Jointless Bridge Research Pays Dividends for Vermont

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Jointless bridges—often referred to as integral abutment bridges—have a superstructure that is cast integrally with the substructure, eliminating costly expansion joints and bearings. The Vermont Agency of Transportation (VTrans) had used jointless bridge designs since the late 1970s, but in 1999, the agency formed an Integral Abutment Committee (IAC) to codify a measured, analytical, and multidisciplinary approach to jointless bridge design and construction. The committee included representatives from the Hydraulics, Structures, Soils and Foundations, Contract Administration, and Construction sections of VTrans, as well as from the Federal Highway Administration.

The 37-meter-long East Montpelier Bridge is part of ongoing research to establish design guidelines for integral abutment bridges.

Problem

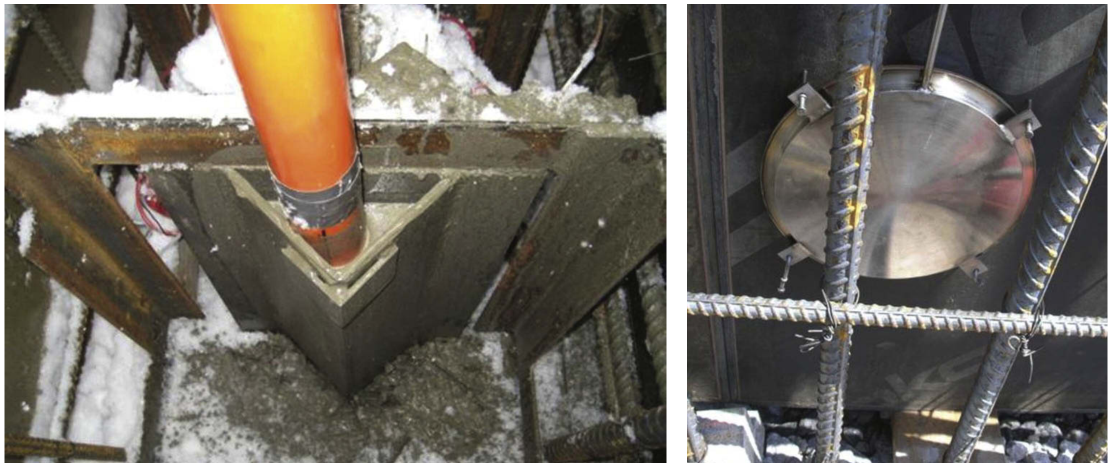
VTrans has constructed several jointless bridges in the past 10 years, finding the structures more advantageous than conventional abutment bridges. The advantages of jointless bridges often include one or more of the following:

The curved-girder, two-span continuous structure in Stockbridge has a total length of 69 meters.

- **Reduced environmental impacts**—abutments farther from the stream banks minimize the effects on stream water and a longer superstructure allows more room below for wildlife passages;
- **Lower construction costs**—placing the abutments farther away from the stream often eliminates the need for cofferdam construction;
- **A more rapid construction schedule**—fewer piles need to be driven; and
- **Elimination of costly future maintenance repairs**, which can affect users—perhaps the primary benefit. Without the need for expansion joints and bearings, costly, complicated, and time-sensitive maintenance activities are eliminated.

Nonetheless, VTrans engineers often have struggled with how best to approach the design of jointless bridges, because no quantitative data are available, and the American Association of State Highway and Transportation Officials offers no specific guidelines for integral abutment design. Without fully developed design guidelines and construction plans and specifications, the benefits of jointless bridges may not be fully realized.

Two instrumentation features of the Stockbridge structure: (*left*) top view of inclinometer casing and (*right*) earth pressure cell.



Solution

A literature search, conducted when the IAC was being formed, found that designs of jointless bridges often were selected simply "because they work." A drawback to this approach is that the structure may not represent the most economical or efficient design; moreover, the safety factors may be undetermined.

With input from the IAC, VTrans initiated a research project, Performance Monitoring of Jointless Bridges, to gain a thorough understanding of how jointless bridges respond to thermal movements and to dead and live loads in a northern climate. The primary research objectives were to provide VTrans engineers with the knowledge and quantitative data to design and construct cost-effective, efficient, safe, reliable, and low-maintenance structures.

The research project comprises three phases. Phases I and II, completed by Wiss, Janney, Elstner Associates in 2002, included a formal literature search and the development of an instrumentation plan. The total cost of Phases I and II was $64,267.

VTrans applied the information and knowledge gained from the research to develop design guidelines, contract plans, and specifications. The agency has used these documents to build several integral abutment bridges since 2002. The design guidelines and construction specifications have been revised to reflect qualitative assessments of construction experiences and field performance.

The 2010 VTrans *Structures Manual* will include guidelines and procedures for integral abutment design developed from the Phase I research. With the application of the Phase I research findings, integral abutment bridges have become the preferred structures at VTrans.

Application

The University of Massachusetts–Amherst is conducting the Phase III research. The research scope includes modifications to the Phase II instrumentation plans, installation and monitoring of instrumentation, data analysis and reduction, and preparation of a final report. Phase III should be completed in February 2013, with an estimated cost of $558,341. The new research findings will serve as the foundation for future revisions of the design

TABLE 1 Estimated Construction Savings for Phase III Integral Abutment Bridges

	East Montpelier	Stockbridge	Middlesex
Total project cost, as bid	$2,369,907	$4,155,879	$2,254,458
Savings by category:			
Cofferdam construction	$100,000	$150,000	—— [a]
Substructure concrete and reinforcing	$250,000	$308,000	$140,000
Steel piling	$ 25,000	$310,000	—— [b]
Granular backfill	$ 22,000	$ 33,000	$ 35,000
Excavation	—— [c]	$ 20,000	$ 40,000
Total savings	$397,000	$821,000	$215,000
Savings from project bid	16.8%	19.8%	9.5%

[a] Conventional abutment did not require a cofferdam.
[b] Conventional abutment would have utilized a spread footing foundation.
[c] Excavation savings are included in the cofferdam construction savings, noted above.

guidelines for integral abutment bridges.

The Phase III research involves three bridges: a straight bridge with a 43-meter span in Middlesex; a 37-meter-long bridge with a 15° skew in East Montpelier; and a curved-girder, two-span continuous structure with 11.25° of curvature and a total length of 69 meters in Stockbridge. Instrumentation includes pile and girder strain gages, earth pressure cells, displacement transducers, inclinometers, tiltmeters, and thermisters.

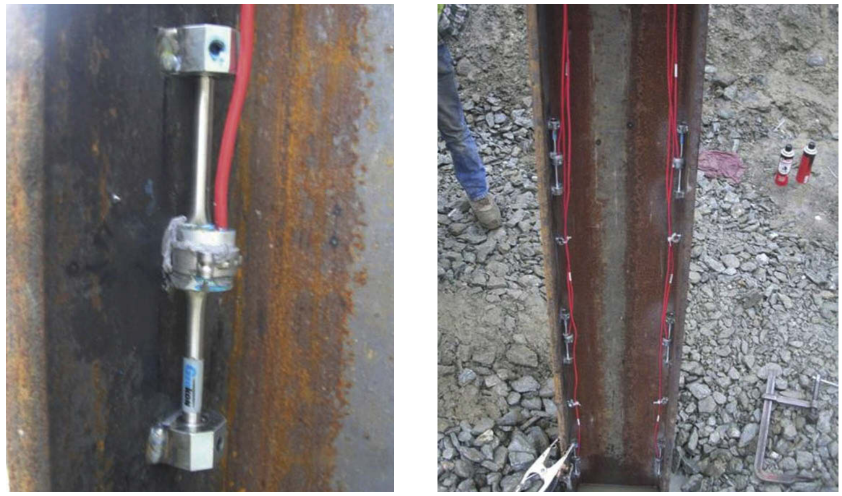
Benefits

The primary benefit expected from this research is the development of design standards from a comprehensive analysis of performance data, producing designs that can maximize efficiency, as well as identify and mitigate known risks. Ancillary benefits include refining construction details and specifications to avoid unnecessary claims related to these structures.

Tangible economic benefits include reductions in maintenance and construction costs. The construction cost savings result from eliminating cofferdams and from using less concrete and reinforcing steel in the substructure and superstructure. The integral abutments have a typical height that is less than that of a conventional abutment, reducing the quantity of excavation and backfill materials. In addition, integral abutments require fewer piles for support than do conventional abutments.

Indirect benefits include savings from a more rapid construction schedule, which decreases user costs; fewer environmental impacts—for example, less sediment pollution of streams; and better access under the bridge for wildlife passage, because the structures are longer. Preserving the environment is a key task in the agency's mission; however, the cost savings from the reduction in environmental impacts are not easily quantified.

Crack meters in reference pile enclosures measure the longitudinal and lateral displacements on East Montpelier Bridge.



Strain gauges (*left*) close up and (*right*) installed on H-piles for Middlesex Bridge.

VTrans engineers therefore calculated the project cost savings by comparing the estimated costs for constructing conventional abutments on the three Phase III bridges with the costs for the integral abutments. The differences between the estimated costs and the actual construction costs in five categories are reported in Table 1 (page 52). The data do not include the reduced construction and maintenance costs from the elimination of expensive bearings and joints; therefore, the direct project-related savings reflect only a portion of the cost savings.

The construction savings shown in Table 1 total more than $1.4 million—more than twice the cost of the entire Performance Monitoring of Jointless Bridges research project. The savings are directly attributable to the application of the Phase I research findings.

When Phase III is completed in 2013, the final research report from the University of Massachusetts will document the results of the field monitoring program. The report will be used to validate current VTrans jointless bridge design practices, using 3-D finite element models developed for each bridge, and will recommend changes to VTrans construction plans and specifications.

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Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, Keck 488, 500 Fifth Street, NW, Washington, DC 20001 (202-334-2952; gjayaprakash@nas.edu).