U.S. Department of Transportation
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# UTC Spotlight

University Transportation Centers Program

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# Design of Integral Abutment Bridges for Extreme Climates

The Southern Plains Transportation Center (SPTC) is a consortium of eight universities in U.S. Department of Transportation Region VI: the University of Oklahoma, Oklahoma State University, Langston University, University of Arkansas, University of New Mexico, Louisiana Tech University, University of Texas at El Paso and Texas Tech University.

Current SPTC-sponsored research uses data collected from an instrumented integral abutment bridge (IAB) and computer models to develop readily implementable design and construction guidelines for bridges of this type. This research is particularly important for IABs subject to extremes in temperature and soil moisture content. The work builds on several years of collaboration between researchers at the University of Oklahoma and the Oklahoma Department of Transportation to improve analysis and design of IABs that will lead to enhanced bridge performance and safety while reducing maintenance costs.

Because IABs are built without expansion joints (see figure 1), thermal expansion and contraction must be accommodated by the movement of the abutments. Thus significant forces can develop in the bridge structure, abutments, piles, and soil surrounding the bridge substructure. The magnitude of these forces and response of the IAB to them is strongly dependent on the stiffness of the bridge structure, pile foundations, and soil. If the piles and soil are too stiff, large unwanted forces may develop in the bridge. On the other hand, if the backfill is relatively flexible and the embankment and foundation soil is stiff, unwanted yielding of the piles may occur at the bottom of the abutment. Complicating matters is the fact that the soil response is strongly dependent on moisture content, which can vary significantly both seasonally and over the life of a structure.

The integral abutment is a complex soil-structure interaction problem that must be carefully analyzed and designed for optimal performance. Not adequately considering the soil-structure interaction at the abutments can reduce bridge service life and result in pile failure.

The complex interactions occurring in an IAB between the superstructure, abutments, foundations, and soils, however, are poorly understood. Furthermore, there are no national design standards for IABs, and each state has adopted its own design and construction practice. This has led to a contradictory and confusing array of design and construction methods. IAB designers in the U.S. Department of Transportation's (U.S. DOT's) Region 6 states (Oklahoma, Texas, New Mexico, Arkansas, and Louisiana) face an additional challenge due to extreme variations in temperature and moisture. Research sponsored by the SPTC is utilizing data collected from an instrumented Oklahoma IAB and computer simulations, along with input from bridge engineers in Region 6, to develop readily implementable design and construction guidelines for IABs in the region and other areas with extreme variations in temperature and moisture.

## Why Integral Abutment Bridges?

IABs provide many advantages over conventional bridges during construction and subsequent maintenance. Unlike conventional bridges, IABs do not have expansion joints within the bridge deck or between the bridge deck and supporting abutments. Expansion joints and bearings in a conventional bridge are costly, and leaking joints cause deterioration of girders and bearings—leading to potentially unsafe conditions and high maintenance costs. Besides cost savings related to construction and maintenance, IABs also provide superior performance during extreme loading events, such as earthquakes and blast loading, and are being built at an increasing rate in the United States.

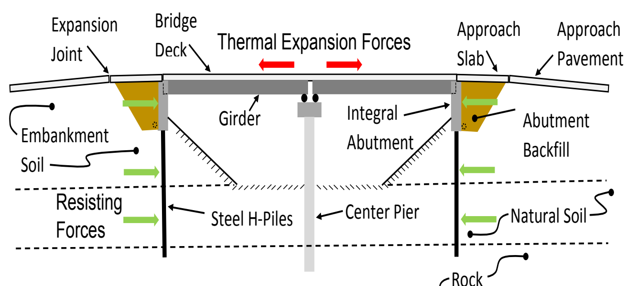


**Figure 1: Schematic of Integral Abutment Bridge Cross-Section**

## Foundational Research

Data collected over 40 months of monitoring instrumentation installed on an IAB in Oklahoma have provided important insights into soil-structure interaction resulting from thermal loading. Located on I-44 near Lawton, OK, the bridge is 210 feet long with three spans and built on a 10 degree skew angle. The bridge was fitted with 46 separate instruments to capture the behavior during thermal loading. Five different types of instruments (pile strain gages, earth pressure cells, crack meters, tilt meters, and thermistors) were employed to study the thermal behavior of this bridge. All the instruments contained vibrating wire type sensors. Two piles on the south abutment and one pile on the north abutment were instrumented with strain gages.

The temperature readings at six different thermistor locations were averaged to calculate a representative bridge temperature and the variation of this temperature during the measurement period is shown in figure 2.

The average temperature change that the bridge superstructure experienced over a 6 month period of time was 95 $^{0}$F. While the data shown in figure 2 represents average temperature variations for the bridge, it should be noted that temperature gradients exist across the depth and the width of the bridge. A temperature variation as much as 20 $^{0}$F was observed during sunny summer days. The measurements revealed that, due to the movement of the sun, there is also a temperature gradient from east to west.

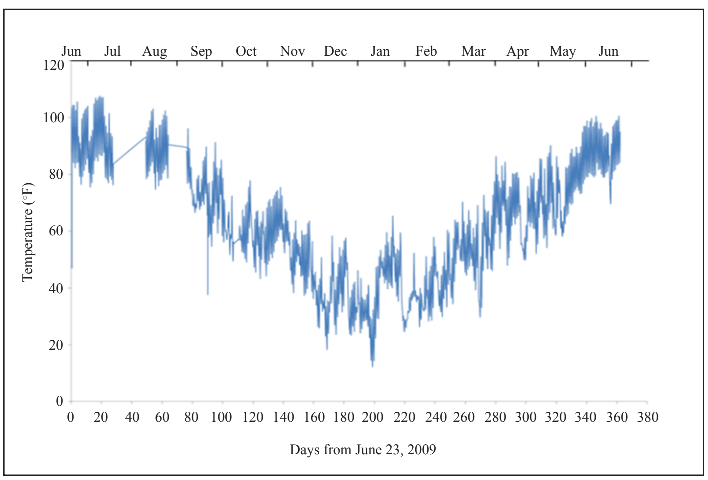


**Figure 2. Average Annual Temperature Variation in IAB**

## Current Research

While many important lessons were learned from prior field research and modeling, it is necessary to extend the results of the instrumentation study to encompass a variety of bridge, subsurface, and climatic conditions. Because instrumenting a large number of bridges and collecting the necessary data over large time frames is impractical, researchers, with support of the SPTC, are conducting extensive parametric analyses to investigate important soil-structure interaction variables. A crucial outcome of the previous work was the calibration and validation of computer models to successfully mimic the observed behavior. Building on this success, researchers are investigating the effects of bridge configuration (abutment geometry, length, skew angle, etc.), foundation type and installation (pile bending stiffness, pre-boring), backfill type (granular, controlled low strength material, etc.), embankment and foundation materials (type, stiffness), as well as impacts of seasonal temperature variations and moisture changes in the soil. The results of this extensive parametric analysis will provide valuable insight into analysis and design of integral abutment bridges. Results will be summarized in readily implemental design and construction guidelines for bridge engineers. In addition numerical modeling tools will be refined for use on challenging projects. This will remove much of the guesswork involved in current design approaches for IABs and allow engineers to explore bridge configurations not currently in use, such as longer bridges and greater skew angles. Ultimately, better performing and longer lasting IABs will be the result of this work.

**About This Project**


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