PREFABRICATED BRIDGE NATIONAL IMPLEMENTATION INITIATIVE

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ABSTRACT

This paper describes the recently created American Association of State Highway and Transportation Officials (AASHTO) Technology Implementation Group (TIG) and its activities related to implementation of one of its first three innovative products—prefabricated bridge elements and systems. Details include examples of various prefabricated bridge elements and systems constructed to date and a vision of the direction needed to address the significant challenges we face now and into the future to "get in, get out, and stay out."

Keywords: Prefabrication, Prefabricated bridges, Bridge elements and systems.

AASHTO AND BRIDGE PREFABRICATION

The American Association of State Highway Transportation Officials (AASHTO) formed a Technology Implementation Group (TIG) in 2000 to facilitate rapid acceptance and implementation of high-payoff and innovative technologies. Recognizing its potential for helping bridge owners meet key public needs, the TIG selected prefabricated bridge elements and systems as one of its areas for implementation in 2001 and assigned a panel to extend the use of prefabricated elements and systems in bridge design and construction. The panel began gathering information about uses of prefabrication in bridge construction throughout the country with the goal of publicizing advantages and specific applications of the technology.

ACTIVITIES OF THE TIG PANEL

Charged by the AASHTO TIG in 2001 with facilitating implementation of prefabricated bridge elements and systems, the Implementation Panel adopted two objectives:

- Provide forums for technology transfer of ideas that have been used
- Identify technology needs and facilitate technology development

Toward fulfillment of these objectives, the panel has developed and published a promotional brochure, sponsored workshops and sessions, provided speakers and produced video clips publicizing advantages of bridge prefabrication, and published a web site providing a wide variety of technology-transfer information on prefabricated bridge elements and systems.

BROCHURE

In May 2002, the Implementation Panel published a brochure title "Prefabricated Bridges – Get in, get out, stay out" that describes the implementation of innovative bridge prefabrication projects by bridge owners, engineers, and builders. The brochure was distributed to State Departments of Transportation, and its distribution continues at appropriate conferences and speaker forums.

WORKSHOPS / SESSIONS

The Implementation Panel hosted a workshop, sponsored by the Federal Highway Administration (FHWA) and the Texas Department of Transportation (TxDOT), on prefabricated bridge elements and systems in September 2001 in Austin. The panel also hosted a Demonstration Workshop in March 2002, again sponsored by FHWA and TxDOT, that featured TxDOT's State Highway 66 Lake Ray Hubbard project with its use of precast bent caps. Attendees for both workshops included representatives from State Departments of Transportation, FHWA, contractors, consultants, academia, and other professionals. Presentations from these workshops are available on CD-ROM.

The panel hosted technical sessions on prefabricated bridges at both the TRB Annual Meeting in Washington, DC, in January 2002 and the International Bridge Conference in Pittsburgh in June 2002. The panel has also sponsored speakers at a number of forums, including the following:

- Annual meeting, AASHTO Highway Subcommittee on Bridges and Structures, Atlantic City, New Jersey, May 2002
- Annual meeting, AASHTO Highway Subcommittee on Materials, Branson, Missouri, August 2002
- Annual meeting, AASHTO Highway Subcommittee on Construction, Rehoboth Beach, Delaware, August 2002.

VIDEO CLIPS

The Implementation Panel produced eight video clips that introduce bridge prefabrication and highlight fifteen bridges in six States and Puerto Rico that were constructed with prefabricated bridge elements and systems. Published in July 2002, the clips are available on CD-ROM, DVD, and VHS media. The clips are also posted on the Internet.

WEB PAGES

The Implementation Panel has posted web pages on www.aashtotig.org that offer in-depth resources on bridge prefabrication, including the following:

- Descriptions of specific prefabricated elements and systems and their advantages.
- One-click retrieval of project records that illustrate each description. These records can also be searched. Each record offers a photograph, and many provide links to detailed drawings and specifications.
- A link to the prefabricated bridges brochure, available in PDF format.
- Access to the video clips on prefabricated bridge elements and systems.
- "Publications" and "Calendar" pages that provide additional information and news of opportunities for the visitor in search of follow-on support.
- Information on the Implementation Panel and its activities.
- "Research" pages that provide descriptions and contact information for relevant research projects, both completed and underway, as well as links to resulting publications.

ADVANTAGES OF BRIDGE PREFABRICATION

Prefabricated bridge elements and systems can be constructed off-site and brought to the project location ready to erect. They can also be constructed adjacent to the project site but out of the way of traffic and then moved into position when they are needed. Their use provides bridge owners, designers, and contractors with options and advantages in terms of construction time, work-zone safety, environmental impact, constructibility, quality and cost.

MINIMIZES TRAFFIC DISRUPTION

The traveling public has lost patience with the extensive highway construction that is necessary today as the interstate highway system approaches its service life at the same time as urban congestion is increasing. Delays for delivery trucks and other commercial vehicles as well as for drivers traveling to and from their workplaces negatively impact commerce. Bridge construction can be a bottleneck because of its sequential nature, with foundations required before columns, and columns required before beams and deck. Innovative bridge design and construction that focuses on minimizing traffic disruption is needed.

Designers who choose prefabricated bridge elements and systems can effectively move a significant portion of the construction, i.e., the fabrication of components, away from the bridge site and the traffic that must maneuver through the construction zone. With the use of prefabricated elements and systems, time-consuming tasks such as formwork erection and removal, steel reinforcement and concrete placement, and concrete curing no longer need to be accomplished in the work zone. Conventional sequential processes can now occur simultaneously as components are fabricated off-site concurrently with on-site construction. Prefabricated components can be transported to the bridge site and quickly erected in place. The construction project timeline is thereby compressed and the traveling public experiences the disruption for a significantly reduced period of time.

INCREASES WORK-ZONE SAFETY

Construction sites often require workers to operate close to moving traffic, over water, at high elevations, near power lines, or in other dangerous situations. Prefabrication allows bridge construction, whether concrete placement and curing or steel fabrication, to occur in safer surroundings, greatly reducing the amount of time that workers must operate in potentially dangerous settings.

REDUCES ENVIRONMENTAL IMPACT

Conventional bridge construction requires significant access underneath the bridge for construction personnel and equipment to perform the activities necessary to construct the bridge. Erection of formwork and placement of steel reinforcement and concrete necessitate access to specific locations. Using prefabricated bridge elements and systems gives the contractor more options and can reduce the access requirements underneath the bridge, thereby reducing the impact to the adjacent landscape. On-site construction time is also reduced. This flexibility facilitates bridge construction and can be especially beneficial in environmentally sensitive areas.

IMPROVES CONSTRUCTIBILITY

Many job sites impose difficult constraints on the constructibility of bridge designs. Examples include heavy traffic on an interstate highway that runs under a neighborhood bridge, high elevations, long stretches over water, and restricted work zones due to adjacent development. Using prefabricated bridge elements and systems allows much of the work to be done off-site, relieving constructibility pressures.

It is important that bridge designers work with the construction industry to ensure that prefabricated component sizes and weights allow transport and erection with available equipment. Also, repeatability is an important consideration if the element or system is not a standard in the region. Initial bridge construction costs are improved when the prefabricated element or system is used multiple times, e.g., economy is improved when an identical precast bent cap system is used on a bridge at multiple support locations. In order for a new prefabricated component to be competitive with conventional construction for initial construction costs, in most cases the multiple use must be adequate to absorb the contractor's cost for the formwork and activities associated with fabrication of the component relative to conventional processes.

INCREASES QUALITY AND LOWERS LIFE-CYCLE COSTS

Prefabricating elements and systems takes them out of the critical path of the project schedule. Work can be done ahead of time, using as much time as necessary, in a controlled environment. The controlled environment, whether at a subcontractor's off-site fabrication plant or at the contractor's adjacent field plant, reduces dependence on weather and increases quality control of the resulting products. Established materials suppliers ensure consistent quality of materials. Plant operations are standardized, thereby ensuring consistent quality of production. Curing of prefabricated components can also be more closely monitored in a controlled environment. Inspection to ensure quality is achieved easier in a plant than in the work zone.

Improved quality translates to improved durability, longer service life, and lower life-cycle costs. When user costs are included, even initial cost comparisons typically show that prefabricated bridge construction is much more cost competitive than conventional construction because of the significantly reduced construction time that can be achieved with prefabrication.

EXAMPLES OF PROJECTS BENEFITING FROM PREFABRICATION

Although prefabricated beams and girders have long been used in bridge construction, innovative bridge owners, designers, and builders have applied the technology to increasingly complex elements and systems.

SUPERSTRUCTURE: DECKS

Partial-depth deck panels act as stay-in-place forms, reducing the volume of site-cast concrete and eliminating formwork removal. Examples of bridges that use prefabricated partial-depth deck panels include the following:

- I-5/South 38th Street Interchange in Tacoma, Washington: The Washington State Department of Transportation minimized traffic disruption by reducing construction time for its two-span, 325-foot replacement bridge over I-5 in Tacoma. With no need to construct and remove conventional deck forms, lane closures on I-5 were greatly reduced.

Fig. 1 Partial-depth precast concrete deck panels on I-5 Interchange in Tacoma, Washington

- Partial-Depth Deck Panels in Texas: In 1963, Texas developed its composite concrete bridge deck system consisting of precast concrete panels in the lower half with cast-in-place concrete completing the upper half of the deck. This partially-prefabricated deck system caught on slowly, but now panels are typically the contractor-preferred system for constructing bridge decks and the majority of bridges in Texas are constructed with panels. TxDOT-sponsored research showed that the use of precast pretensioned concrete deck panels produces a deck that is stronger, stiffer, and more crack-resistant to applied loads than a conventional cast-in-place concrete deck.[1] Texas girder-type bridge plans allow deck panels as a contractor option, and the contractor typically chooses this option because it speeds deck construction, improves worker safety during construction, and lowers costs.

Full-depth deck panels go even further toward reducing on-site construction. Proprietary brands of prefabricated full-depth deck panels are commercially available. Examples of bridges that use prefabricated full-depth deck panels include the following:

- Tappan Zee Bridge over the Hudson River in New York: A key bridge on the New York State Thruway system, the Tappan Zee Bridge carries an average 130,000 vehicles a day in its seven lanes. In the late 1990s, over 250,000 square feet of deck were replaced with proprietary prefabricated full-depth deck panels. During the replacement of the deck, two lanes were closed at 8 PM and a third lane was closed at 10 PM, with all seven lanes open to service by 6 AM.

Fig. 2 Full-depth deck panels on Tappan Zee Bridge over Hudson River in New York

- Dead Run and Turkey Run Bridges on the George Washington Memorial Parkway in Virginia: To minimize traffic disruption for more than 42,000 vehicles per day during deck replacement on these George Washington Memorial Parkway bridges, the National Park Service used prefabricated full-depth deck panels and required construction crews to work on weekends only. Replacing the non-composite deck on one span per bridge per weekend, the crews kept all bridge lanes open for commuter traffic from Monday morning to Friday evening.

TOTAL SUPERSTRUCTURE SYSTEMS

The past decade has supported a trend toward combining prefabricated bridge elements into bridge systems, prefabricated and installed as units. Examples of innovative uses of totally prefabricated superstructure systems include the following:

- I-95 James River Bridge in Richmond, Virginia: I-95 is the main north-south route along the east coast, and the Virginia Department of Transportation (VDOT) needed to keep it open during replacement of the James River Bridge. VDOT used a totally prefabricated superstructure system for most spans. The composite units consisted of an 8-¾-inch concrete deck over steel girders and were cast at a nearby casting yard. Crews were able to cut the old bridge spans into segments and remove them, prepare the gap for the new composite unit, and then set the new unit in place. Taking advantage of the original design of the bridge—the individual northbound and southbound superstructures were supported on a common substructure—VDOT kept one superstructure open carrying both directions of traffic and an emergency access lane during night-only construction. By morning, all traffic lanes were open.

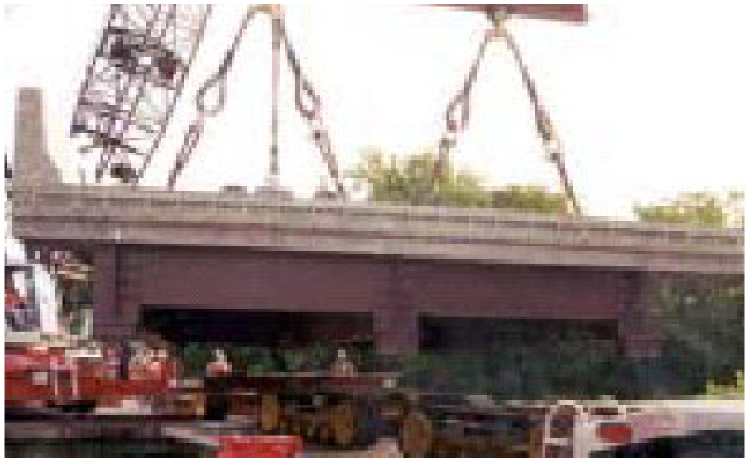

Fig. 3 Totally prefabricated superstructure system on I-95 James River Bridge in Richmond, Virginia

- Main Street over Metro North Railroad in Tuckahoe, New York: Replacement of this through-girder bridge presented a number of challenges to the New York State Department of Transportation. Over a busy commuter railroad in a commercial district, the bridge had to remain open for traffic in both directions while being reconstructed during nighttime hours only. To further complicate construction, an additional 5 inches of vertical clearance was required for the railroad. Designers chose a proprietary precast prestressed concrete and steel superstructure system for the phased construction. The overall depth of the system was less than could be achieved with conventional beam and slab construction. The required vertical clearance was obtained and construction time was reduced with the use of this prefabricated superstructure system.

SUBSTRUCTURE: BENT CAPS

Massive concrete bent caps require extensive formwork and concrete curing times. Prefabrication takes these requirements out of the critical path of construction schedules. Examples of bridges that use prefabricated bent caps include the following:

- Route 57 Bridge over Wolf River in Fayette County, Tennessee: Route 57 is the only east-west corridor through this region of the State, which includes sensitive wetlands. Staged construction maintaining one lane of traffic was required for the bridge replacement in 1999. Using precast concrete bent caps that were fabricated in two segments to accommodate staged construction, the Tennessee Department of Transportation was able to avoid putting equipment in the environmentally sensitive wetlands.

Fig. 4 Precast bent caps on Route 5 Bridge over Wolf River in Tennessee

- US 290 Ramp G in Austin, Texas: The contractor asked TxDOT for approval to precast the straddle bent cap when it became apparent that formwork for a cast-in-place cap would interfere with traffic and require closing the ramp for an estimated 42 days. The cap was precast adjacent to the site and lifted into place, requiring total ramp closure of only 8 days.

TOTAL SUBSTRUCTURE SYSTEMS

A total substructure system can consist of individual prefabricated piers or a prefabricated unit comprised of column(s) and cap. Prefabricated pier systems and prefabricated column(s)/cap systems require less field time to install compared to conventional on-site cast-in-place concrete construction. Individual piers are particularly suited to superstructures that consist of a single girder or widely-spaced girders that do not require bent caps. The Louetta Road Overpass on State Highway 249 near Houston provides an example of prefabricated piers. Constructed in the mid-1990s, each pier consists of several precast hollow-core high performance concrete segments with six post-tensioned bars. After foundation construction was completed, the prefabricated segments were erected and the bars were then tensioned.

Fig. 5 Precast piers at Louetta Road Overpass on State Highway 249 near Houston, Texas

TOTALLY PREFABRICATED BRIDGES

Some of the most exciting uses of prefabrication are demonstrated by totally prefabricated bridges, which offer maximum advantage for rapid construction. In this application, prefabricated bridge elements are assembled on site in a rapid construction process. Examples of totally prefabricated bridges include the following:

- Baldorioty de Castro Avenue Bridges in San Juan, Puerto Rico: The Department of Transportation and Public Works in Puerto Rico constructed two totally prefabricated overpasses (700-ft and 900-ft long) at each of two at-grade intersections that carry over 100,000 vehicles per day. Each of the four bridges was built in two stages, over two weekends. On the first weekend, piles were driven, the footings were cast in place, and asphalt was placed to support at-grade traffic. On the second weekend, the footings were uncovered and the prefabricated substructure components were erected and post-tensioned. After the first two substructures at the middle of the bridge were constructed, the 100-ft long superstructure span was set in place, complete with seven box beams, wearing surface, and parapets. Using two crews, the remaining spans were then erected simultaneously from the center span toward each end, with each span post-tensioned transversely as it was completed. The retaining walls were constructed with select fill on the approaches. The time to complete each overpass ranged from 21 to 36 hours. Commuters used the at-grade intersection on Friday evening and the new overpass on Monday morning.

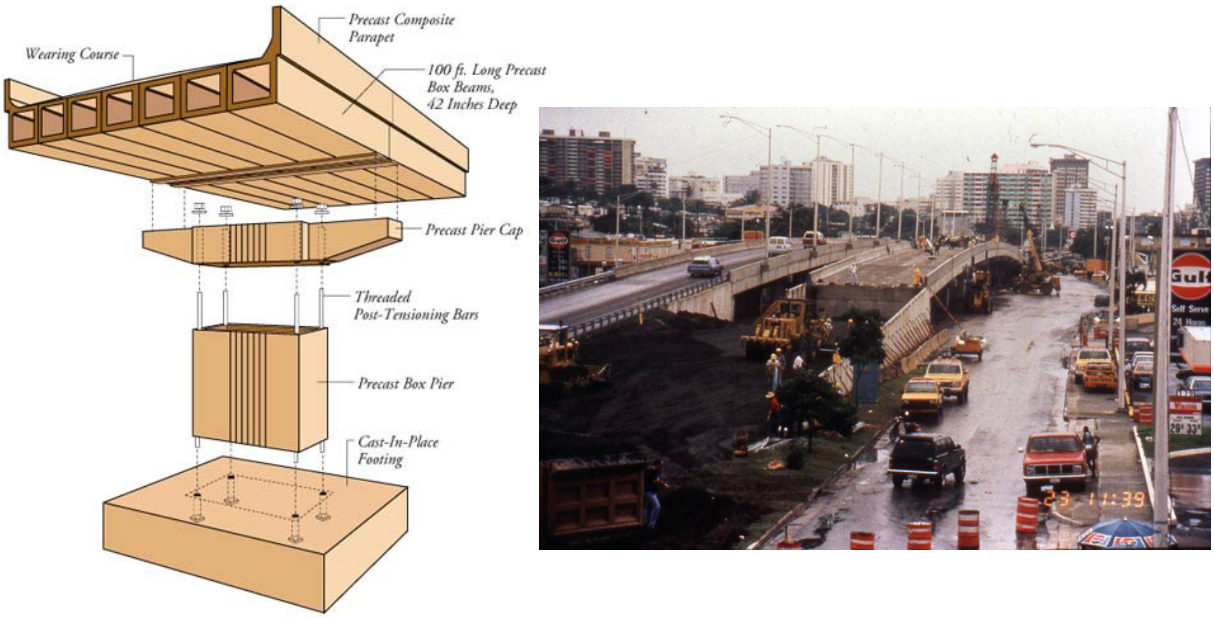

Fig. 6 Baldorioty de Castro Avenue totally prefabricated bridges in San Juan, Puerto Rico

- I-287 Viaducts in Westchester County, New York: During replacement of two major I-287 viaducts in Westchester County, the New York State Department of Transportation accepted the contractor's proposal to incorporate precast segmental piers for each of the 42 piers and to change the cast-in-place deck to precast panels. Up to 15 panels were erected in a single shift, and the prefabricated deck and pier construction reduced the contract's original 34-month schedule to 26 months.

EXPERIENCE OF ONE STATE — TEXAS

Texas has used prefabricated bridge elements – precast concrete beams and partial-depth deck panels – for decades, helped by numerous TxDOT-sponsored research projects to optimize details related to this use. Significant recent TxDOT-sponsored research has been done on prefabricated bent cap design methodologies and construction practices.[2] The State is improving the constructibility and reducing traffic disruption during construction on a growing number of its bridges by using prefabricated bent caps, as the following projects demonstrate:

- I-45/Pierce Elevated in Houston: During plans in 1996 to replace the 113-span Pierce Elevated twin structures on I-45 in Houston's central business district, designers realized that a conventional bridge system using cast-in-place concrete bent caps would require a year and a half to complete construction. With user delay costs estimated at $100,000 a day, TxDOT instead opted to use precast bent caps and completed work on the 226 spans in just 190 days.

- State Highway 66 over Lake Ray Hubbard Bridge near Dallas: When this two-lane crossing, used heavily by commuters from the suburbs east of Dallas, needed to be replaced, TxDOT designed a pair of conventional prestressed concrete I-beam bridges. After the project was let for construction, the contractor asked to precast the substructure bent caps as an alternative to the original design of cast-in-place multi-column bents to accelerate construction over water and reduce the amount of time that workers would need to operate near power lines. Using results of the TxDOT-sponsored research, TxDOT designed a precast bent cap option that included a cap-to-column connection and a specific construction procedure. Using 43 precast bent caps saved nearly a week per cap on the tasks associated with construction of conventional cast-in-place bent caps and allowed 80 percent of the work to be performed on the ground.

- State Highway 36 over Lake Belton Bridge near Waco: These twin bridges, currently under construction, will be 3,840 feet long with 62 interior supports. Because of fluctuating water surface elevations on the lake and uncertainties about performance of underwater precast column joints, designers chose a cast-in-place twin column arrangement for the bridge. The 62 repeating supports made precast bent cap construction the cost-effective solution over conventional cast-in-place bent cap construction. The hammerhead bents on this project require the highest moment-demand cap-to-column connections on precast caps to date.

POTENTIAL FOR USING BRIDGE PREFABRICATION IN TEXAS

Pressure to upgrade and expand its on- and off-system roadways is mounting as Texas' aging infrastructure experiences increasing traffic volumes and loads. Rapid bridge construction has become increasingly important, particularly in urban areas. Texans are demanding more speed in construction, safer work zones, and more protection of environmentally sensitive areas.

One of many projects in Texas, the reconstruction of I-35 in the coming decade will require the construction of numerous bridges. A primary goal for the project is to reduce the time that traffic is disrupted by lane closures and detours during construction. TxDOT has designed five upcoming bridges on this project as totally prefabricated bridges; these bridges will be constructed using rapid field erection techniques. The five bridges have precast concrete pier substructures and superstructure span segments that consist of steel tub girders with composite decks. The prefabricated systems will be cast off the bridge site and erected into place. Narrow longitudinal strips of cast-in-place reinforced concrete will connect the prefabricated superstructure systems.

In 2001, Texas voters affirmed their interest in improving the State's transportation infrastructure by approving Proposition 15, which allows Texas more flexibility in paying for transportation projects through innovative financing alternatives. With additional financial alternatives on the horizon, the Governor of the State initiated a Trans Texas Corridor Plan that outlines a new vision for transportation in Texas. Just as the Interstate Highway System met the needs as envisioned in the 1950s, the Trans Texas Corridor meets the needs of the

21st century. The plan proposes a network of corridors designed to move people and goods faster and more safely than ever before. The corridors consist of separate vehicle and truck lanes, high-speed commuter and freight rail, and a utility zone that can accommodate the transmission of oil, natural gas, electricity, data, and water. Bridge construction with prefabricated bridge elements and systems is anticipated to play an important role in the construction of the Trans Texas Corridor bridges.

CONCLUSIONS

Agencies nationwide are responding to the public demand to minimize traffic disruptions due to bridge construction. The use of prefabricated elements and systems minimizes the need for cast-in-place concrete in restrictive urban work zones, over water, and in remote and environmentally sensitive areas. With prefabrication, a downtown segment of an interstate can be replaced without ever closing a lane to rush-hour traffic, as shown with the I-95 James River Bridge in Virginia. With prefabrication, an entirely new bridge can appear over a weekend, as shown with the Baldorioty de Castro bridges in Puerto Rico.

With many of the Interstate Highway bridges approaching the end of their service lives at the same time as traffic volumes and loads are increasing, the need for rapid bridge rehabilitation and replacement will continue to increase. With increasing population, the need for new bridge construction will continue as traffic patterns and volumes change. Innovative bridge design and construction methods are needed to minimize traffic disruption, increase work-zone safety, reduce environmental impact, improve constructibility, increase quality, and lower life-cycle costs of a bridges. Prefabricated bridge elements and systems meet these demands. Work is needed to further improve this innovative technology.

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