REPORT ON DRILLED SHAFT LOAD TESTING (OSTERBERG METHOD)

Test Shaft 1 - Ninth Street Bridge
Des Moines, Iowa (LT-9149)

Prepared for: Longfellow Drilling
RR 1, Box 123
Clearfield, IA 50840

Attention: Mr. Mike Kemery

PROJECT NUMBER: LT-9149, March 29, 2006

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LOADTEST

DEEP FOUNDATION TESTING, EQUIPMENT & SERVICES • SPECIALIZING IN OSTERBERG CELL (O-cell®) TECHNOLOGY

March 29, 2006

Longfellow Drilling
RR 1, Box 123
Clearfield, IA 50840

Attention: Mr. Mike Kemery

Load Test Report: Test Shaft 1 - Ninth Street Bridge
Location: Des Moines, Iowa (LT-9149)

Dear Mr. Kemery,

The enclosed report contains the data and analysis summary for the O-cell test performed on Test Shaft 1 - Ninth Street Bridge, on March 22, 2006. For your convenience, we have included an executive summary of the test results in addition to our standard detailed data report.

We would like to express our gratitude for the on-site and off-site assistance provided by your team and we look forward to working with you on future projects.

We trust that the information contained herein will suit your current project needs. If you have any questions or require further technical assistance, please do not hesitate to contact us at 800-368-1138.

Best Regards,

William G. Ryan, B.S.C.M.
Regional Manager, LOADTEST, Inc.

EXECUTIVE SUMMARY

On March 22, 2006, we tested a 762-mm (30-inch) diameter dedicated test shaft constructed by Longfellow Drilling. Mr. David J. Jakstis and Mr. John A. Graman of LOADTEST, Inc. carried out the test. The 20.16-meter (66.1-foot) deep shaft was constructed between March 13 and 14, 2006. Sub-surface conditions at the test shaft location consist primarily of silty clay underlain by glacial clay. Representatives of the FHWA (Federal Highway Administration) and the Iowa DOT (Department of Transportation) observed construction and testing of the shaft.

The maximum sustained bi-directional load applied to the shaft was 1.73 MN (390 kips). At the maximum load, the displacements above and below the O-cell were 1.01 mm (0.040 inches) and 39.61 mm (1.559 inches), respectively. Unit shear data calculated from strain gages indicated an average net unit side shear in the glacial clay of 134 kPa (2.8 ksf) between the O-cell and Strain Gage Level 2 and 258 kPa (5.4 ksf) between the O-cell and Strain Gage Level 1 at the above noted displacements, respectively.

Using the procedures described in the report text and in Appendix C, we constructed an equivalent top load curve for the test shaft. For a top loading of 1.1 MN (240 kips), the adjusted test data indicate this shaft would settle approximately 1.5 mm (0.06 inches) of which 1.3 mm (0.05 inches) is estimated elastic compression.

LIMITATIONS OF EXECUTIVE SUMMARY

We include this executive summary to provide a very brief presentation of some of the key elements of this O-cell test. It is by no means intended to be a comprehensive or stand-alone representation of the test results. The full text of the report and the attached appendices contain important information which the engineer can use to come to more informed conclusions about the data presented herein.

TABLE OF CONTENTS

SITE CONDITIONS AND SHAFT CONSTRUCTION

Site Sub-surface Conditions: The sub-surface stratigraphy at the general location of the test shaft is reported to consist of stiff silty clay underlain by firm glacial clay and very firm sandy glacial clay. The generalized subsurface profile is included in Figure A and boring logs indicating conditions near the shaft are presented in Appendix E. More detailed geologic information can be obtained from Jensen Construction Company.

Test Shaft Construction: Longfellow Drilling excavated the dedicated test shaft beginning on March 13 and performed the final cleanout and concreting on March 14, 2006. We understand that the 762-mm (30-inch) test shaft was excavated to a tip elevation of +259.84 meters (+852.5 feet), in the dry. The shaft was started by pre-drilling with an auger and installing a 914-mm (36-inch) O.D. temporary casing to a tip elevation of +277.16 meters (+909.3 feet). After cleaning the base with a cleanout bucket, the reinforcing cage with attached O-cell assembly was inserted into the excavation and temporarily supported from the steel casing. Concrete was then delivered by pump through a 127-mm (5-inch) O.D. pipe into the base of the shaft until the concrete approached the top of casing. The contractor then removed the 914-mm (36-inch) O.D. temporary casing and placed additional concrete to an elevation of +279.34 meters (+916.5 feet). No unusual problems occurred during construction of the shaft. Representatives of the FHWA and Iowa DOT observed construction of the shaft.

OSTERBERG CELL TESTING

Shaft Instrumentation: Test shaft instrumentation and assembly was carried out under the direction of Mr. John A. Graman of LOADTEST, Inc. on March 13, 2006. The loading assembly consisted of one 330-mm O-cell located 2.74 meters (9.0 feet) above the tip of shaft. Calibrations of the O-cell and instrumentation used for this test are included in Appendix B.

O-cell testing instrumentation included three Linear Vibrating Wire Displacement Transducers (LVWDTs) – (Geokon Model 4450 series) positioned between the lower and upper plates of the O-cell assembly to measure expansion (Appendix A, Page 1). Two telltale casings (nominal ½-inch steel pipe) were attached to the reinforcing cage, diametrically opposed, extending from the top of the O-cell assembly to beyond the top of concrete. Compression of the shaft below the O-cell was measured by one section of Embedded Compression Telltales (ECTs), consisting of telltale rods in nominal ½-inch steel pipe casings, with an LVWDT attached. Compression of the shaft within the glacial clay above the O-cell was also measured by one section of ECTs. ECT readings are presented in Appendix A, Page 2.

Strain gages were used to assess the side shear load transfer of the shaft above and below the Osterberg cell assembly. One level of two sister bar vibrating wire strain gages (Geokon Model 4911 Series) was installed, diametrically opposed, in the shaft below the base of the O-cell assembly and three levels of two were installed in the shaft above it. Details concerning the strain gage placement appear in Table B and Figures A & B. The strain gages were positioned as specified by the FHWA and Iowa DOT.

One length of steel pipe was also installed, extending from the top of the shaft to the top of the bottom plate, to vent the break in the shaft formed by the expansion of the O-cell. The pipe was filled with water prior to the start of the test.

Test Arrangement: Throughout the load test, key elements of shaft response were monitored using the equipment and instruments described herein. Shaft compression between the O-cell and top of concrete was measured using ¼-inch telltales installed in the ½-inch steel pipes (described under Shaft Instrumentation) and monitored by Linear Vibrating Wire Displacement Transducers (LVWDTs) (Geokon Model 4450). Two automated digital survey levels (Leica NA3003) were used to monitor the top of shaft movement during testing from an average distance of 8.38 meters (27.5 feet).

Both a Bourdon pressure gage and a vibrating wire pressure transducer were used to measure the pressure applied to the O-cell at each load interval. We used the Bourdon pressure gage for setting and maintaining loads and for data analysis. The transducer readings were used for real time plotting and as a check on the Bourdon gage. There was close agreement between the Bourdon gage and the pressure transducer.

Data Acquisition: All instrumentation were connected through a data logger (Data Electronics - Model 615 Datataker®) to a laptop computer allowing data to be recorded and stored automatically at 30-second intervals and displayed in real time. The same laptop computer synchronized to the data logging system was used to acquire the Leica NA3003 data sets.

Testing Procedures: As with all of our tests, we begin by pressurizing the O-cell in order to break the tack welds that hold it closed (for handling and for placement in the shaft) and to form the fracture plane in the concrete surrounding the base of the O-cell. After the break occurs, we immediately release the pressure and then begin the loading procedure. Zero readings for all instrumentation are taken prior to the preliminary weld-breaking load-unload cycle, which in this case involved a maximum applied pressure of 11.03 MPa (1,600 psi) to the O-cell.

The Osterberg cell load test was conducted as follows: We pressurized the 330-mm (13-inch) diameter O-cell, with its base located 2.74 meters (9.0 feet) above the base of shaft to assess the combined end bearing and lower side shear below the O-cell and the side shear above. We pressurized the O-cell in 11 loading increments to 30.34 MPa (4,400 psi) resulting in a bi-directional gross O-cell load of 1.73 MN (390 kips). The loading was halted during an attempt at additional load interval 1L-12 because the shaft section below the O-cell was displacing rapidly and would not allow additional applied load to be sustained. The O-cell was then depressurized in five decrements and the test was concluded.

We applied the load increments using the Quick Load Test Method for Individual Piles (ASTM D1143 *Standard Test Method for Piles Under Static Axial Load*), holding each successive load increment constant for eight minutes by manually adjusting the O-cell pressure. The data logger automatically recorded the instrument readings every 30 seconds, but herein we report only the 1, 2, 4 and 8-minute readings (where applicable) during each increment of maintained load.

TEST RESULTS AND ANALYSES

General: The loads applied by the O-cell act in two opposing directions, resisted by the capacity of the shaft above and below. Theoretically, the O-cell does not impose an additional upward load until its expansion force exceeds the buoyant weight of the shaft above the O-cell. Therefore, *net load*, which is defined as gross O-cell load minus the buoyant weight of the shaft above, is used to determine side shear resistance above the O-cell and to construct the equivalent top-loaded load-settlement curve. For this test we calculated a buoyant weight of shaft of 0.20 MN (44 kips) above the O-cell.

For the purposes of analyses herein, we use the maximum sustained loading at 1L-11 of 1.73 MN (390 kips). The maximum applied load of 1.77 MN occurred at the 1-minute reading of increment 1L-12, at which point the displacements above and below the O-cell were 1.06 mm (0.042 inches) and 48.90 mm (1.925 inches), respectively. Additional displacements occurred while attempting to sustain this load over a complete load increment (Appendix A, Page 3, Figure 1).

Upper Side Shear Resistance: The maximum sustained upward applied *net load* to the upper side shear was 1.54 MN (346 kips) which occurred at load interval 1L-11. At this loading, the upward movement of the O-cell top was 1.01 mm (0.040 inches).

In order to assess the side shear resistance of the test shaft, loads are calculated based on the strain gage data (Appendix A, Pages 4 and 5) and estimates of shaft stiffness (AE) which are presented below. We used the ACI formula ($E_c=57000\sqrt{f'_c}$) to calculate an elastic modulus for the concrete, where f'_c was reported to be 23.99 MPa (3,480 psi) on the day of the test. This, combined with the area of reinforcing steel and nominal shaft diameter, provided an average shaft stiffness (AE) of 16,100 MN (3,620,000 kips) in the temporarily-cased section and 11,400 MN (2,570,000 kips) in the uncased section. Net unit shear curves are presented in Appendix F. Net unit shear values for loading increment 1L-11 follow in Table A:

TABLE A: Average Net Unit Side Shear Values for 1L-11

Load Transfer Zone	Displacement *	Net Unit Side Shear **
Top of Shaft to Strain Gage Level 4	↑ 0.521 mm	10 kPa (0.2 ksf)
Strain Gage Level 4 to Strain Gage Level 3	↑ 0.612 mm	26 kPa (0.5 ksf)
Strain Gage Level 3 to Strain Gage Level 2	↑ 0.689 mm	36 kPa (0.7 ksf)
Strain Gage Level 2 to O-cell	↑ 0.872 mm	134 kPa (2.8 ksf)
O-cell to Strain Gage Level 1	↓ 39.529 mm	258 kPa (5.4 ksf)

* Average displacement of load transfer zone.

** For upward-loaded shear, the buoyant weight of shaft in each zone has been subtracted from the load shed in the respective zone above the O-cell.

NOTE: Net unit shear values derived from the strain gages above the O-cell assembly may not be ultimate values. See Appendix F for net unit shear vs. average shear zone displacement plots.

Combined End Bearing And Lower Side Shear Resistance: The maximum O-cell load applied to the combined end bearing and lower side shear was 1.73 MN (390 kips) which occurred at load interval 1L-11 (Appendix A, Page 3, Figure 1). At this loading, the average downward movement of the O-cell base was 39.61 mm (1.559 inches). The load taken in shear by the 2.74-meter (9.0-foot) shaft section below the O-cell is calculated to be 1.69 MN (380 kips) assuming an estimated unit side shear value of 258 kPa (5.4 ksf) and a nominal 762-mm (30-inch) shaft diameter. The applied load to end bearing is then 0.04 MN (10 kips) and the unit end bearing at the base of the shaft is calculated to be 95 kPa (2.0 ksf) at the above noted displacement. The low unit end bearing value associated with the downward displacement may be an indication of a disturbed shaft base condition.

Creep Limit: See Appendix D for our O-cell method for determining creep limit. The combined end bearing and lower side shear creep data (Appendix A, Page 3) indicate that a creep limit of 1.3 MN (299 kips) was reached at a movement of 6.1 mm (0.24 inches) (Figure 4). The upper side shear creep data (Appendix A, Page 3) indicate that no apparent creep limit was reached at a movement of 1.0 mm (0.04 inches) (Figure 5). A top-loaded shaft will not begin significant creep until both components begin creep movement. This will occur at the maximum of the movements required to reach the creep limit for each component. We believe that significant creep for this shaft will not begin until a top loading exceeds 2.7 MN (600 kips) by some unknown amount.

Equivalent Top Load: Figure 2 presents the equivalent top-loaded load-settlement curves. The lighter curve, described in Procedure Part I of Appendix C, was generated by using the measured upward top of O-cell and downward base of O-cell data. The curve is extended out to a settlement of 6.1 mm (0.24 inches) by vertically extrapolating the top of O-cell data. This assumes the top of O-cell achieves greater upward displacement under no additional load. Because it is often an important component of the settlements involved, the equivalent top load curve requires an adjustment for the additional elastic compression that would occur in a top-load test. The darker curve as described in Procedure Part II of Appendix C includes this adjustment.

The test shaft was loaded to a combined side shear and end-bearing load of 3.3 MN (735 kips). For a top loading of 1.1 MN (240 kips), the adjusted test data indicate this shaft would settle approximately 1.5 mm (0.06 inches) of which 1.3 mm (0.05 inches) is estimated elastic compression. For a top loading of 2.1 MN (480 kips) the adjusted test data indicate this shaft would settle approximately 3.4 mm (0.14 inches) of which 2.6 mm (0.10 inches) is estimated elastic compression.

Note that, as explained previously, the equivalent top load curve applies to incremental loading durations of eight minutes. Creep effects will reduce the ultimate resistance of both components and increase shaft top movement for a given loading over longer times. The Engineer can estimate such additional creep effects by suitable extrapolation of time effects using the creep data presented herein. However, our experience suggests that such corrections are small and perhaps negligible for top loadings below the creep limit indicated in Figure 2.

Shaft Compression Comparison: The measured maximum shaft compression above the O-cell, averaged from two telltales, is 0.55 mm (0.022 inches) at 1L-11 (Appendix A, Page 2). Using a shaft stiffness of 11,400 MN (2,570,000 kips) in the uncased section and 16,100 MN (3,620,000 kips) in the temporarily-cased section and the load distribution in Figure 3 at 1L-11, we calculated an elastic compression of 0.62 mm (0.024 inches) over the length of the compression telltales.

The measured shaft compression below the O-cell, averaged from two ECTs, is 0.22 mm (0.009 inches) at 1L-11 (Appendix A, Page 2). Using a lower shaft stiffness of 11,400 MN (2,570,000 kips) and the load distribution in Figure 3 at 1L-11 extrapolated to the bottom of the ECTs, we calculated an elastic compression of 0.19 mm (0.007) inches).

We believe these excellent agreements between measured and calculated compressions provide evidence that the values of the estimated shaft stiffness are reasonable and that the O-cell loaded the shaft in accord with its calibration.

LIMITATIONS AND STANDARD OF CARE

The instrumentation, testing services and data analysis provided by LOADTEST, Inc., outlined in this report, were performed in accordance with the accepted standards of care recognized by professionals in the drilled shaft and foundation engineering industry.

Please note that some of the information contained in this report is based on data (i.e. shaft diameter, elevations and concrete strength) provided by others. The engineer, therefore, should come to his or her own conclusions with regard to the analyses as they depend on this information. In particular, LOADTEST, Inc. typically does not observe and record drilled shaft construction details to the level of precision that the project engineer may require. In many cases, we may not be present for the entire duration of shaft construction. Since construction technique can play a significant role in determining the load bearing capacity of a drilled shaft, the engineer should pay close attention to the drilled shaft construction details that were recorded elsewhere.

We trust that this information will meet your current project needs. If you have any questions, please do not hesitate to contact us at 800-368-1138.

Prepared for LOADTEST, Inc. by

David J. Jakstis, P.E.
Geotechnical Engineer

Reviewed by

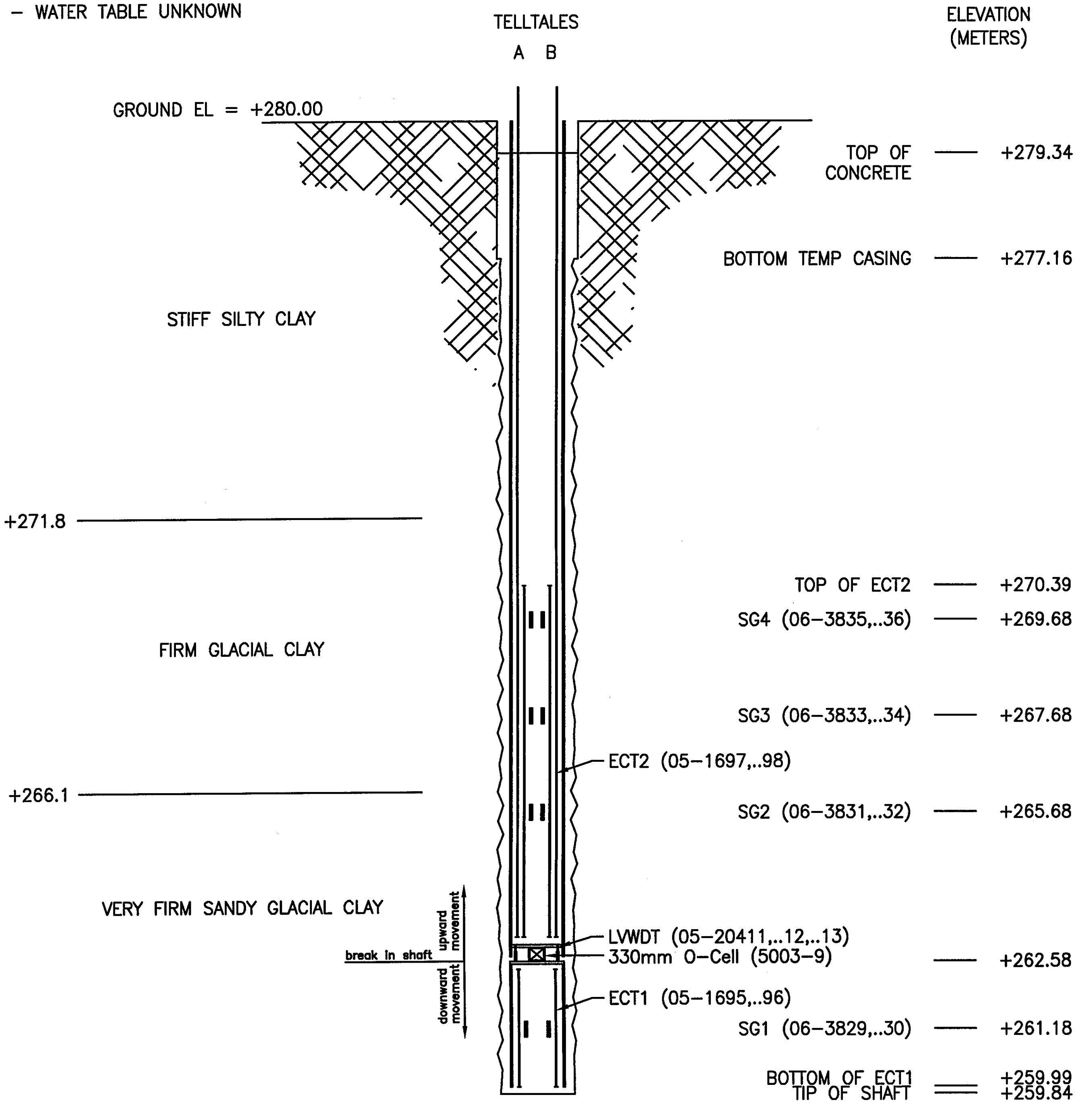
for D. Tilson
Shing K. Pang, P.E.
Geotechnical Engineer

John H. Schmertmann, Ph.D., P.E.
For John H. Schmertmann, Inc.

TABLE B:
SUMMARY OF DIMENSIONS, ELEVATIONS & SHAFT PROPERTIES

Shaft:			
Nominal shaft diameter (EL +279.34 m to +277.16 m)	=	914 mm	36 in
Nominal shaft diameter (EL +277.16 m to +259.84 m)	=	762 mm	30 in
O-cell: 5003-9	=	330 mm	13 in
Length of side shear above break at base of O-cell	=	16.76 m	55.0 ft
Length of side shear below break at base of O-cell	=	2.74 m	9.0 ft
Shaft side shear area above O-cell base	=	41.2 m²	443.1 ft²
Shaft side shear area below O-cell base	=	6.6 m²	70.6 ft²
Shaft base area	=	0.5 m²	4.9 ft²
Bouyant weight of pile above base of O-cell	=	0.20 MN	44 kips
Estimated shaft stiffness, AE (EL +279.34 m to +277.16 m)	=	16,100 MN	3,620,000 kips
Estimated shaft stiffness, AE (EL +277.16 m to +259.84 m)	=	11,400 MN	2,570,000 kips
Elevation of ground surface	=	+280.00 m	+918.6 ft
Elevation of top of shaft concrete	=	+279.34 m	+916.5 ft
Elevation of base of O-cell (The break between upward and downward movement.)	=	+262.58 m	+861.5 ft
Elevation of shaft tip	=	+259.84 m	+852.5 ft
Elevation of water table	=	Unknown	
Casings:			
Elevation of top of outer temporary casing (914 mm O.D.)	=	+280.21 m	+919.3 ft
Elevation of bottom of outer temporary casing (914 mm O.D.)	=	+277.16 m	+909.3 ft
Compression Sections:			
Elevation of top of telltale used for upper shaft compression	=	+279.34 m	+916.5 ft
Elevation of bottom of telltale used for upper shaft compression	=	+262.93 m	+862.6 ft
Elevation of top of ECTs used for middle shaft compression	=	+270.39 m	+887.1 ft
Elevation of bottom of ECTs used for middle shaft compression	=	+262.93 m	+862.6 ft
Elevation of top of ECTs used for lower shaft compression	=	+262.53 m	+861.3 ft
Elevation of bottom of ECTs used for lower shaft compression	=	+259.99 m	+853.0 ft
Strain Gages:			
Elevation of strain gage Level 4	=	+269.68 m	+884.8 ft
Elevation of strain gage Level 3	=	+267.68 m	+878.2 ft
Elevation of strain gage Level 2	=	+265.68 m	+871.7 ft
Elevation of strain gage Level 1	=	+261.18 m	+856.9 ft
Miscellaneous:			
Top plate diameter (50 mm thickness)	=	510 mm	20.1 in
Bottom plate diameter (50 mm thickness)	=	510 mm	20.1 in
ReBar size (10 No.)	=	M 25	# 8
Spiral size (304.8 mm spacing)	=	M 16	# 5
ReBar cage diameter	=	559 mm	22 in
Unconfined compressive concrete strength	=	24.0 MPa	3480 psi
O-cell LVWDTs @ 0°, 180° and 270° with radius	=	255 mm	10.0 in

NOTE:
- NOMINAL TEMP CASING 914mm OD
- NOMINAL SHAFT 762mmø
- WATER TABLE UNKNOWN

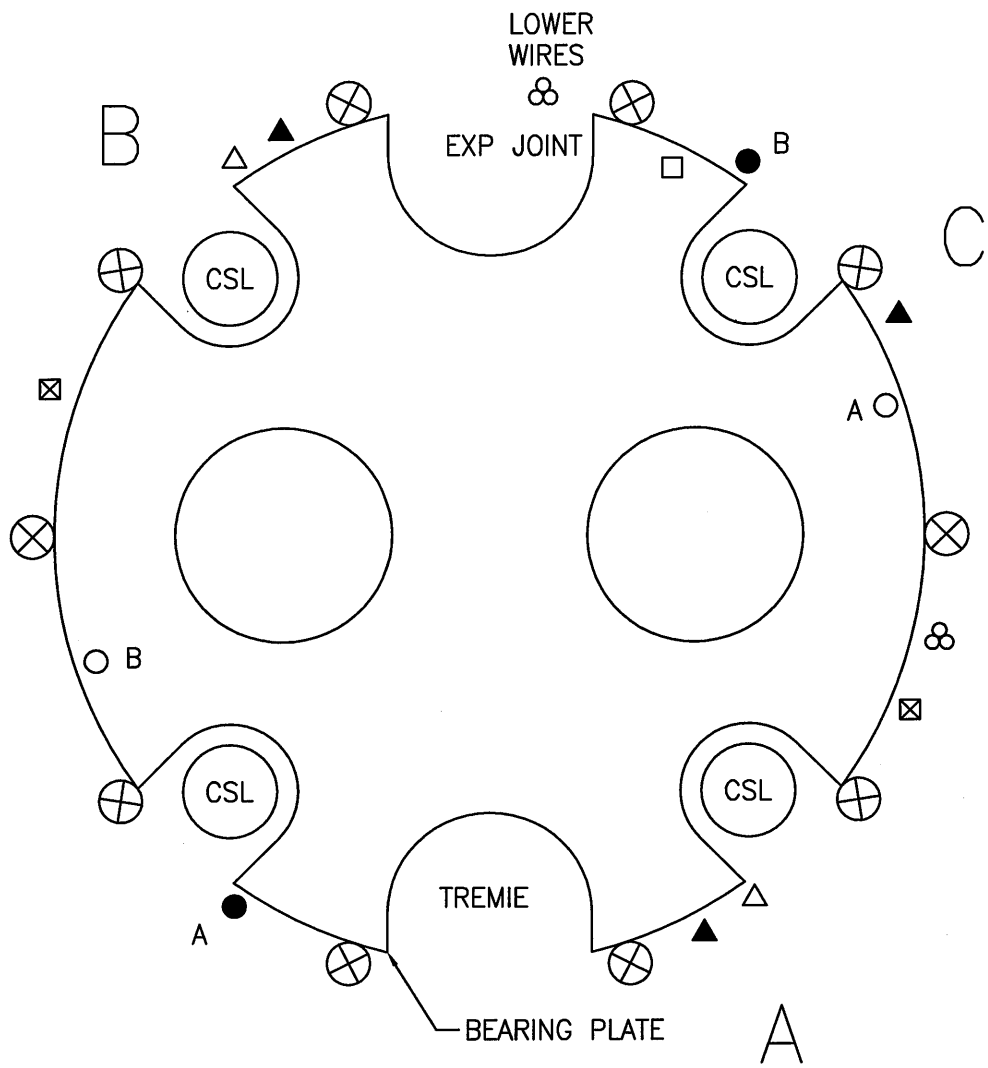


GENERALIZED SOIL PROFILE
BASED ON BORING N-1

LOADTEST
2631-D NW 41st St.
Gainesville, FL 32606
Phone 800-368-1138
FAX 352-378-3934

SCHEMATIC SECTION OF TEST SHAFT
Ninth Street Bridge – Des Moines, IA

DRAWN BY: JAG	DATE: 3/15/06	CHECKED BY:	LT-9149
REVISED BY:	DATE:	SCALE: NTS	FIGURE A



LEGEND:

STRAIN GAGE	△
LVWDT	▲
TELLTALE	○
ECT	●
VENT PIPE	□
HYDRAULIC HOSES	⊠
REBAR	⊗
CABLE BUNDLE	ఇ

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INSTRUMENTATION LAYOUT

Ninth Street Bridge – Des Moines, IA

DWN BY: JAG	DATE: 3/15/06	CHECKED BY:	LT-9149
REVISED BY:	DATE:	SCALE: NTS	FIGURE B

Osterberg Cell Load-Movement Curves

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

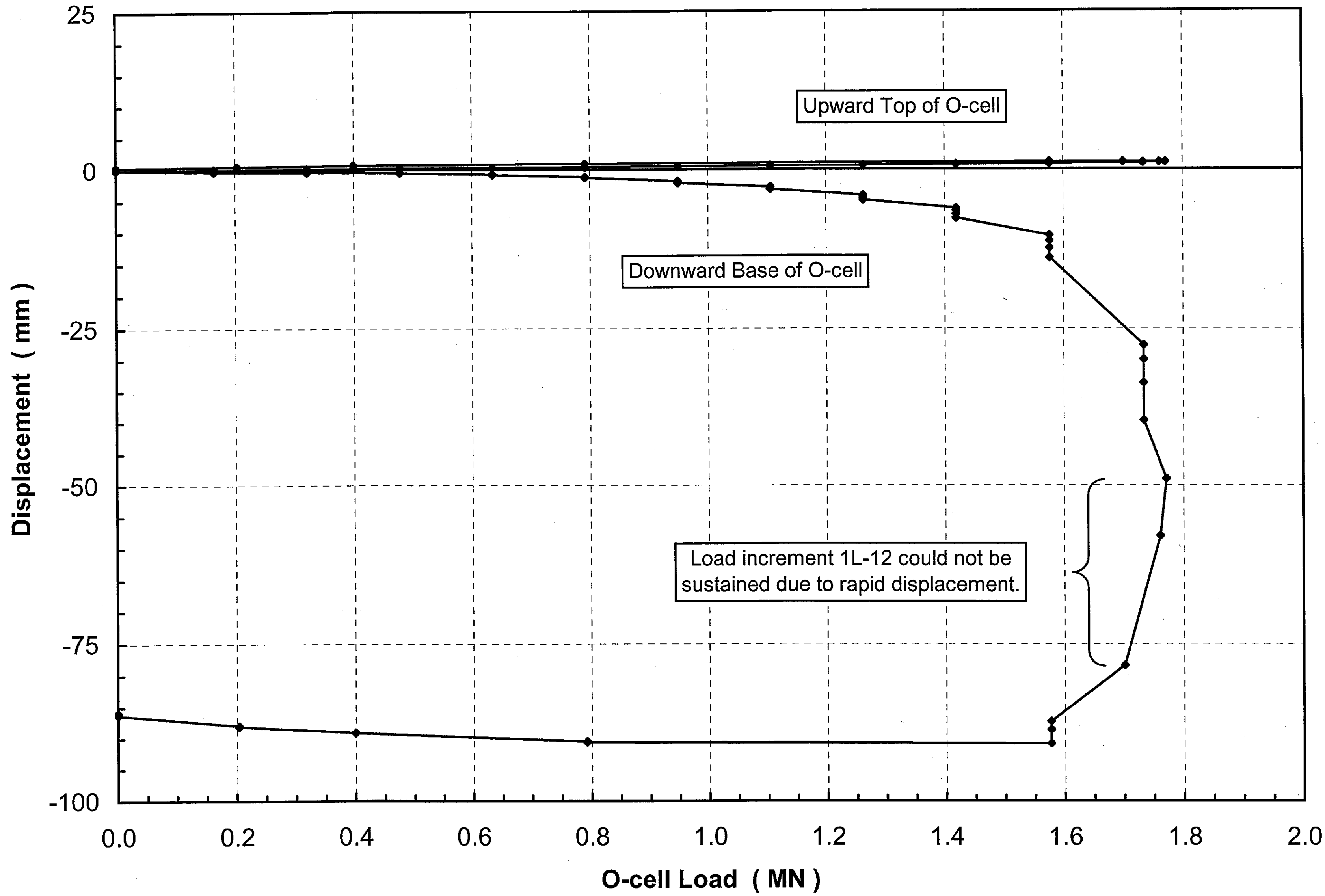

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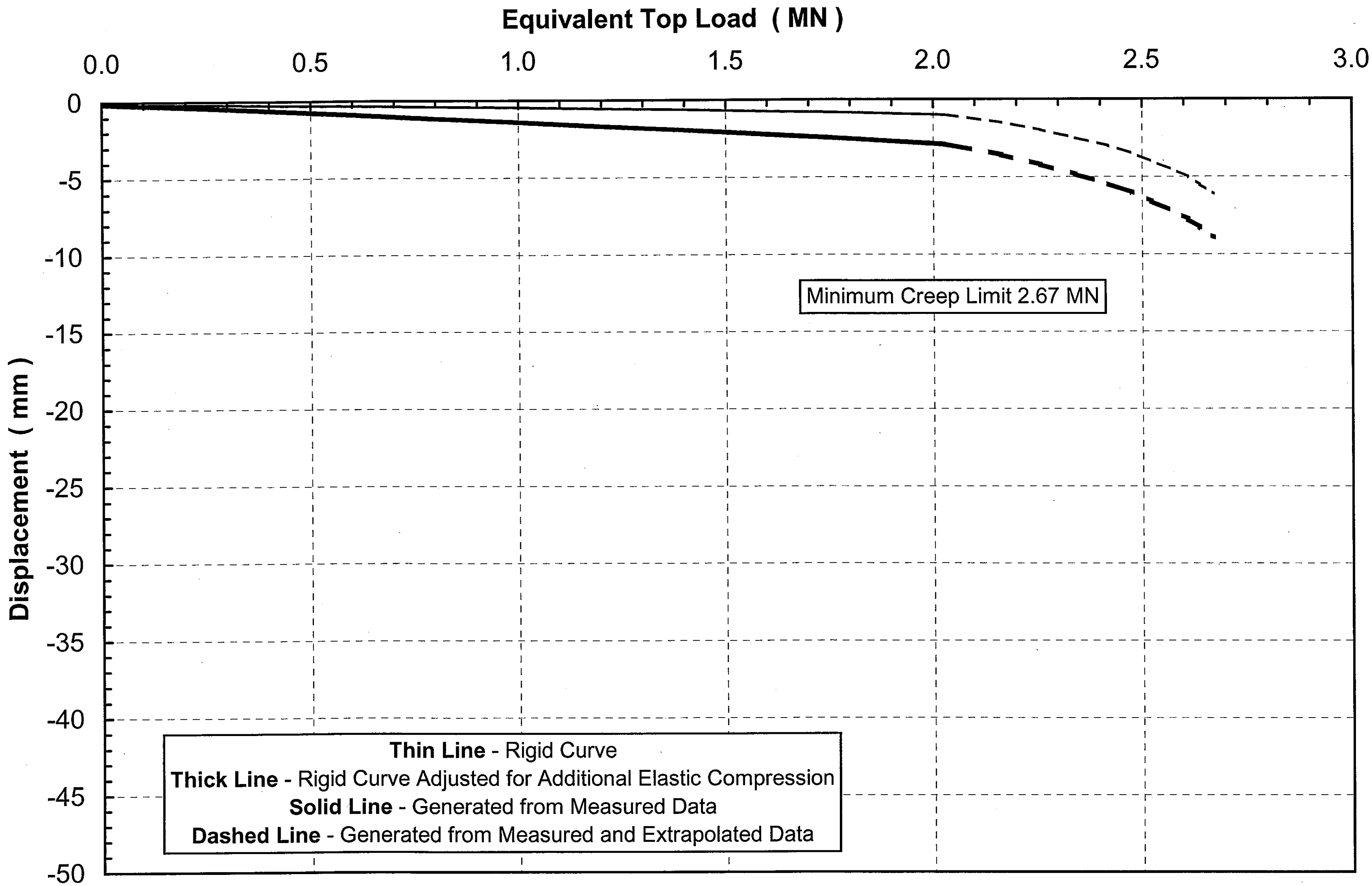
Figure 1 of 5

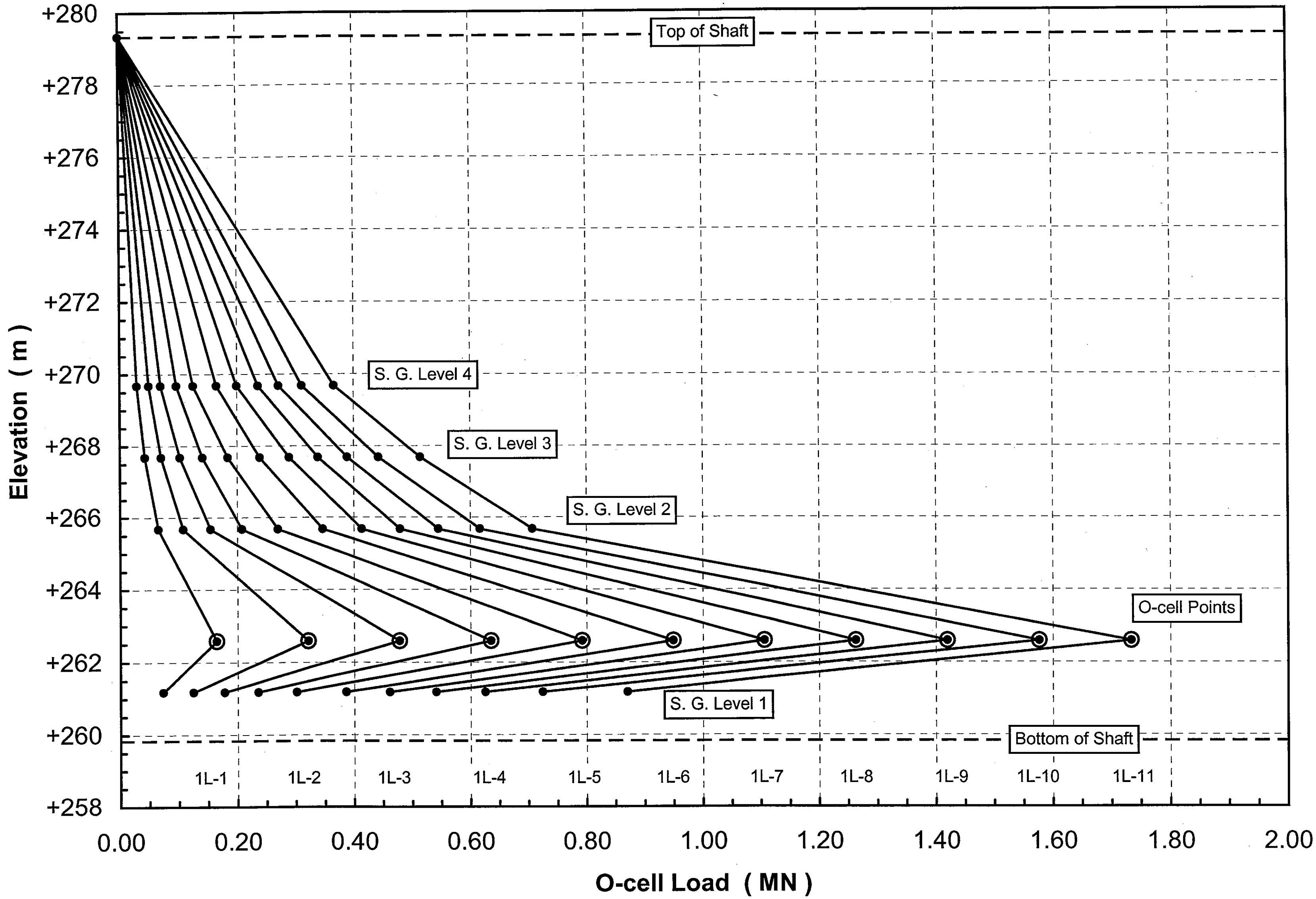
Equivalent Top Load Load-Movement Curve

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa



Strain Gage Load Distribution Curves

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa



Combined End Bearing and Lower Side Shear Creep Limit

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

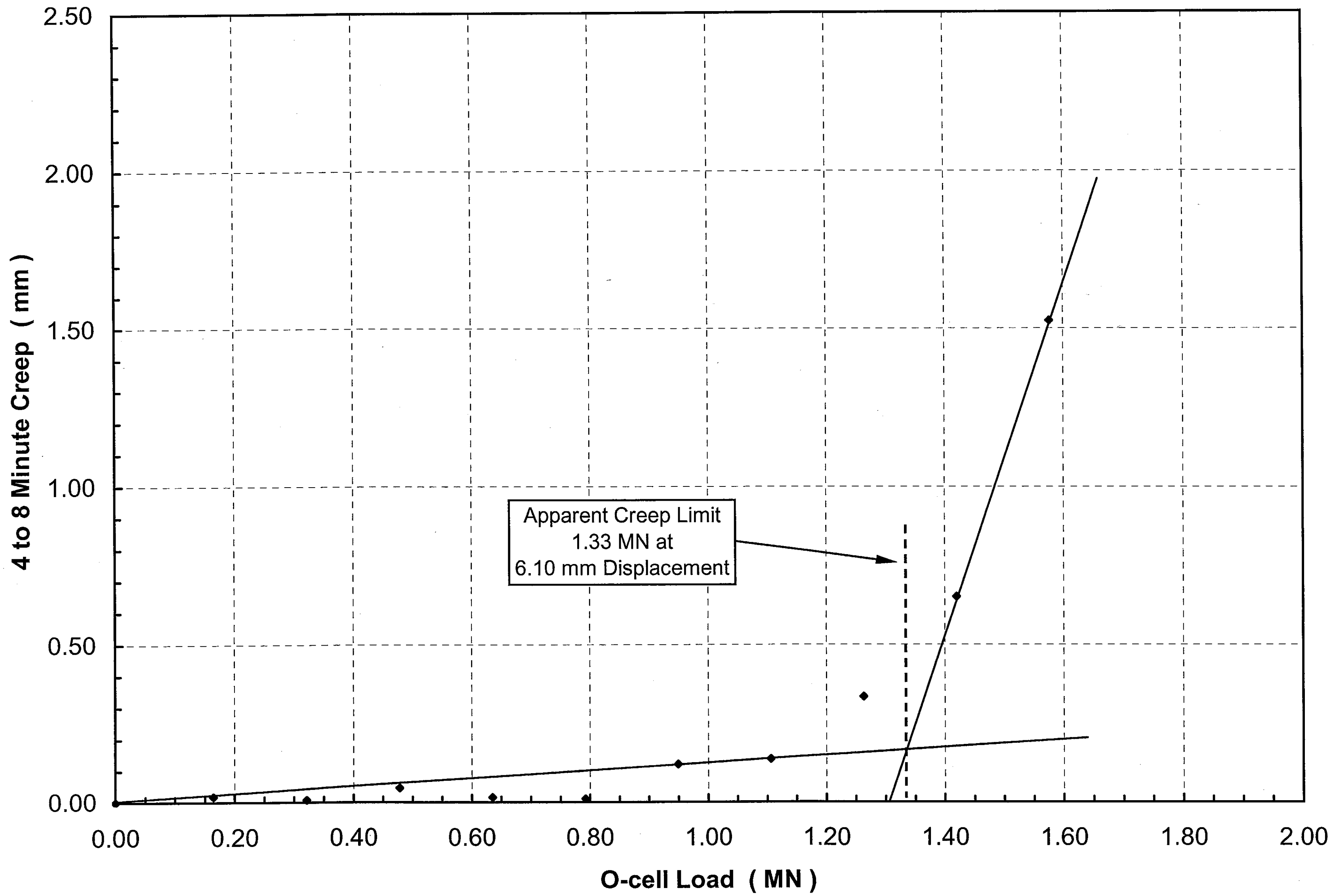


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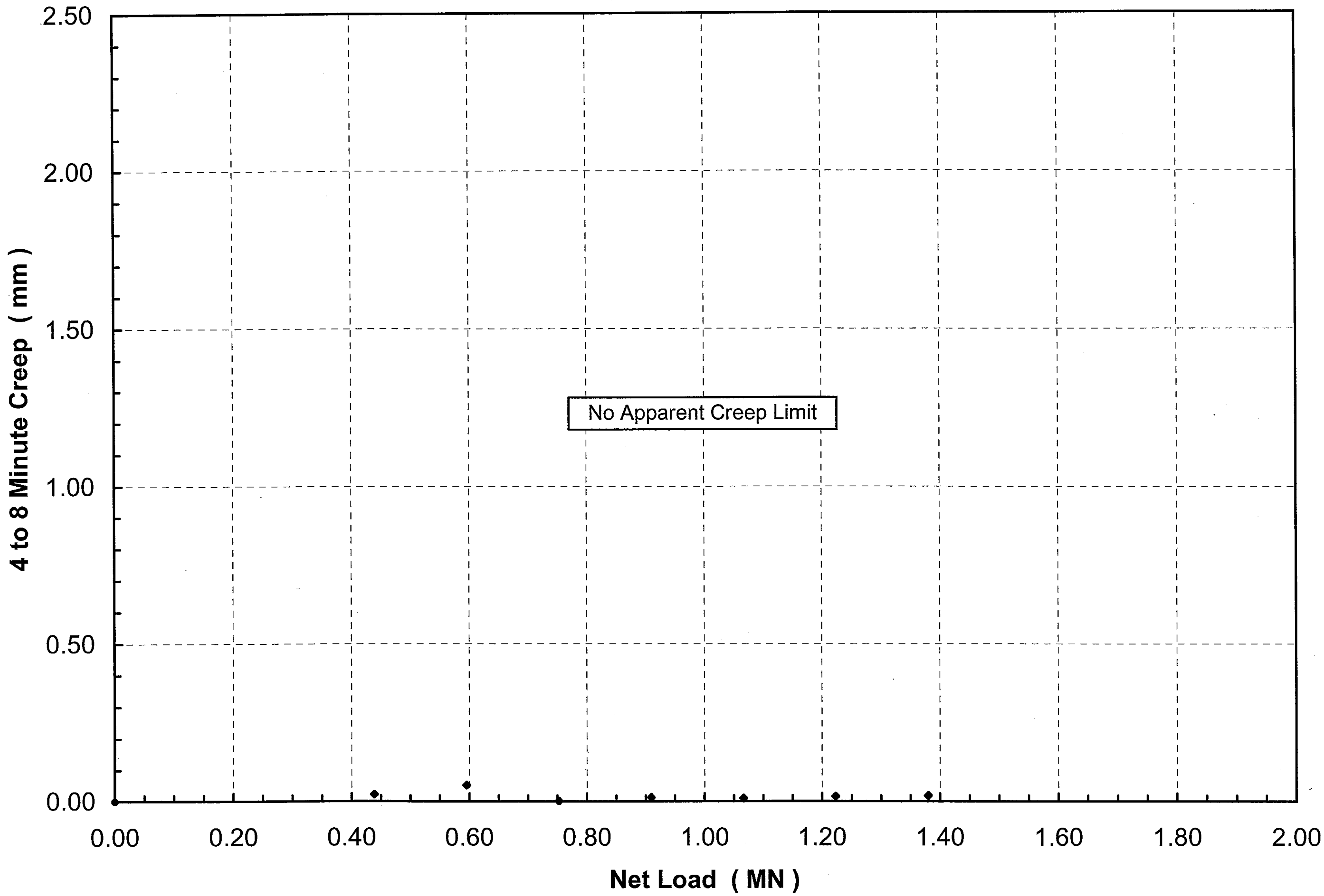
Figure 4 of 5

Upper Side Shear Creep Limit

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa



APPENDIX A

FIELD DATA & DATA REDUCTION

Upward Top of Shaft Movement and O-cell Expansion
Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (MPa)	O-cell Load (MN)	Top of Shaft A (mm)	Top of Shaft B (mm)	Top of Shaft Avg (mm)	O-cell Expansion A - 05-20411 (mm)	O-cell Expansion B - 05-20412* (mm)	O-cell Expansion C - 05-20413 (mm)	O-cell Expansion Average (mm)
1 L - 0	-	11:18:00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 L - 1	1	11:43:30	2.8	0.16	0.06	0.03	0.04	0.27	0.39	0.35	0.31
1 L - 1	2	11:44:30	2.8	0.16	0.06	0.06	0.06	0.28	0.55	0.35	0.31
1 L - 1	4	11:46:30	2.8	0.16	0.02	0.05	0.03	0.28	-0.68	0.35	0.31
1 L - 1	8	11:50:30	2.8	0.16	0.03	0.02	0.02	0.28	-1.22	0.35	0.31
1 L - 2	1	11:52:00	5.5	0.32	0.06	0.05	0.06	0.43	-0.67	0.53	0.48
1 L - 2	2	11:53:00	5.5	0.32	0.04	0.03	0.04	0.44	-1.08	0.54	0.49
1 L - 2	4	11:55:00	5.5	0.32	0.07	0.06	0.06	0.44	0.38	0.53	0.49
1 L - 2	8	11:59:00	5.5	0.32	0.07	0.06	0.06	0.44	-2.08	0.54	0.49
1 L - 3	1	12:01:00	8.3	0.48	0.08	0.08	0.08	0.63	0.05	0.73	0.68
1 L - 3	2	12:02:00	8.3	0.48	0.10	0.09	0.10	0.65	-1.48	0.75	0.70
1 L - 3	4	12:04:00	8.3	0.48	0.12	0.11	0.11	0.66	-0.17	0.75	0.70
1 L - 3	8	12:08:00	8.3	0.48	0.09	0.08	0.08	0.67	-12.32	0.77	0.72
1 L - 4	1	12:09:30	11.0	0.64	0.09	0.12	0.11	0.96	-12.30	1.07	1.02
1 L - 4	2	12:10:30	11.0	0.64	0.09	0.11	0.10	0.99	-12.41	1.10	1.04
1 L - 4	4	12:12:30	11.0	0.64	0.10	0.08	0.09	1.01	-14.45	1.13	1.07
1 L - 4	8	12:16:30	11.0	0.64	0.08	0.13	0.11	1.05	-12.44	1.17	1.11
1 L - 5	1	12:18:30	13.8	0.79	0.15	0.16	0.16	1.50	-12.29	1.62	1.56
1 L - 5	2	12:19:30	13.8	0.79	0.10	0.17	0.14	1.54	-12.32	1.65	1.60
1 L - 5	4	12:21:30	13.8	0.79	0.09	0.14	0.12	1.59	-12.21	1.71	1.65
1 L - 5	8	12:25:30	13.8	0.79	0.16	0.18	0.17	1.65	-8.88	1.77	1.71
1 L - 6	1	12:27:30	16.5	0.95	0.19	0.20	0.19	2.22	-12.31	2.43	2.33
1 L - 6	2	12:28:30	16.5	0.95	0.17	0.15	0.16	2.30	-12.19	2.51	2.41
1 L - 6	4	12:30:30	16.5	0.95	0.19	0.20	0.20	2.40	-12.45	2.60	2.50
1 L - 6	8	12:34:30	16.5	0.95	0.20	0.19	0.19	2.52	-14.45	2.72	2.62
1 L - 7	1	12:36:30	19.3	1.11	0.24	0.24	0.24	3.19	-12.30	3.43	3.31
1 L - 7	2	12:37:30	19.3	1.11	0.20	0.23	0.22	3.29	-12.46	3.54	3.42
1 L - 7	4	12:39:30	19.3	1.11	0.22	0.25	0.23	3.45	-12.45	3.70	3.57
1 L - 7	8	12:43:30	19.3	1.11	0.24	0.24	0.24	3.55	-10.69	3.90	3.72
1 L - 8	1	12:45:30	22.1	1.26	0.24	0.25	0.24	4.53	-12.11	4.87	4.70
1 L - 8	2	12:46:30	22.1	1.26	0.25	0.25	0.25	4.73	-12.48	5.06	4.89
1 L - 8	4	12:48:30	22.1	1.26	0.25	0.25	0.25	4.98	-12.30	5.31	5.15
1 L - 8	8	12:52:30	22.1	1.26	0.26	0.25	0.26	5.33	-12.51	5.65	5.49
1 L - 9	1	12:54:30	24.8	1.42	0.27	0.33	0.30	6.70	-12.36	7.03	6.86
1 L - 9	2	12:55:30	24.8	1.42	0.26	0.30	0.28	7.11	-12.27	7.46	7.29
1 L - 9	4	12:57:30	24.8	1.42	0.31	0.32	0.32	7.66	-12.28	7.99	7.82
1 L - 9	8	13:01:30	24.8	1.42	0.32	0.33	0.33	8.33	-12.46	8.64	8.49
1 L - 10	1	13:03:00	27.6	1.58	0.32	0.36	0.34	11.14	-12.16	11.41	11.28
1 L - 10	2	13:04:00	27.6	1.58	0.36	0.35	0.36	12.04	-12.41	12.26	12.15
1 L - 10	4	13:06:00	27.6	1.58	0.36	0.36	0.36	13.15	-12.52	13.39	13.27
1 L - 10	8	13:10:00	27.6	1.58	0.36	0.37	0.37	14.70	-12.31	14.93	14.81
1 L - 11	1	13:14:30	30.3	1.73	0.42	0.44	0.43	28.38	-12.42	28.82	28.60
1 L - 11	2	13:15:30	30.3	1.73	0.43	0.46	0.44	30.63	-12.16	31.06	30.84
1 L - 11	4	13:17:30	30.3	1.73	0.47	0.50	0.49	34.41	-12.42	34.85	34.63
1 L - 11	8	13:21:30	30.3	1.73	0.45	0.47	0.46	40.45	-12.30	40.79	40.62
1 L - 12	1	13:23:00	31.0	1.77	0.48	0.49	0.48	49.80	-12.40	50.12	49.96
1 L - 12	2	13:24:00	30.8	1.76	0.48	0.49	0.49	58.79	-12.26	59.29	59.04
1 L - 12	4	13:26:00	29.8	1.70	0.51	0.49	0.50	79.26	-12.30	79.68	79.47
1 U - 1	1	13:28:00	27.6	1.58	0.51	0.53	0.52	88.35	-12.47	88.45	88.40
1 U - 1	2	13:29:00	27.6	1.58	0.48	0.56	0.52	89.50	-12.29	89.95	89.72
1 U - 1	4	13:31:00	27.6	1.58	0.54	0.52	0.53	91.67	-10.29	92.17	91.92
1 U - 2	1	13:33:00	13.8	0.79	0.41	0.43	0.42	91.46	-12.48	91.45	91.46
1 U - 2	2	13:34:00	13.8	0.79	0.41	0.43	0.42	91.44	-12.31	91.40	91.42
1 U - 2	4	13:36:00	13.8	0.79	0.42	0.45	0.44	91.37	-12.42	91.35	91.36
1 U - 3	1	13:38:00	6.9	0.40	0.35	0.36	0.36	89.73	-12.26	89.86	89.80
1 U - 3	2	13:39:00	6.9	0.40	0.32	0.36	0.34	89.67	-12.31	89.79	89.73
1 U - 3	4	13:41:00	6.9	0.40	0.28	0.31	0.30	89.65	-12.34	89.73	89.69
1 U - 4	1	13:45:00	3.4	0.20	0.29	0.29	0.29	88.54	-12.02	88.65	88.59
1 U - 4	2	13:46:00	3.4	0.20	0.25	0.27	0.26	88.43	-12.42	88.53	88.48
1 U - 4	4	13:48:00	3.4	0.20	0.27	0.30	0.29	88.40	-12.13	88.50	88.45
1 U - 5	1	13:49:30	0.0	0.00	0.22	0.22	0.22	86.65	-8.39	86.67	86.66
1 U - 5	2	13:50:30	0.0	0.00	0.19	0.24	0.22	86.52	-8.15	86.55	86.54
1 U - 5	4	13:52:30	0.0	0.00	0.25	0.28	0.27	86.39	-12.17	86.42	86.41
1 U - 5	8	13:56:30	0.0	0.00	0.25	0.25	0.25	86.28	-11.94	86.29	86.29

* LVWDT B did not appear to function properly at time of testing and is not included in the analysis.

Shaft Compression
Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell		Telltales			ECT Level 1*			ECT Level 2**		
			Pressure (MPa)	Load (MN)	A - 04-15814 (mm)	A - 04-15815 (mm)	Average (mm)	A - 06-1695 (mm)	B - 06-1696 (mm)	Average (mm)	A - 06-1697 (mm)	B - 06-1698 (mm)	Average (mm)
1 L - 0	-	11:18:00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1 L - 1	1	11:43:30	2.8	0.16	0.06	0.06	0.06	0.02	0.02	0.02	0.04	0.04	0.04
1 L - 1	2	11:44:30	2.8	0.16	0.06	0.06	0.06	0.02	0.02	0.02	0.04	0.04	0.04
1 L - 1	4	11:46:30	2.8	0.16	0.06	0.06	0.06	0.02	0.02	0.02	0.04	0.04	0.04
1 L - 1	8	11:50:30	2.8	0.16	0.06	0.06	0.06	0.02	0.02	0.02	0.04	0.04	0.04
1 L - 2	1	11:52:00	5.5	0.32	0.08	0.08	0.08	0.03	0.03	0.03	0.06	0.06	0.06
1 L - 2	2	11:53:00	5.5	0.32	0.08	0.08	0.08	0.03	0.03	0.03	0.06	0.06	0.06
1 L - 2	4	11:55:00	5.5	0.32	0.09	0.09	0.09	0.03	0.03	0.03	0.06	0.06	0.06
1 L - 2	8	11:59:00	5.5	0.32	0.08	0.08	0.08	0.03	0.03	0.03	0.06	0.06	0.06
1 L - 3	1	12:01:00	8.3	0.48	0.11	0.11	0.11	0.05	0.05	0.05	0.09	0.09	0.09
1 L - 3	2	12:02:00	8.3	0.48	0.11	0.11	0.11	0.05	0.05	0.05	0.09	0.09	0.09
1 L - 3	4	12:04:00	8.3	0.48	0.11	0.11	0.11	0.05	0.05	0.05	0.09	0.09	0.09
1 L - 3	8	12:08:00	8.3	0.48	0.11	0.11	0.11	0.05	0.05	0.05	0.09	0.09	0.09
1 L - 4	1	12:09:30	11.0	0.64	0.15	0.15	0.15	0.06	0.06	0.06	0.12	0.12	0.12
1 L - 4	2	12:10:30	11.0	0.64	0.15	0.15	0.15	0.06	0.06	0.06	0.12	0.12	0.12
1 L - 4	4	12:12:30	11.0	0.64	0.15	0.15	0.15	0.07	0.06	0.06	0.12	0.12	0.12
1 L - 4	8	12:16:30	11.0	0.64	0.16	0.16	0.16	0.07	0.06	0.06	0.12	0.12	0.12
1 L - 5	1	12:18:30	13.8	0.79	0.20	0.20	0.20	0.08	0.08	0.08	0.16	0.16	0.16
1 L - 5	2	12:19:30	13.8	0.79	0.20	0.20	0.20	0.08	0.08	0.08	0.16	0.16	0.16
1 L - 5	4	12:21:30	13.8	0.79	0.20	0.20	0.20	0.08	0.08	0.08	0.16	0.16	0.16
1 L - 5	8	12:25:30	13.8	0.79	0.21	0.20	0.20	0.08	0.08	0.08	0.16	0.16	0.16
1 L - 6	1	12:27:30	16.5	0.95	0.25	0.24	0.24	0.10	0.10	0.10	0.20	0.20	0.20
1 L - 6	2	12:28:30	16.5	0.95	0.25	0.24	0.25	0.11	0.10	0.10	0.20	0.21	0.20
1 L - 6	4	12:30:30	16.5	0.95	0.25	0.24	0.25	0.11	0.10	0.10	0.20	0.21	0.21
1 L - 6	8	12:34:30	16.5	0.95	0.26	0.25	0.25	0.11	0.10	0.10	0.21	0.21	0.21
1 L - 7	1	12:36:30	19.3	1.11	0.30	0.29	0.30	0.12	0.11	0.12	0.24	0.25	0.24
1 L - 7	2	12:37:30	19.3	1.11	0.31	0.30	0.30	0.12	0.11	0.12	0.24	0.25	0.25
1 L - 7	4	12:39:30	19.3	1.11	0.31	0.30	0.30	0.12	0.11	0.12	0.25	0.25	0.25
1 L - 7	8	12:43:30	19.3	1.11	0.32	0.30	0.31	0.13	0.12	0.12	0.25	0.25	0.25
1 L - 8	1	12:45:30	22.1	1.26	0.35	0.34	0.35	0.14	0.13	0.14	0.28	0.29	0.29
1 L - 8	2	12:46:30	22.1	1.26	0.36	0.35	0.35	0.14	0.13	0.14	0.29	0.29	0.29
1 L - 8	4	12:48:30	22.1	1.26	0.37	0.35	0.36	0.14	0.14	0.14	0.29	0.29	0.29
1 L - 8	8	12:52:30	22.1	1.26	0.37	0.35	0.36	0.14	0.14	0.14	0.29	0.29	0.29
1 L - 9	1	12:54:30	24.8	1.42	0.41	0.40	0.40	0.16	0.16	0.16	0.32	0.33	0.33
1 L - 9	2	12:55:30	24.8	1.42	0.42	0.40	0.41	0.16	0.16	0.16	0.33	0.33	0.33
1 L - 9	4	12:57:30	24.8	1.42	0.42	0.41	0.41	0.16	0.16	0.16	0.33	0.33	0.33
1 L - 9	8	13:01:30	24.8	1.42	0.43	0.41	0.42	0.16	0.16	0.16	0.33	0.34	0.33
1 L - 10	1	13:03:00	27.6	1.58	0.47	0.46	0.47	0.18	0.18	0.18	0.37	0.37	0.37
1 L - 10	2	13:04:00	27.6	1.58	0.47	0.46	0.47	0.18	0.19	0.18	0.37	0.37	0.37
1 L - 10	4	13:06:00	27.6	1.58	0.48	0.48	0.48	0.18	0.19	0.18	0.37	0.38	0.38
1 L - 10	8	13:10:00	27.6	1.58	0.49	0.49	0.49	0.18	0.19	0.19	0.38	0.38	0.38
1 L - 11	1	13:14:30	30.3	1.73	0.53	0.54	0.54	0.20	0.22	0.21	0.42	0.43	0.43
1 L - 11	2	13:15:30	30.3	1.73	0.54	0.54	0.54	0.20	0.22	0.21	0.43	0.43	0.43
1 L - 11	4	13:17:30	30.3	1.73	0.54	0.55	0.55	0.21	0.23	0.22	0.43	0.43	0.43
1 L - 11	8	13:21:30	30.3	1.73	0.55	0.55	0.55	0.21	0.23	0.22	0.44	0.44	0.44
1 L - 12	1	13:23:00	31.0	1.77	0.58	0.58	0.58	0.22	0.25	0.23	0.46	0.46	0.46
1 L - 12	2	13:24:00	30.8	1.76	0.59	0.58	0.58	0.22	0.25	0.23	0.46	0.46	0.46
1 L - 12	4	13:26:00	29.8	1.70	0.60	0.60	0.60	0.22	0.26	0.24	0.47	0.48	0.47
1 U - 1	1	13:28:00	27.6	1.58	0.61	0.61	0.61	0.21	0.25	0.23	0.46	0.47	0.46
1 U - 1	2	13:29:00	27.6	1.58	0.61	0.61	0.61	0.21	0.25	0.23	0.46	0.47	0.47
1 U - 1	4	13:31:00	27.6	1.58	0.61	0.62	0.61	0.21	0.25	0.23	0.46	0.47	0.47
1 U - 2	1	13:33:00	13.8	0.79	0.46	0.47	0.46	0.14	0.17	0.15	0.30	0.32	0.31
1 U - 2	2	13:34:00	13.8	0.79	0.45	0.47	0.46	0.13	0.17	0.15	0.30	0.32	0.31
1 U - 2	4	13:36:00	13.8	0.79	0.44	0.46	0.45	0.13	0.17	0.15	0.30	0.31	0.30
1 U - 3	1	13:38:00	6.9	0.40	0.32	0.33	0.32	0.08	0.12	0.10	0.20	0.21	0.20
1 U - 3	2	13:39:00	6.9	0.40	0.32	0.32	0.32	0.08	0.12	0.10	0.20	0.21	0.20
1 U - 3	4	13:41:00	6.9	0.40	0.31	0.32	0.32	0.08	0.12	0.10	0.19	0.21	0.20
1 U - 4	1	13:45:00	3.4	0.20	0.24	0.25	0.25	0.06	0.09	0.08	0.14	0.15	0.15
1 U - 4	2	13:46:00	3.4	0.20	0.24	0.24	0.24	0.05	0.09	0.07	0.14	0.15	0.14
1 U - 4	4	13:48:00	3.4	0.20	0.24	0.24	0.24	0.06	0.09	0.07	0.14	0.15	0.14
1 U - 5	1	13:49:30	0.0	0.00	0.17	0.17	0.17	0.03	0.06	0.04	0.08	0.09	0.09
1 U - 5	2	13:50:30	0.0	0.00	0.16	0.17	0.17	0.03	0.06	0.04	0.08	0.09	0.08
1 U - 5	4	13:52:30	0.0	0.00	0.16	0.16	0.16	0.02	0.06	0.04	0.08	0.08	0.08
1 U - 5	8	13:56:30	0.0	0.00	0.16	0.16	0.16	0.02	0.06	0.04	0.08	0.08	0.08

* Elastic compression below O-cell
** Elastic compression within glacial clay above O-cell

Upward and Downward O-cell Plate Movement and Creep (calculated)
Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (MPa)	O-cell Load (MN)	Top of Shaft (mm)	Total Comp. * (mm)	Top Plate Movement (mm)	O-cell Expansion (mm)	Bot. Plate Movement (mm)	Creep Up Per Hold (mm)	Creep Dn Per Hold (mm)
1 L - 0	-	11:18:00	0.0	0.00	0.00	0.00	0.00	0.00	0.00		
1 L - 1	1	11:43:30	2.8	0.16	0.04	0.06	0.11	0.31	-0.20		
1 L - 1	2	11:44:30	2.8	0.16	0.06	0.06	0.12	0.31	-0.19	0.02	-0.01
1 L - 1	4	11:46:30	2.8	0.16	0.03	0.06	0.10	0.31	-0.22	-0.03	0.03
1 L - 1	8	11:50:30	2.8	0.16	0.02	0.06	0.08	0.31	-0.24	-0.02	0.02
1 L - 2	1	11:52:00	5.5	0.32	0.06	0.08	0.14	0.48	-0.35		
1 L - 2	2	11:53:00	5.5	0.32	0.04	0.08	0.12	0.49	-0.37	-0.02	0.02
1 L - 2	4	11:55:00	5.5	0.32	0.06	0.09	0.15	0.49	-0.34	0.03	-0.03
1 L - 2	8	11:59:00	5.5	0.32	0.06	0.08	0.15	0.49	-0.34	0.00	0.01
1 L - 3	1	12:01:00	8.3	0.48	0.08	0.11	0.19	0.68	-0.49		
1 L - 3	2	12:02:00	8.3	0.48	0.10	0.11	0.21	0.70	-0.49	0.02	-0.01
1 L - 3	4	12:04:00	8.3	0.48	0.11	0.11	0.22	0.70	-0.48	0.02	-0.01
1 L - 3	8	12:08:00	8.3	0.48	0.08	0.11	0.19	0.72	-0.53	-0.03	0.05
1 L - 4	1	12:09:30	11.0	0.64	0.11	0.15	0.25	1.02	-0.76		
1 L - 4	2	12:10:30	11.0	0.64	0.10	0.15	0.25	1.04	-0.79	0.00	0.03
1 L - 4	4	12:12:30	11.0	0.64	0.09	0.15	0.24	1.07	-0.83	-0.01	0.04
1 L - 4	8	12:16:30	11.0	0.64	0.11	0.16	0.26	1.11	-0.85	0.02	0.02
1 L - 5	1	12:18:30	13.8	0.79	0.16	0.20	0.36	1.56	-1.20		
1 L - 5	2	12:19:30	13.8	0.79	0.14	0.20	0.34	1.60	-1.26	-0.02	0.06
1 L - 5	4	12:21:30	13.8	0.79	0.12	0.20	0.32	1.65	-1.32	-0.01	0.06
1 L - 5	8	12:25:30	13.8	0.79	0.17	0.20	0.37	1.71	-1.34	0.05	0.01
1 L - 6	1	12:27:30	16.5	0.95	0.19	0.24	0.44	2.33	-1.89		
1 L - 6	2	12:28:30	16.5	0.95	0.16	0.25	0.41	2.41	-2.00	-0.03	0.11
1 L - 6	4	12:30:30	16.5	0.95	0.20	0.25	0.45	2.50	-2.05	0.04	0.06
1 L - 6	8	12:34:30	16.5	0.95	0.19	0.25	0.45	2.62	-2.17	0.00	0.12
1 L - 7	1	12:36:30	19.3	1.11	0.24	0.30	0.53	3.31	-2.77		
1 L - 7	2	12:37:30	19.3	1.11	0.22	0.30	0.52	3.42	-2.90	-0.02	0.13
1 L - 7	4	12:39:30	19.3	1.11	0.23	0.30	0.54	3.57	-3.04	0.02	0.14
1 L - 7	8	12:43:30	19.3	1.11	0.24	0.31	0.55	3.72	-3.18	0.01	0.14
1 L - 8	1	12:45:30	22.1	1.26	0.24	0.35	0.59	4.70	-4.11		
1 L - 8	2	12:46:30	22.1	1.26	0.25	0.35	0.60	4.89	-4.29	0.01	0.18
1 L - 8	4	12:48:30	22.1	1.26	0.25	0.36	0.61	5.15	-4.54	0.01	0.25
1 L - 8	8	12:52:30	22.1	1.26	0.26	0.36	0.62	5.49	-4.87	0.01	0.33
1 L - 9	1	12:54:30	24.8	1.42	0.30	0.40	0.70	6.86	-6.16		
1 L - 9	2	12:55:30	24.8	1.42	0.28	0.41	0.69	7.29	-6.60	-0.02	0.44
1 L - 9	4	12:57:30	24.8	1.42	0.32	0.41	0.73	7.82	-7.09	0.04	0.49
1 L - 9	8	13:01:30	24.8	1.42	0.33	0.42	0.75	8.49	-7.74	0.02	0.65
1 L - 10	1	13:03:00	27.6	1.58	0.34	0.47	0.80	11.28	-10.47		
1 L - 10	2	13:04:00	27.6	1.58	0.36	0.47	0.82	12.15	-11.33	0.02	0.85
1 L - 10	4	13:06:00	27.6	1.58	0.36	0.48	0.84	13.27	-12.43	0.01	1.11
1 L - 10	8	13:10:00	27.6	1.58	0.37	0.49	0.85	14.81	-13.96	0.02	1.53
1 L - 11	1	13:14:30	30.3	1.73	0.43	0.54	0.97	28.60	-27.63		
1 L - 11	2	13:15:30	30.3	1.73	0.44	0.54	0.98	30.84	-29.86	0.02	2.23
1 L - 11	4	13:17:30	30.3	1.73	0.49	0.55	1.03	34.63	-33.60	0.05	3.74
1 L - 11	8	13:21:30	30.3	1.73	0.46	0.55	1.01	40.62	-39.61	-0.02	6.01
1 L - 12	1	13:23:00	31.0	1.77	0.48	0.58	1.06	49.96	-48.90		
1 L - 12	2	13:24:00	30.8	1.76	0.49	0.58	1.07	59.04	-57.97		
1 L - 12	4	13:26:00	29.8	1.70	0.50	0.60	1.10	79.47	-78.37		
1 U - 1	1	13:28:00	27.6	1.58	0.52	0.61	1.13	88.40	-87.27		
1 U - 1	2	13:29:00	27.6	1.58	0.52	0.61	1.13	89.72	-88.59		
1 U - 1	4	13:31:00	27.6	1.58	0.53	0.61	1.15	91.92	-90.77		
1 U - 2	1	13:33:00	13.8	0.79	0.42	0.46	0.89	91.46	-90.57		
1 U - 2	2	13:34:00	13.8	0.79	0.42	0.46	0.88	91.42	-90.54		
1 U - 2	4	13:36:00	13.8	0.79	0.44	0.45	0.89	91.36	-90.47		
1 U - 3	1	13:38:00	6.9	0.40	0.36	0.32	0.68	89.80	-89.12		
1 U - 3	2	13:39:00	6.9	0.40	0.34	0.32	0.66	89.73	-89.08		
1 U - 3	4	13:41:00	6.9	0.40	0.30	0.32	0.61	89.69	-89.08		
1 U - 4	1	13:45:00	3.4	0.20	0.29	0.25	0.53	88.59	-88.06		
1 U - 4	2	13:46:00	3.4	0.20	0.26	0.24	0.50	88.48	-87.98		
1 U - 4	4	13:48:00	3.4	0.20	0.29	0.24	0.53	88.45	-87.92		
1 U - 5	1	13:49:30	0.0	0.00	0.22	0.17	0.39	86.66	-86.27		
1 U - 5	2	13:50:30	0.0	0.00	0.22	0.17	0.38	86.54	-86.16		
1 U - 5	4	13:52:30	0.0	0.00	0.27	0.16	0.43	86.41	-85.98		
1 U - 5	8	13:56:30	0.0	0.00	0.25	0.16	0.41	86.29	-85.88		

* Elastic compression above the O-cell.

Strain Gage Readings and Loads at Levels 1 and 2
Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

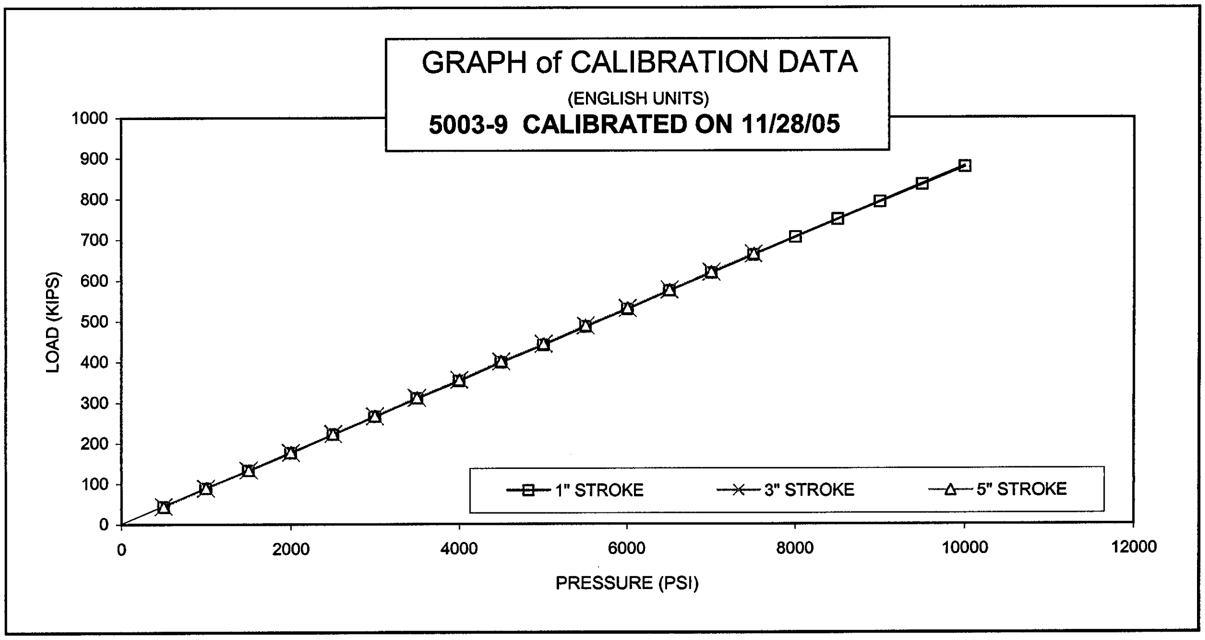
Load Test Increment	Hold Time (minutes)	Time (h:m:s)	O-cell Pressure (MPa)	O-cell Load (MN)	Level 1 A - 06-3829 (με)	Level 1 B - 06-3830 (με)	Level 1 Av. Load (MN)	Level 2 A - 06-3831 (με)	Level 2 B - 06-3832 (με)	Level 2 Av. Load (MN)
1 L - 0	-	11:18:00	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
1 L - 1	1	11:43:30	2.8	0.16	8.0	5.2	0.08	5.4	6.0	0.07
1 L - 1	2	11:44:30	2.8	0.16	8.1	5.0	0.07	5.5	6.0	0.07
1 L - 1	4	11:46:30	2.8	0.16	8.0	4.9	0.07	5.5	5.8	0.06
1 L - 1	8	11:50:30	2.8	0.16	7.8	5.0	0.07	5.5	5.9	0.07
1 L - 2	1	11:52:00	5.5	0.32	13.1	8.6	0.12	8.9	9.8	0.11
1 L - 2	2	11:53:00	5.5	0.32	13.3	8.6	0.13	9.1	9.8	0.11
1 L - 2	4	11:55:00	5.5	0.32	13.4	8.6	0.13	9.1	9.9	0.11
1 L - 2	8	11:59:00	5.5	0.32	13.3	8.5	0.12	9.0	9.8	0.11
1 L - 3	1	12:01:00	8.3	0.48	18.5	12.3	0.18	12.6	13.9	0.15
1 L - 3	2	12:02:00	8.3	0.48	18.4	12.2	0.17	12.8	13.9	0.15
1 L - 3	4	12:04:00	8.3	0.48	18.6	12.5	0.18	12.8	14.2	0.15
1 L - 3	8	12:08:00	8.3	0.48	18.8	12.3	0.18	13.0	14.1	0.15
1 L - 4	1	12:09:30	11.0	0.64	24.7	16.3	0.23	16.9	18.6	0.20
1 L - 4	2	12:10:30	11.0	0.64	25.0	16.2	0.23	17.2	18.9	0.21
1 L - 4	4	12:12:30	11.0	0.64	25.2	16.1	0.24	17.3	18.9	0.21
1 L - 4	8	12:16:30	11.0	0.64	25.4	15.9	0.24	17.5	19.0	0.21
1 L - 5	1	12:18:30	13.8	0.79	32.4	19.8	0.30	22.0	24.2	0.26
1 L - 5	2	12:19:30	13.8	0.79	32.6	19.9	0.30	22.1	24.4	0.27
1 L - 5	4	12:21:30	13.8	0.79	32.8	19.8	0.30	22.3	24.6	0.27
1 L - 5	8	12:25:30	13.8	0.79	33.1	19.8	0.30	22.5	24.8	0.27
1 L - 6	1	12:27:30	16.5	0.95	41.9	25.0	0.38	28.2	31.1	0.34
1 L - 6	2	12:28:30	16.5	0.95	42.3	24.9	0.38	28.4	31.3	0.34
1 L - 6	4	12:30:30	16.5	0.95	42.4	24.9	0.38	28.6	31.6	0.34
1 L - 6	8	12:34:30	16.5	0.95	42.5	25.2	0.39	28.9	31.9	0.35
1 L - 7	1	12:36:30	19.3	1.11	50.1	29.5	0.45	33.6	37.3	0.40
1 L - 7	2	12:37:30	19.3	1.11	50.4	29.6	0.46	33.8	37.3	0.41
1 L - 7	4	12:39:30	19.3	1.11	50.7	29.7	0.46	34.2	37.9	0.41
1 L - 7	8	12:43:30	19.3	1.11	50.8	30.1	0.46	34.5	38.1	0.41
1 L - 8	1	12:45:30	22.1	1.26	57.9	35.3	0.53	39.3	43.3	0.47
1 L - 8	2	12:46:30	22.1	1.26	58.1	35.7	0.53	39.5	43.7	0.47
1 L - 8	4	12:48:30	22.1	1.26	58.1	36.0	0.54	39.7	43.6	0.48
1 L - 8	8	12:52:30	22.1	1.26	58.3	36.6	0.54	40.0	44.1	0.48
1 L - 9	1	12:54:30	24.8	1.42	65.0	42.5	0.61	44.7	49.2	0.54
1 L - 9	2	12:55:30	24.8	1.42	64.9	43.0	0.62	44.8	49.5	0.54
1 L - 9	4	12:57:30	24.8	1.42	65.1	43.9	0.62	45.2	49.9	0.54
1 L - 9	8	13:01:30	24.8	1.42	65.1	44.6	0.63	45.6	50.1	0.55
1 L - 10	1	13:03:00	27.6	1.58	71.6	51.7	0.70	50.3	55.5	0.60
1 L - 10	2	13:04:00	27.6	1.58	71.8	52.6	0.71	50.6	55.8	0.61
1 L - 10	4	13:06:00	27.6	1.58	71.9	53.7	0.72	50.7	56.2	0.61
1 L - 10	8	13:10:00	27.6	1.58	71.9	55.1	0.72	51.3	56.8	0.62
1 L - 11	1	13:14:30	30.3	1.73	79.0	68.5	0.84	57.2	63.6	0.69
1 L - 11	2	13:15:30	30.3	1.73	79.2	69.3	0.85	57.4	64.0	0.69
1 L - 11	4	13:17:30	30.3	1.73	78.9	71.1	0.85	57.8	64.4	0.70
1 L - 11	8	13:21:30	30.3	1.73	78.6	74.1	0.87	58.6	65.4	0.71
1 L - 12	1	13:23:00	31.0	1.77	80.8	80.1	0.92	61.1	68.5	0.74
1 L - 12	2	13:24:00	30.8	1.76	81.5	81.2	0.93	61.6	69.2	0.75
1 L - 12	4	13:26:00	29.8	1.70	81.8	83.5	0.94	62.6	70.7	0.76
1 U - 1	1	13:28:00	27.6	1.58	80.0	81.5	0.92	61.3	70.0	0.75
1 U - 1	2	13:29:00	27.6	1.58	80.3	81.9	0.92	61.4	70.4	0.75
1 U - 1	4	13:31:00	27.6	1.58	80.7	82.0	0.93	61.4	70.5	0.75
1 U - 2	1	13:33:00	13.8	0.79	57.1	57.7	0.65	40.1	47.9	0.50
1 U - 2	2	13:34:00	13.8	0.79	56.8	57.0	0.65	39.6	47.4	0.50
1 U - 2	4	13:36:00	13.8	0.79	56.4	56.5	0.64	39.1	46.8	0.49
1 U - 3	1	13:38:00	6.9	0.40	40.8	40.7	0.46	25.8	32.4	0.33
1 U - 3	2	13:39:00	6.9	0.40	40.6	40.4	0.46	25.6	32.3	0.33
1 U - 3	4	13:41:00	6.9	0.40	40.4	40.1	0.46	25.2	31.9	0.33
1 U - 4	1	13:45:00	3.4	0.20	31.3	31.6	0.36	18.3	24.2	0.24
1 U - 4	2	13:46:00	3.4	0.20	30.5	30.9	0.35	17.7	23.6	0.24
1 U - 4	4	13:48:00	3.4	0.20	31.4	31.3	0.36	18.0	23.9	0.24
1 U - 5	1	13:49:30	0.0	0.00	19.1	22.3	0.24	10.1	15.0	0.14
1 U - 5	2	13:50:30	0.0	0.00	18.7	22.1	0.23	9.9	14.7	0.14
1 U - 5	4	13:52:30	0.0	0.00	18.8	21.6	0.23	9.7	14.4	0.14
1 U - 5	8	13:56:30	0.0	0.00	18.5	21.6	0.23	9.4	14.3	0.14

Strain Gage Readings and Loads at Levels 3 and 4
Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa

Load	Hold	Time	O-cell		Level 3			Level 4		
Test Increment	Time (minutes)	(h:m:s)	Pressure (MPa)	Load (MN)	A - 06-3833 (με)	B - 06-3834 (με)	Av. Load (MN)	A - 06-3835 (με)	B - 06-3836 (με)	Av. Load (MN)
1 L - 0	-	11:18:00	0.0	0.00	0.0	0.0	0.00	0.0	0.0	0.00
1 L - 1	1	11:43:30	2.8	0.16	3.8	3.8	0.04	2.8	2.4	0.03
1 L - 1	2	11:44:30	2.8	0.16	3.8	3.8	0.04	2.8	2.5	0.03
1 L - 1	4	11:46:30	2.8	0.16	3.8	3.7	0.04	2.6	2.5	0.03
1 L - 1	8	11:50:30	2.8	0.16	3.7	3.7	0.04	2.7	2.3	0.03
1 L - 2	1	11:52:00	5.5	0.32	6.1	6.2	0.07	4.4	4.2	0.05
1 L - 2	2	11:53:00	5.5	0.32	6.2	6.2	0.07	4.4	4.2	0.05
1 L - 2	4	11:55:00	5.5	0.32	6.3	6.3	0.07	4.2	4.2	0.05
1 L - 2	8	11:59:00	5.5	0.32	6.1	6.2	0.07	4.3	4.3	0.05
1 L - 3	1	12:01:00	8.3	0.48	8.8	8.7	0.10	6.2	5.9	0.07
1 L - 3	2	12:02:00	8.3	0.48	8.8	8.9	0.10	6.1	6.1	0.07
1 L - 3	4	12:04:00	8.3	0.48	9.0	8.9	0.10	6.3	6.0	0.07
1 L - 3	8	12:08:00	8.3	0.48	9.0	9.0	0.10	6.2	6.1	0.07
1 L - 4	1	12:09:30	11.0	0.64	12.0	11.9	0.14	8.1	8.2	0.09
1 L - 4	2	12:10:30	11.0	0.64	12.1	12.1	0.14	8.2	8.2	0.09
1 L - 4	4	12:12:30	11.0	0.64	12.3	12.1	0.14	8.4	8.3	0.10
1 L - 4	8	12:16:30	11.0	0.64	12.3	12.4	0.14	8.5	8.5	0.10
1 L - 5	1	12:18:30	13.8	0.79	15.8	15.7	0.18	10.9	10.7	0.12
1 L - 5	2	12:19:30	13.8	0.79	15.8	15.8	0.18	10.8	10.8	0.12
1 L - 5	4	12:21:30	13.8	0.79	15.9	15.8	0.18	11.0	10.8	0.12
1 L - 5	8	12:25:30	13.8	0.79	16.2	16.1	0.18	11.0	11.0	0.13
1 L - 6	1	12:27:30	16.5	0.95	20.5	20.3	0.23	14.0	14.1	0.16
1 L - 6	2	12:28:30	16.5	0.95	20.6	20.5	0.23	14.2	14.1	0.16
1 L - 6	4	12:30:30	16.5	0.95	20.8	20.8	0.24	14.3	14.3	0.16
1 L - 6	8	12:34:30	16.5	0.95	21.0	20.8	0.24	14.4	14.6	0.17
1 L - 7	1	12:36:30	19.3	1.11	24.7	24.5	0.28	16.9	17.0	0.19
1 L - 7	2	12:37:30	19.3	1.11	25.0	24.7	0.28	17.2	17.2	0.20
1 L - 7	4	12:39:30	19.3	1.11	25.2	25.0	0.29	17.3	17.4	0.20
1 L - 7	8	12:43:30	19.3	1.11	25.5	25.2	0.29	17.5	17.5	0.20
1 L - 8	1	12:45:30	22.1	1.26	29.2	28.9	0.33	20.1	20.1	0.23
1 L - 8	2	12:46:30	22.1	1.26	29.4	29.1	0.33	20.2	20.4	0.23
1 L - 8	4	12:48:30	22.1	1.26	29.6	29.3	0.34	20.4	20.6	0.23
1 L - 8	8	12:52:30	22.1	1.26	29.9	29.5	0.34	20.6	20.8	0.24
1 L - 9	1	12:54:30	24.8	1.42	33.4	33.1	0.38	22.9	23.3	0.26
1 L - 9	2	12:55:30	24.8	1.42	33.5	33.4	0.38	23.3	23.5	0.27
1 L - 9	4	12:57:30	24.8	1.42	33.9	33.6	0.38	23.5	23.7	0.27
1 L - 9	8	13:01:30	24.8	1.42	34.2	34.0	0.39	23.7	23.9	0.27
1 L - 10	1	13:03:00	27.6	1.58	38.0	37.7	0.43	26.3	26.7	0.30
1 L - 10	2	13:04:00	27.6	1.58	38.2	38.0	0.43	26.5	26.9	0.30
1 L - 10	4	13:06:00	27.6	1.58	38.5	38.2	0.44	26.8	27.2	0.31
1 L - 10	8	13:10:00	27.6	1.58	39.1	38.6	0.44	27.1	27.5	0.31
1 L - 11	1	13:14:30	30.3	1.73	44.0	43.6	0.50	30.8	31.1	0.35
1 L - 11	2	13:15:30	30.3	1.73	44.3	43.8	0.50	31.0	31.4	0.36
1 L - 11	4	13:17:30	30.3	1.73	44.6	44.2	0.51	31.4	31.6	0.36
1 L - 11	8	13:21:30	30.3	1.73	45.4	44.9	0.51	32.0	32.3	0.37
1 L - 12	1	13:23:00	31.0	1.77	47.6	47.0	0.54	33.4	33.8	0.38
1 L - 12	2	13:24:00	30.8	1.76	48.1	47.6	0.55	33.9	34.3	0.39
1 L - 12	4	13:26:00	29.8	1.70	49.3	48.8	0.56	35.0	35.3	0.40
1 U - 1	1	13:28:00	27.6	1.58	47.7	48.1	0.55	32.3	34.9	0.38
1 U - 1	2	13:29:00	27.6	1.58	47.7	48.2	0.55	32.0	35.1	0.38
1 U - 1	4	13:31:00	27.6	1.58	47.8	48.4	0.55	32.0	35.3	0.38
1 U - 2	1	13:33:00	13.8	0.79	32.6	33.0	0.37	21.5	24.2	0.26
1 U - 2	2	13:34:00	13.8	0.79	32.2	32.7	0.37	21.3	24.0	0.26
1 U - 2	4	13:36:00	13.8	0.79	32.0	32.2	0.37	21.1	23.7	0.26
1 U - 3	1	13:38:00	6.9	0.40	21.9	22.4	0.25	14.2	16.5	0.18
1 U - 3	2	13:39:00	6.9	0.40	21.7	22.2	0.25	14.2	16.4	0.17
1 U - 3	4	13:41:00	6.9	0.40	21.6	21.9	0.25	14.1	16.2	0.17
1 U - 4	1	13:45:00	3.4	0.20	16.4	16.8	0.19	10.6	12.2	0.13
1 U - 4	2	13:46:00	3.4	0.20	16.0	16.3	0.18	10.4	12.2	0.13
1 U - 4	4	13:48:00	3.4	0.20	16.1	16.5	0.19	10.6	12.3	0.13
1 U - 5	1	13:49:30	0.0	0.00	10.1	10.5	0.12	6.4	7.9	0.08
1 U - 5	2	13:50:30	0.0	0.00	9.9	10.2	0.11	6.2	7.8	0.08
1 U - 5	4	13:52:30	0.0	0.00	9.7	10.1	0.11	6.0	7.6	0.08
1 U - 5	8	13:56:30	0.0	0.00	9.6	9.9	0.11	6.2	7.4	0.08

APPENDIX B

O-CELL AND INSTRUMENTATION CALIBRATION SHEETS



STROKE:	1 INCH	3 INCH	5 INCH
PRESSURE PSI	LOAD KIPS	LOAD KIPS	LOAD KIPS
0	0	0	0
500	43	44	43
1000	89	89	89
1500	133	133	133
2000	177	177	178
2500	222	223	223
3000	266	267	267
3500	311	311	312
4000	354	356	356
4500	399	401	402
5000	442	445	445
5500	487	489	489
6000	530	532	533
6500	575	577	577
7000	619	620	621
7500	663	664	665
8000	707		
8500	750		
9000	792		
9500	836		
10000	879		

13" O-CELL, SERIAL # 5003-9

LOAD CONVERSION FORMULA

LOAD = PRESSURE * 0.0882 + (1.66)
{KIPS} {PSI}

Regression Output:

Constant	1.6591 kips
X Coefficient	0.0882 kip / psi
R Square	0.9999
No. of Observations	50
Degrees of Freedom	48
Std Err of Y Est	1.72
Std Err of X Coeff	0.0001

CALIBRATION STANDARDS:

All data presented are derived from 6" dia. certified hydraulic pressure gauges and electronic load transducer, manufactured and calibrated by the University of Illinois at Champaign, Illinois. All calibrations and certifications are traceable through the Laboratory Master Deadweight Gauges directly to the National Institute of Standards and Technology. No specific guidelines exist for calibration of load test jacks and equipment but procedures comply with similar guidelines for calibration of gages, ANSI specifications B40.1.

* AE & FC CUSTOMER: LOADTEST Inc	* CONTRACTOR.: JENSEN CONSTRUCTION
* AE & FC JOB NO: 8294	* JOB LOCATION: DES MOINES,IA
* CUSTOMER P.O. NO.: LT-9149	* DATED: 03/02/06

SERVICE ENGINEER: [signature] DATE: 7 Mar 2006

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

Vibrating Wire Displacement Transducer Calibration Report

Range: 150 mm

Calibration Date: February 06, 2006

Serial Number: 05-20411

Temperature: 23.8 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: Erica

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2455	2451	2453	-0.330	-0.22	-0.024	-0.02
30.0	3438	3437	3438	30.09	0.06	30.02	0.02
60.0	4416	4414	4415	60.29	0.19	60.05	0.03
90.0	5384	5382	5383	90.20	0.13	89.96	-0.03
120.0	6350	6347	6349	120.0	0.02	120.0	-0.02
150.0	7309	7310	7310	149.7	-0.19	150.0	0.02

(mm) Linear Gage Factor (G): 0.03090 (mm/ digit) **Regression Zero: 2464**

Polynomial Gage Factors: A: 9.68529E-08 B: 0.02995 C: -74.077

(inches) Linear Gage Factor (G): 0.001216 (inches/ digit)

Polynomial Gage Factors: A: 3.81311E-09 B: 0.001179 C: -2.9164

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4931 Temp(T_0): 21.5 °C Date: March 7, 2006

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

Range: 150 mm

Calibration Date: February 06, 2006

Serial Number: 05-20412

Temperature: 23.8 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: Erica

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2432	2430	2431	-0.271	-0.18	-0.083	-0.06
30.0	3421	3419	3420	30.17	0.11	30.13	0.09
60.0	4397	4396	4397	60.23	0.15	60.08	0.05
90.0	5364	5361	5363	89.96	-0.03	89.81	-0.12
120.0	6341	6340	6341	120.1	0.04	120.0	0.02
150.0	7309	7307	7308	149.8	-0.10	150.0	0.02

(mm) Linear Gage Factor (G): 0.03078 (mm/ digit) **Regression Zero: 2440**

Polynomial Gage Factors: A: 5.87774E-08 B: 0.03021 C: -73.865

(inches) Linear Gage Factor (G): 0.001212 (inches/ digit)

Polynomial Gage Factors: A: 2.31407E-09 B: 0.001189 C: -2.9081

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4897 Temp(T_0): 22.0 °C Date: March 7, 2006

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

Range: 150 mm

Calibration Date: February 06, 2006

Serial Number: 05-20413

Temperature: 23.8 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: Elice

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2415	2414	2415	-0.295	-0.20	-0.081	-0.05
30.0	3400	3398	3399	30.15	0.10	30.11	0.07
60.0	4373	4371	4372	60.25	0.17	60.08	0.05
90.0	5337	5336	5337	90.08	0.05	89.91	-0.06
120.0	6303	6301	6302	119.9	-0.04	119.9	-0.07
150.0	7270	7269	7270	149.9	-0.09	150.1	0.05

(mm) Linear Gage Factor (G): 0.03093 (mm/ digit) **Regression Zero: 2424**

Polynomial Gage Factors: A: 6.75178E-08 B: 0.03027 C: -73.573

(inches) Linear Gage Factor (G): 0.001218 (inches/ digit)

Polynomial Gage Factors: A: 2.65818E-09 B: 0.001192 C: -2.8966

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 4874 Temp(T_0): 22.0 °C Date: March 7, 2006

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

Range: 25 mm

Calibration Date: February 14, 2006

Serial Number: 06-1695

Temperature: 23 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: *ERice*

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2328	2324	2326	-0.075	-0.30	-0.011	-0.04
5.0	3542	3538	3540	5.031	0.12	5.018	0.07
10.0	4736	4733	4735	10.05	0.22	10.00	0.02
15.0	5921	5919	5920	15.04	0.16	14.99	-0.04
20.0	7101	7098	7100	20.00	0.00	19.99	-0.04
25.0	8276	8274	8275	24.94	-0.22	25.01	0.03

(mm) Linear Gage Factor (G): 0.004206 (mm/ digit) **Regression Zero: 2344**

Polynomial Gage Factors: A: 1.34201E-08 B: 0.004063 C: -9.5349

(inches) Linear Gage Factor (G): 0.0001656 (inches/ digit)

Polynomial Gage Factors: A: 5.28352E-10 B: 0.0001600 C: -0.37539

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5090 Temp(T_0): 22.5 °C Date: March 7, 2006

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

Range: 25 mm

Calibration Date: February 14, 2006

Serial Number: 06-1696

Temperature: 23 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: Erica

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2302	2300	2301	-0.078	-0.31	-0.011	-0.04
5.0	3518	3516	3517	5.032	0.13	5.018	0.07
10.0	4713	4712	4713	10.06	0.23	10.00	0.01
15.0	5900	5898	5899	15.04	0.17	14.99	-0.03
20.0	7079	7078	7079	20.00	0.00	19.99	-0.04
25.0	8254	8254	8254	24.94	-0.23	25.01	0.04

(mm) Linear Gage Factor (G): 0.004203 (mm/ digit)

Regression Zero: 2320

Polynomial Gage Factors: A: 1.41366E-08 B: 0.004054 C: -9.4135

(inches) Linear Gage Factor (G): 0.0001655 (inches/ digit)

Polynomial Gage Factors: A: 5.56558E-10 B: 0.0001596 C: -0.37061

Calculated Displacement:

Linear, $D = G(R_1 - R_0)$

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5073

Temp(T_0): 22.7 °C

Date: March 7, 2006

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

Range: 25 mm

Calibration Date: February 14, 2006

Serial Number: 06-1697

Temperature: 23 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: Erica

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2391	2389	2390	-0.071	-0.28	-0.010	-0.04
5.0	3609	3607	3608	5.029	0.11	5.016	0.06
10.0	4809	4807	4808	10.05	0.21	10.00	0.02
15.0	6000	5997	5999	15.04	0.15	14.99	-0.04
20.0	7187	7183	7185	20.00	0.02	19.99	-0.02
25.0	8366	8364	8365	24.95	-0.22	25.01	0.03

(mm) Linear Gage Factor (G): 0.004187 (mm/ digit) **Regression Zero: 2407**

Polynomial Gage Factors: A: 1.27948E-08 B: 0.004049 C: -9.7602

(inches) Linear Gage Factor (G): 0.0001648 (inches/ digit)

Polynomial Gage Factors: A: 5.03734E-10 B: 0.0001594 C: -0.38426

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5122 Temp(T_0): 22.4 °C Date: March 7, 2006

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

Range: 25 mm

Calibration Date: February 14, 2006

Serial Number: 06-1698

Temperature: 23 °C

Cal. Std. Control Numbers: 406, 344, 057, 529

Calibration Instruction: CI-4400 Rev: C

Technician: ERice

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2404	2403	2404	-0.068	-0.27	-0.010	-0.04
5.0	3614	3610	3612	5.029	0.12	5.017	0.07
10.0	4803	4801	4802	10.05	0.19	10.00	0.01
15.0	5985	5984	5985	15.04	0.15	14.99	-0.04
20.0	7163	7161	7162	20.00	0.01	19.99	-0.03
25.0	8335	8334	8335	24.95	-0.20	25.01	0.03

(mm) Linear Gage Factor (G): 0.004218 (mm/ digit) **Regression Zero: 2420**

Polynomial Gage Factors: A: 1.23328E-08 B: 0.004086 C: -9.9009

(inches) Linear Gage Factor (G): 0.0001661 (inches/ digit)

Polynomial Gage Factors: A: 4.85545E-10 B: 0.0001608 C: -0.38980

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5104 Temp(T_0): 22.2 °C Date: March 7, 2006

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

Range: 50 mm

Serial Number: 04-15814

Cal. Std. Control Numbers: 529, 057, 373, 344

Calibration Date: January 07, 2005

Temperature: 22.9 °C

Calibration Instruction: CI-4400 Rev: C

Technician: KLBellavance

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2858	2855	2857	-0.114	-0.23	-0.013	-0.03
10.0	3844	3843	3844	10.05	0.10	10.03	0.05
20.0	4818	4816	4817	20.07	0.14	19.99	-0.02
30.0	5790	5788	5789	30.08	0.16	30.00	0.00
40.0	6754	6753	6754	40.01	0.02	39.99	-0.02
50.0	7716	7714	7715	49.91	-0.19	50.01	0.02

(mm) Linear Gage Factor (G): 0.01030 (mm/ digit) **Regression Zero: 2868**

Polynomial Gage Factors: A: 3.18705E-08 B: 0.009959 C: -28.720

(inches) Linear Gage Factor (G): 0.0004053 (inches/ digit)

Polynomial Gage Factors: A: 1.25474E-09 B: 0.0003921 C: -1.1307

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5260 Temp(T_0): 25.0 °C Date: February 01, 2005

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

Range: 50 mm

Serial Number: 04-15815

Cal. Std. Control Numbers: 529, 057, 373, 344

Calibration Date: January 07, 2005

Temperature: 22.9 °C

Calibration Instruction: CI-4400 Rev: C

Technician: KlBellavance

GK-401 Reading Position B

Actual Displacement (mm)	Gage Reading 1st Cycle	Gage Reading 2nd Cycle	Average Gage Reading	Calculated Displacement (Linear)	Error Linear (%FS)	Calculated Displacement (Polynomial)	Error Polynomial (%FS)
0.0	2912	2911	2912	-0.079	-0.16	-0.004	-0.01
10.0	3890	3888	3889	10.02	0.04	10.00	0.01
20.0	4862	4861	4862	20.07	0.13	20.01	0.01
30.0	5829	5828	5829	30.06	0.11	30.00	-0.01
40.0	6792	6791	6792	40.00	0.01	39.99	-0.02
50.0	7754	7751	7753	49.93	-0.14	50.01	0.01

(mm) Linear Gage Factor (G): 0.01033 (mm/ digit) **Regression Zero: 2919**

Polynomial Gage Factors: A: 2.37229E-08 B: 0.01008 C: -29.546

(inches) Linear Gage Factor (G): 0.0004067 (inches/ digit)

Polynomial Gage Factors: A: 9.33974E-10 B: 0.0003968 C: -1.1632

Calculated Displacement: **Linear, $D = G(R_1 - R_0)$**

Polynomial, $D = AR_1^2 + BR_1 + C$

Refer to manual for temperature correction information.

Function Test at Shipment:

GK-401 Pos. B : 5271 Temp(T_0): 24.7 °C Date: February 01, 2005

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: 06-3829

Prestress: 35,000 psi

Temperature: 21.7 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 84 ft.

Factory Zero Reading: 7460

Regression Zero: 7465

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7525	7529	7527		
1,500	8212	8217	8215	688	-0.30
3,000	8975	8977	8976	762	-0.20
4,500	9739	9741	9740	764	-0.02
6,000	10503	10509	10506	766	0.22
100	7531				

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

Gage Factor: 0.337 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 percent

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: 06-3830

Prestress: 35,000 psi

Temperature: 21.7 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 84 ft.

Factory Zero Reading: 7135

Regression Zero: 7128

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7190	7193	7192		
1,500	7866	7866	7866	675	-0.59
3,000	8639	8643	8641	775	0.04
4,500	9399	9401	9400	759	0.15
6,000	10153	10152	10153	753	0.04
100	7193				

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

Gage Factor: 0.338 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 percent

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: 06-3831

Prestress: 35,000 psi

Temperature: 21.6 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 59 ft.

Factory Zero Reading: 7135

Regression Zero: 7125

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7196	7200	7198		
1,500	7894	7900	7897	699	-0.38
3,000	8670	8676	8673	776	-0.63
4,500	9471	9477	9474	801	-0.09
6,000	10273	10278	10276	802	0.47
100	7201				

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

Gage Factor: 0.330 Microstrain/Digit (GK-401 Pos."B")

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

Note: The above calibration uses the linear regression method.

<u>Users are advised to establish their own zero conditions.</u>

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 percent
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: 06-3832

Prestress: 35,000 psi

Temperature: 21.8 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 59 ft.

Factory Zero Reading: 7316

Regression Zero: 7317

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7382	7392	7387		
1,500	8077	8084	8081	694	-0.35
3,000	8845	8856	8851	770	-0.49
4,500	9631	9642	9637	786	-0.12
6,000	10427	10429	10428	792	0.44
100	7392				

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

Gage Factor: 0.332 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 percent
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: 06-3833

Prestress: 35,000 psi

Temperature: 21.8 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 52 ft.

Factory Zero Reading: 7357

Regression Zero: 7374

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7420	7424	7422		
1,500	8110	8113	8112	690	0.05
3,000	8848	8847	8848	736	0.05
4,500	9583	9585	9584	737	0.06
6,000	10316	10318	10317	733	-0.04
100	7425				

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

Gage Factor: 0.345 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 percent

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: 06-3834

Prestress: 35,000 psi

Temperature: 21.8 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 52 ft.

Factory Zero Reading: 7385

Regression Zero: 7394

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7465	7466	7466		
1,500	8162	8168	8165	700	-0.40
3,000	8943	8946	8945	780	-0.52
4,500	9740	9744	9742	798	-0.07
6,000	10543	10538	10541	799	0.41
100	7466				

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

Gage Factor: 0.330 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 percent
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: 06-3835

Prestress: 35,000 psi

Temperature: 21.5 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 46 ft.

Factory Zero Reading: 7147

Regression Zero: 7163

Technician: J. Ouellette

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7217	7220	7219		
1,500	7903	7903	7903	685	-0.19
3,000	8652	8654	8653	750	-0.04
4,500	9402	9404	9403	750	0.11
6,000	10145	10148	10147	744	0.04
100	7220				

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

Gage Factor: 0.342 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 percent

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: 06-3836

Prestress: 35,000 psi

Temperature: 21.3 °C

Calibration Instruction: CI-VW Rebar Rev: C

Calibration Date: March 07, 2006

Cal. Std. Control Numbers: 85888-1, 043

Cable Length: 46 ft.

Factory Zero Reading: 6969

Regression Zero: 6996

Technician: J. Ouellette

Applied Load: (pounds)	Readings Cycle #1	Cycle #2	Average	Change	Linearity % Max.Load
100	7048	7043	7046		
1,500	7734	7731	7733	687	-0.06
3,000	8475	8473	8474	742	0.04
4,500	9216	9214	9215	741	0.13
6,000	9945	9949	9947	732	-0.09
100	7044				

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

Gage Factor: 0.344 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 percent

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.

APPENDIX C

CONSTRUCTION OF THE EQUIVALENT TOP-LOADED LOAD-SETTLEMENT 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 first converting gross to net loads. For 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 centroid 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 centroid 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

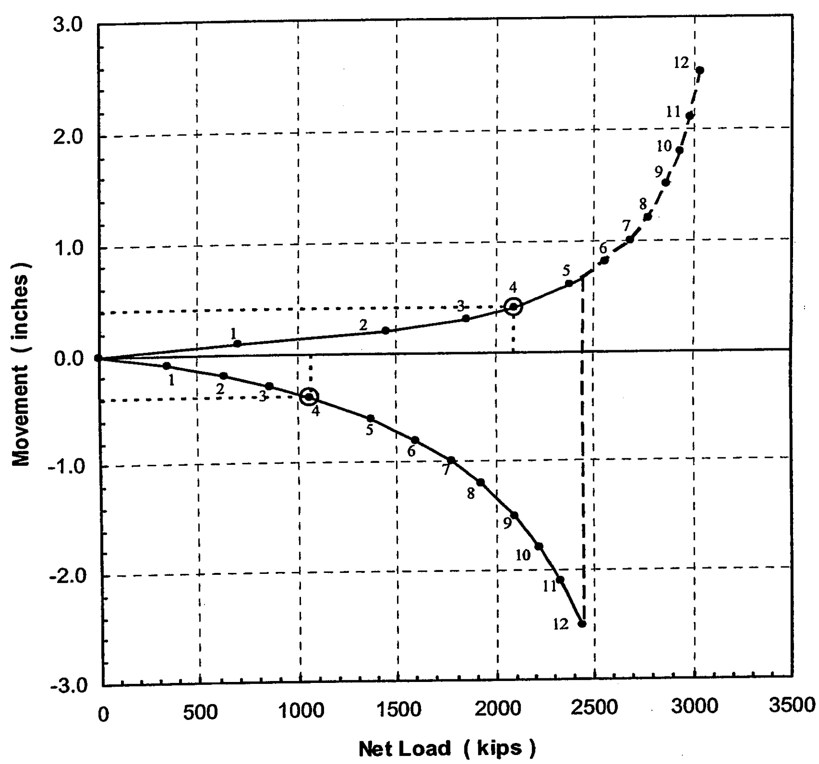
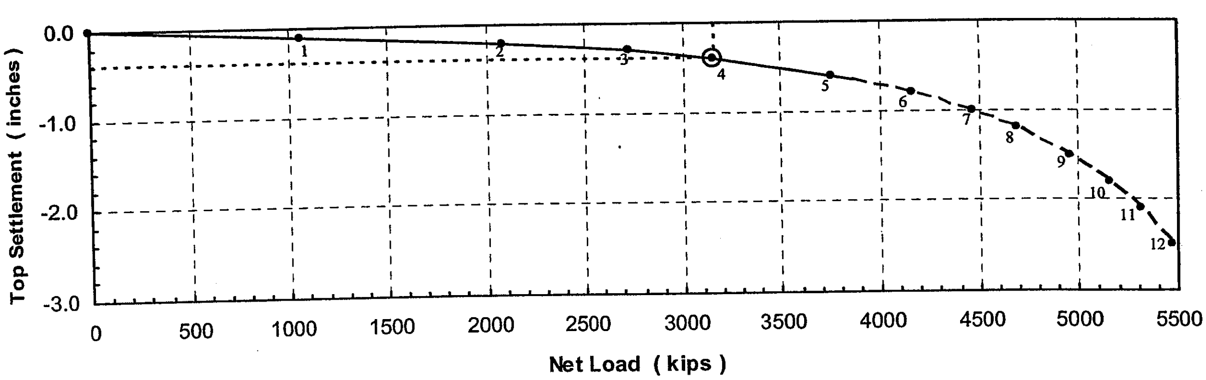
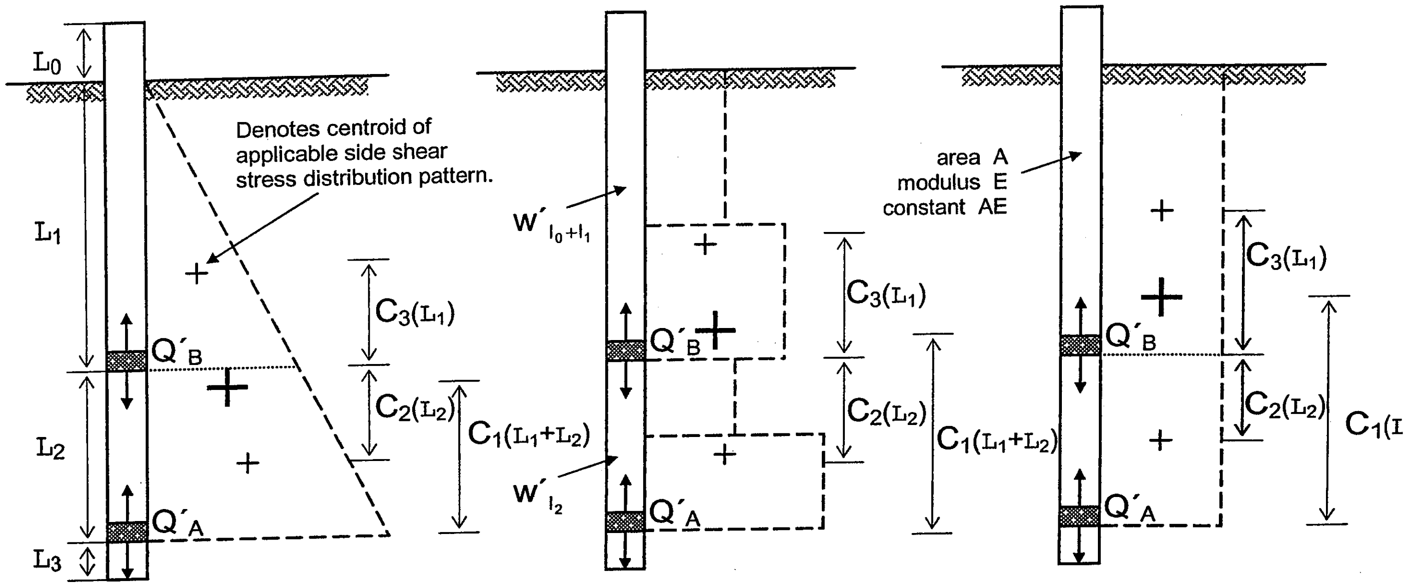


Figure B



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



1-Stage Single Level Test (Q´A only): $\delta_{OLT} = \delta_{\uparrow(l_1+l_2)}$

$C_1 = \frac{1}{3}$	$\text{Centroid Factor} = C_1$	$C_1 = \frac{1}{2}$
$\delta_{\uparrow(l_1+l_2)} = \frac{1}{3}\frac{Q'_{\uparrow A}(l_1+l_2)}{AE}$	$\delta_{\uparrow(l_1+l_2)} = C_1\frac{Q'_{\uparrow A}(l_1+l_2)}{AE}$	$\delta_{\uparrow(l_1+l_2)} = \frac{1}{2}\frac{Q'_{\uparrow A}(l_1+l_2)}{AE}$

3-Stage Multi Level Test (Q´A and Q´B): $\delta_{OLT} = \delta_{\uparrow l_1} + \delta_{\downarrow l_2}$

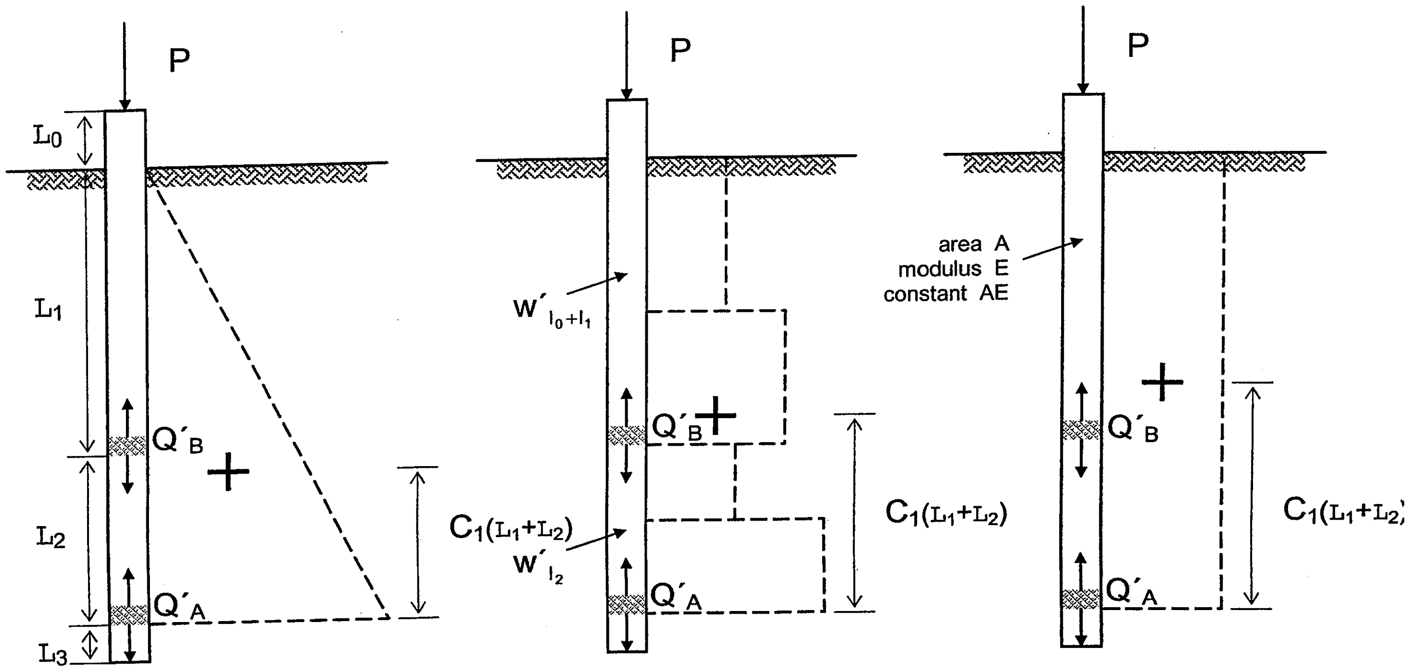
$C_3 = \frac{1}{3}$	$\text{Centroid Factor} = C_3$	$C_3 = \frac{1}{2}$
$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B} l_1}{AE}$	$\delta_{\uparrow l_1} = C_3\frac{Q'_{\uparrow B} l_1}{AE}$	$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B} l_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)$	$\text{Centroid Factor} = C_2$	$C_2 = \frac{1}{2}$
$\delta_{\downarrow l_2} = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)\frac{Q'_{\downarrow B} l_2}{AE}$	$\delta_{\downarrow l_2} = C_2\frac{Q'_{\downarrow B} l_2}{AE}$	$\delta_{\downarrow l_2} = \frac{1}{2}\frac{Q'_{\downarrow B} l_2}{AE}$

Net Loads:

$Q'_{\uparrow A} = Q_{\uparrow A} - W'_{l_0+l_1+l_2}$ $\quad$ $Q'_{\uparrow B} = Q_{\uparrow B} - W'_{l_0+l_1}$ $\quad$ $Q'_{\downarrow B} = Q'_{\downarrow B} + W'_{l_2}$

W' = pile weight, buoyant where below water table

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



Top Loaded Test: $\delta_{TLT} = \delta_{\downarrow l_0} + \delta_{\downarrow l_1+l_2}$

$\delta_{\downarrow l_0} = \dfrac{Pl_0}{AE}$	$\delta_{\downarrow l_0} = \dfrac{Pl_0}{AE}$	$\delta_{\downarrow l_0} = \dfrac{Pl_0}{AE}$
$C_1 = \dfrac{1}{3}$	Centroid Factor $= C_1$	$C_1 = \dfrac{1}{2}$
$\delta_{\downarrow l_1+l_2} = \dfrac{(Q'_{\downarrow A}+2P)}{3}\dfrac{(l_2+l_2)}{AE}$	$\delta_{\downarrow l_1+l_2} = [(C_1)Q'_{\downarrow A}+(1-C_1)P]\dfrac{(l_1+l_2)}{AE}$	$\delta_{\downarrow l_1+l_2} = \dfrac{(Q'_{\downarrow A}+P)}{2}\dfrac{(l_1+l_2)}{AE}$

Net and Equivalent Loads:

$Q'_{\downarrow A} = Q_{\downarrow A} - W'_{l_0+l_1+l_2}$ $\quad P_{single} = Q'_{\downarrow A} + Q'_{\uparrow A}$ $\quad P_{multi} = Q'_{\downarrow A} + Q'_{\uparrow B} + Q'_{\downarrow B}$

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

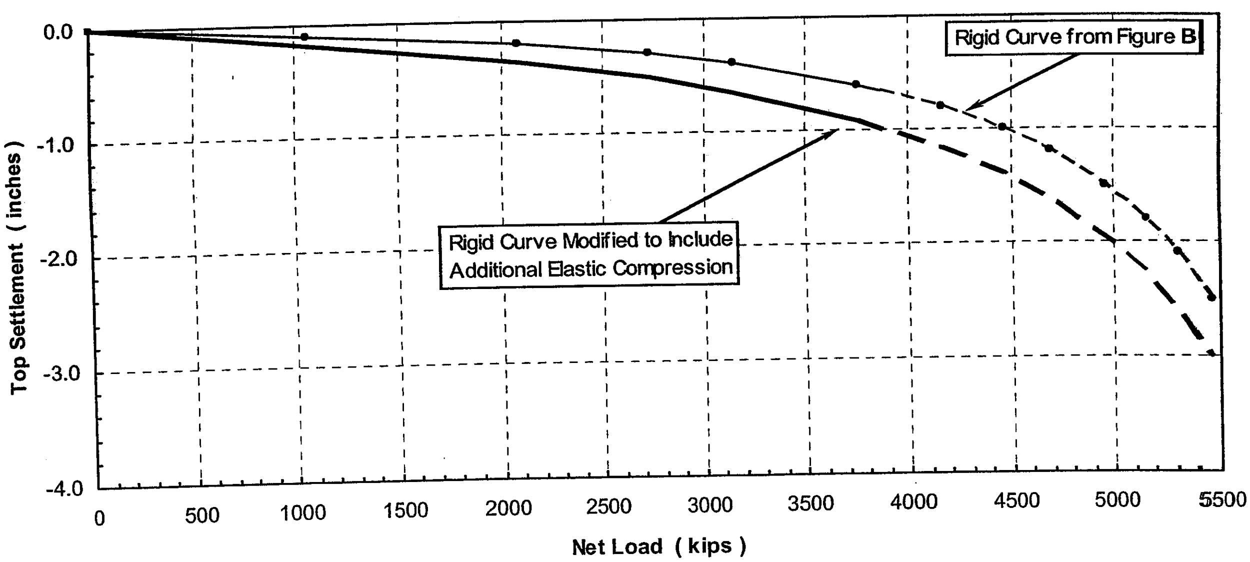
Example Calculation for the Additional Elastic Compression Correction For Single Level Test (English Units)

Given:

	C_1	=	0.441
	AE	=	3,820,000 kips (assumed constant throughout test)
	I_0	=	5.9 ft
	I_1	=	30.0 ft (embedded length of shaft above O-cell)
	I_2	=	0.00 ft
	I_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

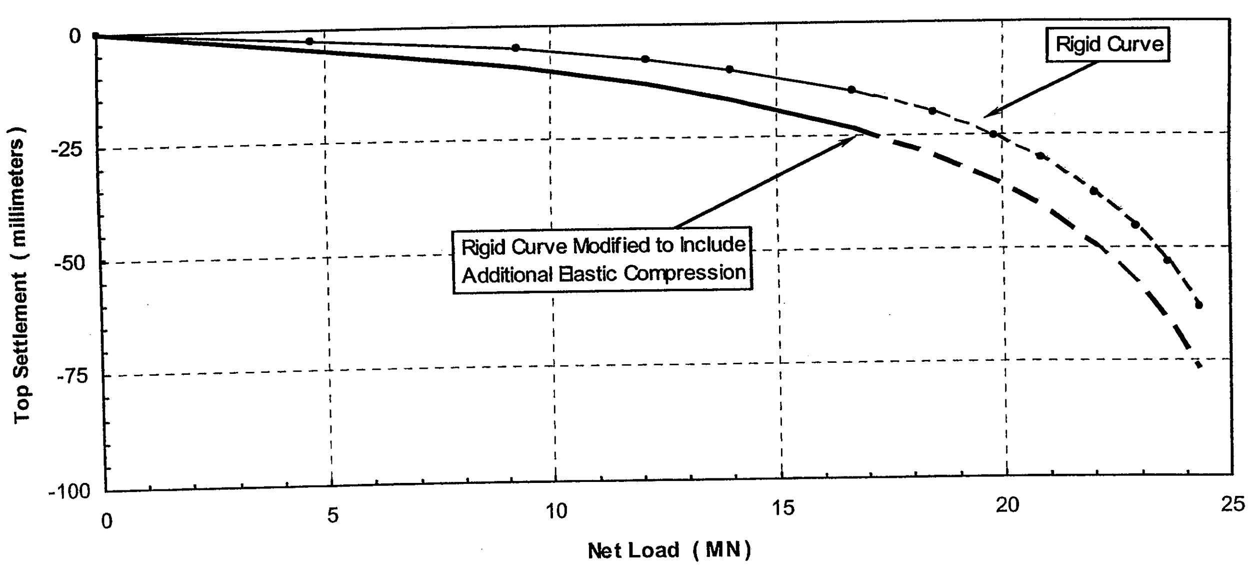


Example Calculation for the Additional Elastic Compression Correction For Single Level Test (SI Units)

Given:	C_1	=	0.441	
	AE	=	17,000	MN (assumed constant throughout test)
	I_0	=	1.80	m
	I_1	=	14.69	m (embedded length of shaft above mid-cell)
	I_2	=	0.00	m
	I_3	=	0.0	m
	Shear reduction factor	=	1.00	(cohesive soil)

Δ_{OLT} (mm)	$Q'_{\downarrow A}$ (MN)	$Q'_{\uparrow A}$ (mm)	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



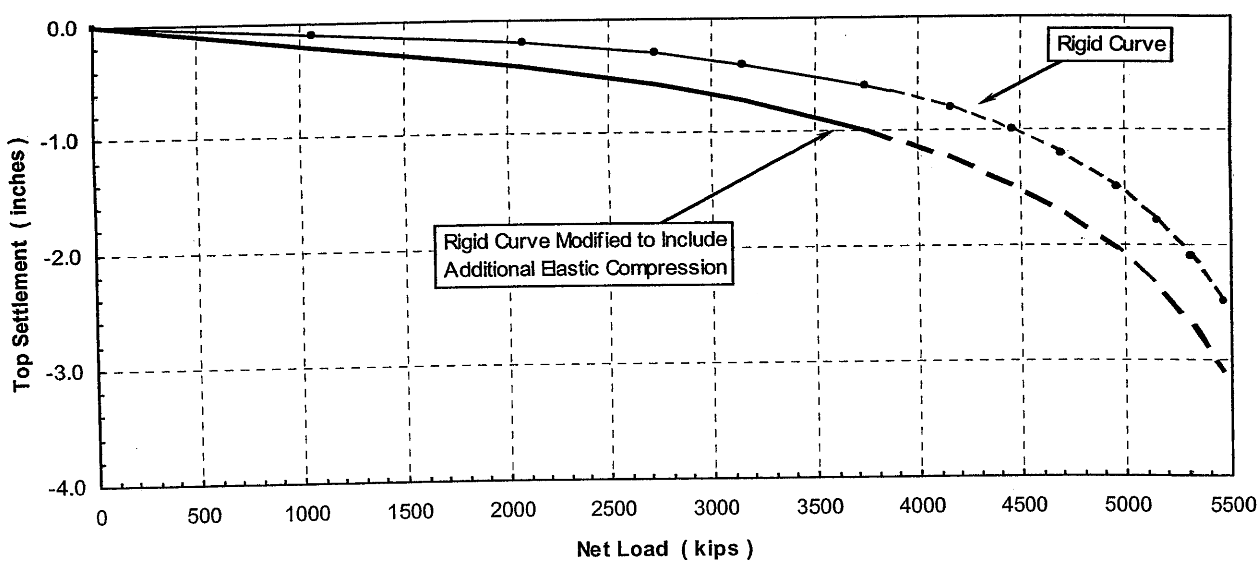
Example Calculation for the Additional Elastic Compression Correction For Multi Level Test (English Units)

Given:

C_1	=	0.441	
C_2	=	0.579	
C_3	=	0.396	
AE	=	3,820,000	kips (assumed constant throughout test)
I_0	=	5.9	ft
I_1	=	30.0	ft (embedded length of shaft above mid-cell)
I_2	=	18.2	ft (embedded length of shaft between O-cells)
I_3	=	0.0	ft
Shear reduction factor	=	1.00	(cohesive soil)

Δ_{OLT} (in)	$Q'_{\downarrow A}$ (kips)	$Q'_{\downarrow B}$ (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	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



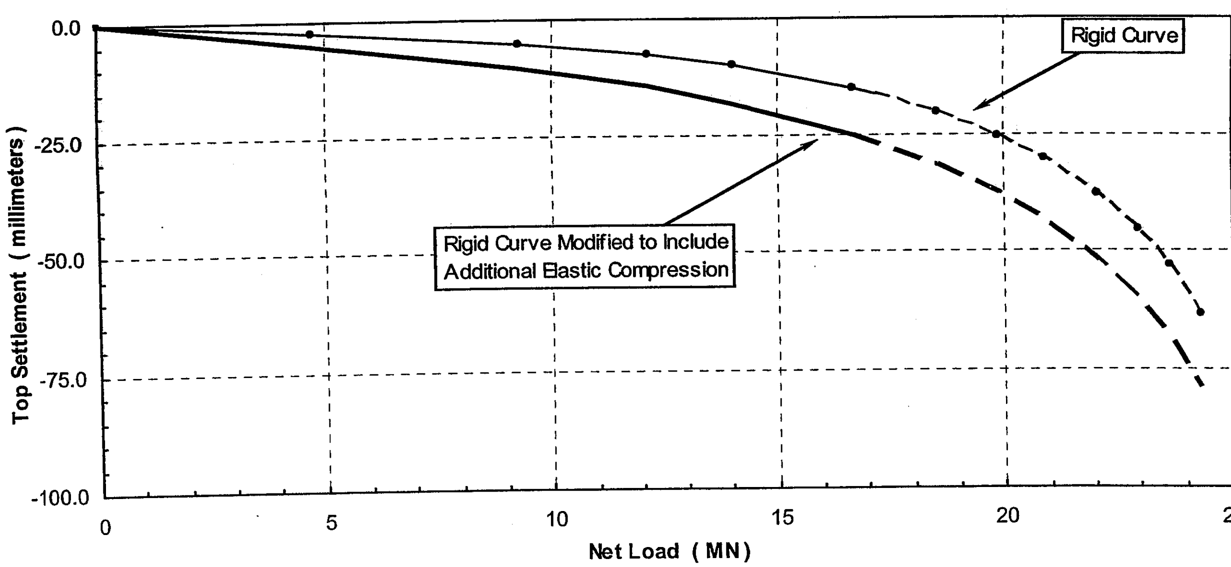
Example Calculation for the Additional Elastic Compression Correction For Multi Level Test (SI Units)

Given:

	C_1	=	0.441	
	C_2	=	0.579	
	C_3	=	0.396	
	AE	=	17,000	MN (assumed constant throughout test)
	I_0	=	1.80	m
	I_1	=	9.14	m (embedded length of shaft above mid-cell)
	I_2	=	5.55	m (embedded length of shaft between O-cells)
	I_3	=	0.00	m
Shear reduction factor		=	1.00	(cohesive soil)

Δ_{OLT} (mm)	$Q'_{\downarrow A}$ (MN)	$Q'_{\downarrow B}$ (MN)	$Q'_{\uparrow B}$ (mm)	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	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 LOADING

O-CELL METHOD FOR DETERMINING A CREEP LIMIT LOADING ON THE EQUIVALENT TOP-LOADED SHAFT (September, 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 4 to 8 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.

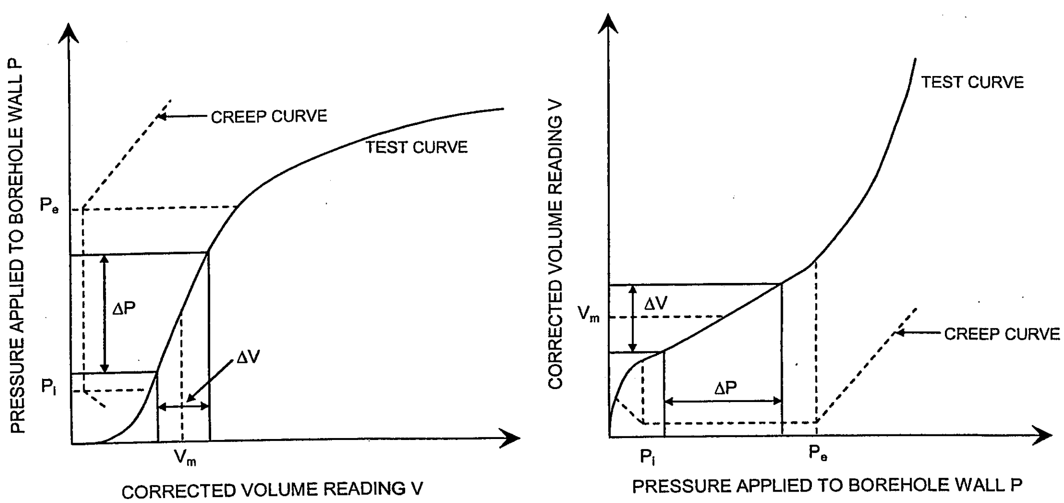


FIG. 8 Pressuremeter Test Curves for Procedure A

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

SOIL BORING LOGS

LOG OF BORING NO. N-1

CLIENT
PARSONS TRANSPORTATION GROUP

SITE NINTH STREET BRIDGE
DES MOINES, IOWA

PROJECT
I-235 GROUP BRIDGES

Approx. Boring Location: St. 20030+29, 20m rt

Approx. Surface Elev.: 280 m

GRAPHIC LOG / DESCRIPTION	DEPTH, m.	USCS SYMBOL	SAMPLES NUMBER	TYPE	RECOVERY, m.	SPT - N ** BLOWS / 0.3m.	TESTS WATER CONTENT, %	DRY UNIT WT kg/m3	UNCONFINED STRENGTH, kPa
FIRM CLAY FILL (USCS: FILL: LEAN TO FAT CLAY, TRACE SAND AND ORGANICS) Olive Brown, Moist				HS					
	1		1	BLO	0.46	10			
1.8 — 278.2				HS					
STIFF SILTY CLAY (USCS: LEAN CLAY, TRACE SAND) Light Olive Gray, Light Olive Brown and Yellowish Brown Moist	2		2	DC	0.36		25	1400	
				HS					
	3		3	BLO	0.46	6			
				HS					
	4		4	BLO	0.46	4			
				HS					
	5		5	DC			29	1450	
				HS					
	6		6	BLO	0.46	6			
				HS					
			7	SH			28	1540	
	7			WB					
			8	BLO	0.46	5			
	8			WB					
8.2 — 271.8									
FIRM GLACIAL CLAY (USCS: SANDY LEAN CLAY, TRACE GRAVEL) Dark Yellowish Brown Moist	9		9	BLO	0.46	10			
				WB					
	10								

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
**140 Lbs Automatic SPT Hammer

WATER LEVEL OBSERVATIONS, m		
WL	▽	▼
WL	▼	▽
WL	None to 7.3 m (WB)	

Terracon

BORING STARTED	7-26-00		
BORING COMPLETED	7-27-00		
RIG	84	FOREMAN	JG
APPROVED	TMW	JOB #	08005014

LOG OF BORING NO. N-1

CLIENT	
PARSONS TRANSPORTATION GROUP	
SITE: NINTH STREET BRIDGE, DES MOINES, IOWA	PROJECT: I-235 GROUP BRIDGES

GRAPHIC LOG	DESCRIPTION	DEPTH, m.	USCS SYMBOL	SAMPLES NUMBER	SAMPLES TYPE	SAMPLES RECOVERY, m.	SAMPLES SPT - N ** BLOWS / 0.3m.	TESTS WATER CONTENT, %	TESTS DRY UNIT WT kg/m3	TESTS UNCONFINED STRENGTH, kPa
	FIRM GLACIAL CLAY (USCS: SANDY LEAN CLAY, TRACE GRAVEL) Dark Yellowish Brown Moist			10	BLO	0.46	13			
		11			WB					
		12		11	BLO	0.46	13			
					WB					
	Cobbles at about 13 m	13		12	BLO	0.46	16			
	13.9 / 266.1									
	VERY FIRM SANDY GLACIAL CLAY (USCS: SANDY LEAN CLAY, TRACE GRAVEL) Dark Yellowish Brown Moist	14			WB					
		15		13	BLO	0.41	24			
					WB					
		16		14	BLO	0.41	24			
	17.1 / 262.9									
	VERY FIRM SANDY GLACIAL CLAY (USCS: SANDY LEAN CLAY, TRACE GRAVEL) Very Dark Gray Moist	17			WB					
		18		15	BLO	0.41	21			
					WB					
		19		16	BLO	0.46	24			
		20								

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
**140 Lbs Automatic SPT Hammer

WATER LEVEL OBSERVATIONS, m		
WL	∇	▼
WL	∇	∇
WL	None to 7.3 m (WB)	

Terracon

BORING STARTED	7-26-00		
BORING COMPLETED	7-27-00		
RIG	84	FOREMAN	JG
APPROVED	TMW	JOB #	08005014

LOG OF BORING NO. N-1

CLIENT
PARSONS TRANSPORTATION GROUP

SITE **NINTH STREET BRIDGE**
DES MOINES, IOWA

PROJECT
I-235 GROUP BRIDGES

GRAPHIC LOG	DESCRIPTION	DEPTH, m.	USCS SYMBOL	SAMPLES: NUMBER	SAMPLES: TYPE	SAMPLES: RECOVERY, m.	SAMPLES: SPT - N ** BLOWS / 0.3m.	TESTS: WATER CONTENT, %	TESTS: DRY UNIT WT kg/m3	TESTS: UNCONFINED STRENGTH, kPa
	Cobbles at about 20 m **VERY FIRM SANDY GLACIAL CLAY** (USCS: SANDY LEAN CLAY, TRACE GRAVEL) Very Dark Gray Moist				WB					
		21		17	BLO	0.46	18			
		22			WB					
				18	BLO	0.46	16			
		23			WB					
		24		19	BLO	0.41	37			
	Cobbles at about 24.5 m				WB					
		25								
26.1	253.9	26		20	BLO	0.46	18			
	BOTTOM OF BORING									

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

*Calibrated Hand Penetrometer
**140 Lbs Automatic SPT Hammer

WATER LEVEL OBSERVATIONS, m		
WL	∇	▼
WL	▼	∇
WL	None to 7.3 m (WB)	

Terracon

BORING STARTED	7-26-00
BORING COMPLETED	7-27-00
RIG 84	FOREMAN JG
APPROVED TMW	JOB # 08005014

BORE1 14 9TH NW.GPJ TERRACON.GDT 4/5/05

APPENDIX F

NET UNIT SHEAR CURVES

INCREMENTAL CURVES OF UNIT SIDE SHEAR VS. UPWARD SHAFT MOVEMENT

Engineers generally find that an estimate of unit side shear stress versus displacement is a useful deep foundation design parameter. Typically we will report these values for various shaft zones versus O-cell bearing plate displacement. In cases where significant movements occur and the ultimate capacity is approached, the displacement of each shear zone is very close to the measured O-cell plate movement. However, in cases with minimal movement, O-cell bearing plate displacement is primarily due to elastic compression of the shaft. In these cases, a more refined analysis is warranted to estimate the average displacement of each respective shear zone noting that the shear zone adjacent to the O-cell will displace more than subsequent zones. Plotting the unit shear values against the average shear zone displacement is more representative of the actual unit shear versus movement characteristics of the tested shaft.

The figure(s) in this Appendix provide information about the progressive mobilization of unit side shear stress as it developed during the upward shear movement between the shaft and the soil above the O-cell. Separate curves provide this information for the following shaft zones: Between the O-cell and the closest level of strain gages that provided usable data, between the levels of strain gages that provided usable data, and between the highest strain gage level with usable data and the level above which the side shear becomes negligible.

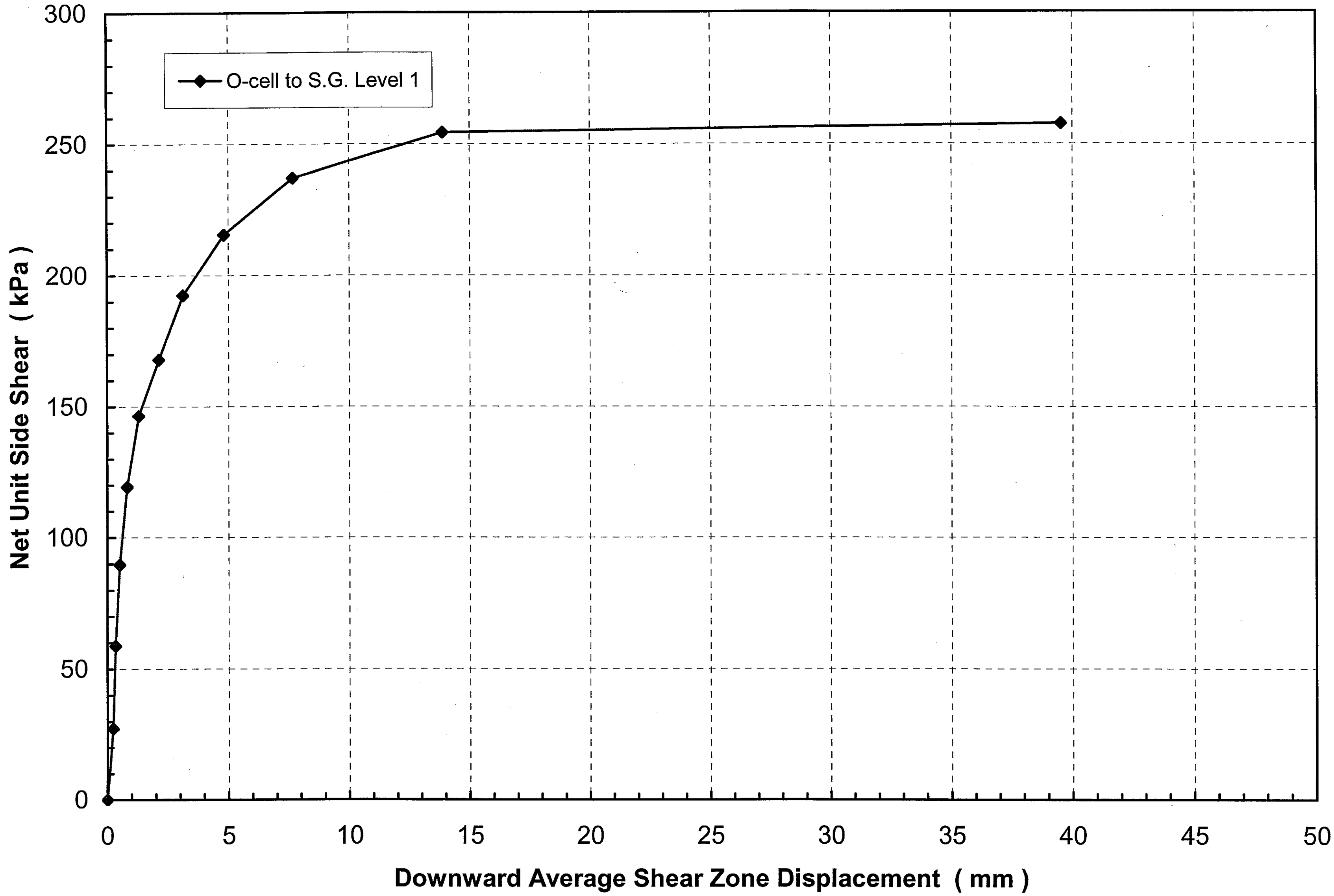
Our analysis assumes an average, constant unit side shear resistance along the above shaft zones, and that the movement represents the average for that zone.

The analysis uses the measured upward cell movement, the measured total elastic compression of the shaft, and with the computed elastic compression over each zone corrected to match the measured total. We also assume that the ground surface beside the shaft heaves only a negligible amount, and report the net unit side shears after correcting for the self weight of each respective shaft zone.

Based on tests and FE modeling, we suggest that the upward shear mobilization curves herein from the O-cell test also apply, approximately, to the downward movement shear mobilization from conventional top compression loading. We suggest a 0.95 shear correction factor for cohesionless soils. For top tension loading we suggest a 0.80 factor for all soils.

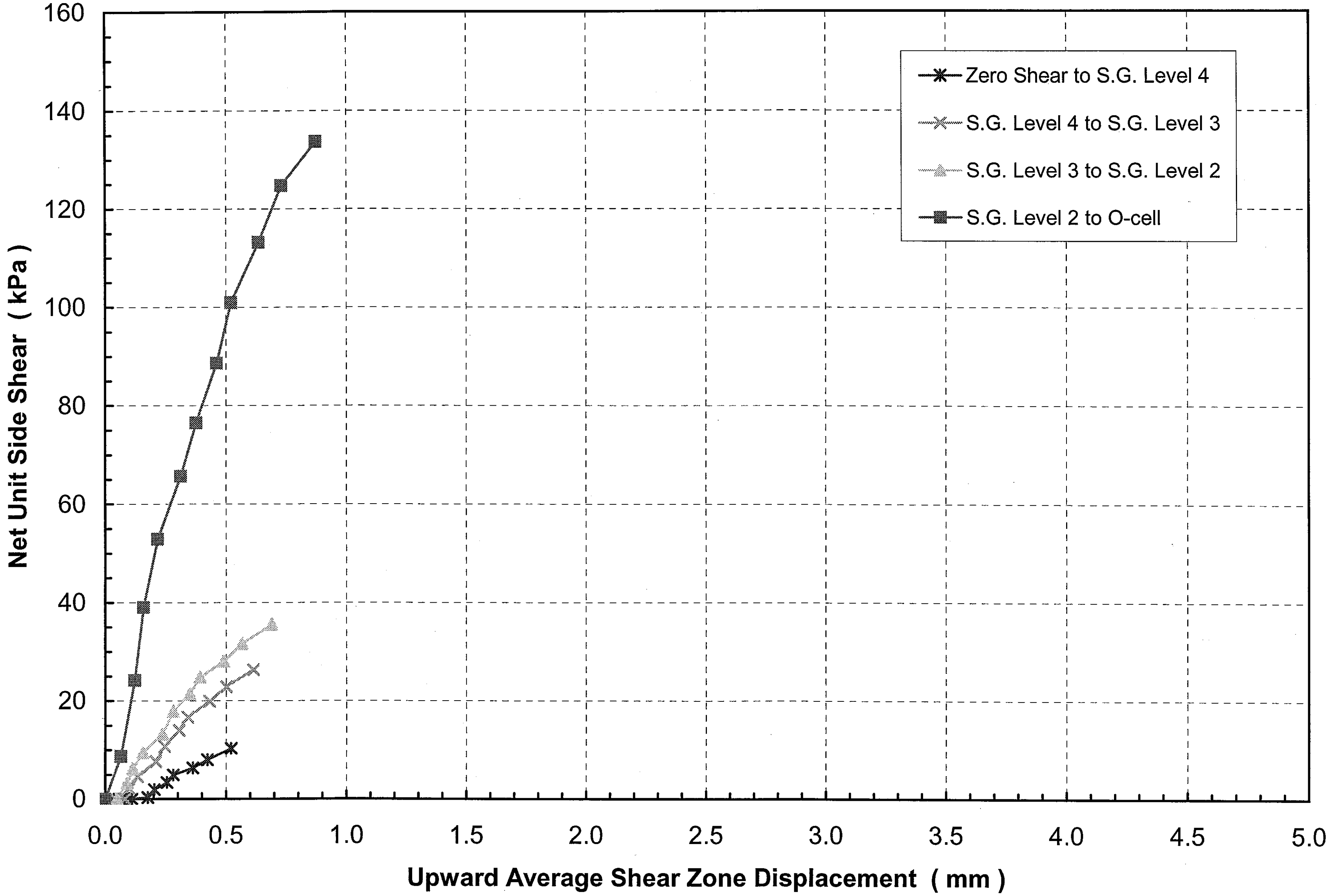
Net Unit Side Shear Curves

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa



Net Unit Side Shear Curves

Test Shaft 1 - Ninth Street Bridge - Des Moines, Iowa



LOADTEST, Inc. Project No. LT-9149

Appendix F