The Ohio Department of Transportation
Office of Research & Development
Executive Summary Report

Effectiveness of RWIS Bridge Temperature Simulators

Start date: December 15, 2004

Duration: 2.5 years

Completion Date: June 30, 2007

Report Date: May 2007

State Job Number: 134216

Report Number: FHWA/OH-2007/09

Funding: $239,428

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Problem

ODOT has installed over 40 bridge deck simulators (BDSs) in several districts in Ohio as part of its expanded RWIS deployment. The BDS consists of a temperature probe embedded in a 6"x6"x6.5" (15.2cm x 15.2cm x 16.5cm) block of concrete which is mounted to the same pole as the air weather sensors at an RWIS installation. The air weather sensors measure air temperature, wind speed and direction, relative humidity, precipitation, and visibility distance.

The BDSs are intended as a cost-effective solution to represent conditions found on bridge decks in the area. These BDSs need to be evaluated and correlated to actual bridge deck temperatures to determine how to best interpret their temperature data for predicting bridge deck temperatures for use in winter maintenance.

Objectives

The objectives of this project are as follows:

- Perform literature search and review and summarize applicable materials.
- Survey ODOT Districts and/or Counties and other state DOT's relative to their utilization of bridge deck simulators.
- For use in operational decisions, design the best possible process for reducing data from all the simulators and providing indications of the true condition of nearby bridge decks.
- In all phases of the study, exploit opportunities to redesign and interpret the output from the BDSs to improve their value. Investigate available heat exchange models applicable for bridges under varying climatic conditions.
- Utilize available heat exchange models for bridges, refine available models or develop a new model within the scope of the project that can be used for weather related bridge operational activities.
- Establish confidence levels for readings.

Description

To evaluate the effectiveness of the BDSs, ODOT selected nine bridges and nearby BDS sites. Six sites are in the north eastern region and three sites are in the southwestern region of Ohio. Each of the sites used in this project were instrumented with bridge deck pavement sensors, all but one also with road sensors, and a BDS block. All sites were inspected and documented by ORITE personnel.

The RWIS data were recorded at five minute intervals during the 2005 winter season. The unusable data were weeded out and modified by removing entries that were redundant, where one or more temperatures were blank, had extremely unlikely values and or where data were repeated. The number of remaining data points with simultaneous values for the correlations varied from 6646 (31.63%) to 21382 (99.05%) out of 21588 possible during the 75 days analyzed at all the sites.

Correlation analyses were performed on the “cleaned” data by plotting Excel scatter plots for air versus BDS, air versus bridge, air versus road, BDS versus bridge and BDS versus road temperatures for whole day and for nighttimes only. The nighttime only data excluded the distorting effects of solar radiation. The correlation analysis yielded regression equations and R^2 values; the slope and intercept values of the regression equations were not equal to the theoretical values of 1 and 0 respectively anticipated.

The data were analyzed for 90%, 95%, and 99% prediction limits for prediction of bridge temperature using BDS temperature and the regression equations previously found. The average 90% prediction limits obtained for the bridge deck temperatures were 1.66ºC (2.99ºF) on an average for values above the regression line and -1.84ºC (-3.31ºF) below the regression line for a given BDS value. For 95% prediction limits the average upper and lower limits were 1.99ºC (3.58ºF) and -2.27ºC (4.09ºF) respectively, while the corresponding average 99% prediction limits were 2.64ºC (4.75ºF) and -3.08ºC (5.54ºF).

Similarly, prediction limits for larger distances (20 to 40 miles or 32 to 64 km) between the BDS and the bridge decks were analyzed and were on average 35% higher than the prediction limits obtained for nearby bridge locations.

The 90%, 95% and 99% prediction limits using the air temperature instead of the BDS temperature are about 135% to 142% of the prediction limits obtained using the BDS temperature, indicating the BDS gives a better prediction of bridge temperature than the air temperature.

Finite element analysis (FEA) software was used to model the temperature behavior of the bridge deck and BDS at each site. The FEA was performed using ALGOR V18 based on selected actual air temperature profiles during periods of large cooling or warming during night time. The FEA simulation of about 5 hours of weather on one bridge took about 1.5 hr on a fast personal computer with dual Xeon processors with 2 GB RAM.

Larger BDS sizes up to 24”x24”x24” (61.0cm x 61.0cm x 61.0cm) were investigated in an exploratory manner to determine the temperature behavior in relation to the bridge decks. The 24”x24”x24” (61.0cm x 61.0cm x 61.0cm) block almost exactly matched the bridge deck temperature profile.

Conclusions

BDS temperatures at most sites have a bias relative to bridge and road temperatures, and this bias varies from site to site. Nighttime air-BDS and bridge-BDS R^2 values were at least 95%, however. The BDS-bridge and BDS-road correlations were higher than the air-bridge and air-road correlations.

The 90%, 95%, and 99% prediction limits established for the night time are fairly broad and thus of limited usefulness. Predictions of bridge deck temperatures for nighttime or heavy cloud cover conditions are about 25-30% better when based on BDS temperatures than when based on air temperatures.

The FEA modeling provided information about how the BDS and the bridge deck temperature change as a function of the air temperature and time. The FEA profile showed that the present size of the BDS does not closely represent the true temperature behavior of the bridge deck.

The long distance analyses performed for nighttime temperatures resulted in about 30-40% higher prediction limit ranges. According to the literature review no other states appear to use BDS. Further, a limited survey of 24 of 88 counties in the state of Ohio indicated only limited use of the BDSs in counties that had them available.

Recommendations

The present dimensions of the BDS do not seem to be large enough to predict the bridge deck temperatures closely during periods of rapid changes in air temperature. Therefore a FEA and field investigation using a much larger BDS block of 24”x24”x24” (61.0cm x 61.0cm x 61.0cm) is recommended.

The long distance analysis shows increased variability of the prediction limits, so more BDSs may be needed located near important bridges to reduce the long distance effect, or other improvements made to the system to reduce variability.

In the future, more precise instrumentation and periodic calibration for air, bridge, road and BDS sensors is recommended to decrease the broad range of the prediction limits.

Yearly training in the use of the RWIS network, including the BDS, at each county garage is recommended.

The impact of solar radiation and possible cloud cover would require additional instrumentation and a field investigation in order to reduce the range of the prediction limits for daytime.

Implementation Potential

Yearly training of maintenance personnel in the use of RWIS with BDS would help the state more fully realize the benefits of the RWIS system.