DATA REPORT ON DRILLED SHAFT LOAD TESTING (OSTERBERG METHOD)

Pier 1 West, US 75 at 77th Street
Topeka, Kansas

Prepared for: **King Construction**
301 N. Lancaster Ave.
Hesston, KS 67062

Attention: **Mr. Don King**

PROJECT NUMBER: LT-8733

February 15, 2001

- Based on this report, what allowables would KDOT Geotec give?
- 6' shaft, 22.5' length tested
- Proposed 3' shaft, 22.5' length ?? SF = 6
SF = 10

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LOADTEST INC.

Project: 75-89 K 7317 - 01
Bridge: 269

Sample No.	Station	Dist. ft	Depth ft	C Description T.H.E.= N/A	Qu. kPa	Tangent Modulus E kPa	Dry Unit Weight kg/m3	Moisture (% of Dry Wt.)
S-1	182+88	85 Lt.	9.8-10.4	Sandstone	913.7	56815	1918	13.6
S-2	□		13.8-14.3	Sandstone	7891.4	725400	1819	16.5
S-3*	□		17.8-18.4	Sandstone	7514.8	849800	1832	16.9
S-4	□		23.3-23.8	Sandstone	17247.4	1785000	1948	14.8
S-5*	□		25.6-26.0	Limestone	1477.2	70000	2240	6.7
S-6	□		29.2-29.7	Black shale	2746	167000	2088	9.8
S-7	□		35.2-35.7	Limestone	28974.2	Test Failed	2366	6.7
S-8	□		41.9-42.4	Limestone	15016.9	1234000	2317	6.3
S-9	□		45.7-46.3	Limestone	29439.3	4626000	2261	7.6

			Depth (ft.)	Description	Qu. (tsf)	E (Ksi)	Weight (pcf)	
S-1	182+88	85 Lt.	9.8-10.4	Sandstone	9.539	8	119.7	13.6
S-2			13.8-14.3	Sandstone	82.386	105	113.6	16.5
S-3*			17.8-18.4	Sandstone	78.455	123	114.4	16.9
S-4			23.3-23.8	Sandstone	180.063	259	121.6	14.8
S-5*			25.6-26.0	Limestone	15.422	10	139.8	6.7
S-6			29.2-29.7	Black shale	28.668	24	130.3	9.8
S-7			35.2-35.7	Limestone	302.491		147.7	6.7
S-8			41.9-42.4	Limestone	156.776	179	144.6	6.3
S-9			45.7-46.3	Limestone	307.346	671	141.1	7.6

$$\frac{179 + 671}{2} = 425$$

use 123 ksi = E

	Elevation (ft.)	Dist. From Top (ft.)	Depth (ft.)	Qu (tsf)	Qu (psf)	Qu/2 (psf)
Ground	1016.1					
Top	1008.85	0	7.25			
	999.6	9.25	16.5	2.42	4840	2420
	995.2	13.65	20.9	15.13	30260	15130
	990	18.85	26.1	9.11	18220	9110
	980.5	28.35	35.6	22.1	44200	22100
Bottom	974.85	34	41.25			
	973.9	34.95	42.2	23.9	47800	23900
	966.2	42.65	49.9	25.2	50400	25200
	958.6	50.25	57.5	59.41	118820	59410
	955.6	53.25	60.5	102.36	204720	102360
	952.5	56.35	63.6	699.14	1398280	699140

Input

February 15, 2001

King Construction
301 N. Lancaster Ave.
Hesston, KS 67062

Attention: Mr. Don King

Fax: 316-327-2873

Data Report: US 75 at 77th Street - Topeka, KS
Location: Pier 1 West

Dear Sirs,

Loadtest Inc. performed an Osterberg Cell load test on a production shaft for King Construction on Pier 1 - West (LTI projectLT-8733). The test was carried out on February 1, 2001 by LOADTEST Inc. under the direction of Mr. Robert Simpson.

The test shaft was constructed by King Construction on January 23, 2001. The shaft was constructed dry with a total length of 38.6 feet (11.8 meters). Shaft construction and installation was observed by William Ryan of LOADTEST Inc. The shaft was drilled to top or rock with an auger. A surface casing was then placed after over-reaming the shaft excavation by 3 inches. The shaft excavation was then continued until the tip elevation was reached. The bottom was hand cleaned. The tip of shaft was located 0.38 feet (0.12 meters) below the O-cell™. Three feet of concrete was placed at the bottom of the shaft and then the O-cell was placed into the wet concrete attached to the rebar cage until it settled down to its final elevation. Concrete for the rest of the shaft was then poured. The shaft was inspected and approved by the Kansas Department of Transportation. A summary of dimensions, elevations, areas and properties for analysis purposes is provided in Table B.

The sub-surface stratigraphy at the test shaft location is reported to consist of clayey overburden down to elevation +997.7 feet (+304.1 meters). Below elevation +997.7 feet (+304.1 meters). to an undetermined depth sandy shale was present (Severy Shale Formation). Boring logs, located in the vicinity of the shaft, are presented in Appendix F. Detailed geologic information can be obtained from the Kansas Department of Transportation.

This report uses English units as the primary units and SI units in parentheses.

The key elements of the acquired data are as follows:

- Net Unit Side Shear Values from Strain Gage Data, Table A.
- Summary of Dimensions, Elevations, Areas & Weights, Table B.

- Schematic Section of Test Shaft, Figure A.
- Osterberg Cell Load-Movement Curves, Figure 1.
- Strain Gage Load Distribution Curves, Figure 2.
- Equivalent Top Load Curve, Figure 3.
- Side Shear Creep Limit Plot, Figure 4.
- End Bearing Creep Limit Plot, Figure 5.

- Field Data and Reduction, Appendix A (7 pages).
- Calibration of the O-cell™ and Instrumentation, Appendix B.
- Equivalent Top Load Method, Appendix C.
- O-Cell™ Method for Determining Creep Limit, Appendix D.
- Net Unit Side Shear Values vs. Displacement, Appendix E.
- Boring Logs, Appendix F.
- Grouting Procedures, Appendix G.

Standard O-cell™ instrumentation included three LVWDTs positioned between the lower and upper plates to measure O-cell™ expansion. Compression of the shaft was measured by a two telltales located between the top of the O-cell™ and the top of the shaft. Telltale movements were measured by LVDTs at the top of the shaft. The top of shaft movement was monitored by two LVDTs attached to a reference beam. The reference beam consisted of a 14 inch by 40 foot H-beam. The beam was supported at each end by dunnage placed perpendicular to the reference beam. The beam was fully protected (covered) by a tarp over a frame.

Both a Bourdon-type pressure gage (0-10,000 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-type pressure gage for calculations and the transducer as a check. All checks were acceptable.

A pressure vs. load calibration of the O-cell™ was carried out to 3050 kips (13.6 MN) by American Equipment and Fabricating Corporation prior to delivery to the test site. (See Appendix B)

Two levels of four sister bar vibrating wire strain gages were installed in the shaft above the base of the O-cell™. 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 and below the Osterberg cell. The strain gages were positioned as directed by the Kansas Department of Transportation.

The construction of the shaft included placing two lines of PVC pipe, starting at the top-of-shaft and terminating at the top of the bottom plate to vent the void created at the break in the shaft between upward and downward movement It also provides access for any final grouting to close the crack after completing the testing.

Note: The loads applied by the O-cell™ act in two opposing directions, resisted by side shear above the O-cell™ and by side shear and/or end bearing 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 cells' calibrations. Net load is defined as 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 the equivalent top load curve for top loaded compression shafts. In addition, the buoyant weight of the shaft above the O-cell™ assembly is subtracted a second time, since in a top load test, the applied load is equal to the soil resistance less the buoyant weight of the shaft. For this test we calculated a buoyant weight of 153.2 kips (0.68 MN).

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 unload the pressure and then begin the test. The loads and movements reported herein follow the unreported but small movements (less than 0.003 inches) associated with the above preliminary weld-breaking load-unload cycle, which in this case involved a maximum applied O-cell™ pressure of 1500 psi (10.4 MPa).

The Osterberg cell load test was conducted as follows: The 26 inch (660 mm) diameter O-cell™, with its base located 0.38 feet (0.12 meters) above the base of shaft was pressurized to assess the combined end bearing and lower side shear below the O-cell™ and the upper side shear above the O-cell™. The O-cell™ was pressurized in 20 loading increments to 10000 psi (69.0 Mpa) resulting in a bi-directional load of 3660 kips (16.3 MN). The loading was halted after load interval 1L-20 because the O-cell™ had exceeded its load capacity. The O-cell™ was unloaded and then reloaded in 5 loading increments to a bi-directional O-cell™ load of 2930 kips (13.0 MN) at 2L-5 in order to demonstrate that no significant weakening of the shaft occurred as a result of the load test.

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 one minute to move between increments. The data logger automatically recorded the instrument readings every 30 seconds, but herein we report only the 1, 2 and 4 minute readings during each increment of maintained load. The various plotted results generally use the four minute readings, but the creep results use the difference between the two and four minute readings.

DISCUSSION OF RESULTS

Side Shear: The maximum net load applied to the side shear was 3,510 kips (15.6 MN) which occurred at load interval 1L-20 (Table 1 and 4, Figure 1). At this loading, the total upward movement of the top of O-cell™ was 0.201 inches (5.1 mm). The following section provides net unit side shear estimates based on strain gage data.

Strain Gage Results: The strain gage data appear in Table 7. At the time of testing, the concrete unconfined compressive strength was reported to be 5,620 psi (38.7 Mpa). We used the ACI formula (Ec=57000√f'c) to calculate an elastic modulus for the concrete. This, combined with the area of reinforcing steel, was used to determine a weighted shaft modulus of 4,920 ksi (33,900 Mpa) in the 72 inch(1829 mm) diameter shaft. Estimated net unit side shear values for the shaft based on the strain gage data, estimated shaft modulus and shaft area are as follows for 1L-20:

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

Load Transfer Zone	Net Unit Side Shear
Estimated Zero Shear (EL+997.7 ft.) to Strain Gage Level 2	7.38 ksf (476 kPa)
Strain Gage Level 2 to Strain Gage Level 1 APC 8.51	8.19 ksf (392 kPa)
Strain Gage Level 1 to O-cell™	9.95 ksf (476 kPa)

Note: Net unit shear values derived from the strain gages above the O-cell™ may not be ultimate values. See Figure E1 for unit shear vs. displacement plots.

Side shear load distribution curves generated from strain gage data are shown in Figure 2. A unit side shear value for the shaft between the Level 1 Strain Gages and the O-cell™ was calculated for 1L-20 to obtain an estimate of the side shear component of resistance to the downward movement below the O-cell™.

End Bearing: The maximum O-cell™ load applied to the base of the shaft was 3,660 kips (16.3 MN) which occurred at load interval 1L-20 (Table 6, Figure 1). At this loading, the total downward movement of the O-cell™ base was 0.675 inches (17.1 mm). The side shear load applied to the 0.38 feet (0.12 meter) shaft section below the O-cell™ is calculated to be 71.3 kips (0.32 MN) assuming a unit side shear value of 9.95 ksf (476 kPa) and a shaft diameter of 72 inches (1829 mm). The maximum applied load to end bearing is then 3590 kips (16.0 MN) and the unit end-bearing pressure applied at the base of the shaft is calculated to be 127 ksf (6,080 kPa).

Creep Limit: See Appendix D for our O-cell™ method for determining creep limit. The side shear creep data (Table 4) indicate that no creep limit was reached at a movement of 0.201 inches (5.1 mm) (Figure 4). The combined end bearing and lower side shear creep data (Table 6) indicate that a creep limit of 2700 kips (12.0 MN) may have been reached at a movement of 0.35 inches (8.9 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 5350 kips (23.8 MN) by some unknown amount.

Equivalent Top Load: Figure 3 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 is 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 7330 kips (32.6 MN). For a top loading of 5000 kips (22.2 MN), the adjusted test data indicate this shaft would settle approximately 0.20 inches (5.1 mm) of which 0.056 inches (1.42 mm) is estimated elastic compression. The equivalent top load curve is shown in Figure 3.

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 in Figure 3.

Shaft Compression Telltales: The measured maximum shaft compression, averaged from 2 telltales, is 0.015 inches (0.38 mm). Using the nominal 72 inch (1830 mm) shaft diameter and a shaft modulus of 4,920 ksi (33,900 MPa) for the shaft and the load distribution in Figure 2, we calculated an elastic compression of 0.020 inches (0.53 mm) over the length of the compression telltales. We believe this fair agreement provides some evidence that the assumed shaft moduli are reasonable.

O-cell™ Tilting: The three LVWDTs measuring O-cell™ expansion allow us to evaluate the tilt of the bottom plate. Table 5 shows these measurements. We calculate a maximum tilt angle of 0.4 degrees and a total tilt of 0.50 inches (12.7 mm) across the nominal 72 inch (1830 mm) diameter of the bottom of the shaft at the 1L-20 maximum loading, assuming only the bottom plate tilts.

Need to Grout O-cell™: Sinse this shaft tested is intended to carry structural loading (a "production shaft"), the contractor needs to fill the void in the shaft created by the expansion of the O-cell™ and the resultant horizontal breaking of the shaft. The shaft includes the piping to permit filling the O-cell™ and void with grout. If not already grouted, we recommend that this be done as soon as possible. See Appendix G.

The analysis provided 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/her own conclusions with regard to the analytical information.

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

Robert C. Simpson, M.S.E.,
Project Manager

Reviewed by

William Ryan
Project Manager

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

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

Shaft:

Nominal shaft diameter: EL+1008.85 to EL+974.85	=	72 inches	1828.8 mm
O-cell™ size: (9056-15)	=	26 inches	660 mm
Length of concrete from break at base of cell to zero shear	=	33.6 feet	10.2 meters
Length of concrete from break at base of cell to tip	=	0.38 feet	0.12 meters
Shaft shear area from break at base of lower cell to tip	=	7.2 $feet^2$	0.67 $meters^2$
Shaft end area	=	28.3 $feet^2$	2.63 $meters^2$
Weight of concrete from break at base of cell to tip	=	153.2 kips	0.68 MN
Estimated shaft unit stiffness (AE): EL+1008.9 to EL+997.7	=	1.98E+07 kips	88.0 GN
Estimated shaft unit stiffness (AE): EL+997.7 to EL+974.9	=	2.00E+07 kips	89.1 GN
Elevation of top of shaft concrete	=	+1008.9 feet	+307.5 meters
Elevation of ground surface	=	+1013.9 feet	+309.0 meters
Elevation of break at base of lower cell		+975.2 feet	+297.3 meters
Elevation of shaft tip	=	+974.9 feet	+297.1 meters

Casings:

Elevation of top of inner permanent casing: 72 O.D.	=	+1013.9 feet	+309.0 meters
Elevation of bottom of inner permanent casing: 72 O.D.	=	+997.7 feet	+304.1 meters

Compression Sections:

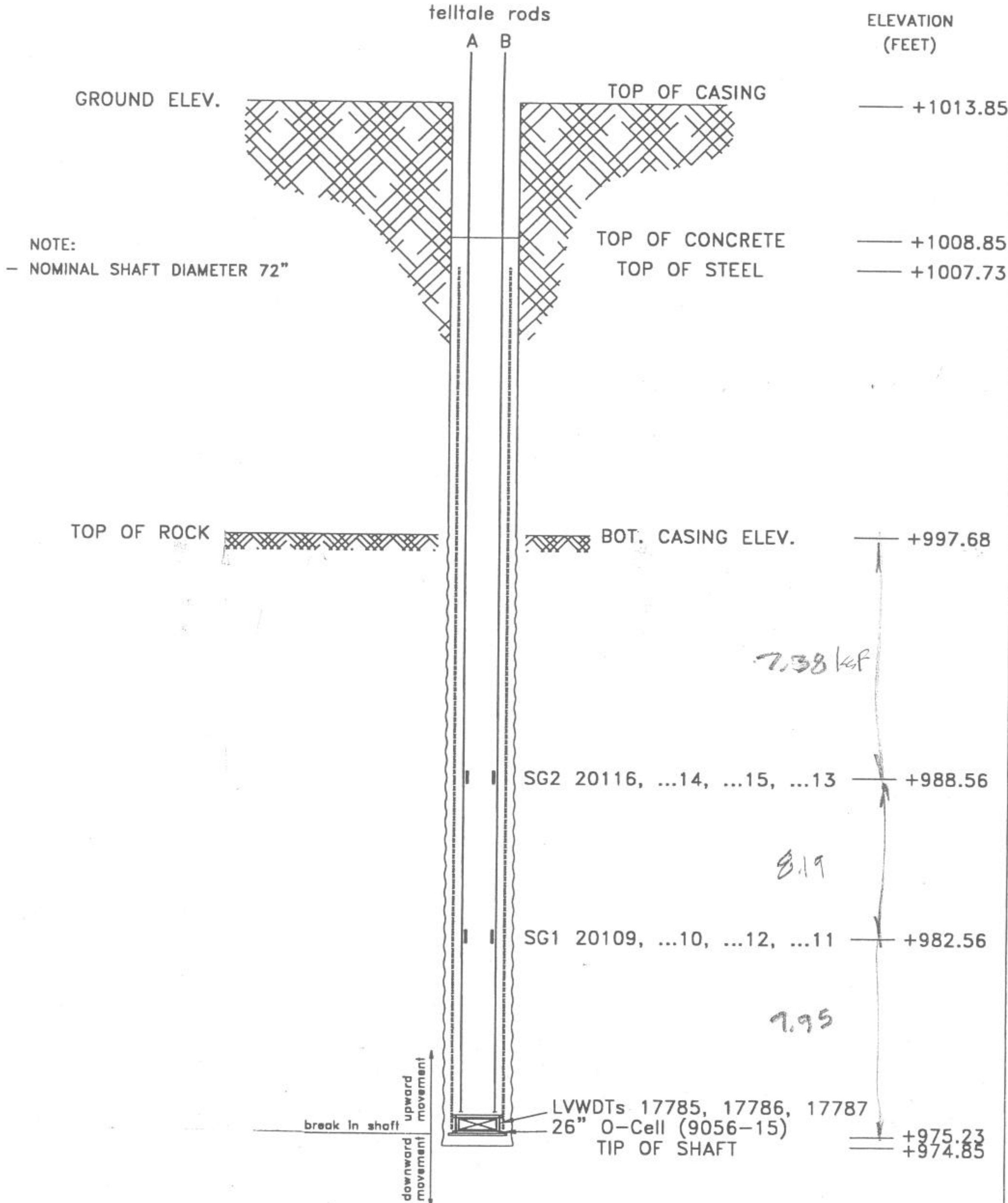
Elevation of top of telltale used for shaft compression	=	+1011.9 feet	+308.4 meters
Elevation of bottom of telltale used for shaft compression	=	+976.6 feet	+297.7 meters

Strain Gages:

Elevation of strain gage Level 2	=	+988.6 feet	+301.3 meters
Elevation of strain gage Level 1	=	+982.6 feet	+299.5 meters

Miscellaneous:

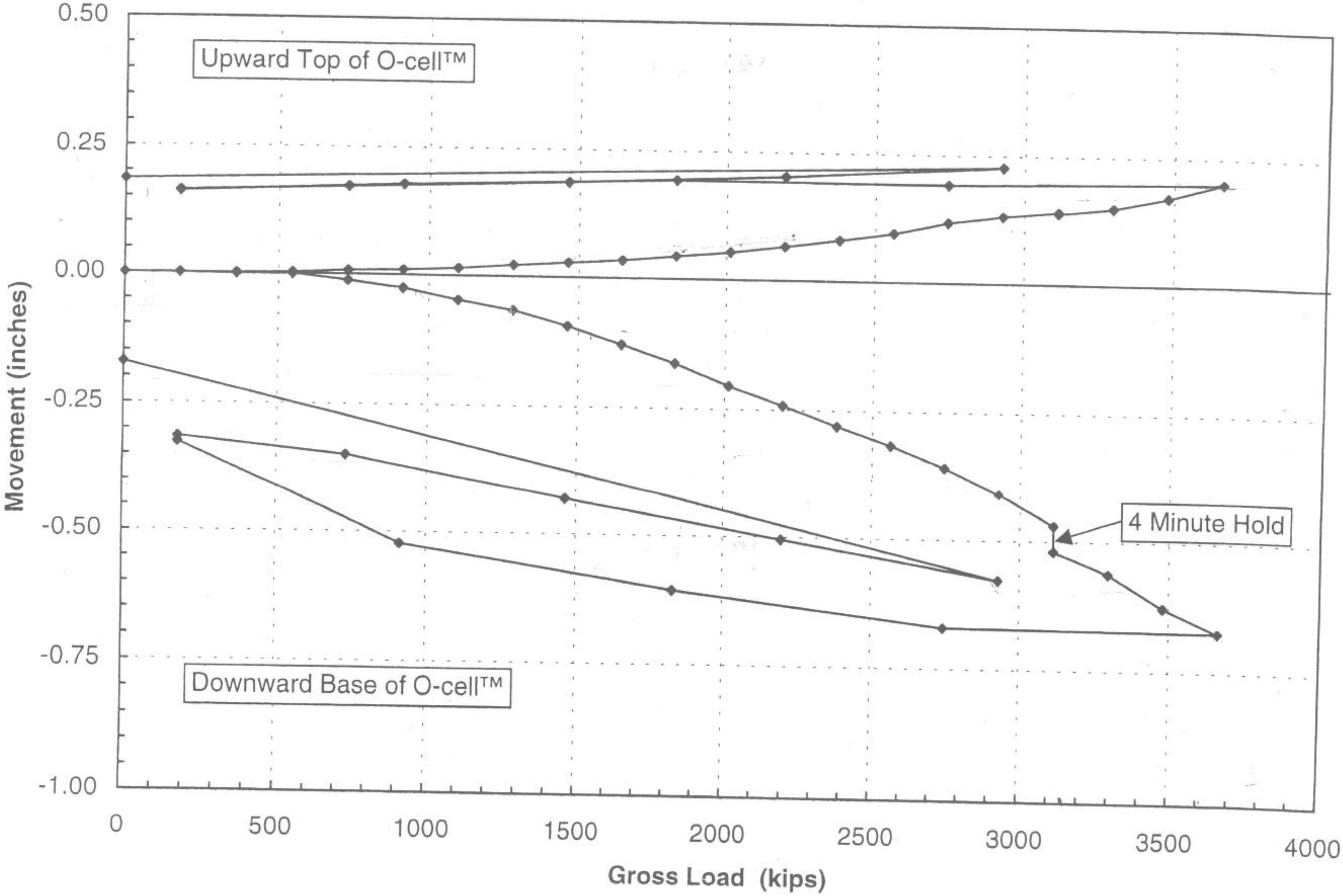
Top plate diameter	=	55.8 inches	1416 mm
Top plate thickness	=	2.0 inches	50.8 mm
Bottom plate diameter	=	60.0 inches	1524 mm
Bottom plate thickness	=	2.0 inches	50.8 mm
Water elevation	=	+60.0 feet	+18.3 meters
LVWDT radii	=	29.0 inches	736.6 mm
LVWDT orientation	=	0, 180, 90	degrees
Vertical re-bar size	=	# 10	#32
Hoop re-bar size	=	# 5	#16
Number of vertical bars	=	33	



LOADTEST INC.	2631-D NW 41st St. Gainesville, FL 32606 Phone 800-368-1138 FAX (352) 378-3934	SCHEMATIC SECTION OF TEST SHAFT	LT-8733 US 75 77th Street Topeka, Kansas FIGURE A

Osterberg Cell Load-Movement Curves

US 75 at 77th Street - Topeka, KS - Pier 1 West



LOADTEST, Inc. Project No. LT-8733

Figure 1 of 5

Strain Gage Load Distribution Curves

US 75 at 77th Street - Topeka, KS - Pier 1 West

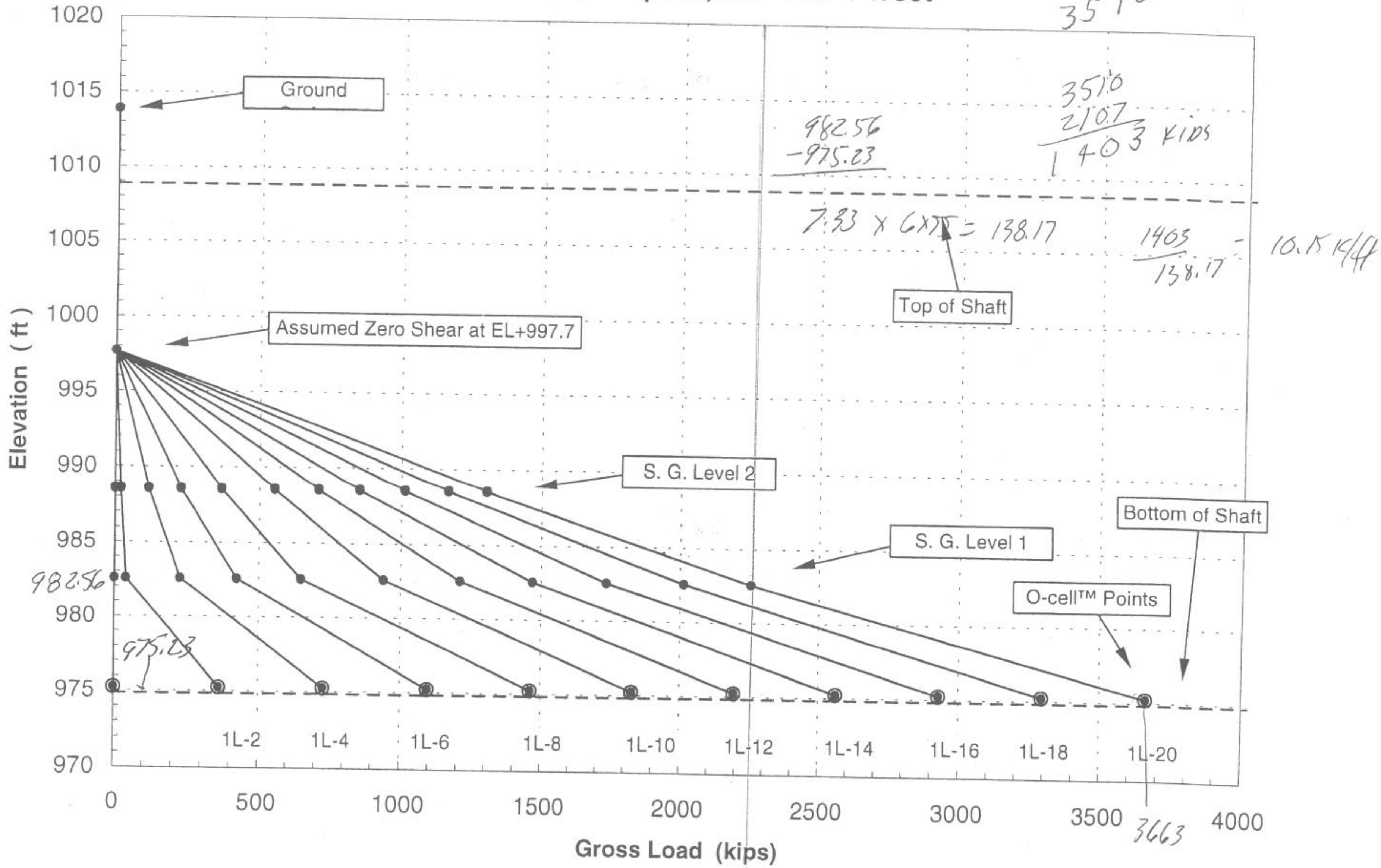


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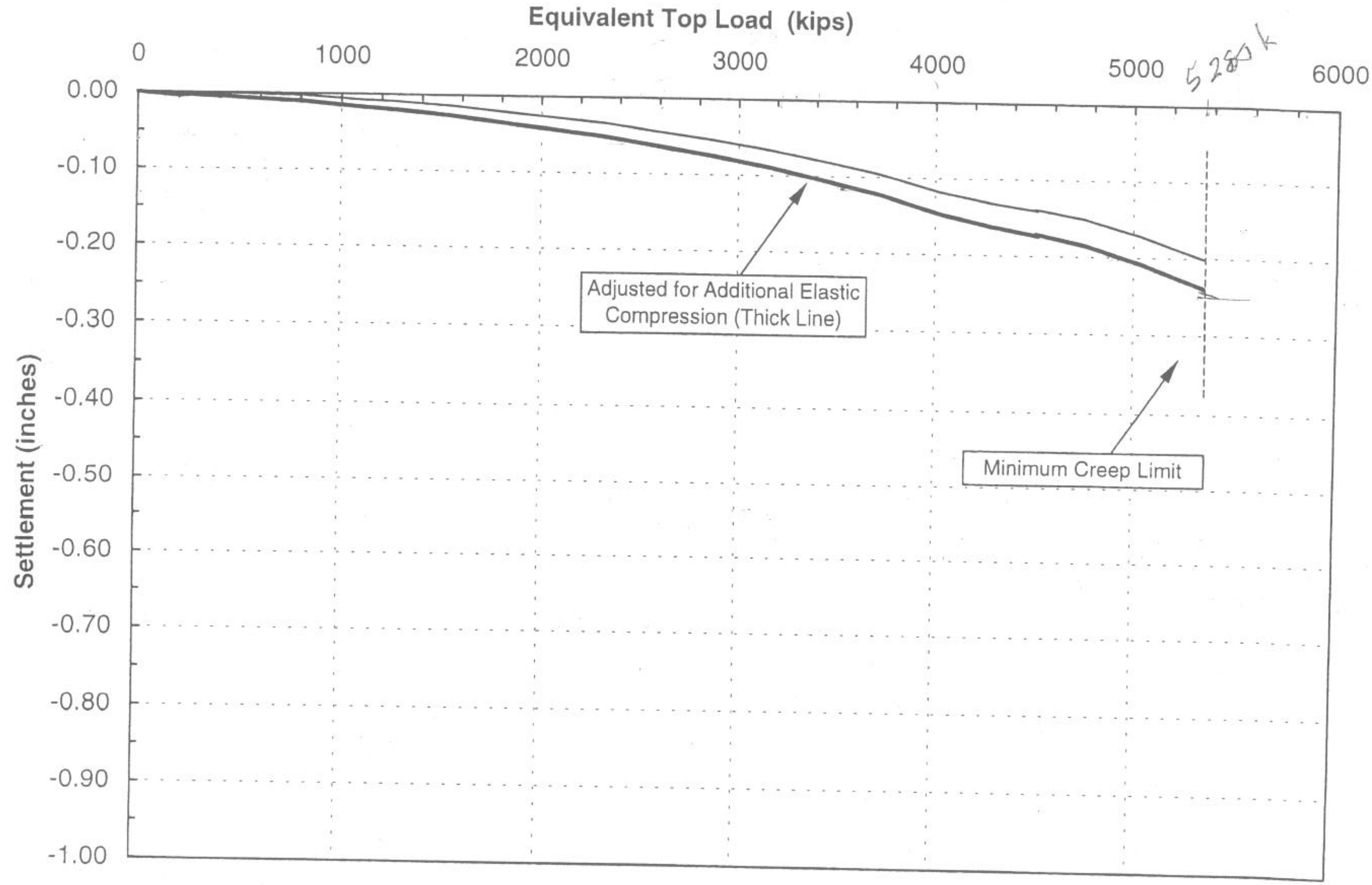
Figure 2 of 5

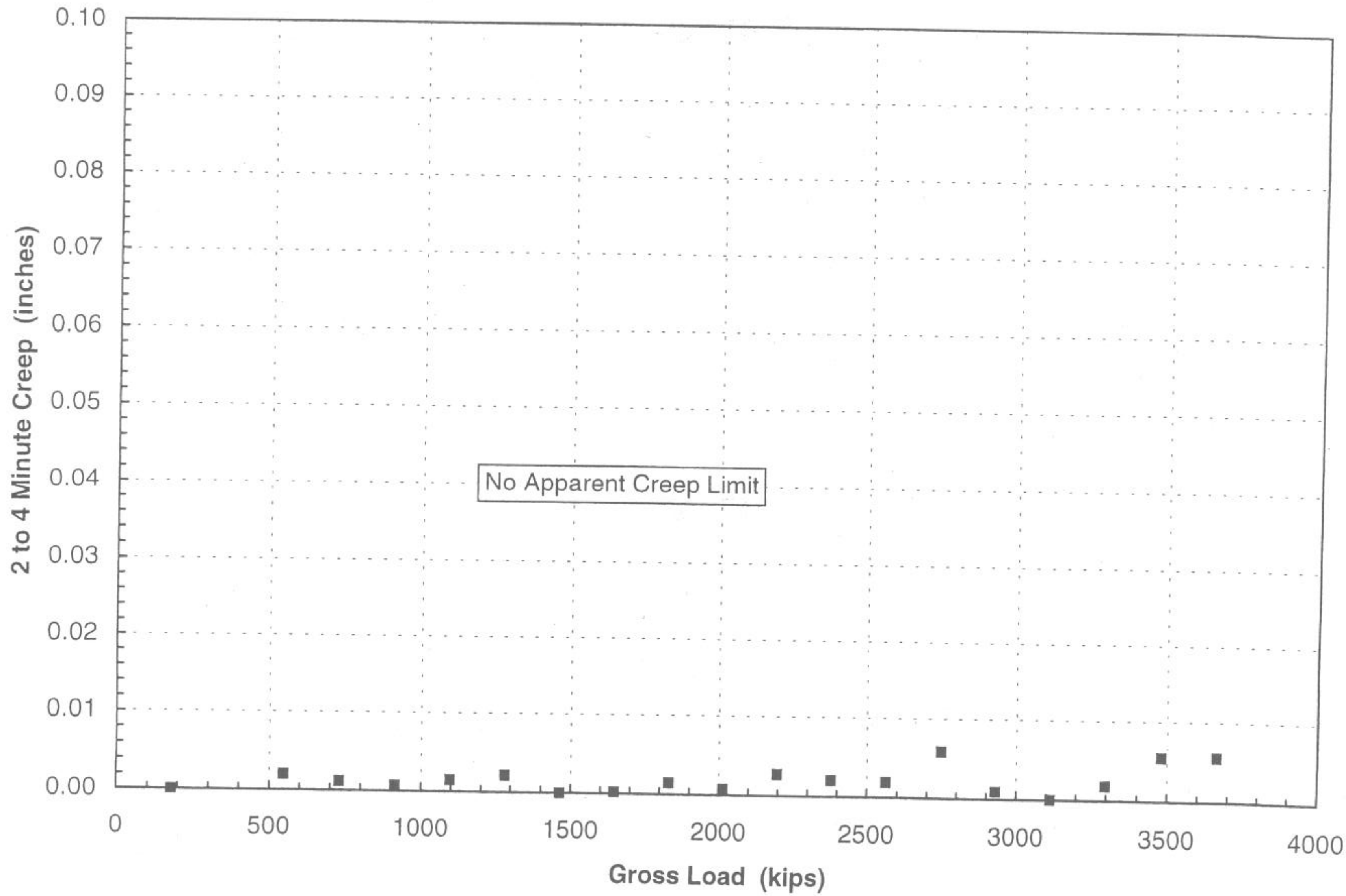
Equivalent Top Load-Movement Curves

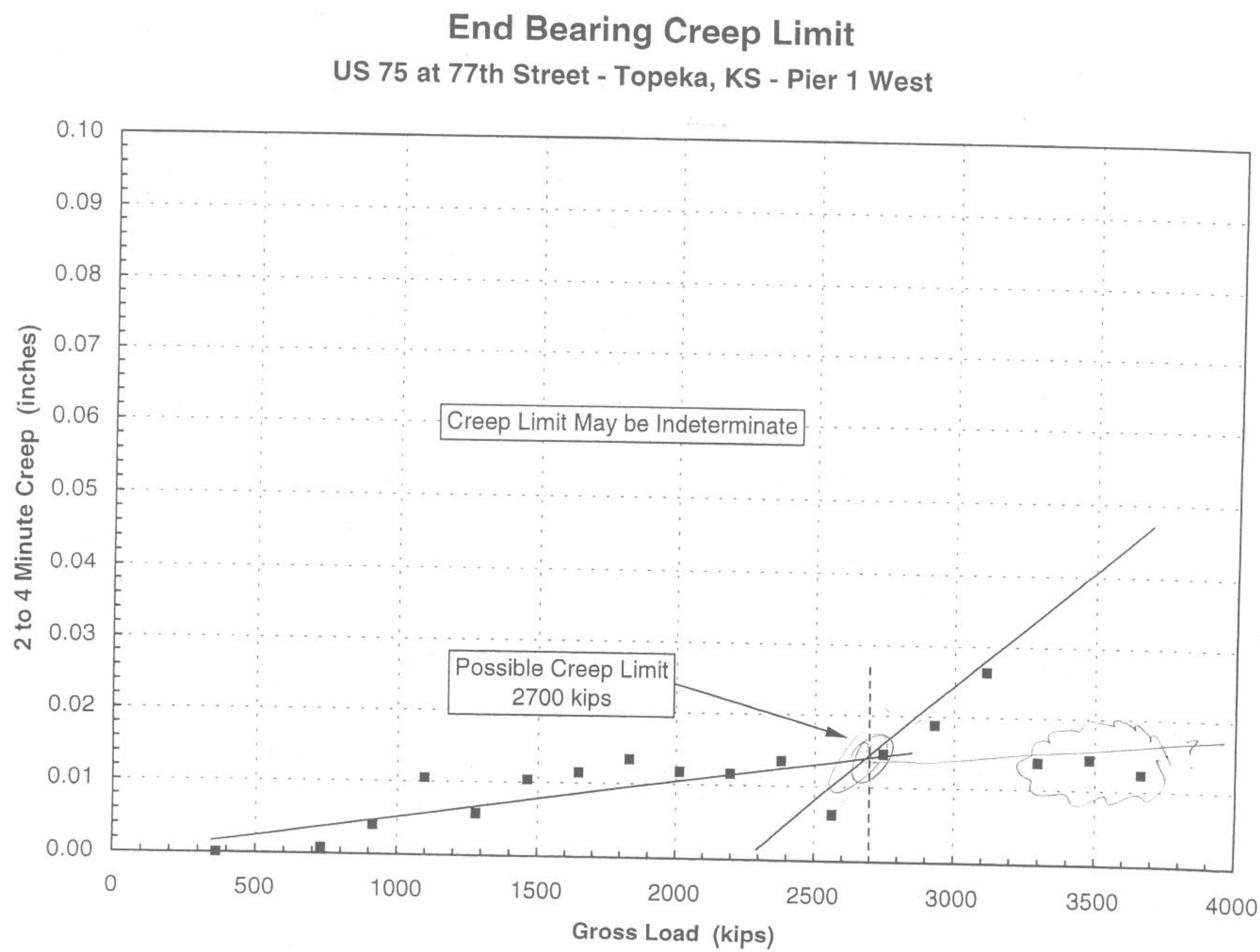
US 75 at 77th Street - Topeka, KS - Pier 1 West



Side Shear Creep Limit

US 75 at 77th Street - Topeka, KS - Pier 1 West





LOADTEST, Inc. Project No. LT-8733

Figure 5 of 5

APPENDIX A

FIELD DATA & DATA REDUCTION

Gross and Net O-cell™ Loads
US 75 at 77th Street - Topeka, KS

Load Test	Time	Pressure	Gross O-cell™ Load			Gross Load	Net Load
		O-cells™	Pos. A1	Pos. B1	Pos. C1	O-cells™	
Increment	(h:m:s)	(psi)	(kips)	(kips)	(kips)	(kips)	(kips)
1L -0	10:47:00	0	0	0	0	0	0
1L -1	10:49:00	500	179	0	0	179	26
1L -2	10:53:00	1000	363	0	0	363	209
1L -3	10:57:00	1500	546	0	0	546	393
1L -4	11:01:00	2000	729	0	0	729	576
1L -5	11:05:00	2500	913	0	0	913	759
1L -6	11:09:00	3000	1096	0	0	1,096	943
1L -7	11:13:00	3500	1279	0	0	1,279	1126
1L -8	11:17:00	4000	1463	0	0	1,463	1309
1L -9	11:21:00	4500	1646	0	0	1,646	1493
1L -10	11:25:00	5000	1829	0	0	1,829	1676
1L -11	11:29:00	5500	2013	0	0	2,013	1860
1L -12	11:33:00	6000	2196	0	0	2,196	2043
1L -13	11:37:00	6500	2379	0	0	2,379	2226
1L -14	11:41:00	7000	2563	0	0	2,563	2410
1L -15	11:44:00	7500	2746	0	0	2,746	2593
1L -16	11:48:00	8000	2930	0	0	2,930	2776
1L -17	11:52:00	8500	3113	0	0	3,113	2960
1H-17	11:57:30	8500	3113	0	0	3,113	2960
1L-18	12:01:30	9000	3296	0	0	3,296	3143
1L-19	12:09:00	9500	3480	0	0	3,480	3326
1L-20	12:15:00	10000	3663	0	0	3,663	3510
1U-1	12:19:00	7500	2746	0	0	2,746	2593
1U-2	12:28:00	5000	1829	0	0	1,829	1676
1U-3	12:32:00	2500	913	0	0	913	759
1U-4	12:38:00	500	179	0	0	179	26
2L-1	12:42:00	500	179	0	0	179	26
2L-2	12:48:00	2000	729	0	0	729	576
2L-3	12:54:00	4000	1463	0	0	1,463	1309
2L-4	13:00:00	6000	2196	0	0	2,196	2043
2L-5	13:06:00	8000	2930	0	0	2,930	2776
2U-1	13:10:30	0	0	0	0	0	0

-153K

Upward Top of Shaft Movement
US 75 at 77th Street - Topeka, KS

Load Test Increment	Time	O-cell™ Pressure	Applied Load	TOS Indicator A Readings			TOS Indicator B Readings			Average Top of Shaft		
				1 min	2 min	4 min	1 min	2 min	4 min	1 min	2 min	4 min
	(h:m:s)	(psi)	(kips)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)
1 L - 0	10:47:00	0	0	0.0000			0.0000			0.0000		
1 L - 1	10:49:00	500	179	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1 L - 2	10:53:00	1,000	363	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1 L - 3	10:57:00	1,500	546	0.0000	0.0000	0.0034	0.0000	0.0000	0.0007	0.0000	0.0000	0.0020
1 L - 4	11:01:00	2,000	729	0.0048	0.0054	0.0061	0.0026	0.0040	0.0054	0.0037	0.0047	0.0057
1 L - 5	11:05:00	2,500	913	0.0076	0.0073	0.0077	0.0069	0.0066	0.0073	0.0072	0.0070	0.0075
1 L - 6	11:09:00	3,000	1,096	0.0099	0.0109	0.0119	0.0087	0.0095	0.0112	0.0093	0.0102	0.0115
1 L - 7	11:13:00	3,500	1,279	0.0144	0.0155	0.0166	0.0149	0.0163	0.0194	0.0147	0.0159	0.0180
1 L - 8	11:17:00	4,000	1,463	0.0211	0.0218	0.0217	0.0246	0.0251	0.0250	0.0229	0.0235	0.0234
1 L - 9	11:21:00	4,500	1,646	0.0258	0.0259	0.0258	0.0293	0.0300	0.0304	0.0275	0.0280	0.0281
1 L - 10	11:25:00	5,000	1,829	0.0324	0.0334	0.0347	0.0368	0.0374	0.0386	0.0346	0.0354	0.0366
1 L - 11	11:29:00	5,500	2,013	0.0428	0.0433	0.0448	0.0454	0.0461	0.0460	0.0441	0.0447	0.0454
1 L - 12	11:33:00	6,000	2,196	0.0529	0.0548	0.0574	0.0534	0.0549	0.0578	0.0532	0.0548	0.0576
1 L - 13	11:37:00	6,500	2,379	0.0663	0.0688	0.0710	0.0662	0.0683	0.0700	0.0663	0.0685	0.0705
1 L - 14	11:41:00	7,000	2,563	0.0802	0.0836	0.0856	0.0788	0.0819	0.0834	0.0795	0.0827	0.0845
1 L - 15	11:44:00	7,500	2,746	0.0977	0.1013	0.1065	0.0954	0.0999	0.1064	0.0966	0.1006	0.1065
1 L - 16	11:48:00	8,000	2,930	0.1164	0.1191	0.1205	0.1164	0.1181	0.1188	0.1164	0.1186	0.1196
1 L - 17	11:52:00	8,500	3,113	0.1285	0.1305	0.1306	0.1261	0.1271	0.1269	0.1273	0.1288	0.1288
1 H- 17	11:57:30	8,500	3,113	0.1315	0.1281	0.1261	0.1285	0.1256	0.1246	0.1300	0.1269	0.1253
1 L- 18	12:01:30	9,000	3,296	0.1331	0.1352	0.1389	0.1328	0.1357	0.1363	0.1330	0.1354	0.1376
1 L- 19	12:09:00	9,500	3,480	0.1493	0.1531	0.1567	0.1491	0.1529	0.1607	0.1492	0.1530	0.1587
1 L- 20	12:15:00	10,000	3,663	0.1744	0.1793	0.1851	0.1782	0.1819	0.1873	0.1763	0.1806	0.1862
1 U- 1	12:19:00	7,500	2,746	0.1793			0.1810			0.1802		
1 U- 2	12:28:00	5,000	1,829	0.1779	0.1792	0.1812	0.1831	0.1848	0.1875	0.1805	0.1820	0.1843
1 U- 3	12:32:00	2,500	913	0.1699	0.1695	0.1695	0.1755	0.1753	0.1753	0.1727	0.1724	0.1724
1 U- 4	12:38:00	500	179	0.1562	0.1553	0.1552	0.1615	0.1606	0.1609	0.1589	0.1580	0.1581
2 L- 1	12:42:00	500	179	0.1560	0.1563	0.1579	0.1616	0.1620	0.1619	0.1588	0.1592	0.1599
2 L- 2	12:48:00	2,000	729	0.1640	0.1640	0.1651	0.1695	0.1705	0.1718	0.1668	0.1672	0.1684
2 L- 3	12:54:00	4,000	1,463	0.1745	0.1755	0.1762	0.1807	0.1828	0.1830	0.1776	0.1792	0.1796
2 L- 4	13:00:00	6,000	2,196	0.1841	0.1854	0.1844	0.1951	0.1976	0.2044	0.1896	0.1915	0.1944
2 L- 5	13:06:00	8,000	2,930	0.1971	0.2006	0.2026	0.2251	0.2256	0.2303	0.2111	0.2131	0.2164
2 U- 1	13:10:30	0	0	0.1694	0.1666	0.1677	0.1974	0.1961	0.1961	0.1834	0.1813	0.1819

Shaft Compression
US 75 at 77th Street - Topeka, KS

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Applied Load (kips)	Compression A Readings 1 min (inches)	Compression A Readings 2 min (inches)	Compression A Readings 4 min (inches)	Compression B Readings 1 min (inches)	Compression B Readings 2 min (inches)	Compression B Readings 4 min (inches)	Average Compression 1 min (inches)	Average Compression 2 min (inches)	Average Compression 4 min (inches)
1 L - 0	10:47:00	0	0	0.0000			0.0000			0.0000		
1 L - 1	10:49:00	500	179	-0.0004	-0.0003	-0.0002	0.0006	0.0005	0.0006	0.0001	0.0001	0.0002
1 L - 2	10:53:00	1,000	363	-0.0003	-0.0002	-0.0002	0.0007	0.0005	0.0005	0.0002	0.0002	0.0001
1 L - 3	10:57:00	1,500	546	0.0000	-0.0001	-0.0004	0.0008	0.0008	0.0011	0.0004	0.0004	0.0003
1 L - 4	11:01:00	2,000	729	0.0007	0.0012	0.0016	0.0020	0.0017	0.0015	0.0013	0.0014	0.0015
1 L - 5	11:05:00	2,500	913	0.0019	0.0017	0.0009	0.0022	0.0023	0.0036	0.0021	0.0020	0.0022
1 L - 6	11:09:00	3,000	1,096	0.0025	0.0031	0.0031	0.0029	0.0026	0.0028	0.0027	0.0029	0.0030
1 L - 7	11:13:00	3,500	1,279	0.0040	0.0041	0.0047	0.0034	0.0034	0.0029	0.0037	0.0037	0.0038
1 L - 8	11:17:00	4,000	1,463	0.0071	0.0071	0.0068	0.0023	0.0023	0.0029	0.0047	0.0047	0.0049
1 L - 9	11:21:00	4,500	1,646	0.0077	0.0076	0.0075	0.0038	0.0041	0.0043	0.0057	0.0059	0.0059
1 L - 10	11:25:00	5,000	1,829	0.0081	0.0081	0.0075	0.0059	0.0061	0.0070	0.0070	0.0071	0.0073
1 L - 11	11:29:00	5,500	2,013	0.0082	0.0083	0.0081	0.0083	0.0083	0.0085	0.0082	0.0083	0.0083
1 L - 12	11:33:00	6,000	2,196	0.0090	0.0090	0.0090	0.0090	0.0093	0.0093	0.0090	0.0091	0.0091
1 L - 13	11:37:00	6,500	2,379	0.0096	0.0096	0.0096	0.0104	0.0104	0.0106	0.0100	0.0100	0.0101
1 L - 14	11:41:00	7,000	2,563	0.0105	0.0105	0.0104	0.0114	0.0114	0.0118	0.0109	0.0110	0.0111
1 L - 15	11:44:00	7,500	2,746	0.0107	0.0106	0.0106	0.0127	0.0127	0.0127	0.0117	0.0116	0.0117
1 L - 16	11:48:00	8,000	2,930	0.0110	0.0110	0.0108	0.0136	0.0135	0.0135	0.0123	0.0123	0.0122
1 L - 17	11:52:00	8,500	3,113	0.0113	0.0111	0.0113	0.0145	0.0146	0.0146	0.0129	0.0129	0.0129
1 H- 17	11:57:30	8,500	3,113	0.0107	0.0107	0.0107	0.0148	0.0144	0.0173	0.0128	0.0125	0.0140
1 L- 18	12:01:30	9,000	3,296	0.0116	0.0116	0.0119	0.0170	0.0156	0.0149	0.0143	0.0136	0.0134
1 L- 19	12:09:00	9,500	3,480	0.0117	0.0096	0.0108	0.0161	0.0189	0.0173	0.0139	0.0143	0.0141
1 L- 20	12:15:00	10,000	3,663	0.0109	0.0110	0.0108	0.0184	0.0185	0.0187	0.0147	0.0148	0.0148
1 U- 1	12:19:00	7,500	2,746	0.0079			0.0164			0.0121		
1 U- 2	12:28:00	5,000	1,829	0.0033	0.0027	0.0037	0.0140	0.0149	0.0133	0.0086	0.0088	0.0085
1 U- 3	12:32:00	2,500	913	0.0000	0.0038	0.0038	0.0111	0.0064	0.0064	0.0056	0.0051	0.0051
1 U- 4	12:38:00	500	179	-0.0024	-0.0032	-0.0043	0.0081	0.0086	0.0097	0.0029	0.0027	0.0027
2 L- 1	12:42:00	500	179	-0.0036	-0.0039	-0.0037	0.0088	0.0092	0.0087	0.0026	0.0026	0.0025
2 L- 2	12:48:00	2,000	729	0.0000	-0.0006	-0.0005	0.0073	0.0079	0.0078	0.0036	0.0037	0.0037
2 L- 3	12:54:00	4,000	1,463	0.0018	0.0016	0.0013	0.0100	0.0106	0.0111	0.0059	0.0061	0.0062
2 L- 4	13:00:00	6,000	2,196	0.0042	0.0048	0.0062	0.0131	0.0127	0.0110	0.0086	0.0087	0.0086
2 L- 5	13:06:00	8,000	2,930	0.0106	0.0112	0.0126	0.0120	0.0114	0.0098	0.0113	0.0113	0.0112
2 U- 1	13:10:30	0	0	0.0029	0.0032	0.0050	0.0008	0.0000	-0.0019	0.0018	0.0016	0.0016

Upward Top of Lower O-cell™ Movement (calculated)
US 75 at 77th Street - Topeka, KS

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Applied Load (kips)	Top of Shaft (tbl 2) 1 min (inches)	Top of Shaft (tbl 2) 2 min (inches)	Top of Shaft (tbl 2) 4 min (inches)	Total Comp (tbl 3) 1 min (inches)	Total Comp (tbl 3) 2 min (inches)	Total Comp (tbl 3) 4 min (inches)	Top of O-cell™ 1 min (inches)	Top of O-cell™ 2 min (inches)	Top of O-cell™ 4 min (inches)	Creep 2-4 min (inches)
1 L - 0	10:47:00	0	0	0.0000			0.0000			0.0000			
1 L - 1	10:49:00	500	179	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0001	0.0001	0.0002	0.0001
1 L - 2	10:53:00	1,000	363	0.0000	0.0000	0.0000	0.0002	0.0002	0.0001	0.0002	0.0002	0.0001	0.0000
1 L - 3	10:57:00	1,500	546	0.0000	0.0000	0.0020	0.0004	0.0004	0.0003	0.0004	0.0004	0.0024	0.0020
1 L - 4	11:01:00	2,000	729	0.0037	0.0047	0.0057	0.0013	0.0014	0.0015	0.0050	0.0061	0.0072	0.0012
1 L - 5	11:05:00	2,500	913	0.0072	0.0070	0.0075	0.0021	0.0020	0.0022	0.0093	0.0090	0.0097	0.0007
1 L - 6	11:09:00	3,000	1,096	0.0093	0.0102	0.0115	0.0027	0.0029	0.0030	0.0120	0.0130	0.0145	0.0015
1 L - 7	11:13:00	3,500	1,279	0.0147	0.0159	0.0180	0.0037	0.0037	0.0038	0.0184	0.0196	0.0218	0.0022
1 L - 8	11:17:00	4,000	1,463	0.0229	0.0235	0.0234	0.0047	0.0047	0.0049	0.0275	0.0282	0.0282	0.0000
1 L - 9	11:21:00	4,500	1,646	0.0275	0.0280	0.0281	0.0057	0.0059	0.0059	0.0333	0.0338	0.0340	0.0002
1 L - 10	11:25:00	5,000	1,829	0.0346	0.0354	0.0366	0.0070	0.0071	0.0073	0.0416	0.0425	0.0439	0.0015
1 L - 11	11:29:00	5,500	2,013	0.0441	0.0447	0.0454	0.0082	0.0083	0.0083	0.0523	0.0530	0.0537	0.0007
1 L - 12	11:33:00	6,000	2,196	0.0532	0.0548	0.0576	0.0090	0.0091	0.0091	0.0622	0.0640	0.0667	0.0028
1 L - 13	11:37:00	6,500	2,379	0.0663	0.0685	0.0705	0.0100	0.0100	0.0101	0.0763	0.0786	0.0806	0.0021
1 L - 14	11:41:00	7,000	2,563	0.0795	0.0827	0.0845	0.0109	0.0110	0.0111	0.0904	0.0937	0.0956	0.0019
1 L - 15	11:44:00	7,500	2,746	0.0966	0.1006	0.1065	0.0117	0.0116	0.0117	0.1083	0.1122	0.1181	0.0059
1 L - 16	11:48:00	8,000	2,930	0.1164	0.1186	0.1196	0.0123	0.0123	0.0122	0.1287	0.1308	0.1318	0.0010
1 L - 17	11:52:00	8,500	3,113	0.1273	0.1288	0.1288	0.0129	0.0129	0.0129	0.1402	0.1416	0.1417	0.0001
1 H- 17	11:57:30	8,500	3,113	0.1300	0.1269	0.1253	0.0128	0.0125	0.0140	0.1427	0.1394	0.1393	
1 L- 18	12:01:30	9,000	3,296	0.1330	0.1354	0.1376	0.0143	0.0136	0.0134	0.1473	0.1490	0.1509	0.0019
1 L- 19	12:09:00	9,500	3,480	0.1492	0.1530	0.1587	0.0139	0.0143	0.0141	0.1631	0.1673	0.1728	0.0055
1 L- 20	12:15:00	10,000	3,663	0.1763	0.1806	0.1862	0.0147	0.0148	0.0148	0.1910	0.1953	0.2010	0.0056
1 U- 1	12:19:00	7,500	2,746	0.1802			0.0121			0.1923			
1 U- 2	12:28:00	5,000	1,829	0.1805	0.1820	0.1843	0.0086	0.0088	0.0085	0.1891	0.1908	0.1929	
1 U- 3	12:32:00	2,500	913	0.1727	0.1724	0.1724	0.0056	0.0051	0.0051	0.1782	0.1775	0.1775	
1 U- 4	12:38:00	500	179	0.1589	0.1580	0.1581	0.0029	0.0027	0.0027	0.1617	0.1606	0.1608	
2 L- 1	12:42:00	500	179	0.1588	0.1592	0.1599	0.0026	0.0026	0.0025	0.1614	0.1618	0.1624	
2 L- 2	12:48:00	2,000	729	0.1668	0.1672	0.1684	0.0036	0.0037	0.0037	0.1704	0.1709	0.1721	
2 L- 3	12:54:00	4,000	1,463	0.1776	0.1792	0.1796	0.0059	0.0061	0.0062	0.1835	0.1853	0.1858	
2 L- 4	13:00:00	6,000	2,196	0.1896	0.1915	0.1944	0.0086	0.0087	0.0086	0.1983	0.2002	0.2030	
2 L- 5	13:06:00	8,000	2,930	0.2111	0.2131	0.2164	0.0113	0.0113	0.0112	0.2224	0.2244	0.2276	
2 U- 1	13:10:30	0	0	0.1834	0.1813	0.1819	0.0018	0.0016	0.0016	0.1852	0.1829	0.1835	

O-cell™ Expansion
US 75 at 77th Street - Topeka, KS

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Applied Load (kips)	LVWDT 17785 1 min (inches)	LVWDT 17785 2 min (inches)	LVWDT 17785 4 min (inches)	LVWDT 15882 1 min (inches)	LVWDT 15882 2 min (inches)	LVWDT 15882 4 min (inches)	LVWDT 15882* 1 min (inches)	LVWDT 15882* 2 min (inches)	LVWDT 15882* 4 min (inches)	Average Expansion 1 min (inches)	Average Expansion 2 min (inches)	Average Expansion 4 min (inches)
1 L - 0	10:47:00	0	0	0.0000			0.0000			0.0000			0.0000		
1 L - 1	10:49:00	500	179	0.0005	0.0005	0.0005	0.0005	0.0007	0.0007	0.0007	0.0007	0.0006	0.0005	0.0006	0.0006
1 L - 2	10:53:00	1,000	363	0.0011	0.0012	0.0012	0.0013	0.0015	0.0015	0.0019	0.0018	0.0019	0.0012	0.0013	0.0013
1 L - 3	10:57:00	1,500	546	0.0025	0.0027	0.0033	0.0027	0.0029	0.0034	0.0037	0.0042	0.0052	0.0026	0.0028	0.0033
1 L - 4	11:01:00	2,000	729	0.0098	0.0260	0.0267	0.0078	0.0097	0.0129	0.0165	0.0196	0.0231	0.0088	0.0179	0.0198
1 L - 5	11:05:00	2,500	913	0.0364	0.0399	0.0449	0.0189	0.0218	0.0263	0.0328	0.0357	0.0398	0.0276	0.0308	0.0356
1 L - 6	11:09:00	3,000	1,096	0.0575	0.0619	0.0703	0.0344	0.0391	0.0547	0.0501	0.0537	0.0625	0.0459	0.0505	0.0625
1 L - 7	11:13:00	3,500	1,279	0.0875	0.0931	0.1017	0.0631	0.0675	0.0746	0.0756	0.0814	0.0889	0.0753	0.0803	0.0881
1 L - 8	11:17:00	4,000	1,463	0.1213	0.1278	0.1381	0.0943	0.0998	0.1104	0.1046	0.1098	0.1178	0.1078	0.1138	0.1242
1 L - 9	11:21:00	4,500	1,646	0.1607	0.1680	0.1793	0.1289	0.1359	0.1481	0.1355	0.1413	0.1496	0.1448	0.1520	0.1637
1 L - 10	11:25:00	5,000	1,829	0.2062	0.2111	0.2263	0.1708	0.1752	0.1899	0.1709	0.1743	0.1850	0.1885	0.1931	0.2081
1 L - 11	11:29:00	5,500	2,013	0.2587	0.2685	0.2819	0.2171	0.2254	0.2371	0.2088	0.2135	0.2302	0.2379	0.2469	0.2595
1 L - 12	11:33:00	6,000	2,196	0.3101	0.3209	0.3363	0.2607	0.2676	0.2810	0.2465	0.2529	0.2624	0.2854	0.2943	0.3087
1 L - 13	11:37:00	6,500	2,379	0.3660	0.3778	0.3955	0.3030	0.3130	0.3266	0.2851	0.2927	0.3039	0.3345	0.3454	0.3611
1 L - 14	11:41:00	7,000	2,563	0.4282	0.4415	0.4506	0.3446	0.3665	0.3736	0.3280	0.3365	0.3421	0.3864	0.4040	0.4121
1 L - 15	11:44:00	7,500	2,746	0.4830	0.5006	0.5222	0.4008	0.4107	0.4303	0.3678	0.3778	0.3924	0.4419	0.4557	0.4763
1 L - 16	11:48:00	8,000	2,930	0.5539	0.5710	0.5925	0.4603	0.4707	0.4888	0.4149	0.4309	0.4420	0.5071	0.5208	0.5406
1 L - 17	11:52:00	8,500	3,113	0.6269	0.6416	0.6708	0.5189	0.5283	0.5520	0.4642	0.4789	0.4943	0.5729	0.5849	0.6114
1 H- 17	11:57:30	8,500	3,113	0.6961	0.7006	0.7238	0.5761	0.5766	0.5931	0.5110	0.5140	0.5351	0.6361	0.6386	0.6584
1 L- 18	12:01:30	9,000	3,296	0.7493	0.7640	0.7837	0.6158	0.6320	0.6438	0.5499	0.5564	0.5811	0.6825	0.6980	0.7138
1 L- 19	12:09:00	9,500	3,480	0.8418	0.8559	0.8768	0.6953	0.7035	0.7224	0.6177	0.6269	0.6403	0.7685	0.7797	0.7996
1 L- 20	12:15:00	10,000	3,663	0.9326	0.9460	0.9688	0.7651	0.7693	0.7826	0.6767	0.6844	0.6980	0.8488	0.8577	0.8757
1 U- 1	12:19:00	7,500	2,746	0.9367			0.7917			0.6684			0.8642	0.8642	0.8642
1 U- 2	12:28:00	5,000	1,829	0.8796	0.8781	0.8749	0.7291	0.7291	0.7246	0.6217	0.6205	0.6177	0.8043	0.8036	0.7998
1 U- 3	12:32:00	2,500	913	0.7846	0.7749	0.7749	0.6377	0.6260	0.6260	0.5419	0.5293	0.5293	0.7112	0.7005	0.7005
1 U- 4	12:38:00	500	179	0.5948	0.5856	0.5767	0.4193	0.4065	0.3969	0.3614	0.3521	0.3437	0.5070	0.4960	0.4868
2 L- 1	12:42:00	500	179	0.5746	0.5735	0.5680	0.3969	0.3968	0.3874	0.3418	0.3408	0.3356	0.4857	0.4851	0.4777
2 L- 2	12:48:00	2,000	729	0.6156	0.6166	0.6170	0.4263	0.4262	0.4261	0.3859	0.3870	0.3875	0.5210	0.5214	0.5216
2 L- 3	12:54:00	4,000	1,463	0.6963	0.7025	0.7086	0.5150	0.5248	0.5255	0.4597	0.4629	0.4743	0.6056	0.6136	0.6170
2 L- 4	13:00:00	6,000	2,196	0.7871	0.7925	0.7978	0.6093	0.6163	0.6163	0.5384	0.5416	0.5456	0.6982	0.7044	0.7071
2 L- 5	13:06:00	8,000	2,930	0.8852	0.8913	0.9000	0.7008	0.7108	0.7104	0.6198	0.6248	0.6316	0.7930	0.8010	0.8052
2 U- 1	13:10:30	0	0	0.5187	0.4975	0.4784	0.2801	0.2535	0.2332	0.2618	0.2380	0.2168	0.3994	0.3755	0.3558

* LVWDT 15882 was a redundant gage and was used for tilt calculation only. Not used in average.

Downward Base of O-cell™ Movement (calculated)

US 75 at 77th Street - Topeka, KS

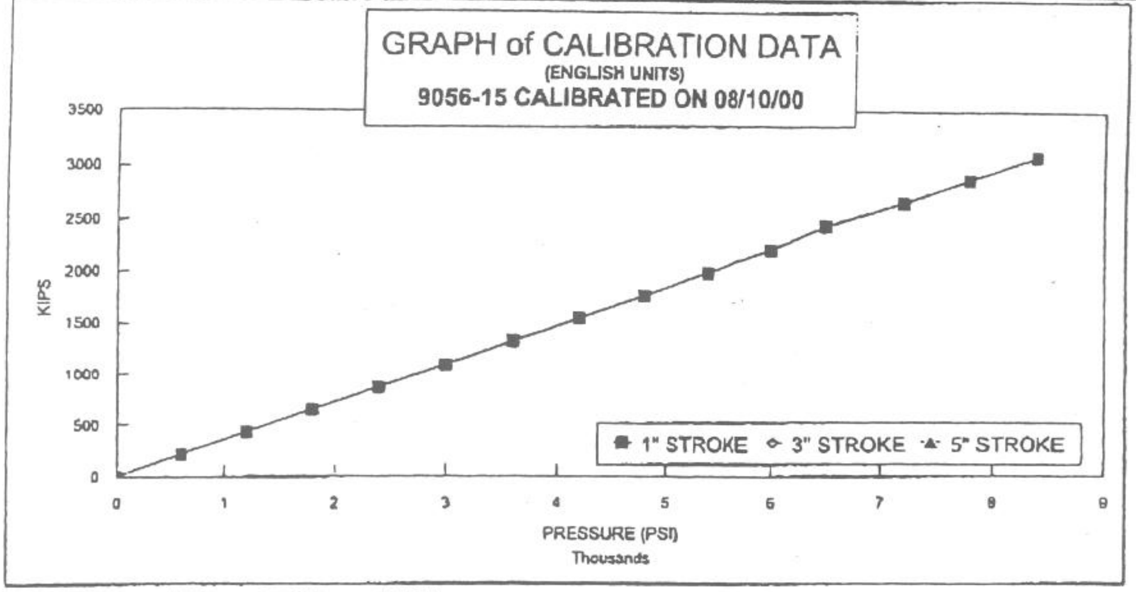
Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Applied Load (kips)	O-cell™ Exp. (tbl 5) 1 min (inches)	O-cell™ Exp. (tbl 5) 2 min (inches)	O-cell™ Exp. (tbl 5) 4 min (inches)	Upward Movement (tbl 4) 1 min (inches)	Upward Movement (tbl 4) 2 min (inches)	Upward Movement (tbl 4) 4 min (inches)	Downward Movement 1 min (inches)	Downward Movement 2 min (inches)	Downward Movement 4 min (inches)	Creep 2-4 min (inches)
1 L - 0	10:47:00	0	0	0.0000			0.0000			0.0000			
1 L - 1	10:49:00	500	179	0.0005	0.0006	0.0006	0.0001	0.0001	0.0002	0.0004	0.0005	0.0004	-0.0001
1 L , 2	10:53:00	1,000	363	0.0012	0.0013	0.0013	0.0002	0.0002	0.0001	0.0010	0.0012	0.0012	0.0000
1 L - 3	10:57:00	1,500	546	0.0026	0.0028	0.0033	0.0004	0.0004	0.0024	0.0022	0.0024	0.0010	-0.0015
1 L - 4	11:01:00	2,000	729	0.0088	0.0179	0.0198	0.0050	0.0061	0.0072	0.0038	0.0118	0.0126	0.0008
1 L - 5	11:05:00	2,500	913	0.0276	0.0308	0.0356	0.0093	0.0090	0.0097	0.0183	0.0218	0.0259	0.0040
1 L - 6	11:09:00	3,000	1,096	0.0459	0.0505	0.0625	0.0120	0.0130	0.0145	0.0340	0.0375	0.0480	0.0105
1 L - 7	11:13:00	3,500	1,279	0.0753	0.0803	0.0881	0.0184	0.0196	0.0218	0.0569	0.0607	0.0663	0.0057
1 L - 8	11:17:00	4,000	1,463	0.1078	0.1138	0.1242	0.0275	0.0282	0.0282	0.0802	0.0856	0.0960	0.0104
1 L - 9	11:21:00	4,500	1,646	0.1448	0.1520	0.1637	0.0333	0.0338	0.0340	0.1115	0.1181	0.1296	0.0115
1 L - 10	11:25:00	5,000	1,829	0.1885	0.1931	0.2081	0.0416	0.0425	0.0439	0.1468	0.1507	0.1641	0.0135
1 L - 11	11:29:00	5,500	2,013	0.2379	0.2469	0.2595	0.0523	0.0530	0.0537	0.1856	0.1940	0.2058	0.0118
1 L - 12	11:33:00	6,000	2,196	0.2854	0.2943	0.3087	0.0622	0.0640	0.0667	0.2232	0.2303	0.2420	0.0117
1 L - 13	11:37:00	6,500	2,379	0.3345	0.3454	0.3611	0.0763	0.0786	0.0806	0.2583	0.2668	0.2804	0.0136
1 L - 14	11:41:00	7,000	2,563	0.3864	0.4040	0.4121	0.0904	0.0937	0.0956	0.2960	0.3103	0.3165	0.0062
1 L - 15	11:44:00	7,500	2,746	0.4419	0.4557	0.4763	0.1083	0.1122	0.1181	0.3336	0.3434	0.3581	0.0147
1 L - 16	11:48:00	8,000	2,930	0.5071	0.5208	0.5406	0.1287	0.1308	0.1318	0.3783	0.3900	0.4088	0.0188
1 L - 17	11:52:00	8,500	3,113	0.5729	0.5849	0.6114	0.1402	0.1416	0.1417	0.4327	0.4433	0.4697	0.0264
1 H- 17	11:57:30	8,500	3,113	0.6361	0.6386	0.6584	0.1427	0.1394	0.1393	0.4934	0.4992	0.5191	
1 L- 18	12:01:30	9,000	3,296	0.6825	0.6980	0.7138	0.1473	0.1490	0.1509	0.5352	0.5490	0.5628	0.0139
1 L- 19	12:09:00	9,500	3,480	0.7685	0.7797	0.7996	0.1631	0.1673	0.1728	0.6054	0.6124	0.6268	0.0144
1 L- 20	12:15:00	10,000	3,663	0.8488	0.8577	0.8757	0.1910	0.1953	0.2010	0.6579	0.6623	0.6747	0.0124
1 U- 1	12:19:00	7,500	2,746	0.8642			0.1923			0.6719			
1 U- 2	12:28:00	5,000	1,829	0.8043	0.8036	0.7998	0.1891	0.1908	0.1929	0.6152	0.6128	0.6069	
1 U- 3	12:32:00	2,500	913	0.7112	0.7005	0.7005	0.1782	0.1775	0.1775	0.5329	0.5230	0.5230	
1 U- 4	12:38:00	500	179	0.5070	0.4960	0.4868	0.1617	0.1606	0.1608	0.3453	0.3354	0.3260	
2 L- 1	12:42:00	500	179	0.4857	0.4851	0.4777	0.1614	0.1618	0.1624	0.3243	0.3233	0.3153	
2 L- 2	12:48:00	2,000	729	0.5210	0.5214	0.5216	0.1704	0.1709	0.1721	0.3506	0.3505	0.3495	
2 L- 3	12:54:00	4,000	1,463	0.6056	0.6136	0.6170	0.1835	0.1853	0.1858	0.4221	0.4284	0.4313	
2 L- 4	13:00:00	6,000	2,196	0.6982	0.7044	0.7071	0.1983	0.2002	0.2030	0.5000	0.5042	0.5041	
2 L- 5	13:06:00	8,000	2,930	0.7930	0.8010	0.8052	0.2224	0.2244	0.2276	0.5706	0.5767	0.5776	
2 U- 1	13:10:30	0	0	0.3994	0.3755	0.3558	0.1852	0.1829	0.1835	0.2142	0.1926	0.1723	

Strain Gage Readings and Loads at Levels 1 and 2
US 75 at 77th Street - Topeka, KS

Load Test Incr.	Time	O-cell™ Pressure	Applied Load	Level 1					Level 2				
				20109	20110	20112	20111	Av. Load	20116	20114	20115	20113	Av. Load
	(h:m:s)	(psi)	(kips)	με	με	με	με	(kips)	με	με	με	με	(kips)
1 L - 0	10:47:00	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 L - 1	10:49:00	500	179	0.7	1.1	1.0	0.8	17.9	0.4	0.5	0.3	0.1	6.4
1 L - 2	10:53:00	1,000	363	1.9	2.4	2.1	1.6	39.9	1.0	1.0	0.9	1.1	19.7
1 L - 3	10:57:00	1,500	546	3.9	4.8	4.0	3.4	81.0	1.8	1.9	2.1	2.2	40.2
1 L - 4	11:01:00	2,000	729	11.9	12.8	10.3	10.2	226.2	5.1	5.9	6.2	5.8	115.1
1 L - 5	11:05:00	2,500	913	17.6	18.3	14.4	14.4	324.2	7.6	8.6	9.2	8.1	167.7
1 L - 6	11:09:00	3,000	1,096	22.7	23.6	18.8	19.2	422.4	10.4	11.6	12.2	11.1	227.0
1 L - 7	11:13:00	3,500	1,279	27.7	29.0	24.6	25.0	531.9	13.4	14.8	15.8	14.4	292.4
1 L - 8	11:17:00	4,000	1,463	32.1	32.4	32.1	33.0	648.8	16.8	17.7	20.0	19.0	368.1
1 L - 9	11:21:00	4,500	1,646	39.5	35.8	39.0	41.2	779.2	20.8	20.5	24.7	25.3	457.6
1 L - 10	11:25:00	5,000	1,829	47.3	43.0	47.4	49.9	939.7	24.9	24.0	30.2	31.3	552.8
1 L - 11	11:29:00	5,500	2,013	52.8	50.7	55.6	57.0	1082.4	28.2	27.5	35.3	35.0	631.3
1 L - 12	11:33:00	6,000	2,196	58.3	57.1	62.6	63.5	1209.7	31.2	31.2	40.1	39.0	708.7
1 L - 13	11:37:00	6,500	2,379	64.0	64.5	70.8	69.7	1347.5	34.2	35.3	45.3	42.7	788.5
1 L - 14	11:41:00	7,000	2,563	69.0	70.6	77.9	75.6	1467.9	36.8	38.9	49.6	44.9	852.4
1 L - 15	11:44:00	7,500	2,746	74.9	78.1	86.5	82.9	1614.6	39.9	43.6	55.0	49.0	938.9
1 L - 16	11:48:00	8,000	2,930	79.7	84.4	93.9	88.5	1735.3	42.3	47.5	59.5	52.7	1012.1
1 L - 17	11:52:00	8,500	3,113	85.0	91.2	102.3	95.1	1871.1	45.4	51.9	64.0	55.2	1084.6
1 H- 17	11:57:30	8,500	3,113	85.0	91.7	103.0	94.9	1875.9	45.0	52.1	64.0	54.3	1078.9
1 L- 18	12:01:30	9,000	3,296	90.3	97.3	110.8	103.6	2013.0	48.7	57.0	69.0	58.0	1165.6
1 L- 19	12:09:00	9,500	3,480	94.3	102.1	118.3	110.6	2130.3	51.2	60.4	73.0	60.5	1227.3
1 L- 20	12:15:00	10,000	3,663	98.4	107.9	126.6	117.4	2255.2	54.3	64.4	77.9	63.4	1302.2
1 U- 1	12:19:00	7,500	2,746	78.3	85.8	105.4	97.5	1838.1	45.2	55.5	69.1	54.8	1124.6
1 U- 2	12:28:00	5,000	1,829	52.3	59.3	80.3	72.6	1324.9	32.8	43.1	56.3	41.7	871.5
1 U- 3	12:32:00	2,500	913	27.8	34.4	55.3	49.2	834.5	21.4	32.1	45.2	32.0	655.0
1 U- 4	12:38:00	500	179	6.3	12.4	31.0	27.5	387.4	9.3	20.5	32.7	21.2	419.3
2 L- 1	12:42:00	500	179	6.0	12.1	30.7	27.3	381.2	8.9	19.8	32.6	21.3	414.2
2 L- 2	12:48:00	2,000	729	17.0	23.5	41.3	37.7	598.7	13.7	24.4	36.7	26.1	505.4
2 L- 3	12:54:00	4,000	1,463	35.7	42.7	59.2	55.0	964.5	22.0	32.6	45.4	34.4	673.0
2 L- 4	13:00:00	6,000	2,196	55.7	63.5	79.4	74.0	1364.5	31.6	41.8	54.7	43.1	857.3
2 L- 5	13:06:00	8,000	2,930	75.7	84.9	101.7	94.4	1786.0	42.5	52.0	64.7	51.5	1055.3
2 U- 1	13:10:30	0	0	1.8	7.4	25.1	22.4	284.0	6.2	17.2	28.8	18.6	354.3

APPENDIX B

CALIBRATION OF O-CELLS STRAIN GAGES AND LVWDT'S



STROKE:	1 INCH	3 INCH	5 INCH
PRESSURE PSI	LOAD KIPS	LOAD KIPS	LOAD KIPS
0	0	0	0
600	214	215	213
1200	433	433	433
1800	656	655	650
2400	879	876	871
3000	1099	1096	1092
3600	1321	1318	1312
4200	1539	1537	1533
4800	1758	1757	1754
5400	1979	1980	1972
6000	2197	2196	2189
6500	2419	2413	2410
7200	2636	2635	2629
7800	2851	2849	2842
8400	3064	3064	3060

26" O-CELL, SERIAL # 9056-15

LOAD CONVERSION FORMULA

LOAD = PRESSURE * 0.3667 + (-4.1)
{KIPS} (PSI)

Regression Output:

Constant	-4.085
X Coefficient	0.367
R Squared	1.000
No. of Observations	42
Degrees of Freedom	40
Std Err of Y Est	10.913
Std Err of X Coef.	0.001

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.	*CONTRACTOR: KING CONSTRUCTION CO.
*AE & FC JOB NO.: 1643	*JOB LOCATION: HESSTON, KS
*CUSTOMER P.O.NO.: LT-8733	*DATED: 01/09/01

SERVICE ENGINEER: G R Reef

DATE: 1/10/01

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

Vibrating Wire Displacement Transducer Calibration Report

Model Number: 4450-3-6

Range: 6"

Serial Number: 17785

Mfg. Number: 00-1170

Customer: Loadtest, Inc.

Temperature: 23.2 °C

Cust. I.D. #: n/a

Cal. Std. Control #(s): 124, 249, 406, 524

Job Number: 16400

Date of Calibration: January 02, 2001

Technician: KDB

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	3132	3128	3130		-0.18
1.200	4345	4342	4344	1214	0.04
2.400	5551	5550	5551	1207	0.16
3.600	6749	6746	6748	1197	0.10
4.800	7944	7943	7944	1196	0.03
6.000	9133	9132	9133	1189	-0.16

Calibration Factor (C): 0.0009998 (Inches/Digit)

Regression Zero: 3141

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B":* 5886

or

Position "F":* ________

Date: January 11, 2001

Temperature: 24.2 °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: 17786

Mfg. Number: 00-1171

Customer: Loadtest, Inc.

Temperature: 23.2 °C

Cust. I.D. #: n/a

Cal. Std. Control #(s): 124, 249, 406, 524

Job Number: 16400

Date of Calibration: January 02, 2001

Technician: KDB

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	2810	2810	2810		-0.18
1.200	4032	4032	4032	1222	0.07
2.400	5244	5242	5243	1211	0.14
3.600	6448	6446	6447	1204	0.10
4.800	7648	7648	7648	1201	0.01
6.000	8847	8845	8846	1198	-0.14

Calibration Factor (C): 0.0009945 (Inches/Digit)

Regression Zero: 2821

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B":* 5594

or

Position "F":* ________

Date: January 11, 2001

Temperature: 24.0 °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: 17787

Mfg. Number: 00-1172

Customer: Loadtest, Inc.

Temperature: 23.2 °C

Cust. I.D. #: n/a

Cal. Std. Control #(s): 124, 249, 406, 524

Job Number: 16400

Date of Calibration: January 02, 2001

Technician: KDB

Displacement (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.000	3205	3203	3204		-0.24
1.200	4411	4409	4410	1206	0.09
2.400	5603	5602	5603	1193	0.18
3.600	6787	6786	6787	1184	0.13
4.800	7969	7967	7968	1182	0.04
6.000	9142	9140	9141	1173	-0.20

Calibration Factor (C): 0.0010110 (Inches/Digit)

Regression Zero: 3218

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B":* 5892

or

Position "F":* ____

Date: January 11, 2001

Temperature: 23.9 °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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20109

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 21.8 °C

Calibration Date: January 11, 2001

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

Cable Length: 60 ft.

Factory Zero Reading: 6975

Regression Zero: 6976

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7024	7034	7029		
1,500	7704	7707	7706	677	-0.12
3,000	8439	8442	8441	735	-0.05
4,500	9176	9177	9177	736	0.05
6,000	9909	9910	9910	733	0.05
100	7035				

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

Gage Factor:

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20110

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 21.8 °C

Calibration Date: January 11, 2001

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

Cable Length: 60 ft.

Factory Zero Reading: 6746

Regression Zero: 6769

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	6836	6833	6835		
1,500	7510	7508	7509	675	-0.47
3,000	8267	8269	8268	759	-0.30
4,500	9035	9032	9034	766	0.08
6,000	9792	9791	9792	758	0.20
100	6834				

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

Gage Factor:

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20111

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.2 °C

Calibration Date: January 11, 2001

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

Cable Length: 50 ft.

Factory Zero Reading: 7286

Regression Zero: 7287

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7337	7342	7340		
1,500	8009	8007	8008	669	-0.17
3,000	8738	8737	8738	730	-0.05
4,500	9466	9470	9468	731	0.10
6,000	10191	10191	10191	723	0.00
100	7343				

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

Gage Factor:

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Calibration Date: January 11, 2001

Serial Number: 20112

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

Customer: Loadtest, Inc.

Cable Length: 50 ft.

Job Number: 16400

Factory Zero Reading: 6996

Cust. I.D. #: n/a

Regression Zero: 7009

Prestress: 35,000 psi

Technician: KOB

Temperature: 22.0 °C

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7067	7068	7068		
1,500	7741	7741	7741	674	-0.34
3,000	8489	8491	8490	749	-0.11
4,500	9237	9241	9239	749	0.13
6,000	9979	9979	9979	740	0.06
100	7068				

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

Gage Factor:

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20113

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.1 °C

Calibration Date: January 11, 2001

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

Cable Length: 40 ft.

Factory Zero Reading: 7142

Regression Zero: 7147

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7205	7203	7204		
1,500	7873	7871	7872	668	-0.27
3,000	8611	8612	8612	740	-0.05
4,500	9349	9351	9350	739	0.13
6,000	10082	10080	10081	731	0.06
100	7203				

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

Gage Factor:

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20114

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.0 °C

Calibration Date: January 11, 2001

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

Cable Length: 40 ft.

Factory Zero Reading: 7040

Regression Zero: 7051

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7114	7112	7113		
1,500	7789	7789	7789	676	-0.37
3,000	8543	8542	8543	754	-0.21
4,500	9300	9297	9299	756	0.02
6,000	10053	10052	10053	754	0.19
100	7113				

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 per cent

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20115

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.2 °C

Calibration Date: January 11, 2001

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

Cable Length: 30 ft.

Factory Zero Reading: 6966

Regression Zero: 6977

Technician: KDB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7029	7028	7029		
1,500	7710	7711	7711	682	-0.10
3,000	8453	8451	8452	742	0.08
4,500	9189	9186	9188	736	0.05
6,000	9923	9922	9923	735	0.01
100	7028				

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 per cent

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

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

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

Sister Bar Calibration Report

Model Number : 4911-4

Serial Number: 20116

Customer: Loadtest, Inc.

Job Number: 16400

Cust. I.D. #: n/a

Prestress: 35,000 psi

Temperature: 22.0 °C

Calibration Date: January 11, 2001

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

Cable Length: 30 ft.

Factory Zero Reading: 7145

Regression Zero: 7150

Technician: KOB

Applied Load: (pounds)	Readings				Linearity % Max.Load
	Cycle #1	Cycle #2	Average	Change	
100	7202	7205	7204		
1,500	7886	7872	7879	676	-0.10
3,000	8607	8610	8609	730	-0.18
4,500	9347	9348	9348	739	0.07
6,000	10079	10080	10080	732	0.07
100	7206				

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

Gage Factor:

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

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

Note: The above calibration uses the linear regression method.

Users are advised to establish their own zero conditions.

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

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

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

APPENDIX C

CONSTRUCTION OF EQUIVALENT TOP-LOADED CURVE

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

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

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

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

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

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

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

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

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

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

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

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

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

The attached analysis p. 6 gives the equations for the elastic compressions that occur in the OLT with one or two levels of O-cells™. Analysis p. 7 gives the equations for the elastic compressions that occur in the equivalent TLT. Both sets of equations do not include the elastic compression below the O-cell™ because the same compression takes place in both the OLT and the TLT. This is equivalent to taking $L_3 = 0$.

Subtracting the OLT from the TLT compression gives the desired additional elastic compression at the top of the TLT. We then add the additional elastic compression to the 'rigid' equivalent curve obtained from Part I to obtain the final, corrected equivalent load-settlement curve for the TLT on the same pile as the actual OLT.

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

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

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

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

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

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

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

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

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

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

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

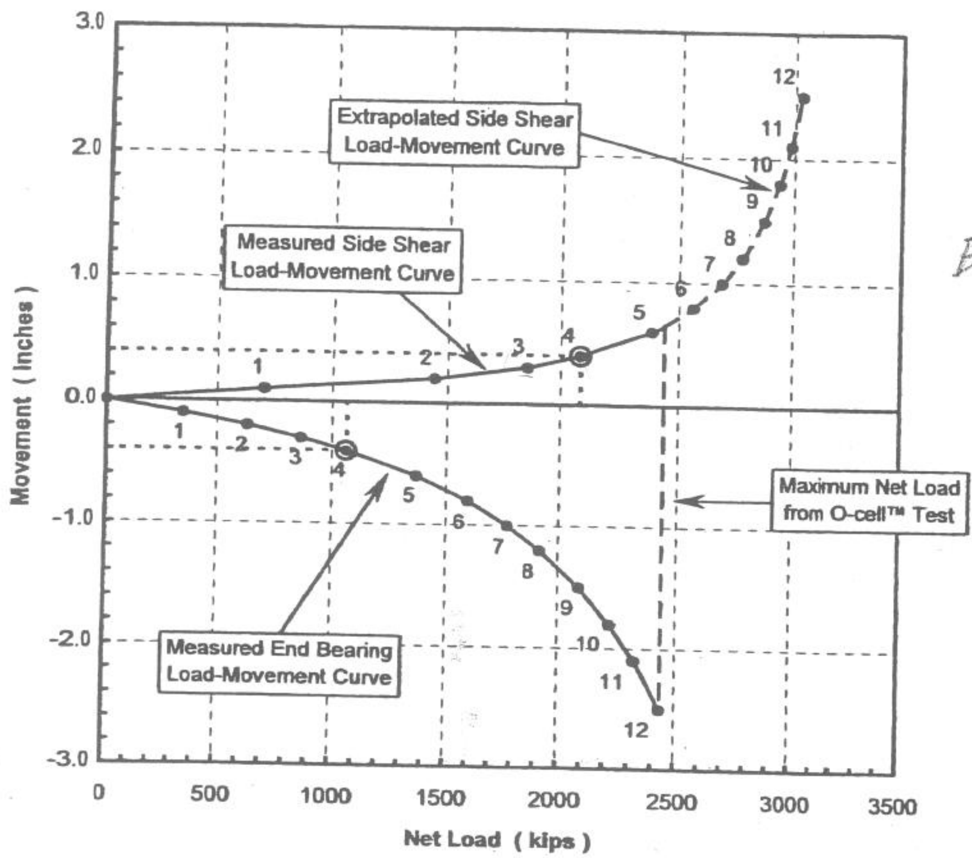
B. H. Fellenius has made several finite element method (FEM) studies of an OLT in which he adjusted the parameters to produce good load-deflection matches with the OLT up and down load-deflection curves. He then used the same parameters to predict the TLT deflection curve. We compared the FEM-predicted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

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

August, 2000

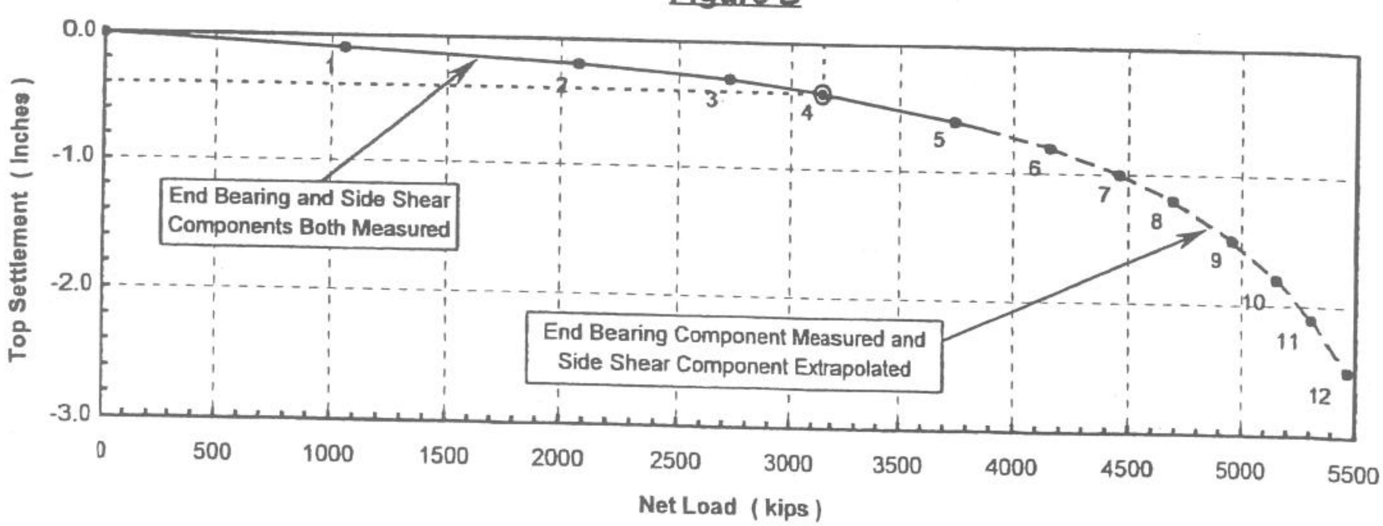
Example of the Construction of an Equivalent Top-Loaded Settlement Curve (Figure B) From Osterberg Cell Test Results (Figure A)

Figure A

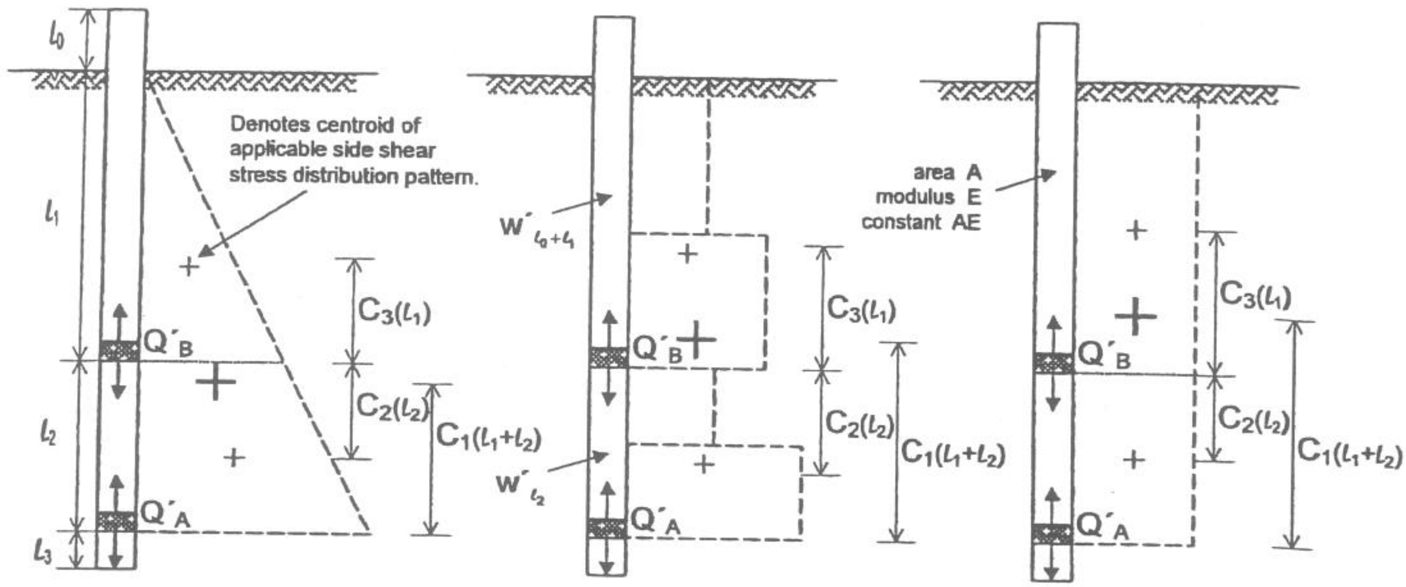


SF = 2100
End Brg = 1100
Σ = 3200 K

Figure B



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



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

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

3-Stage Multi Level Test (Q'_A and Q'_B): $\delta_{OLT} = \delta_{\uparrow\ell_1} + \delta_{\downarrow\ell_2}$

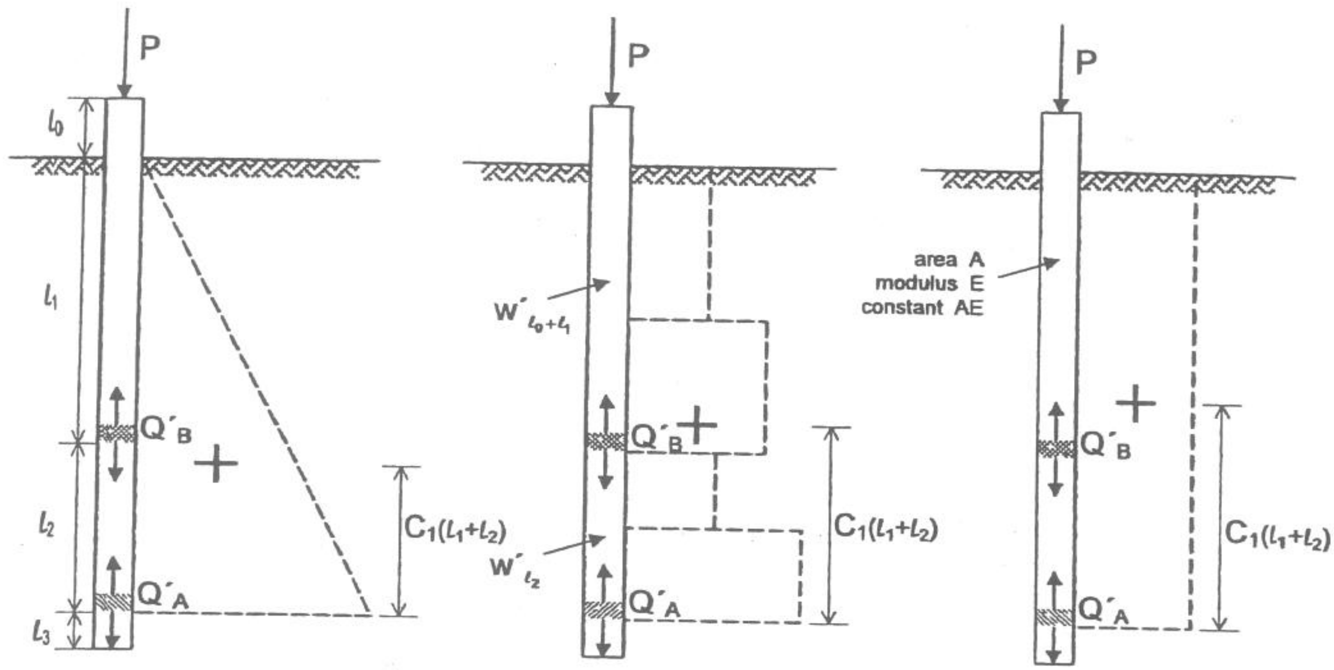
$C_3 = \dfrac{1}{3}$	$\text{Centroid Factor} = C_3$	$C_3 = \dfrac{1}{2}$
$\delta_{\uparrow\ell_1} = \dfrac{1}{3}\dfrac{Q'_{\uparrow B}\ell_1}{AE}$	$\delta_{\uparrow\ell_1} = C_3\dfrac{Q'_{\uparrow B}\ell_1}{AE}$	$\delta_{\uparrow\ell_1} = \dfrac{1}{3}\dfrac{Q'_{\uparrow B}\ell_1}{AE}$
$C_2 = \dfrac{1}{3}\left(\dfrac{3\ell_1+2\ell_2}{2\ell_1+\ell_2}\right)$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

Net Loads:

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

W' = pile weight, bouyant where below water table

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



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

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

Net and Equivalent Loads:

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

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

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

Given:

$C_1 =$ 0.441

$AE =$ 3820000 **kips** (assumed constant throughout test)

$l_0 =$ 5.9 ft

$l_1 =$ 48.2 ft (embedded length of shaft above O-cell™)

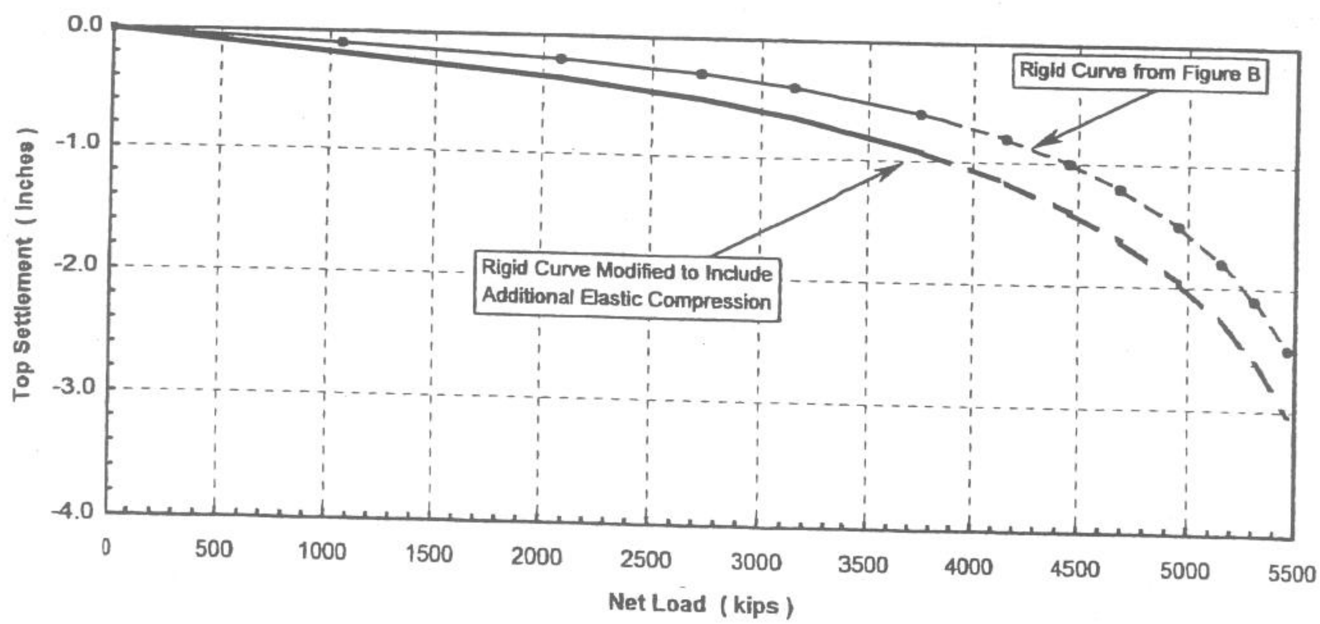
$l_2 =$ 0.0 ft

$l_3 =$ 0.0 ft

Shear reduction factor = 1.00 (cohesive soil)

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

Figure C



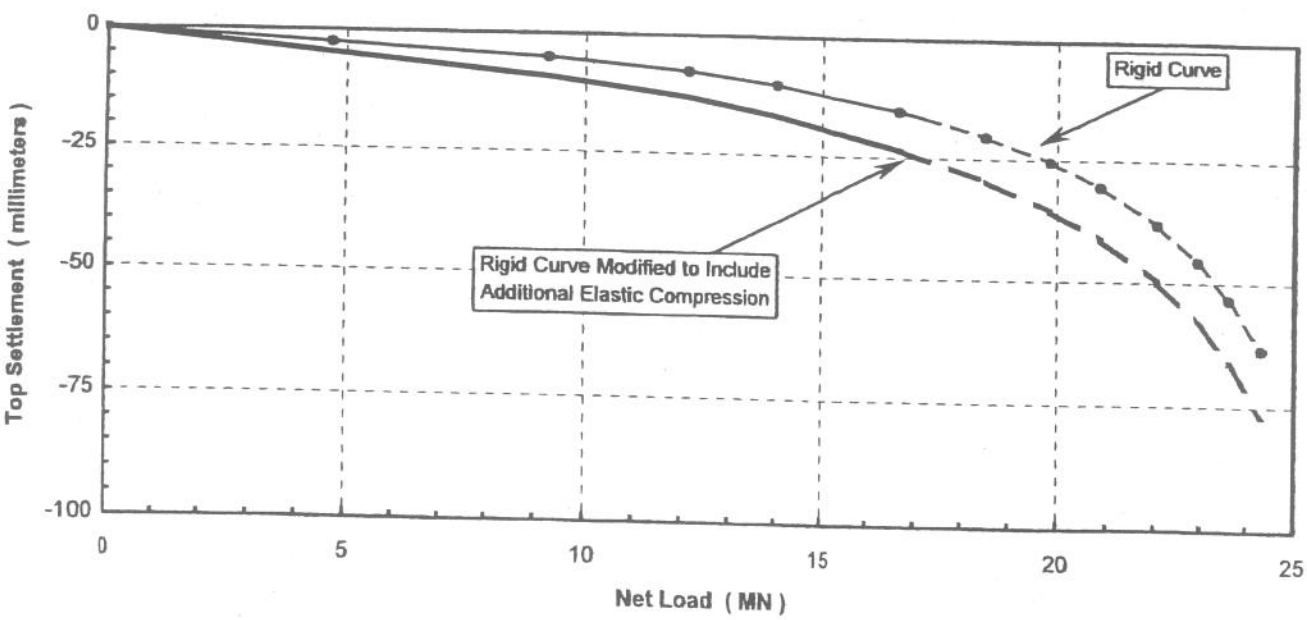
Example Calcuation for the Additional Elastic Compression Correction for Single Level Test (SI Units)

Given:

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

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

Figure D



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

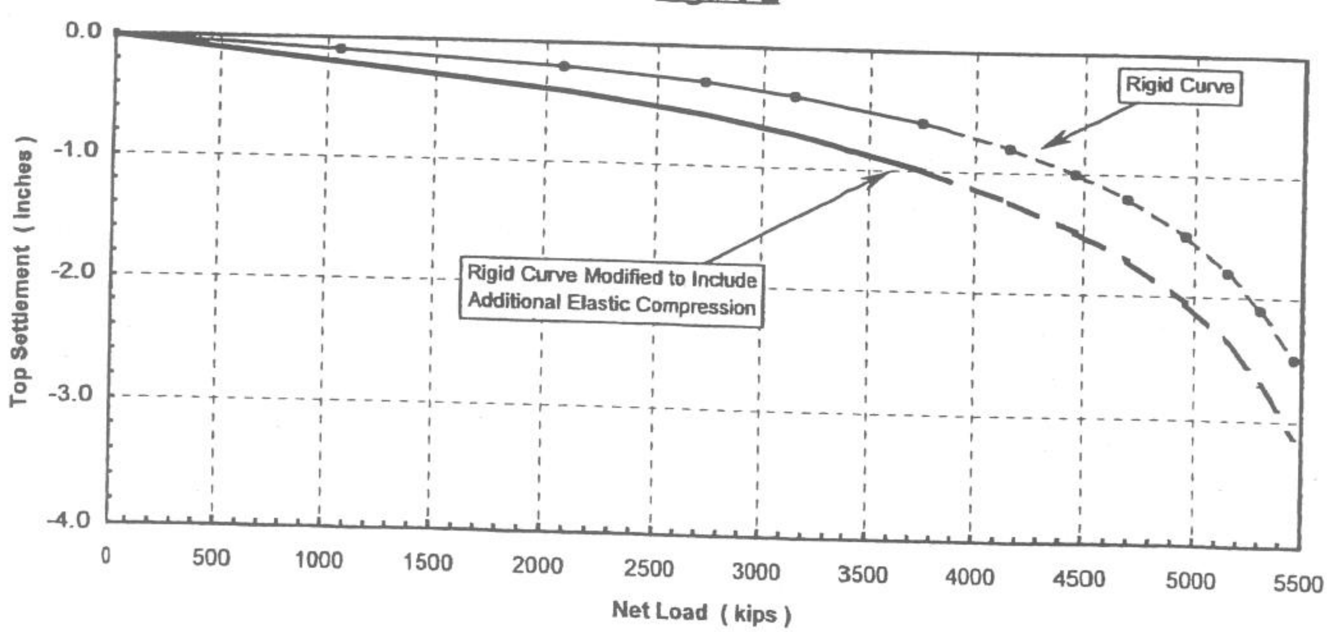
Given:

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

Shear reduction factor = 1.00 (cohesive soil)

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

Figure E



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

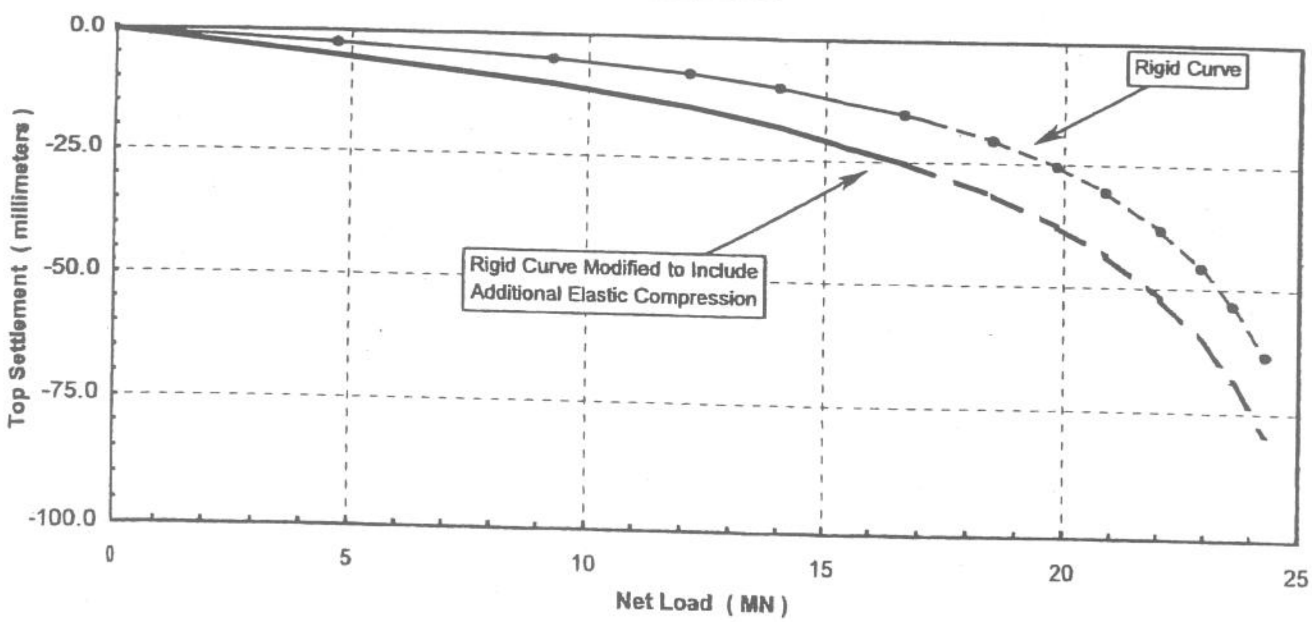
Given:

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

Shear reduction factor = 1.00 (cohesive soil)

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

Figure F



APPENDIX D

O-CELL^{TM} METHOD FOR DETERMINING CREEP LIMIT

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

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

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

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

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

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

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

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

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

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

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

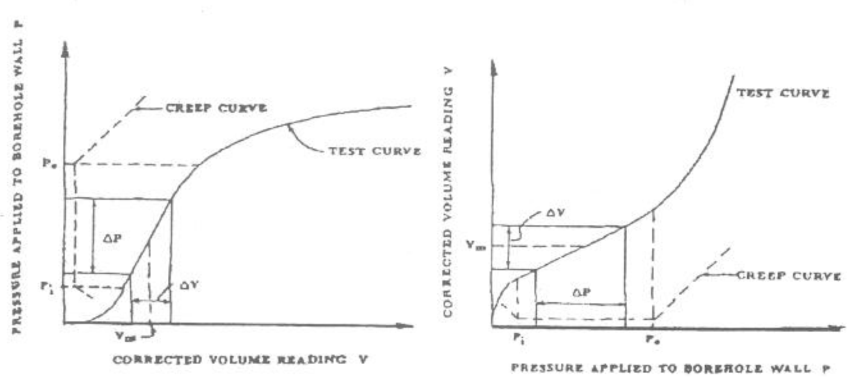


FIG. 8 Pressuremeter Test Curves for Procedure A

References

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

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

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

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

APPENDIX E

NETUNIT SIDE SHEAR VALUES VS. DISPLACEMENT

Net Unit Shear vs. Upward O-cell Movement

US 75 at 77th Street - Topeka, KS - Pier 1 West

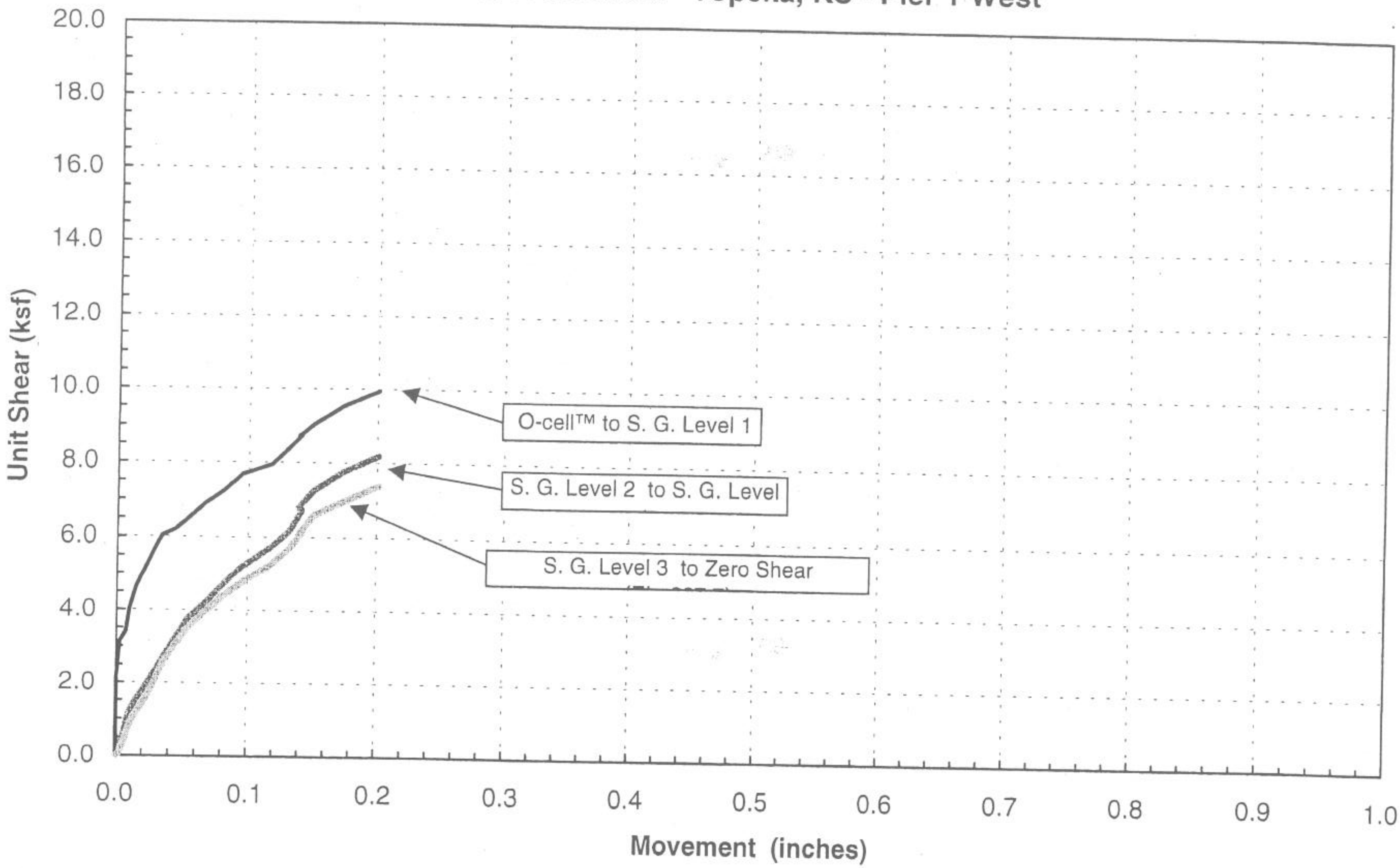


Figure E1

APPENDIX F

BORING LOGS

KANSAS DEPARTMENT OF TRANSPORTATION

ROUTE-COUNTY NO. 4-89	SOUNDING NO. CD #1	SHEET 1 OF 2
BRIDGE STA. 235+48.99	PROJECT NO. K-7317-01	BRIDGE NO. 75-89-4.48(270)
DESCRIPTION S.B. US-75 over 77th Street		HOLE STA. 236+55, 78 ± Lt. Rr
GEOLOGIST Randy Billinger	VERTICLE SCALE	DATE 4-24-00
DRILLER Rob Vervynck	RIG Mobile B-61	ELEVATION TOP OF HOLE 1016.10
GROUND WATER ELEV. 1010.10	TOTAL DEPTH OF HOLE 85^{70}	ELEVATION TOP OF ROCK 1004.10

BIT TYPE & NO.	GEOLOGIC NAME	STRATIGRAPHIC COLUMN	DEPTH	ELEVATION	CLASSIFICATION OF MATERIALS DESCRIPTION AND REMARKS
			0^{0}	1016.10	
	Mantle	Casing Set		1010	Silty Clay, brown.
			12^{0}	1004.10	
	Severy Shale Formation	Core 1 – Core 7		1000, 990, 980	Shale, Sandy, Cross-bedded, gray. Sandstone lenses.
			45^{90}	$970.^{2}$	
					Sandstone, shaly, gray.
			48^{70}	967^{4}	
		Core 8, Core 9			Shale, Sandy, gray.
			57^{90}	958^{2} (960)	
		Core 10			Sandstone, shaly, gray
			62^{6}	953^{5}	
	Coal Creek Mbr.	Core 11	63^{5}	952^{6}	Limestone, hard, dense, blue-gray.
			66^{2}	949^{9}	Shale, limy, dark gray, fossiliferous.
			67^{6}	948^{5}	Limestone, shaly, gray, fossiliferous.
	Holt Mbr.	Core 12	69^{2}	946^{9}	Shale, black, fissile.
	Du Bois Mbr.		71^{10}	945^{0}	Limestone, hard, gray.
			71.90	944.20	
			72.0	944.10	Shale, limy, gray. Bottom O' Limestone

UNCONFINED COMPRESSION	STANDARD PENETRATION OR CASING DRIVE: BLOWS	ELEV.
2.42		999^{6}
15.13		995^{2}
9.11		990^{0}
22.10		980^{5}
23.90		973^{9}
25.20		966^{2}
59.41		958^{6}
102.36		955^{6}
699.14		952^{5}
54.30		949^{1}
63.03		947^{1}
387.95		945^{5}
92.28		943^{2}

APPENDIX G

GROUTING PROCEDURES

POST-TEST GROUTING PROCEDURES FOR PRODUCTION DRILLED SHAFTS TESTED WITH AN OSTERBERG CELL

During the O-cell™ test the shaft breaks, on a horizontal plane, separating the upper section above the O-cell™ (upper side-shear) from the lower section below the O-cell™ (combined end bearing and lower side shear). This creates an annular space, the size of which depends on the shaft/O-cell™ geometry and the expansion of the O-cell™.

When a production shaft has been tested, the engineer may want to include the end bearing component from the lower section in order to obtain sufficient capacity of the production shaft. In such cases the contractor will be required to grout the O-cell™ and the annular space around the O-cell™ in order to allow load transfer to the lower side shear and end bearing.

POST-TEST GROUTING OF OSTERBERG CELLS

a) The grout shall consist of Portland cement and water only, <u>NO SAND</u>. The grout shall be fluid and pumpable. An initial mix consisting of 4 to 6 gallons of water per 95-lb bag of cement is recommended. Adjust water to obtain desired consistency.
b) The mixing shall be thorough to ensure that there are no lumps of dry cement. Pass the grout through a window screen mesh before pumping.
c) Connect the grout pump outlet to one hydraulic line of the O-cell™. Open the other line and establish a flow of water through the system.
d) Pump the grout through the O-cell™ hydraulic line while collecting the effluent from the bleed line. Monitor characteristics of effluent material and when it becomes equivalent to the grout being pumped, stop pumping.
e) Take three samples of the grout for compression testing @ 28 days, if required.

Recommended pre-mixed amount of grout for grouting of O-cell™:				
O-cell Diameter (Inches)	13	21	26	34
Grout Volume (Cubic Feet)	4	7	9	13

POST-TEST GROUTING OF ANNULAR SPACE AROUND OSTERBERG CELLS

a) Prepare a fluid grout mix consisting of Portland cement and water only, <u>NO SAND</u>. The mixing procedures should be as outlined for grouting the O-cells™. The quantity of grout should be at least three (3) times the theoretical volume required to fill the annular space and grout pipes.
b) Pump water and establish a flow through each of the PVC grout pipes (two or three per shaft).
c) Pump the fluid grout through one of the PVC pipes until the grout is observed flowing from the second grout pipe or until 1.5 times the theoretical volume has been pumped.
d) If no return of grout is observed from the second grout pipe, transfer the pump to the second pipe and pump grout through it until 1.5 times the theoretical volume has been pumped.
e) If higher strength grout is deemed necessary, immediately proceed with pumping the higher strength grout (which may be a sand mix). The pumping procedures for this grout will be the same as described above for the initial cement-water grout. **The entire grouting operation must be completed before the set time for the initial grout has elapsed.**
f) Take three (3) samples of each type of grout for compression testing @ 28 days.

Recommended pre-mix amount of grout for grouting of annular space:								
Shaft Diameter (Feet)	2	3	4	5	6	7	8	9
Grout Volume (Cubic Feet)	25	30	40	50	65	80	100	125