Test and Evaluation Report

Drilled Shaft Load Testing
I-235 over Union Pacific Railroad

January 5, 2006

Prepared For

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Introduction

On September 26, 2005, a research team from the Iowa State University Bridge Engineering Center performed a load test to document the behavior of a single drilled shaft foundation of the eastbound I-235 bridge over the Union Pacific Railroad. The test was performed on a closed roadway, using two loaded tandem dump trucks positioned directly above the shaft in question. This test was performed with the trucks in a static position and no attempt was made to collect data under moving load conditions.

Data Collection

The drilled shaft foundation was instrumented with a total of 12 - Geokon 4911-4 vibrating wire rebar strainmeters and 16 - Geokon 3911 rebar resistance-type strain gauges. The strain sensors were attached to the reinforcing steel cage prior to concrete casting by means of a "sister bar" as shown in Figure 1.

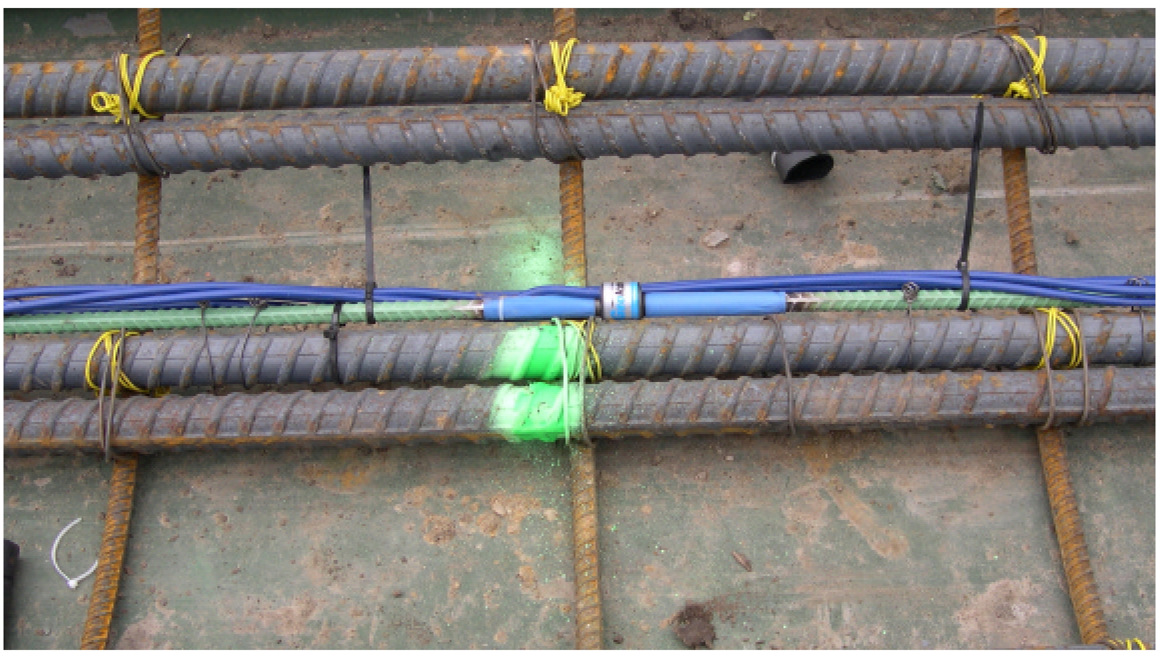

Figure 1. Strain sensor attached to reinforcing steel cage using sister bar

The strain sensors were located at approximately the quarter points around the perimeter of the drilled shaft (see Figure 2) and at elevations corresponding to changes in the subsurface soil profile. At each elevation where a group of strain sensors was installed, two vibrating wire sensors and two resistance strain sensors were placed on opposite sides of the reinforcing cage. During construction, efforts were made to ensure than the pairs of resistance sensors were oriented parallel with future traffic to facilitate collection of strain data during future live traffic conditions.

For reference, the vibrating wire sensors are designated V5 – V16 and the resistance-type sensors are designated S1 – S16. No vibrating wire sensors were installed in the uppermost group.

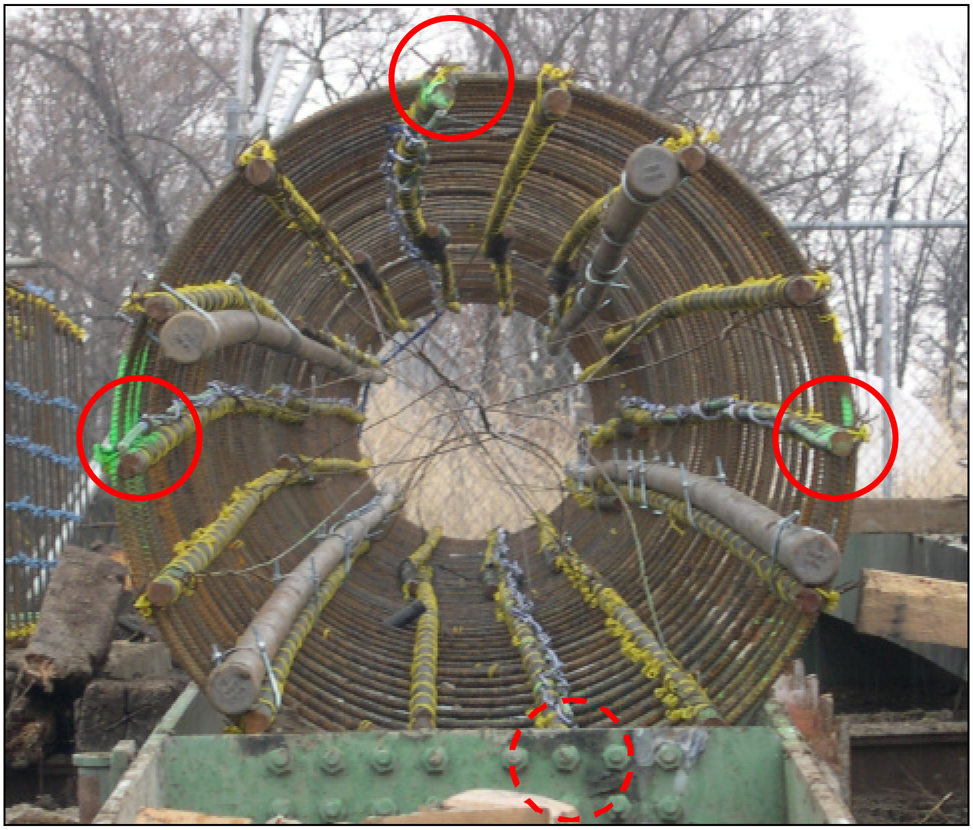

Figure 2. Strain gauges (circled) located at four equally-spaced points on reinforcing cage

In addition, the shaft was instrumented with a Geokon 4810 contact pressure cell, which was installed at the interface between the drilled shaft and the column concrete. A schematic view of the installed instrumentation is presented in Figure 3.

Two Iowa DOT-furnished dump trucks were used to provide the live load for testing. The total live load applied load was measured as 86.1 kips.

It was assumed that the strain distribution at a particular cross-section of the drilled shaft was relatively uniform. Additional assumptions made for data reduction:

- Strain distribution within concrete identical to strain sensor reading
- Cross sectional area of 4'-0" diameter drilled shaft = 1810 square inches
- Reinforcing steel area = 21.84 square inches
- Effective area of composite shaft & reinforcing = 1963 square inches
- Design concrete strength = 24 MPa (3481 psi)
- Modulus of elasticity (concrete) = 3360 ksi

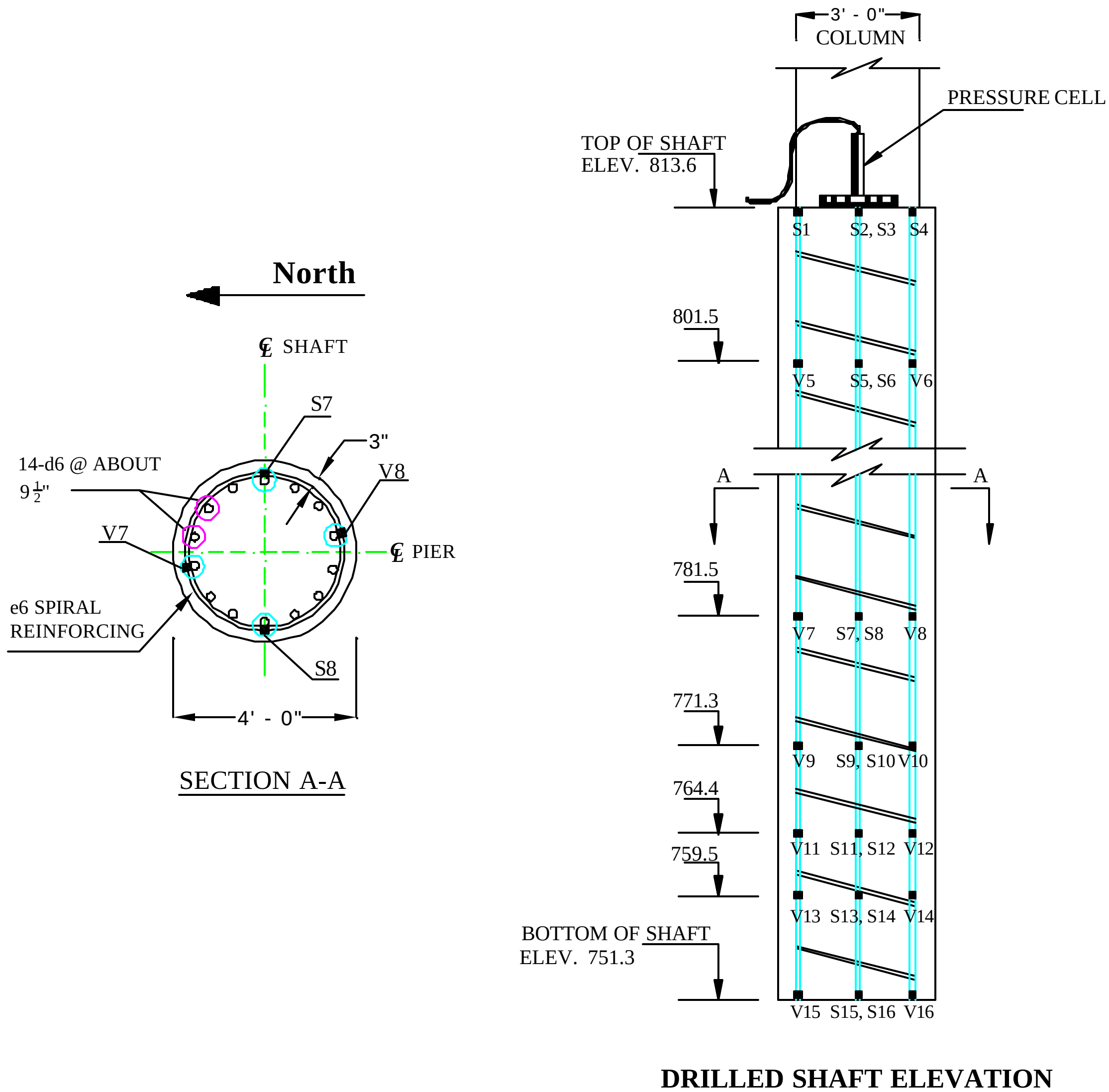

Figure 3. Schematic view of drilled shaft and installed instrumentation

Discussion of Results

The collected load test data are presented in Tables 1 and 2. It should be noted that sensor S1 did not appear to function correctly and its results will not be presented. It should also be noted that the magnitude of measured live load strain was quite small; especially when compared to the variation in initial-values of the gauges measured before the load was applied and once again after the load was removed.

The data collected from the north-south gauges indicate a maximum drilled shaft load of approximately 22 kips. It should be noted that the drilled shaft load was calculated using an average strain over the shaft cross-section equal to the measured value from the sensor of interest. The reduction in strain from gauges near the top of the shaft to those located near the bottom occurs at a relatively linear rate. This decrease in strain (and thus drilled shaft load) provides evidence that applied truck loads are being transferred to the surrounding soil through surface friction. A plot of these results with respect to elevation is presented in Figure 4.

In addition, the north gauges indicate a slightly higher strain than those on the south side of the shaft, which may be evidence of some minimal flexural behavior in the transverse direction. It is very possible that the truck loads were applied with a slight eccentricity with respect to the column. This variation in strain appears much smaller at gauge locations near the bottom of the shaft. These locations are much nearer the point of transverse fixity in the foundation.

The data collected from the east-west gauges indicate a much larger maximum drilled shaft load of approximately 92 kips. The total weight of the live load vehicles was measured at 86.1 kips, so the actual shaft load must be considerably less than the measured value. However, two of the three functioning gauges at this same elevation indicate a more reasonable value of approximately 72 kips. These data are presented in Figure 5.

The measured drilled shaft loads from all gauges are presented in Figure 6. A much more dramatic decrease in strain from top to bottom of the shaft was measured using the east-west gauges. These data indicate that approximately 67 percent of the drilled shaft load has been transferred to the surrounding soil within the uppermost 32 feet of the shaft length. However, the north-south gauges indicate that only 24 percent of the same load was transferred at that same elevation.

Data collected from the contact pressure cell indicate a value of 19 psi (compression) at the top of the drilled shaft. This pressure, if uniform over the entire area of the drilled shaft, would indicate an applied column load of 34.3 kips at the top of the drilled shaft.

A highly simplified structural analysis of the subject pier was used to validate the instrumentation results. The pier was modeled with applied wheel loads matching those from the load test vehicle. The results of this modeling indicate a drilled shaft reaction ranging from 50 to 58 kips. This range of results includes a simplified parametric study of the estimated elevation of foundation fixity as well as slight errors in positioning the loaded trucks.

Table 1. Collected live load test data - vibrating wire (N-S) strain gauges

Gauge No.	Installed Elevation (m)	Installed Elevation (ft)	Measured LL Strain (microstrain)	Approximate Load (kips)
V1	----	----	----	----
V2	----	----	----	----
V3	----	----	----	----
V4	----	----	----	----
V5	244.3	801.5	-3.4	22.3
V6	244.3	801.5	-3.1	20.7
V7	238.2	781.5	-2.7	17.8
V8	238.2	781.5	-2.3	14.9
V9	235.1	771.3	-2.3	15.2
V10	235.1	771.3	-1.9	12.7
V11	233.0	764.4	-1.3	8.8
V12	233.0	764.4	-1.4	9.0
V13	231.5	759.5	-1.0	6.5
V14	231.5	759.5	-1.2	8.0
V15	229.0	751.3	-1.0	6.8
V16	229.0	751.3	-0.8	5.2

Table 2. Collected live load test data – resistance-type (E-W) strain gauges

Gauge No	Installed Elevation (m)	Installed Elevation (ft)	Measured LL Strain (microstrain)	Calculated Shaft Load (kips)
S1	248.0	813.6	1	-----
S2	248.0	813.6	-11	72.6
S3	248.0	813.6	-11	72.6
S4	248.0	813.6	-14	92.4
S5	244.3	801.5	-6	39.6
S6	244.3	801.5	-5	33.0
S7	238.2	781.5	-3	19.8
S8	238.2	781.5	-5	33.0
S9	235.1	771.3	-3	19.8
S10	235.1	771.3	-3	19.8
S11	233.0	764.4	-2	13.2
S12	233.0	764.4	-2	13.2
S13	231.5	759.5	-1	6.6
S14	231.5	759.5	0	0.0
S15	229.0	751.3	0	0.0
S16	229.0	751.3	-1	6.6

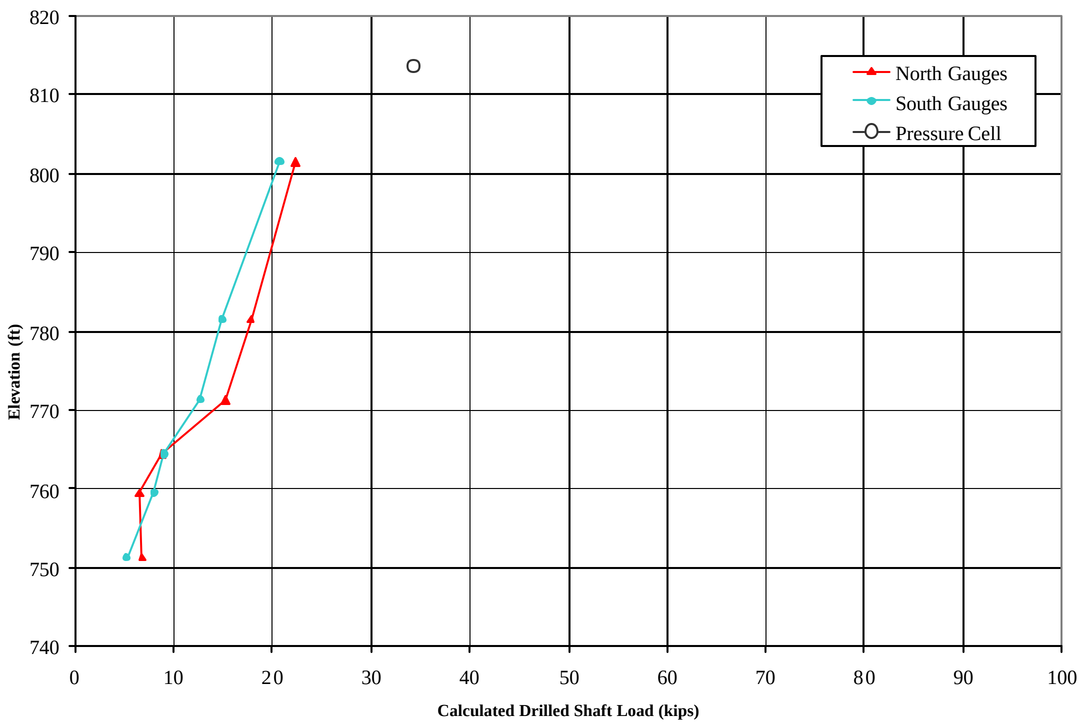

Figure 4. Drilled shaft load calculated from vibrating wire (N-S) strain sensors

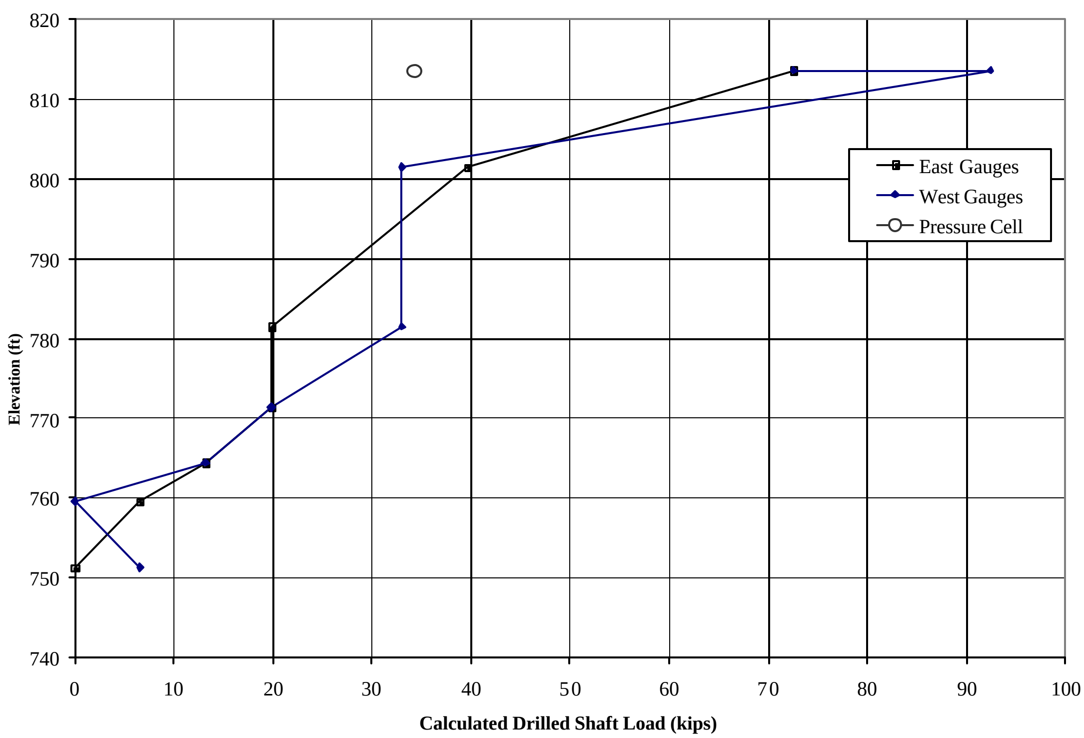

Figure 5. Drilled shaft load calculated from resistance-type (E-W) strain sensors

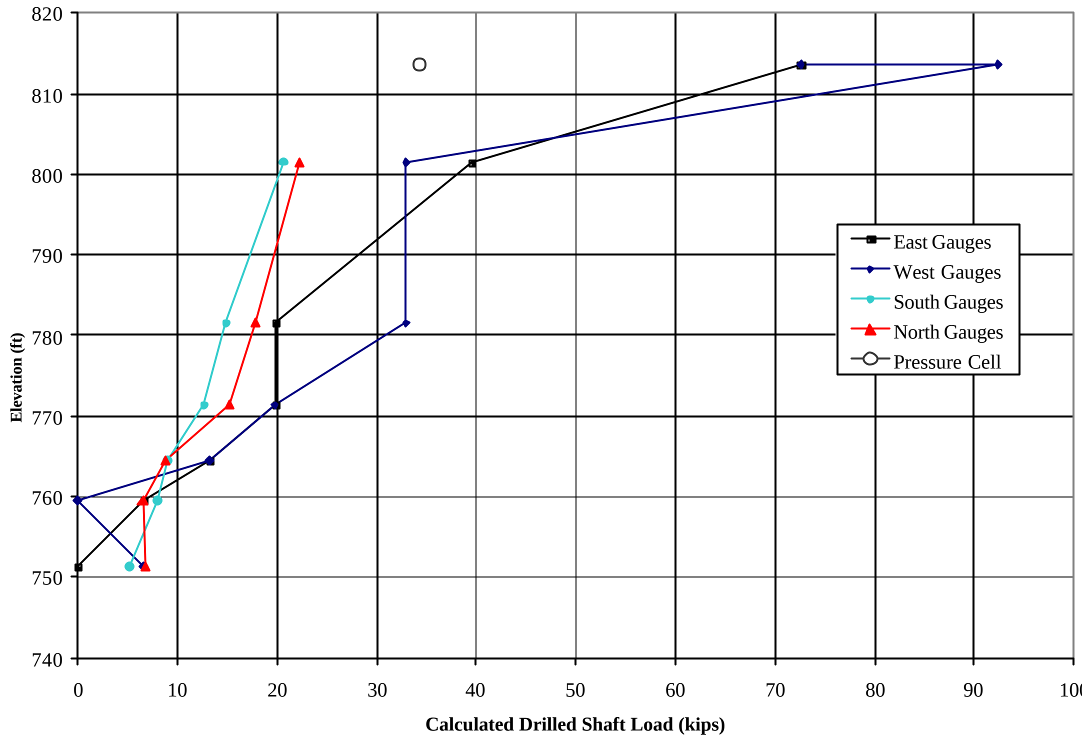

Figure 6. Drilled shaft load calculated from all strain sensors

Conclusions and Recommendations for Future Study

This study was able to quantify the load transfer from a loaded drilled shaft foundation to the surrounding soil material in at least a limited way. The complex nature of the soil/shaft interaction and the difficulty of accurately placing the loaded trucks in order to induce a nearly axial load in the shaft were known prior to beginning the study.

In addition, the very small strain values induced by a pair of loaded trucks on a 4'-0" drilled shaft make it difficult to isolate these values from their associated initial values and assess the presence of axial and flexural behavior in the shaft. Due to these very small magnitude strain values, it is unlikely that an investigation of dynamically-applied loads due to live traffic will offer much value in the current study.

A laboratory study utilizing an accurately applied, controlled load on a smaller scale drilled shaft model could provide the necessary background and load-strain relationships prior to any future field studies.