ACCELERATED BRIDGE CONSTRUCTION TECHNOLOGY

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Abstract
Transportation is an important and integral part of the American's overall economy. The United States of America is a highly mobile society and many businesses are relying on "just-in-time" deliveries. Existing highway capacity on the network is being temporarily reduced during reconstruction while it is being continuously challenged due to increasing traffic demands. The average age of our bridges is about 45 years and one-third of our bridges are in need of repairs or replacement. During peak travel seasons as much as 20 percent of the national highway systems are under reconstruction, which further reduce traffic capacity and aggravate congestion. Congestion affects our mobility, safety and economy. The Federal Highway Administration (FHWA) has been developing and promoting accelerated bridge construction since 2001. This paper presents the various prefabricated bridge systems for accelerating construction found to be effective from all over the world and in the U.S.A. FHWA published a decision-making framework to help bridge owners and designers decide when accelerated bridge construction could be most effective.

INTRODUCTION

Transportation is an important and integral part of the nation's overall healthy economy. While enjoying economic growth and prosperity, we are faced with a great challenge: increasing travels demand and preserving an aging and extensive infrastructure. With 600,000 bridges in the national bridge inventory, the average age of our bridges is about 45 years and one-third of our bridges are due for repairs or replacement. Existing highway capacities on the network are overflowed with increasing high traffic volumes and longer rush hour periods. In a recent study, as much as 6,400 work zones or 20 percent of the National Highway System were under reconstruction during peak travel seasons, which further reduced highway capacities and increased congestion. Being a highly mobile society and having many businesses providing and relying on "just-in-time" delivery of goods and services, there is a great challenge for transportation officials to deliver projects on accelerated schedules.

Congestion affects our productivity and mobility and it increases the costs of doing business. The Texas Transportation Institute's *2003 Urban Mobility Report* estimated that the cost of congestion in 75 of the Nation's large urban areas in 2001 was $69.5 billion. Corresponding to the dollar losses were 3.5 billion hours of delay and 5.7 billion gallons of excess fuel consumed [1]. That amount today might be much higher today due to the recent escalated fuel cost. The benefits of accelerating bridge construction to restore a facility for traffic use with minimum disruption are well documented and some sample projects are being further discussed here below.

Conventional practice in bridge construction is typically on the critical path because of the inherent sequential order and extended period required for completing the foundation, the substructure, the superstructure components (girders and decks), the railings, and other accessories. The public is being frustrated with congestion caused by extended reconstruction activities and is demanding that public works be completed much quicker than usual practice. With increased highway funding authorized in the current legislation, there will be more construction activities on our aging infrastructure days ahead. However, we can no longer conduct business as usual by allowing extended period of construction activities to reduce highway capacities through work zones. The bridge engineering community will use more prefabricated bridge elements and systems to meet this challenge and the Federal Highway Administration is compiling a manual of previously proven connection details as requested by designers. The first draft of the manual is under review and is scheduled for a June 2008 release.

THE BENEFITS OF PREFABRICATED BRIDGES

For highway agencies, the use of prefabricated bridge elements and systems, ranging from substructures to entire bridges, is proving to be not only a best practice but also good business. These systems allow components to be fabricated off-site, under controlled conditions, and brought to the job site ready to install. When properly designed and detailed, these systems can be erected in a matter of hours. As a result, the use of these prefabricated systems reduces congestion and environmental impacts of bridge construction projects and enhances work zone safety for both workers and motorists.

Products made under controlled environment, without the limitations that a job site may present, lead to better quality that ensures long-term durability and improved constructibility. By specifying the use of high performance materials, corrosion protection systems, and good connection details, the owner can be assured that the bridge will perform adequately for the required 75- or more year design life.

Numerous prefabricated bridges have been successfully constructed in urban and rural areas over weekends without interfering with peak hour traffic. In some of the fast tracked projects studied by the author, the bids came in much lower than the engineer’s estimates. The author believes prefabrication bypasses the restrictive sequential construction operations, allowing the work to be done ahead of time and off the critical path, and reducing the risks posed by bad weather. Prefabricated bridges allow the contractor to quickly deliver the project and move off the construction zone, thus reducing his liability insurance, accident coverage costs and overhead. The direct cost savings from a reduced maintenance of traffic operations through the construction work zone, especially in urban areas, were passed on to the bridge owner in the reflected lower bids. The owners also benefited from having the quick turnover of their project staff assigned to cover other projects.

PREFABRICATED BRIDGES OFFER COST AND TIME SAVINGS

The more rapid deployment made possible by prefabrication can also result in time and cost savings. Bridge owners are willing to provide incentives to contractors who can deliver projects ahead of schedule. For some projects, the cost of time ranges $50,000 and $340,000 a day. Getting a project delivered even a day sooner by using prefabricated bridge elements can mean significant savings and would earn the contractor a sufficient bonus to make up for lower profit margin. In analyzing one project example, the author observed a contractor focusing his work activities and won the maximum 30-day bonus worth more than a million dollars, equating to 50% of the project cost as compared to the low normal profit margin.

The Connecticut Department of Transportation (CTDOT), for example, saved $1.1 million by using a prefabricated truss center span when constructing a new bridge over the New Haven Interlocking and Rail Yard. To minimize disruption to both traffic and train service and improve work zone safety for a crew working over active rail lines, CTDOT required that this portion of the bridge be installed in a single night operation over a weekend. The 97-m (320-ft) long, 850-ton steel truss center span was constructed over several months next to the rail lines and then lifted into place on a Sunday morning in May 2003, using a mobile, high-capacity crane.

Another reported successful project is the Wells Street Bridge in Chicago, Illinois. The 1899 steel bridge, which carries the Chicago Transit Authority's (CTA) elevated trains, was rebuilt as part of a larger development of the Wacker Drive in Chicago. The project originally called for rebuilding the bridge in sections over one month consisting of weekends. However, the Chicago Department of Transportation approved a value engineering change proposal by the contractor to prefabricate the bridge offsite and then move it into position in a single weekend. The contractor faced a financial penalty of $1,000 per minute for any delay. The work was completed over a weekend in May 2002, coming in two hours ahead of schedule.

The 425-ton, 34-m (111-ft) long, and 7.6-m (25-ft) high main steel superstructure span was constructed near the site and then moved into place using a self-propelled modular transporter (SPMT). These multi-axle, computer controlled vehicles can move in any horizontal direction, while maintaining equal axle loads and payload geometry from undesirable distortions. The bridge was placed on new foundations and connected to two shorter spans on either side. The use of prefabricated bridge elements meant that drivers and transit users were only inconvenienced for a single weekend as opposed to normal extended duration. In addition, CTA saved money by no having to provide costly shuttle services for transit riders.

The use of prefabricated bridge elements also provide significant advantages and cost savings to a joint project by the Oregon and Washington State Departments of Transportation to widen and replace the deteriorating deck on the historic 1929 Lewis and Clark Bridge in Washington. Full closure of the steel through-truss bridge was only allowed between 9:30 p.m. and 5:30 a.m. for 124 nights, in addition to three weekend closures. To meet the scheduling constraints, the contractor used prefabricated concrete deck panels built adjacent to and below the existing bridge. A truss gantry supported on SPMT was used to pick up the new panel and move it to the top of the bridge. The gantry is designed to hold two panels at each pass. The front portion of the gantry picked up an existing panel that work crews had cut out and the SPMT moved the rig forward to allow the new panel to be dropped into place from behind. The contractor optimized his construction operations and replaced each panel and reopened the bridge each morning, averaging five hours for each pass. The work was completed in August 2004 and the low bid came in 38% under the $29-million engineer's estimate. If prefabricated elements had not been used, replacing the deck lane by lane would have taken 4 years. Alternately, full closure of the bridge would have lasted several months, or the bridge would have been closed to traffic every weekend for 6 months.

To minimize traffic disruption, for example, the Virginia DOT recently replaced 100 span of superstructure of its I-95 James River Bridge without closing a lane to rush hour traffic by using prefabricated superstructure segments with low permeability lightweight concrete decks and accelerated construction requirements in the contract. With 110,000 vehicles per day, the James River Bridge was reconstructed from 7 p.m. to 6 a.m. Monday through Thursday nights only, with disincentives that could reach $250,000 a day for failure to restore all lanes to traffic. Throughout the nighttime construction, half the structure remained open to carry traffic. The superstructure replacement was completed with partial closures on 167 nights, and would have required total closure for three years using conventional construction methods. The low bid came in 11% less than the engineer's estimate.

The new Graves Avenue bridges are part of a $27.6 million Interstate Route-4 (I-4) widening and ramp project (from 4 lanes to six) in Volusia County, Florida. It took the self-propelled modular transporter (SPMT) precision machines in less than an hour each to install the two new spans. The old Graves Avenue over I-4 was closed December 12, 2005 for demolition and traffic were detoured to State Route-472 over I-4. In January 2006, two existing spans (weighing 250 ton each) were lifted and moved off to the side of the highway using the self-propelled modular transporters. The contractor demolished the two spans without interfering with or creating a potential hazard for the I-4 traffic. Two new replacement spans (weighing 1300 ton each) were built in a staging area a quarter-mile from the bridge site and along the Interstate route. On June 4, the first new span was erected over the I-4 westbound lanes using two 24-axle lines, SPMTs. The second new span was erected over the eastbound lanes the following weekend. Drivers were detoured between 11:30 p.m., Saturday June 10, and 6:00 a.m.

PREFABRICATED BRIDGE TECHNOLOGY ANSWERS THE CALL AFTER EMERGENCY EVENTS.

When Hurricanes Ivan, Katrina and Rita landed in succession along the Gulf Coast states in 2005 and 2006, numerous twin bridges on Interstate I-10 were either destroyed or put out of commission for several days. The states were being challenged to restore those bridges as quickly as possible to provide emergency relief to disaster stricken communities and the SPMTs answered the call. The contractors used the barge-mounted SPMTs to borrow good spans from one of the worse damaged twin structures and restore partial service to its other structure to quickly restore partial service for emergency service and delivery vehicles to reach affected communities. Several contractors earned their full bonus for delivery days ahead of schedule.

Owners are willing to pay high incentive award for accelerated bridge construction. In the most recent two projects tracked by the author, the size of the bonus has become much bigger then ever before; one with $5 million bonus ($200,000 per day up to 25 days) for a contract under one million dollars, and another with total bonus up to $27 million for a contract over $230 million.

TOTAL BRIDGE MOVEMENTS ARE STANDARD PRACTICE FOR RAILROAD AND HIGHWAY STRUCTURES THROUGHOUT THE WORLD.

In April 2004, FHWA and AASHTO co-sponsored a world bridge scan to Japan and four select countries in Europe. The published summary report is available through the Internet at http://www.fhwa.dot.gov/bridge/prefab. This author served as one of the team's co-chairs and the team reported several bridge elements/systems and methods of rapid deployment technology that will enable an owner and contractor to get in and out of the construction zone in unprecedented reduced time. The European communities depend a great deal on rail commute. The railroad companies will never allow their rail lines to be shut down during the weekdays because it will affect millions of daily commuters. As such, railroad bridges are being shut down for up to 48 hours during the weekends for replacement; and comes Monday morning, the facility must be re-opened to run trains. The same restriction downtime applies to the main arterial highways in the European communities during its peak travel periods. The scan team reported numerous bridge movement techniques, and some of the specific examples are discussed immediately to follow. The team also reported the moving of several prefabricated systems used in Japan on the Aritas Expressway, Furukawa Viaduct, and Arimatsu Viaduct. Construction involved limiting the closure of Route 23 (Aritas) to weekend nights and 12-hour window at night on the Arimatsu Viaduct over Route 23.

Self-Propelled Modular Transporters:

The use of SPMTs to move heavy structures with fine precision is a standard practice in Europe. It has been observed that large bridge components or even complete bridges weighing several thousand metric tons have been built at one location and then lifted and transported to their final location using a series of the SPMTs. These multi-axle computer-controlled vehicles have independent suspension and axle units that are capable of rotating 360 degrees; they can manipulate around tight places and ride on uneven ground while maintaining equal tire pressure on its tires. They come in four- and six-axle units, with each axle priced about $150,000. These are incredible machines and they are becoming very popular in the United States.

Other Bridge Installation Systems:

In addition to using SPMTs and conventional land or barge-mounted cranes to erect large structures, other traditional/conventional methods of moving large bridge components are found to be equally effective. A bridge could be prefabricated adjacent to an existing bridge and skidded into place. The bridge could be built on temporary support and moved into place either by SPMTs or on roller bearings and skid supports. It could also be built behind one of the existing abutments and incremental launched across a valley or above an existing highway. Hydraulic jacking systems have been employed successfully in numerous projects moving large components into their final positions both horizontally and vertically.

A bridge could also be erected on barges and ballast its payload with high capacity pumps. This method allows a contractor to install a bridge it its final position with tolerable allowance. The team held discussions with two contractors who had completed several steel tied arch bridges or trusses using barges and moved into its final positions. When water is abundance or in areas with high water tables, a bridge could be constructed in temporary dry dock channel and then flooded to float it into its final position. The team also reported on a prefabricated bridge built parallel to a highway and then rotated into place to connect the structure to it adjacent spans.

DECISION MAKING TOOL IS AVAILABLE

Is building a prefabricated structure the best choice for your bridge project? Will prefabrication be achievable and effective for a specific bridge location in your State? These questions and more are covered in the Federal Highway Administration’s (FHWA) new *Framework for Prefabricated Bridge Elements and Systems Decision-Making.* As numerous States have demonstrated, the use of prefabricated bridge elements and systems offers significant advantages over onsite cast-in-place construction, including faster and safer construction and better quality. Depending on the specific project, construction costs can also be comparable to or lower than conventional construction. Costs can particularly be reduced where repetitive components and systems are needed for long water crossings, high traffic corridors with minimized traffic control and maintenance needs under accelerated construction schedules, and reduced contractors' overhead.

Careful planning, design, and implementation will help transportation departments realize the significant advantages of prefabricated bridge construction. FHWA's new framework provides a quick and useful tool for making a decision on using prefabrication. It is offered in three formats for users: a one-page flow chart, a one-page matrix, and a more detailed question-and-discussion format. The flow chart guides the user through a series of questions about different elements of the bridge project, such as "high traffic volumes," "emergency replacement," and "environmentally sensitive site" The matrix provides more detail on these and other questions, while the question-and-discussion format presents an in-depth evaluation of the use of prefabrication. The three different formats are designed to accommodate the different responsibilities of users, who might range from a State Bridge Engineer to a bridge design engineer or project manager.

The Utah Department of Transportation (UDOT) is using a "Decision Tree" adapted from FHWA's new framework to make decisions on when to use prefabricated bridge systems. UDOT has used prefabricated bridge technology on a rapid deck replacement project on I-80 near Coalville and for a project on I-215 in Salt Lake City. The I-215 project involved a deck replacement on one bridge and the whole bridge replacement of another structure. The use of prefabricated elements allowed both projects to be completed faster, with improved quality and less disruption to traffic. Among the lessons learned on the projects to date is the need to familiarize contractors and other industry personnel with the process; involve contractors and prefabricators in the design process; and consider construction issues, such as staging areas needed, work hours required, and contingency plans.

To obtain a copy of the decision-making framework or to learn more about prefabricated bridge technology, visit FHWA's prefabricated bridge elements and systems Web site at http://www.fhwa.dot.gov/bridge/prefab/index.htm. The Web site includes brochures and other information on best practices, video clips of bridge projects, a slide presentation on prefabricated technology, and details on how prefabricated bridge elements and systems are being used around the country and in Japan and Europe.

CONCLUSION

The increasing traffic demand is presenting many challenges to our transportation network. The traveling public is demanding that this rehabilitation and replacement be done more quickly to reduce congestion and improve safety. The FHWA and the industry partners are advancing current state-of-the-practice in accelerating project delivery, and developing new bridge designs and systems. The scan team reported numerous available bridge systems and technologies for accelerating construction in record delivery time. These technologies enable the owner to reduce traffic disruption times from months to days or hours, restore the use of existing highways in significantly less time, improve work zone safety, minimize environmental impact, and improve constructibility. They are proven systems from around the world. The enormous user delay costs and public inconvenience have been the driving criteria for facility owners to require project delivery over a weekend. Owners are more than willing to provide substantial incentive awards for quicker use of their facilities whenever the user and delay costs are high. The bridge engineering community has embraced these innovative systems for bridge reconstruction and applying them in their projects to quickly get in and get out. With increasing traffic demands and a robust infrastructure renewal program, accelerated bridge construction is becoming conventional practice.

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