Monitoring of an Integral-Abutment Bridge Supported on Steel Piles/Concrete Drilled Shafts in Glacial Clay

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EXTENDED ABSTRACT

Bridge designs consisting of the use of integral abutments supported on steel piles that are embedded in concrete drilled shafts are unique and not prevalent in the U.S. infrastructure. As a result, information is not readily available regarding the design and performance of this specific bridge system. This lack of information or bridge performance history can be an issue for a bridge designer.

This unique integral-abutment design was implemented in the construction of the 9th Street Bridge over I-235 in Des Moines, IA. Because of geotechnical concerns regarding the preservation of nearby historical sites that could be damaged by large vibrations, pile driving was prohibited. Therefore, the bridge’s integral abutments were designed to be supported by steel H-Piles that are embedded in concrete drilled shafts. The steel piles provide horizontal flexibility for bridge movement, and the concrete drilled shafts transfer the bridge loads to the supporting soil strata. Unlike other uses of concrete drilled shafts in Iowa, the shafts are embedded in glacial clay instead of bedrock.

Through the use of bridge instrumentation devices and surveying techniques, the bridge has been monitored through construction and will continue to be monitored to determine bridge behavior by engineers with the Iowa State University (ISU) Bridge Engineering Center (BEC). Monthly surveying of the bridge has established bridge movements relative to nearby benchmarks. During construction, seven steel piles were instrumented to monitor strains in the members. Displacement meters were also placed near the bottom flange of the center girder to measure change in bridge length. Monitoring of bridge behavior will be performed for approximately 18 months. The study of this unique bridge should provide
confidence in the use of surveying as a method of monitoring for bridges, as well as confidence in future designs of this specific bridge type.

The bridge monitoring has produced results of bridge displacement behavior with respect to changes in temperature. Using surveying methodologies, strain gages, and displacement meters, the change in the bridge length is being evaluated over time and compared with the theoretical change in length based on the effective coefficient of thermal expansion and contraction of the bridge superstructure, bridge length, and temperature of the wire for the displacement meter. As seen in Figure 1, the change in length measured by the displacement meter and as theoretically predicted is plotted versus temperature with a zero date of September 30, 2008. Also included in this figure are boxes that represent the change in the bridge length as measured using surveying for seven different months. The height of each box represents the 95% confidence interval calculated for that specific survey, with the width of the box being the range of temperatures the displacement meter measured during the surveying period. By using these results, the method of surveying as a technique of bridge monitoring can be compared with the other methods of measurement. The boxes, for the most part, fall within the change in length ranges calculated by the displacement meter and theoretical values, which are the traditional methods of measurement in bridge monitoring. Also, Figure 1 illustrates the general trend of change in the bridge length with temperature. As expected, with higher temperatures, there is a positive change in length of the bridge, or expansion, and with colder temperatures, there is a decrease in the bridge length, or contraction. The change in bridge length calculated in the temperature ranges higher than 60°F show a larger spread as can be seen in Figure 1. This may be due to the larger variation in temperatures throughout the day in warmer months rather than in colder months of the year.

Figure 1. Bridge change in length vs. meter temperature for displacement meter, theoretical and surveying values
Another analysis technique for this bridge was to relate the bridge’s behavior with time. Figure 2 shows the same data used in Figure 1 plotted with respect to time. A cyclical pattern can be seen in the graph, which is expected as a result of temperature cycles involving warming and cooling of the bridge. The yellow bars placed over the displacement meter and theoretical data represent the surveying data. The height of a surveying bar is the 95% confidence intervals for that specific survey. Except for the March 2009 survey, the surveying data fits within the data taken for the meter and theoretical calculations. A gap in the displacement meter and theoretical data represent missing results for April 2008 due to a malfunction in the equipment.

![Bridge change in length vs. time for displacement meter, theoretical, and surveying values](image)

**Figure 2. Bridge change in length vs. time for displacement meter, theoretical, and surveying values**

Further analysis is being performed on the collected data. The data collected from the strain gages placed on the steel piles is still being evaluated. One of the main issues in the analysis is correlating the three different methods of measurement and the interpretation of the data regarding bridge movements. The initial pile displacements results calculated from the strain gage measurements have been somewhat different from the results calculated through the use of surveying measurements. This discrepancy may be caused by a temperature gradient through the depth of the bridge superstructure that induces curvature of the bridge in the vertical plane. The top of the bridge slab may be warmer or cooler than the bottom of the girders, depending on the weather conditions and time of the year. Other reasons for this discrepancy may be due to assumptions made about the steel piles’ end fixity, cross-sectional properties, and alignment and exact strain gage positioning. The accuracy is still being evaluated of measuring bridge movements using surveying. Since the bridge’s abutments are skewed, transverse movements of the bridge will also be evaluated in the future.

**Key words: drilled concrete shafts—integral abutment—steel piles—surveying**