RESEARCH news
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ABC - achieving the need for *speed*

Accelerated bridge construction in Iowa heightens safety, and reduces traffic disruptions

By Ahmad Abu-Hawash, P.E., James Nelson, P.E., and Dean Bierwagen, P.E.

Engineers from the Iowa Department of Transportation (DOT)—aided by researchers from Iowa State University (ISU)—have developed a time-saving, safer way of building stronger bridges. The entire nation will benefit from accelerated bridge construction (ABC) research and new bridge design methodologies because ABC reduces construction time, minimizes traffic disruption, improves safety, reduces environmental impacts, enhances constructability, and improves quality and lifecycle costs.

One task currently underway to assist with ABC includes the Federal Highway Administration's (FHWA) development of standardized, prefabricated bridge elements and systems (PBES). Once these standards are in place, bridge components can be constructed before the first work zone cones are set. New bridges can be installed in hours instead of taking months to build because of time-consuming, labor-intensive cast-in-place element construction. Standardization of precast elements, including abutments, piers, girders, and decks, makes it possible to fabricate an entire bridge off-site, resulting in much less traffic disruption. With the roadway closed only for demolition and a swift assembly of the pieces on-site, bridges can be built efficiently over the course of a weekend (Figure 1).

Safety, convenience and time savings are major benefits of ABC. Accomplishing demolition while construction is being done off-site saves time—then quickly installing the new bridge elements after the site has been prepared increases safety (Figure 2). By fabricating bridge elements

Figure 1 - *Placing full-depth, precast deck panels at the Boone County project site*

Figure 2 - *Precast bridge elements mean easier and faster installation in the field, eliminating the need for prolonged closures and time spent in construction areas for workers*

off-site, manufacturers have better control over materials, and environment and fabrication processes. This results in better building materials and stronger, more durable bridges.

For some ABC projects there can be significant cost savings by eliminating the need to erect temporary bridges while permanent structures are being built. Another cost-saving element centers on the motorist, who experiences little disruption with an ABC project. However, budgeted costs may be up to 20 percent higher for an ABC project. Unfortunately, while safety, convenience and time savings are very real for bridge owners, builders, and motorists, they cannot be reflected in the project's budget.

Vasant Mistry, FHWA

According to Vasant Mistry, bridge and tunnel team leader in the FHWA's Office of Bridge Technology, the need to move quickly and efficiently for renovation or replacement of bridges, while keeping costs as low as possible, is paramount for the future of our nation's infrastructure. "ABC can help keep costs low, and reduce traffic and environmental impacts while bridges are being replaced or repaired," Mistry said. "The way we replace bridges is becoming more

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and more important in today's traffic environment, because the impacts of bridge building on the motoring public and the environment are tremendous with longer duration of construction time."

To address this tremendous need to update bridges, the Iowa DOT is working with the FHWA's Highways for LIFE (HfL) program with the goal of making it easier and quicker for bridge owners to adopt new, innovative technologies. This will help to improve safety and quality while reducing traffic congestion caused during construction.

Sharing the vision – the 2008 ABC workshop

Recently, Iowa DOT and FHWA collaboration brought more than 100 transportation professionals to Des Moines for an ABC conference. Held in August 2008, the conference made information from recent advances in ABC—and the results from three of Iowa's past ABC projects—available to attendees, including personnel from various state departments of transportation as well as industry and academic professionals. The workshop also explored the potential of future Iowa ABC projects and examined current ABC details being implemented in Iowa.

During three of the four breakout sessions, Iowa DOT engineers targeted three specific upcoming bridge projects for discussion. Each bridge presented a very different design situation and need (replacement of an urban viaduct in Council Bluffs, replacement of a historic bridge in Iowa Falls and rehabilitation of a congested interstate bridge in Des Moines). Participants were able to identify various techniques needed to accomplish a distinctive goal at each site. Accelerated construction methods, prefabricated components and innovative contracting methods are a few examples of ABC solutions that were identified by participants. Ideas collected during this workshop are under evaluation by Iowa DOT personnel for possible incorporation into the final designs.

Another workshop session focused on examining standard ABC details currently used in Iowa and identified potential improvements (Figure 3). The topic of connection details for prefabricated pieces was of special interest. "Connectivity is key to the success of ABC," said Michael Culmo, an engineer with CME Associates from East Hartford, Conn., who presented information on the development of standards for connection of prefabricated bridge elements and systems. "The push to build it and get it out there can work well, as long as the quality details, durability of the elements, design methodologies, training opportunities, and construction methodologies are all in place."

Figure 3 - *Michael Culmo, CME Associates, presents a workshop session at the ABC conference held in August 2008*

Iowa's ABC Projects

The workshop also included presentations by state representatives from Iowa, California, Texas, Utah, and Washington on their local ABC projects and successes. These presentations are available online at: www.iowadot.gov/bridge/abc.htm.

Past, present and future

Iowa's ABC projects to date include replacement of the historic Mackey Bridge in Boone County, 24th Street bridge over I-80/29 in Council Bluffs and a timber bridge in Madison County—all part of the FHWA's Innovative Bridge Research and Construction (IBRC) program.

Boone County project

Figure 4 - *Completed Boone PPC beam bridge*

At the Boone County project site, the existing Marsh Rainbow Arch Bridge (the Mackey Bridge) over Squaw Creek was replaced by a pretensioned, prestressed concrete (PPC) beam bridge (Figure 4). The replacement structure is a continuous, 151- by 33-foot, three-span bridge with a four-girder cross section. The prestressed concrete girders support a full-depth, precast concrete deck.

Figure 5 - *PPC deck panels at the Boone County project site*

2007 Precast/Prestressed Concrete Institute (PCI) Design Awards

Best Owner-Designed Bridge

Mackey Bridge, Boone County, Iowa

Engineer: James Nelson and Stuart Nielsen, Iowa DOT

Owner: Boone County

General Contractor: Peterson Contractors Inc., Reinbeck, Iowa

Precaster: Andrews Prestress Concrete Inc., Clear Lake, Iowa

Norman McDonald, Iowa DOT's Office of Bridges and Structures (right), accepts the award for the Best Owner-Designed Bridge at the October 2007 PCI Bridge Conference in Phoenix, Ariz., from M. Myint Lwin, bridge and tunnel team leader in the FHWA's Office of Bridge Technology (left) and Bridge Awards Selection Committee Judge Jugesh Kapur, state bridge and structures engineer, Washington State Department of Transportation (center).

The Boone County PPC bridge was an Innovative Bridge Research and Construction program project and incorporates precast abutments, pier caps, beams, and full-depth deck panels. This is the first time the Iowa DOT has used the precast abutment and pier cap in Iowa. It is the second time this type of deck panel has been used in the United States. Iowa DOT officials used this research to determine the feasibility of using precast-concrete bridge components to accelerate construction for future projects in the state.

Iowa Quality Initiative Structures Award

Merit Award Winner for Concrete Beam Bridge on Local Road System: Mackey Bridge, Boone County, Iowa

Engineer: James Nelson and Stuart Nielsen, Iowa DOT

Owner: Boone County, Iowa

General Contractor: Peterson Contractors Inc., Reinbeck, Iowa

Precaster: Andrews Prestress Concrete Inc., Clear Lake, Iowa

Accepting their Merit Award for concrete beam bridge on Local Road System at the Iowa Quality Initiative Structures Award Ceremony March 2007 are (pictured from left to right): James Nelson, designer, Iowa DOT; Justin Clausen, project manager, Peterson Contractors Inc.; Joel Taylor, foreman, Peterson Contractors Inc.; Scott Kruse inspector, Boone County; John Benjamin, foreman, Peterson Contractors Inc.. Not pictured: Stuart Nielsen, designer, Iowa DOT

The deck panels, 16-feet wide by 8-feet long by 8-inch thick (Figure 5), span half the width of the bridge and were joined at the center by a longitudinal cast-in-place construction joint. Each panel was pretensioned in the transverse direction and had two full-depth channels located over the prestressed girders for longitudinal post-tensioning. Once the panels were erected, the entire bridge deck was post-tensioned in the longitudinal direction. Then concrete was cast in the four post-tensioning channels and in the longitudinal joint at the center of the bridge. Although this exact design had not previously been constructed, a similar full-depth deck system on steel girders had been constructed and tested in Nebraska.

The substructure for the Boone County project included precast abutment footings (Figure 6) and precast pier caps supported on H-piling and pipe piling, respectively. The units were reinforced with mild reinforcing and included blockouts for the piling that were created using corrugated metal pipe (CMP). The fairly conservative connection design was later validated by testing. A high, early strength concrete mix was used for filling the substructure blockouts. This bridge construction demonstrated the feasibility of precast substructure, full-depth deck panels, and various connection details for both substructure and superstructure precast components.

The Boone County bridge is an IBRC program project and incorporates precast abutments, pier caps, beams, and full-depth deck panels. This is the first time the Iowa DOT has used the precast abutment and pier cap. It is the second time this type of deck panel has been used in the United States. Iowa DOT officials used this replacement bridge to determine the feasibility of using precast concrete bridge components to accelerate construction for future projects in the state.

Figure 6 - *Placement of precast abutment footing was accomplished in less than 15 minutes at the Boone County site.*

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Council Bluffs 24th Street project

The 24th Street project provided an opportunity to modify the previously used deck system on the Boone County project and implement it on a high-profile project, allowing further evolution of ABC concepts. In Council Bluffs, the project concept called for reconstruction of the 24th Street interchange over I-80/29 by replacing the existing structure with a two-span, steel bridge using staged construction to maintain one lane of traffic in each direction, plus a turning lane. The 24th Street interchange is an important transportation link in Council Bluffs serving a truck stop, casino, the Mid-America Center, and considerable commercial and retail properties. Primary project goals were to construct this bridge quickly while maintaining traffic flow and building it to last under heavy traffic use.

The new bridge at 24th Street (Figure 7) is a two-span, 353-foot continuous steel girder bridge with composite precast deck panels (Figure 8). The bridge has an overall width of 105-feet, 8-inches, including sidewalks and a shared use lane. The bridge deck is comprised of 52-feet 4-inches wide by 10-feet long by 8-inches thick precast concrete deck panels joined together with a 1-foot wide cast-in-place longitudinal joint. The deck panels are pretensioned transversely and post-tensioned longitudinally after placement. The deck panels (Figure 9) were compositely bonded to the girders by shear studs and grouted stud pockets.

Figure 7 - *Rendering of completed 24th Street project (HDR Inc.)*

Figure 8 - *Preparation of precast deck panels for placement on the 24th Street bridge (HDR Inc.)*

Figure 9 - *Deck panel placement at 24th Street project site*

The project was let using A+B bidding, a method of rewarding a contractor for completing a project as quickly as possible. By providing a cost for each working day, the contract combines the cost to perform the work ("A" component) with the cost of the impact to the public ("B" component) to provide the lowest cost to the public. The winning bid on the project bid was 175 calendar days, 35 days less than the maximum allowable bid of 210 calendar days. Intelligent transportation systems were used to manage traffic delays during construction and ease post-construction congestion. Using ABC techniques allowed this bridge to be constructed in a single construction season (typically a two season project) while staging minimized traffic disruptions.

On Sept. 25, 2008, the Iowa DOT hosted a HfL project showcase. The showcase was to facilitate technology transfer and present project innovations used on the 24th Street bridge project.

TRB 88th Annual Meeting Papers Available

In January 2009, the 88th meeting of the Transportation Research Board (TRB) in Washington, D.C. was held with more than 10,000 in attendance. Approximately 1,800 papers were presented over the five day conference. The papers are now available on DVD at the Iowa DOT library and from the Research and Technology Bureau. Sixty of the paper presentations are available as e-sessions directly from the TRB website. E-sessions have recorded audio to accompany the PowerPoint slide presentation. You can access these e-sessions at **www.trb.org/conferences/e-session/default.asp**. For more information contact Ed Engle at edward.engle@dot.iowa.gov.

The 88th Annual TRB Meeting Compendium of Papers, published by The National Academies, is also available for purchase online at: **www.trb.org/news/blurb_detail.asp?id=9904**. All Iowa DOT employees can visit W:\CDCache\TRB\TRB2009\isv7\default2.htm to view the collection. Click the **blue** link to open the DVD index.

Remember to make plans to attend the TRB 89th Annual Meeting January 10-14, 2010!

Best Paper 2008 FHWA Accelerated Bridge Construction

Highways for LIFE Conference

The paper titled “Accelerated Construction and Innovations: The 24th Street Bridge” was awarded Best Paper at the 2008 FHWA Accelerated Bridge Construction: Highways for Life Conference held March 20-21, 2008, in Baltimore, MD. Authors of the paper are Ahmad Abu-Hawash, Iowa DOT; Hussein Khalil, HDR Inc.; Norman McDonald, Iowa DOT; Brent Phares, ISU’s Center for Transportation Research and Education; and Patricia Schwarz, Iowa DOT.

The showcase was organized by the FHWA and Utah Local Technical Assistance Program (LTAP). Attendees of the project showcase included professionals from academia, city agencies, consultants, FHWA, and state DOTs. The showcase included project presentations, a site visit while the bridge was under construction, and a question and answer session with the contractor, bridge designer and owner.

One of the challenges of planning a project showcase in advance that includes a site visit is the fact that ABC bridge projects move fast. The showcase planning team had to use the contractor’s critical-path method schedule to pick a date for hosting the event because the team wanted attendees to be able to see key steps in the precast, full-depth deck panel installation. A date was picked when the contractor would be setting deck panels, but the contractor was ahead of schedule by the showcase date. Attendees were able to see the bridge construction at the point just after the precast deck panel shear stud pockets had been filled with concrete (to make them composite with the steel girders). The site visit was still well received. According to Joe Jurasic, FHWA’s HfL contact, “The showcases are being utilized as a public relations program to demonstrate how innovative construction techniques have been used by DOTs. We’re highlighting what we’ve done in Iowa so other states can use it [innovative techniques]. The HfL program is advancement of proven innovation into routine practice.”

Madison County project

While the replacement bridge is far less romantic than the covered bridges immortalized in literature and film, safety and fast, efficient replacement was the goal for this Madison County bridge. The previous bridge, which carried a county road over a small stream, was a 21-foot single-span structure with a roadway width of 18 feet. Constructed in 1940, the bridge was built on timber piles and had a timber back wall. The superstructure consisted of timber girders and railings, with a timber deck overlaid with gravel.

The replacement precast structure (Figure 10) is a longitudinally pretensioned, two-lane, single-span, box-girder bridge that spans 46-feet 8-inches center-to-center of supports and has an out-to-out deck width of 24-feet 1-inch.

Figure 10 - *Completed Madison County bridge*

Figure 11 - *Placement of box girders at the Madison County site*

The bridge consists of six 2- by 4-foot box girders placed side by side (Figure 11) with a hand-tightened transverse tie located at the midspan. The supporting substructure consists of five HP10x42 piles at each abutment and a precast abutment footing. The precast abutment footing is 27-feet 4-inches long, 3-feet wide and varies in depth from 3-feet 6-inches at the ends to 3-feet 9-inches in the middle. The precast abutment footings have five corrugated metal pipe blockouts placed vertically at the pile locations for connection to the piles.

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The bump at the end of the bridge

The Iowa DOT recognizes that approach slab pavements of integral abutment bridges are prone to settlement and cracking, which manifests itself as a "bump at the end of the bridge." The bump is not only a safety problem, it is also an expensive maintenance issue.

To address the problem an accelerated repair solution was developed and successfully demonstrated on projects across the state. This innovative solution consists of precast concrete components that can be erected overnight with minimum traffic interference. The Iowa DOT sought to prove that using the precast panels can reduce a traditional three-week bridge closure to a short-term, possibly even weekend, construction project. This concept of precast approaches has been successfully demonstrated on three projects so far. Deteriorated paving notches were replaced with precast units in Marion County, and precast approach panels were used on a new bridge project in O'Brien County, as well as on existing bridges in Bremer County.

O'Brien County project

Figure 12 - *Iowa 60 award-winning precast, post-tensioned approach slab in O'Brien County*

A new integral abutment bridge on Iowa 60 in O'Brien County near Sheldon was chosen as a test bridge for the installation of precast, post-tensioned concrete approaches—the first known application in the United States. The structure is a three-span, continuous prestressed, concrete-girder bridge, 303- by 40-feet, with a right-ahead, 30° skew angle (Figure 12).

To simplify the precast panels, trapezoidal-shaped transition panels were used at the bridge abutment, effectively removing the skewed joints for the rest of the approach slab. This minimized the number of specialty panels and permitted use of standard 14- by 20-foot panels for the majority of the approach. Additionally, because the approach slab had a crowned cross section, separate precast panels were placed on either side of the roadway centerline. This not only simplified panel fabrication, but also simulated lane-by-lane construction (Figure 13) that will likely be necessary for future approach slab replacement projects where staged replacement is generally required.

Based on the precast panel layout and panel dimensions, a transversely pretensioned, longitudinal post-tensioned approach slab was not practical. Instead, two-way post-tensioning was used to tie all of the precast panels together and provide the necessary structural prestressing for the connections.

Figure 13 - *Precast approach slab being placed at the O'Brien County project site*

Marion County project

As previously noted, bridge approach pavement settlement and the resulting formation of bumps at the end of bridges is a recurring problem. One of the contributing factors in this settlement is failure of the bridge paving notch. A paving notch (also known as a corbel or paving support) consists of a horizontal shelf constructed on the back face of a bridge abutment and is used to support the adjacent roadway pavement. Over time, these paving notches have been observed to deteriorate/fail due to a number of conditions, including horizontal abutment movement due to seasonal temperature changes or loss of backfill materials by erosion. In most cases, the condition of the paving notch deterioration is not known until the deterioration reaches a critical state and the approach pavement is removed.

Bridge owners are frequently faced with the need to replace critical bridge components during strictly limited or overnight road closure periods. The conventional replacement method requires the bridge be taken out of service for an extended period of time, which disrupts the traveling public. The notable number of bridges that exhibit the failing paving notch problem and, more importantly, their location on highly traveled roadways, necessitate the development of a standardized replacement method for quick installation. With use of a standardized system, situations where deterioration is unknown (before approach pavement removal) can be addressed quickly with minimal traffic disruptions.

The objective of the Marion County project was to develop a new paving notch system that could be installed with a single overnight bridge closure, and verify and investigate the structural capacity and feasibility of the system. Researchers at ISU performed full-scale laboratory testing of the paving notch replacement system and verified that the system could be used successfully.

2007 Precast/Prestressed Concrete Institute (PCI) Design Awards

Best Custom Solution Iowa 60: Precast Bridge Approach Slabs

Engineer: Iowa DOT

Owner: Iowa DOT

General Contractor: Dixon Construction Co., Correctionville, Iowa

Precaster: IPC Inc., Iowa Falls, Iowa

Specialty Pavement Engineer: The Transtec Group, Austin, Texas

PCI 2007 Best Custom Solution Award for the Iowa 60 precast bridge approach slabs demonstration project

The Iowa DOT worked with FHWA to consider different types of precast projects before deciding on the bridge approach slab project. There have been multiple pavement demonstration projects around the country, but this was the first bridge-related project.

The precast paving notch system was intended for use in either new construction or as rapid replacement for installation in single-lane widths to allow for staged construction under traffic with a single overnight bridge closure. The system consists of a rectangular block, 16- by 16-inches precast, prestressed concrete element that is connected to the back face of the abutment using high-strength, threaded stainless steel rods and an epoxy adhesive similar to that used in segmental bridge construction (Figure 14).

Figure 14 - *Precast paving notch system during placement at Marion County bridge site*

Bremer County project

The concept of using precast concrete panels on bridge approaches was successfully demonstrated on the O'Brien County project. As a result, the Iowa DOT collected enough data to ensure it was feasible to apply this ABC solution under strict time parameters; and a bridge approach slab replacement project in Bremer County was identified. The approaches of the dual bridges on U.S. 63 over Bremer County Road C-50 at Denver were replaced with a system of 24- by 12-foot precast concrete panels (one panel in each lane), plus complementary precast shoulder panels on the median and outside shoulders.

On the Bremer County project, the contractor was required to complete each stage (one traffic lane and adjacent shoulder) during a 12-hour lane closure period. The contractor had ample time to remove the existing approach pavement, place special base material and the panels (Figures 15).

Figure 15 - *Bridge approach replacement operations under restricted traffic at the Bremer County bridge site*

The future of ABC in Iowa

Iowa DOT has future projects in sight and is currently working with the Buena Vista County engineer in planning construction of a single-span, 50- by 28-foot precast, pretensioned concrete box-girder bridge on a local road. This bridge will incorporate prefabricated components for both the substructure (precast abutment footings), and superstructure (precast box girders), and is currently under design (Figure 16). The goal is to build this county bridge using precast components during the summer of 2009 in two weeks or less.

Figure 16 - *Rendering of the upcoming Buena Vista bridge project (Stuart Nielsen, Iowa DOT)*

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As more projects are completed and standard ABC details developed, Iowa will continue leading the way in improved production methods, safety initiatives and cost reductions, with the goal of contributing to a better infrastructure and more sustainable transportation system for our country.

The Iowa DOT has had discussions regarding the use of precast concrete panels to replace deteriorated bridge approach paving on heavily travelled roads such as Interstate 80 in Des Moines where extended lane closures cause extensive travel issues; and as demonstrated through past projects, there is confidence that such work can be accomplished in a single-lane overnight closure. Iowa will continue the investigation of using ABC techniques on various projects across the state. In addition to critical projects on the Primary Road System, the Iowa DOT is also working with local county engineers to advance and standardize implementation of ABC on the Secondary Road System.

The Iowa Highway Research Board (IHRB) has assisted the counties in obtaining federal grants, plan development and construction monitoring support, and has also provided funding and support for laboratory and field testing, as well as performance evaluation for several projects. The IHRB anticipates future project developments and continues to be an integral part of implementation of ABC in Iowa.

IHRB IOWA HIGHWAY RESEARCH BOARD

For more information on developments, implementation, and approved technologies in research and technology in Iowa that can positively impact your construction projects, visit the Iowa DOT's Research and Technology Bureau Web site at **www.iowadot.gov/research/index.htm**.

About the authors

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VIDEO RELEASE!

The Iowa Department of Transportation's Research and Technology Bureau's new video, ***Transportation Research Projects at Work – Making a Difference***, is now online at www.iowadot.gov/research/index.htm. The video is approximately six minutes in length, and highlights four innovative research projects.

Topics

- Precast bridge approach pavement
- Urban teen driver study
- Winter maintenance snow plow blade research
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