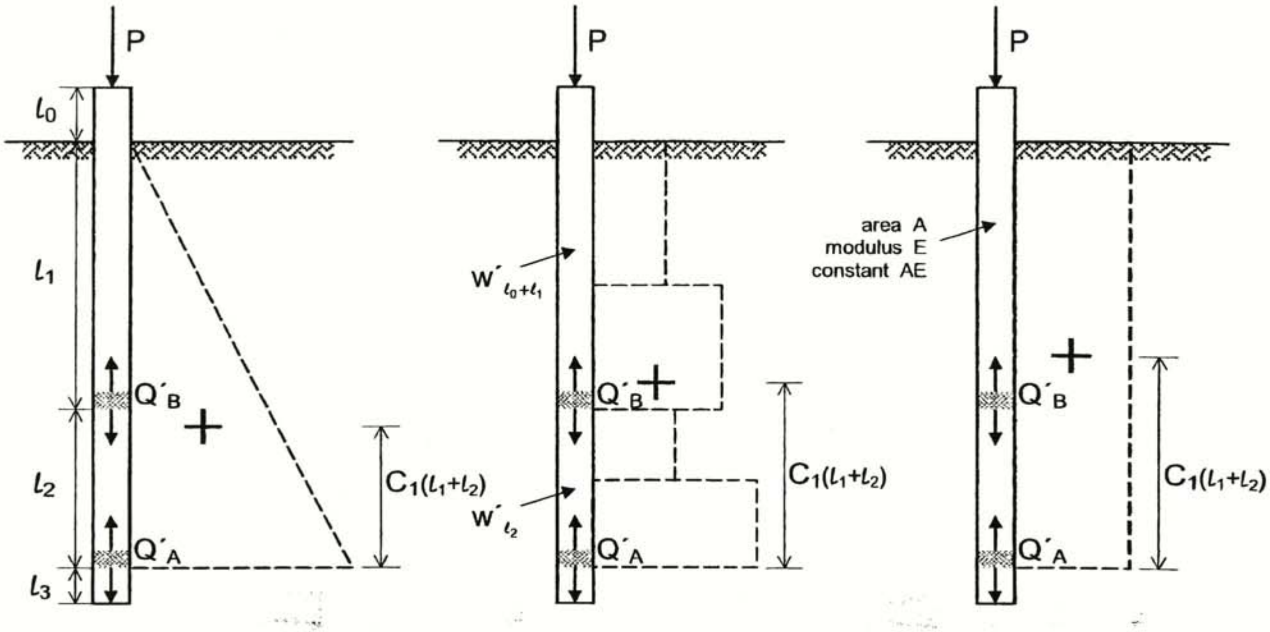
$C_3 = \frac{1}{3}$	$\text{Centroid Factor} = C_3$	$C_3 = \frac{1}{2}$
$\delta_{\uparrow\ell_1} = \frac{1}{3}\frac{Q'_{\uparrow B}\ell_1}{AE}$	$\delta_{\uparrow\ell_1} = C_3\frac{Q'_{\uparrow B}\ell_1}{AE}$	$\delta_{\uparrow\ell_1} = \frac{1}{3}\frac{Q'_{\uparrow B}\ell_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3\ell_1+2\ell_2}{2\ell_1+\ell_2}\right)$	$\text{Centroid Factor} = C_2$	$C_2 = \frac{1}{2}$
$\delta_{\downarrow\ell_2} = \frac{1}{3}\left(\frac{3\ell_1+2\ell_2}{2\ell_1+\ell_2}\right)\frac{Q'_{\downarrow B}\ell_2}{AE}$	$\delta_{\downarrow\ell_2} = C_2\frac{Q'_{\downarrow B}\ell_2}{AE}$	$\delta_{\downarrow\ell_2} = \frac{1}{2}\frac{Q'_{\downarrow B}\ell_2}{AE}$

Net Loads:

$Q'_{\uparrow A} = Q_{\uparrow A} - W'_{\ell_0+\ell_1+\ell_2}$ $\qquad$ $Q'_{\uparrow B} = Q_{\uparrow B} - W'_{\ell_0+\ell_1}$ $\qquad$ $Q'_{\downarrow B} = Q'_{\downarrow B} + W'_{\ell_2}$

W´ = pile weight, bouyant where below water table

Theoretical Elastic Compression in Top Loaded Test
Based on Pattern of Developed Side Shear Stress



Top Loaded Test: $\delta_{TLT} = \delta_{\downarrow \ell_0} + \delta_{\downarrow \ell_1+\ell_2}$

$\delta_{\downarrow \ell_0} = \dfrac{P\ell_0}{AE}$	$\delta_{\downarrow \ell_0} = \dfrac{P\ell_0}{AE}$	$\delta_{\downarrow \ell_0} = \dfrac{P\ell_0}{AE}$
$C_1 = \dfrac{1}{3}$	$\text{Centroid Factor} = C_1$	$C_1 = \dfrac{1}{2}$
$\delta_{\downarrow \ell_1+\ell_2} = \dfrac{(Q'_{\downarrow A}+2P)}{3}\dfrac{(\ell_2+\ell_2)}{AE}$	$\delta_{\downarrow \ell_1+\ell_2} = [(C_1)Q'_{\downarrow A}+(1-C_1)P]\dfrac{(\ell_1+\ell_2)}{AE}$	$\delta_{\downarrow \ell_1+\ell_2} = \dfrac{(Q'_{\downarrow A}+P)}{2}\dfrac{(\ell_1+\ell_2)}{AE}$

Net and Equivalent Loads:

$Q'_{\downarrow A} = Q_{\downarrow A} - W'_{\ell_0+\ell_1+\ell_2}$ $\qquad P_{single} = Q'_{\downarrow A} + Q'_{\uparrow A}$ $\qquad P_{multi} = Q'_{\downarrow A} + Q'_{\uparrow B} + Q'_{\downarrow B}$

Component loads Q selected at the same (±) Δ_{OLT}.

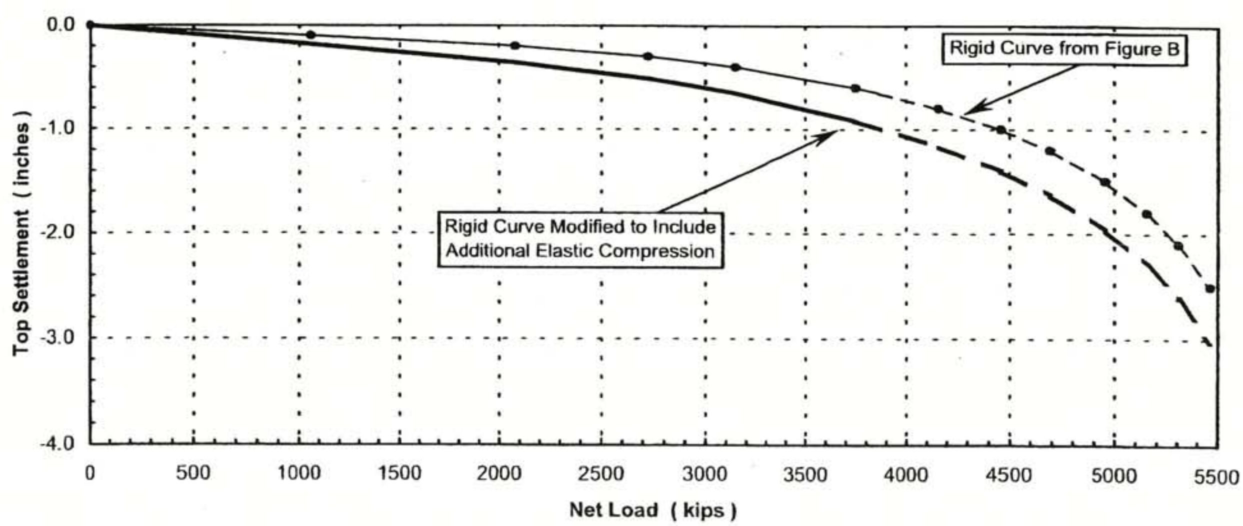
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (English Units)

Given:

$C_1 =$ 0.441
$AE =$ 3820000 **kips** (assumed constant throughout test)
$\ell_0 =$ 5.9 **ft**
$\ell_1 =$ 48.2 **ft** (embedded length of shaft above O-cell™)
$\ell_2 =$ 0.0 **ft**
$\ell_3 =$ 0.0 **ft**
Shear reduction factor = 1.00 (cohesive soil)

Δ_{OLT} (in)	$Q'_{\downarrow A}$ (kips)	$Q'_{\uparrow A}$ (kips)	P (kips)	δ_{TLT} (in)	δ_{OLT} (in)	Δ_δ (in)	$\Delta_{OLT} + \Delta_\delta$ (in)
0.000	0	0	0	0.000	0.000	0.000	0.000
0.100	352	706	1058	0.133	0.047	0.086	0.186
0.200	635	1445	2080	0.257	0.096	0.160	0.360
0.300	867	1858	2725	0.339	0.124	0.215	0.515
0.400	1061	2088	3149	0.396	0.139	0.256	0.656
0.600	1367	2382	3749	0.478	0.159	0.319	0.919
0.800	1597	2563	4160	0.536	0.171	0.365	1.165
1.000	1777	2685	4462	0.579	0.179	0.400	1.400
1.200	1921	2773	4694	0.613	0.185	0.427	1.627
1.500	2091	2867	4958	0.651	0.191	0.460	1.960
1.800	2221	2933	5155	0.680	0.196	0.484	2.284
2.100	2325	2983	5308	0.703	0.199	0.504	2.604
2.500	2434	3032	5466	0.726	0.202	0.524	3.024

Figure C



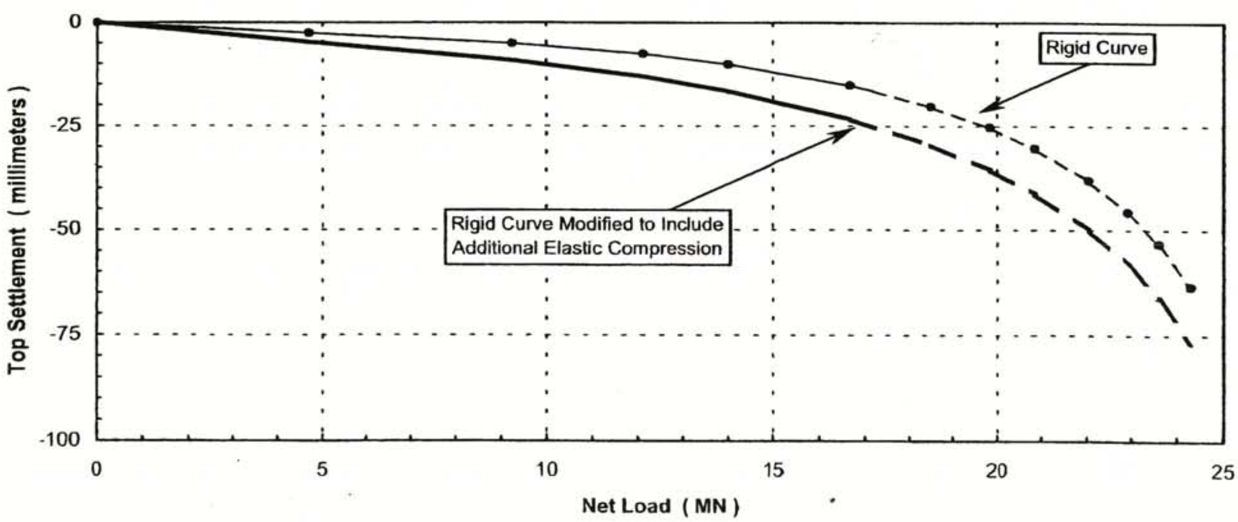
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (SI Units)

Given:

$C_1 =$ 0.441
AE = 17000 **MN** (assumed constant throughout test)
$\ell_0 =$ 1.80 **m**
$\ell_1 =$ 14.69 **m** (embedded length of shaft above O-cell™)
$\ell_2 =$ 0.00 **m**
$\ell_3 =$ 0.00 **m**
Shear reduction factor = 1.00 (cohesive soil)

Δ_{OLT} (mm)	$Q'_{\downarrow A}$ (MN)	$Q'_{\uparrow A}$ (MN)	P (MN)	δ_{TLT} (mm)	δ_{OLT} (mm)	Δ_δ (mm)	$\Delta_{OLT} + \Delta_\delta$ (mm)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.54	1.57	3.14	4.71	3.37	1.20	2.17	4.71
5.08	2.82	6.43	9.25	6.52	2.45	4.07	9.15
7.62	3.86	8.27	12.12	8.61	3.15	5.46	13.08
10.16	4.72	9.29	14.01	10.05	3.54	6.51	16.67
15.24	6.08	10.60	16.68	12.14	4.04	8.10	23.34
20.32	7.11	11.40	18.50	13.60	4.34	9.26	29.58
25.40	7.90	11.94	19.85	14.70	4.55	10.15	35.55
30.48	8.55	12.33	20.88	15.55	4.70	10.85	41.33
38.10	9.30	12.75	22.05	16.53	4.86	11.67	49.77
45.72	9.88	13.05	22.93	17.27	4.97	12.29	58.01
53.34	10.34	13.27	23.61	17.84	5.06	12.79	66.13
63.50	10.83	13.48	24.31	18.44	5.14	13.30	76.80

Figure D



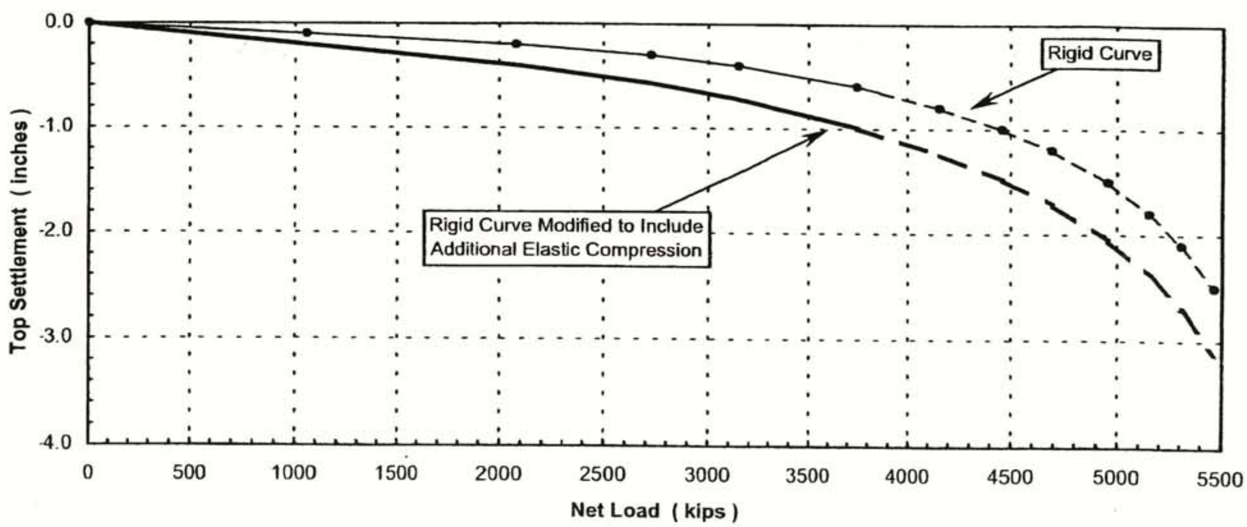
Example Calcuation for the Additional Elastic Compression Correction for Multi Level Test (English Units)

Given:

$C_1 =$ 0.441
$C_2 =$ 0.579
$C_3 =$ 0.396
AE = 3820000 **kips** (assumed constant throughout test)
$\ell_0 =$ 5.9 **ft**
$\ell_1 =$ 30.0 **ft** (embedded length of shaft above mid-cell)
$\ell_2 =$ 18.2 **ft** (embedded length of shaft between O-cells™)
$\ell_3 =$ 0.0 **ft**
Shear reduction factor = 1.00 (cohesive soil)

Δ_{OLT} (in)	$Q'_{\downarrow A}$ (kips)	$Q'_{\downarrow B}$ (kips)	$Q'_{\uparrow B}$ (kips)	P (kips)	δ_{TLT} (in)	δ_{OLT} (in)	Δ_δ (in)	$\Delta_{OLT} + \Delta_\delta$ (in)
0.000	0	0	0	0	0.000	0.000	0.000	0.000
0.100	352	247	459	1058	0.133	0.025	0.107	0.207
0.200	635	506	939	2080	0.257	0.052	0.205	0.405
0.300	867	650	1208	2725	0.339	0.067	0.272	0.572
0.400	1061	731	1357	3149	0.396	0.075	0.321	0.721
0.600	1367	834	1548	3749	0.478	0.085	0.393	0.993
0.800	1597	897	1666	4160	0.536	0.092	0.444	1.244
1.000	1777	940	1745	4462	0.579	0.096	0.483	1.483
1.200	1921	971	1802	4694	0.613	0.099	0.513	1.713
1.500	2091	1003	1864	4958	0.651	0.103	0.548	2.048
1.800	2221	1027	1907	5155	0.680	0.105	0.575	2.375
2.100	2325	1044	1939	5308	0.703	0.107	0.596	2.696
2.500	2434	1061	1971	5466	0.726	0.109	0.618	3.118

Figure E



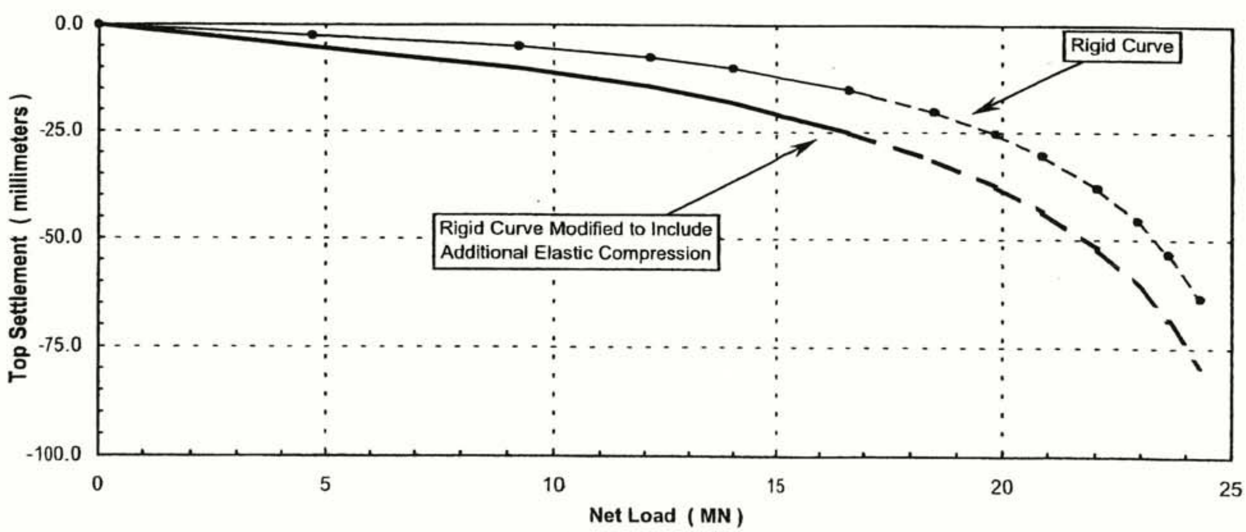
Example Calcuation for the Additional Elastic Compression Correction for Multi Level Test (SI Units)

Given:

$C_1 =$ 0.441
$C_2 =$ 0.579
$C_3 =$ 0.396
AE = 17000 **MN** (assumed constant throughout test)
$\ell_0 =$ 1.80 **m**
$\ell_1 =$ 9.14 **m** (embedded length of shaft above mid-cell)
$\ell_2 =$ 5.55 **m** (embedded length of shaft between O-cells™)
$\ell_3 =$ 0.00 **m**
Shear reduction factor = 1.00 (cohesive soil)

Δ_{OLT} (in)	$Q'_{\downarrow A}$ (kips)	$Q'_{\downarrow B}$ (kips)	$Q'_{\uparrow B}$ (kips)	P (kips)	δ_{TLT} (in)	δ_{OLT} (in)	Δ_δ (in)	$\Delta_{OLT} + \Delta_\delta$ (in)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.54	1.57	1.10	2.04	4.71	3.37	0.64	2.73	5.27
5.08	2.82	2.25	4.18	9.25	6.52	1.31	5.21	10.29
7.62	3.86	2.89	5.37	12.12	8.61	1.69	6.92	14.54
10.16	4.72	3.25	6.04	14.01	10.05	1.90	8.15	18.31
15.24	6.08	3.71	6.89	16.68	12.14	2.17	9.97	25.21
20.32	7.11	3.99	7.41	18.50	13.60	2.33	11.27	31.59
25.40	7.90	4.18	7.76	19.85	14.70	2.44	12.26	37.66
30.48	8.55	4.32	8.02	20.88	15.55	2.52	13.03	43.51
38.10	9.30	4.46	8.29	22.05	16.53	2.61	13.92	52.02
45.72	9.88	4.57	8.48	22.93	17.27	2.67	14.60	60.32
53.34	10.34	4.64	8.62	23.61	17.84	2.71	15.13	68.47
63.50	10.83	4.72	8.76	24.31	18.44	2.76	15.68	79.18

Figure F



APPENDIX D

O-CELL™ METHOD FOR DETERMINING CREEP LIMIT

O-CELL METHOD FOR DETERMINING A CREEP LIMIT LOADING ON THE EQUIVALENT TOP-LOADED SHAFT (April, 2000)

Background: O-cell testing provides a sometimes useful method for evaluating that load beyond which a top-loaded drilled shaft might experience significant unwanted creep behavior. We refer to this load as the "creep limit," also sometimes known as the "yield limit" or "yield load".

To our knowledge, Housel (1959) first proposed the method described below for determining the creep limit. Stoll (1961), Bourges and Levillian (1988), and Fellenius (1996) provide additional references. This method also follows from long experience with the pressuremeter test (PMT). Figure 8 and section 9.4 from ASTM D4719-94, reproduced below, show and describe the creep curve routinely determined from the PMT. The creep curve shows how the movement or strain obtained over a fixed time interval, 30 to 60 seconds, changes versus the applied pressure. One can often detect a distinct break in the curve at the pressure P_e in Figure 8. Plastic deformations may become significant beyond this break loading and progressively more severe creep can occur.

Definition: Similarly with O-cell testing using the ASTM Quick Method, one can conveniently measure the additional movement occurring over the final time interval at each constant load step, typically 2 to 4 minutes. A break in the curve of load vs. movement (as at P_e with the PMT) indicates the creep limit.

We usually indicate such a creep limit in the O-cell test for either one, or both, of the side shear and end bearing components, and herein designate the corresponding movements as M_{CL1} and M_{CL2}. We then combine the creep limit data to predict a creep limit load for the equivalent top loaded shaft.

Procedure if both M_{CL1} and M_{CL2} available: Creep cannot begin until the shaft movement exceeds the M_{CL} values. A conservative approach would assume that creep begins when movements exceed the lesser of the M_{CL} values. However, creep can occur freely only when the shaft has moved the greater of the two M_{CL} values. Although less conservative, we believe the latter to match behavior better and therefore set the creep limit as that load on the equivalent top-loaded movement curve that matches the greater M_{CL}.

Procedure if only M_{CL1} available: If we cannot determine a creep limit in the second component before it reaches its maximum movement M_x, we treat M_x as M_{CL2}. From the above method one can say that the creep limit load exceeds, by some unknown amount, that obtained when using $M_{CL2} = M_x$.

Procedure if no creep limit observed: Then, according to the above, the creep limit for the equivalent top-loaded shaft will exceed, again by some unknown amount, that load on the equivalent curve that matches the movement of the component with the maximum movement.

Limitations: The accuracy in estimating creep limits depends, in part, on the scatter of the data in the creep limit plots. The more scatter, the more difficult to define a limit. The user should make his or her own interpretation if he or she intends to make important use of the creep limit interpretations. Sometimes we obtain excessive scatter of the data and do not attempt an interpretation for a creep limit and will indicate this in the report.

Excerpts from ASTM D4719
"Standard Test Method for Pressuremeter Testing in Soils"

9.4 For Procedure A, plot the volume increase readings (V_{60}) between the 30 s and 60 s reading on a separate graph. Generally, a part of the same graph is used, see Fig. 8. For Procedure B, plot the pressure decrease reading between the 30 s and 60 s reading on a separate graph. The test curve shows an almost straight line section within the range of either low volume increase readings (V_{60}) for Procedure A or low pressure decrease for Procedure B. In this range, a constant soil deformation modulus can be measured. Past the so-called creep pressure, plastic deformations become prevalent.

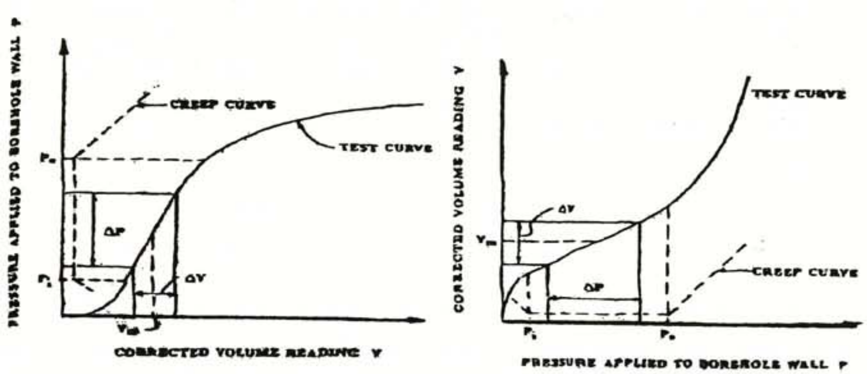


FIG. 8 Pressuremeter Test Curves for Procedure A

References

Housel, W.S. (1959), "Dynamic & Static Resistance of Cohesive Soils", ASTM STP 254, pp. 22-23.

Stoll, M.U.W. (1961, Discussion, Proc. 5th ICSMFE, Paris, Vol. III, pp. 279-281.

Bourges, F. and Levillian, J-P (1988), "force portante des rideaux plans metalliques charges verticalmement," Bull. No. 158, Nov.-Dec., des laboratoires des ponts et chaussees, p. 24.

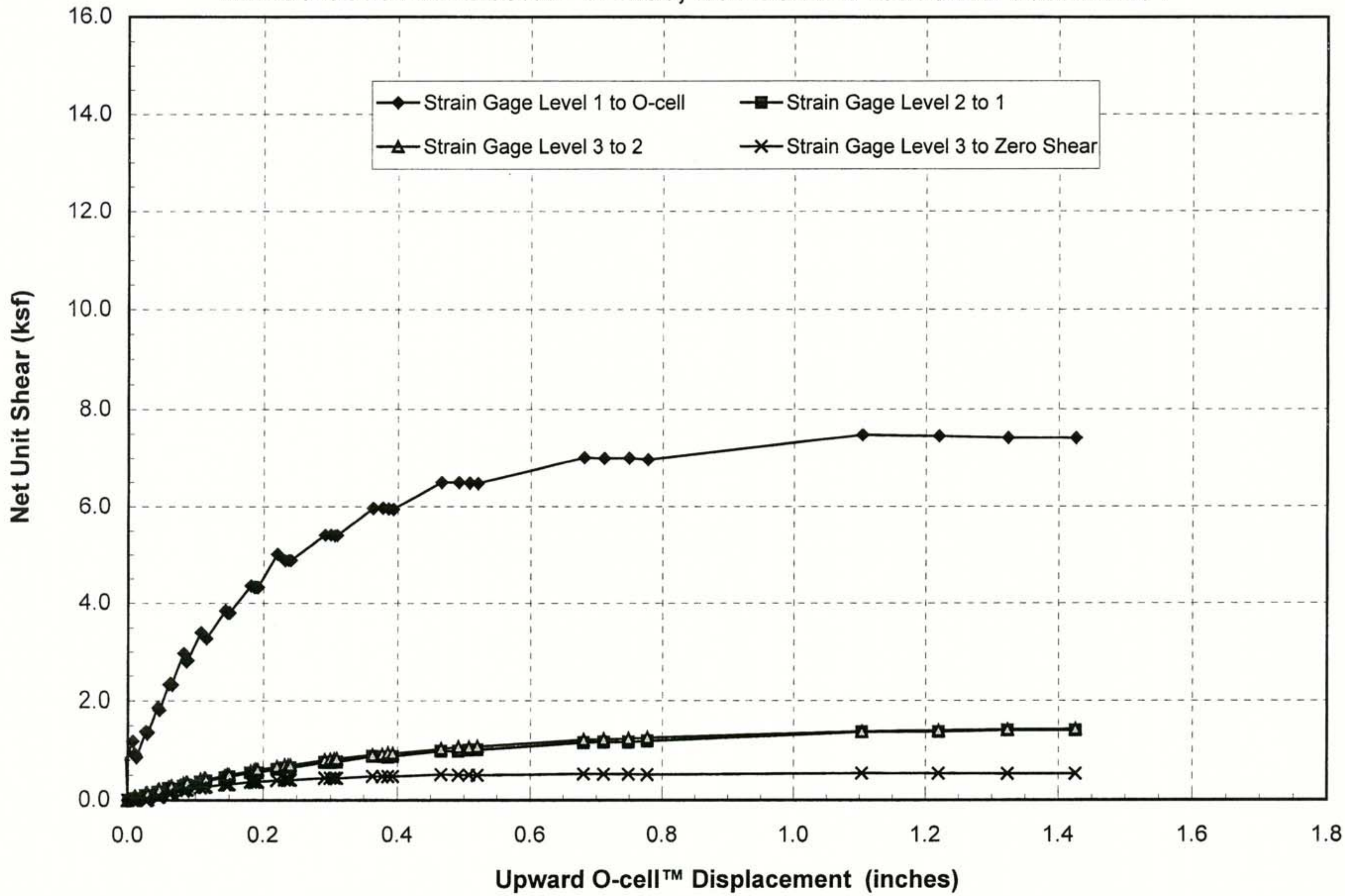
Fellenius, Bengt H. (1996), Basics of Foundation Design, BiTech Publishers Ltd., p.79.

APPENDIX E

NET UNIT SIDE SHEAR VALUES VS. DISPLACEMENT

Net Unit Shear vs. Upward O-cell™ Movement

Wahoo South Connector - Wahoo, Nebraska - Production Test Shaft 1



LOADTEST, Inc. Project No. LT-8810

Figure E-1

APPENDIX F

BORING LOGS

LOG OF BORING NO. 1

CLIENT	ARCHITECT/ENGINEER
HAWKINS CONSTRUCTION COMPANY	
SITE: WAHOO, NEBRASKA	PROJECT: WAHOO SOUTH BRIDGE

Boring Location: STA 352+85.0

Approx. Surface Elev.: 1181.0 ft

DESCRIPTION	DEPTH, ft.	USCS SYMBOL	NUMBER	TYPE	RECOVERY, in.	SPT - N ** BLOWS / ft.	WATER CONTENT, %	DRY UNIT WT pcf	UNCONFINED STRENGTH, psf
LEAN TO FAT CLAY, TRACE SAND Dark Brown Stiff				HS					
		CL CH	1	SS	18	6	26.6		2500*
	5			HS					
7 — 1174									
LEAN CLAY, TRACE SAND Gray-Brown Soft		CL	2	SS	18	4	28.0		<500*
	10			HS					
Medium at 13.5 to 15'		CL	3	SS	18	3	29.1		1500*
	15			HS					
Gray With Silty Fine Sand Seams at 18.5 to 20'		CL	4	SS	18	3	28.5		500*
21 — 1160	20			HS					
SANDY LEAN CLAY, TRACE GRAVEL Dark Brown		CL	5	SS	18	5	30.5		
	25			HS					
27 — 1154									
FINE TO MEDIUM SAND, TRACE GRAVEL Gray-Brown Loose With Occasional Clay Seams		SP	6	SS	18	3	15.9		
	30			WB					

Continued Next Page

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME Automatic Hammer

WATER LEVEL OBSERVATIONS, ft			
WL	∇ 18	WD ▼ 8	AB
WL	∇	∇	
WL			

Terracon

BORING STARTED			6-25-01
BORING COMPLETED			6-26-01
RIG	CME 55	FOREMAN	DM
APPROVED	RLM	JOB #	05015121

BOREHOLE 05015121.GPJ TERRACON.GDT 7/16/01

LOG OF BORING NO. 1

CLIENT	ARCHITECT/ENGINEER
HAWKINS CONSTRUCTION COMPANY	
SITE	**PROJECT**
WAHOO, NEBRASKA	WAHOO SOUTH BRIDGE

GRAPHIC LOG (depth)	DESCRIPTION	Elev.
33	FINE TO MEDIUM SAND Brown Medium Dense	1148
37	FINE SAND WITH SILT Light Gray Dense	1144
43	FINE SAND, TRACE GRAVEL Orangish Brown Dense Hard Drilling in Cobbles or Possible Boulder at 43 to 43.5'	1138
47	MEDIUM TO COARSE SAND Brown With Fat Clay Seams	1134
51	SILTY FINE SAND Gray, Medium Dense Hard Drilling on Possible Cobbles at 55'	1130
57	FINE TO MEDIUM SAND, TRACE GRAVEL Orangish Brown Medium Dense	1124
62	FAT CLAY (Residual Shale) Gray, Soft	1119

DEPTH, ft.	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY, in.	SPT - N ** BLOWS / ft.	TESTS WATER CONTENT, %	DRY UNIT WT pcf	UNCONFINED STRENGTH, psf
	SP	7	SS	12	19	13.0		
35			WB					
	SP	8	SS	12	33	11.6		
40			WB					
	SP	9	SS	12	36	13.6		
45			WB					
	SW	10	SS	12	6	25.0		
50			WB					
	SM	11	SS	12	9	24.4		
55			WB					
	SP	12	SS	12	14	13.0		
60			WB					
	CH	13	SS	12	12	41.1		1000*
65								

Continued Next Page

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME Automatic Hammer

WATER LEVEL OBSERVATIONS, ft				BORING STARTED	6-25-01
WL	▽ 18	WD ▼ 8	AB	BORING COMPLETED	6-26-01
WL	▽	▽		RIG CME 55	FOREMAN DM
WL				APPROVED RLM	JOB # 05015121

Terracon

LOG OF BORING NO. 1

CLIENT	ARCHITECT/ENGINEER
HAWKINS CONSTRUCTION COMPANY	
SITE	**PROJECT**
WAHOO, NEBRASKA	WAHOO SOUTH BRIDGE

DESCRIPTION	Depth, ft.	Elevation
FAT CLAY (Residual Shale) Gray, Soft	68	1113
SANDY LEAN CLAY, TRACE GRAVEL (Residual Sandstone) Orangish Brown With Sand Seams Hard Drilling at 70 to 71.5'	73	1108
LEAN CLAY WITH SAND (Residual Shale) Gray	77	1104
FINE TO MEDIUM SAND, TRACE GRAVEL (Weathered Sandstone) Orangish Brown Very Dense to Dense	88	1093
LEAN CLAY, TRACE SAND (Weathered Shale) Yellowish Brown	92	1089
FAT CLAY (Shale) Gray	95	1086
BOTTOM OF BORING		

USCS SYMBOL	SAMPLES: NUMBER	TYPE	RECOVERY, in.	SPT - N ** BLOWS / ft.	TESTS: WATER CONTENT, %	DRY UNIT WT pcf	UNCONFINED STRENGTH, psf
		WB					
CL	14	SS	18	49	15.8		
		WB					
CL	15	SS	18	25	17.7		
		WB					
SP	16	SS	18	58	14.8		
		WB					
SP	17	SS	18	36	16.0		
		WB					
CL	18	SS	12	50/4"	15.7		6500*
		WB					
CH	19	SS	11	50/5"	17.9		8500*

DEPTH, ft.: 70, 75, 80, 85, 90, 95

The stratification lines represent the approximate boundary lines between soil and rock types: in-situ, the transition may be gradual.

*Calibrated Hand Penetrometer
**CME Automatic Hammer

WATER LEVEL OBSERVATIONS, ft			
WL	▽ 18	WD ▼ 8	AB
WL	▼	▽	
WL			

Terracon

BORING STARTED			6-25-01
BORING COMPLETED			6-26-01
RIG	CME 55	FOREMAN	DM
APPROVED	RLM	JOB #	05015121