DATA GATHERING AND DESIGN DETAILS OF AN INTEGRAL ABUTMENT BRIDGE

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Abstract

An integral-abutment bridge is designed to transfer the temperature and traffic-induced horizontal loading to its foundation by the use of a continuous joint between the superstructure and its abutment. The connection eliminates the need for bearings, which have been a source of expensive rehabilitation, and accommodates the horizontal movement through a flexible stub-abutment supported on piles. Although integral abutments have been used successfully by many states, a nationally accepted design methodology does not exist for their design and construction. Instead, each highway department depends on the experience of its engineers to push the design envelope.

Design parameters of interest include the flexural behavior of the pile-bent that supports the abutment, the soil-pressure distribution behind the abutment, and the displacement and rotation of the superstructure. To study such behavior, we instrumented the Scotch Road Integral Abutment Bridge at Trenton, New Jersey and have been observing the reaction of the bridge and its foundation to annual and daily thermal loading. Specifically, we have gathered data every two hours for the past four years on displacement, rotation, strains, and pressures on the bridge and its foundation. It is our intention in this paper to share the data and discuss some of the most relevant conclusions of our studies.

In general, we have been witnessing an excellent correlation between the temperature and displacement, expected behavior from the horizontally loaded piles, and a steady built up of soil pressure behind the abutment.

Introduction

Integral abutment bridges are seen as the best design for medium-length highway bridges. One of the questions about their design that still remains is the behavior of the piles that support the abutment. The piles undergo a cyclic horizontal loading during the thermal expansion and contraction of the bridge. To study their behavior, several piles were instrumented during a large-scale test of an integral abutment bridge. A summary of the data on pile bending is the focus of this paper.

Large Scale Testing of Integral Bridge

A bridge built over I-95 in Trenton, N.J. on Scotch Road was used as a test bed for integral abutments. The superstructure is a 2-span continuous HPS485W (HPS70W) steel- girder structure supported on a conventional pier with fixed bearings and integral abutments. It is 90.9 m (298 ft.) long, built of steel plate girders spaced at 3.35 m (11 ft.) on centers across a width of 31.8 m (104.3 ft.) The structure has a skew of about 15^o measured from the centerline of bearing to the centerline of bridge. The superstructure was design using the LRFD method. The piles and foundations were designed using service load design by AASHTO (1996) and following the design objectives set by Abendroth et al. (1989).

The abutments are approximately 3.34 m (11 ft.) high and 900 mm (3 ft.) thick. Each of the abutments is supported on a single row of 19 HP14x102 (HP360x152) piles, oriented for weak-axis bending. The piles are embedded in concrete at a depth of 3.6m(13.68 ft) below the abutment. A 600 mm (2 ft.) diameter corrugated steel sleeve was placed around each pile and was backfilled with sand to increase the flexibility of the system. An MSE wall was built, using compacted crushed stone, in front of the abutment and around the piles. The soil behind the abutment and below the approach slab is well-compacted I-9 porous fill. The foundation is sketched in Figure 1.

The bridge was instrumented during construction and has been monitored continually during April, 2003 to June, 2006. The piles were instrumented with strain gauges along their depth as shown in Figure 1. Three piles were instrumented in the first stage of the construction, and produced the data that is presented in this summary.

A comprehensive literature review of integral abutment bridges can be found in Roman (2004). Numerical evaluation of the Scotch Road Bridge can be found in Khodair (2005) that also summarizes a finite element and LPILE analysis of the piles. In this paper we intend to present the latest set of data and a broader data analysis.

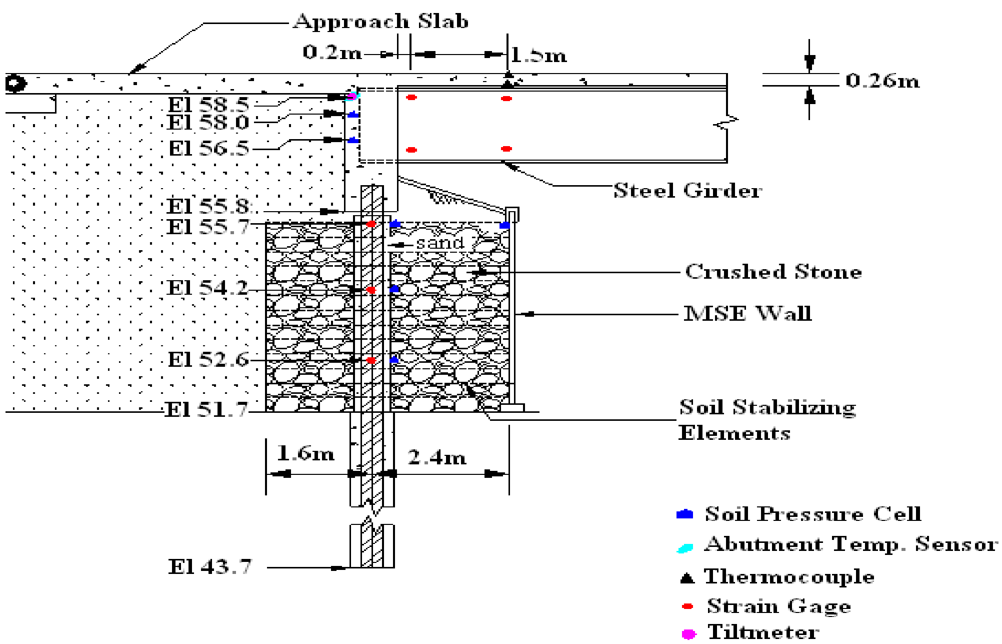

Figure 1. Plan View of Instrumentation.

Analysis of Piles

Figure 2 shows the displacement of the bridge during 2003 to 2006. Figure 3 shows the bending moment along the piles during the first year of operation. Figure 4 is a representative of the bending moment during all subsequent years.

Figures 5 and 6 show the average data and predictions of bending moment using LPILE (Ensoft, 1999). Internal variables used in the calculation of p-y curves were chosen to represent dense sand. The upper layer of sand around the piles was assigned an angle of internal friction, ϕ, of 48 degrees and a reaction coefficient, k, of 125 lbs/in^3. The high values represent the dense state that sand can achieve when undergoing cyclic displacements. The lower part of the sand was assigned a ϕ of 25 degrees and a k of 90lbs/in^3.

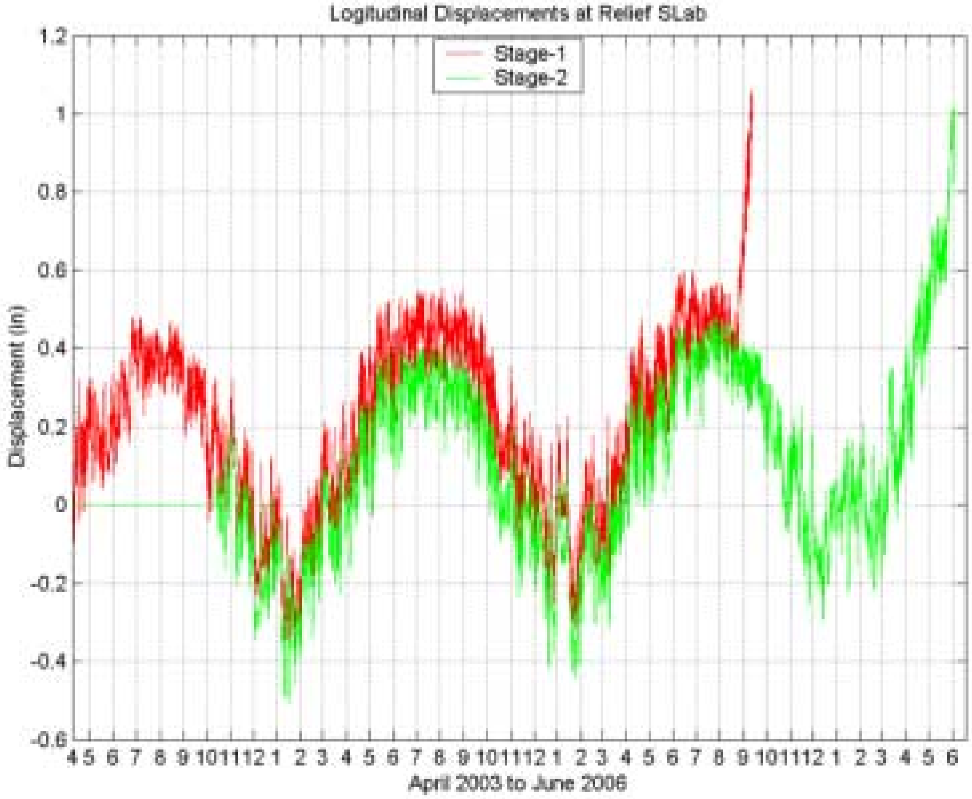

Figure 2. Displacement of superstructure.

The boundary conditions that were input in LPILE are the average displacement of the bridge at the time of the measurement, (Figure 2), and the bending moment that was measured at the top of the pile.

Rotations were also measured at the bridge. The measurements were taken at the abutment, at the base of the girder. The rotations oscillate like the displacement and achieve a magnitude within plus or minus 0.08 degrees. The bending moment of the pile is very sensitive to such rotations. Small rotations (in the order of 0.02 degrees) alleviate to a large degree the moments expected at the top of the pile. As a result, maximum moments can occur lower in the pile.

Summary and Conclusions

Data taken from the piles of an integral bridge are summarized. The measurements and analysis has shown that small rotations that are delivered to the pile top from the movement of the bridge alleviate, to a large degree, the maximum moments that are expected at the pile top. In many instances, the rotations are responsible to shifting the largest moments lower in the pile.

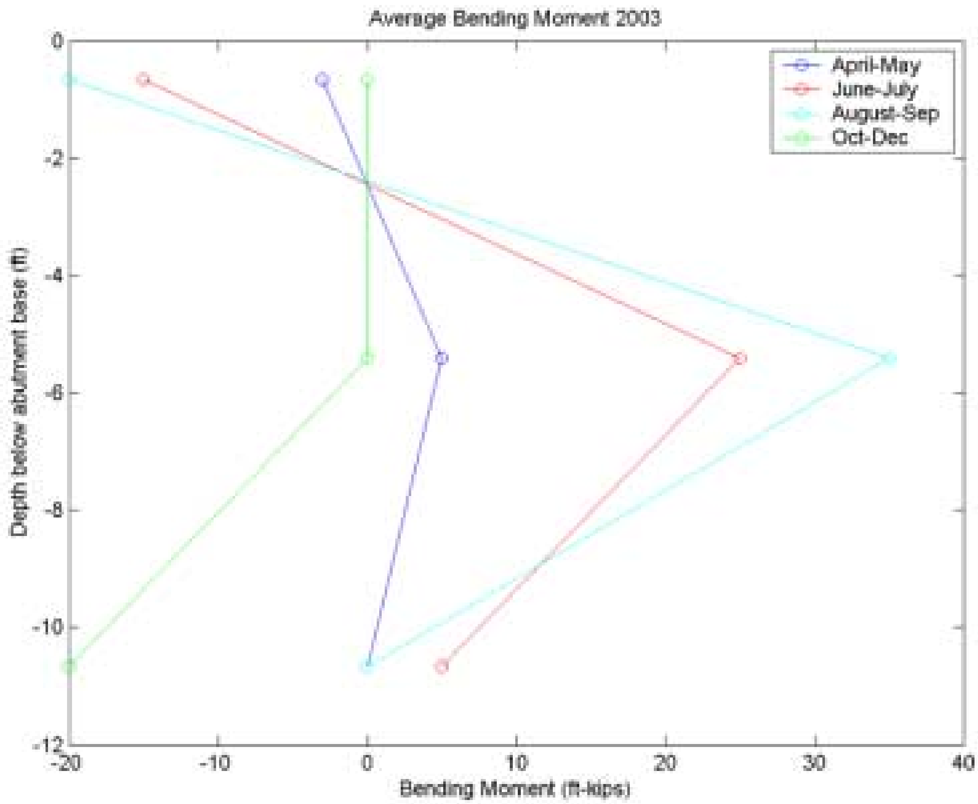

Figure 3. Average Bending Moment on three piles in 2003.

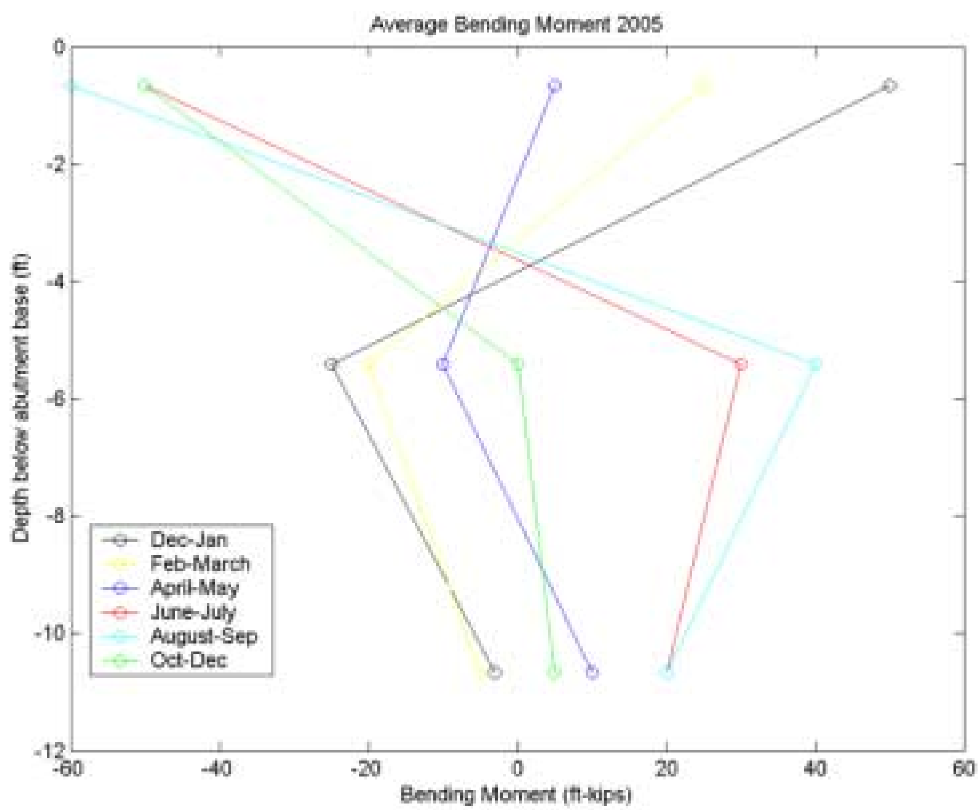

Figure 4. Average Bending Moment on three piles in 2005.

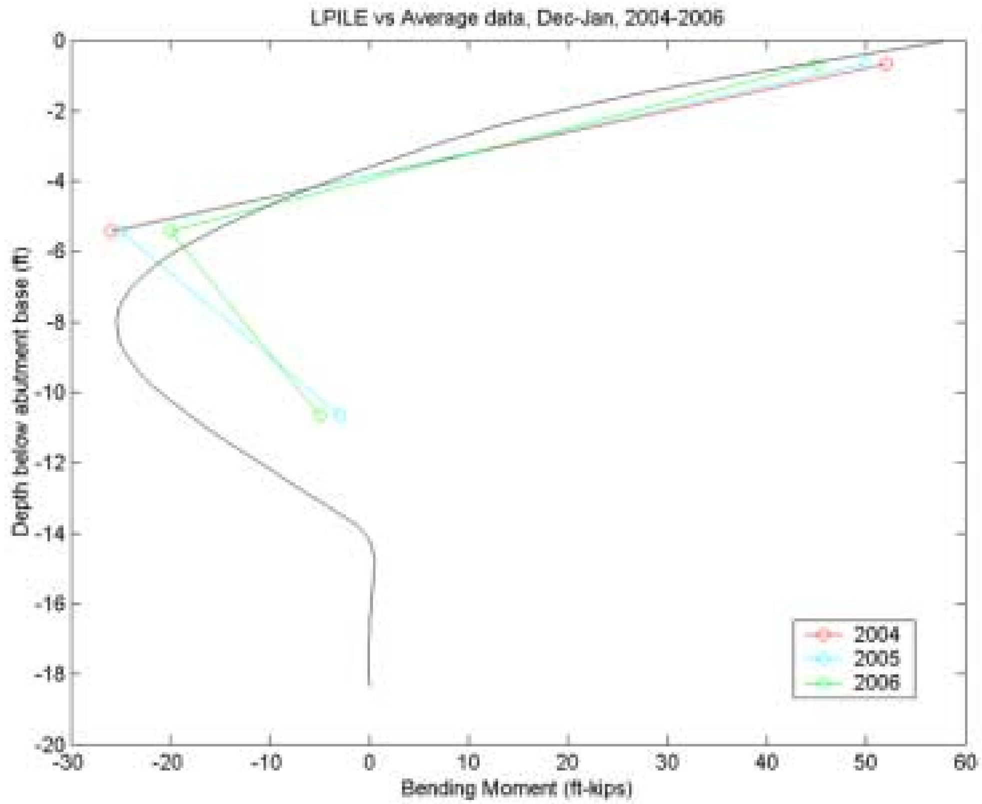

Figure 5. LPILE vs average data, Dec-Jan, 2004-2006.

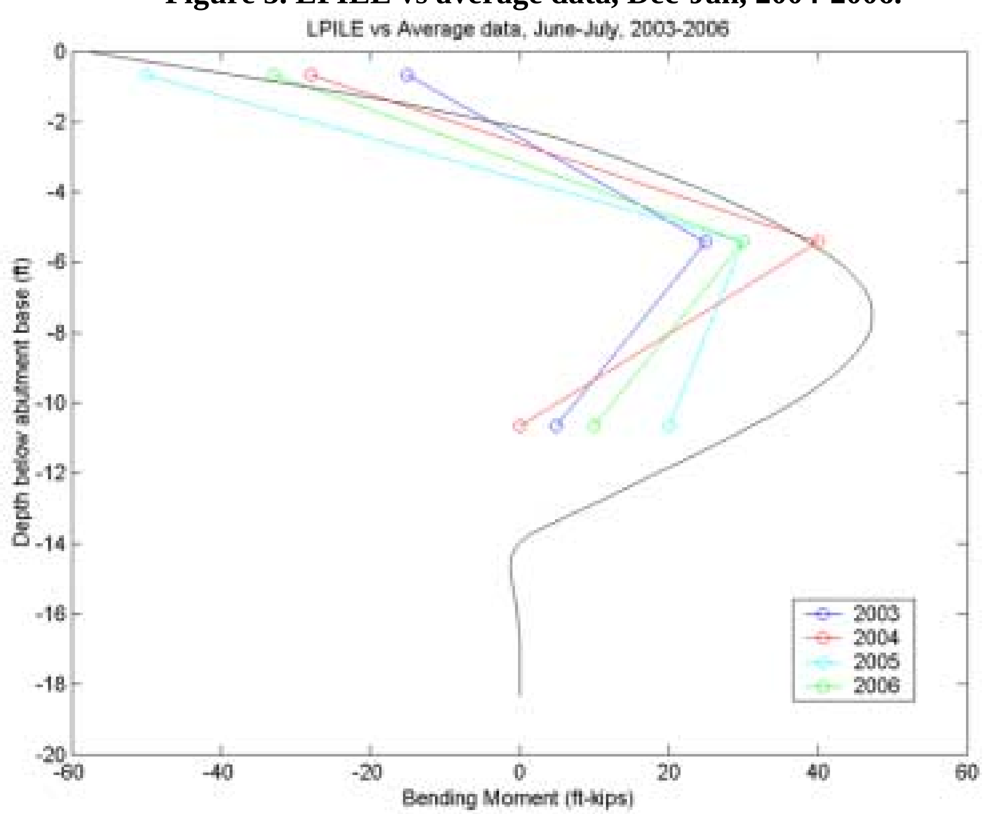

Figure 6. LPILE vs average data, June-July, 2004-2006.

Acknowledgements

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