Final Report VTRC 06-R35

Virginia Transportation Research Council

research report

Field Measurements on Skewed Semi-Integral Bridge With Elastic Inclusion: Instrumentation Report

http:/www.virginiadot.org/vtrc/main/online_reports/pdf/06-r35.pdf

EDWARD J. HOPPE, Ph.D., P.E.
Senior Research Scientist

Virginia Transportation Research Council, 530 Edgemont Road,
Charlottesville, VA 22903-2454, www.vtrc.net, (434) 293-1900

Standard Title Page - Report on Federally Funded Project

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/VTRC 06-R35		

4. Title and Subtitle Field Measurements on Skewed Semi-Integral Bridge with Elastic Inclusion: Instrumentation Report	5. Report Date June 2006
	6. Performing Organization Code
7. Author(s) Edward J. Hoppe, Ph.D., P.E.	8. Performing Organization Report No. VTRC 06-R35
9. Performing Organization and Address Virginia Transportation Research Council 530 Edgemont Road Charlottesville, VA 22903	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. 75447
12. Sponsoring Agencies' Name and Address Virginia Department of Transportation 1401 E. Broad Street Richmond, VA 23219 FHWA P.O. Box 10249 Richmond, VA 23240	13. Type of Report and Period Covered Final: January 2006–May 2006.
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This project was designed to enhance the Virginia Department of Transportation's expertise in the design of integral bridges, particularly as it applies to highly skewed structures. Specifically, the project involves extensive monitoring of a semi-integral (integral backwall) bridge with a 45-degree skew. Long-term, continuous monitoring of strains developed in foundation piles, earth pressures exerted on the backwall by the adjacent approach embankment, and concrete buttress reactions preventing the superstructure from rotating in the horizontal plane will be performed. Overall, 120 strain gages, 16 earth pressure cells, and 2 high-capacity load cells, interfaced with electronic dataloggers, will be used in the study.

This report provides a record of work carried out from the start of construction in January 2006 to the beginning of May 2006. It specifically describes the instrumentation of the bridge. Future reports will provide an analysis of the results of the field monitoring program. The study is expected to continue for the next 2 years in order to capture the bridge's response over a wide range of climatic conditions.

17 Key Words	18. Distribution Statement
Skewed, semi-integral, integral backwall, integral bridge, monitoring, elastic inclusion, EPS.	No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	14	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FINAL REPORT

FIELD MEASUREMENTS ON SKEWED SEMI-INTEGRAL BRIDGE WITH ELASTIC INCLUSION: INSTRUMENTATION REPORT

Edward J. Hoppe, Ph.D., P.E.
Senior Research Scientist

Virginia Transportation Research Council
(A partnership of the Virginia Department of Transportation and
the University of Virginia since 1948)

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Charlottesville, Virginia

June 2006
VTRC 06-R35

DISCLAIMER

ABSTRACT

This project was designed to enhance the Virginia Department of Transportation's expertise in the design of integral bridges, particularly as it applies to highly skewed structures. Specifically, the project involves extensive monitoring of a semi-integral (integral backwall) bridge with a 45-degree skew. Long-term, continuous monitoring of strains developed in foundation piles, earth pressures exerted on the backwall by the adjacent approach embankment, and concrete buttress reactions preventing the superstructure from rotating in the horizontal plane will be performed. Overall, 120 strain gages, 16 earth pressure cells, and 2 high-capacity load cells, interfaced with electronic dataloggers, will be used in the study.

This report provides a record of work carried out from the start of construction in January 2006 to the beginning of May 2006. It specifically describes the instrumentation of the bridge. Future reports will provide an analysis of the results of the field monitoring program. The study is expected to continue for the next 2 years in order to capture the bridge's response over a wide range of climatic conditions.

FINAL REPORT

FIELD MEASUREMENTS ON SKEWED SEMI-INTEGRAL BRIDGE WITH ELASTIC INCLUSION: INSTRUMENTATION REPORT

Edward J. Hoppe, Ph.D., P.E.
Senior Research Scientist

INTRODUCTION

The Virginia Department of Transportation (VDOT) has actively supported the construction of jointless bridges, primarily as an effective means of reducing life cycle maintenance costs. In addition to considering this type of design where feasible, VDOT, in cooperation with the Virginia Transportation Research Council (VTRC), has embarked on a process of revising office standards and producing new design guidelines for fully integral (integral abutment) and semi-integral (integral backwall) bridges. These efforts, aimed at optimizing the integral bridge design process, include field monitoring to evaluate the structure's performance during service and verify design assumptions.

Over the past decade, VTRC conducted long-term monitoring projects of semi-integral bridges on Route 257 over Interstate 81 and on Route 60 over the Jackson River.[1,2] Field data collected over a period of several years were used to verify design assumptions and confirm the suitability of using elastic inclusion to reduce stresses and minimize the approach settlement.

These projects involved a relatively small number of sensors placed at key structural locations. As the complexity of integral designs undertaken by VDOT increased over the years, so did the need for a more sophisticated field monitoring. This is especially true in cases involving skewed integral bridges, where the actual distribution of stresses acting on a structure in service is not very well documented.

PURPOSE AND SCOPE

This project was designed to enhance the Virginia Department of Transportation's expertise in the design of integral bridges, particularly as it applies to highly skewed structures. Specifically, the project involves extensive monitoring of a semi-integral (integral backwall) bridge with a 45-degree skew. Long-term, continuous monitoring of strains developed in foundation piles, earth pressures exerted on the backwall by the adjacent approach embankment, and concrete buttress reactions preventing the superstructure from rotating in the horizontal plane will be performed. Overall, 120 strain gages, 16 earth pressure cells, and 2 high-capacity load cells, interfaced with electronic dataloggers, will be used in the study.

This report provides a record of work carried out from the start of construction in January 2006 to the beginning of May 2006. It specifically describes the instrumentation of the bridge. Future reports will provide an analysis of the results of the field monitoring program. The study is expected to continue for the next 2 years in order to capture the bridge's response over a wide range of climatic conditions.

METHODOLOGY

Description of Bridge

The project involves a replacement bridge on Route 18 over Blue Spring Run in Alleghany County, Virginia, as shown in Figures 1 and 2. Significant deterioration of the old bridge, as evidenced by corrosion, delamination, and increased scour susceptibility, was the main reason for this construction.

The new semi-integral bridge is 110 ft (33.5 m) long, 42.7 ft (13 m) wide, with one-span steel girders, built at a 45-degree skew. There are no approach slabs constructed at the bridge approaches. The average daily traffic (ADT) is 1,706 vehicles with 2 percent trucks (2004 traffic data).[3]

The design incorporates a 15-in-thick (38 cm) layer of elasticized expanded polystyrene (EPS) faced with a separation geotextile, installed at the integral backwall of Abutment A. The EPS serves as an elastic inclusion, effectively accommodating thermally induced movements of the superstructure while reducing the lateral earth pressures and minimizing the approach embankment settlement. Figure 3 shows the cross-section detail of Abutment A, with the elastic inclusion placed at the integral backwall.

Figure 1. Old Bridge on Route 18 Over Blue Springs Run

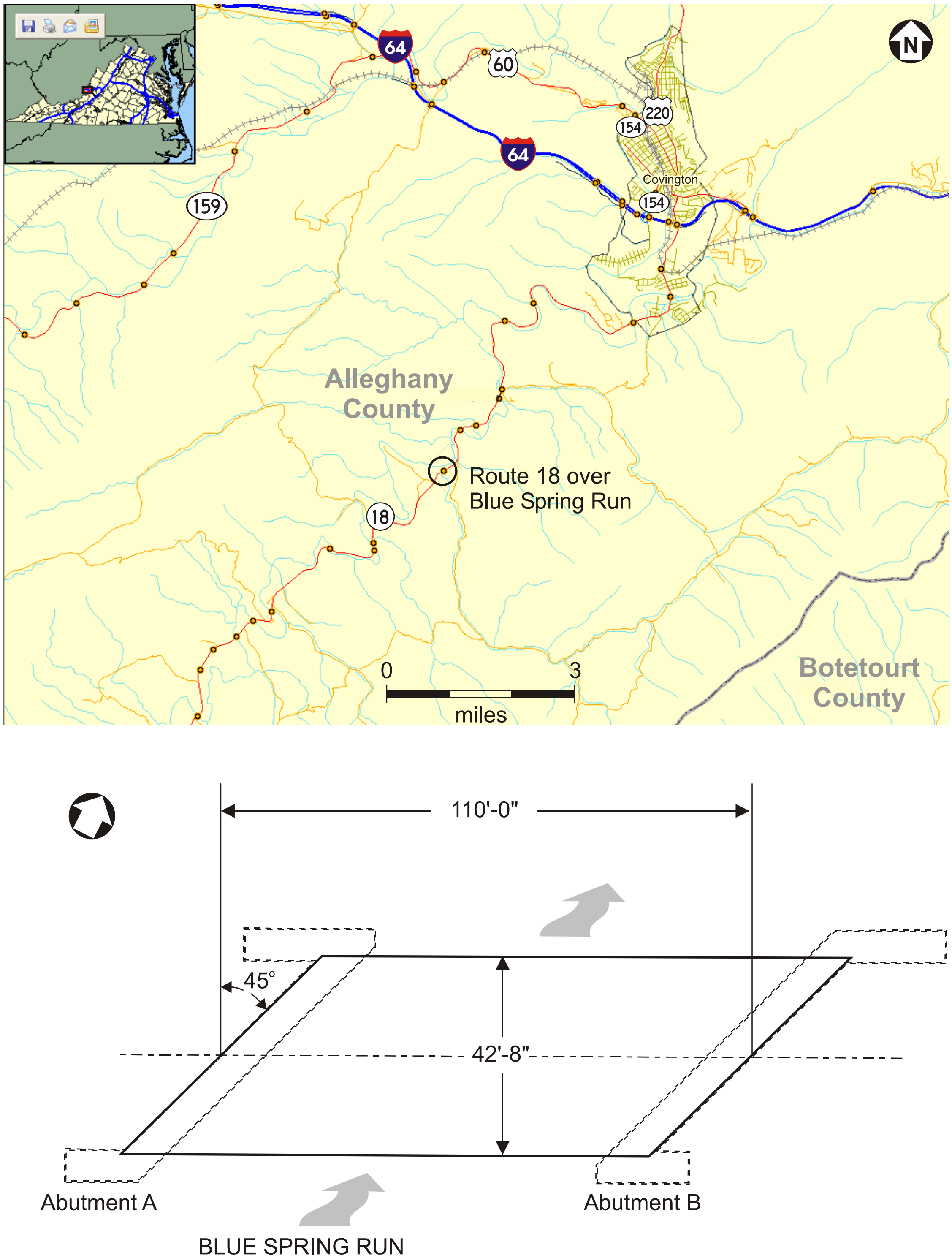

Figure 2. Site Location and New Bridge Layout

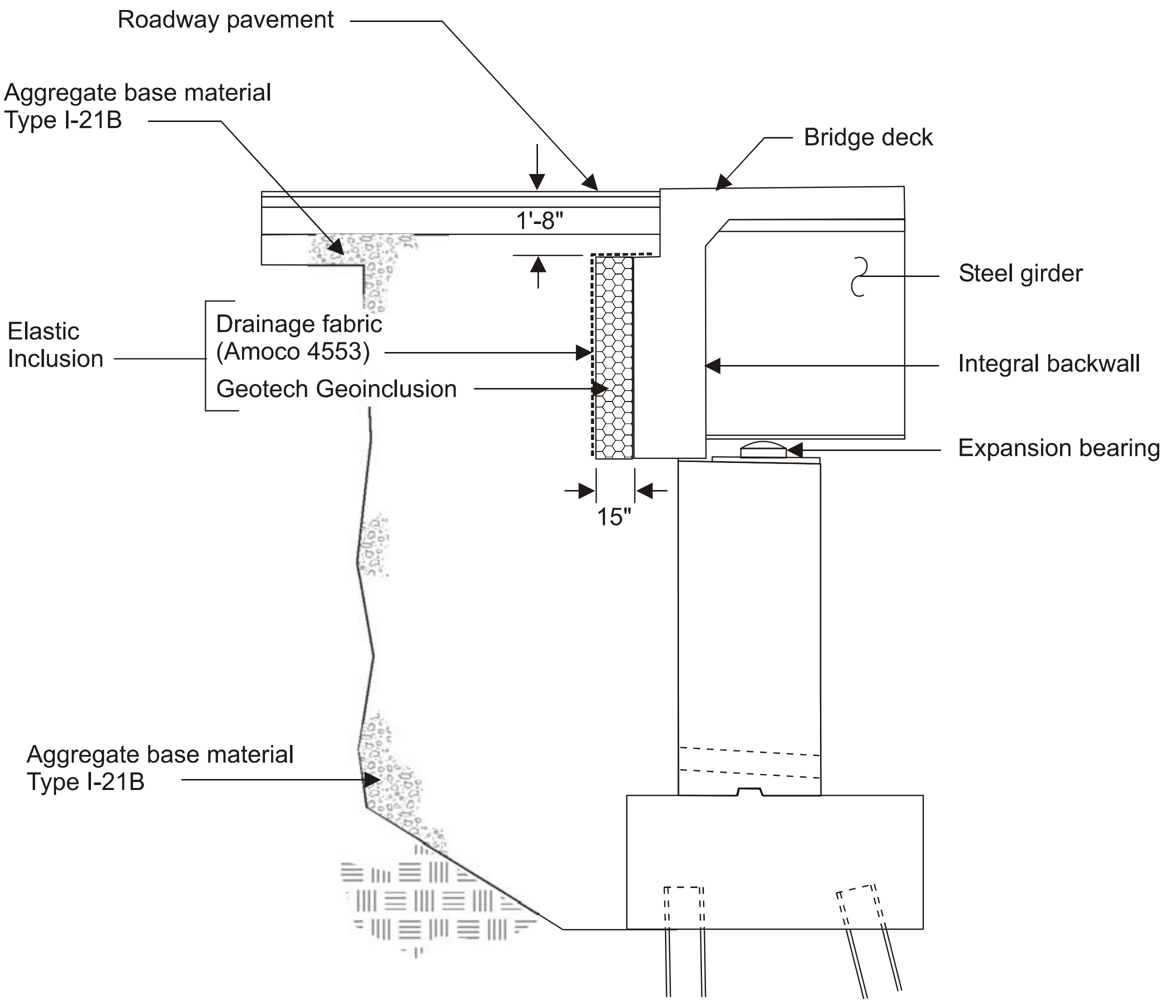

Figure 3. Cross Section of Abutment A

Instrumentation

Electronic instrumentation installed at the bridge consisted of strain gages, earth pressure cells, and high-capacity load cells. The following tasks are planned:

1. monitoring of strains in foundation piles

2. monitoring of the load (reaction) required to restrain the superstructure from horizontal rotation attributable to a non-collinear force couple acting on the backwalls

3. monitoring of lateral earth pressures exerted on backwalls and wingwalls

4. monitoring of the thickness of the EPS layer at various ambient temperatures

5. monitoring of the shape of the concrete deck surface at various ambient temperatures.

The results of precise field surveys are expected to show how the bridge expands and contracts (along the long diagonal or the centerline).

RESULTS

The bridge replacement project was designed in two stages to allow for uninterrupted traffic flow on Route 18. Figures 4 through 7 show the progress of construction from January to May 2006.

Figure 4. Foundation Piles at Abutment B

Figure 5. Formwork for Abutment B

Figure 6. Placement of Structural Steel

Figure 7. View of Completed Deck and Backwall

Stage I construction began with pile driving in January 2006. HP10x42 piles were used for foundation support. Figure 8 shows a plan view of the instrumented piles.

Each instrumented pile had two levels of Rocktest SM-5A vibrating wire strain gages welded prior to driving, as shown in Figure 9. Sensor layout is shown in Figure 10. The uppermost layer (Level 3) of sensors was added after the pile was installed, with the center of each gage placed at the abutment footing elevation. In all instrumented piles, the surface bound by gages 1 and 2 was oriented to face the structural fill of the adjoining embankment.

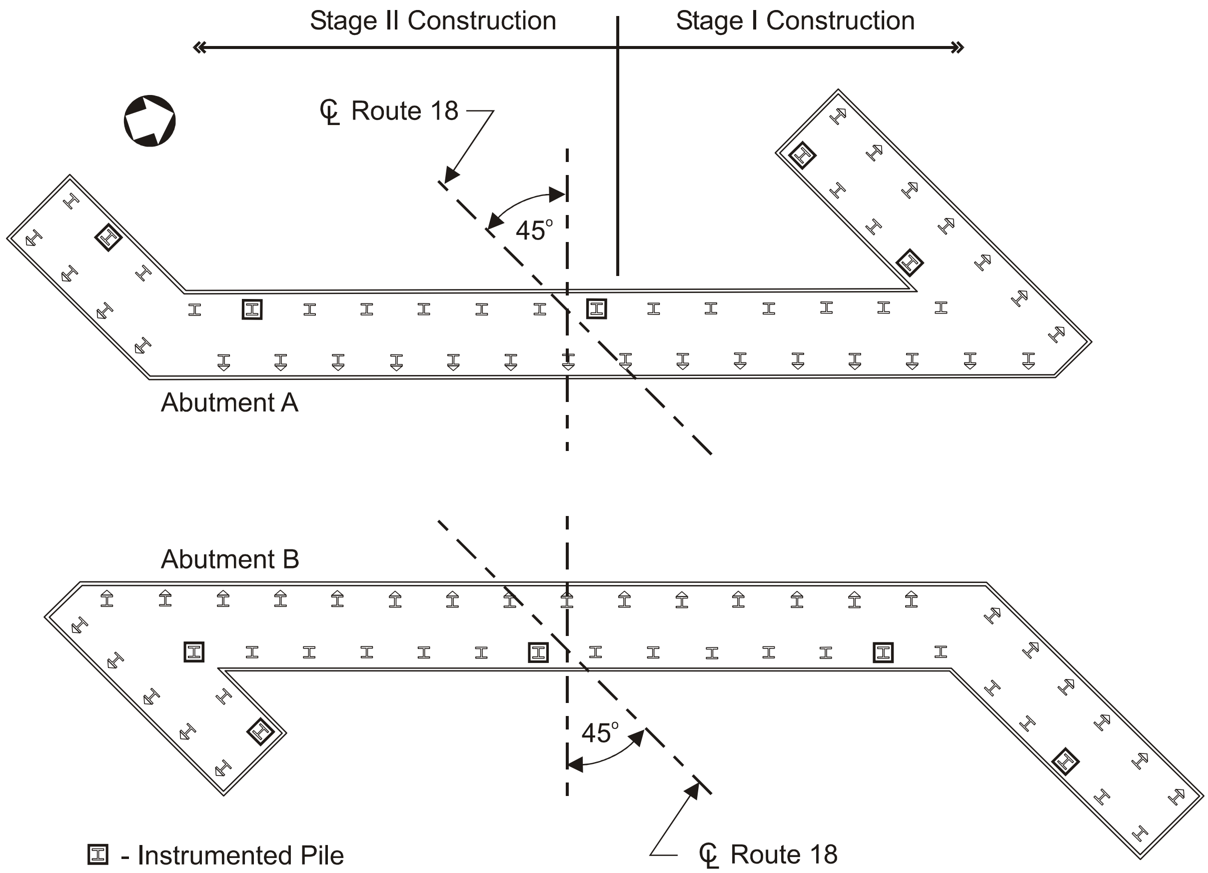

Figure 8. Layout of Foundation Piles

Figure 9. Strain Gage Welded To to Foundation Pile

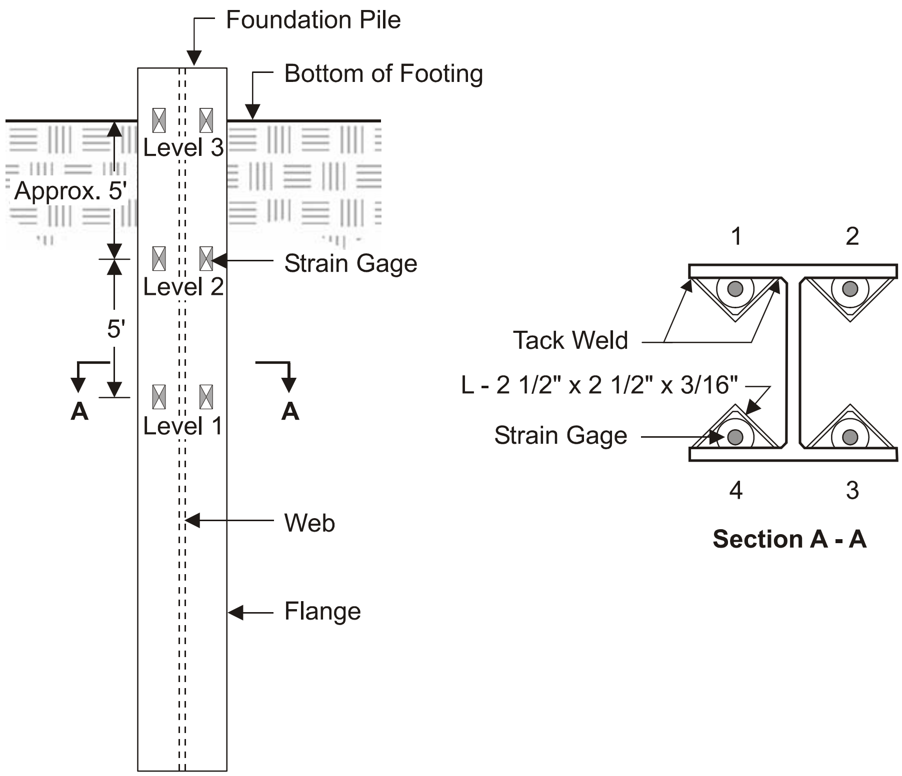

Figure 10. Strain Gage Layout

Readings of the foundation pile strain gages were conducted as follows:

1. After the pile installation: initial baseline readings on 02/07/06
2. After the abutment construction: 03/02/06
3. After the steel girder placement: 03/09/06
4. After the concrete deck pour: 04/26/06.

Figure 11 shows an example of data, reflecting increased loading, collected from one foundation pile strain gage.

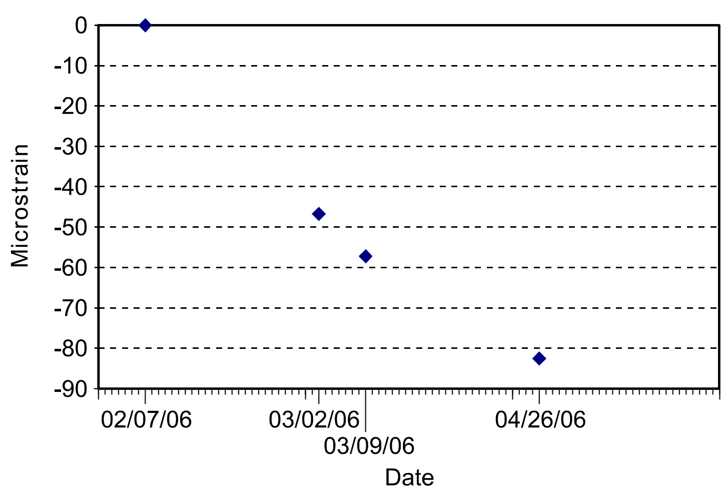

Figure 11. Example of Strain Gage Response

Figure 12 shows a Geokon Model 4900 vibrating wire load cell embedded into the Abutment B buttress. Its purpose is to measure the magnitude of the lateral load exerted by the adjacent superstructure as a result of thermally induced displacements. The load is transferred from the superstructure through a set of thick stainless steel rub plates that allow for transverse sliding while the load cell registers the axial force. A bearing plate is attached at the back of the load cell to distribute the load inside the abutment buttress. Initial baseline load cell readings were collected on April 26, 2006, with the superstructure in place, but with no backfill placed behind the backwall.

Figure 13 shows two Geokon Model 4810 vibrating wire earth pressure cells installed on the integral backwall at Abutment B. There were also two earth pressure cells installed on the integral backwall and one on the wingwall of Abutment A. Initial baseline readings at five installed pressure cells were recorded on May 4, 2006.

Figure 12. Load Cell at Abutment B

Figure 13. Earth Pressure Cells at Abutment B

As of May 5, 2006, the installation of all sensors associated with Stage I of the bridge replacement project was completed.

CONCLUSION

- *The instrumentation was successfully installed on the skewed integral bridge on Route 18 over the Blue Springs Run.* The monitoring is expected to provide meaningful feedback for optimizing future integral bridge designs. Data from earth pressure cells will be indicative of actual stresses exerted on the backwall by the adjoining embankment. Data from load cells will show how much lateral restraint is required to keep the skewed integral superstructure in place. Data from strain gages will show in-service stresses generated in the foundation piles.

RECOMMENDATION

1. *VTRC should continue field monitoring, data collection, and data analysis for at least 2 years following the opening of the bridge to traffic in order to capture the bridge's response over a wide range of climatic conditions.*

BENEFITS AND COSTS ASSESSMENT

This study is expected to result in a more economical integral bridge design process, with potentially significant cost savings to VDOT. Field data will provide meaningful feedback to bridge designers, leading to a new generation of minimal maintenance bridges, detailed for inherent durability.

ACKNOWLEDGMENTS

The author expresses his appreciation to Park Thompson, Keith Weakley, and Eulogio Javier of VDOT's Staunton District Bridge Office for their helpful guidance in this study. Arthur Wagner of VTRC assisted with the sensor installation and field data collection. Linda DeGrasse of VTRC helped with data processing. Randy Combs, Ed Deasy, and Linda Evans of VTRC assisted with the graphics and the editorial process.

REFERENCES

1. Hoppe, E.J., and Gomez, J.P. (1996). *Field Study of an Integral Backwall Bridge* (Report No. VTRC 97-R7). Virginia Transportation Research Council, Charlottesville.

2. Hoppe, E.J. (2005). *Field Study of Integral Backwall with Elastic Inclusion* (Report No. VTRC 05-R28). Virginia Transportation Research Council, Charlottesville.

3. Weakley, K.P., Virginia Department of Transportation. (2006). Personal communication.