

# SEGMENTS

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## Editorial

### TRANSPORTATION FUNDING AND THE 21ST ANNUAL ASBI CONVENTION

The uncertainty of future transportation funding is affecting project planning and delivery for state transportation departments across the nation. Much of the focus has shifted to maintenance and repair projects that can be brought to contract with the available funds rather than the development of projects to address the aging bridge infrastructure and the congestion in urban areas.

The American Recovery and Reinvestment Act (ARRA) signed into law on February 17, 2009, provided \$48.1 billion of stimulus funds for transportation investment. Of this, \$26.6 billion was apportioned to the states for highway projects with the stipulation that 50% of the funds be obligated within 120 days. “Shovel ready” projects consisting of repaving and widening of roads account for the majority of approved projects.

Congress approved, and the President signed into law, H.R. 3357, providing for \$7 billion in funds to keep the Highway Trust Fund solvent through the federal fiscal year ending September 30th. The White House and Senate favor an 18-month extension of the current transportation authorization,

SAFETEA-LU, while the House of Representatives are moving ahead in support of House Transportation and Infrastructure Committee Chairman James Oberstar’s proposed 6-year transportation bill. The Surface Transportation Authorization Act of 2009 is a \$500 billion program that would authorize \$337.4 billion for highway construction, \$99.8 billion for mass transit, and \$12.6 billion for highway safety programs. These funds represent a 38% increase in authorizations established by SAFETEA-LU. An additional \$50 billion would be provided for high-speed rail. This legislation, if approved, will significantly increase highway and transit funding and spur on the development and delivery of needed transportation projects nationwide.

The October 26-27 ASBI Convention at the Hilton

Minneapolis provides a forum to showcase current



Editorial by W. R. "Randy" Cox  
Manager, ASBI

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segmental bridge design and construction innovations. Five presentations will focus on transit and rail projects in the U.S. and abroad. Other presentations will demonstrate the advantages of segmental bridge technology to address the nation's infrastructure needs. Case studies of the I-35W St. Anthony Falls Bridge replacement and the Minneapolis Crosstown Project will be presented. Both of these sites, along with the Wakota Bridge Project, will be visited during the bridge tour on the afternoon of October 27th. Information about the convention program and registration may be found on the ASBI website at [www.asbi-assoc.org](http://www.asbi-assoc.org). *We hope to see you in Minneapolis!*

### **New ASBI Organizational Member**

We are pleased to welcome Unistress Corporation as a returning member. The address and contact information is as follows:

**UNISTRESS CORPORATION**  
 550 Cheshire Road  
 Pittsfield, MA 01201  
 (413) 499-1441  
 FAX: (413) 499-1254  
 e-mail: [steven.cote@unistresscorp.com](mailto:steven.cote@unistresscorp.com)  
[www.unistresscorp.com](http://www.unistresscorp.com)  
**Steve Cote**

### **Change of Address**

Please make a note of the following address changes:

**AECOM USA, Inc.**  
 4840 Cox Road  
 Glen Allen, VA 23060  
 (804) 290-7920  
 FAX: (804) 290-7921

**PTI Post-Tensioning Institute®**  
 38800 Country Club Drive  
 Farmington Hills, MI 48331  
 (248) 848-3180  
 FAX: (248) 848-3181

### **Moved and Have a New Address**

Please let us know if you have had an address change so we may publish the correct information in the upcoming 2010 Membership Directory. Don't forget to include new telephone and fax numbers, as well as e-mail addresses. You may send any updates to [info@asbi-assoc.org](mailto:info@asbi-assoc.org).

### **Grouting Certification Training**

**2009** ASBI's annual Grouting Training held on April 20-21 at the J.J. Pickle Research Campus in Austin, Texas, was attended by 55 registrants with 23 certified as Technicians.

**2010** Next year's training will again be held at the J.J. Pickle Research Campus on April 12-13 in Austin. Please check the ASBI website [www.asbi-assoc.org](http://www.asbi-assoc.org) for online registration.

### **2009 Convention**

The 2009 ASBI Convention will be held October 25-27 at the Hilton Minneapolis. The Tuesday afternoon bridge tour is scheduled to include the Wakota Bridge Project, the I-35W St. Anthony Falls Bridge, and the Crosstown Project.

You may register online at [www.asbi-assoc.org](http://www.asbi-assoc.org).

### **2010 Convention**

*Mark Your Calendar!*

ASBI Annual Convention to be held in Vancouver, B.C. on October 17-19, 2010.



### **Dawn White Joins FINLEY Engineering Group as Director of Marketing**

TALLAHASSEE, FL (Mar. 26, 2009) – **Dawn White**, the former Director of Marketing and Communications for the American Segmental Bridge Institute (ASBI), has joined **Finley Engineering Group (FINLEY)** as its Director of Marketing.

White was with ASBI from 2003 until January 31, 2009, when the organization moved its headquarters from Phoenix, Arizona to Buda, Texas.

White is a member of the Society for Marketing Professional Services (SMPS), the National Steel Bridge Alliance (NSBA), and ASBI.



# PROJECT NEWS



## **John Crigler Named President of VSL**

BALTIMORE, MD – (Jan. 27, 2009) – **VStructural, LLC (VSL)** – a supplier of post-tensioning systems and services – has appointed **John Crigler, P.E.** as the President of VSL, a Structural Group company. He previously served as a Senior Vice President of VSL.

With nearly 30 years of experience at VSL, Crigler is a recognized expert in post-tensioning, stay cable and concrete bridge construction. He is an active member of several industry associations including the American Segmental Bridge Institute (ASBI), Post-Tensioning Institute (PTI), American Society of Civil Engineers (ASCE) and American Concrete Institute (ACI). He is currently serving as the Vice President of ASBI and received the prestigious 2008 ASBI Leadership Award given for outstanding leadership for the development of the segmental bridge industry.

Crigler received his Bachelor of Civil Engineering from Virginia Polytechnic Institute and is a registered professional engineer in Virginia, as well as numerous other states.



*Figure 1 - Kanawha River Bridge main span before closure. (Photo courtesy of T.Y. Lin International).*

## **Construction for Kanawha River Bridge's 760-foot Main Span Complete**

On June 17, 2009, workers cast the closure segment on the 760' main span of the Kanawha River Bridge, between Dunbar and South Charleston, West Virginia. With the main span closure, this is now the longest box girder span in the U.S. Of the total superstructure, three cantilevers remain to be completed, along with the bridge parapets, overlay, and roadway all due to be completed by October 2010.

The new bridge will carry I-64 eastbound traffic on an improved curved alignment as part of the widening of I-64 in Kanawha County. Westbound traffic will remain on the existing steel plate girder bridge.

The new Kanawha River Bridge (**Fig. 1**) will have a total length of 2,975', including the 760' river span, 460' and 540' side spans and five additional approach spans, ranging from 144' to 295'. The 66'-8" wide deck will accommodate four lanes of traffic plus shoulders, all on a single cell box girder. The continuous girder has a varying depth of 16' to 38' at the main span and a constant 16' depth at the approaches. This low-cost design was selected over a steel alternative, saving \$30 million and simplifying construction in the process. The final result is an elegant and distinct design that blends into its surroundings and adheres to a limited budget.

*Owner:* West Virginia Department of Transportation

*Designer:* **T.Y. Lin International**

*Contractor:* Brayman Construction Corporation

*Construction Engineer:* **FINLEY Engineering Group, Inc.**

Michael Baker Corporation

*Construction Engineering Inspection:* West Virginia Department of Transportation

*Formwork for Precast Segments:* **DOKA USA, Ltd.**

*Form Travelers for Cast-in-Place Segments:* **STRUKTURAS**

*Post-Tensioning Materials/Stay Cables:* **VSL**

*Bearings and Expansion Joints: Bearings –* R.J. Watson Inc.;

*Joints –* **Watson Bowman Acme - A BASF Company**

*Epoxy Supplier and Prepackaged Grout:* **BASF Construction Chemicals, LLC**

Figure 2 - Rendering - The new US 191 Bridge over the Colorado River will complement its surroundings while replacing a functionally obsolete crossing. (Photo courtesy of FIGG).



**US 191 Bridge over the Colorado River, Moab, Utah**

Construction of Utah's first concrete segmental bridge (Fig. 2) began in January 2009. The new concrete segmental bridge is the gateway to Arches National Park and has a strong emphasis on blending with the canyon walls so that the landscape remains the focus of the pristine environment. Aesthetics selected by the community, including a rock texture on the piers and a mineral stain for the concrete, will help to blend the bridge with its surroundings.

Concrete segmental balanced cantilever construction from above will minimize impacts to the river and recreational users.

The layout of the twin 1,025' long bridges, each with a 438' main span and only one pier in the water, was planned to further reduce impacts to the river.

*Owner:* Utah Department of Transportation

*Designer:* FIGG

*Contractor:* Wadsworth Brothers Construction

*Construction Engineer:* Summit Engineering Group, Inc.

*Construction Engineering Inspection:* FIGG

*Form Travelers for Cast-in-Place Segments:* NRS - Asia

*Post-Tensioning Materials/Stay Cables:* **DYWIDAG Systems International, USA, Inc.**

*Bearings and Expansion Joints: Bearings - The D.S. Brown Company; Joints - Watson Bowman Acme - A BASF Company*

**Segmental "Channel Bridge" Begins Construction, Massachusetts**

The DCR Access Road over Route 24 Bridge (Figs. 3, 4 and 5) is beginning construction in Randolph, Massachusetts. Located in the scenic Blue Hills Reservation southwest of Boston, the 2-span, segmental "Channel Bridge" will replace an existing 4-span, steel girder structure.

The new bridge will have a length of 248', a width of 29'-8", and a total depth (including barriers) of only 5'-4". The low profile of the bridge increases the vertical clearance over the heavily traveled Route 24 from 14'-3" to 16'-9" without altering the approach grade. Additionally, the side piers of the original

structure have been eliminated, thus increasing safety for the drivers on Route 24.

The shallow depth of the DCR Bridge is achieved by using edge beams located above the deck surface that function as both main supporting members as well as bridge barriers. The edge beams are fully post-tensioned, using a mix of 19-strand and 12-strand tendons. Additional longitudinal tendons are provided in the deck slab,

using flat 4-strand tendons. Transversely, the structure is fully post-tensioned using flat 4-strand tendons.

Demolition of the existing bridge, construction of the new substructure, and precasting of the superstructure segments are scheduled to begin in late summer. Erection of the new superstructure segments will begin in spring 2010, with the bridge scheduled to open in October, 2010.

*Owner:* Massachusetts Highway Department

*Designer:* Purcell Associates / **International Bridge Technologies, Inc.**

*Contractor:* R. Zoppo Corporation

*Construction Engineer:* **FINLEY Engineering Group, Inc.**

*Construction Engineering Inspection:* Massachusetts Highway Department

*Formwork for Precast Segments:* EFCO

*Post-Tensioning Materials:* **VSL**



Figure 3 - Cross-section. (Illustration courtesy of International Bridge Technologies, Inc.).



Figure 4 - Proposed Channel Bridge. (Illustration courtesy of International Bridge Technologies, Inc.).



Figure 5 - Existing Bridge. (Illustration courtesy of International Bridge Technologies, Inc.).

Figure 6 -  
(Photo top)  
July 2009 -  
Variable depth  
cantilevers  
extend out 192'  
to form a gentle  
arch over the  
rail yard while  
maintaining  
appropriate  
clearances for  
construction.  
(Photo courtesy  
of FIGG).



#### **Fourth Street Bridge, Pueblo, Colorado**

The Colorado Department of Transportation's new Fourth Street Bridge in Pueblo, Colorado is taking shape. Construction of the twin 1,137' long concrete bridges began on October 17, 2007 and is proceeding on schedule. Three of the four end spans and the majority of substructure work have been completed. In addition, the first cantilever was completed in June 2009. Cantilevers now extend over the 28 sets of active heavy rail tracks in the Pueblo Rail Yard, as well as the Arkansas River.

Concrete segmental balanced cantilever construction (Figs. 6 and 7) allows railroad operations and recreational use of the river to continue below. Slender piers create a minimal footprint and feature aesthetic features selected by the community. The new bridge will also include two lanes of traffic in each direction, with wide safety shoulders and a multi-use path, to provide a high-quality and sustainable solution for the community.



Figure 7 -  
(Photo inset)  
July 2009 -  
Concrete  
segmental  
box girders  
cantilever  
over active  
rail tracks in  
the Pueblo  
Rail Yard.  
Once closure  
is made, this  
378' span will  
be Colorado's  
longest highway  
span. (Photo  
courtesy of  
FIGG).

*Owner:* Colorado Department of Transportation  
*Designer:* **FIGG**  
*Contractor:* **Flatiron Intermountain Constructors**  
*Construction Engineer:* **FINLEY Engineering Group, Inc.**  
*Construction Engineering Inspection:* **FIGG**  
*Pier Formwork:* **EFCO and DOKA**  
*Form Travelers for Cast-in-Place Segments:* **VSL**  
*Post-Tensioning Materials/Stay Cables:* **VSL**  
*Bearings and Expansion Joints:* **Joints – Watson Bowman Acme - A BASF Company; Bearings – The D.S. Brown Company**  
*Prepackaged Grout:* **Sika Corporation**

**Pearl Harbor Memorial Bridge, Connecticut**

On July 31, 2009, the joint venture of Walsh Construction Company and **PCL Civil Constructors, Inc.** was awarded a \$417 million contract to build the new Pearl Harbor Memorial Bridge (**Figs. 8 and 9**) on Interstate 95 in New Haven, Connecticut. The existing six-lane steel plate girder bridge, known locally as the ‘Q-Bridge’ because it spans the Quinnipiac River, is being replaced by a 10-lane, 1,013' extradosed structure.

Walsh/PCL submitted the low bid, electing to construct the cast-in-place segmental box alternate. The finished structure will have six 144' tall towers and three planes of stay cables. In addition to the main span structure, the scope of work includes over 3,500' of approach structure, as well as demolition of the existing bridge. Construction is expected to begin in December 2009 and will be complete by the summer of 2015.

*Owner:* Connecticut  
Department of Transportation  
*Designer:* **URS Corporation**  
*Contractor:* Walsh-PCL Joint  
Venture  
*Construction Engineer:*  
Buckland & Taylor  
*Construction Engineering*  
*Inspection:* H.W. Lochner / FIGG



**ASBI 7**



*Figures 8 and 9 -  
The Pearl Harbor Memorial Bridge shown in these  
renderings will be a 10-lane, 1,013' extradosed structure.  
Construction is expected to begin in December 2009.  
(Illustrations courtesy of URS Corporation).*

Figure 10 -  
(Photo top)  
February 2009 -  
Long, open  
variable depth  
spans are built  
using concrete  
segmental  
balanced  
cantilever  
construction  
to maintain  
mobility and  
preserve the  
environment.  
(Photo courtesy  
of FIGG).

Figure 11 -  
(Photo inset)  
July 2009 -  
Concrete  
segmental  
cantilever  
construction  
proceeds out  
from the piers,  
nearly 100'  
above the  
Allegheny River.  
A stone texture  
on the piers  
will be stained  
to complement  
the surrounding  
landscape.  
(Photo courtesy  
of FIGG).



**I-76 Allegheny River Bridge,  
Oakmont, Pennsylvania**

As the next major golf tournament at Oakmont Country Club draws near, the new Allegheny River Bridge (Figs. 10 and 11) for the Pennsylvania Turnpike Commission continues to make great progress. Construction of the twin 2,350' structures by Walsh Construction



began in May 2007 with the goal of a safer, more pleasing experience for Turnpike customers. The 532' main span will be Pennsylvania's longest concrete segmental span. This environmentally sensitive bridge is being built using concrete segmental balanced cantilever construction to keep rail, vehicular, and marine traffic operational. The long open spans also minimize impacts to river habitats and archaeological areas below the bridge.

*Owner:* Pennsylvania Turnpike Commission  
*Designer:* FIGG  
*Contractor:* Walsh Construction  
*Construction Engineer:* T.Y. Lin International  
*Construction Engineering Inspection:* McTish with FIGG  
*Form Travelers for Cast-in-Place Segments:* NRS  
*Post-Tensioning Materials/Stay Cables:* Schwager Davis, Inc.  
*Epoxy Supplier and Prepackaged Grout:* Sika Corporation



**The Benyamina Bridges, Israel**

The Benyamina Bridges (Figs. 12 and 13) are two 417-meter, 8-span, precast segmental box girder bridge structures spanning over a railway near Benyamina, Israel. Each of the Benyamina bridges — one westbound and the other eastbound — will carry three lanes of traffic. The six lanes will comprise more than 9,500 square meters of bridge deck. Individual span lengths range from 39 meters to 66 meters.

The design tender for the bridges called for a precast segmental concept erected in balanced cantilever with a launching gantry. Danya Cebus successfully bid an alternative method based on their recent experience working with **FINLEY Engineering Group, Inc.** (FINLEY) on the Section 18 and Road 431 bridges in that country.

Each bridge will be constructed using the balanced cantilever method with existing Danya Cebus equipment, and forms including ground-based cranes and falsework support systems. FINLEY offered an innovative design detail of pre-tied, weld wire cages for segment reinforcement.

These bridges mark the third use of external tendons on a bridge project in Israel. FINLEY introduced this post-tensioning method with Danya Cebus to Israel on four Road 431 bridges in 2007. As with the Road 431 project, FINLEY and Danya Cebus proposed the use of external tendons to allow for simplified precasting of the segments, reduction in segment cross-sectional area and foundation loads, fewer tendon stressing operations and a reduced design schedule.

The project was not without challenges specifically rigorous requirements for working over and around the railroad, an aggressive timeline and strict safety requirements. The scheme, equipment and experienced personnel were able to overcome the challenges in a manner that gave the Owner a great deal of confidence. The Team was able to illustrate the efficiency and innovation it brought to the country on the Section 18 and Road 431 projects, then offer refinement of those techniques on the Benyamina Bridges from its experience with the 12 previous precast segmental bridges in Israel.

The Benyamina Bridges are scheduled for completion late 2009.

*Owner:* Public Works Department  
*Designer:* **FINLEY Engineering Group, Inc.**  
*Contractor:* Cebus Rimon Industrialized Construction, Ltd.  
*Construction Engineer:* **FINLEY Engineering Group, Inc.**

*Figure 12 - (top) Cantilever Segment Erection. (Photo courtesy of Danya Cebus).*

*Figure 13 - (bottom) Completed cantilevers. (Photo courtesy of Danya Cebus).*





Figure 14 - Rendering of New Indian River Inlet Bridge looking towards the Northeast. One of the primary objectives behind the design of the new structure was driven by the community. The existing structure provides spectacular views of the Atlantic Ocean while crossing it. The community did not want the new structure to obstruct this view in any way and so the new bridge is designed to allow open views to the ocean. It's slender and open form does not overpower the pristine nature of the surrounding landscape. (Illustration courtesy of AECOM).



Figure 15 - The current construction progress as of the end of August 2009 includes 80% of the 36" square prestressed concrete pile foundations have been driven to 1800 ton capacity; pylon footing and tower construction has begun (photo of Northeast Pylon footing); and installation of temporary falsework used for the cable stay superstructure erection over land has begun. (Photo courtesy of AECOM).

**SR1 Bridge over Indian River Inlet, Delaware**

The design-build team of Skanska USA Civil Southeast and AECOM USA are currently designing and constructing the new SR1 Bridge (Figs. 14 and 15) over the Indian River Inlet for the Delaware Department of Transportation. The design-build

team started in September 2008 and the new 2,600' long cable-stayed bridge will be opened to traffic by April of 2011. The cable-stayed main span unit is comprised of 3 spans: 400'-950'-400'. Approach spans are prestressed concrete Bulb-T girders. The new bridge will carry four lanes of traffic with

shoulders and a pedestrian sidewalk on the Atlantic Ocean side of the bridge.

Overall design of the bridge is about 75% complete. The wind tunnel testing, coastal hydraulics, scour, and geotechnical analyses are all complete. Foundation static load testing is also complete for the 1,800 ton capacity 36" square prestressed concrete pile foundations. Installation of all production piles and the four (4) pylon footings will be completed by the end of September 2009. Cable-stay erection will begin in March of 2010. Skanska is building the bridge from both sides of the inlet simultaneously.

Several innovative design-build features have led to both an economical and aesthetic structure:

- The cable-stayed superstructure consists of cast-in-place (cip) concrete edge girders with both precast and cip transverse floor beams. The portion of the cable-stayed structure over land will be constructed using falsework and includes the precast floor beams. The portion of structure over the inlet will be constructed using a form traveler and cip concrete. Floor beam spacing was limited to 24' on centers

*Owner:* Delaware Department of Transportation

*Design-Build Team:* Skanska USA Civil Southeast (Design Builder)

**AECOM USA** (Lead Design)

AECOM Asia (Erection Engineering)

**International Bridge Technologies** (Bridge Design)

RWDI (Wind Tunnel Testing)

S&ME (Geotechnical)

**Parsons Brinckerhoff, Inc.** (Independent Design Review & CEI)

**FINLEY Engineering Group, Inc.** (Construction Engineering)

**Freyssinet, LLC** (Cable-Stay Supplier)

to reduce the deck thickness to 8½". Minimizing the deck thickness in turn significantly reduced the dead load forces, which in turn reduced the size of the stays, demand on the pylons, and size of foundations.

- The edge girders and semi-harped cable-stays remain in a vertical plane and the edge girders deviate around the pylons using a compression and tension strut system. This system helps minimize the out-to-out footprint of the structure.
- Maintaining a vertical plane of cable-stays and optimizing the pylon cross section so that the downward stay force acts along the center of gravity of the pylon cross section allowed the use of single mast pylons with no cross struts above or below the deck. The single mast pylons without heavy cross struts significantly improve the aesthetic value of the bridge as well as improving the overall constructability and maintainability.

The design theme was simple for this structure: *Maintain unobtrusive views of the Atlantic Ocean and don't overpower the quiet beach community with a massive structure.* The design-build team has created a simple and slender structure that is being embraced by the community. An open wave-shaped pedestrian railing; semi-harped stay arrangement replicating sails; blue cable stay sheathing; and subtle blue lighting at night will keep the bridge from interfering with the natural beauty of the surrounding areas.

## Seismic Joint Testing Program Completion

by Paul A. Bradford, P.E., PhD, Development Engineer,  
Watson Bowman Acme – BASF



Seismic Joint Testing In January of 2009 Watson Bowman Acme completed an 11 year program of seismic joint testing (Figs. 16 and 17) at the University of California at Berkeley, Richmond Fieldhouse Station. The project included three phases: proof of concept, value engineering, and performance limits. The joint tested, the *XCel multi-movement modular expansion joint*, is designed to respond elastically in all six degrees of freedom at high velocities. Its primary use is on long span structures where it is critical to

accommodate vehicular traffic immediately after an extreme event. It has been implemented in other applications where its multi-movement capabilities are needed for everyday service, e.g. structures with severe skew.

The proof of concept stage, started in 1998, included identifying a system that would remain undamaged during an earthquake. Initial testing showed that standard systems modified with additional movement capacities incurred significant damage, rendering the joint inoperable. Gaps were so large that traffic would not have been able to pass over the joint. The joint was retrofitted with a special equidistance mechanism, along with bearings capable of high speed multi-rotational movement, and after several design iterations the joint worked well.

The value engineering phase included simplification and standardization of the system, with emphasis placed on using

Figure 16 - Fabrication manager Kurt Schoenbals and the XCel at the UC Berkeley test lab.



Figure 17 - Elevation view underneath showing the yoked connection to the support bar.

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standard materials and near standard components. An outgrowth of this phase was the XR bearing, a wear resistant polyurethane bearing that has since been used to retrofit problematic installations with bearing rotation/wear issues.

The final phase of testing included pushing the joint to the maximum capacity of the test equipment, exceeding parameters of all expansion joints tested to date. In all, hundreds of tests were run and thousands of man-hours were spent during the joint's evolution to produce the XCel design.

Much was learned during the course of the project, including;

- Joints respond much differently at high speeds than at slow speeds.
- Friction forces are predictable, and friction components can be implemented such that the expansion joint can act as force limiter to the adjoining structure segments.
- Testing components is necessary but not sufficient to establish system viability.
- Test failure modes sometimes came from unexpected sources.
- Consideration should be given to real world conditions, i.e. less than ideal sliding surfaces, installation misalignments, etc.
- Fabrication tolerances, alignments, and quality control measures are more important for high speed applications than for slow speed applications.

- Spring based equidistance systems used alongside sliding friction components do not perform well due to their slow response time.
- PTFE bearings, when designed correctly, are exceptionally durable. Metal on metal surfaces tended to bind and "screech" at high speeds.
- If it is critical that the joint perform correctly on a project with a high level of reliability, a section of the project joint should be tested. This is because at high speeds small variations in fabrication processes, materials, etc. can sometimes lead to large changes in system performance.

The test program showed that it is possible to modify standard modular joints to accommodate large displacements at high speeds. Peak velocities approached 50 inches per second, reaching the limits of the hydraulic pump system. Peak total displacements were 34 and 20 inches in the longitudinal and transverse directions respectively. Test excitations included harmonic motions at various displacements and frequencies, as well as seismic simulations of real time earthquakes.

Segmental bridges tend to be longer span structures, often assigned an Importance Category of "Critical". They are typically designed for extreme events such that the structure responds with minimal damage, and must allow traffic to pass. The XCel provides a means to accomplish this design objective at the expansion joint locations.