KB Technologies®

Load Test Program
Kentucky Transportation Cabinet
U.S. Hwy 60/U.S. Hwy 231
Bridge Over Ohio River

Load Test at Station 890+95, 10 ft. left

Owner:
Federal Highway Administration/
Kentucky Transportation Cabinet

Contractor:
Traylor Brothers, Inc.

Slurry:
SlurryPro® CDP™
KB Technologies Ltd

Loadtest by:
LOADTEST, Inc.
Project N0. LT-8415-2

Test Date:
February 1993

DATA REPORT ON DRILLED SHAFT LOAD TESTING (OSTERBERG METHOD)

Test Shaft at Sta. 890+95 ft
U.S. 231 over the Ohio River
Owensboro, Kentucky

Prepared for: **Traylor Brothers**
P.O. Box 5165
Evansville, IN

Attention: **Mr. Larry Owens**

PROJECT NUMBER: LT-8415-2, September 30, 1998

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LOADTEST

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

September 30, 1998

December 08, 1998 (Revised)

Traylor Brothers
P.O. Box 5165
Evansville, IN

Attention: Mr. Larry Owens

Fax: (812) 474-3231

Data Report: U.S. 231 over the Ohio River - Owensboro, Kentucky
Location: Test Shaft at Sta. 890+95 ft, 10 ft. left

Dear Sirs,

Loadtest Inc. performed an Osterberg Cell load test for Traylor Brothers on the dedicated test shaft at Sta. 890+95 ft., 10 ft. left (LTI project LT-8415-2). The test was carried out on September 28, 1998 by LOADTEST Inc. under the direction of Mr. Michael D. Ahrens and observed by Mr. Darrin Beckett, P.E. of the Kentucky Transportation Cabinet.

Traylor Brothers constructed the test shaft between July 13 and September 22, 1998; the rock socket was excavated from September 17 – 21, 1998 and concrete was placed September 21 – 22, 1998. The rock socket was excavated with a shale style drag bit using a reverse circulation drilling method. Polymer slurry with a minimum viscosity of approximately 50 sec/qt was maintained during the rock socket excavation. Sidewall roughening was performed with cables placed on the sides of the drilling tool and concreting to the top of the rock socket was completed within approximately 10 hours after sidewall roughening. Final bottom cleaning was performed with an airlift approximately 5 hours prior to the beginning of concreting. The shaft was constructed with a total length of 32.06 meters (105.2 feet) and the O-cells™ were located 0.91 meters (3.0 feet) above the tip of the shaft. The shaft was inspected and approved by the Kentucky Transportation Cabinet. A summary of dimensions, elevations, areas and properties for analysis purposes is provided in Table A.

The sub-surface stratigraphy at the test shaft location is reported to consist of overburden soil underlain by gray shale beginning at EL. +266.3 ft. A log of the test shaft soil boring is presented in Appendix E. Detailed geologic information can be obtained from the Kentucky Transportation Cabinet.

The key elements of the acquired data are as follows:

- Summary of Dimensions, Elevations, Areas & Weights in Table A.
- Schematic Section of Test Shaft Figure A.

- Plan View of Instrumentation Figure B.
- Osterberg Cell Load-Movement Curves, Figure 1.
- ECT Midpiont Load Distribution Curves, Figure 2.
- ECT Endpoint Load Distribution Curve for Load 1L-19, Figure 3.
- Comparison of ECTs and Full Length Telltales, Figure 4.
- Equivalent Top Load-Movement Curves, Figure 5.
- Upper Side Shear Creep Limit, Figure 6.
- Combined End Bearing and Lower Side Shear Creep Limit, Figure 7.
- Field Data and Reduction, Appendix A (8 pages).
- Calibration of the O-cells™ and Instrumentation, Appendix B.
- Equivalent Top Load Method, Appendix C.
- O-cell™ Method for Determining Creep Limit, Appendix D.
- Boring Log, Appendix E.

Standard O-cell™ instrumentation included four LVWDTs positioned between the lower and upper plates to measure O-cell™ expansion (Table 5). Compression of the shaft was measured by a pair of telltales located between the top of the O-cells™ and the top of the shaft. Telltale movements were measured by LVDTs at the top of the shaft (Table 3). The top of shaft movement was monitored by two LVDTs attached to a reference beam (Table 2).

Four levels of four embedded compression telltales (ECTs) were installed in the shaft above the O-cells™. The ECTs ranged in length from 4 feet to 10 feet and measured the strain under load over these lengths. In addition to measuring shaft compression the ECTs were used to assess the side shear load transfer of the shaft above the Osterberg cell. Details concerning the ECT placement appear in Table A and Figures A and B. The embedded compression telltales were positioned as directed by the Kentucky Transportation Cabinet.

A pressure vs. load calibration of the O-cells™ was carried out by American Equipment and Fabricating Corporation prior to delivery to the test site (see Appendix B). Both a Bourdon pressure gage (0-10,000 psi) and a vibrating wire pressure transducer were used to measure the pressure applied to the O-cells™ at each load interval. We used the Bourdon pressure gage for calculations and the transducer as a check. All checks were acceptable.

Note: The loads applied by the O-cell™ act in two opposing directions, resisted by the upper side shear above the O-cell™ and by the combined end bearing and lower side shear below the O-cell™. Theoretically, the O-cell™ does not impose an additional side shear and end-bearing load until its expansion force exceeds the buoyant weight of the shaft above the O-cell™. Therefore, *net load*, which is defined as gross O-cell™ load minus the buoyant weight of the shaft, is used throughout this report, unless otherwise noted. For this test we calculated a buoyant weight of 2.18 MN (245 tons).

The Osterberg cell load test was conducted as follows: Three 660 mm (26 inch) diameter O-cells™, with bases located 0.91 meters (3.0 feet) above the base of shaft were pressurized to assess the combined end bearing and lower side shear below the O-cells™ and the upper side shear above the O-cells™. The O-cells™ were pressurized in 19 loading increments to 53.8 MPa (7800 psi) resulting in a gross load of 37.9 MN (4257 tons) upward and 37.9 MN (4257 tons) downward.

During the test, after load increment 1L-16, an attempt was made to correct a minor differential movement in the O-cell™ assembly (see Table 5). The O-cell™ with the greatest expansion was hydraulically isolated and held at 44.1 MPa (6400 psi). The pressure to the other two O-cells™ was increased to 46.9 MPa (6800 psi). A small correction occurred, however, at that point a decision was made by LOADTEST personnel to continue the test using the same pressure in O-cells™ all since the upper side shear component of the shaft was approaching ultimate capacity. The loading was halted after load interval 1L-19 because the ultimate capacity in the upper side shear had been reached.

DISCUSSION OF RESULTS

Upper Side Shear: The maximum load applied to the side shear was 35.7 MN (4,012 tons) which occurred at load interval 1L-19 (Table 4, Figure 1). At this loading, the total upward movement of the top of the O-cells™ was 36.1 mm (1.42 inches) and the ultimate capacity of the shaft above the O-cells™ was reached. The average unit side shear capacity of the embedded 22.59 meter (74.1 feet) shaft section above the O-cells™ is calculated to be 199 kPa (2.08 tsf). The following section provides additional unit side shear estimates based on embedded compression telltale data.

Embedded Compression Telltale Results: The ECT data appear in Tables 7 and 8. At the time of testing, the average concrete unconfined compressive strength was reported to be 29.6 MPa (4,295 psi) and the average concrete modulus was 27.3 GPa (3,960 ksi). This, combined with the area of reinforcing steel and casing, was used to determine a weighted shaft modulus of 34.1 GPa (4,941 ksi) in the 2.59 meter (8.5 ft.) diameter cased part of the shaft and 28.4 GPa (4,112 ksi) in the 2.44 meter (8.0 ft.) diameter socket.

Side shear load distribution curves based on the midpoint of ECT data are shown in Figure 2. An additional set of points is generated as the difference of the total shaft compression and the sum of levels 1 through 4. Figure 3 shows a load distribution curve based on the endpoints of the ECTs at 1L-19. The plot was generated using the average load at the middle of the ECT gages and assuming approximately equal side shear in the strata where Level 3 and 4 ECTs were located (see Appendix E for an Idealized Rock Profile provided by the Kentucky Transportation Cabinet). Estimated unit side shear capacity values for the shaft based on the ECT gage data, estimated shaft modulus and shaft area are as follows for 1L-19:

Load Transfer Zone	Unit Side Shear
Mudline to Top of ECT Level 4	59 kPa (0.61 tsf)
Top of ECT Level 4 to Top of ECT Level 3	222 kPa (2.32 tsf)
Top of ECT Level 3 to Top of ECT Level 2	222 kPa (2.32 tsf)
Top of ECT Level 2 to Top of ECT Level 1	626 kPa (6.54 tsf)
Top of ECT Level 1 to O-cell™	915 kPa (9.56 tsf)

It should be noted that the measured compression varied in the four gages at each ECT level indicating variation in shear around the perimeter of the pile. As seen in Figure 4, the sum of the ECT measurements in quadrants B and D are compared with the full-length telltales at B and D. The comparison confirms that the ECT data is reliable.

Combined End Bearing and Lower Side Shear: The maximum load applied to the base of the shaft was 35.7 MN (4,012 tons) which occurred at load interval 1L-19 (Table 6, Figure 1). At this loading, the total downward movement of the O-cell™ base was 34.0 mm (1.34 inches) and the ultimate capacity of the shaft below the O-cells™ was not reached. The side shear capacity of the 0.91 meter (3.0 feet) shaft section below the O-cells™ is calculated to be 4.4 MN (493 tons) assuming a unit side shear value of 626 kPa (6.54 tsf) and a shaft diameter of 2.44 meters (8.0 feet). The unit side shear for the Level 2 ECTs was used in the calculation based on information in Appendix E that indicates that the strength characteristics of the stratum below the O-cell™ and the stratum of the Level 2 ECT are similar. The maximum applied load to end bearing is then 31.3 MN (3,519 tons) and the unit end-bearing capacity at the base of the shaft is calculated to be 6703 kPa (70.0 tsf).

Creep Limit: See Appendix D for our O-cell™ method for determining creep limit. The upper side shear creep data (Table 4) indicate that a creep limit of 26.7 MN (3000 tons) was reached at a movement of 9.9 mm (0.39 inches) (Figure 6). The combined end bearing and lower side shear creep data (Table 6) indicate no apparent creep limit (Figure 7). 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 71.2 MN (8,000 tons) by some unknown amount.

Equivalent Top Load: Figure 5 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 often an important component of the settlements involved, the equivalent top load curve includes an adjustment for the additional elastic compression below the mudline which would occur in a top-load test. The darker curve as described in Procedure Part II of Appendix C includes such an adjustment. It should be noted that the elastic compression of the pile above the mudline is not included in the adjusted curve.

The test shaft was successfully loaded to a combined side shear and end bearing of more than 71.4 MN (8,024 tons). For a top loading of 20.6 MN (2315 tons), 6.4 mm (0.25 inches) of which 2.8 mm (0.11 inches) is estimated elastic compression. For a top loading of 35.3 MN (3965 tons) the adjusted test data indicate this shaft would settle approximately 12.7 mm (0.50 inches) of which 4.8 mm (0.19 inches) is estimated elastic compression. The equivalent top load curve is shown in Figure 5.

Shaft Compression Telltales: The measured maximum shaft compression, averaged from 2 telltales, is 1.1 mm (0.042 inches). Using the nominal diameters and moduli of Table A and the load distribution in Figure 3, we calculated an elastic compression of 1.2 mm (0.047 inches) over the length of the compression telltales. We believe this agreement provides good evidence that the O-cell™ loaded the shaft in accord with the calibration used herein.

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

Michael D. Ahrens

Michael D. Ahrens, M.E.
Project Manager

Reviewed by

J. A. Hayes

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

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

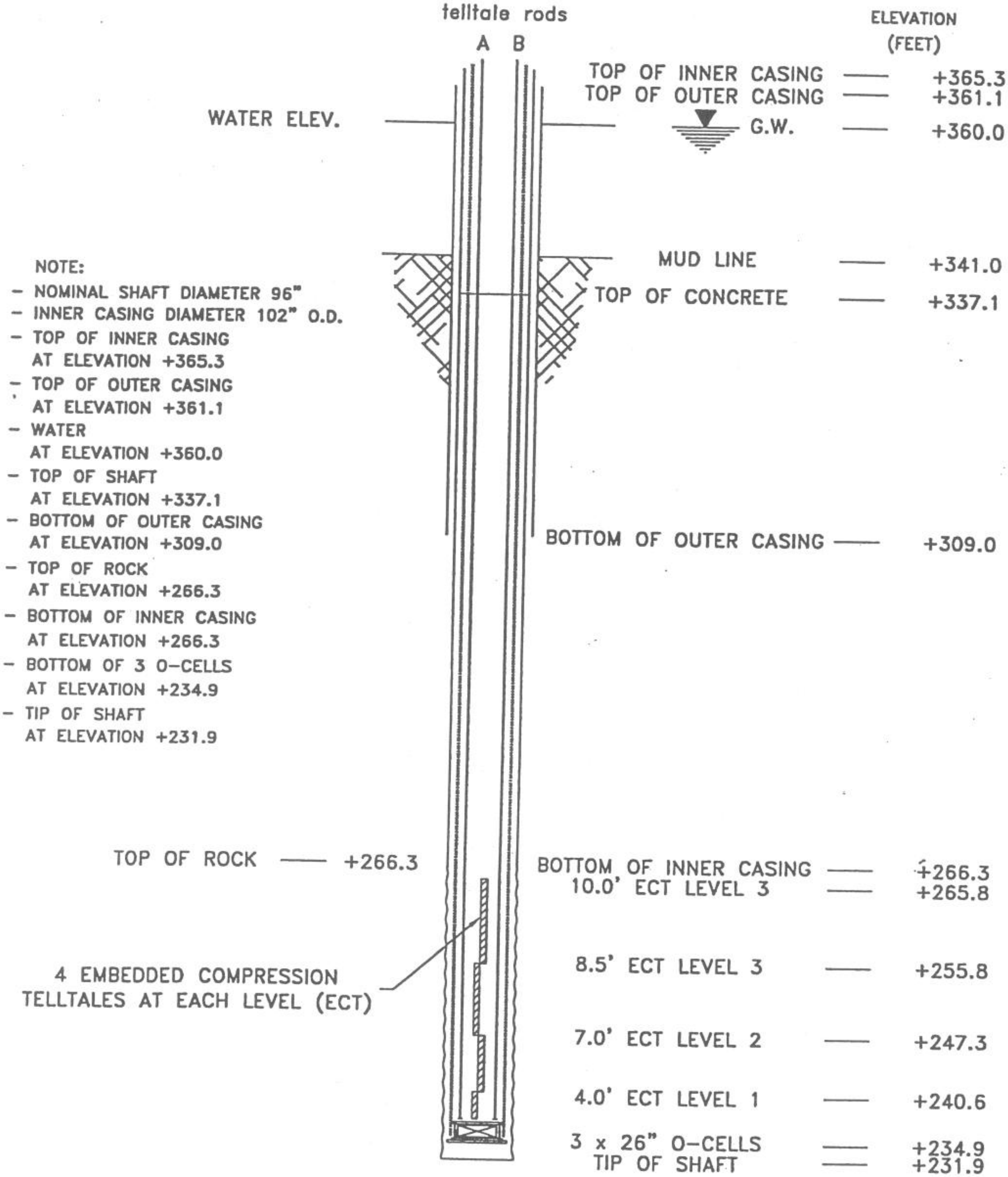
TABLE A: SUMMARY OF DIMENSIONS, ELEVATIONS, AREAS & PROPERTIES FOR ANALYSIS PURPOSES

Shaft:			
Nominal shaft diameter (EL+337.1 to EL+266.3 ft)	=	2.59 meters	102.0 inches
Nominal shaft diameter (EL+266.3 to EL+231.9 ft)	=	2.44 meters	96.0 inches
O-cell™ size: 7020-13, 7020-14, 7020-15)	=	667 mm	26 inches
Length of shaft between base of O-cell™ and base of outer casing	=	22.59 meters	74.1 feet
Length of side shear socket below break at base of O-cell™	=	0.91 meters	3.0 feet
Shaft shear area above O-cell™ base	=	179.2 $meters^2$	1929.4 $feet^2$
Shaft shear area below O-cell™base	=	7.00 $meters^2$	75.4 $feet^2$
Shaft end area	=	4.67 $meters^2$	50.3 $feet^2$
Buoyant weight of concrete (above bottom of O-cell™)	=	2.18 MN	245 tons
Estimated shaft modulus (EL+337.1 to EL+266.3 ft)	=	34.1 GPa	4,941 ksi
Estimated shaft modulus (EL+266.3 to EL+231.9 ft)	=	28.4 GPa	4,112 ksi
Elevation of mud line	=	+103.94 meters	+341.0 feet
Elevation of top of shaft concrete	=	+102.75 meters	+337.1 feet
Elevation of bottom of Osterberg Cell (The break between upward side shear movement and downward side shear and end bearing movement.)	=	+71.60 meters	+234.9 feet
Elevation of shaft tip	=	+70.68 meters	+231.9 feet
Casings:			
Elevation of top of inner casing (102.0" O.D./100.5" I.D.)	=	+111.34 meters	+365.3 feet
Elevation of top of outer outer (120.0" O.D./118.5" I.D.)	=	+110.06 meters	+361.1 feet
Elevation of bottom of outer casing (120.0" O.D./118.5" I.D.)	=	+94.18 meters	+309.0 feet
Elevation of bottom of inner casing (102.0" O.D./100.5" I.D.)	=	+81.17 meters	+266.3 feet
Compression Sections:			
Elevation of top of telltale used for total shaft compression	=	+102.75 meters	+337.1 feet
Elevation of bottom of telltale used for total shaft compression (on top of upper O-cell™ bearing plate)	=	+71.93 meters	+236.0 feet
Elevation of top of telltale used for level 4 shaft compression	=	+81.02 meters	+265.8 feet
Elevation of bottom of telltale used for level 4 shaft compression	=	+77.97 meters	+255.8 feet
Elevation of top of telltale used for level 3 shaft compression	=	+77.97 meters	+255.8 feet
Elevation of bottom of telltale used for level 3 shaft compression	=	+75.38 meters	+247.3 feet
Elevation of top of telltale used for level 2 shaft compression	=	+75.38 meters	+247.3 feet
Elevation of bottom of telltale used for level 2 shaft compression	=	+73.25 meters	+240.3 feet
Elevation of top of telltale used for level 1 shaft compression	=	+73.32 meters	+240.6 feet
Elevation of bottom of telltale used for level 1 shaft compression (on top of upper O-cell™ bearing plate)	=	+72.11 meters	+236.6 feet

LOADTEST, Inc. Project No. LT-8415-2

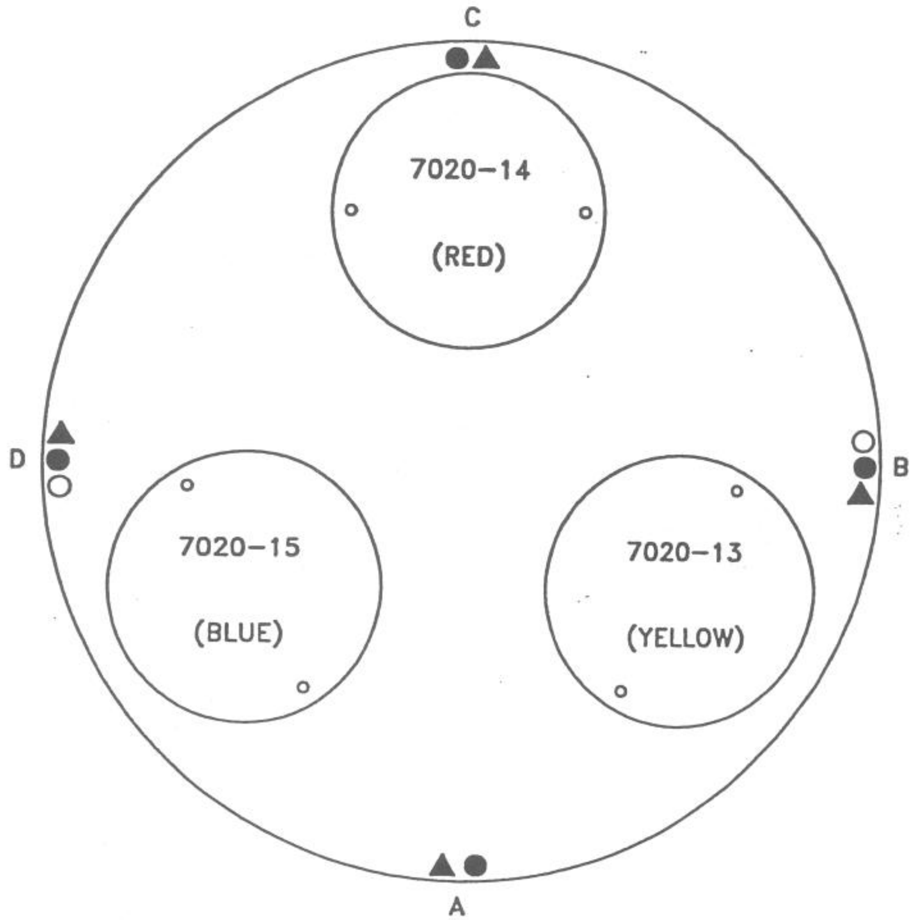
Schematic For Load Test Shaft At Station 890+95, 10ft. Left

NOTE:
- NOMINAL SHAFT DIAMETER 96"
- INNER CASING DIAMETER 102" O.D.
- TOP OF INNER CASING AT ELEVATION +365.3
- TOP OF OUTER CASING AT ELEVATION +361.1
- WATER AT ELEVATION +360.0
- TOP OF SHAFT AT ELEVATION +337.1
- BOTTOM OF OUTER CASING AT ELEVATION +309.0
- TOP OF ROCK AT ELEVATION +266.3
- BOTTOM OF INNER CASING AT ELEVATION +266.3
- BOTTOM OF 3 O-CELLS AT ELEVATION +234.9
- TIP OF SHAFT AT ELEVATION +231.9



LOADTEST	2631-D NW 41st St. Gainesville, FL 32606 Phone 800-368-1138 FAX (352) 378-3934	SCHEMATIC SECTION OF TEST SHAFT AT STATION 890+95	Owensboro US 252 Bridge, Owensboro, KY LT-8415-2 FIGURE A

Plan View Of Instrumentation



○ COMPRESSION TELLTALE

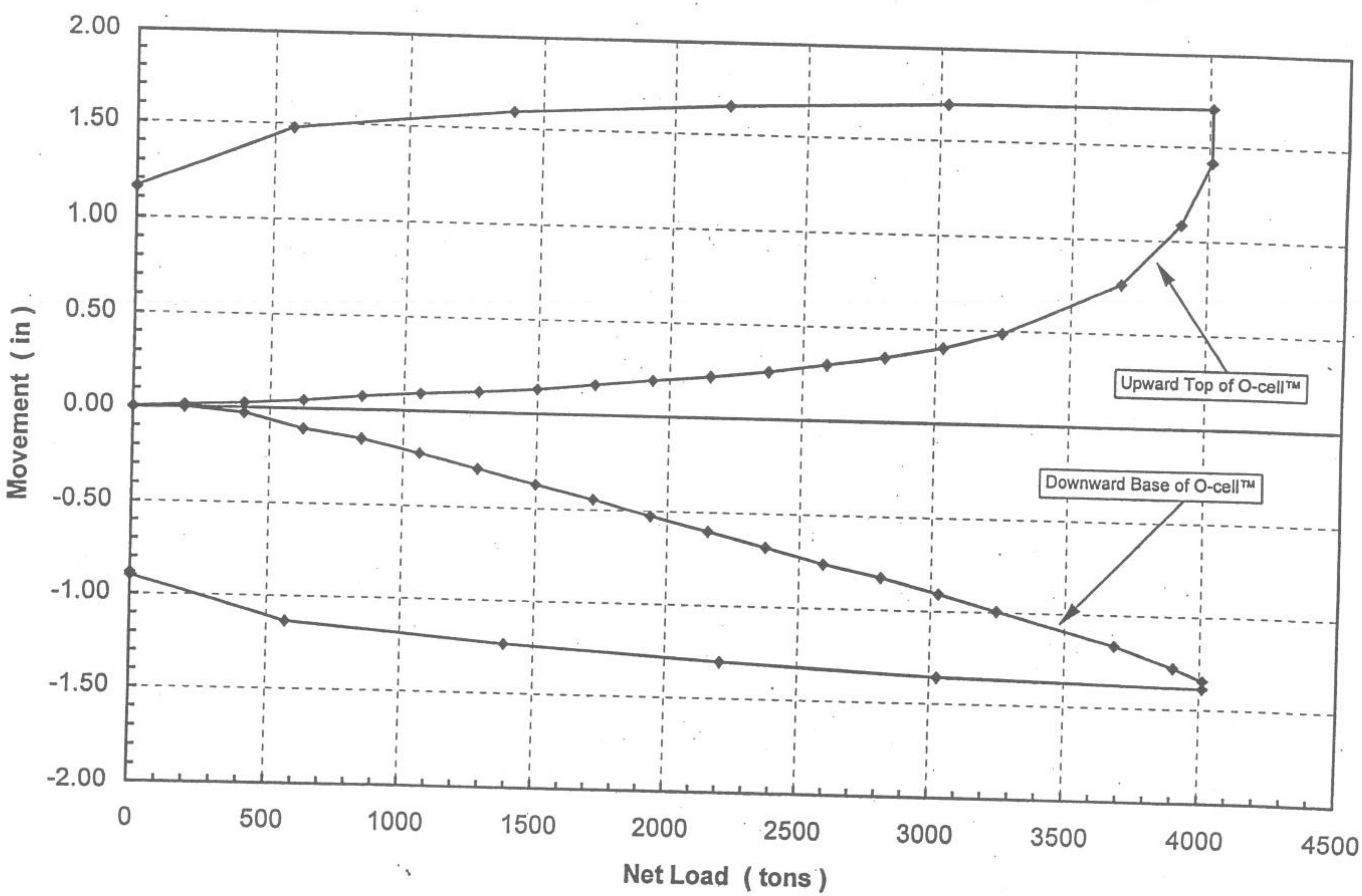
● EMBEDDED COMPRESSION TELLTALE (ECT)

▲ EXPANSION LVWDT

LOADTEST	2631-D NW 41st St. Gainesville, FL 32606 Phone 800-368-1138 FAX (352) 378-3934	PLAN VIEW OF INSTRUMENTATION AT TEST SHAFT AT STATION 890+95	Owensboro US 252 Bridge, Owensboro, KY LT-8415-2 FIGURE B

Osterberg Cell Load-Movement Curves

Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY



LOADTEST, Inc. Project No. LT-8415-2

Figure 1 of 7

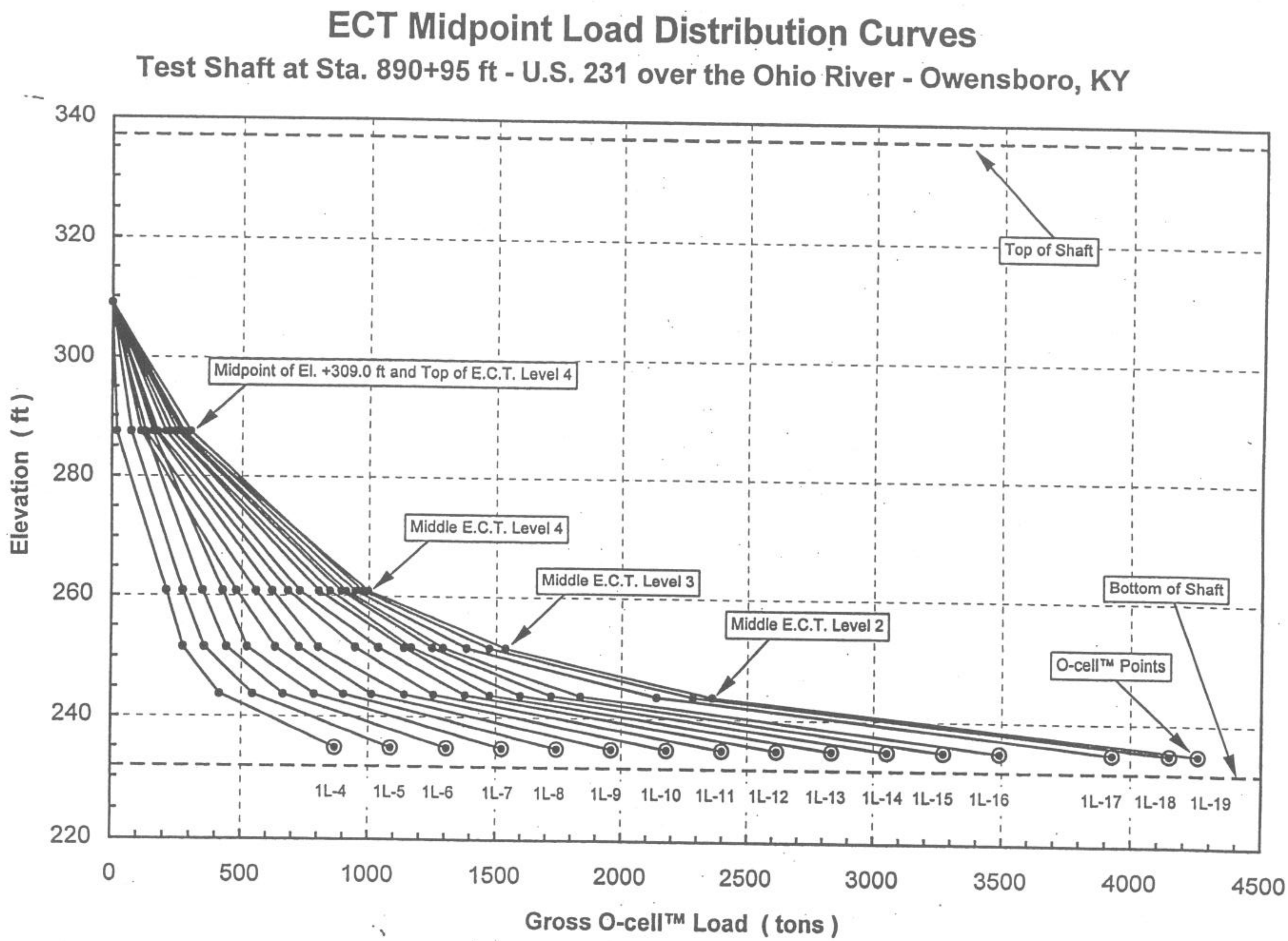


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Figure 2 of 7

ECT Endpoint Load Distribution Curve for 1L-19

U.S. 231 over the Ohio River - Owensboro, Kentucky

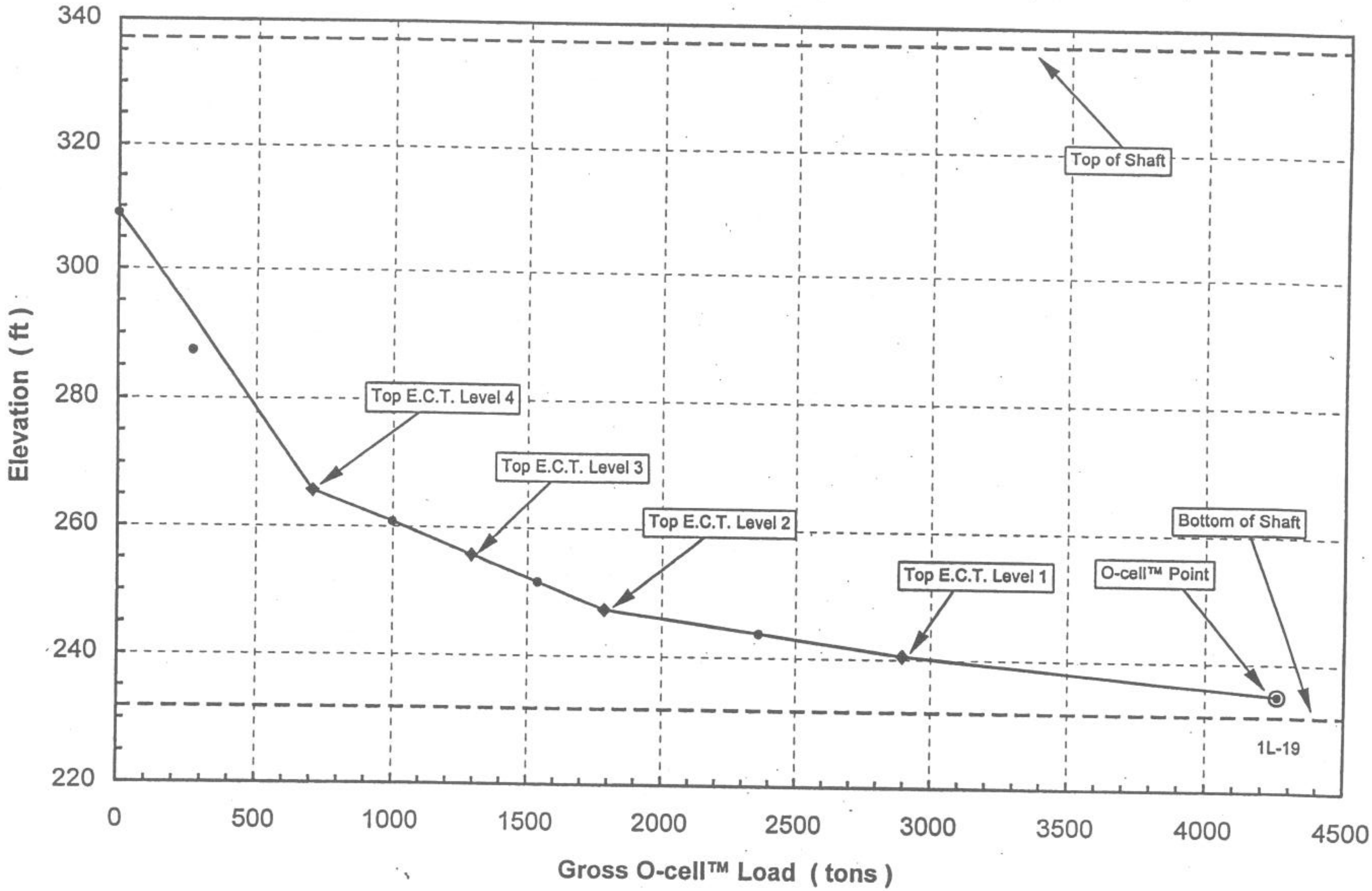

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Figure 3 of 7

Comparison of ECTs and Full Length Telltales

U.S. 231 over the Ohio River - Owensboro, Kentucky

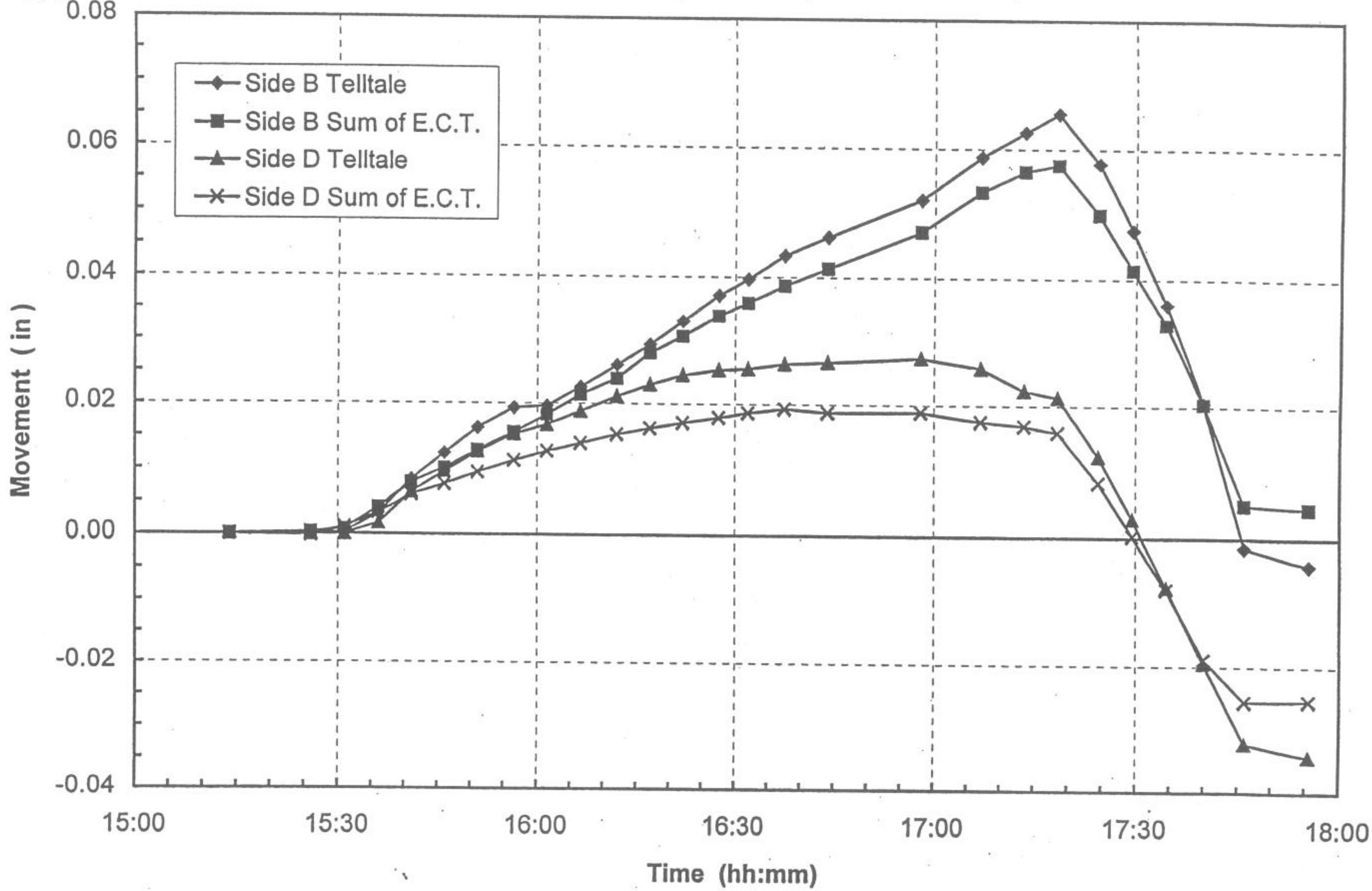

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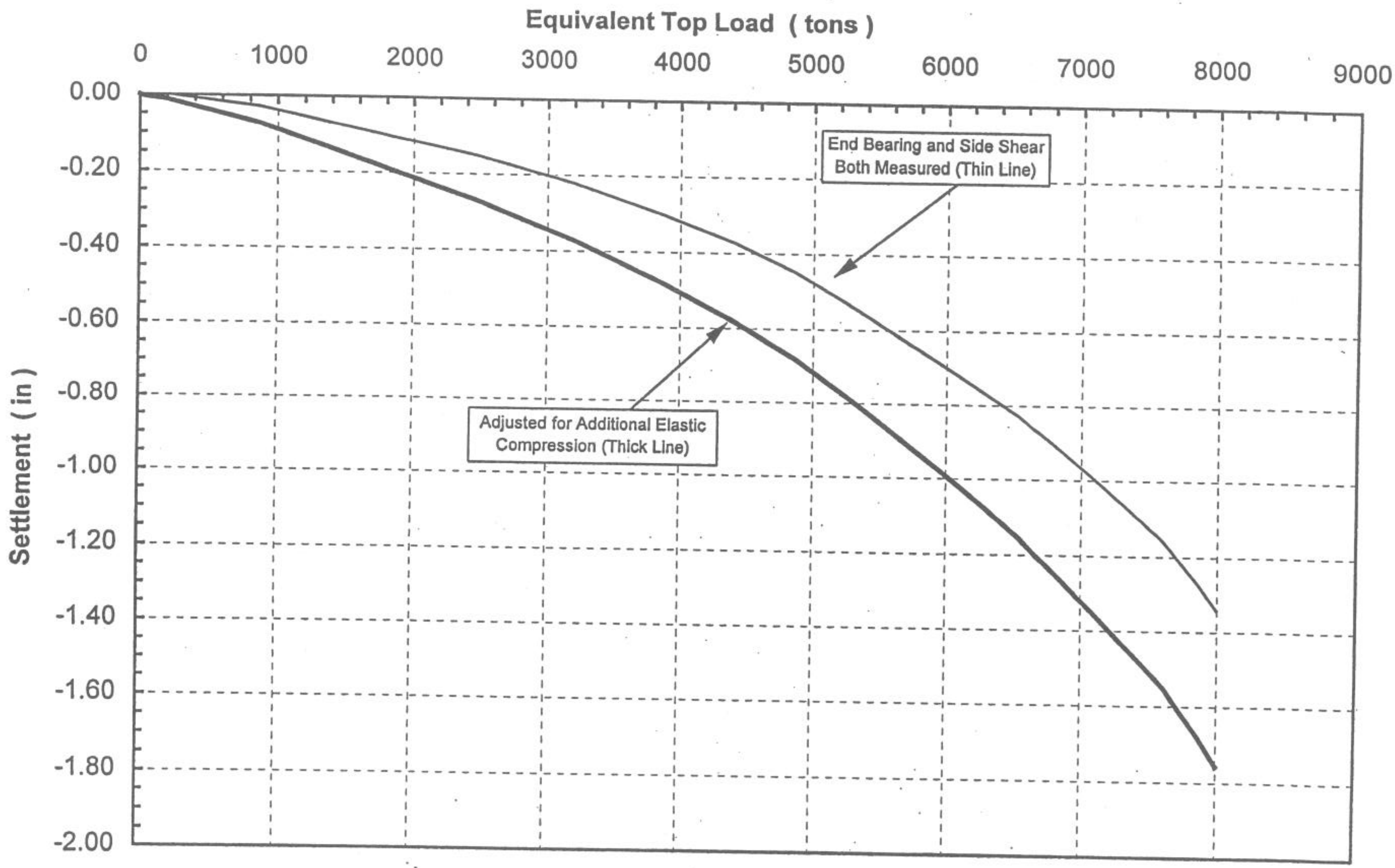
Figure 4 of 7

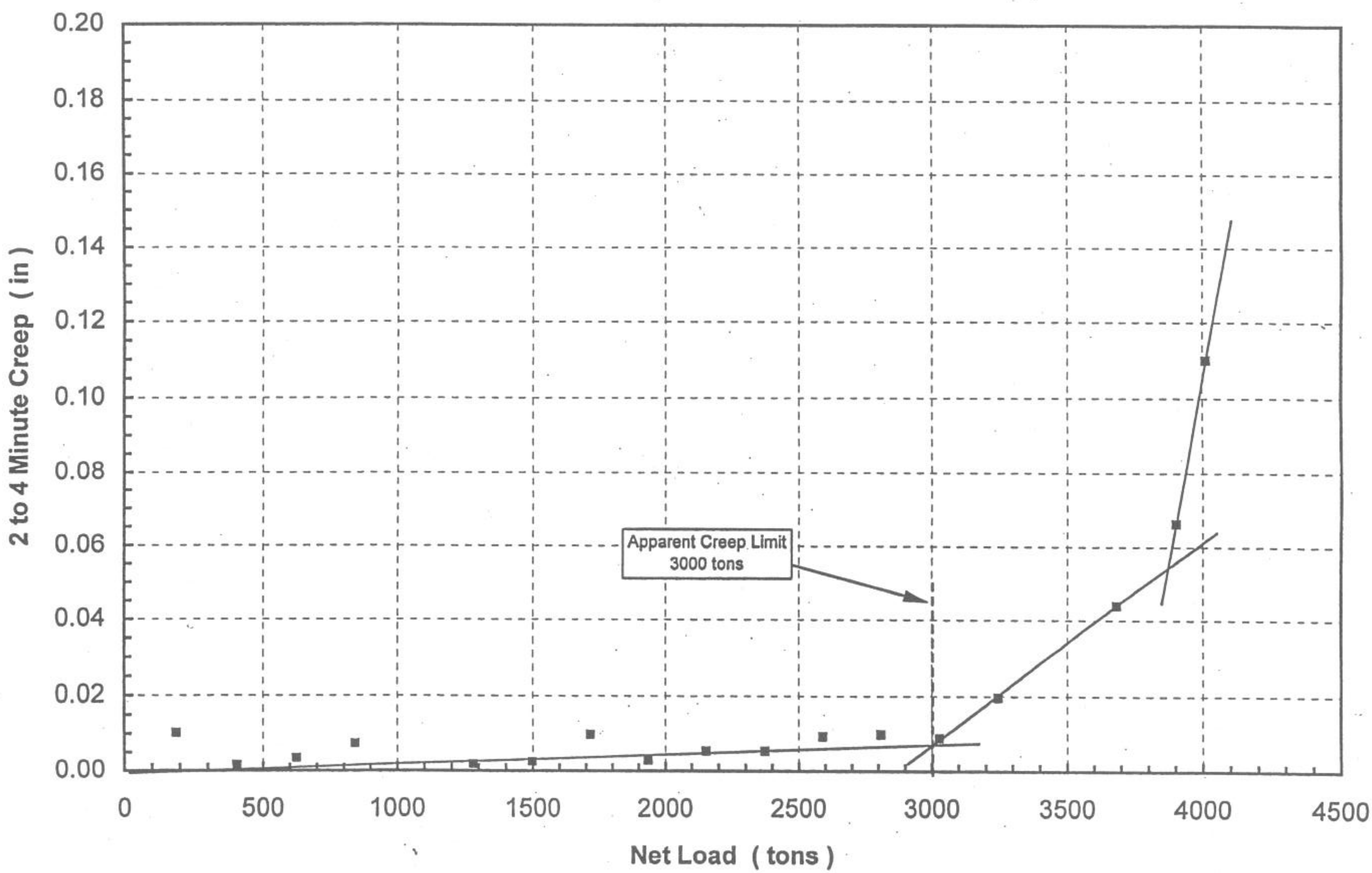
Equivalent Top Load-Movement Curves

Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY



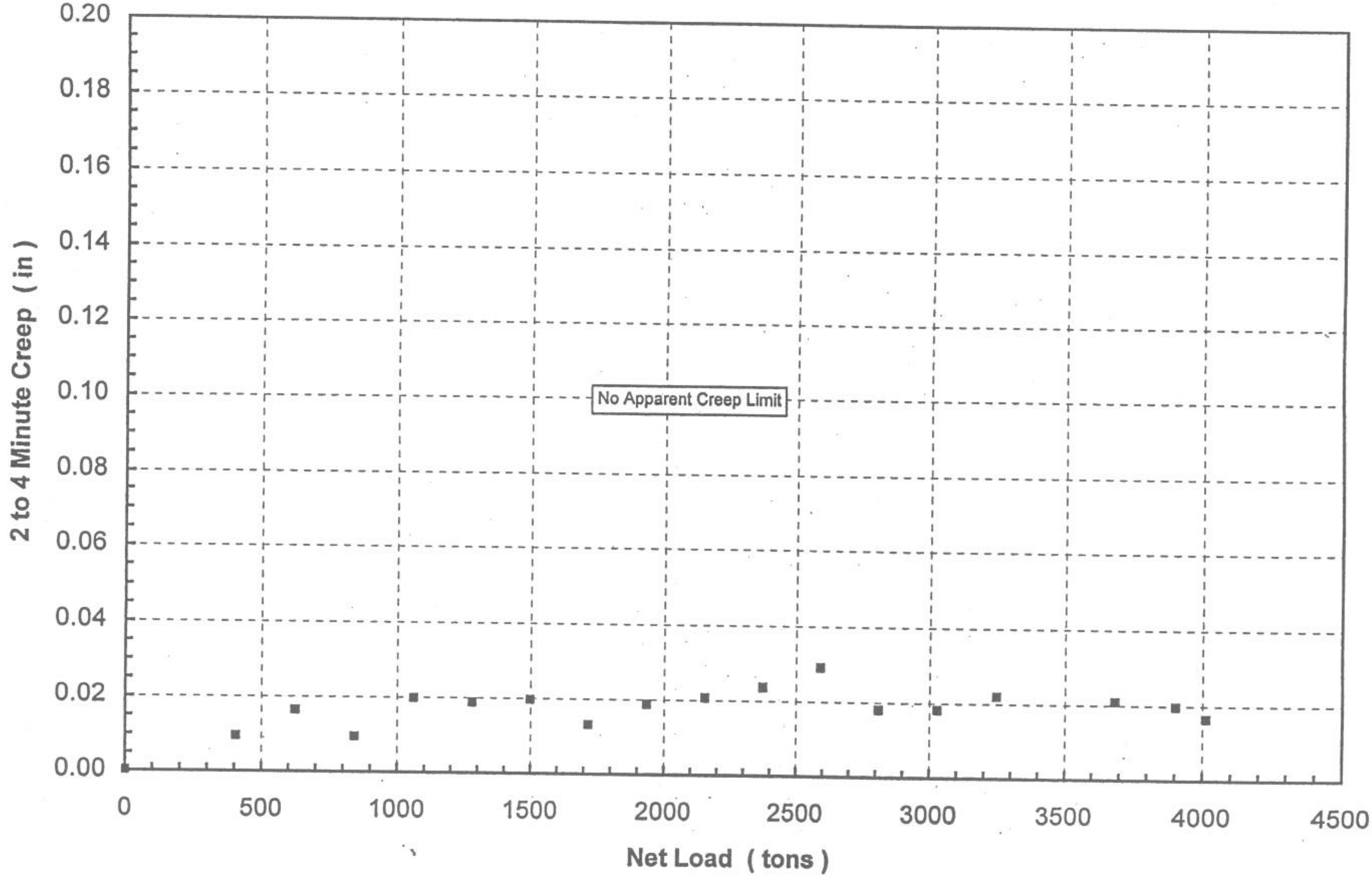
Upper Side Shear Creep Limit

Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY



Combined End Bearing and Lower Side Shear Creep Limit

Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY



APPENDIX A

FIELD DATA & DATA REDUCTION

Gross and Net O-cell™ Loads

Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	Gross O-cell™ Load Pos. A (tons)	Gross O-cell™ Load Pos. B (tons)	Gross O-cell™ Load Pos. C (tons)	Total Gross O-cell™ Load (tons)
1 L - 0	15:14:00	0	0	0	0	0	0
1 L - 1	15:26:00	400	0	72	70	72	214
1 L - 2	15:31:00	800	187	146	143	144	432
1 L - 3	15:36:00	1,200	406	220	215	216	651
1 L - 4	15:41:00	1,600	624	294	287	288	869
1 L - 5	15:46:00	2,000	843	368	359	361	1,088
1 L - 6	15:51:00	2,400	1,061	442	432	433	1,306
1 L - 7	15:56:30	2,800	1,280	516	504	505	1,525
1 L - 8	16:01:30	3,200	1,498	590	576	577	1,743
1 L - 9	16:06:30	3,600	1,717	664	648	650	1,962
1 L - 10	16:12:00	4,000	1,935	738	721	722	2,181
1 L - 11	16:17:00	4,400	2,154	812	793	794	2,399
1 L - 12	16:22:00	4,800	2,373	886	865	867	2,618
1 L - 13	16:27:30	5,200	2,591	960	937	939	2,836
1 L - 14	16:32:00	5,600	2,810	1,034	1,010	1,011	3,055
1 L - 15	16:37:30	6,000	3,028	1,108	1,082	1,083	3,273
1 L - 16	16:44:00	6,400	3,247	1,182	1,154	1,156	3,492
1 L - 17	16:58:00	7,200	3,684	1,330	1,299	1,300	3,929
1 L - 18	17:07:00	7,600	3,902	1,404	1,371	1,372	4,147
1 L - 19	17:13:30	7,800	4,012	1,441	1,407	1,409	4,257
1 H - 19	17:18:30	7,800	4,012	1,441	1,407	1,409	4,257
1 U - 1	17:24:30	6,000	3,028	1,108	1,082	1,083	3,273
1 U - 2	17:29:30	4,500	2,209	830	811	812	2,454
1 U - 3	17:34:30	3,000	1,389	553	540	541	1,634
1 U - 4	17:40:00	1,500	570	275	269	270	815
1 U - 5	17:46:00	0	0	0	0	0	0
1 U - 6	17:55	0	0	0	0	0	0

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

LOADTEST Inc. Project No. LT-8415-2

Table 1 of 8

Upward Top of Shaft Movement
Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	TOS Indicator B Readings 1 min (inches)	TOS Indicator B Readings 2 min (inches)	TOS Indicator B Readings 4 min (inches)	TOS Indicator D Readings 1 min (inches)	TOS Indicator D Readings 2 min (inches)	TOS Indicator D Readings 4 min (inches)	Average Top of Shaft 1 min (inches)	Average Top of Shaft 2 min (inches)	Average Top of Shaft 4 min (inches)	Creep 2-4 min (inches)
1 L - 0	15:14:00	0	0	0.0000			0.0000			0.0000			
1 L - 1	15:26:00	400	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1 L - 2	15:31:00	800	187	0.0000	0.0031	0.0144	0.0000	0.0042	0.0135	0.0000	0.0036	0.0140	0.0103
1 L - 3	15:36:00	1,200	406	0.0206	0.0206	0.0226	0.0197	0.0207	0.0207	0.0202	0.0207	0.0217	0.0010
1 L - 4	15:41:00	1,600	624	0.0319	0.0339	0.0370	0.0310	0.0341	0.0372	0.0315	0.0340	0.0371	0.0031
1 L - 5	15:46:00	2,000	843	0.0534	0.0544	0.0626	0.0517	0.0558	0.0620	0.0526	0.0551	0.0623	0.0072
1 L - 6	15:51:00	2,400	1,061	0.0801	0.0811	0.0801	0.0806	0.0806	0.0806	0.0804	0.0809	0.0804	-0.0005
1 L - 7	15:56:30	2,800	1,280	0.0924	0.0914	0.0924	0.0910	0.0920	0.0941	0.0917	0.0917	0.0933	0.0016
1 L - 8	16:01:30	3,200	1,498	0.1099	0.1119	0.1140	0.1096	0.1116	0.1147	0.1098	0.1118	0.1144	0.0026
1 L - 9	16:06:30	3,600	1,717	0.1304	0.1325	0.1427	0.1313	0.1333	0.1426	0.1309	0.1329	0.1427	0.0097
1 L - 10	16:12:00	4,000	1,935	0.1653	0.1684	0.1704	0.1643	0.1674	0.1705	0.1648	0.1679	0.1705	0.0026
1 L - 11	16:17:00	4,400	2,154	0.1889	0.1910	0.1951	0.1891	0.1912	0.1974	0.1890	0.1911	0.1963	0.0052
1 L - 12	16:22:00	4,800	2,373	0.2166	0.2218	0.2269	0.2191	0.2232	0.2284	0.2179	0.2225	0.2277	0.0051
1 L - 13	16:27:30	5,200	2,591	0.2546	0.2597	0.2680	0.2563	0.2614	0.2707	0.2555	0.2606	0.2694	0.0088
1 L - 14	16:32:00	5,600	2,810	0.2936	0.3008	0.3100	0.2976	0.3048	0.3152	0.2956	0.3028	0.3126	0.0098
1 L - 15	16:37:30	6,000	3,028	0.3490	0.3583	0.3665	0.3524	0.3616	0.3709	0.3507	0.3600	0.3687	0.0088
1 L - 16	16:44:00	6,400	3,247	0.4188	0.4301	0.4496	0.4226	0.4329	0.4525	0.4207	0.4315	0.4511	0.0196
1 L - 17	16:58:00	7,200	3,684	0.6477	0.6774	0.7205	0.6519	0.6808	0.7252	0.6498	0.6791	0.7229	0.0438
1 L - 18	17:07:00	7,600	3,902	0.9401	0.9729	1.0386	0.9441	0.9771	1.0433	0.9421	0.9750	1.0410	0.0660
1 L - 19	17:13:30	7,800	4,012	1.2058	1.2602	1.3700	1.2105	1.2653	1.3758	1.2082	1.2628	1.3729	0.1102
1 H - 19	17:18:30	7,800	4,012	1.4839	1.5383	1.6542	1.4894	1.5482	1.6639	1.4867	1.5433	1.6591	
1 U - 1	17:24:30	6,000	3,028	1.6553	1.6501	1.6542	1.6618	1.6608	1.6608	1.6586	1.6555	1.6575	
1 U - 2	17:29:30	4,500	2,209	1.6244	1.6234	1.6224	1.6319	1.6308	1.6308	1.6282	1.6271	1.6266	
1 U - 3	17:34:30	3,000	1,389	1.5762	1.5752	1.5731	1.5823	1.5802	1.5792	1.5793	1.5777	1.5762	
1 U - 4	17:40:00	1,500	570	1.4808	1.4777	1.4746	1.4862	1.4831	1.4800	1.4835	1.4804	1.4773	
1 U - 5	17:46:00	0	0	1.1903	1.1842	1.1770	1.1960	1.1898	1.1826	1.1932	1.1870	1.1798	
1 U - 6	17:55	0	0	1.1719	1.1719	1.1719	1.1764	1.1764	1.1764	1.1742	1.1742	1.1742	

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

LOADTEST Inc. Project No. LT-8415-2

Table 2 of 8

Shaft Compression

Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	Comp. Indicator B Readings 1 min (inches)	Comp. Indicator B Readings 2 min (inches)	Comp. Indicator B Readings 4 min (inches)	Comp. Indicator D Readings 1 min (inches)	Comp. Indicator D Readings 2 min (inches)	Comp. Indicator D Readings 4 min (inches)	Average Compression 1 min (inches)	Average Compression 2 min (inches)	Average Compression 4 min (inches)
1 L - 0	15:14:00	0	0	0.0000			0.0000			0.0000		
1 L - 1	15:26:00	400	0	0.0000	0.0000	0.0000	0.0003	0.0003	0.0000	0.0001	0.0001	0.0000
1 L - 2	15:31:00	800	187	0.0000	0.0002	0.0002	0.0003	0.0000	0.0000	0.0001	0.0001	0.0001
1 L - 3	15:36:00	1,200	406	0.0015	0.0021	0.0031	0.0010	0.0013	0.0016	0.0013	0.0017	0.0023
1 L - 4	15:41:00	1,600	624	0.0073	0.0078	0.0083	0.0057	0.0062	0.0064	0.0065	0.0070	0.0074
1 L - 5	15:46:00	2,000	843	0.0117	0.0120	0.0123	0.0090	0.0093	0.0095	0.0104	0.0107	0.0109
1 L - 6	15:51:00	2,400	1,061	0.0157	0.0157	0.0162	0.0121	0.0123	0.0126	0.0139	0.0140	0.0144
1 L - 7	15:56:30	2,800	1,280	0.0188	0.0188	0.0193	0.0149	0.0152	0.0152	0.0169	0.0170	0.0173
1 L - 8	16:01:30	3,200	1,498	0.0198	0.0198	0.0196	0.0165	0.0167	0.0167	0.0182	0.0183	0.0182
1 L - 9	16:06:30	3,600	1,717	0.0222	0.0222	0.0225	0.0188	0.0188	0.0188	0.0205	0.0205	0.0207
1 L - 10	16:12:00	4,000	1,935	0.0256	0.0256	0.0259	0.0208	0.0208	0.0211	0.0232	0.0232	0.0235
1 L - 11	16:17:00	4,400	2,154	0.0287	0.0290	0.0292	0.0226	0.0226	0.0229	0.0257	0.0258	0.0261
1 L - 12	16:22:00	4,800	2,373	0.0324	0.0324	0.0329	0.0242	0.0244	0.0244	0.0283	0.0284	0.0287
1 L - 13	16:27:30	5,200	2,591	0.0358	0.0360	0.0371	0.0252	0.0252	0.0252	0.0305	0.0306	0.0312
1 L - 14	16:32:00	5,600	2,810	0.0392	0.0394	0.0397	0.0254	0.0254	0.0254	0.0323	0.0324	0.0326
1 L - 15	16:37:30	6,000	3,028	0.0426	0.0431	0.0434	0.0260	0.0260	0.0262	0.0343	0.0346	0.0348
1 L - 16	16:44:00	6,400	3,247	0.0457	0.0460	0.0462	0.0265	0.0265	0.0265	0.0361	0.0362	0.0363
1 L - 17	16:58:00	7,200	3,684	0.0514	0.0517	0.0520	0.0272	0.0272	0.0272	0.0393	0.0395	0.0396
1 L - 18	17:07:00	7,600	3,902	0.0574	0.0577	0.0587	0.0267	0.0262	0.0257	0.0421	0.0420	0.0422
1 L - 19	17:13:30	7,800	4,012	0.0611	0.0616	0.0626	0.0241	0.0236	0.0223	0.0426	0.0426	0.0425
1 H - 19	17:18:30	7,800	4,012	0.0637	0.0642	0.0655	0.0218	0.0215	0.0213	0.0427	0.0429	0.0434
1 U - 1	17:24:30	6,000	3,028	0.0579	0.0577	0.0577	0.0128	0.0125	0.0123	0.0354	0.0351	0.0350
1 U - 2	17:29:30	4,500	2,209	0.0480	0.0477	0.0475	0.0033	0.0030	0.0028	0.0257	0.0254	0.0252
1 U - 3	17:34:30	3,000	1,389	0.0365	0.0365	0.0360	-0.0072	-0.0072	-0.0075	0.0147	0.0147	0.0143
1 U - 4	17:40:00	1,500	570	0.0208	0.0208	0.0206	-0.0193	-0.0196	-0.0196	0.0008	0.0006	0.0005
1 U - 5	17:46:00	0	0	-0.0006	-0.0009	-0.0014	-0.0319	-0.0321	-0.0321	-0.0162	-0.0165	-0.0168
1 U - 6	17:55	0	0	-0.0040	-0.0040	-0.0040	-0.0342	-0.0342	-0.0342	-0.0191	-0.0191	-0.0191

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

Upward Top of O-cell™ Movement (calculated)
Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time	O-cell™ Pressure	Net * Load	Top of Shaft (tbl 2)			Shaft Compression (tbl 3)			Top of O-cell™			Creep
				1 min	2 min	4 min	1 min	2 min	4 min	1 min	2 min	4 min	2-4 min
	(h:m:s)	(psi)	(tons)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)	(inches)
1 L - 0	15:14:00	0	0	0.0000			0.0000			0.0000			
1 L - 1	15:26:00	400	0	0.0000	0.0000	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	-0.0001
1 L - 2	15:31:00	800	187	0.0000	0.0036	0.0140	0.0001	0.0001	0.0001	0.0001	0.0038	0.0141	0.0103
1 L - 3	15:36:00	1,200	406	0.0202	0.0207	0.0217	0.0013	0.0017	0.0023	0.0214	0.0224	0.0240	0.0017
1 L - 4	15:41:00	1,600	624	0.0315	0.0340	0.0371	0.0065	0.0070	0.0074	0.0380	0.0410	0.0445	0.0034
1 L - 5	15:46:00	2,000	843	0.0526	0.0551	0.0623	0.0104	0.0107	0.0109	0.0629	0.0658	0.0732	0.0075
1 L - 6	15:51:00	2,400	1,061	0.0804	0.0809	0.0804	0.0139	0.0140	0.0144	0.0943	0.0949	0.0948	-0.0001
1 L - 7	15:56:30	2,800	1,280	0.0917	0.0917	0.0933	0.0169	0.0170	0.0173	0.1086	0.1087	0.1105	0.0018
1 L - 8	16:01:30	3,200	1,498	0.1098	0.1118	0.1144	0.0182	0.0183	0.0182	0.1279	0.1300	0.1325	0.0025
1 L - 9	16:06:30	3,600	1,717	0.1309	0.1329	0.1427	0.0205	0.0205	0.0207	0.1514	0.1534	0.1633	0.0099
1 L - 10	16:12:00	4,000	1,935	0.1648	0.1679	0.1705	0.0232	0.0232	0.0235	0.1880	0.1911	0.1940	0.0029
1 L - 11	16:17:00	4,400	2,154	0.1890	0.1911	0.1963	0.0257	0.0258	0.0261	0.2147	0.2169	0.2223	0.0054
1 L - 12	16:22:00	4,800	2,373	0.2179	0.2225	0.2277	0.0283	0.0284	0.0287	0.2462	0.2509	0.2563	0.0054
1 L - 13	16:27:30	5,200	2,591	0.2555	0.2606	0.2694	0.0305	0.0306	0.0312	0.2860	0.2912	0.3005	0.0093
1 L - 14	16:32:00	5,600	2,810	0.2956	0.3028	0.3126	0.0323	0.0324	0.0326	0.3279	0.3352	0.3452	0.0099
1 L - 15	16:37:30	6,000	3,028	0.3507	0.3600	0.3687	0.0343	0.0346	0.0348	0.3850	0.3945	0.4035	0.0090
1 L - 16	16:44:00	6,400	3,247	0.4207	0.4315	0.4511	0.0361	0.0362	0.0363	0.4568	0.4677	0.4874	0.0197
1 L - 17	16:58:00	7,200	3,684	0.6498	0.6791	0.7229	0.0393	0.0395	0.0396	0.6891	0.7185	0.7624	0.0439
1 L - 18	17:07:00	7,600	3,902	0.9421	0.9750	1.0410	0.0421	0.0420	0.0422	0.9842	1.0170	1.0832	0.0662
1 L - 19	17:13:30	7,800	4,012	1.2082	1.2628	1.3729	0.0426	0.0426	0.0425	1.2507	1.3054	1.4154	0.1100
1 H - 19	17:18:30	7,800	4,012	1.4867	1.5433	1.6591	0.0427	0.0429	0.0434	1.5294	1.5861	1.7024	
1 U - 1	17:24:30	6,000	3,028	1.6586	1.6555	1.6575	0.0354	0.0351	0.0350	1.6939	1.6906	1.6925	
1 U - 2	17:29:30	4,500	2,209	1.6282	1.6271	1.6266	0.0257	0.0254	0.0252	1.6538	1.6525	1.6518	
1 U - 3	17:34:30	3,000	1,389	1.5793	1.5777	1.5762	0.0147	0.0147	0.0143	1.5939	1.5924	1.5904	
1 U - 4	17:40:00	1,500	570	1.4835	1.4804	1.4773	0.0008	0.0006	0.0005	1.4843	1.4810	1.4778	
1 U - 5	17:46:00	0	0	1.1932	1.1870	1.1798	-0.0162	-0.0165	-0.0168	1.1769	1.1705	1.1630	
1 U - 6	17:55	0	0	1.1742	1.1742	1.1742	-0.0191	-0.0191	-0.0191	1.1551	1.1551	1.1551	

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

O-cell™ Expansion
Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	LVWDT 13459 1 min (inches)	LVWDT 13459 2 min (inches)	LVWDT 13459 4 min (inches)	LVWDT 13460 1 min (inches)	LVWDT 13460 2 min (inches)	LVWDT 13460 4 min (inches)	LVWDT 13461 1 min (inches)	LVWDT 13461 2 min (inches)	LVWDT 13461 4 min (inches)	LVWDT 13462 1 min (inches)	LVWDT 13462 2 min (inches)	LVWDT 13462 4 min (inches)
1 L - 0	15:14:00	0	0	0.0000			0.0000			0.0000			0.0000		
1 L - 1	15:26:00	400	0	0.0020	0.0022	0.0023	0.0016	0.0008	0.0010	0.0043	0.0052	0.0050	0.0031	0.0031	0.0031
1 L - 2	15:31:00	800	187	0.0114	0.0122	0.0132	0.0082	0.0097	0.0112	0.0134	0.0144	0.0157	0.0102	0.0116	0.0134
1 L - 3	15:36:00	1,200	406	0.0340	0.0406	0.0540	0.0377	0.0444	0.0595	0.0402	0.0456	0.0561	0.0317	0.0365	0.0420
1 L - 4	15:41:00	1,600	624	0.1115	0.1271	0.1489	0.1183	0.1329	0.1535	0.1241	0.1374	0.1566	0.1058	0.1192	0.1376
1 L - 5	15:46:00	2,000	843	0.1975	0.2088	0.2268	0.2013	0.2132	0.2296	0.2062	0.2182	0.2347	0.1814	0.1904	0.2074
1 L - 6	15:51:00	2,400	1,061	0.2824	0.2955	0.3151	0.2936	0.3033	0.3214	0.2939	0.3075	0.3285	0.2637	0.2767	0.2975
1 L - 7	15:56:30	2,800	1,280	0.3709	0.3825	0.4021	0.3825	0.3942	0.4148	0.3928	0.4045	0.4263	0.3564	0.3671	0.3879
1 L - 8	16:01:30	3,200	1,498	0.4627	0.4725	0.4947	0.4696	0.4894	0.5082	0.4930	0.5069	0.5316	0.4506	0.4630	0.4867
1 L - 9	16:06:30	3,600	1,717	0.5546	0.5682	0.5880	0.5738	0.5879	0.6089	0.6034	0.6199	0.6467	0.5509	0.5663	0.5914
1 L - 10	16:12:00	4,000	1,935	0.6599	0.6729	0.6919	0.6808	0.6958	0.7174	0.7274	0.7452	0.7703	0.6651	0.6815	0.7029
1 L - 11	16:17:00	4,400	2,154	0.7504	0.7632	0.7868	0.7863	0.7984	0.8220	0.8431	0.8588	0.8875	0.7679	0.7806	0.8094
1 L - 12	16:22:00	4,800	2,373	0.8478	0.8621	0.8848	0.8897	0.9049	0.9338	0.9622	0.9798	1.0122	0.8743	0.8878	0.9202
1 L - 13	16:27:30	5,200	2,591	0.9513	0.9667	1.0043	1.0126	1.0210	1.0604	1.0863	1.1045	1.1490	0.9879	1.0117	1.0443
1 L - 14	16:32:00	5,600	2,810	1.0591	1.0788	1.1052	1.1216	1.1422	1.1709	1.2160	1.2380	1.2693	1.1036	1.1227	1.1488
1 L - 15	16:37:30	6,000	3,028	1.1870	1.2078	1.2322	1.2629	1.2843	1.3117	1.3642	1.3889	1.4176	1.2398	1.2598	1.2887
1 L - 16	16:44:00	6,400	3,247	1.3364	1.3544	1.3908	1.4205	1.4415	1.4830	1.5288	1.5526	1.5990	1.3941	1.4145	1.4574
1 L - 17	16:58:00	7,200	3,684	1.7156	1.7536	1.8147	1.8279	1.8695	1.9355	1.9454	1.9932	2.0598	1.7931	1.8311	1.8973
1 L - 18	17:07:00	7,600	3,902	2.1038	2.1426	2.2238	2.2447	2.2872	2.3744	2.3748	2.4183	2.5091	2.2000	2.2412	2.3261
1 L - 19	17:13:30	7,800	4,012	2.4251	2.4856	2.6107	2.5828	2.6467	2.7749	2.7271	2.7922	2.9174	2.5359	2.5982	2.7260
1 H - 19	17:18:30	7,800	4,012	2.7381	2.8028	2.9295	2.9088	2.9734	3.1056	3.0541	3.1234	3.2568	2.8578	2.9231	3.0522
1 U - 1	17:24:30	6,000	3,028	2.8810	2.8793	2.8789	3.0586	3.0562	3.0556	3.2531	3.2521	3.2529	3.0010	2.9979	2.9987
1 U - 2	17:29:30	4,500	2,209	2.7966	2.7942	2.7921	2.9683	2.9665	2.9642	3.1567	3.1542	3.1530	2.9099	2.9085	2.9059
1 U - 3	17:34:30	3,000	1,389	2.6725	2.6711	2.6667	2.8412	2.8390	2.8336	3.0209	3.0199	3.0125	2.7814	2.7803	2.7754
1 U - 4	17:40:00	1,500	570	2.4793	2.4718	2.4648	2.6359	2.6284	2.6220	2.8104	2.8022	2.7961	2.5808	2.5754	2.5664
1 U - 5	17:46:00	0	0	1.9623	1.9473	1.9326	2.0989	2.0831	2.0685	2.2544	2.2366	2.2187	2.0667	2.0488	2.0333
1 U - 6	17:55	0	0	1.9081	1.9081	1.9081	2.0464	2.0464	2.0464	2.1944	2.1944	2.1944	2.0112	2.0112	2.0112

* Net load calculated as O-cell™ load minus bouyant weight of shaft 245.1 tons

Downward Base of O-cell™ Movement (calculated)
Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	Avg. O-cell™ Expansion (tbl 5) 1 min (inches)	2 min (inches)	4 min (inches)	Upward Movement (tbl 4) 1 min (inches)	2 min (inches)	4 min (inches)	Downward Movement 1 min (inches)	2 min (inches)	4 min (inches)	Creep 2-4 min (inches)
1 L - 0	15:14:00	0	0	0.0000			0.0000			0.0000			
1 L - 1	15:26:00	400	0	0.0027	0.0028	0.0029	0.0001	0.0001	0.0000	0.0026	0.0027	0.0029	0.0002
1 L - 2	15:31:00	800	187	0.0108	0.0120	0.0134	0.0001	0.0038	0.0141	0.0107	0.0082	-0.0007	-0.0089
1 L - 3	15:36:00	1,200	406	0.0359	0.0418	0.0529	0.0214	0.0224	0.0240	0.0145	0.0194	0.0289	0.0095
1 L - 4	15:41:00	1,600	624	0.1149	0.1292	0.1492	0.0380	0.0410	0.0445	0.0770	0.0882	0.1047	0.0165
1 L - 5	15:46:00	2,000	843	0.1966	0.2077	0.2246	0.0629	0.0658	0.0732	0.1337	0.1419	0.1514	0.0095
1 L - 6	15:51:00	2,400	1,061	0.2834	0.2957	0.3156	0.0943	0.0949	0.0948	0.1891	0.2009	0.2209	0.0200
1 L - 7	15:56:30	2,800	1,280	0.3756	0.3870	0.4078	0.1086	0.1087	0.1105	0.2671	0.2783	0.2973	0.0189
1 L - 8	16:01:30	3,200	1,498	0.4690	0.4829	0.5053	0.1279	0.1300	0.1325	0.3411	0.3529	0.3728	0.0198
1 L - 9	16:06:30	3,600	1,717	0.5707	0.5856	0.6088	0.1514	0.1534	0.1633	0.4193	0.4322	0.4455	0.0133
1 L - 10	16:12:00	4,000	1,935	0.6833	0.6988	0.7206	0.1880	0.1911	0.1940	0.4953	0.5077	0.5267	0.0189
1 L - 11	16:17:00	4,400	2,154	0.7869	0.8003	0.8264	0.2147	0.2169	0.2223	0.5723	0.5834	0.6041	0.0208
1 L - 12	16:22:00	4,800	2,373	0.8935	0.9087	0.9378	0.2462	0.2509	0.2563	0.6473	0.6578	0.6815	0.0237
1 L - 13	16:27:30	5,200	2,591	1.0095	1.0260	1.0645	0.2860	0.2912	0.3005	0.7236	0.7348	0.7640	0.0291
1 L - 14	16:32:00	5,600	2,810	1.1250	1.1454	1.1735	0.3279	0.3352	0.3452	0.7971	0.8102	0.8284	0.0182
1 L - 15	16:37:30	6,000	3,028	1.2635	1.2852	1.3125	0.3850	0.3945	0.4035	0.8785	0.8907	0.9090	0.0183
1 L - 16	16:44:00	6,400	3,247	1.4199	1.4407	1.4826	0.4568	0.4677	0.4874	0.9632	0.9730	0.9951	0.0221
1 L - 17	16:58:00	7,200	3,684	1.8205	1.8619	1.9268	0.6891	0.7185	0.7624	1.1314	1.1433	1.1644	0.0211
1 L - 18	17:07:00	7,600	3,902	2.2308	2.2723	2.3584	0.9842	1.0170	1.0832	1.2466	1.2554	1.2752	0.0198
1 L - 19	17:13:30	7,800	4,012	2.5677	2.6307	2.7573	1.2507	1.3054	1.4154	1.3170	1.3253	1.3419	0.0166
1 H - 19	17:18:30	7,800	4,012	2.8897	2.9557	3.0860	1.5294	1.5861	1.7024	1.3603	1.3696	1.3836	
1 U - 1	17:24:30	6,000	3,028	3.0484	3.0464	3.0465	1.6939	1.6906	1.6925	1.3545	1.3558	1.3540	
1 U - 2	17:29:30	4,500	2,209	2.9579	2.9558	2.9538	1.6538	1.6525	1.6518	1.3041	1.3034	1.3020	
1 U - 3	17:34:30	3,000	1,389	2.8290	2.8276	2.8220	1.5939	1.5924	1.5904	1.2351	1.2352	1.2316	
1 U - 4	17:40:00	1,500	570	2.6266	2.6194	2.6123	1.4843	1.4810	1.4778	1.1423	1.1384	1.1345	
1 U - 5	17:46:00	0	0	2.0956	2.0790	2.0633	1.1769	1.1705	1.1630	0.9186	0.9085	0.9002	
1 U - 6	17:55	0	0	2.0400	2.0400	2.0400	1.1551	1.1551	1.1551	0.8850	0.8850	0.8850	

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

Compression Telltale Readings and Loads at Levels 1 and 2
Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	Level 1 13443 (inches)	Level 1 13444 (inches)	Level 1 13450 (inches)	Level 1 13445 (inches)	Level 1 Av. Load (tons)	Level 2 13446 (inches)	Level 2 13447 (inches)	Level 2 13448 (inches)	Level 2 13449 (inches)	Level 2 Av. Load (tons)
1 L - 0	15:14:00	0	0	0.0000	0.0000	0.0000	0.0000	0.0	0.0000	0.0000	0.0000	0.0000	0.0
1 L - 1	15:26:00	400	0	-0.0001	0.0000	0.0000	-0.0001	-18.5	0.0000	0.0002	0.0001	-0.0002	6.1
1 L - 2	15:31:00	800	187	-0.0001	0.0001	0.0003	0.0002	33.4	0.0003	0.0004	0.0005	0.0002	64.1
1 L - 3	15:36:00	1,200	406	0.0002	0.0005	0.0006	0.0004	137.8	0.0010	0.0017	0.0014	0.0007	213.6
1 L - 4	15:41:00	1,600	624	0.0002	0.0009	0.0018	0.0010	297.3	0.0019	0.0031	0.0030	0.0014	416.3
1 L - 5	15:46:00	2,000	843	0.0005	0.0011	0.0023	0.0011	390.0	0.0025	0.0040	0.0039	0.0019	545.2
1 L - 6	15:51:00	2,400	1,061	0.0008	0.0014	0.0027	0.0013	474.6	0.0031	0.0049	0.0045	0.0025	664.9
1 L - 7	15:56:30	2,800	1,280	0.0009	0.0017	0.0032	0.0014	555.0	0.0035	0.0059	0.0053	0.0031	787.4
1 L - 8	16:01:30	3,200	1,498	0.0008	0.0018	0.0037	0.0015	610.8	0.0039	0.0067	0.0061	0.0036	902.2
1 L - 9	16:06:30	3,600	1,717	0.0008	0.0020	0.0042	0.0017	672.8	0.0043	0.0077	0.0072	0.0038	1012.9
1 L - 10	16:12:00	4,000	1,935	0.0009	0.0021	0.0046	0.0018	722.5	0.0047	0.0085	0.0083	0.0043	1140.7
1 L - 11	16:17:00	4,400	2,154	0.0010	0.0023	0.0050	0.0018	777.0	0.0050	0.0095	0.0092	0.0046	1254.4
1 L - 12	16:22:00	4,800	2,373	0.0010	0.0023	0.0053	0.0018	811.1	0.0055	0.0104	0.0102	0.0050	1378.6
1 L - 13	16:27:30	5,200	2,591	0.0010	0.0024	0.0057	0.0019	846.5	0.0059	0.0113	0.0110	0.0051	1476.3
1 L - 14	16:32:00	5,600	2,810	0.0011	0.0023	0.0059	0.0021	884.7	0.0063	0.0123	0.0120	0.0055	1597.8
1 L - 15	16:37:30	6,000	3,028	0.0013	0.0023	0.0062	0.0021	921.5	0.0067	0.0132	0.0129	0.0060	1721.2
1 L - 16	16:44:00	6,400	3,247	0.0013	0.0023	0.0065	0.0020	939.1	0.0073	0.0143	0.0138	0.0061	1837.6
1 L - 17	16:58:00	7,200	3,684	0.0015	0.0020	0.0070	0.0025	1014.2	0.0087	0.0162	0.0160	0.0074	2140.7
1 L - 18	17:07:00	7,600	3,902	0.0015	0.0024	0.0075	0.0030	1116.5	0.0089	0.0177	0.0173	0.0076	2284.0
1 L - 19	17:13:30	7,800	4,012	0.0016	0.0024	0.0073	0.0034	1135.8	0.0097	0.0182	0.0175	0.0080	2361.2
1 H - 19	17:18:30	7,800	4,012	0.0020	0.0026	0.0070	0.0035	1168.8	0.0104	0.0180	0.0170	0.0079	2363.8
1 U - 1	17:24:30	6,000	3,028	0.0014	0.0018	0.0051	0.0023	816.8	0.0077	0.0150	0.0137	0.0055	1855.8
1 U - 2	17:29:30	4,500	2,209	0.0009	0.0011	0.0035	0.0013	524.9	0.0054	0.0122	0.0109	0.0029	1389.7
1 U - 3	17:34:30	3,000	1,389	0.0002	0.0004	0.0020	0.0001	212.4	0.0029	0.0093	0.0080	0.0004	912.6
1 U - 4	17:40:00	1,500	570	-0.0001	-0.0002	0.0005	-0.0010	-63.9	0.0005	0.0061	0.0047	-0.0018	422.2
1 U - 5	17:46:00	0	0	-0.0005	-0.0005	-0.0004	-0.0016	-233.7	-0.0012	0.0026	0.0015	-0.0029	0.1
1 U - 6	17:55	0	0	-0.0005	-0.0005	-0.0005	-0.0017	-244.6	-0.0013	0.0024	0.0016	-0.0029	-8.8

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

LOADTEST Inc. Project No. LT-8415-2

Table 7 of 8

Compression Telltale Readings and Loads at Levels 3 and 4
Test Shaft at Sta. 890+95 ft - U.S. 231 over the Ohio River - Owensboro, KY

Load Test Incr.	Time (h:m:s)	O-cell™ Pressure (psi)	Net * Load (tons)	Level 3 13451 (inches)	Level 3 13452 (inches)	Level 3 13453** (inches)	Level 3 13454 (inches)	Level 3 Av. Load (tons)	Level 4 13455 (inches)	Level 4 13456 (inches)	Level 4 13457 (inches)	Level 4 13458 (inches)	Level 4 Av. Load (tons)
1 L - 0	15:14:00	0	0	0.0000	0.0000	0.0000	0.0000	0.0	0.0000	0.0000	0.0000	0.0000	0.0
1 L - 1	15:26:00	400	0	0.0000	0.0001	-0.0070	0.0001	6.7	0.0000	0.0000	0.0001	0.0000	1.1
1 L - 2	15:31:00	800	187	0.0003	0.0002	0.0733	0.0003	42.1	0.0002	0.0000	0.0002	0.0004	21.4
1 L - 3	15:36:00	1,200	406	0.0008	0.0009	0.0740	0.0009	125.5	0.0007	0.0009	0.0006	0.0012	106.1
1 L - 4	15:41:00	1,600	624	0.0017	0.0023	0.0752	0.0017	273.7	0.0018	0.0016	0.0014	0.0019	208.8
1 L - 5	15:46:00	2,000	843	0.0023	0.0029	0.0636	0.0021	356.2	0.0024	0.0021	0.0019	0.0024	272.0
1 L - 6	15:51:00	2,400	1,061	0.0029	0.0037	0.0768	0.0026	443.0	0.0029	0.0028	0.0025	0.0030	348.4
1 L - 7	15:56:30	2,800	1,280	0.0033	0.0044	0.0122	0.0030	523.0	0.0036	0.0035	0.0029	0.0037	426.5
1 L - 8	16:01:30	3,200	1,498	0.0038	0.0058	0.0063	0.0034	634.2	0.0040	0.0039	0.0035	0.0041	479.2
1 L - 9	16:06:30	3,600	1,717	0.0042	0.0069	0.0212	0.0038	726.2	0.0045	0.0049	0.0041	0.0045	556.5
1 L - 10	16:12:00	4,000	1,935	0.0044	0.0079	0.0154	0.0042	802.8	0.0051	0.0054	0.0046	0.0050	621.1
1 L - 11	16:17:00	4,400	2,154	0.0050	0.0100	0.0231	0.0044	947.2	0.0055	0.0061	0.0051	0.0054	682.7
1 L - 12	16:22:00	4,800	2,373	0.0054	0.0112	0.0310	0.0048	1038.4	0.0058	0.0066	0.0056	0.0055	727.9
1 L - 13	16:27:30	5,200	2,591	0.0057	0.0127	0.0182	0.0050	1138.5	0.0063	0.0074	0.0062	0.0059	803.9
1 L - 14	16:32:00	5,600	2,810	0.0057	0.0132	0.0193	0.0051	1166.3	0.0065	0.0081	0.0067	0.0060	847.7
1 L - 15	16:37:30	6,000	3,028	0.0060	0.0144	0.0204	0.0052	1248.0	0.0068	0.0087	0.0072	0.0060	890.8
1 L - 16	16:44:00	6,400	3,247	0.0060	0.0154	0.0074	0.0051	1290.1	0.0069	0.0095	0.0075	0.0056	911.2
1 L - 17	16:58:00	7,200	3,684	0.0063	0.0173	0.0095	0.0048	1383.6	0.0067	0.0115	0.0081	0.0042	946.3
1 L - 18	17:07:00	7,600	3,902	0.0063	0.0199	0.0033	0.0042	1473.8	0.0065	0.0132	0.0090	0.0027	976.0
1 L - 19	17:13:30	7,800	4,012	0.0068	0.0210	0.0312	0.0038	1538.0	0.0063	0.0148	0.0094	0.0017	998.4
1 H - 19	17:18:30	7,800	4,012	0.0076	0.0210	0.0235	0.0036	1569.4	0.0063	0.0159	0.0095	0.0010	1010.8
1 U - 1	17:24:30	6,000	3,028	0.0055	0.0187	0.0063	0.0013	1236.8	0.0045	0.0143	0.0079	-0.0007	806.9
1 U - 2	17:29:30	4,500	2,209	0.0029	0.0156	0.0102	-0.0011	848.5	0.0025	0.0124	0.0059	-0.0028	558.9
1 U - 3	17:34:30	3,000	1,389	0.0005	0.0129	0.0208	-0.0031	499.9	0.0002	0.0103	0.0038	-0.0052	281.8
1 U - 4	17:40:00	1,500	570	-0.0013	0.0078	-0.0256	-0.0043	107.8	-0.0057	0.0067	-0.0002	-0.0117	-340.6
1 U - 5	17:46:00	0	0	-0.0026	0.0030	0.0738	-0.0041	-181.7	-0.0136	-0.0001	-0.0076	-0.0169	-1184.0
1 U - 6	17:55	0	0	-0.0026	0.0029	0.0738	-0.0041	-185.1	-0.0136	-0.0003	-0.0078	-0.0167	-1189.9

* Net load calculated as O-cell™ load minus bouyant weight of shaft : 245.1 tons

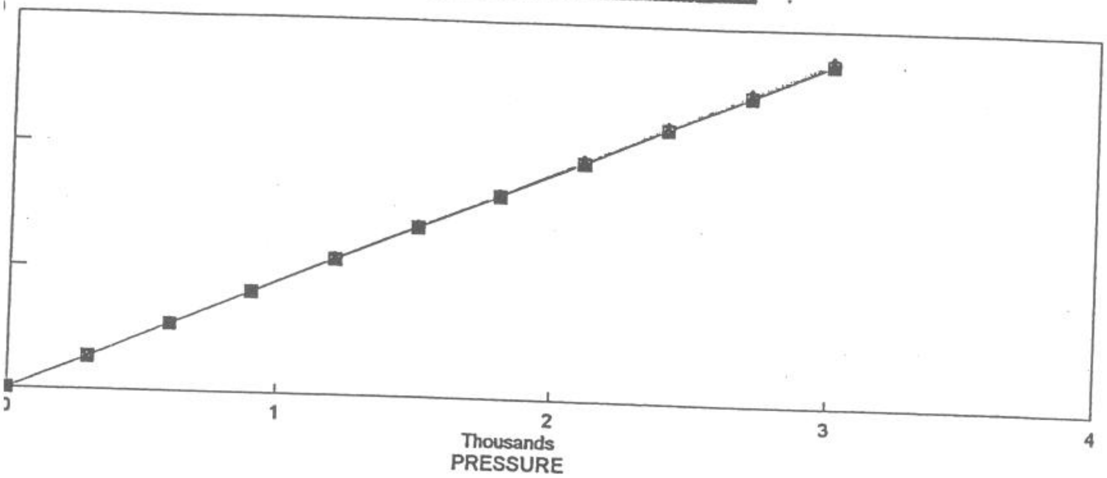
** Not included in the average.

LOADTEST Inc. Project No. LT-8415-2

Table 8 of 8

LOAD TEST GRAPH

7020-13 CALIBRATED ON 02/23/98



Coefficient*(pressure)+CONSTANT
ERBERG CELL, SERIAL # 7020-13

	1 INCH	3 INCH	5 INCH
E	TONS	TONS	TONS
0	0	0	0
0	53.41	52.27	52.65
0	108.71	108.71	109.85
0	164.02	164.39	163.64
)	218.94	221.21	219.70
)	273.48	275.76	275.00
)	327.27	329.17	329.17
)	382.20	386.36	384.47
)	438.64	442.80	440.15
)	492.42	497.35	494.32
	546.21	552.65	549.24
	603.03	607.95	605.30

Regression Output:		1 INCH
Constant		-0.9573
Std Err of Y Est		0.729408
R Squared		0.999986
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.182771	
Std Err of Coef.	0.000232	

Regression Output:		3 INCH
Constant		-2.31405
Std Err of Y Est		0.885968
R Squared		0.999979
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.185055	
Std Err of Coef.	0.000282	

Regression Output:		5 INCH
Constant		-1.31543
Std Err of Y Est		0.680052
R Squared		0.999988
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.183735	
Std Err of Coef.	0.000216	

ON STANDARDS:

ented is derived from 6" dia. certified hydraulic
uges and electronic load transducer,
d and calibrated by the University of Illinois at
Illinois. All calibrations and certifications are
ough the Laboratory Master Deadweight
ctly to the National Institute of Standards and
No Specific guidelines exist for calibration of
s and equipment but procedures comply with
lines for calibration of gauges, ANSI
s B40.1.

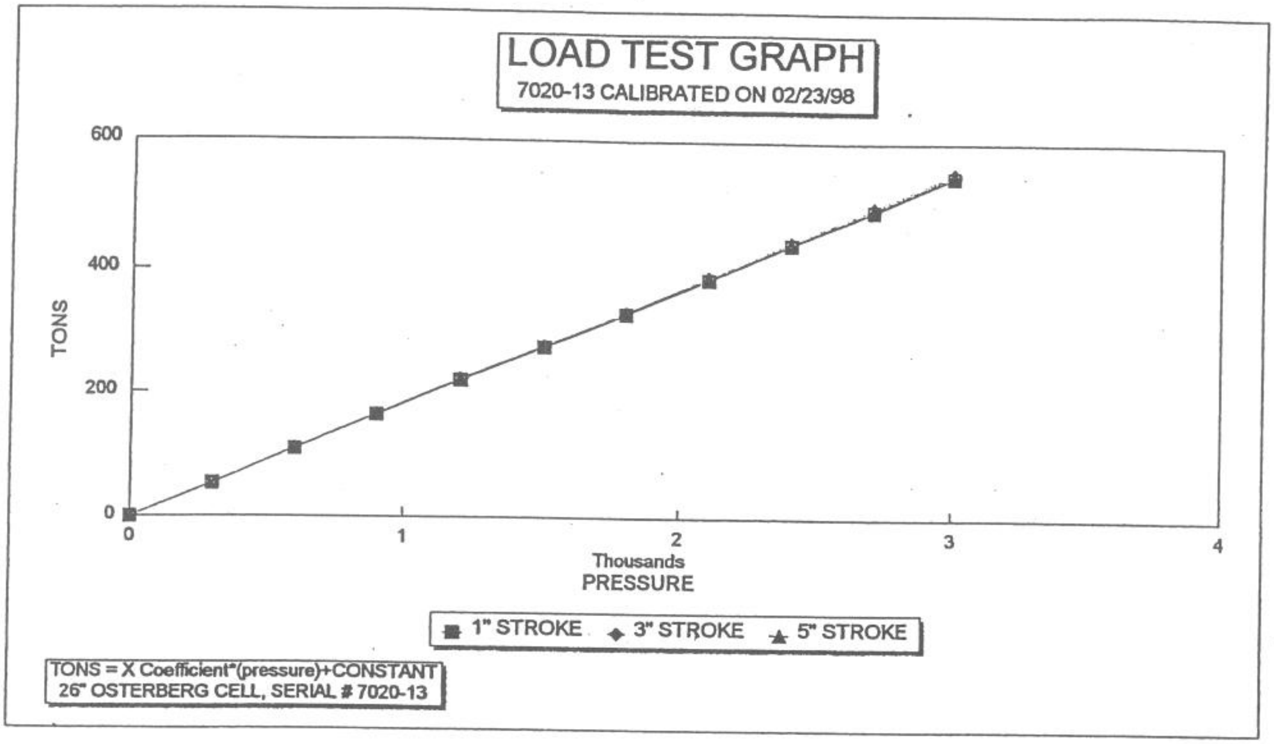
STOMER:LOADTEST INC.
NO.:8537
P.O.NO.:LT-8415

*CONTRACTOR:TRAYLOR
*JOB LOCATION:MACEO, KY
*DATED:05/21/98

DATE: 2-25-98

APPENDIX B

CALIBRATION OF O-CELLS™ STRAIN GAGES AND LVWDTs



STROKE:	1 INCH	3 INCH	5 INCH
PRESSURE	TONS	TONS	TONS
0	0	0	0
300	53.41	52.27	52.65
600	108.71	108.71	109.85
900	164.02	164.39	163.64
1200	218.94	221.21	219.70
1500	273.48	275.76	275.00
1800	327.27	329.17	329.17
2100	382.20	386.36	384.47
2400	438.64	442.80	440.15
2700	492.42	497.35	494.32
3000	546.21	552.65	549.24
3300	603.03	607.95	605.30

Regression Output:		1 INCH
Constant		-0.9573
Std Err of Y Est		0.729408
R Squared		0.999986
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.182771	
Std Err of Coef.	0.000232	

Regression Output:		3 INCH
Constant		-2.31405
Std Err of Y Est		0.885968
R Squared		0.999979
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.185055	
Std Err of Coef.	0.000282	

Regression Output:		5 INCH
Constant		-1.31543
Std Err of Y Est		0.680052
R Squared		0.999988
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.183735	
Std Err of Coef.	0.000216	

CALIBRATION STANDARDS:

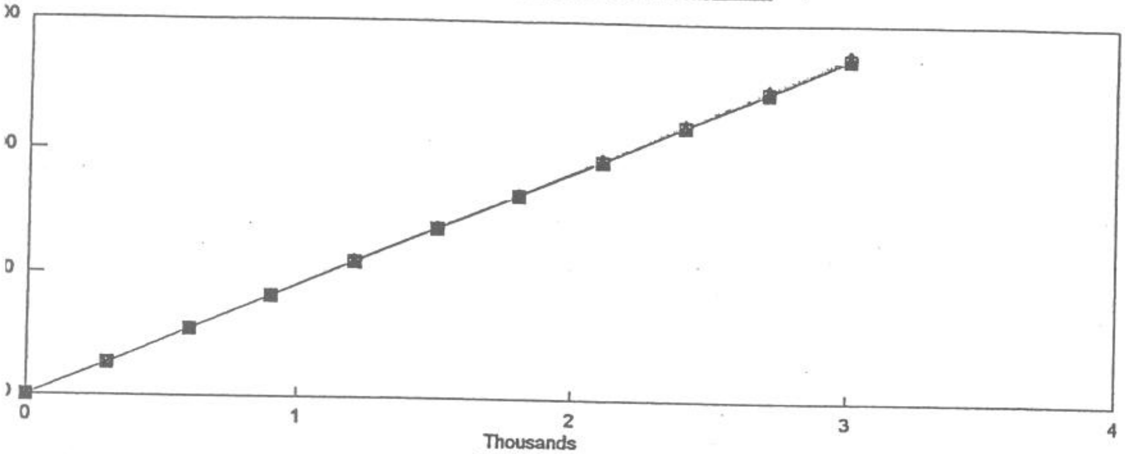
All data presented is derived from 6" dia. certified hydraulic pressure gauges and electronic load transducer, manufactured and calibrated by the University of Illinois at Champaign, Illinois. All calibrations and certifications are traceable through the Laboratory Master Deadweight Gauges directly to 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.:8537 *CUSTOMER P.O.NO.:LT-8415	*CONTRACTOR:TRAYLOR *JOB LOCATION:MACEO, KY *DATED:05/21/98

:VICE ENGINEER: [signature] DATE: 2-25-98

LOAD TEST GRAPH

7020-13 CALIBRATED ON 02/23/98



= X Coefficient*(pressure)+CONSTANT
STERBERG CELL, SERIAL # 7020-13

E:	1 INCH	3 INCH	5 INCH
RE	TONS	TONS	TONS
0	0	0	0
300	53.41	52.27	52.65
500	108.71	108.71	109.85
900	164.02	164.39	163.64
200	218.94	221.21	219.70
00	273.48	275.76	275.00
00	327.27	329.17	329.17
00	382.20	386.36	384.47
00	438.64	442.80	440.15
00	492.42	497.35	494.32
00	546.21	552.65	549.24
00	603.03	607.95	605.30

Regression Output:		1 INCH
Constant		-0.9573
Std Err of Y Est		0.729408
R Squared		0.999986
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.182771	
Std Err of Coef.	0.000232	

Regression Output:		3 INCH
Constant		-2.31405
Std Err of Y Est		0.885968
R Squared		0.999979
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.185055	
Std Err of Coef.	0.000282	

Regression Output:		5 INCH
Constant		-1.31543
Std Err of Y Est		0.680052
R Squared		0.999988
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	0.183735	
Std Err of Coef.	0.000216	

TION STANDARDS:

esented is derived from 6" dia. certified hydraulic gauges and electronic load transducer, ured and calibrated by the University of Illinois at gn, Illinois. All calibrations and certifications are through the Laboratory Master Deadweight irectly to the National Institute of Standards and gy. No Specific guidelines exist for calibration of acks and equipment but procedures comply with idelines for calibration of gauges, ANSI ons B40.1.

CUSTOMER:LOADTEST INC.
JOB NO.:8537
ER P.O.NO.:LT-8415

*CONTRACTOR:TRAYLOR
*JOB LOCATION:MACEO, KY
*DATED:05/21/98

R: [signature] DATE: 2-25-98

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13444

Mfg. Number: 98-766

Customer: Loadtest, Inc.

Temperature: 23 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 13, 1998

Technician: [illegible signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2485	2484	2485		
0.25	3926	3927	3927	1442	0.16
0.50	5347	5347	5347	1421	0.16
0.75	6763	6762	6763	1416	0.07
1.00	8169	8169	8169	1407	0.18

Calibration Factor (C): 0.00017599 (Inches/Digit)

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5169

or

Position "F": ________

Date: July 31, 1998

Temperature: 23.9 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13445

Mfg. Number: 98-767

Customer: Loadtest, Inc.

Temperature: 23 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 13, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2621	2618	2620		
0.25	4054	4051	4053	1433	0.14
0.50	5466	5465	5466	1413	0.09
0.75	6881	6880	6881	1415	0.08
1.00	8284	8284	8284	1404	0.14

Calibration Factor (C): 0.00017659 (Inches/Digit)

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5261

or

Position "F": ________

Date: July 31, 1998

Temperature: 24.3 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13443

Mfg. Number: 98-765

Customer: Loadtest, Inc.

Temperature: 23 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 13, 1998

Technician: Peter Clark

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2517	2513	2515		
0.25	3951	3949	3950	1435	0.15
0.50	5366	5364	5365	1415	0.14
0.75	6777	6778	6778	1413	0.09
1.00	8179	8177	8178	1401	0.18

Calibration Factor (C): 0.00017663 (Inches/Digit)

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5174

or

Position "F": ______

Date: July 31, 1998

Temperature: 23.9 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13447

Mfg. Number: 98-868

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: Peter Clark

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2235	2236	2236		-0.18
0.25	3854	3855	3855	1619	0.12
0.50	5455	5457	5456	1602	0.15
0.75	7048	7047	7048	1592	0.02
1.00	8638	8638	8638	1591	-0.12

Calibration Factor (C): 0.00015627 (Inches/Digit)

Regression Zero: 2247

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5071

or

Position "F":

Date: July 31, 1998

Temperature: 23.4 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13448

Mfg. Number: 98-869

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: Peter Arnold

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2138	2138	2138		-0.23
0.25	3736	3735	3736	1598	0.17
0.50	5306	5308	5307	1572	0.16
0.75	6872	6873	6873	1566	0.05
1.00	8431	8431	8431	1559	-0.17

Calibration Factor (C): 0.00015900 (Inches/Digit)

Regression Zero: 2152

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5121

or

Position "F":

Date: July 31, 1998

Temperature: 23.8 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Number: 4450-1-1

Range: 1"

Number: 13449

Mfg. Number: 98-870

istomer: Loadtest, Inc.

Temperature: 22.8 °C

I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Iumber: 12289

Date: July 22, 1998

Technician: [signature]

placement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2240	2238	2239		-0.14
0.25	3848	3847	3848	1609	0.14
0.50	5433	5432	5433	1585	0.05
0.75	7022	7023	7023	1590	0.03
1.00	8606	8607	8607	1584	-0.08

Calibration Factor (C): 0.00015713 (Inches/Digit)

Regression Zero: 2248

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5183

or

Position "F": ________

Date: July 31, 1998

Temperature: 23.8 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

mber: 4450-1-1

Range: 1"

mber: 13450

Mfg. Number: 98-871

omer: Loadtest, Inc.

Temperature: 22.8 °C

). #: n/a

Cal. Std. Control Numbers: 327, 406, 249

iber: 12289

Date: July 22, 1998

Technician: [signature]

cement nge ies)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
)0	2555	2553	2554		-0.17
5	3996	3997	3997	1443	0.13
0	5422	5421	5422	1425	0.13
5	6841	6841	6841	1420	0.03
)	8258	8258	8258	1417	-0.12

:alibration Factor (C): 0.00017541 (Inches/Digit)

Regression Zero: 2564

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

ition "B": 5200
or
ition "F":

Date: July 31, 1998

Temperature: 24.4 °C

e: Red and Black: Gage White and Green: Thermistor

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13451

Mfg. Number: 98-872

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2254	2254	2254		-0.27
0.25	3720	3719	3720	1466	0.22
0.50	5157	5155	5156	1437	0.20
0.75	6583	6583	6583	1427	0.02
1.00	8010	8009	8010	1427	-0.17

Calibration Factor (C): 0.00017391 (Inches/Digit)

Regression Zero: 2270

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4985
or
Position "F": ________

Date: July 31, 1998

Temperature: 23.6 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

l Number: 4450-1-1

Range: 1"

l Number: 13452

Mfg. Number: 98-873

Customer: Loadtest, Inc.

Temperature: 22.8 °C

t. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Number: 12289

Date: July 22, 1998

Technician: [signature]

isplacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2568	2567	2568		-0.17
0.25	4029	4030	4030	1462	0.14
0.50	5473	5473	5473	1444	0.12
0.75	6910	6911	6911	1438	0.00
1.00	8349	8349	8349	1439	-0.10

Calibration Factor (C): 0.00017308 (Inches/Digit)

Regression Zero: 2577

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5183

or

Position "F": ______

Date: July 31, 1998

Temperature: 24.0 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13453

Mfg. Number: 98-874

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician:

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2444	2441	2443		-0.20
0.25	3888	3885	3887	1444	0.13
0.50	5314	5311	5313	1426	0.15
0.75	6735	6734	6735	1422	0.10
1.00	8143	8142	8143	1408	-0.19

Calibration Factor (C): 0.00017546 (Inches/Digit)

Regression Zero: 2454

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5065

or

Position "F": ______

Date: July 31, 1998

Temperature: 25.7 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13454

Mfg. Number: 98-875

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2270	2270	2270		-0.18
0.25	3738	3737	3738	1468	0.13
0.50	5188	5187	5188	1450	0.13
0.75	6632	6633	6633	1445	0.05
1.00	8071	8072	8072	1439	-0.14

Calibration Factor (C): 0.00017244 (Inches/Digit)

Regression Zero: 2280

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 4947
or
Position "F": ________

Date: July 31, 1998

Temperature: 23.8 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13455

Mfg. Number: 98-876

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2596	2595	2596		-0.12
0.25	4053	4052	4053	1457	0.12
0.50	5494	5495	5495	1442	0.09
0.75	6930	6930	6930	1436	-0.04
1.00	8373	8373	8373	1443	-0.05

Calibration Factor (C): 0.00017322 (Inches/Digit)

Regression Zero: 2603

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5336

or

Position "F": ________

Date: July 31, 1998

Temperature: 23.7 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13456

Mfg. Number: 98-877

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician:

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2180	2179	2180		-0.20
0.25	3781	3780	3781	1601	0.12
0.50	5366	5367	5367	1586	0.19
0.75	6938	6939	6939	1572	0.05
1.00	8507	8506	8507	1568	-0.16

Calibration Factor (C): 0.00015810 (Inches/Digit)

Regression Zero: 2192

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5226

or

Position "F": ________

Date: July 31, 1998

Temperature: 24.4 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13457

Mfg. Number: 98-878

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2489	2490	2490		-0.18
0.25	3973	3974	3974	1484	0.14
0.50	5437	5437	5437	1464	0.11
0.75	6900	6899	6900	1463	0.07
1.00	8353	8352	8353	1453	-0.14

Calibration Factor (C): 0.00017062 (Inches/Digit)

Regression Zero: 2500

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5052

or

Position "F": ______

Date: July 31, 1998

Temperature: 24.0 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-1-1

Range: 1"

Serial Number: 13458

Mfg. Number: 98-879

Customer: Loadtest, Inc.

Temperature: 22.8 °C

Cust. I.D. #: n/a

Cal. Std. Control Numbers: 327, 406, 249

Job Number: 12289

Date: July 22, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.00	2403	2403	2403		-0.18
0.25	3996	3995	3996	1593	0.15
0.50	5567	5568	5568	1572	0.15
0.75	7130	7129	7130	1562	-0.01
1.00	8696	8696	8696	1567	-0.10

Calibration Factor (C): 0.00015903 (Inches/Digit)

Regression Zero: 2414

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5184
or
Position "F": ________

Date: July 31, 1998

Temperature: 24.3 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-3-6

Range: 6"

Serial Number: 13459

Mfg. Number: 98-808

Customer: Loadtest, Inc.

Temperature: 23.6 °C

Cust. I.D. #: n/a

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

Job Number: 12289

Date: July 21, 1998

Technician:

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.0	2516	2513	2515		-0.25
1.5	4121	4120	4121	1606	0.16
3.0	5704	5703	5704	1583	0.22
4.5	7274	7274	7274	1571	0.07
6.0	8837	8836	8837	1563	-0.21

Calibration Factor (C): 0.00094949 (Inches/Digit)

Regression Zero: 2530

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5499

or

Position "F": ________

Date: July 31, 1998

Temperature: 23.1 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-3-6

Range: 6"

Serial Number: 13461

Mfg. Number: 98-810

Customer: Loadtest, Inc.

Temperature: 23.6 °C

Cust. I.D. #: n/a

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

Job Number: 12289

Date: July 21, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.0	2485	2484	2485		-0.21
1.5	4082	4081	4082	1597	0.12
3.0	5662	5665	5664	1582	0.21
4.5	7231	7232	7232	1568	0.08
6.0	8790	8790	8790	1559	-0.20

Calibration Factor (C): 0.00095169 (Inches/Digit)

Regression Zero: 2498

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5503

or

Position "F": ________

Date: July 31, 1998

Temperature: 22.6 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-3-6 Range: 6"

Serial Number: 13460 Mfg. Number: 98-809

Customer: Loadtest, Inc. Temperature: 23.6 °C

Cust. I.D. #: n/a Cal. Std. Control Numbers: 124, 406, 249

Job Number: 12289 Date: July 21, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.0	2632	2630	2631		-0.18
1.5	4225	4225	4225	1594	0.12
3.0	5803	5805	5804	1579	0.18
4.5	7371	7368	7370	1566	0.03
6.0	8935	8933	8934	1565	-0.14

Calibration Factor (C): 0.00095234 (Inches/Digit)

Regression Zero: 2643

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5512
or
Position "F": ________

Date: July 31, 1998

Temperature: 25.8 °C

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

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

GEOKON

Vibrating Wire Displacement Transducer Calibration

Model Number: 4450-3-6

Range: 6"

Serial Number: 13462

Mfg. Number: 98-811

Customer: Loadtest, Inc.

Temperature: 23.6 °C

Cust. I.D. #: n/a

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

Job Number: 12289

Date: July 21, 1998

Technician: [signature]

Displacement Change (inches)	GK-401 Reading Position B Cycle 1	Cycle 2	Average	Change	% Linearity
0.0	2668	2665	2667		-0.22
1.5	4262	4262	4262	1596	0.14
3.0	5838	5839	5839	1577	0.19
4.5	7405	7406	7406	1567	0.09
6.0	8961	8960	8961	1555	-0.20

Calibration Factor (C): 0.00095348 (Inches/Digit)

Regression Zero: 2680

Refer to manual for temperature correction information.

Function Test at Shipment (GK-401 Reading)

Position "B": 5592

or

Position "F": ________

Date: July 31, 1998

Temperature: 22.8 °C

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

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

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 F = 0.95 for compression and F = 0.80 for 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.

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 a initially assumed a rigid pile, the top of moves downward the same as the bottom. Therefore, find point 4 with 0.40 inches of downward 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 $r^2 = 0.965$) with the result shown as points 6 to 12 on the dotted extension of the measured end bearing 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.

Analysis p. 4 gives the equations for the elastic compressions that occur in the equivalent TLT for an OLT with two levels of O-cells™ and tested in three stages (as shown along the right edge). The attached analysis p.3 gives the equations for the elastic compressions that occur in the OLT. Subtracting 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. 3 and 4 give equations for each of three assumed patterns of developed side shear stress along the pile. As illustrated on the bottom of p. 4, adjusting the length ℓ_o with negligible or no side shear expands the usefulness of the three basic patterns approximating above the O-cells™. Experience has shown that one or more of these three patterns, with a possible ℓ_o adjustment, usually suffices as an approximation of the actual pattern in the OLT and TLT, which are assumed similar. Experience has also 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.

For the case of using Part II with an OLT with only a single level of cell(s), $Q_A = Q_B$, $\ell_2 = 0$, and the choice of three side shear patterns reduces to two.

The final analysis pp. 5 and 6 provide comparative examples of calculated results on hypothetical OLTs using the simplified method in Part II, with all three assumed side shear distribution patterns and in both SI (p. 5) and English (p. 6) units.

<u>Other Tests</u>: The example illustrated in <u>Figure A</u> 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 <u>Figure A</u> for the equivalent top-loaded displacement curve.

<u>Expected Accuracy</u>: 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. <u>et al</u>., 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 five 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.

Limitations: The engineer using these results should judge the conservatism 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 used usually produces reasonable extrapolations.

July, 1998

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

Figure A

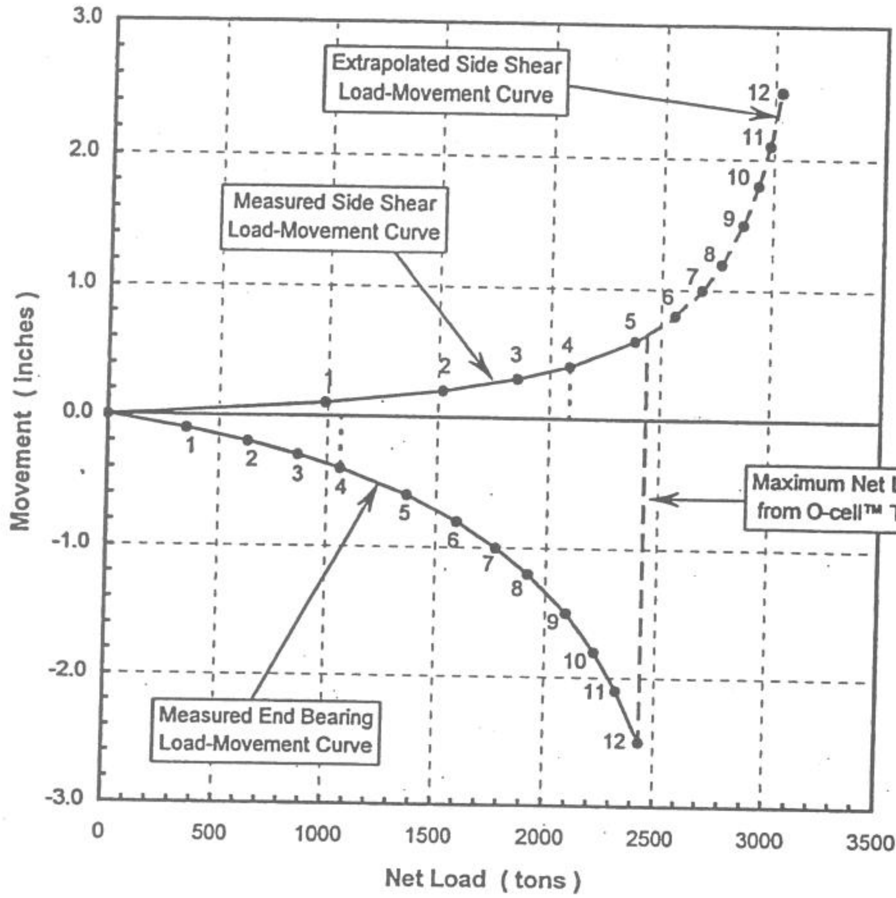
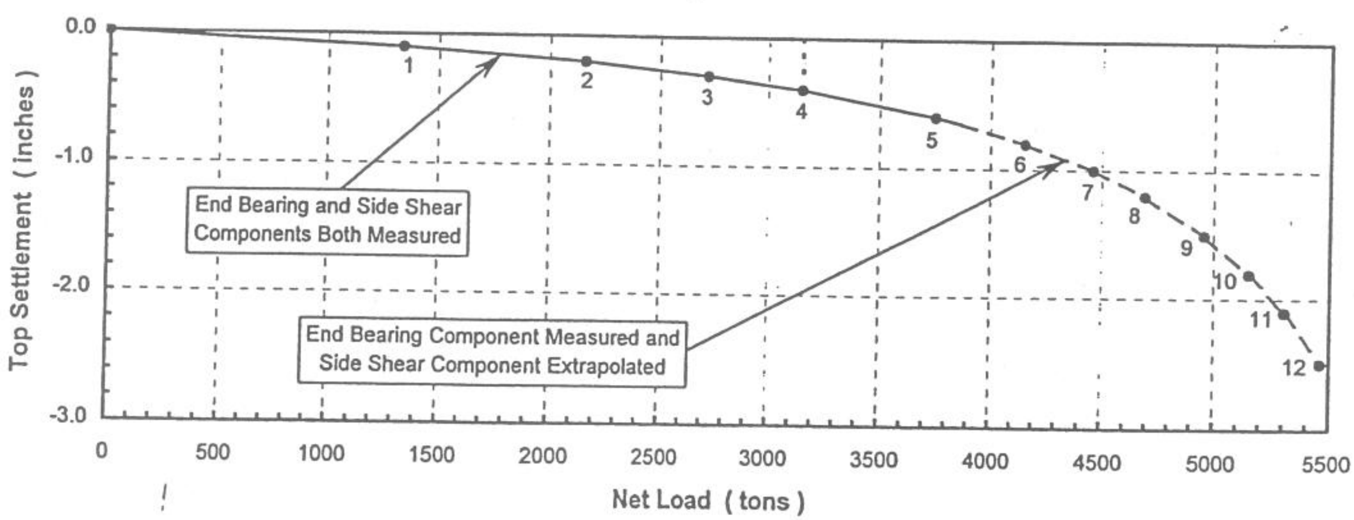


Figure B



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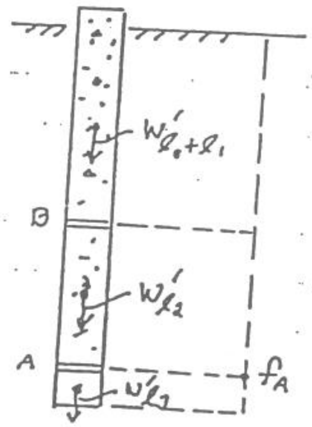
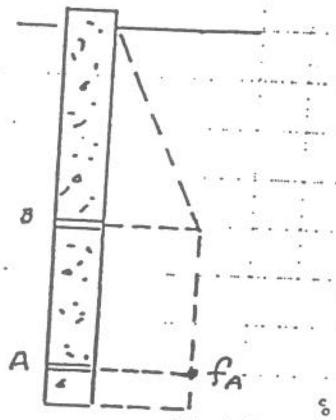
FAX (352) 378-3934

JOB TLT APPENDIX PART II
SHEET NO. 3 OF
CALCULATED BY JHS DATE April 98
CHECKED BY DATE
SCALE

CONSIDER ELASTIC COMPRESSIONS (δ) IN 3-PHASE O-CELL TEST, AND IN EQUIVALENT TOP-LOADED TEST, FOR THREE ASSUMED PATTERNS OF DEVELOPED SIDE SHEAR STRESS

① ② ③ TEST PHASE OR STAGE





①	②	③	Test phase or stage
$\frac{\ell_3}{2AE}(E + Q'_A)$ $E = Q'_A - f_{A_{II}} p \ell_3$ Stage II $\frac{(\ell_1+\ell_2)}{\ell_1+\ell_2} \frac{Q'_{B_{II}}}{p\ell_2}$	" $f_{A_{II}} = \frac{Q'_{B_{II}}}{p\ell_2}$	" $f_{A_{II}} = \frac{Q'_{B_{II}}}{p\ell_2}$	I $Q'_A\downarrow$ to test ℓ_3 to ult. SS & EB
$-\left(\frac{3\ell_1+2\ell_2}{2\ell_1+\ell_2}\right)\frac{Q_B\ell_2}{AE}$	$= \frac{1}{2}\left(\frac{Q_B\ell_2}{AE}\right)$	$= \frac{1}{2}\left(\frac{Q_B\ell_2}{AE}\right)$	II $Q'_B\downarrow$ to test ℓ_2 to ult SS
$\frac{1}{3}\frac{Q_B\ell_1}{AE}$	$= \frac{1}{2}\left(\frac{Q_B\ell_1}{AE}\right)$	$= \frac{1}{3}\left(\frac{Q_B\ell_1}{AE}\right)$	III $Q'_B\uparrow$ to test ℓ_1 to ult. SS

above =
c compression
cell test

during phase (stage) I $\rightarrow Q'_{A\downarrow} = (Q_A - W'_{\ell_0+\ell_1+\ell_2})$
II $\rightarrow Q'_{B\downarrow} = (Q_B + W'_{\ell_2})$
III $\rightarrow Q'_{B}\uparrow = (Q_B - W'_{\ell_0+\ell_1})$

$\left.\begin{matrix} Q_A' \\ Q_B' \end{matrix}\right\}$ = cell load $\pm$ corrections for self wt.

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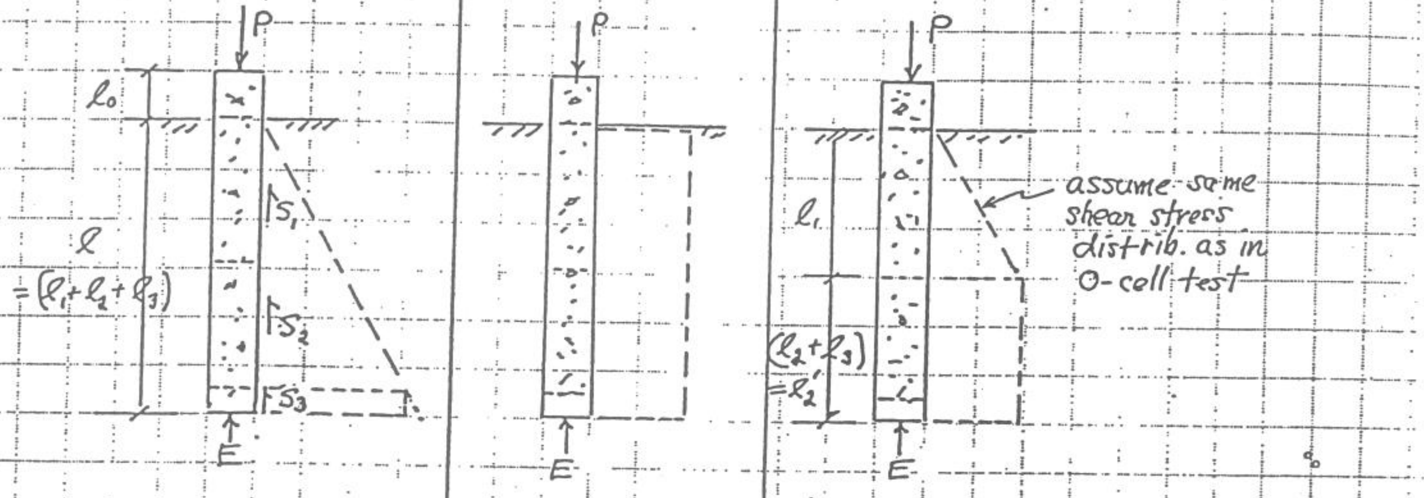
JOB TLT APPENDIX PART II
SHEET NO. 4 OF
CALCULATED BY JHS DATE April 98
CHECKED BY DATE
SCALE

NOW CONSIDER EQUIVALENT TOP-LOADED TESTS:

① ② ③



$$\delta_{0\downarrow} = \frac{P\ell_0}{AE} \longrightarrow \text{"} \longrightarrow \text{"}$$

① $$\delta_{1\downarrow} = \frac{(E+2P)\ell}{3AE}$$

② $$\delta_{1\downarrow} = \frac{(E+P)\ell}{2AE}$$

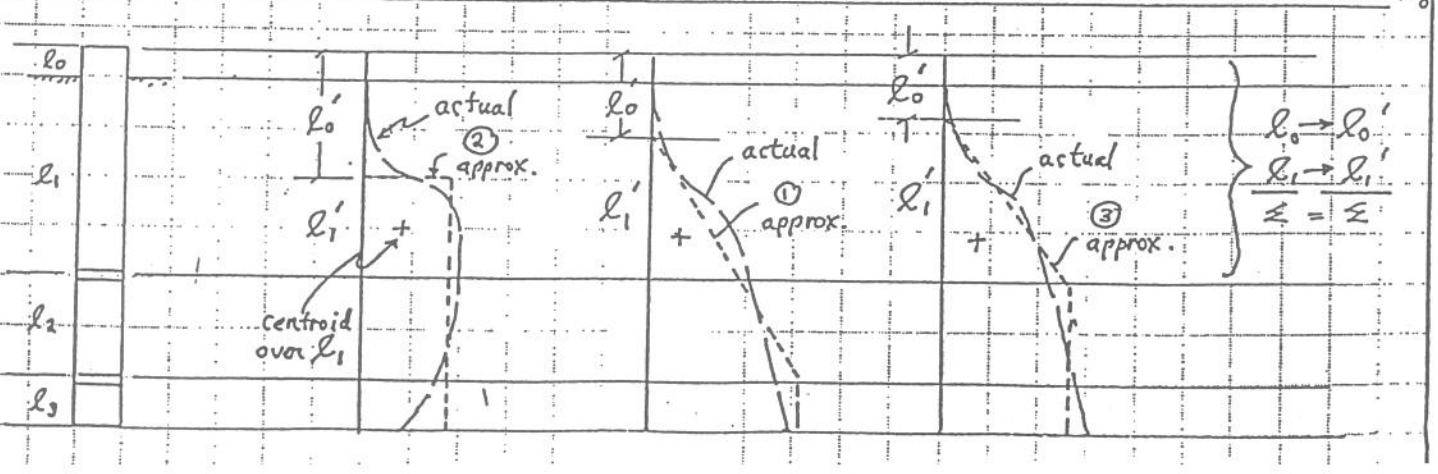
③ $$\delta_{1\downarrow} = \frac{\ell}{AE}\left[E + \left(\frac{\frac{2}{3}\ell_1^2 + \ell_1\ell_2' + \ell_2'^2}{\ell_1 + 2\ell_2'}\right)\frac{(P-E)}{\ell}\right]$$

$$\Sigma\delta_{\downarrow} = \delta_{0\downarrow} + \delta_{1\downarrow}$$

note: $P = S_1 + S_2 + S_3 + E$

$S_3 + E = Q'_{A\downarrow}$ from phase I
$S_2 = Q'_{B\downarrow}$ " " II
$S_1 = (-Q'_{D\uparrow})$ " " III
$\simeq F\,Q'_{B\downarrow}$

EXPANDING THE USEFULNESS OF THE ABOVE 3 SIDE SHEAR PATTERNS BY ARTIFICIALLY INCREASING ℓ_0



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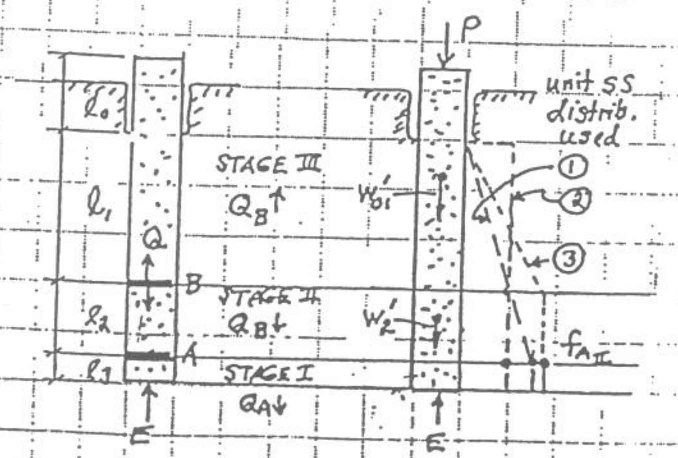
JOB: APPENDIX EXAMPLE SI UNITS
SHEET NO.: 5 OF:
CALCULATED BY: JHS DATE: April 98
CHECKED BY: DATE:
SCALE: Using HP41 JHS #185A, "Sd3"

EQUIV. 'RIGID' + SIMPLIFIED ELASTIC COMPRESSION @ TOP PILE IN TLT, FROM 1 & 3 STAGE OLTs

			1-stage test			3-stage test		
01 Avg. for pile	UNITS	Reg.	assume ss distr. 1	2	3	1	2	3
perim. p	(m)	02	3.142			3.142		
area A	(m^2)		0.7854			0.7854		
mod. E_p	(MPa)	03	25,000			25,000		
ℓ_0	(m)	04	5			5		
ℓ_1	"	05	20			15		
ℓ_2	"	06	0			5		
02 ℓ_3	"	07	5			5		
buoy wt. W_{01}'	(MN)	09	0.3			0.25		
03 " " W_2'	"	10	0			0.06		
For Δ_i 'rigid'	(mm)		10			10		
$Q_{A_I}\downarrow$	(MN)	15	6			6		
$Q_{B_{II}}\downarrow$	"	13	0			3		
04 $Q_{B_{III}}\uparrow$	"	14	10			7		
05 side shear distrib. 1, 2, 3			1	2	3	1	2	3
elastic δ_{TLT}	(mm)		16.82	15.38	17.68	17.66	15.19	17.24
" δ_{OLT}	"	23	4.23	6.24	4.54	3.19	4.12	3.22
14 $\Delta\delta$ @ top	"		12.59	9.14	13.14	14.48	11.07	14.02
P	(MN)	21	14.92	14.92	14.92	15.16	15.16	15.16
@ $\Delta_i + \Delta\delta$	(mm)		22.6	19.1	23.1	24.5	21.1	24.0
$f_{A_{II}}$	(MPa)	12	0.309	0.154	0.154	0.223	0.195	0.195
E	(MN)	24	0.85	3.28	3.28	2.19	2.63	2.63
$F =$ 0.95		35						



3-STAGE OLT EQUIV.- TOP-LOAD TEST

Notes:

1 & 3 stage O-cell test

(if 1, use $Q_{B_{II}}\downarrow = 0$, $\ell_2 = 0$, $W_2' = 0$)

EXAMPLES USING SI UNITS

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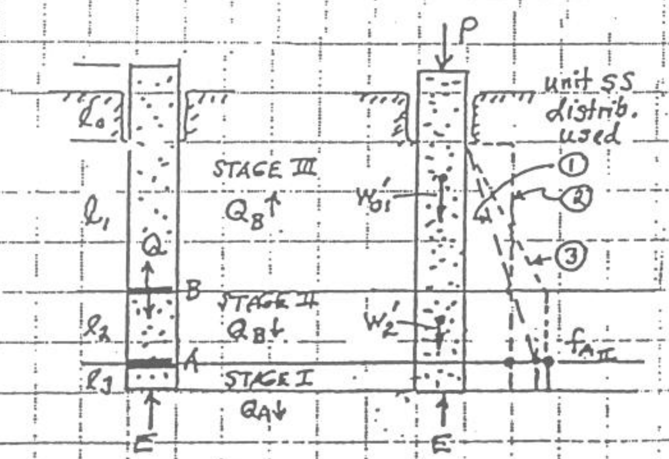
JOB APPENDIX EXAMPLES   ENGLISH UNITS
SHEET NO. 6   OF
CALCULATED BY JHS   DATE April 98
CHECKED BY   DATE
SCALE Using HP41 JHS #185A, "Sd3"

EQUIV. 'RIGID' + SIMPLIFIED ELASTIC COMPRESSION @ TOP PILE IN TLT, FROM 1 & 3 STAGE OLTs

			1-stage test			3-stage test		
01 Avg. for pile	UNITS	Reg.	assume SS distr. 1	2	3	1	2	3
perim. p	(in)	02	124			124		
area A	(in^2)		1,217			1,217		
mod. E_p	(ksi)	03	25,000			25,000		
ℓ_0	(in)	04	197			197		
ℓ_1	"	05	787			591		
ℓ_2	"	06	0			197		
ℓ_3	"	07	197			197		
02 buoy wt. W_{01}'	(kips)	09	75			55		
" " W_2'	"	10	0			20		
03 For Δ_i 'rigid'	(in)		0.40			0.40		
$Q_{A_I}\downarrow$	( )	15	1,350			1,350		
$Q_{B_{II}}\downarrow$	"	13	0			680		
04 $Q_{B_{III}}\uparrow$	"	14	2,250			1,570		
05 side shear distrib. ①, ②, ③			1	2	3	1	2	3
elastic δ_{TLT}	(in)		0.660	0.603	0.694	0.697	0.598	0.679
" δ_{OLT}	"	23	0.166	0.245	0.179	0.125	0.162	0.127
$\Delta\delta$ @ top	"		0.494	0.358	0.515	0.571	0.436	0.553
11 P	(kips)	21	3,341	3,341	3,341	3,414	3,414	3,414
@ $\Delta_i + \Delta\delta$	(in)		0.894	0.758	0.915	0.971	0.836	0.953
$f_{A_{II}}$	(ksf)	12	6.42	3.21	3.21	4.72	4.13	4.13
E	(kips)	24	186	731	731	475	575	575
$F =$ 0.95		35						



3-STAGE OLT   EQUIV.- TOP-LOAD TEST

Notes:

1 & 3 stage O-cell test

(if 1, use $Q_{B_{II}}\downarrow = 0$, $\ell_2 = 0$, $W_2' = 0$)

**Approx. = to SI example, p. 5

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.

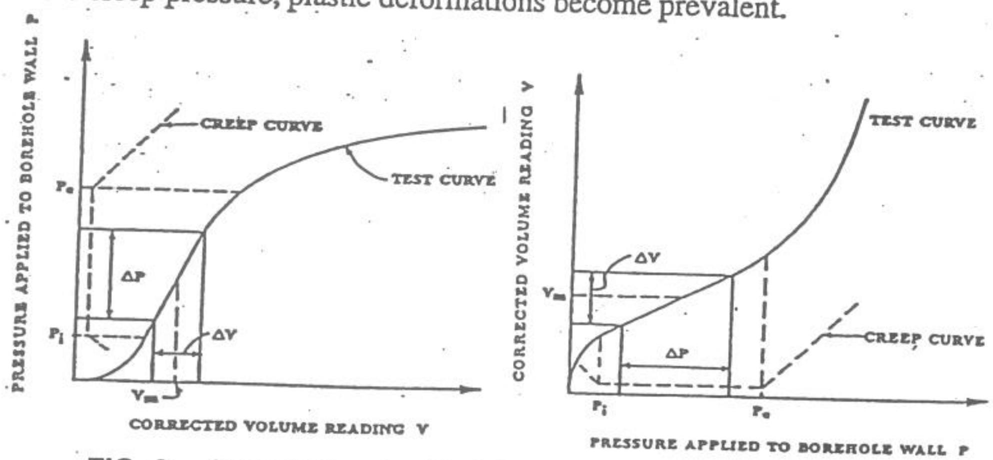


FIG. 8 Pressuremeter Test Curves for Procedure A

References

Housel, W.S. (1959), "Dynamic & Static Resistance of Coshesive Soils" 1846-1959, ASTM STP 254, pp. 22-23.

Stoll, M.U.W. (1961, Discussion, Proc. 3rd 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. (1966), Basics of Foundation Design, BiTech Publishers Ltd., p.79.

APPENDIX E

BORING LOGS

Daviess Co. - US 231 over the Ohio River
BRO 00101-007; FD52 030 8530 078 C
River Test Shaft Construction Phase Data Summary - Station 890+15
DPB, Rev 8/12/98

Offset	Ref. Elevation (ft.)	Depth (ft.)	Elevation (ft.)	UC Strength (psi)	SDI	JS	Layer	Elev
								266.3
10 ft. L	371.7	111.0	260.7		31	3	1	256.2
10 ft. L	371.7	116.0	255.7		7	1	2	
10 ft. L	371.7	118.1	253.6	6.3 87				
10 ft. L	371.7	121.0	250.7		39	3		247.7
10 ft. L	371.7	125.0	246.7		53	4	3	
10 ft. L	371.7	130.0	241.7		53	4		240.7
10 ft. L	371.7	135.0	236.7		35	3	4	
10 ft. L	371.7	135.5	236.2	39.5 549				
10 ft. L	371.7	137.5	234.2	1320	95			234.2
10 ft. L	371.7	140.0	231.7		53	4	5	228.2
10 ft. L	371.7	144.8	226.9	836	60.2		6	
10 ft. L	371.7	145.0	226.7		87	6		
10 ft. L	371.7	149.7	222.0	462	33.3			221.7
10 ft. L	371.7	150.0	221.7		82	6	7	
10 ft. L	371.7	155.0	216.7		92	6		
10 ft. L	371.7	156.1	215.6	2224				
10 ft. L	371.7	158.0	213.7	13568				213.7
10 ft. L	371.7	160.0	211.7		5	1		
10 ft. L	371.7	165.0	206.7		95	6		
10 ft. L	371.7	166.2	205.5	1354				

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FIELD LOG OF TEST BORING

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BLUEGRASS REGION 50 E. RIVERCENTER BLVD., STE 400 COVINGTON, KY 41011 (606) 292-2575 FAX (606) 292-5415

CLIENT:	Traylor Brothers, Incorporated	BORING NO.:	Test Shaft Boring
PROJECT:	Owensboro Bridge	DATE STARTED:	5-27-98
BORING LOCATION:	Sta. 890 + 95 10' Lt.	DATE COMPLETED:	6-1-98
ELEVATION REFERENCE:	From top of Drill Casing 371.7	WORK ORDER NO.:	71135.003

ELEV (Feet)	DEPTH (Feet)	DESCRIPTION OF MATERIALS	SAMPLE #	TYPE	DEPTH (Feet)	PENN	RECOVERY (Inches)	SOIL PROPERTIES W (%)	LL/PL (%)	RQD
	0.0									
		9.7' Drill casing to water surface								
	9.7	21.0 Water depth								
	30.7	74.7' Soil - overburden								
	105.4	16.0' Casing set in bedrock 10.54 to 106.2=0.8, gray SHALE, soft to very soft	1 2 3	core core core	106.2-107.7 107.7-117.7 117.7-127.7	1.5 10 10	1.4 10 10			 50% 49% 59%
	121.4	2.0' Coal, soft								
	123.4	7.9' Gray SHALE, soft	4	core	127.7-137.7	10	9.8			60%
	131.3	1.6' Gray SHALE, medium hard to hard								
	132.9	2.3' Gray SHALE, soft								
	135.2	4.7' Gray sandy SHALE, soft	5 6	core core	137.7-147.7 147.7-157.7	10 10	10 10			56% 94%
	139.9	12.4' Gray SHALE, soft								
	152.3	6.4' Gray SHALE, medium hard to hard	7	core	157.7-167.7	10	9.5			43%
	158.7	1.5' Gray SHALE, soft								
	160.2	1.0' Coal, soft								
	161.2	4.5' Gray SHALE, soft								
	165.7	2.0' Gray sandy SHALE, soft to medium hard								
	167.7	TEST BORING COMPLETED (Bottom of borehole at Elev. 204.0)								

* Pocket Penetrometer Reading - Unconfined Compressive Strength, Tons/Sq. Ft.

General Notes		Remarks	Water Level Observations	
Driller	K.MULLINS		Immediate	9.7 Ft.
Rig No.	48	* ADD AT 30.7'	At Completion	18.7 Ft.
Rig Type	CME-55		After Hours	Ft.
Method	3" CASING		Water Used in drilling	* Ft.
	TRIPLE BARREL CORE		(Measured from ground surface)	

Kiver Shaft Load Test
Sta. 890+95, 10 ft. Lt.
Idealized Rock Profile

270

266.3
1 - Gray Shale w/ Sandstone Laminations
SDI ≃ 30, q_u ≃ 100-300 psi

260

256.2
2 - Gray Clayey Shale (Coal 248.6-250.2)
SDI ≃ 5-40, q_u ≃ 100-200 psi

250

247.7
3 - Light Gray Shale; Silty, Sandy, Clayey
SDI ≃ 55, q_u ≃ 200-300 psi

240 — 240.7
4 - Light Gray Shale; Clayey, Sandy Partings (Limestone 238.8-240.3)
SDI ≃ 35-55, q_u ≃ 550-1300 psi

234.2
5 - Gray Shale w/ Sandy Partings ← Tip 233.2
SDI ≃ 55, q_u ≃ 200-500 psi

230

228.2
6 - Dark Gray Shale
SDI ≃ 80-90, q_u ≃ 500-1000 psi

220 — 221.7
7 - Dark Gray Shale
SDI ≃ 90, q_u ≃ 2000-13000 psi

213.7

4
240.3
Limestone
238.8
Clayey Shale SDI ≃ 35
236.2
Light Gray Shale SDI ≃ 50 q_u ≃ 550-1300 psi
234.2

River Shaft Load Test
Capacity Estimate

p 1/2

$Q_s = f_s \pi d h$, $d = 8.0$ ft

	Lower Q_s (tons)	Upper Q_s (tons)
Layer 1		
Elev = 266.3 − 256.2 = 10.1 ft		
$q_u \simeq 100 - 300$ psi → 7 − 21 tsf	254	762
$f_s \simeq 0.15 q_u$ → 1.0 − 3.0 tsf		
Layer 2		
Elev = 256.2 − 247.7 = 8.5 ft.		
$q_u \simeq 100 - 200$ psi → 7 − 14 tsf	213	426
$f_s \simeq 0.15 q_u$ → 1.0 − 2.0 tsf		
Layer 3		
Elev = 247.7 − 240.7 = 7.0 ft		
$q_u \simeq 200 - 300$ psi → 14 − 21 tsf		
$f_s \simeq 0.15 q_u$ → 2.0 − 3.0 tsf	351	528
Layer 4		
Elev = 240.7 − 234.2 = 6.5 ft		
$q_u \simeq 550 - 1300$ psi → 40 − 94 tsf	980	2287
$f_s \simeq 0.15 q_u$ → 6 − 14 tsf		
$\Sigma =$	1798	4003

$f_s \simeq 2.5\sqrt{q_u} = 2.5\sqrt{1300} = 90$ psi

$\simeq 6$ tsf

River Shaft Load Test
Capacity Estimate

Overburden Side Shear = 500 - 1000 tons

Rock Socket Side Shear = 1800 - 4000 tons

Total Side Shear = 2300 - 5000 tons

End Bearing

$q_{cb} = N_c s_u$

$N_c = 7.0$

$s_u = \frac{1}{2} q_u \simeq 100 - 250$ psi

$\simeq 7 - 18$ tsf

lower $q_{cb} = 7.0 (7) = 49$ tsf

upper $q_{cb} = 7.0 (18) = 126$ tsf

lower $Q_{cb} = \frac{\pi (8.0 ft)^2}{4} (49 tsf) \simeq 2500$ tons

upper $Q_{cb} = \frac{\pi (8.0 ft)^2}{4} (126 tsf) \simeq 6300$ tons

Bottom 3 ft

$\pi d h f_s = \pi (8.0)(3.0)(6.0) \simeq 450$ tons

" " " (14.0) ~ 1050 tons