DATA REPORT ON DRILLED SHAFT LOAD TESTING (OSTERBERG METHOD)

Rt. 65 Missouri River Bridge - Waverly, MO

Prepared for: **Jensen Construction**
5550 NE 22nd Street
Des Moines, IA 50316

Attention: **Mr. Dan Timmons**
Fax: **515-266-5152**

PROJECT NUMBER: LT-8785, October 2, 2002

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LOADTEST INC.

DEEP FOUNDATION TESTING, EQUIPMENT & SERVICES • SPECIALIZING IN OSTERBERG CELL TECHNOLOGY

October 2, 2002

Jensen Construction
5550 NE 22nd Street
Des Moines, IA 50316

Attention: Dan Timmons

Data Report: Rt. 65 Missouri River Bridge - Waverly, MO
Location: Test Shaft at Pier 11

The enclosed report contains the data and analysis summary for the O-cell™ test performed on Test Shaft at Pier 11 (LTI project LT-8785) on September 30, 2002. 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 this information will meet your current project needs. If you have any questions, please do not hesitate to contact us at (800) 368-1138.

Best Regards,

D Tilson

for Robert Simpson
For LOADTEST, Inc.

EXECUTIVE SUMMARY

Loadtest Inc. tested a 78-inch (1,980-mm) production shaft over water on September 30, 2002. Shaft construction was completed by Jensen Construction on September 22, 2002. Robert Simpson and William Ryan of LOADTEST, Inc. carried out the test. Jensen Construction excavated the 79.5 feet (24.2 meters) long shaft (from mud line to tip), socketed in rock, under polymer slurry. Excavation began by employing an 84-inch (2,130-mm) O.D. permanent surface casing to stabilize the upper soils. A 48-inch (1,220-mm) pilot hole was excavated to tip. An auger was then used for drilling the shaft to the full nominal diameter. The shaft bottom was cleaned with a down hole pump. After base cleaning a mini-SID was used to determine base cleanliness. The installation of the reinforcing and O-cell™ assembly then proceeded and an attempt was made to deliver concrete into the base of the shaft through a tremie pipe. Some concreting problems occurred and the pour was cancelled. Concreting then recommenced and was completed the following day. The Missouri Department of Transportation observed construction of the shaft.

The maximum bi-directional load applied to the shaft was 5,050 kips (22.5 MN), corresponding to a total load of 10,100 kips (44.9 MN). At the maximum load, the displacements above and below the O-cell were 0.043 inches (1.10 mm) and 0.078 inches (1.99 mm), respectively. Average unit shear data calculated from strain gages in the rock socket included a calculated net unit side shear of 12.3 ksf (587 kPa), occurring between the Level 1 Strain Gages and the O-cell. Using this average side shear value, we calculate a corrected maximum applied end bearing pressure of 110 ksf (5,270 kPa)

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: Boring logs of conditions in the vicinity of the shaft and other detailed geologic information can be obtained from the Missouri Department of Transportation.

Shaft Instrumentation: Test shaft instrumentation and assembly was carried out under the direction of William Ryan of LOADTEST Inc. The test assembly included a single 26-inch (660-mm) O-cell™. The base of the O-cell™ assembly was located 5.58 feet (1.70 meters) above the tip of shaft. A pressure vs. load calibration of the O-cell™ was carried out to 3,050 kips (13.6 MN) by American Equipment and Fabricating Corporation prior to delivery to the test site (see Appendix B). Standard O-cell™ instrumentation included three LVWDTs (Linear Vibrating Wire Displacement Transducers - Geokon Model 4450 series) positioned between the lower and upper plates to measure O-cell™ expansion (Appendix A, Page 3). Two lengths of ½-inch (13 mm) steel pipe (180 degrees opposed) were attached to the test shaft assembly to measure compression of the shaft between the cell and the top of the shaft with traditional telltales that were installed later.

One level of two sister bar vibrating wire strain gages were installed in the shaft below the base of the O-cell™ assembly and three levels of two sister bar vibrating wire strain gages were installed in the shaft above the base of the O-cell™ assembly. Details concerning the strain gage placement appear in Table B and Figure A. The strain gages were used to assess the side shear load transfer of the shaft above the Osterberg cell. The strain gages were positioned as directed by the Missouri Department of Transportation.

The test shaft assembly also included two lines of steel pipe, starting at the top-of-shaft and terminating at the top of the bottom plate to vent the break in the shaft between upward and downward movement and the resulting annular void. If desired it permits the application of excess fluid pressure to reduce the possibility of soil entering the void.

Test Shaft Construction: Jensen Construction excavated the 79.5 feet (24.2 meters) long shaft (from mud line to tip), socketed in rock, under polymer slurry. Excavation began by employing an 84-inch (2,130-mm) O.D. permanent surface casing to stabilize the upper soils. A 48-inch (1,220-mm) pilot hole was excavated to tip. An auger was then used for drilling the shaft to the full nominal diameter. The shaft bottom was cleaned with a down hole pump. After base cleaning a mini-SID was used to determine base cleanliness. The installation of the reinforcing and O-cell™ assembly then proceeded and an attempt was made to deliver concrete into the base of the shaft through a tremie pipe. Some concreting problems occurred and the pour was cancelled. Concreting then recommenced and was completed the following day. Concrete was placed until the top of the concrete reached an elevation of +627.5 feet (+191.3 meters). The Missouri Department of Transportation observed construction of the shaft. Table B contains a summary of dimensions, elevations and shaft properties used in the data evaluations.

OSTERBERG CELL TESTING

Test Arrangement: Telltales were provided and inserted from the cell to the top of shaft in pre-installed steel pipe (see above). LVWDTs (Geokon) at the top of shaft were attached to the traditional telltales. Two LVWDTs attached to a reference beam were provided to measure the top of shaft movement. The reference beam consisted of a 30-foot (9.1-meter) wide flange beam. The beam was supported at each end by driven 84-inch (2,130-mm) casings. A surveying level was utilized in order to monitor the reference beam from shore to a precision of 0.001 feet (0.30 mm).

Both a Bourdon-type pressure gage (0-15,000 psi) 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 of the movement indicators, LVWDTs and strain gages were connected to a data logger (Data Electronics - Model 615 Datataker®). The logger, in turn was connected to a laptop computer. This arrangement allowed movement indicator, LVWDT, strain gage and thermistor readings to be recorded and stored automatically at 30 second intervals during the test. It also allowed the automatic importation of all test data into a laptop computer for real-time display and additional data back-up.

Note: Required calibrations are included in Appendix B.

Testing Procedures: We applied the load increments using the Quick Load Test Method (ASTM D1143), holding each successive load increment constant for four minutes by manually adjusting the O-cell™ pressure. We used approximately 5 seconds to move between increments. The data logger automatically recorded the instrument readings every 30 seconds, but herein we report only the one, two, three and four minute readings during each increment of maintained load. The various plotted results generally use the one, two, three and four minute readings, but the creep results use the difference between the two and four minute readings.

As with all our tests, we begin the load test by pressurizing the O-cell™ in order to break the tack welds that hold the cell closed (for handling and construction of 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 test. 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 2,400 psi (16.6 MPa).

The Osterberg cell load test was conducted as follows: The 26-inch (660-mm) diameter O-cell™, with its base located 5.58 feet (1.70 meters) above the tip of shaft was pressurized to assess the base resistance below the O-cell™ assembly and the side shear above the O-cell™ assembly. The O-cell™ was pressurized in 23 loading increments to 13,800 psi (95.2 MPa) resulting in a bi-directional load of 5,050 kips (22.5 MN). The loading was halted after load interval 1L-23 because the O-cell™ capacity had been exceeded by over 40%. The O-cell™ was then unloaded in 4 decrements and the test was concluded.

TEST RESULTS AND ANALYSES

General: The loads applied by the O-cell™ act in two opposing directions, resisted by side shear above the O-cell™ and by base resistance below the O-cell™. Gross, or applied O-cell™ load is defined as load applied above and below the O-cell™ as calculated from the cell's calibration. Net load is defined as the O-cell™ load minus the buoyant weight of the shaft above the cell for upward movements. Net load is used in this report when analyzing average net unit shear values above the cell and also when reconstructing an equivalent top load curve for top loaded compression shafts. For this test we calculated a buoyant weight of 231 kips (1.03 MN).

Measurement of the top of shaft movement depends on the stability of reference beam. The beam was monitored during the test. The movement for the center of the beam was random and small and likely due to the distance and resultant accuracy of the level. The data indicate that the beam movement was negligible.

Side Shear Resistance: The maximum upward net load applied to the side shear was 4,820 kips (21.4 MN) which occurred at load interval 1L-23 (Appendix A, Pages 3 and 4, Figure 1). At this loading, the total upward movement of the top of O-cell™ assembly was 0.043 inches (1.10 mm). The following net unit side shear estimates are based on the strain gage data which appear in Appendix A, Pages 5 and 6 and the shaft stiffnesses computed below.

At the time of testing, the concrete unconfined compressive strength was reported to be 7,520 psi (51.8 MPa). We used the ACI formula ($E_c=57000\sqrt{f'c}$) to calculate an elastic modulus for the concrete. This, combined with the area of reinforcing steel, was used to determine a weighted average shaft stiffness of 27,000,000 kips (120,300 MN) for the nominal shaft. This average was used when computing top-down compression and theoretical O-cell™ compression. A shaft stiffness of 24,900,000 kips (111,000 MN) was calculated for the shaft below the casing tip and was used for computing loads from the strain gages. Estimated net unit side shear values for the shaft based on the strain gage data, estimated shaft stiffness and shaft area are as follows:

Table A: Net Unit Side Shear Values (Based on Net Loads)

Load Transfer Zone	Direction* of Loading	Load Increment	Net Unit Side* Shear
Top of Shaft to Strain Gage Level 4	↑	1L-23	0.19 ksf (9 kPa)
Strain Gage Level 4 to Strain Gage Level 3	↑	1L-23	1.95 ksf (94 kPa)
Strain Gage Level 3 to Strain Gage Level 2	↑	1L-23	6.39 ksf (306 kPa)
Strain Gage Level 2 to O-cell™	↑	1L-23	12.3 ksf (587 kPa)

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

Note: Net unit shear values derived from the strain gages above the O-cell™ assembly may not be ultimate values. See Figure E-1 for net unit shear vs. displacement plots.

Side shear load distribution curves generated from strain gage data are shown in Figure 3. A unit side shear value for the shaft between the Level 1 Strain Gages and the O-cell™ was calculated for 1L-23 to obtain an estimate of the base shear component of resistance to the downward movement below the O-cell™. Note that Strain Gage Level 1 data was not included in this analysis. However, the data is presented in Appendix A. The strain gages at Level 1 functioned properly but recorded tension instead of compression. We have found that this often occurs in rock sockets where the gage location is less that one to two shaft diameters from the cell and the cell diameter is significantly smaller than the shaft diameter.

Base Resistance: The maximum O-cell™ load applied to the base of the shaft was 5,050 kips (22.5 MN) which occurred at load interval 1L-23 (Appendix A, Pages 3 and 4, Figure 1). At this loading, the total downward movement of the O-cell™ base was 0.078 inches (1.99 mm). The base resistance includes a component of base shear which must be subtracted to obtain unit end bearing values. The shear component of resistance for the 5.58 feet (1.70 meter) shaft base below the O-cell™ is calculated to be 1,400 kips (6.22 MN) assuming a unit side shear value of 12.3 ksf (587 kPa) and a shaft diameter of 78 inches (1,830 mm). The applied load to end bearing is then 3,650 kips (16.2 MN) and the end-bearing pressure applied at the tip of the shaft is calculated to be 110 ksf (5,270 kPa).

Creep Limit: See Appendix D for our O-cell™ method for determining creep limit. The side shear creep data (Appendix A, Pages 3 and 4) indicate that no creep limit was reached at a movement of 0.043 inches (1.10 mm) (Figure 4). The combined end bearing and lower side shear creep data (Appendix A, Pages 3 and 4) indicate that no creep limit was reached at a movement of 0.078 inches (1.99 mm) (Figure 5). A top loaded shaft will begin significant creep when 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 9,870 kips (43.9 MN) by some unknown amount.

Equivalent Top Load: Figure 2 presents the equivalent top load-settlement curve. The unadjusted 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. Because it can be an important component of the settlements involved, the equivalent top load curve includes an adjustment for the additional elastic compression which would occur in a top-load test. The darker curve as described in Procedure Part II of Appendix C includes such an adjustment.

The test shaft was successfully loaded to a combined side shear and end bearing of more than 9,870 kips (43.9 MN). For a top loading of 7,880 kips (35.0 MN), the adjusted test data indicate this shaft would settle approximately 0.21 inches (5.2 mm) of which 0.19 inches (4.7 mm) is estimated elastic compression. The equivalent top load curve is shown in Figure 2. Note: as explained previously, the equivalent top load curve applies to a loading duration of four minutes. Creep effects will reduce the ultimate resistance of both components and increase pile 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 above.

Shaft Compression Comparison: The measured maximum shaft compression, averaged from 2 telltales, is 0.021 inches (0.52 mm). Using the shaft nominal diameters (Table B and Figure A) and a weighted average shaft stiffness of 27,000,000 kips (120,300 MN) for the shaft and the load distribution in Figure 3, we calculated an elastic compression of 0.023 inches (0.53 mm) over the length of the compression telltales. We believe this excellent agreement provides good evidence that the assumed shaft stiffnesses are reasonable and that the O-cell™ loaded the shaft in accord with the calibration used herein.

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

for. Robert Simpson
For LOADTEST Inc.

Reviewed by

J. A. Hayes, P. Eng., D.I.C.
President, LOADTEST Inc.

TABLE B: SUMMARY OF DIMENSIONS, ELEVATIONS, AREAS & PROPERTIES FOR ANALYSIS PURPOSES

Shaft:			
Nominal shaft diameter: EL 637.5 ft to 607.6 ft	=	84 inches	2134 mm
Nominal shaft diameter: EL 607.58 ft to 558 ft	=	78 inches	1981 mm
O-cell size: (Serial nos.: 1004-18A)	=	26 inches	660 mm
Length of concrete from break at base of cell to tip	=	5.6 feet	1.7 meters
Shaft shear area from break at base of cell to tip	=	113.9 $feet^2$	10.59 $meters^2$
Shaft end area	=	33.2 $feet^2$	3.08 $meters^2$
Weight of shaft from break at base of cell to top of shaft	=	230.6 kips	1.03 MN
Shaft unit stiffness: EL 637.5 ft to 607.6 ft	=	3.18E+07 kips	141.5 GN
Shaft unit stiffness: EL 607.58 ft to 558 ft	=	2.49E+07 kips	110.7 GN
Elevation of top of shaft concrete	=	+627.5 feet	+191.3 meters
Elevation of ground surface (mud line)	=	+637.5 feet	+194.3 meters
Elevation of break at base of O-cell™	=	+563.6 feet	+171.8 meters
Elevation of shaft tip	=	+558.0 feet	+170.1 meters
Casings:			
Elevation of top of permanent casing: 84 inches O.D. *	=	+665.5 feet	+202.8 meters
Elevation of bottom of permanent casing: 84 inches O.D.	=	+607.6 feet	+185.2 meters
Compression Sections:			
Elevation of top of telltale used for shaft compression	=	+629.5 feet	+191.9 meters
Elevation of bottom of telltale used for shaft compression	=	+565.0 feet	+172.2 meters
Strain Gages:			
Elevation of strain gage Level 4	=	+599.6 feet	+182.8 meters
Elevation of strain gage Level 3	=	+584.6 feet	+178.2 meters
Elevation of strain gage Level 2	=	+574.6 feet	+175.1 meters
Elevation of strain gage Level 1	=	+560.6 feet	+170.9 meters
Miscellaneous:			
Top plate diameter	=	60.5 inches	1537 mm
Top plate thickness	=	2.0 inches	50.8 mm
Bottom plate diameter	=	60.5 inches	1537 mm
Bottom plate thickness	=	2.0 inches	50.8 mm
Water elevation	=	+657.5 feet	+200.4 meters
LVWDT radii - no: 22017	=	30.3 inches	768 mm
LVWDT orientation - no.: 22017	=	0 degrees	
LVWDT radii - no: 22018	=	30.3 inches	768 mm
LVWDT orientation - no.: 22018	=	180 degrees	
LVWDT radii - no: 22019	=	30.3 inches	768 mm
LVWDT orientation - no.: 22019	=	90 degrees	
Vertical re-bar size	=	# 14	
Hoop re-bar size	=	# 5	
Number of vertical bars	=	22	

* 6 feet of casing added prior to test.

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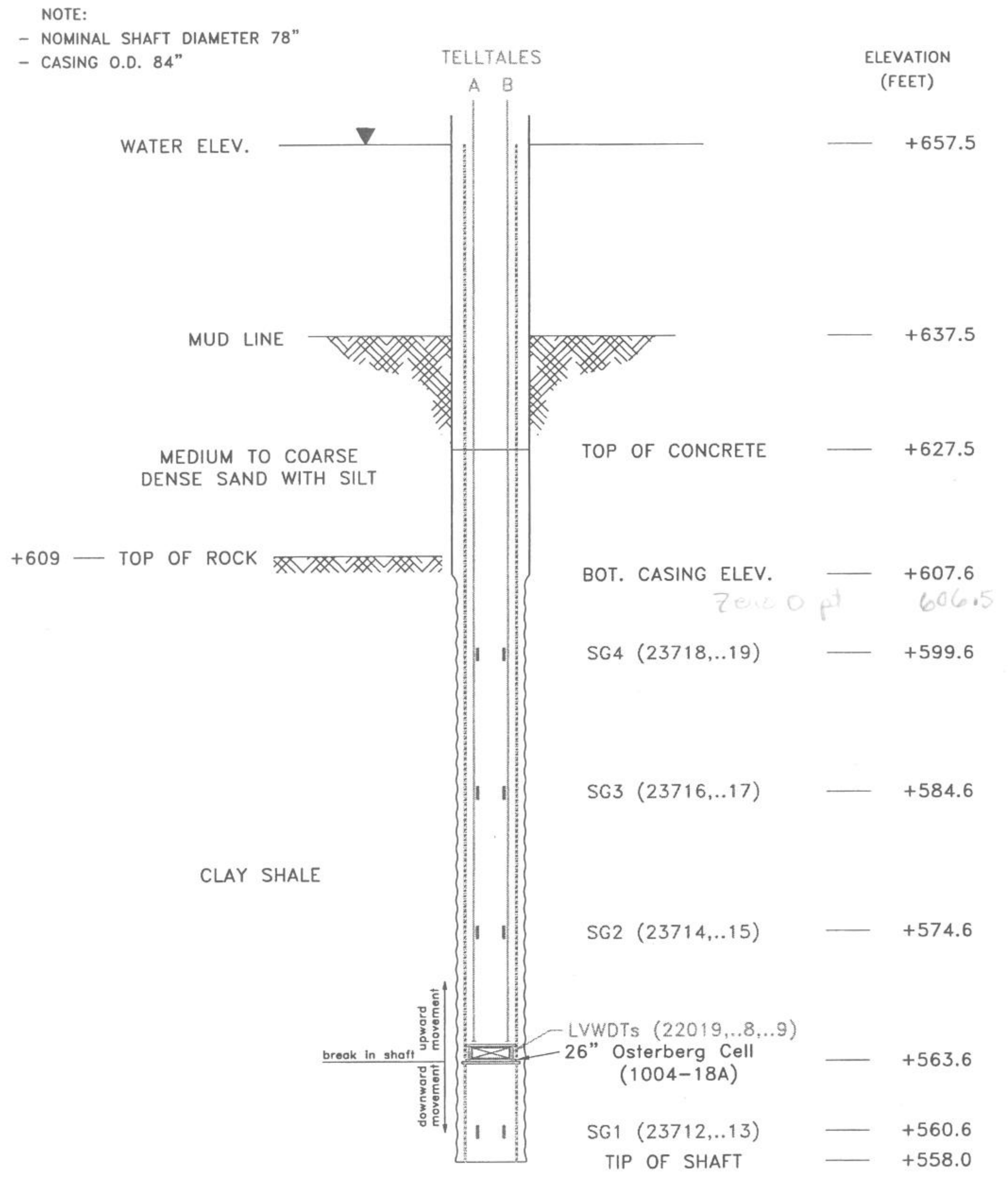

LOADTEST INC

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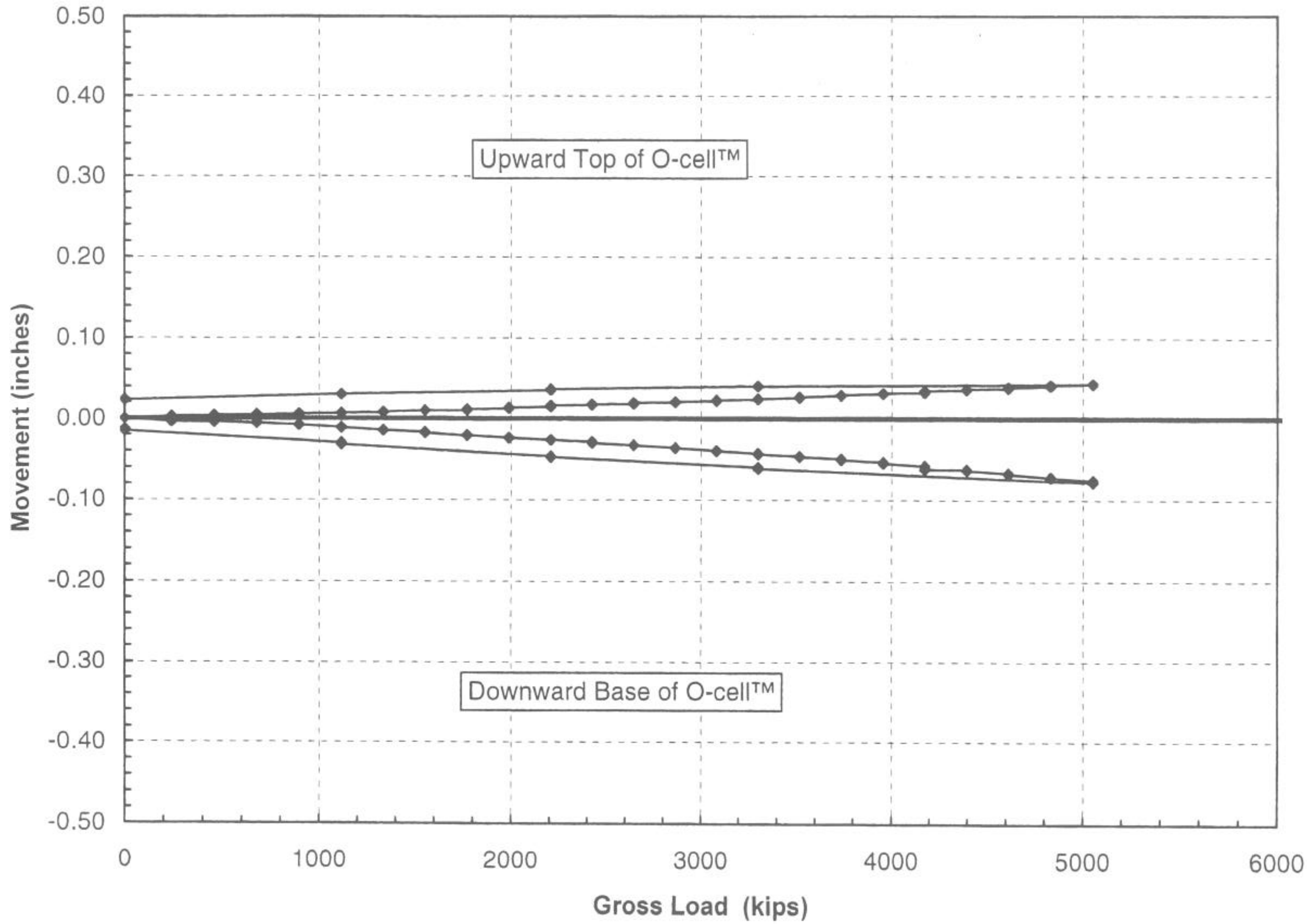
SCHEMATIC SECTION OF TEST SHAFT

LT-8785 Route 65
Missouri River Bridge
Waverly, MO

FIGURE A

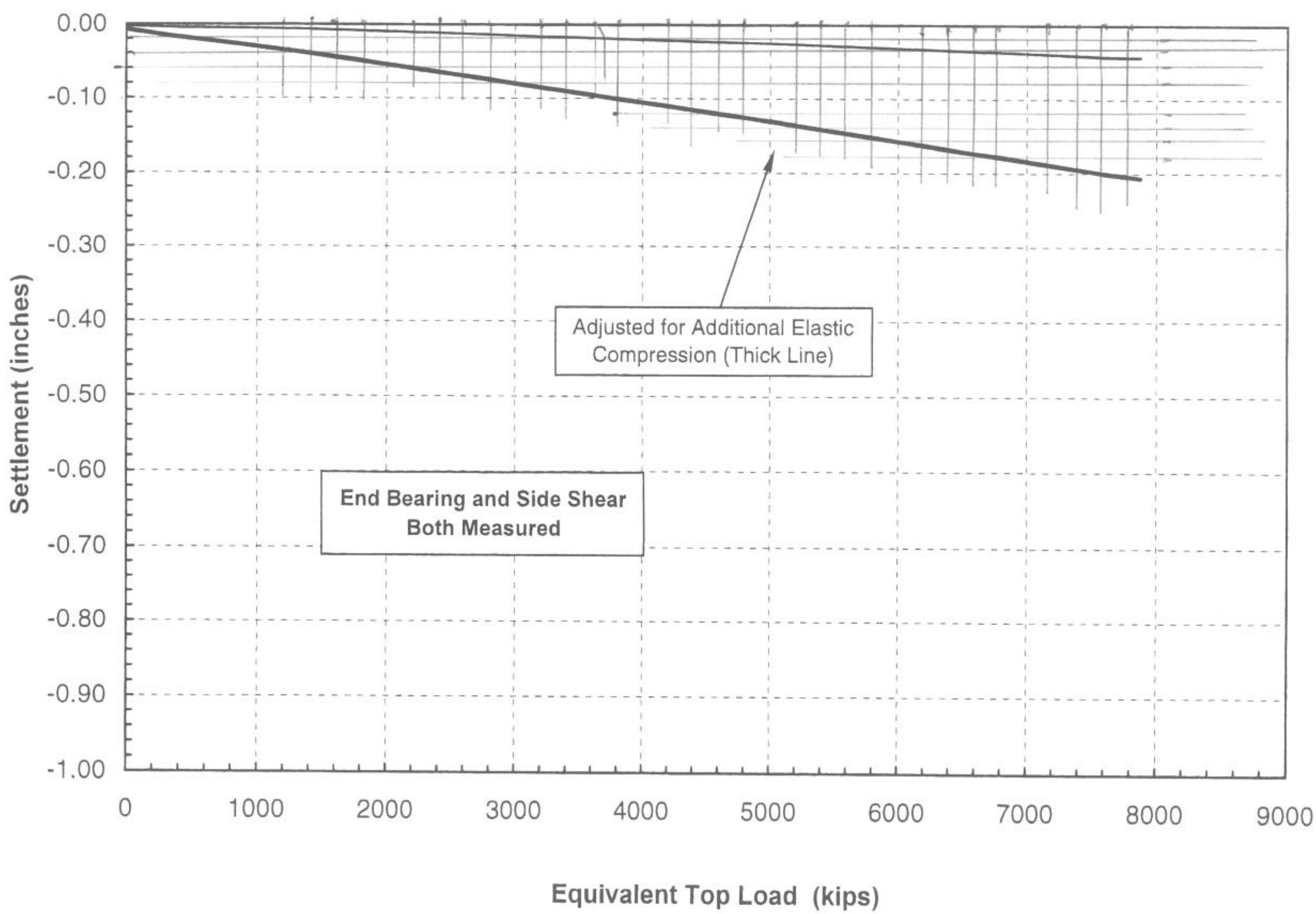
Osterberg Cell Load-Movement Curves

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11



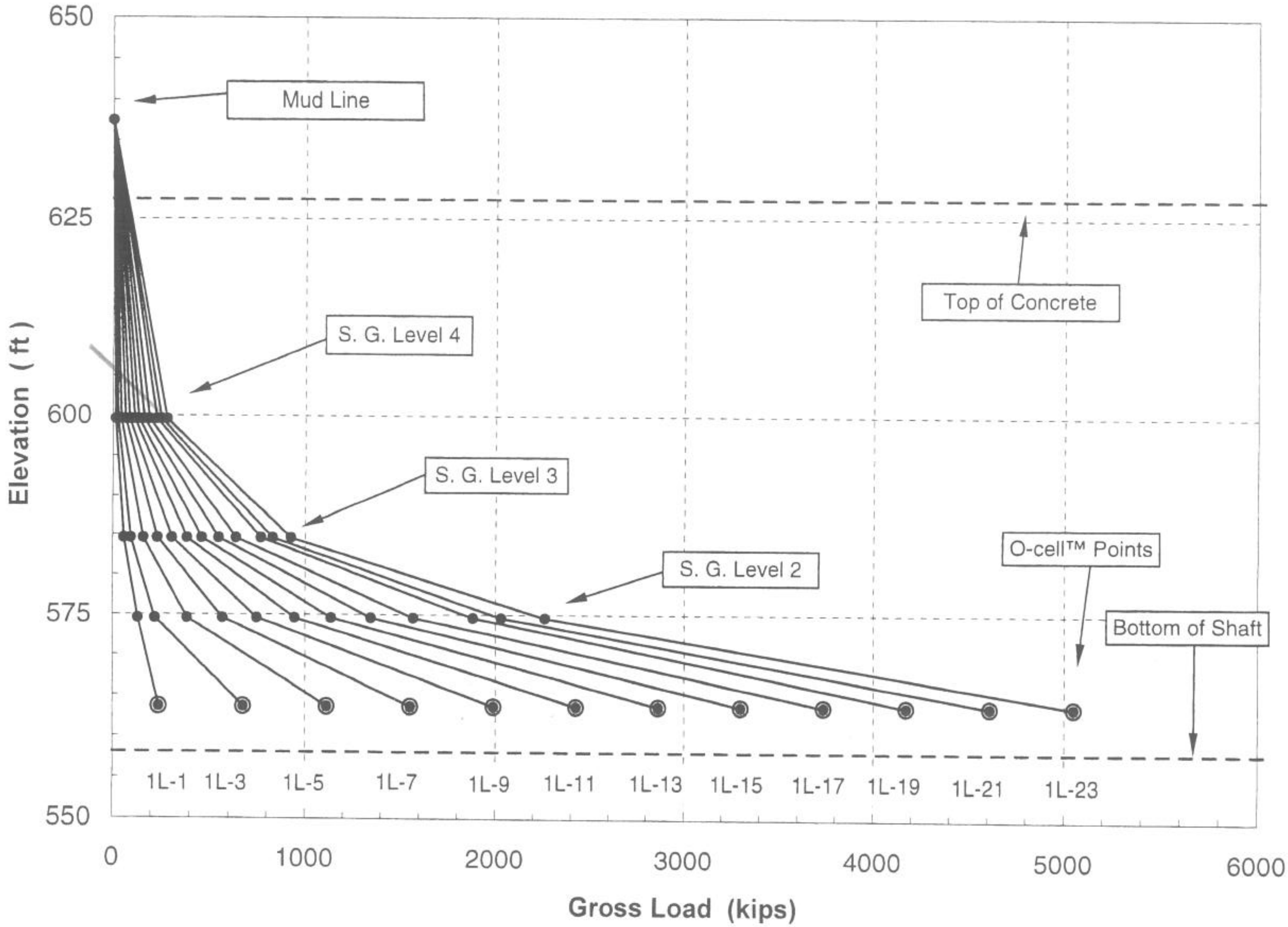
Equivalent Top Load-Movement Curves

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11



Strain Gage Load Distribution Curves

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

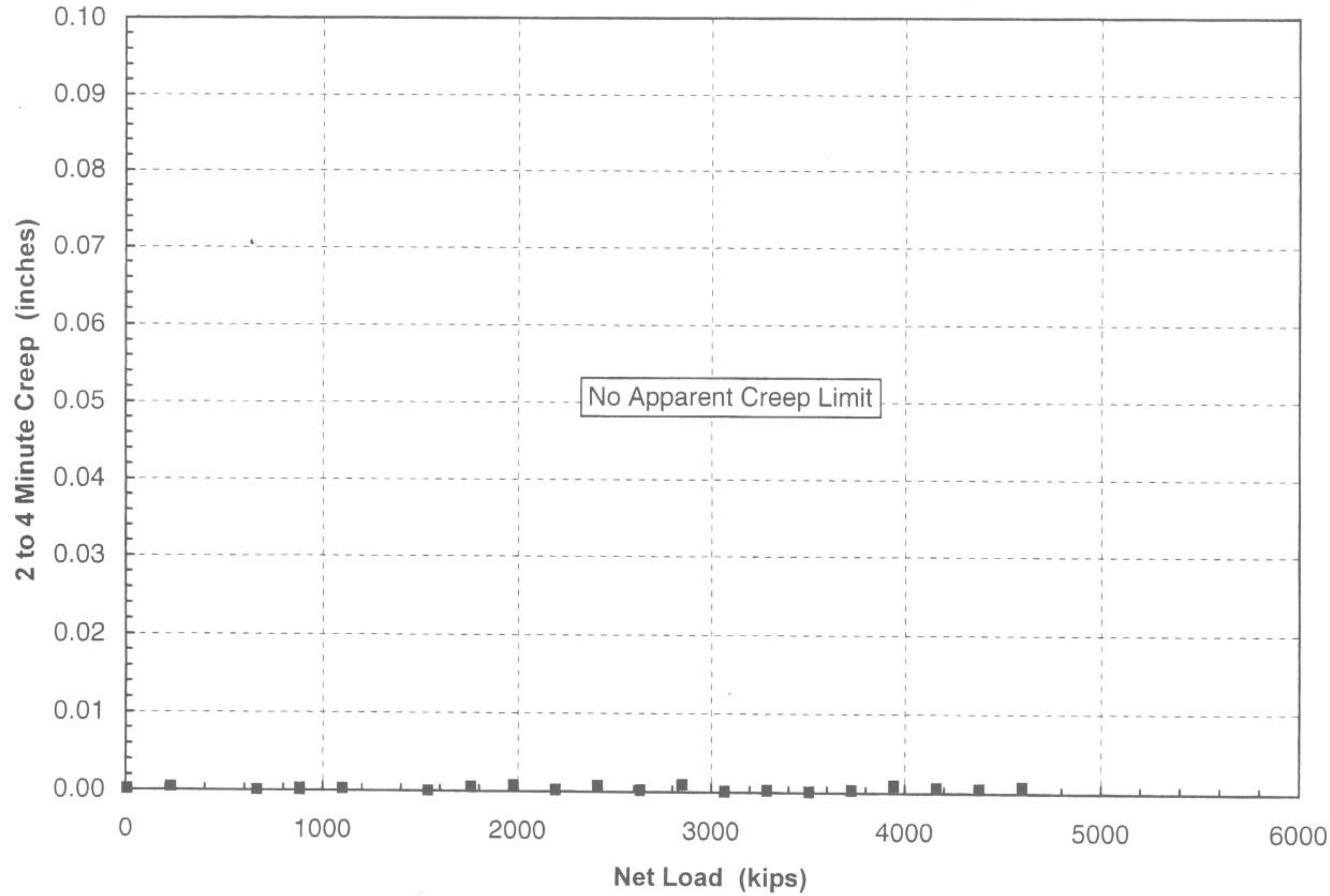


LOADTEST, Inc. Project No. LT-8785

Figure 3 of 5

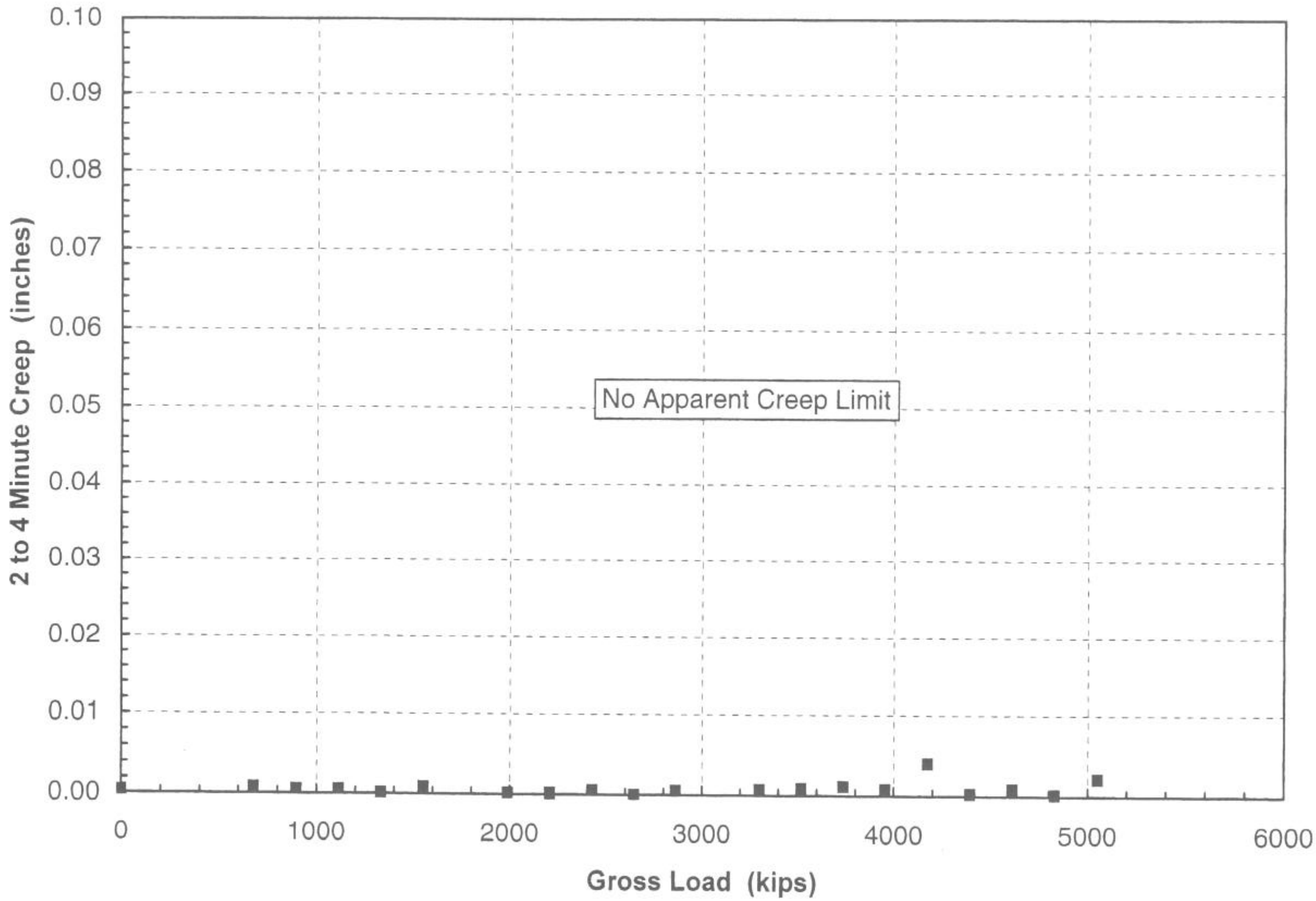
Side Shear Creep Limit

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11



Base Creep Limit

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11



APPENDIX A

FIELD DATA & DATA REDUCTION

Top of Shaft and Compression

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

Load Test Increment	Time (h:m:s)	Time After Start Minutes	O-cell™ Pressure (psi)	Applied Load (kips)	Net Load (kips)	TOS Indicator Readings Side A (inches)	TOS Indicator Readings Side B (inches)	TOS Indicator Readings Average (inches)	Telltale Compression Side A (inches)	Telltale Compression Side B (inches)	Telltale Compression Average (inches)
1L -0	12:14:00	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000
1L -1	12:32:00	1	600	239	9	0.003	0.001	0.002	0.001	0.001	0.001
1L -1	12:33:00	2	600	239	9	0.002	0.001	0.001	0.001	0.001	0.001
1L -1	12:34:00	3	600	239	9	0.002	0.000	0.001	0.001	0.001	0.001
1L -1	12:35:00	4	600	239	9	0.002	0.000	0.001	0.001	0.001	0.001
1L -2	12:36:00	1	1,200	458	227	0.002	0.001	0.002	0.002	0.001	0.001
1L -2	12:37:00	2	1,200	458	227	0.003	0.001	0.002	0.002	0.001	0.002
1L -2	12:38:00	3	1,200	458	227	0.003	0.001	0.002	0.002	0.002	0.002
1L -2	12:39:00	4	1,200	458	227	0.003	0.002	0.002	0.002	0.001	0.002
1L -3	12:40:00	1	1,800	677	446	0.004	0.002	0.003	0.002	0.002	0.002
1L -3	12:41:00	2	1,800	677	446	0.005	0.002	0.003	0.002	0.001	0.002
1L -3	12:42:00	3	1,800	677	446	0.005	0.001	0.003	0.002	0.002	0.002
1L -3	12:43:00	4	1,800	677	446	0.004	0.002	0.003	0.002	0.002	0.002
1L -4	12:44:00	1	2,400	895	665	0.005	0.002	0.003	0.002	0.002	0.002
1L -4	12:45:00	2	2,400	895	665	0.005	0.002	0.003	0.002	0.002	0.002
1L -4	12:46:00	3	2,400	895	665	0.005	0.002	0.004	0.002	0.002	0.002
1L -4	12:47:00	4	2,400	895	665	0.004	0.002	0.003	0.002	0.002	0.002
1L -5	12:48:00	1	3,000	1,114	883	0.005	0.003	0.004	0.003	0.003	0.003
1L -5	12:49:00	2	3,000	1,114	883	0.005	0.003	0.004	0.003	0.002	0.003
1L -5	12:50:00	3	3,000	1,114	883	0.005	0.003	0.004	0.003	0.003	0.003
1L -5	12:51:00	4	3,000	1,114	883	0.005	0.003	0.004	0.003	0.002	0.003
1L -6	12:52:00	1	3,600	1,333	1,102	0.005	0.003	0.004	0.004	0.003	0.003
1L -6	12:53:00	2	3,600	1,333	1,102	0.005	0.004	0.004	0.004	0.003	0.004
1L -6	12:54:00	3	3,600	1,333	1,102	0.005	0.004	0.004	0.004	0.003	0.004
1L -6	12:55:00	4	3,600	1,333	1,102	0.005	0.004	0.005	0.004	0.003	0.004
1L -7	12:56:00	1	4,200	1,551	1,321	0.006	0.004	0.005	0.005	0.004	0.004
1L -7	12:57:00	2	4,200	1,551	1,321	0.007	0.004	0.006	0.005	0.004	0.005
1L -7	12:58:00	3	4,200	1,551	1,321	0.007	0.004	0.006	0.005	0.004	0.005
1L -7	12:59:00	4	4,200	1,551	1,321	0.006	0.005	0.005	0.005	0.004	0.005
1L -8	13:00:00	1	4,800	1,770	1,539	0.005	0.005	0.005	0.006	0.004	0.005
1L -8	13:01:00	2	4,800	1,770	1,539	0.007	0.005	0.006	0.006	0.005	0.005
1L -8	13:02:00	3	4,800	1,770	1,539	0.008	0.005	0.006	0.006	0.005	0.005
1L -8	13:02:00	3	4,800	1,770	1,539	0.008	0.005	0.006	0.006	0.005	0.005
1L -9	13:03:00	1	5,400	1,988	1,758	0.008	0.005	0.007	0.007	0.005	0.006
1L -9	13:04:00	2	5,400	1,988	1,758	0.008	0.006	0.007	0.007	0.006	0.006
1L -9	13:05:00	3	5,400	1,988	1,758	0.008	0.006	0.007	0.007	0.006	0.006
1L -9	13:06:00	4	5,400	1,988	1,758	0.008	0.006	0.007	0.007	0.006	0.006
1L -10	13:07:00	1	6,000	2,207	1,976	0.008	0.007	0.008	0.008	0.006	0.007
1L -10	13:08:00	2	6,000	2,207	1,976	0.009	0.007	0.008	0.008	0.007	0.007
1L -10	13:09:00	3	6,000	2,207	1,976	0.009	0.007	0.008	0.009	0.007	0.008
1L -10	13:10:00	4	6,000	2,207	1,976	0.010	0.007	0.008	0.009	0.007	0.008
1L -11	13:11:00	1	6,600	2,426	2,195	0.010	0.007	0.009	0.009	0.008	0.008
1L -11	13:12:00	2	6,600	2,426	2,195	0.010	0.007	0.009	0.009	0.008	0.008
1L -11	13:13:00	3	6,600	2,426	2,195	0.011	0.007	0.009	0.010	0.008	0.009
1L -11	13:14:00	4	6,600	2,426	2,195	0.010	0.007	0.009	0.009	0.008	0.009
1L -12	13:15:00	1	7,200	2,644	2,414	0.011	0.008	0.009	0.010	0.008	0.009
1L -12	13:16:00	2	7,200	2,644	2,414	0.011	0.008	0.009	0.010	0.009	0.009
1L -12	13:17:00	3	7,200	2,644	2,414	0.011	0.009	0.010	0.011	0.009	0.010
1L -12	13:18:00	4	7,200	2,644	2,414	0.011	0.009	0.010	0.010	0.009	0.010
1L -13	13:19:00	1	7,800	2,863	2,632	0.012	0.009	0.010	0.011	0.010	0.010
1L -13	13:20:00	2	7,800	2,863	2,632	0.012	0.009	0.010	0.011	0.010	0.010
1L -13	13:21:00	3	7,800	2,863	2,632	0.012	0.009	0.010	0.011	0.010	0.010
1L -13	13:22:00	4	7,800	2,863	2,632	0.012	0.009	0.011	0.011	0.010	0.010
1L -14	13:23:00	1	8,400	3,082	2,851	0.012	0.009	0.011	0.012	0.011	0.011
1L -14	13:24:00	2	8,400	3,082	2,851	0.012	0.009	0.010	0.012	0.011	0.012
1L -14	13:25:00	3	8,400	3,082	2,851	0.013	0.010	0.012	0.012	0.011	0.012
1L -14	13:26:00	4	8,400	3,082	2,851	0.013	0.010	0.011	0.012	0.011	0.012
1L -15	13:27:00	1	9,000	3,300	3,070	0.013	0.011	0.012	0.013	0.012	0.012
1L -15	13:28:00	2	9,000	3,300	3,070	0.013	0.011	0.012	0.013	0.012	0.013
1L -15	13:29:00	3	9,000	3,300	3,070	0.013	0.011	0.012	0.013	0.012	0.013
1L -15	13:30:00	4	9,000	3,300	3,070	0.014	0.011	0.012	0.013	0.012	0.013
1L -16	13:31:00	1	9,600	3,519	3,288	0.014	0.011	0.013	0.014	0.014	0.014
1L -16	13:32:00	2	9,600	3,519	3,288	0.015	0.011	0.013	0.014	0.014	0.014
1L -16	13:33:00	3	9,600	3,519	3,288	0.015	0.012	0.013	0.014	0.014	0.014
1L -16	13:34:00	4	9,600	3,519	3,288	0.015	0.011	0.013	0.014	0.014	0.014
1L -17	13:35:00	1	10,200	3,738	3,507	0.016	0.013	0.014	0.015	0.015	0.015
1L -17	13:36:00	2	10,200	3,738	3,507	0.016	0.013	0.015	0.015	0.015	0.015
1L -17	13:37:00	3	10,200	3,738	3,507	0.016	0.013	0.014	0.015	0.015	0.015
1L -17	13:38:00	4	10,200	3,738	3,507	0.016	0.013	0.014	0.015	0.015	0.015
1L -18	13:39:00	1	10,800	3,956	3,726	0.017	0.014	0.015	0.016	0.016	0.016
1L -18	13:40:00	2	10,800	3,956	3,726	0.017	0.014	0.016	0.016	0.016	0.016
1L -18	13:41:00	3	10,800	3,956	3,726	0.017	0.014	0.015	0.016	0.017	0.016
1L -18	13:42:00	4	10,800	3,956	3,726	0.017	0.014	0.016	0.016	0.017	0.016

Top of Shaft and Compression

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

Load Test Increment	Time (h:m:s)	Time After Start Minutes	O-cell™ Pressure (psi)	Applied Load (kips)	Net Load (kips)	TOS Indicator Readings Side A (inches)	TOS Indicator Readings Side B (inches)	TOS Indicator Readings Average (inches)	Telltale Compression Side A (inches)	Telltale Compression Side B (inches)	Telltale Compression Average (inches)
1L -19	13:43:00	1	11,400	4,175	3,944	0.017	0.015	0.016	0.017	0.017	0.017
1L -19	13:44:00	2	11,400	4,175	3,944	0.018	0.016	0.017	0.017	0.017	0.017
1L -19	13:45:00	3	11,400	4,175	3,944	0.019	0.016	0.017	0.017	0.017	0.017
1L -19	13:46:00	4	11,400	4,175	3,944	0.019	0.016	0.017	0.018	0.018	0.018
1L -20	13:47:00	1	12,000	4,394	4,163	0.020	0.016	0.018	0.018	0.018	0.018
1L -20	13:48:00	2	12,000	4,394	4,163	0.021	0.016	0.019	0.018	0.018	0.018
1L -20	13:49:00	3	12,000	4,394	4,163	0.021	0.016	0.019	0.018	0.019	0.018
1L -20	13:50:00	4	12,000	4,394	4,163	0.021	0.017	0.019	0.018	0.018	0.018
1L -21	13:51:00	1	12,600	4,612	4,382	0.022	0.016	0.019	0.019	0.019	0.019
1L -21	13:52:00	2	12,600	4,612	4,382	0.024	0.016	0.020	0.019	0.019	0.019
1L -21	13:53:00	3	12,600	4,612	4,382	0.023	0.018	0.020	0.018	0.019	0.019
1L -21	13:54:00	4	12,600	4,612	4,382	0.023	0.018	0.021	0.018	0.019	0.019
1L -22	13:57:00	1	13,200	4,831	4,600	0.024	0.018	0.021	0.019	0.020	0.020
1L -22	13:58:00	2	13,200	4,831	4,600	0.024	0.019	0.022	0.019	0.020	0.020
1L -22	13:59:00	3	13,200	4,831	4,600	0.025	0.019	0.022	0.019	0.020	0.020
1L -22	14:00:00	4	13,200	4,831	4,600	0.025	0.020	0.022	0.019	0.021	0.020
1L -23	14:01:00	1	13,800	5,049	4,819	0.025	0.020	0.023	0.020	0.021	0.021
1L -23	14:02:00	2	13,800	5,049	4,819	0.026	0.020	0.023	0.020	0.022	0.021
1L -23	14:03:00	3	13,800	5,049	4,819	0.025	0.021	0.023	0.020	0.022	0.021
1L -23	14:04:00	4	13,800	5,049	4,819	0.024	0.021	0.023	0.020	0.022	0.021
1U-1	14:06:00	1	9,000	3,300	3,070	0.024	0.019	0.021	0.018	0.021	0.019
1U-1	14:07:00	2	9,000	3,300	3,070	0.024	0.019	0.021	0.018	0.021	0.019
1U-1	14:08:00	3	9,000	3,300	3,070	0.024	0.019	0.022	0.018	0.021	0.019
1U-1	14:09:00	4	9,000	3,300	3,070	0.024	0.019	0.022	0.018	0.021	0.019
1U-2	14:10:00	1	6,000	2,207	1,976	0.022	0.018	0.020	0.016	0.018	0.017
1U-2	14:11:00	2	6,000	2,207	1,976	0.021	0.017	0.019	0.016	0.017	0.017
1U-2	14:12:00	3	6,000	2,207	1,976	0.022	0.016	0.019	0.016	0.017	0.017
1U-2	14:13:00	4	6,000	2,207	1,976	0.021	0.017	0.019	0.016	0.017	0.017
1U-3	14:14:00	1	3,000	1,114	883	0.019	0.015	0.017	0.013	0.014	0.014
1U-3	14:15:00	2	3,000	1,114	883	0.018	0.015	0.017	0.013	0.013	0.013
1U-3	14:16:00	3	3,000	1,114	883	0.019	0.015	0.017	0.013	0.014	0.013
1U-3	14:17:00	4	3,000	1,114	883	0.019	0.015	0.017	0.013	0.014	0.013
1U-4	14:19:00	1	0	0	0	0.015	0.012	0.014	0.010	0.009	0.010
1U-4	14:20:00	2	0	0	0	0.016	0.012	0.014	0.010	0.009	0.010
1U-4	14:21:00	3	0	0	0	0.016	0.012	0.014	0.010	0.009	0.010
1U-4	14:22:00	4	0	0	0	0.015	0.011	0.013	0.010	0.009	0.010

O-cell™ Expansion and Upward and Downward Movement

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

Load Test Increment	Time (h:m:s)	Time After Start Minutes	O-cell™ Pressure (psi)	Applied Load (kips)	LVWDT Readings (Expansion) 22017 (inches)	22018* (inches)	22019 (inches)	Average (inches)	Upward Movement (inches)	Upward Creep (inches)	Downward Movement (inches)	Downward Creep (inches)
1L -0	12:14:00	0	0	0	0.000	0.000	0.000	0.000	0.000		0.000	
1L -1	12:32:00	1	600	239	0.007	0.006	0.006	0.006	0.003		0.004	
1L -1	12:33:00	2	600	239	0.007	0.007	0.006	0.006	0.003		0.004	
1L -1	12:34:00	3	600	239	0.007	0.007	0.006	0.006	0.002		0.004	
1L -1	12:35:00	4	600	239	0.007	0.007	0.006	0.006	0.003	0.000	0.004	0.000
1L -2	12:36:00	1	1,200	458	0.008	0.006	0.008	0.008	0.003		0.005	
1L -2	12:37:00	2	1,200	458	0.008	0.006	0.008	0.008	0.004		0.004	
1L -2	12:38:00	3	1,200	458	0.008	0.006	0.008	0.008	0.004		0.004	
1L -2	12:39:00	4	1,200	458	0.009	0.007	0.008	0.008	0.004	0.000	0.004	0.000
1L -3	12:40:00	1	1,800	677	0.010	0.007	0.010	0.010	0.004		0.006	
1L -3	12:41:00	2	1,800	677	0.010	0.007	0.010	0.010	0.005		0.005	
1L -3	12:42:00	3	1,800	677	0.011	0.008	0.010	0.010	0.005		0.006	
1L -3	12:43:00	4	1,800	677	0.011	0.007	0.010	0.010	0.005	-0.001	0.006	0.001
1L -4	12:44:00	1	2,400	895	0.013	0.007	0.013	0.013	0.005		0.008	
1L -4	12:45:00	2	2,400	895	0.014	0.006	0.013	0.013	0.005		0.008	
1L -4	12:46:00	3	2,400	895	0.014	0.007	0.013	0.014	0.006		0.008	
1L -4	12:47:00	4	2,400	895	0.014	0.006	0.013	0.014	0.005	0.000	0.008	0.001
1L -5	12:48:00	1	3,000	1,114	0.018	0.007	0.017	0.017	0.006		0.011	
1L -5	12:49:00	2	3,000	1,114	0.018	0.012	0.017	0.018	0.007		0.011	
1L -5	12:50:00	3	3,000	1,114	0.018	0.010	0.018	0.018	0.007		0.011	
1L -5	12:51:00	4	3,000	1,114	0.019	0.047	0.018	0.018	0.007	0.000	0.012	0.001
1L -6	12:52:00	1	3,600	1,333	0.022	0.031	0.022	0.022	0.008		0.014	
1L -6	12:53:00	2	3,600	1,333	0.023	0.028	0.022	0.022	0.008		0.014	
1L -6	12:54:00	3	3,600	1,333	0.023	0.032	0.022	0.023	0.008		0.015	
1L -6	12:55:00	4	3,600	1,333	0.023	0.030	0.023	0.023	0.008	0.000	0.015	0.000
1L -7	12:56:00	1	4,200	1,551	0.026	0.160	0.026	0.026	0.010		0.017	
1L -7	12:57:00	2	4,200	1,551	0.028	0.139	0.027	0.027	0.010		0.017	
1L -7	12:58:00	3	4,200	1,551	0.028	0.072	0.027	0.027	0.010		0.017	
1L -7	12:59:00	4	4,200	1,551	0.028	0.063	0.027	0.028	0.010	0.000	0.018	0.001
1L -8	13:00:00	1	4,800	1,770	0.031	0.085	0.031	0.031	0.010		0.021	
1L -8	13:01:00	2	4,800	1,770	0.032	0.082	0.032	0.032	0.011		0.021	
1L -8	13:02:00	3	4,800	1,770	0.033	0.022	0.032	0.033	0.012		0.021	
1L -8	13:02:00	3	4,800	1,770	0.033	0.022	0.032	0.033	0.012		0.021	
1L -9	13:03:00	1	5,400	1,988	0.036	0.023	0.036	0.036	0.013		0.023	
1L -9	13:04:00	2	5,400	1,988	0.037	0.024	0.037	0.037	0.013		0.024	
1L -9	13:05:00	3	5,400	1,988	0.037	0.027	0.037	0.037	0.014		0.023	
1L -9	13:06:00	4	5,400	1,988	0.037	0.024	0.037	0.037	0.014	0.001	0.024	0.000
1L -10	13:07:00	1	6,000	2,207	0.041	0.216	0.041	0.041	0.015		0.026	
1L -10	13:08:00	2	6,000	2,207	0.042	0.220	0.042	0.042	0.015		0.026	
1L -10	13:09:00	3	6,000	2,207	0.042	0.209	0.042	0.042	0.016		0.026	
1L -10	13:10:00	4	6,000	2,207	0.043	0.230	0.042	0.042	0.016	0.001	0.026	0.000
1L -11	13:11:00	1	6,600	2,426	0.046	0.263	0.046	0.046	0.017		0.029	
1L -11	13:12:00	2	6,600	2,426	0.047	0.303	0.047	0.047	0.017		0.029	
1L -11	13:13:00	3	6,600	2,426	0.047	0.290	0.047	0.047	0.018		0.029	
1L -11	13:14:00	4	6,600	2,426	0.048	0.221	0.047	0.048	0.018	0.000	0.030	0.001
1L -12	13:15:00	1	7,200	2,644	0.051	0.230	0.051	0.051	0.019		0.033	
1L -12	13:16:00	2	7,200	2,644	0.052	0.234	0.051	0.052	0.019		0.033	
1L -12	13:17:00	3	7,200	2,644	0.053	0.292	0.052	0.052	0.019		0.033	
1L -12	13:18:00	4	7,200	2,644	0.053	0.293	0.052	0.052	0.020	0.001	0.033	0.000
1L -13	13:19:00	1	7,800	2,863	0.057	0.268	0.056	0.056	0.020		0.036	
1L -13	13:20:00	2	7,800	2,863	0.057	0.294	0.056	0.057	0.021		0.036	
1L -13	13:21:00	3	7,800	2,863	0.058	0.267	0.057	0.057	0.021		0.036	
1L -13	13:22:00	4	7,800	2,863	0.058	0.281	0.056	0.057	0.021	0.000	0.036	0.001
1L -14	13:23:00	1	8,400	3,082	0.062	0.294	0.060	0.061	0.022		0.039	
1L -14	13:24:00	2	8,400	3,082	0.063	0.295	0.061	0.062	0.022		0.040	
1L -14	13:25:00	3	8,400	3,082	0.063	0.277	0.061	0.062	0.023		0.039	
1L -14	13:26:00	4	8,400	3,082	0.064	0.227	0.062	0.063	0.023	0.001	0.040	0.000
1L -15	13:27:00	1	9,000	3,300	0.068	0.271	0.066	0.067	0.024		0.043	
1L -15	13:28:00	2	9,000	3,300	0.068	0.212	0.066	0.067	0.025		0.043	
1L -15	13:29:00	3	9,000	3,300	0.069	0.206	0.067	0.068	0.025		0.043	
1L -15	13:30:00	4	9,000	3,300	0.069	0.271	0.067	0.068	0.025	0.000	0.043	0.001
1L -16	13:31:00	1	9,600	3,519	0.073	0.229	0.071	0.072	0.026		0.046	
1L -16	13:32:00	2	9,600	3,519	0.074	0.250	0.072	0.073	0.027		0.046	
1L -16	13:33:00	3	9,600	3,519	0.075	0.213	0.073	0.074	0.027		0.046	
1L -16	13:34:00	4	9,600	3,519	0.075	0.214	0.073	0.074	0.027	0.000	0.047	0.001
1L -17	13:35:00	1	10,200	3,738	0.079	0.143	0.077	0.078	0.029		0.049	
1L -17	13:36:00	2	10,200	3,738	0.079	0.160	0.078	0.079	0.029		0.049	
1L -17	13:37:00	3	10,200	3,738	0.080	0.144	0.078	0.079	0.030		0.050	
1L -17	13:38:00	4	10,200	3,738	0.081	0.154	0.079	0.080	0.030	0.000	0.050	0.001
1L -18	13:39:00	1	10,800	3,956	0.085	0.116	0.083	0.084	0.031		0.053	
1L -18	13:40:00	2	10,800	3,956	0.087	0.112	0.085	0.086	0.032		0.054	
1L -18	13:41:00	3	10,800	3,956	0.087	0.106	0.085	0.086	0.032		0.054	
1L -18	13:42:00	4	10,800	3,956	0.088	0.110	0.086	0.087	0.032	0.000	0.055	0.001

O-cell™ Expansion and Upward and Downward Movement

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

Load Test Increment	Time (h:m:s)	Time After Start Minutes	O-cell™ Pressure (psi)	Applied Load (kips)	LVWDT Readings (Expansion) 22017 (inches)	22018 * (inches)	22019 (inches)	Average (inches)	Upward Movement (inches)	Upward Creep (inches)	Downward Movement (inches)	Downward Creep (inches)
1L -19	13:43:00	1	11,400	4,175	0.092	0.109	0.090	0.091	0.033		0.058	
1L -19	13:44:00	2	11,400	4,175	0.093	0.110	0.091	0.092	0.034		0.058	
1L -19	13:45:00	3	11,400	4,175	0.094	0.113	0.092	0.093	0.035		0.058	
1L -19	13:46:00	4	11,400	4,175	0.098	0.119	0.096	0.097	0.035	0.001	0.062	0.004
1L -20	13:47:00	1	12,000	4,394	0.100	0.124	0.098	0.099	0.036		0.062	
1L -20	13:48:00	2	12,000	4,394	0.100	0.123	0.098	0.099	0.036		0.063	
1L -20	13:49:00	3	12,000	4,394	0.101	0.153	0.098	0.100	0.037		0.063	
1L -20	13:50:00	4	12,000	4,394	0.101	0.127	0.099	0.100	0.037	0.001	0.063	0.000
1L -21	13:51:00	1	12,600	4,612	0.106	0.129	0.103	0.105	0.038		0.067	
1L -21	13:52:00	2	12,600	4,612	0.107	0.126	0.104	0.106	0.039		0.067	
1L -21	13:53:00	3	12,600	4,612	0.108	0.128	0.105	0.107	0.039		0.068	
1L -21	13:54:00	4	12,600	4,612	0.108	0.129	0.106	0.107	0.039	0.001	0.068	0.001
1L -22	13:57:00	1	13,200	4,831	0.114	0.130	0.111	0.113	0.041		0.072	
1L -22	13:58:00	2	13,200	4,831	0.115	0.127	0.112	0.114	0.041		0.072	
1L -22	13:59:00	3	13,200	4,831	0.116	0.128	0.113	0.114	0.042		0.073	
1L -22	14:00:00	4	13,200	4,831	0.116	0.131	0.113	0.115	0.042	0.001	0.072	0.000
1L -23	14:01:00	1	13,800	5,049	0.120	0.132	0.118	0.119	0.044		0.076	
1L -23	14:02:00	2	13,800	5,049	0.122	0.131	0.119	0.120	0.044		0.076	
1L -23	14:03:00	3	13,800	5,049	0.122	0.131	0.119	0.120	0.044		0.076	
1L -23	14:04:00	4	13,800	5,049	0.123	0.130	0.120	0.122	0.043	-0.001	0.078	0.002
1U-1	14:06:00	1	9,000	3,300	0.103	0.125	0.101	0.102	0.041		0.061	
1U-1	14:07:00	2	9,000	3,300	0.102	0.152	0.100	0.101	0.041		0.060	
1U-1	14:08:00	3	9,000	3,300	0.102	0.181	0.099	0.101	0.041		0.060	
1U-1	14:09:00	4	9,000	3,300	0.102	0.184	0.099	0.101	0.041	0.000	0.060	0.000
1U-2	14:10:00	1	6,000	2,207	0.085	0.253	0.083	0.084	0.037		0.047	
1U-2	14:11:00	2	6,000	2,207	0.084	0.294	0.082	0.083	0.036		0.047	
1U-2	14:12:00	3	6,000	2,207	0.083	0.293	0.081	0.082	0.036		0.046	
1U-2	14:13:00	4	6,000	2,207	0.083	0.292	0.081	0.082	0.035	0.000	0.046	0.000
1U-3	14:14:00	1	3,000	1,114	0.063	0.321	0.062	0.063	0.030		0.032	
1U-3	14:15:00	2	3,000	1,114	0.062	0.266	0.060	0.061	0.030		0.031	
1U-3	14:16:00	3	3,000	1,114	0.061	0.300	0.060	0.061	0.030		0.031	
1U-3	14:17:00	4	3,000	1,114	0.061	0.270	0.059	0.060	0.030	0.000	0.030	-0.001
1U-4	14:19:00	1	0	0	0.039	0.274	0.038	0.038	0.023		0.015	
1U-4	14:20:00	2	0	0	0.038	0.262	0.036	0.037	0.024		0.014	
1U-4	14:21:00	3	0	0	0.038	0.252	0.036	0.037	0.024		0.013	
1U-4	14:22:00	4	0	0	0.037	0.235	0.035	0.036	0.023	-0.001	0.013	0.000

* Gage did not function properly and is not used in average.

Strain Gage Readings and Loads at Levels 1, 2, 3 and 4

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (psi)	Applied Load (kips)	Level 1			Level 2			Level 3			Level 4		
					23712 με	23713 με	Av. Load (kips)	23714 με	23715 με	Av. Load (kips)	23716 με	23717 με	Av. Load (kips)	23718 με	23719 με	Av. Load (kips)
1L -0	12:14:00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1L -1	12:32:00	1	600	239	2	6	103	5	6	129	2	2	58	1	1	17
1L -1	12:33:00	2	600	239	2	6	104	5	6	131	3	2	59	1	1	17
1L -1	12:34:00	3	600	239	2	6	104	5	6	131	2	2	56	1	1	16
1L -1	12:35:00	4	600	239	2	6	103	5	6	131	2	2	58	1	1	15
1L -2	12:36:00	1	1,200	458	3	6	119	7	7	168	3	3	75	1	1	22
1L -2	12:37:00	2	1,200	458	3	6	117	7	7	168	3	3	71	1	1	22
1L -2	12:38:00	3	1,200	458	3	6	117	7	7	170	3	3	75	1	1	23
1L -2	12:39:00	4	1,200	458	3	6	116	7	7	171	3	3	75	1	1	20
1L -3	12:40:00	1	1,800	677	3	7	125	9	9	215	4	4	89	1	1	25
1L -3	12:41:00	2	1,800	677	3	7	124	9	9	214	4	4	91	1	1	24
1L -3	12:42:00	3	1,800	677	3	7	126	9	9	221	4	4	92	1	1	24
1L -3	12:43:00	4	1,800	677	3	7	125	9	9	220	4	4	94	1	1	27
1L -4	12:44:00	1	2,400	895	3	9	146	11	11	281	5	5	118	1	1	31
1L -4	12:45:00	2	2,400	895	3	9	147	12	11	283	5	5	120	1	1	30
1L -4	12:46:00	3	2,400	895	3	9	145	12	11	287	5	5	122	1	1	32
1L -4	12:47:00	4	2,400	895	3	9	146	12	11	288	5	5	119	1	1	36
1L -5	12:48:00	1	3,000	1,114	3	12	179	15	14	370	6	6	155	2	1	42
1L -5	12:49:00	2	3,000	1,114	3	12	177	16	15	378	7	6	158	2	2	40
1L -5	12:50:00	3	3,000	1,114	3	11	176	16	15	377	7	6	159	2	2	43
1L -5	12:51:00	4	3,000	1,114	3	12	176	16	15	385	7	6	159	2	2	45
1L -6	12:52:00	1	3,600	1,333	3	14	204	20	18	464	8	8	193	2	2	55
1L -6	12:53:00	2	3,600	1,333	3	14	201	20	18	467	8	8	193	2	2	56
1L -6	12:54:00	3	3,600	1,333	3	13	199	20	18	473	8	8	195	2	2	55
1L -6	12:55:00	4	3,600	1,333	3	13	196	20	18	471	8	8	196	2	2	55
1L -7	12:56:00	1	4,200	1,551	3	15	225	24	21	554	9	9	227	3	2	64
1L -7	12:57:00	2	4,200	1,551	3	15	222	24	21	564	9	9	230	3	3	68
1L -7	12:58:00	3	4,200	1,551	3	15	218	24	22	569	9	9	232	3	2	66
1L -7	12:59:00	4	4,200	1,551	2	15	215	24	22	569	10	9	233	3	2	66
1L -8	13:00:00	1	4,800	1,770	2	17	234	28	24	643	11	10	266	3	3	77
1L -8	13:01:00	2	4,800	1,770	2	16	230	28	24	646	11	10	264	3	3	77
1L -8	13:02:00	3	4,800	1,770	2	17	233	28	25	660	11	11	273	3	3	76
1L -8	13:02:00	3	4,800	1,770	2	17	233	28	25	660	11	11	273	3	3	76
1L -9	13:03:00	1	5,400	1,988	2	18	251	32	28	742	12	12	304	4	3	88
1L -9	13:04:00	2	5,400	1,988	1	18	243	32	28	742	12	12	305	4	3	87
1L -9	13:05:00	3	5,400	1,988	1	18	244	32	28	748	13	12	306	4	3	87
1L -9	13:06:00	4	5,400	1,988	1	18	240	32	28	749	13	12	308	4	3	87
1L -10	13:07:00	1	6,000	2,207	1	20	258	36	31	832	14	13	338	4	4	101
1L -10	13:08:00	2	6,000	2,207	1	20	260	36	31	838	14	14	342	4	4	101
1L -10	13:09:00	3	6,000	2,207	1	20	260	37	31	847	14	14	346	4	4	100
1L -10	13:10:00	4	6,000	2,207	1	20	256	37	31	849	14	14	346	4	4	98
1L -11	13:11:00	1	6,600	2,426	1	21	275	40	34	925	15	15	376	5	4	109
1L -11	13:12:00	2	6,600	2,426	0	21	270	41	34	936	16	15	382	5	4	111
1L -11	13:13:00	3	6,600	2,426	0	21	265	41	34	935	16	15	381	5	4	109
1L -11	13:14:00	4	6,600	2,426	0	21	266	41	35	946	16	15	384	5	4	113
1L -12	13:15:00	1	7,200	2,644	0	23	279	45	37	1025	17	16	417	5	5	122
1L -12	13:16:00	2	7,200	2,644	0	22	273	45	38	1034	17	16	420	5	4	121
1L -12	13:17:00	3	7,200	2,644	-1	22	269	46	38	1039	17	17	422	5	4	121
1L -12	13:18:00	4	7,200	2,644	-1	22	263	46	38	1038	17	17	421	5	4	121
1L -13	13:19:00	1	7,800	2,863	-1	23	271	50	41	1123	19	18	457	6	5	134
1L -13	13:20:00	2	7,800	2,863	-2	22	253	50	41	1130	19	18	459	6	5	135
1L -13	13:21:00	3	7,800	2,863	-2	21	242	50	41	1135	19	18	461	6	5	134
1L -13	13:22:00	4	7,800	2,863	-2	21	234	50	41	1137	19	18	462	6	5	136
1L -14	13:23:00	1	8,400	3,082	-3	20	201	55	44	1229	21	19	499	6	6	150
1L -14	13:24:00	2	8,400	3,082	-4	20	199	55	44	1231	21	20	500	6	5	146
1L -14	13:25:00	3	8,400	3,082	-4	22	219	55	45	1239	21	20	503	6	5	146
1L -14	13:26:00	4	8,400	3,082	-5	24	237	55	45	1239	21	20	504	6	5	146
1L -15	13:27:00	1	9,000	3,300	-6	29	288	59	48	1333	23	21	544	7	6	159
1L -15	13:28:00	2	9,000	3,300	-7	30	293	60	48	1338	23	21	545	7	6	161
1L -15	13:29:00	3	9,000	3,300	-7	31	299	60	48	1347	23	21	548	7	6	161
1L -15	13:30:00	4	9,000	3,300	-8	32	301	60	48	1347	23	21	549	7	6	164
1L -16	13:31:00	1	9,600	3,519	-9	35	319	64	51	1434	24	23	584	7	6	171
1L -16	13:32:00	2	9,600	3,519	-10	35	313	65	51	1443	25	23	588	7	6	171
1L -16	13:33:00	3	9,600	3,519	-11	36	312	65	52	1453	25	23	592	8	6	173
1L -16	13:34:00	4	9,600	3,519	-11	36	304	66	52	1460	25	23	595	8	6	176
1L -17	13:35:00	1	10,200	3,738	-14	37	285	70	55	1545	26	24	629	8	7	184
1L -17	13:36:00	2	10,200	3,738	-15	37	275	70	55	1549	26	24	633	8	7	186
1L -17	13:37:00	3	10,200	3,738	-16	37	271	70	55	1561	27	24	636	8	7	186
1L -17	13:38:00	4	10,200	3,738	-16	38	270	71	55	1568	27	25	640	8	7	191
1L -18	13:39:00	1	10,800	3,956	-18	39	265	75	58	1662	28	26	678	9	8	205
1L -18	13:40:00	2	10,800	3,956	-18	39	258	76	59	1677	29	26	684	9	8	207
1L -18	13:41:00	3	10,800	3,956	-19	39	253	76	59	1681	29	26	686	9	7	202
1L -18	13:42:00	4	10,800	3,956	-19	39	247	77	59	1686	29	26	688	9	8	205

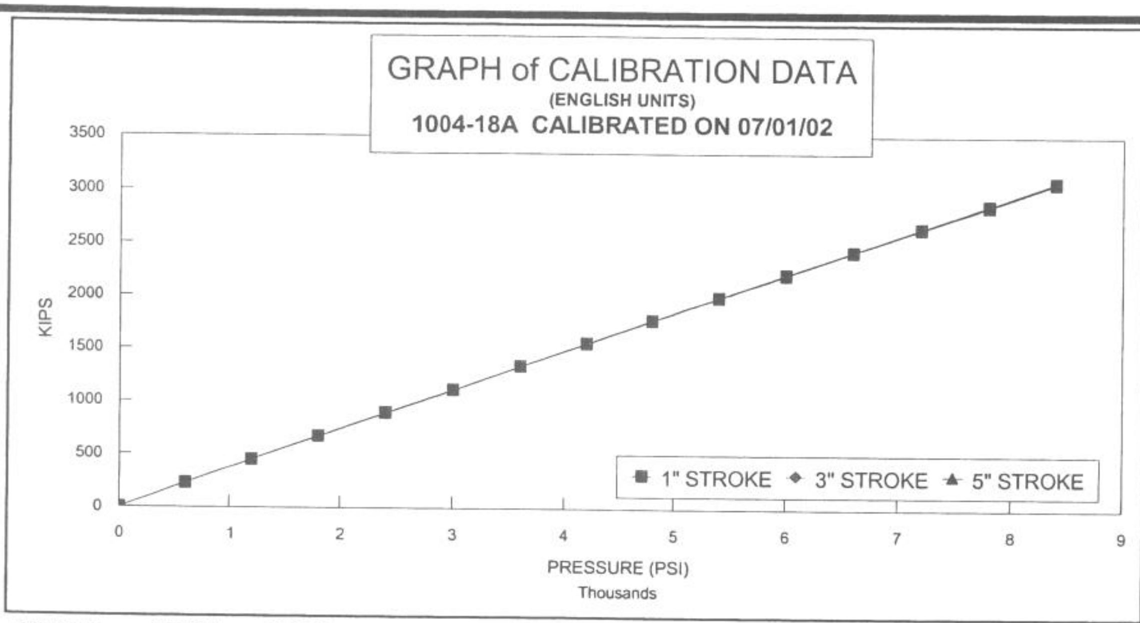
Strain Gage Readings and Loads at Levels 1, 2, 3 and 4

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

Load Test Increment	Time 0 (h:m:s)	Time After Start Minutes	O-cell™ Pressure (psi)	Applied Load (kips)	Level 1			Level 2			Level 3			Level 4		
					23712	23713	Av. Load	23714	23715	Av. Load	23716	23717	Av. Load	23718	23719	Av. Load
					με	με	(kips)	με	με	(kips)	με	με	(kips)	με	με	(kips)
1L -19	13:43:00	1	11,400	4,175	-20	39	238	81	61	1767	30	28	723	9	8	214
1L -19	13:44:00	2	11,400	4,175	-20	38	232	82	62	1787	31	28	731	9	8	219
1L -19	13:45:00	3	11,400	4,175	-19	38	238	82	62	1791	31	28	734	9	8	218
1L -19	13:46:00	4	11,400	4,175	-18	39	262	86	65	1882	33	29	769	10	8	229
1L -20	13:47:00	1	12,000	4,394	-19	39	252	87	65	1902	33	30	778	10	9	232
1L -20	13:48:00	2	12,000	4,394	-19	39	244	88	65	1910	33	30	781	10	9	232
1L -20	13:49:00	3	12,000	4,394	-20	38	229	88	65	1912	33	30	782	10	9	237
1L -20	13:50:00	4	12,000	4,394	-20	38	224	89	66	1918	33	30	785	10	9	236
1L -21	13:51:00	1	12,600	4,612	-27	40	157	93	69	2012	35	31	824	11	9	247
1L -21	13:52:00	2	12,600	4,612	-30	39	112	93	69	2017	35	31	826	11	9	252
1L -21	13:53:00	3	12,600	4,612	-32	39	84	94	69	2027	35	31	829	11	9	250
1L -21	13:54:00	4	12,600	4,612	-33	39	70	94	69	2030	35	31	831	11	9	251
1L -22	13:57:00	1	13,200	4,831	-45	39	-76	99	72	2134	37	33	875	11	10	261
1L -22	13:58:00	2	13,200	4,831	-48	38	-126	100	72	2139	38	33	878	11	10	268
1L -22	13:59:00	3	13,200	4,831	-50	37	-167	100	72	2146	38	33	880	11	10	266
1L -22	14:00:00	4	13,200	4,831	-52	36	-199	100	72	2141	38	33	878	11	10	266
1L -23	14:01:00	1	13,800	5,049	-62	35	-340	104	75	2231	39	34	914	12	10	278
1L -23	14:02:00	2	13,800	5,049	-65	33	-400	105	76	2247	40	34	921	12	11	279
1L -23	14:03:00	3	13,800	5,049	-67	32	-437	105	76	2255	40	35	923	12	10	277
1L -23	14:04:00	4	13,800	5,049	-70	31	-477	106	76	2261	40	35	925	12	11	281
1U-1	14:06:00	1	9,000	3,300	-77	18	-734	82	58	1739	31	27	718	9	8	218
1U-1	14:07:00	2	9,000	3,300	-76	17	-736	81	57	1717	31	26	708	9	8	215
1U-1	14:08:00	3	9,000	3,300	-76	18	-730	81	57	1719	31	26	709	9	8	217
1U-1	14:09:00	4	9,000	3,300	-76	18	-728	81	57	1720	31	26	710	9	8	216
1U-2	14:10:00	1	6,000	2,207	-78	8	-866	62	43	1311	24	20	547	7	6	170
1U-2	14:11:00	2	6,000	2,207	-77	8	-859	61	43	1295	24	20	542	7	6	168
1U-2	14:12:00	3	6,000	2,207	-77	9	-854	61	43	1290	24	20	538	7	6	168
1U-2	14:13:00	4	6,000	2,207	-77	9	-849	61	43	1291	24	20	540	7	6	165
1U-3	14:14:00	1	3,000	1,114	-71	-1	-902	41	27	845	16	13	358	5	4	115
1U-3	14:15:00	2	3,000	1,114	-71	-1	-894	40	27	828	15	13	353	5	4	110
1U-3	14:16:00	3	3,000	1,114	-71	-1	-886	40	27	830	16	13	354	5	4	113
1U-3	14:17:00	4	3,000	1,114	-70	-1	-882	40	27	828	16	13	353	5	4	112
1U-4	14:19:00	1	0	0	-59	-9	-852	19	11	374	7	6	165	3	2	62
1U-4	14:20:00	2	0	0	-59	-9	-845	18	11	366	7	6	162	3	2	57
1U-4	14:21:00	3	0	0	-59	-9	-842	18	11	359	7	6	158	3	2	58
1U-4	14:22:00	4	0	0	-58	-9	-836	18	11	354	7	6	156	3	2	57

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
600	231	227	231
1200	455	452	452
1800	679	673	672
2400	902	896	893
3000	1121	1114	1112
3600	1343	1338	1336
4200	1564	1556	1552
4800	1783	1774	1770
5400	2001	1996	1988
6000	2216	2209	2202
6600	2433	2426	2420
7200	2652	2645	2639
7800	2865	2856	2848
8400	3082	3071	3064

26" O-CELL, SERIAL # 1004-18A

LOAD CONVERSION FORMULA

LOAD = PRESSURE * 0.3644 + (20.7)
{KIPS} {PSI}

Regression Output:

Constant	**20.693**
X Coefficient	**0.364**
R Squared	1.000
No. of Observations	42
Degrees of Freedom	40
Std Err of Y Est	7.430
Std Err of X Coef.	0.000

CALIBRATION STANDARDS:

All data presented is 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 gauges, ANSI specifications B40.1.

*AE & FC CUSTOMER: LOADTEST INC. *AE & FC JOB NO.: 3424 *CUSTOMER P.O.NO.: LT-8785	*CONTRACTOR: JENSEN CONSTRUCTION *JOB LOCATION: WAVERLY, MO *DATED: 08/13/02

SERVICE ENGINEER: [signature] DATE: 14 Aug 2002

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

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Range: 6"

Serial Number: 22017

Mfg. Number: 02-1583

Customer: Loadtest Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 124, 249, 406, 524, 529

Job Number: 19269

Calibration Date: June 06, 2002

Technician: KOB

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2374	2369	2372		-0.27
1.200	3634	3632	3633	1262	0.08
2.400	4884	4884	4884	1251	0.26
3.600	6119	6115	6117	1233	0.14
4.800	7347	7343	7345	1228	-0.05
6.000	8579	8577	8578	1233	-0.17

Calibration Factor (C): 0.0009677 (Inches/ Digit)

Regression Zero: 2388

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5552

or

Position "F":

Date: August 19, 2002

Temperature: 25.3 °C

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 23713

Customer: Loadtest Inc.

Job Number: 19269

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.2 °C

Calibration Date: August 19, 2002

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

Cable Length: 134 ft.

Factory Zero Reading: 6455

Regression Zero: 6505

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6561	6548	6555		
1,500	7235	7225	7230	676	0.01
3,000	7961	7944	7953	723	-0.06
4,500	8686	8678	8682	730	0.10
6,000	9412	9395	9404	722	-0.01
100	6547				

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

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Range: 6"

Serial Number: 22018

Mfg. Number: 02-1584

Customer: Loadtest Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 124, 249, 406, 524, 529

Job Number: 19269

Calibration Date: June 06, 2002

Technician: KDB

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2377	2374	2376		-0.19
1.200	3605	3602	3604	1228	0.07
2.400	4822	4820	4821	1218	0.15
3.600	6032	6029	6031	1210	0.10
4.800	7238	7236	7237	1207	0.00
6.000	8442	8440	8441	1204	-0.14

Calibration Factor (C): 0.0009897 (Inches/ Digit)

Regression Zero: 2387

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5489

or

Position "F":

Date: August 19, 2002

Temperature: 25.9 °C

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

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

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

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

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Range: 6"

Serial Number: 22019

Mfg. Number: 02-1585

Customer: Loadtest Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 124, 249, 406, 524, 529

Job Number: 19269

Calibration Date: June 06, 2002

Technician: KOB

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2396	2397	2397		-0.31
1.200	3664	3660	3662	1266	0.14
2.400	4906	4906	4906	1244	0.25
3.600	6137	6135	6136	1230	0.13
4.800	7363	7364	7364	1228	-0.03
6.000	8592	8591	8592	1228	-0.19

Calibration Factor (C): 0.0009697 (Inches/ Digit)

Regression Zero: 2416

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5588

or

Position "F":

Date: August 19, 2002

Temperature: 26.1 °C

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

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

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

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

Sister Bar Calibration Report

Model Number :	4911-4	Calibration Date:	August 19, 2002
Serial Number:	23712	Cal. Std. Control Numbers:	85888-1, 398
Customer:	Loadtest Inc.	Cable Length:	134 ft.
Job Number:	19269	Factory Zero Reading:	7116
Cust. I.D. #:	n/a	Regression Zero:	7110
Prestress:	35,000 psi	Technician:	KDB
Temperature:	23.7 °C		

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7168	7177	7173		
1,500	7821	7828	7825	652	-0.49
3,000	8562	8561	8562	737	-0.20
4,500	9302	9302	9302	741	0.20
6,000	10024	10032	10028	726	0.11
100	7182				

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

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

Calibration Date: August 19, 2002

Serial Number: 23714

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

Customer: Loadtest Inc.

Cable Length: 99 t.

Job Number: 19269

Factory Zero Reading: 6853

Cust. I.D. #: n/a

Regression Zero: 6886

Prestress: 35,000 psi

Technician: KDB

Temperature: 23.4 °C

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6945	6936	6941		
1,500	7606	7603	7605	664	-0.22
3,000	8340	8327	8334	729	-0.07
4,500	9065	9056	9061	727	0.00
6,000	9790	9786	9788	728	0.09
100	6945				

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

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 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	Calibration Date:	August 19, 2002
Serial Number:	23715	Cal. Std. Control Numbers:	85888-1, 398
Customer:	Loadtest Inc.	Cable Length:	99 ft.
Job Number:	19269	Factory Zero Reading:	6906
Cust. I.D. #:	n/a	Regression Zero:	6926
Prestress:	35,000 psi	Technician:	KDB
Temperature:	23.6 °C		

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6984	6985	6985		
1,500	7667	7668	7668	683	-0.32
3,000	8421	8431	8426	759	-0.07
4,500	9185	9186	9186	760	0.22
6,000	9930	9930	9930	745	0.00
100	6987				

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

Gage Factor: 0.340 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	Calibration Date:	August 19, 2002
Serial Number:	23716	Cal. Std. Control Numbers:	85888-1, 398
Customer:	Loadtest Inc.	Cable Length:	85 ft.
Job Number:	19269	Factory Zero Reading:	7022
Cust. I.D. #:	n/a	Regression Zero:	7019
Prestress:	35,000 psi	Technician:	KDB
Temperature:	23.5 °C		

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7074	7080	7077		
1,500	7758	7761	7760	683	-0.35
3,000	8518	8524	8521	762	-0.01
4,500	9273	9276	9275	754	0.07
6,000	10021	10028	10025	750	0.04
100	7082				

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

Gage Factor: 0.340 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: 23717

Customer: Loadtest Inc.

Job Number: 19269

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 23.4 °C

Calibration Date: August 19, 2002

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

Cable Length: 85 ft.

Factory Zero Reading: 7061

Regression Zero: 7075

Technician: [signature]

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7129	7132	7131		
1,500	7792	7801	7797	666	-0.16
3,000	8524	8525	8525	728	-0.11
4,500	9251	9259	9255	731	0.04
6,000	9981	9987	9984	729	0.13
100	7138				

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

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

Linearity: ((Calculated Load-Applied Load)/ Max.Applied Load) X 100 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	Calibration Date:	August 19, 2002
Serial Number:	23716	Cal. Std. Control Numbers:	85888-1, 398
Customer:	Loadtest Inc.	Cable Length:	85 ft.
Job Number:	19269	Factory Zero Reading:	7022
Cust. I.D. #:	n/a	Regression Zero:	7019
Prestress:	35,000 psi	Technician:	KDB
Temperature:	23.5 °C		

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7074	7080	7077		
1,500	7758	7761	7760	683	-0.35
3,000	8518	8524	8521	762	-0.01
4,500	9273	9276	9275	754	0.07
6,000	10021	10028	10025	750	0.04
100	7082				

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

Gage Factor: 0.340 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 EQUIVALENT TOP-LOAD CURVE

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

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

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

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

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

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

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

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

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

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

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

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

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

The attached analysis p. 6 gives the equations for the elastic compressions that occur in the OLT with one or two levels of O-cells™. Analysis p. 7 gives the equations for the elastic compressions that occur in the equivalent TLT. Both sets of equations do not include the elastic compression below the O-cell™ because the same compression takes place in both the OLT and the TLT. This is equivalent to taking $L_3 = 0$. Subtracting the OLT from the TLT compression gives the desired additional elastic compression at the top of the TLT. We then add the additional elastic compression to the 'rigid' equivalent curve obtained from Part I to obtain the final, corrected equivalent load-settlement curve for the TLT on the same pile as the actual OLT.

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

The analysis p. 8 provides an example of calculated results in English units on a hypothetical 1-stage, single level OLT using the simplified method in Part II with the 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

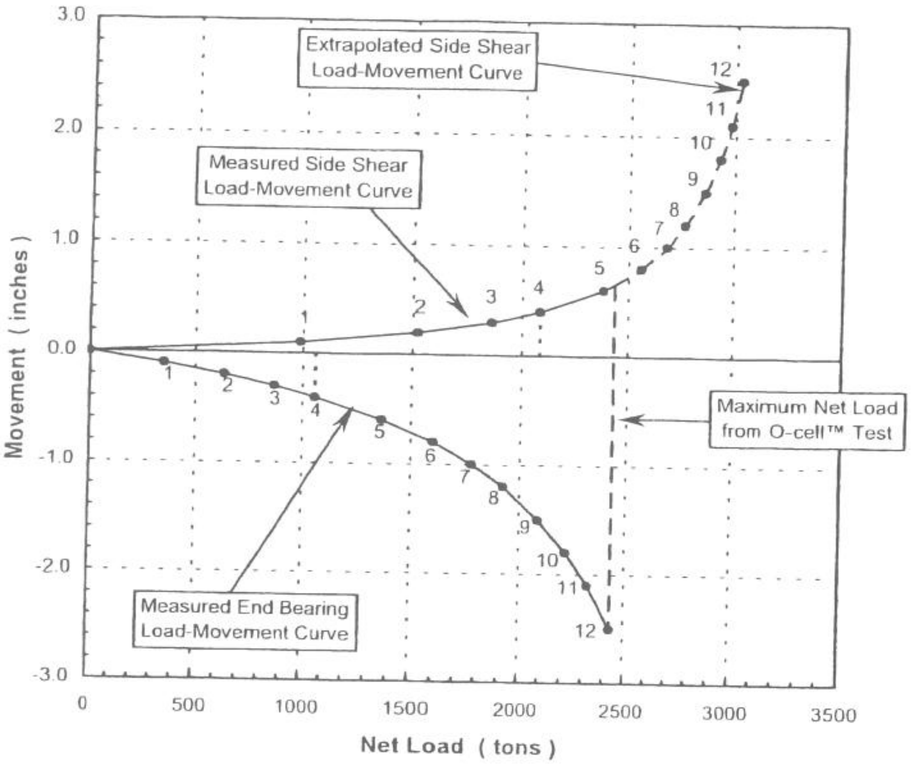
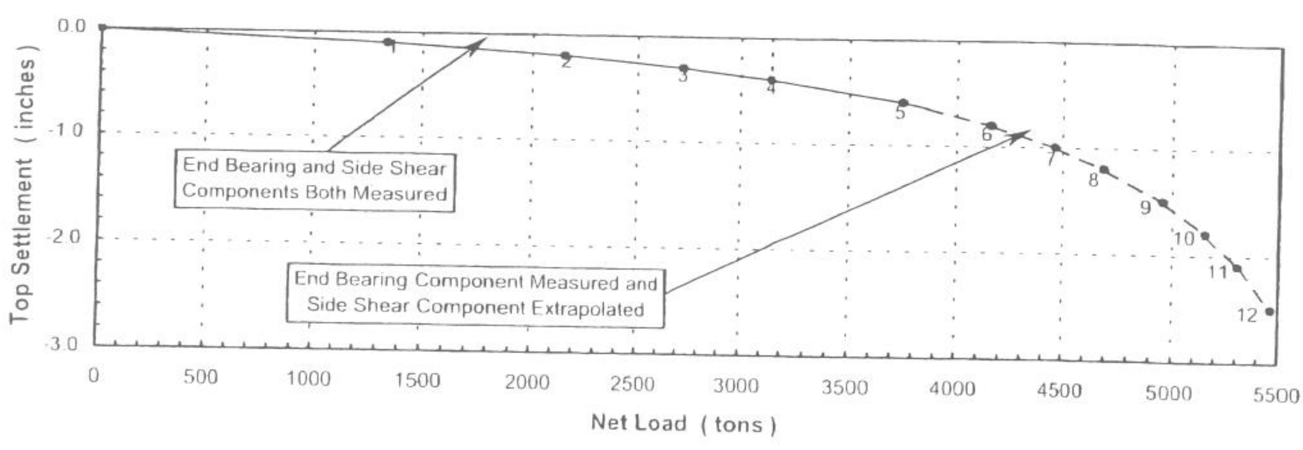
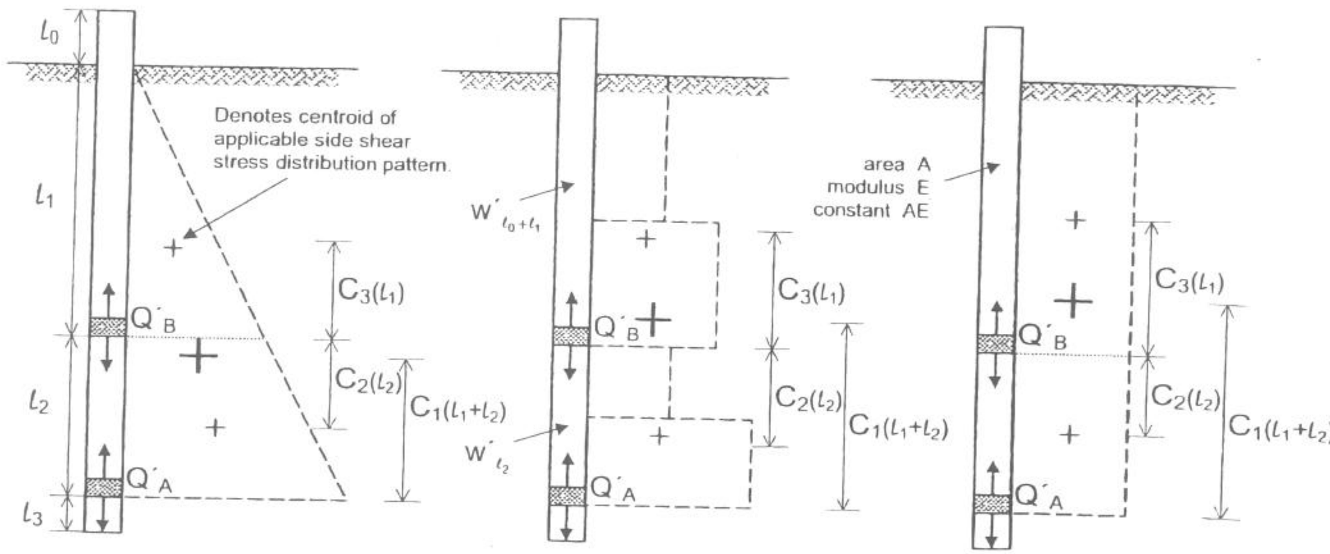


Figure B



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



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

$C_1 = \frac{1}{3}$	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): $\delta_{OLT} = \delta_{\uparrow l_1} + \delta_{\downarrow l_2}$

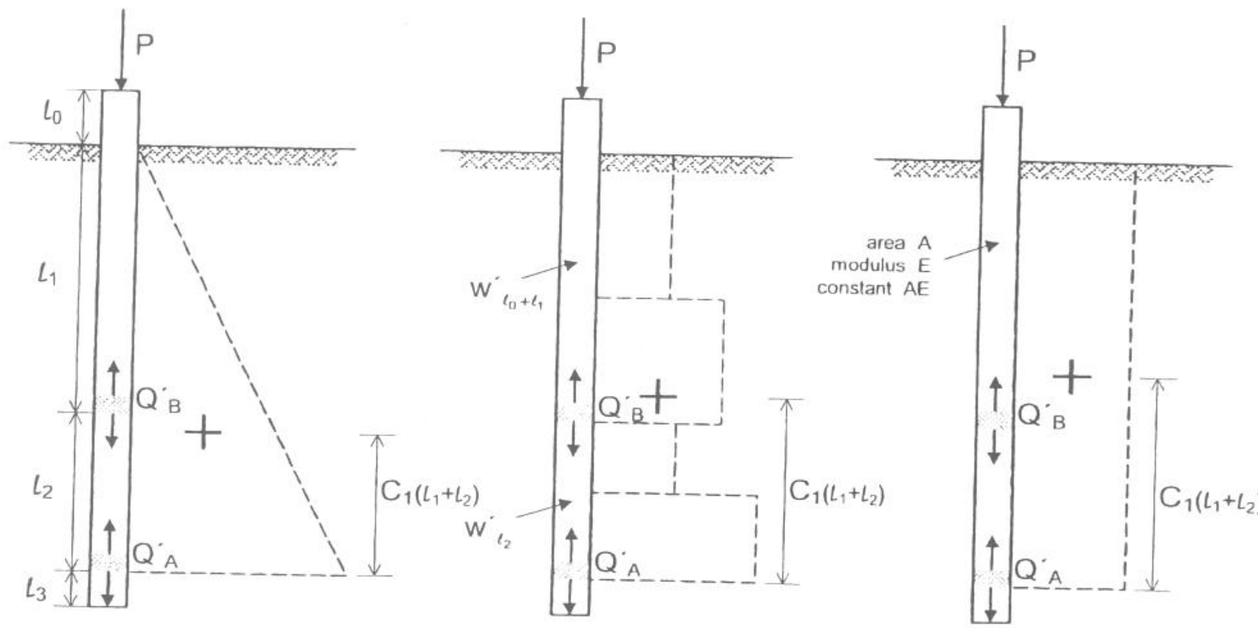
$C_3 = \frac{1}{3}$	Centroid Factor $= C_3$	$C_3 = \frac{1}{2}$
$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B}l_1}{AE}$	$\delta_{\uparrow l_1} = C_3\frac{Q'_{\uparrow B}l_1}{AE}$	$\delta_{\uparrow l_1} = \frac{1}{3}\frac{Q'_{\uparrow B}l_1}{AE}$
$C_2 = \frac{1}{3}\left(\frac{3l_1+2l_2}{2l_1+l_2}\right)$	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, bouyant where below water table

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



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

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

Net and Equivalent Loads:

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

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

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

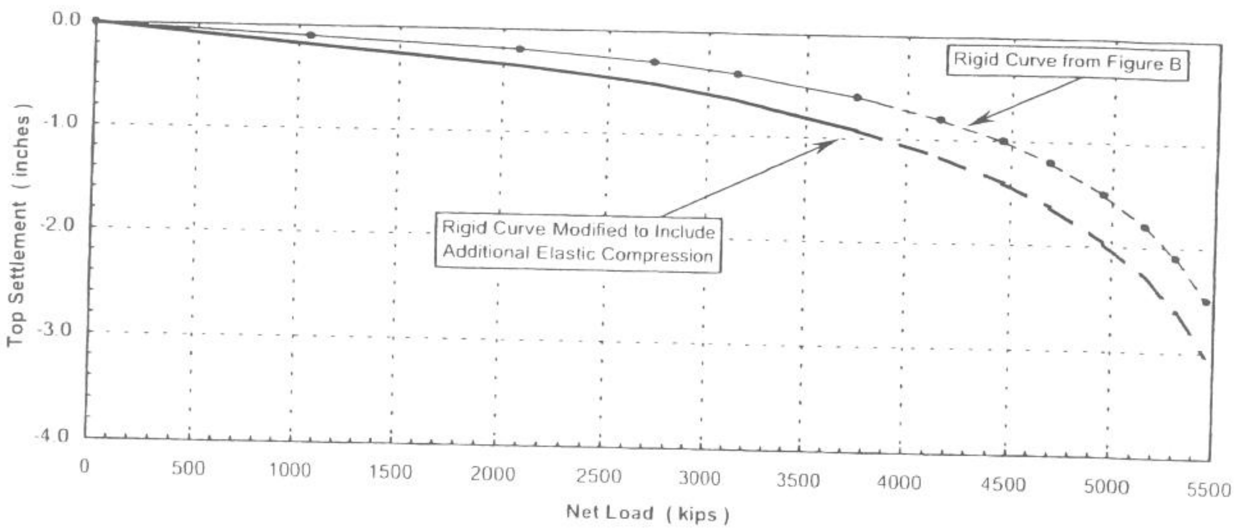
Given:

C_1 = 0.441
AE = 3820000 **kips** (assumed constant throughout test)
ℓ_0 = 5.9 **ft**
ℓ_1 = 48.2 **ft** (embedded length of shaft above O-cell™)
ℓ_2 = 0.0 **ft**
ℓ_3 = 0.0 **ft**

Shear reduction factor = 1.00 (cohesive soil)

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

Figure C



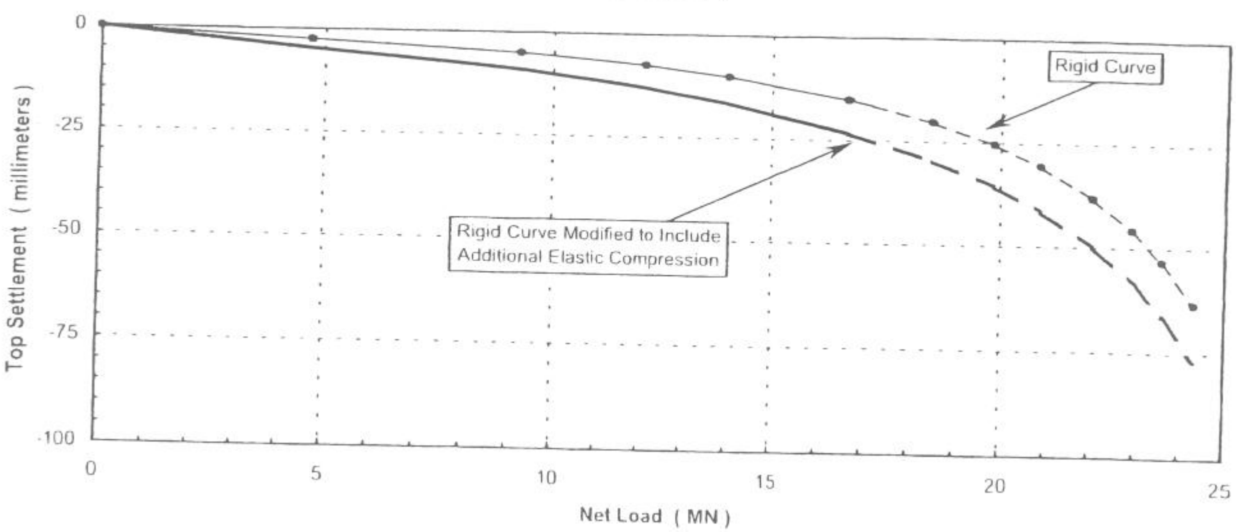
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (SI Units)

Given:

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

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

Figure D



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

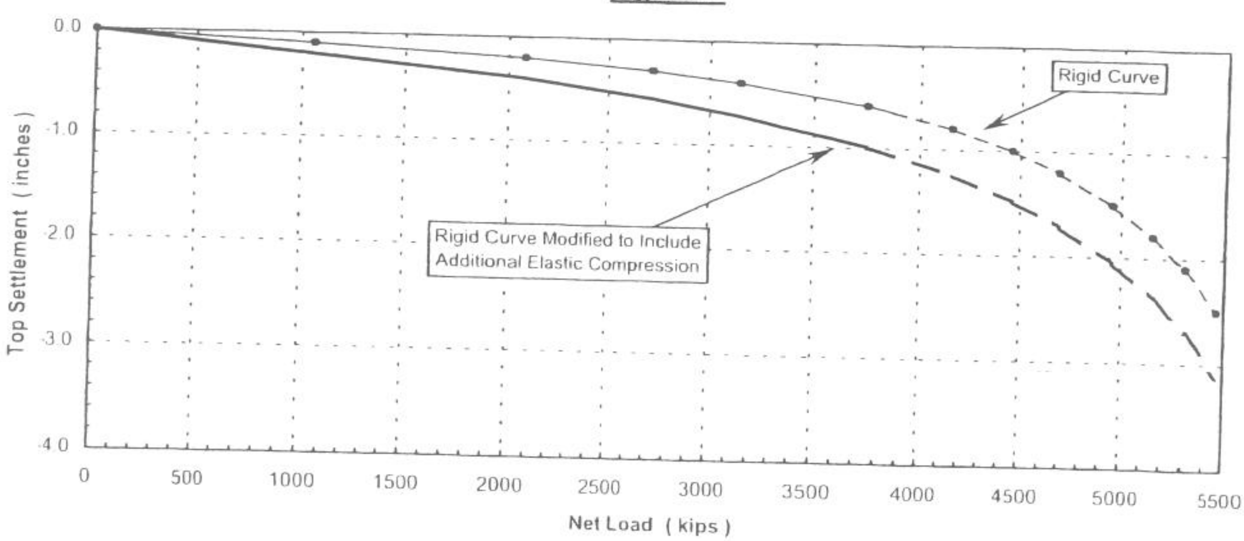
Given:

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

Shear reduction factor = 1.00 (cohesive soil)

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

Figure E



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

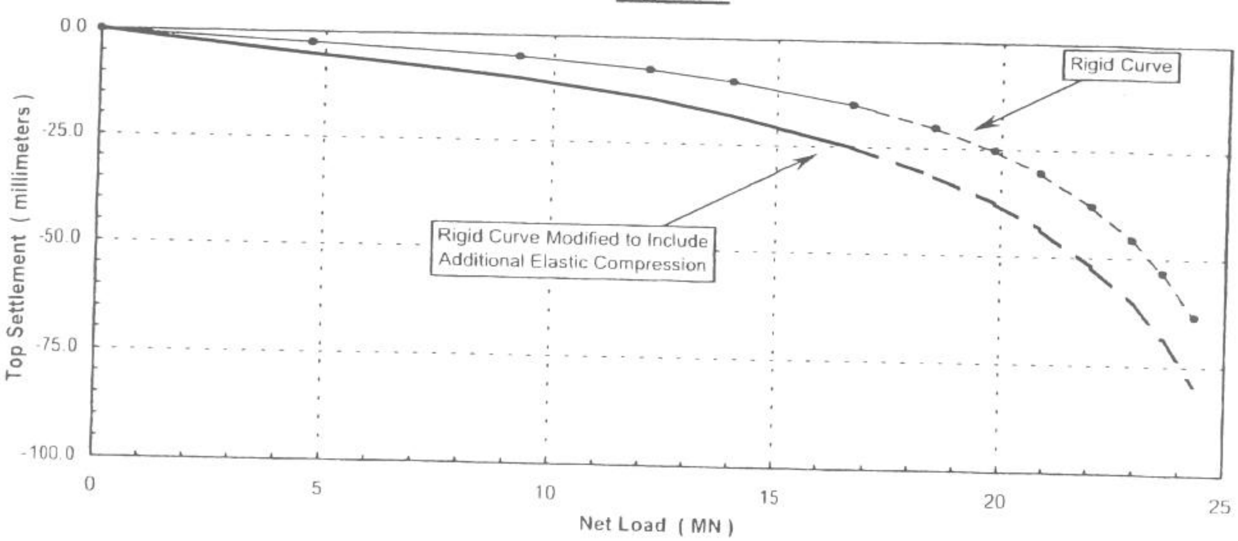
Given:

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

Shear reduction factor = 1.00 (cohesive soil)

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

Figure F



APPENDIX D

O-CELL™ METHOD FOR DETERMINING CREEP LIMIT

O-CELL METHOD FOR DETERMINING A CREEP LIMIT LOADING ON THE EQUIVALENT TOP-LOADED SHAFT

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, 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 become significant beyond this break loading and progressively more severe creep can occur.

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

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

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

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

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

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

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

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

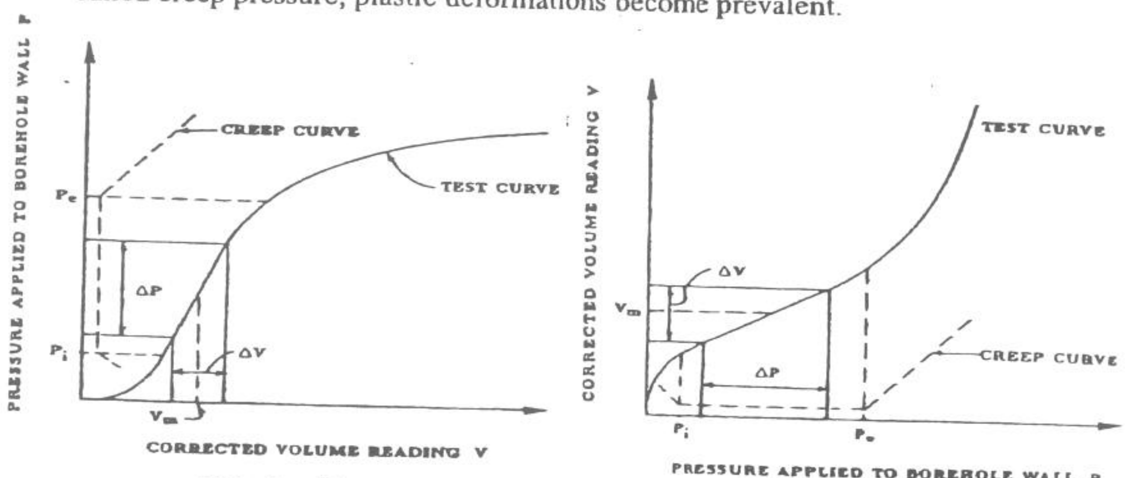


FIG. 8 Pressuremeter Test Curves for Procedure A

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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.

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APPENDIX E

NET UNIT SHEAR VERSUS UPWARD O-CELL™ MOVEMENT CURVES

Net Unit Shear vs. Upward O-cell™ Movement

Rt. 65 Missouri River Bridge - Waverly, MO - Test Shaft at Pier 11

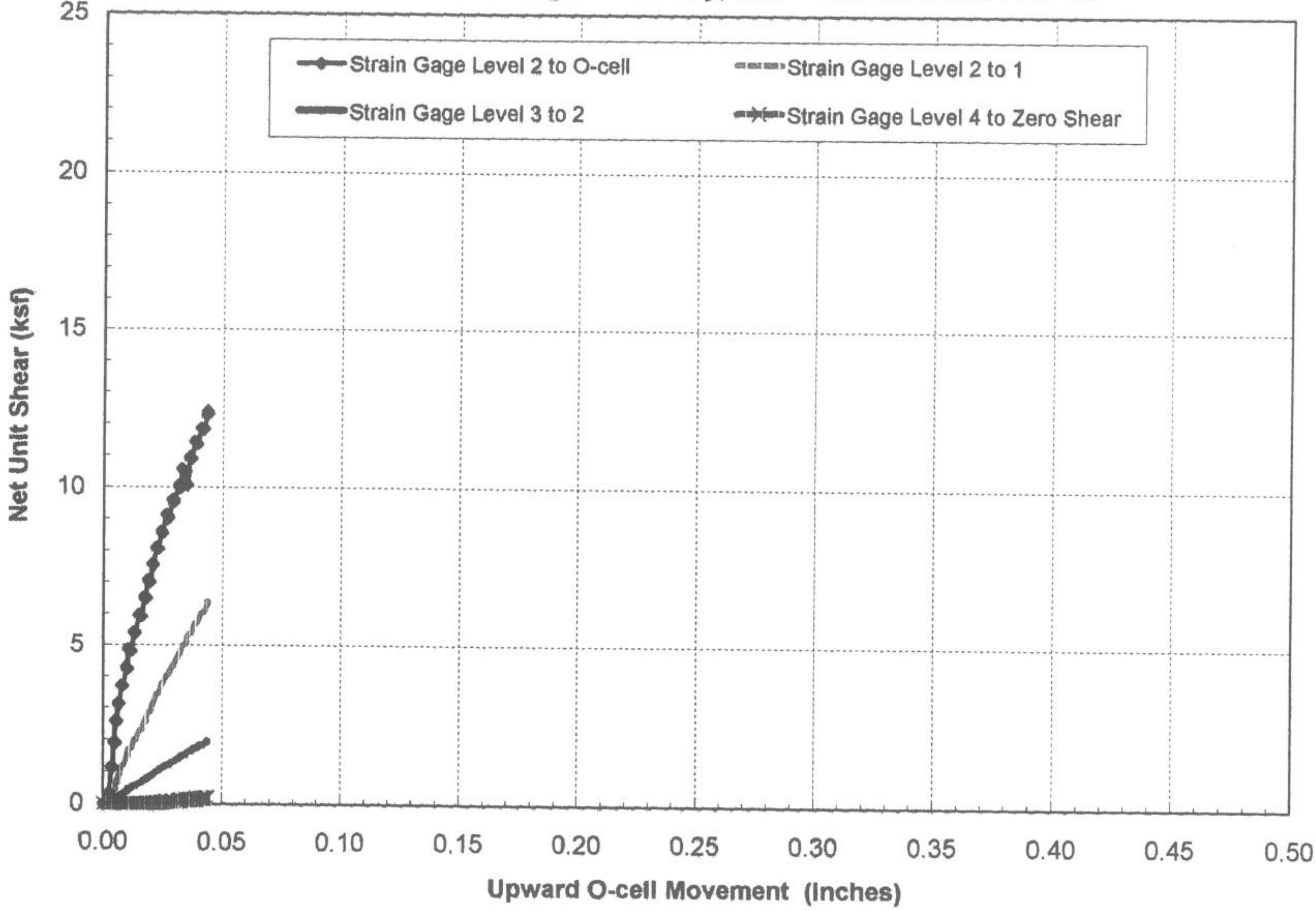

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Figure E-1