OVERNIGHT DELIVERY –
NEW JERSEY DOT RAPID BRIDGE REPLACEMENT

Xiaohua H. Cheng[1] and Harry A. Capers, Jr.[2]

Abstract

The aging highway bridge infrastructure in the US is being subjected to increasing traffic volumes, structural deficiency and functional obsolete. They must be continuously renewed while accommodating traffic flow. This paper demonstrates application of prefabrication technology where traffic control issues demanded rapid construction and decision making risk of total facility showdown. It shows an example supporting the FHWA's Accelerated Bridge Construction Decision Making Framework. Using the lessons learned from previous experience with the emergency repair/replacement, the Rt.1 reconstruction project involved replacing superstructures of two bridges with prefabricated components installed in 59-hour time window over a weekend. The experience becomes standard practice of "Hyperbuild".

Introduction

The aging highway bridge infrastructure in the United States is being subjected to increasing traffic volumes, structural deficiency and functional obsolete. They must be continuously renewed while accommodating traffic flow. The traveling public is demanding that the rehabilitation and replacement be done more quickly to reduce congestion and improve safety. Conventional bridge reconstruction is typically on the critical path because of the sequential labor-intensive processes of completing the foundation, the substructure, the superstructure components, railings, and other accessories. Prefabricated bridge systems can allow components to be fabricated off-site and moved into place quickly while maintaining traffic flow. Depending on the specific site conditions, the use of prefabricated bridge systems can minimize traffic disruption, improve work-zone safety, minimize impact to the environment, improve constructability, increase quality, and lower life-cycle costs. New Jersey Department of Transportation (NJDOT) clearly demonstrated the truth of these statements with their approach to replacement of the superstructures of two structurally deficient bridges carrying a freeway section of US Rt.1 through the Capital City of Trenton.

The project involved completely replacing three superstructures of two bridges with new ones designed for a 75 year life, made off site and installed over three weekend shutdowns of 59 hours each. The design and construction of this project learned lessons from the past experience of two emergency repair/replacement projects. A project of this magnitude would typically take the Department approximately 2 years to design and construct as a traditional deck replacement and bridge rehabilitation

[1] Senior Engineer, Bureau of Structural Engineering, New Jersey Department of Transportation (NJDOT), Trenton, NJ 08625, USA
[2] Vice President, Arora and Associates, P.C., Lawrenceville, NJ 08648, USA

project. The project approach saved more than 22 months and an estimated design and construction cost, including delay-related user costs in excess of $2M. The results? An extremely happy motoring public, bridge owner and contractor.

This paper will outline the application of prefab technology on the project where traffic control issues demanded rapid bridge construction techniques. The paper will also demonstrate a past project where decision makers took the risk of total facility shutdown to allow for rapid emergency repair/replacement as lessons learned for this project.

Needs for Accelerated Bridge Construction

Bridge engineers have successfully used accelerated bridge construction (ABC) practices for many years around the globe. Our good fortune in this country to experience continued growth has also had the result of developing a greater dependence on our transportation infrastructure and less tolerance to interruptions caused by taking lanes out of service for routine maintenance. With the advent of high performance materials and emerging advanced technologies, the FHWA is attempting to provide leadership in meeting the public's expectations as illustrated in their Vision and Mission Statements. They identified three "Vital Few" important items to be focused on by the agency, those being Safety, Congestion Mitigation, and Environmental Stewardship and Streamlining.

In focusing on these priorities and goals the FHWA has led to the recommendation for modular prefabricated construction, among other things. The concept of prefabricated bridge elements and systems (PBES) is being researched as well as applied and put to use in building bridges as illustrated in the FHWA Decision-making Framework (FHWA, 2005)

To obtain information about technologies being used in other industrialized countries, a scanning tour of five countries was made in April 2004 (Ralls et. al, 2005). The overall objectives of the scanning tour were to identify international uses of prefabricated bridge elements and systems and to identify decision processes, design methodologies, construction techniques, costs, and maintenance and inspection issues associated with use of the technology. The prefab bridge elements and systems consisted of foundations, abutments, piers or columns, pier caps, beams or girders, and decks. Bridges with span lengths in the range of 20 to 140 feet (6 to 43m) were the major focus, although longer spans were of interest if a large amount of innovative prefabrication was used.
The focus areas of the study were, therefore, prefabricated bridge systems that

- Minimize traffic disruption,
- Improve work zone safety,
- Minimize environmental impact,
- Improve constructability,
- Increase quality, and
- Lower life-cycle costs.

During the tour, it was observed that precast deck panels were used on steel beams to produce both composite and non-composite members. The use of full depth prefabricated concrete decks reduces construction time by eliminating the need to provide cast-in-place concrete. Composite action was developed through the use of studs located in pockets in the concrete deck slab. In addition, use of innovative equipment, e.g. self-propelled modular transporters (SPMTs) were observed. These provided a means to accelerate bridge construction using a factory produced product for the state bridge owners.

According to the Year 2006 National Bridge Inventory (NBI), New Jersey has nearly 6,500 highway bridges (2,580 NJDOT bridges). About 35% are structurally deficient and functionally obsolete. The average age is close to 50 years old, while 52.5 years old for steel bridges. The most projects under plan, design, and construction are rehab and replacement related. Furthermore, New Jersey is the most highly urbanized and densely populated state in the US. Therefore, rapid bridge construction for both new and old bridges using prefab elements and systems is extremely vital in New Jersey.

In 2004 NJDOT established "Hyperbuild" program for accelerated roadway and bridge constructions. The term "Hyperbuild" was coined by the NJDOT Commissioner Jack Lettiere. Hyperbuild projects acknowledge the tremendous need to minimize traffic impacts for all of the previously mentioned reasons and recognize the potential savings of millions of dollars in design, construction, and road user costs that could be realized. The Commissioner's vision was to reduce the time from initiation of design to the opening of the finished project to traffic ("project end date") and require roads be functional while constructing, by utilizing innovative methods of design and procurement for certain types of projects. Such projects have to have a well-defined scope and, if possible, require *limited* right-of-way acquisition, utility relocations and environmental impacts. With the past experience of rapid emergency replacement of I-295 project, the US Rt.1 Freeway reconstruction became the first "Hyperbuild" project. These two projects will be presented in the following sections, respectively.

Rapid Emergency Bridge Replacement

Creek Road Over I-295 Bridge Emergency Repair/Replacement

In May 30, 2002, a tractor trailer traveling along I-295 South struck the overpass for Creek Road over I-295 in Bellmawr, Camden County, New Jersey near the border of Gloucester County (NJDOT, 2002a). The location is very sensitive because the estimated ADT in that area of I-295 is 80,000-120,000. The impact of the oversized and over height piece of earth-moving equipment that the tractor-trailer was carrying shattered the fascia beam and the fifth interior beam causing serious damage and potential catastrophic failure of the overpass (**Figure 1**). The overpass was a two simple span bridge having eight prestressed concrete girders and was classified structurally deficient (SD) and functionally obsolete (FO) with the permit underclearance of 13'-9" (4.19m) per the inspection prior to the accident, while NJDOT currently requires 16'-6" (5.03m) underclearance for bridge design.

After initial inspection by the NJDOT bridge staff, the overpass was found to be structurally unsound requiring closure of the both I-295 mainline and Creek Road until temporary repairs could be made. The bridge was strengthened with a new, reinforced beam that was installed from the top of the bridge deck (strongback). Options to repair the bridge from under the deck were evaluated, but ultimately rejected, because they would have further restricted the bridge's maximum height safety requirements. The mainline of Route I-295 was reopened after the installation of a temporary support beam, but replacement of a portion of the deck and structural members down to the abutments was required before Creek Road could be reopened.

Figure 1 Exposed Prestressing Strands of Damaged Interior and Fascia Girder of Creek Road Overpass Bridge

Creek Road overpass is a major route supporting commercial and emergency services for the City of Bellmawr and any traffic diversions on Creek Road or from I-295 onto surrounding network roads would cause unacceptable abnormally heavy traffic in those areas. Such conditions constituted an emergency in the region and it was determined by the Governor's office that damage to the overpass required immediate repairs on an emergency basis.

The Governor's declaration of an emergency allowed the department's structural engineers to quickly search various proprietary prefabricated bridge systems to rapidly put the bridge back into service (McGreevy, 2002; NJDOT, 2002b). The chosen strategy was to advertise for a superstructure system consists of a prefabricated composite concrete deck and stringer unit usually produced for simple spans manufactured by a supplier.

Several stipulations were that the systems would be designed in accordance with current American Association of State Highway and Transportation Official's Bridge Design Standards (AASHTO), would utilize weathering steel, concrete with corrosion inhibitors (high performance concrete (HPC)) to increase service life and would provide a shallower superstructure depth than existed prior to the accident.

The permanent replacement was made utilizing "Inverset" deck panels (**Figure 2**). The panels provided are cast inverted in forms suspended from the support girders and when turned upright the decks are precompressed which should provide for increased durability. Panels come in lengths up to about 100 feet (30.48m) (86.5' (26.37m) for this bridge) with widths usually in the 8 to 12-foot (2.44 to 3.66m) range. Stringer spacing of the panels was arranged to permit the construction of new bearing seats under the existing bridge between existing stringers prior to demolition of the damaged superstructure. It should be noted that these bearing seats were also prefabricated to minimize construction time on site. Spacing the stringers to allow this construction of the bridge bearing seats also resulted in closer spacing allowing for a 9-inch (0.23m) increase in vertical underclearance.

Upon completion of off-site fabrication and delivery on site, required modifications to the bearings, staged demolition of existing structure, erection of the new modular panels (four units) was performed on successive weekend night shutdowns, tremendously minimizing traffic impacts to the interstate I-295 and Creek Road (**Figure 3**). Besides replacement of the damaged span, the other existing span was repaired on concrete spalls and previous minor collision impact.

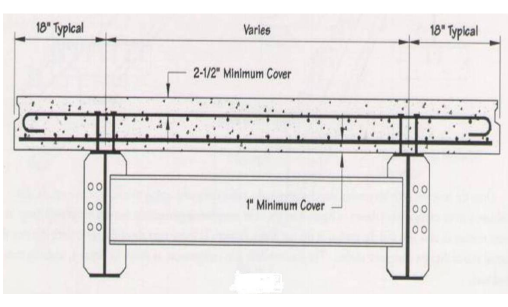


Figure 2 Prefabricated "Inverset" Deck Panel (Modular Deck-Girder Unit)

Figure 3 Night Time Erection of Modular Deck Panels Over I-295

Rt.70 Friendship Creek Bridge Emergency Replacement

The Rt.70 Friendship Creek Bridge was a concrete encased steel girder bridge with concrete gravity abutments at both ends. On July 12, 2004, 13 inches of rain fell in a 12 hour period in the area that was equivalent to a 1,000 year event storm. The storm caused that six dams were breached and the bridge collapsed with abutment failure on July 13, 2004 in the early morning due to scour. The State Police and NJDOT closed the road and established the detour for local traffic. A temporary bridge was built using prefabricated steel truss and the road opened to traffic on July 19, 2004 (**Figure 4**). It was followed by a new bridge construction including new abutments and new superstructures. The replaced superstructure is of precast concrete box beams with asphalt overlay. The replacement substructures is PZ steel sheeting with pipe piles bearing support and tiebacks. The first half of the replacement bridge completed on September 9, 2004 and the full bridge opened to traffic in October, 2004 **(Figure 4**).

Figure 4 Temporary Bridge and Replacement Bridge Using Prefabricated system and Components

<u>US Rt.1 Freeway Bridge Reconstruction Project</u>

Each day the US Route 1 carries more than 50,000 vehicles through the City of Trenton, the capital of the State of New Jersey. The US Rt. 1 serves as a vital link to adjacent Pennsylvania and is a heavily traveled land service route for those communities along the Northeast Corridor between New York City and Philadelphia. Just north of the City of Trenton in Lawrence Township, Rt. 1 divides into two Routes, Rt.1 Business which carries local traffic to points in the city and Rt. 1 Freeway which was intended to provide faster access to downtown Trenton, the State Government Offices, and the crossing of the Delaware River between Trenton of New Jersey and Morrisville of Pennsylvania.

The freeway section configuration of the highway was constructed on embankment and provides for two lanes of traffic in each direction divided by a Jersey Barrier along its entire length creating significant challenges for maintenance of traffic for any work performed within its limits. However, three bridge decks on the Route 1

Freeway mainline, one at the Olden Avenue Connector and two at Mulberry Street, had deteriorated to the point where they were in need of constant maintenance. Both bridges (3 superstructures) were single-span simply supported steel girder bridges built in 1953 with skew of 56 degrees and 10 degrees, respectively. Although the steel girders and bearings were repainted in 2000, the inspection report and evaluation revealed and classified the superstructures as structurally deficient due to poor condition of concrete decks and bearings (**Figure 5**; **Figure 6**). The deteriorations included large concrete spalls of decks with exposed rebars, patch spalls, fine transverse and map cracks underneath decks, steel girder and stiffener buckling due to prior collision impact, undermined concrete pedestals and rusted anchor bolts of bearings.

Figure 5 Deteriorated Decks of the Route 1 Bridge over the Olden Avenue Connector

Figure 6 Deteriorated Pedestal of Bearings

In 2005 the replacement of these three bridge superstructures was undertaken in one project that was to become the NJDOT's first "Hyperbuild" project. The three bridges in the project were actually located at two points along the mainline of US Rt.1 separated by approximately a half mile. The Rt. 1 Bridge over the Olden Avenue Connector is a highly-skewed steel girder bridge with concrete deck (**Figure 5**). The 35.0-ft (10.67m) wide single-span bridge has a span of 86.8-ft (26.46m) and carries 2-lanes of traffic. The Rt. 1 Bridge over Mulberry Street consists of two parallel bridge superstructures on a common abutment with a median barrier separating each direction of traffic. The 82.2-ft (25.05m) wide bridge has a 60.0-ft (18.29m) long single-span and carries 4-lane of traffic over Mulberry Street.

Preliminary review of the sites of these deficient bridges indicated that they met the criteria of "Hyperbuild". Several prefabrication options were considered for rehabilitation of these bridges based on the past emergency repair experience and availability of precast products (capers, 2005; 2006). Using the lessons learned during the previous emergency repairs of the Creek Road Bridge over I-295, NJDOT's structural engineers concluded that a similar approach of using prefabricated superstructure modular panels for the rapid replacement of these bad decks would be an effective strategy due to the very limiting project site space and significant need for rapid project development/design and construction. Use of SPMTs for an entire prefab bridge superstructure system was not an option due to the limited site space to accommodate either the prefeb units or the SPMT equipment.

Each superstructure was designed using 5 full-length modular segments of varying width, each with two Grade 50W steel girders and a 9-inch (229mm) thick composite concrete “Inverset” deck system. The 86.8-ft (26.46m) long bridge span over Olden Avenue utilized W36x182 girders, and the 60-ft (18.29m) long bridge spans over Mulberry Street utilized W30x99 girders. Segments sizes considered the transportability and erection restrictions associated with urban nature of the project site. All new structures were designed for 75 year design life.

The 15 modular segments were designed and fabricated in Schuylerville, New York, assembled at the plant to verify field tolerances, and trucked to an airport parking lot near the bridge (**Figure 7**). The segments were required to be on site 24 hours prior to the start of demolition of the existing bridge. The contract specified high performance concrete (HPC) to be used for all concrete on the job.

Figure 7 Prefabricated Modular Segment in Transportation

The construction was planned to occur using only weekends to shut downs mainline traffic to minimize disruption along the corridor. Each of the 3 superstructures was allowed a 59-hour window commencing Friday evening (7:00pm) with all activities off the roadway and both lanes re-opened before the morning rush (6:00am) on Monday. If this window was exceeded, a Lane Occupancy Charge would be assessed, up to $10,000 per day.

As is typical on NJDOT projects, incentives and disincentives) were included on this project to encourage the contractor to minimize onsite construction time even further than 59 hours per bridge. For the bridge over the Olden Avenue Connector, an incentive (or disincentive) of $1,500 per hour was specified if the work was completed in less (or more) than 59 hours, not to exceed a maximum of $27,000. For each structure over Mulberry Street, an incentive (or disincentive) of $2,000 per hour was specified if the work was completed early (or late), not to exceed $36,000.

Liquidated damages were also specified. The contractor would be charged $4,200 per day if the bridges weren't substantially completed by the specified completion date in the contract, and an additional $900 per day if all work was not completed within 3 months following that.

The engineer's estimate for this project was $3.8M. The low bid of $3.5M was 8% or $297,000 less than the engineer's estimate. There were 5 bidders on this project. The second lowest bid was 10% higher than the low bid.

The Rt. 1 Bridge over the Olden Avenue Connector was replaced during a weekend closure in August 2005. The Rt. 1 Southbound Bridge over Mulberry Street was replaced during a weekend closure in September 2005, followed by the Rt. 1 Northbound Bridge over Mulberry Street during a weekend closure in October 2005. Design and construction of such bridges would have taken 22 months using conventional methods.

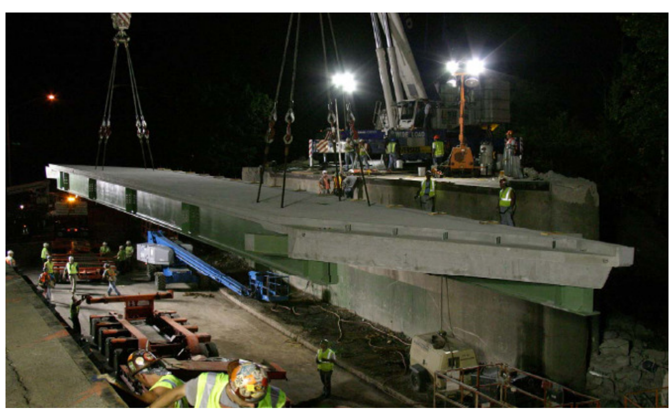
Olden Avenue Bridge The Route 1 Bridge over the Olden Avenue Connector was closed at 7 p.m. on a Friday in August 2005, and traffic was rerouted onto a 5-mile detour. The bridge was demolished in place using conventional methods. The existing abutments were repaired and new bearing seats were constructed. The prefabricated superstructure was then erected during nighttime. The longitudinal joints between superstructure segments were then sealed, and the expansion joints at the ends of the span were completed. The cast-in-place (CIP) parapets were connected to the outside segments with bars in threaded inserts.

Mulberry Street Bridge The Rt. 1 Southbound and Northbound bridges over Mulberry Street were closed at 7 p.m. on a Friday in September and October 2005, respectively, and traffic was rerouted onto a 5-mile detour for Southbound Mulberry, while off- and on-ramps were used for Northbound Mulberry. The construction methods and time required to replace these bridges were similar to the bridge over the Olden Avenue Connector. Parapets were cast-in-place (CIP) concrete and median barriers were precast. The typical construction time frame was as follows.

- Weekend closure: Friday 7:00 pm to Monday 6:00 am
- New bearing pedestal installation: prior to and during the project
- Demolition and removal of old structure: Friday/Saturday (**Figure 8(a)**)
- Bearing and expansion joint replacement: Saturday
- Prefab modular bridge unit erection: Saturday night (**Figure 8(b)**; **Figure 8(c)**)
- Bridge installation completion: Sunday morning (**Figure 8(d)**)
- CIP parapets and prefab median barriers: Sunday
- Cleaning and Reopen: Monday early morning

(a) Demolition/Removal of Existing Structure

(b) Initiation of Erection of Route 1 Southbound Bridge over Mulberry Street



(c) Erection of Prefabricated Modular Segment

(d) Erection of Final Deck Panel of Route 1 Southbound Bridge over Mulberry Street

Figure 8 Reconstruction of Two US Rt.1 Freeway Bridges

All three bridges were opened in less than the required 59 hours. The bridge over the Olden Avenue Connector was opened in 56 hours, the bridge over Southbound Mulberry was opened in 51 hours, and the bridge over Northbound Mulberry was opened in 54.5 hours. With all three bridges opened well before Monday morning rush hour, the contractor earned an $18,500 incentive.

<u>Summary</u>

Each of the 3 bridge superstructures in the New Jersey DOT's first "Hyperbuild" project was replaced over a weekend, during a total of 6 days in 3 consecutive months. The replacements were completed in significantly less than the 22 months required for conventional design and construction, and they were completed under budget. The design and construction savings, including delay-related user costs, are in excess of $2M.

Each bridge is expected to see a 75-100 year service life due to the quality of its prefabricated superstructure, the use of high performance concrete, and the attention given to connection details. Conventionally constructed bridges have an average minimum 50-year life in New Jersey.

There are a large number of such bridges to repair and rehabilitate in New Jersey. The experience of Rt.1 Freeway reconstruction set a good example for the future work and became standard practice of "Hyperbuild" projects. The project clearly demonstrated the benefits that can be reaped by applying accelerated construction strategies: less construction time, increase work zone safety, less maintenance, more durability, higher quality, reduce user cost and life-cycle cost, and minimize traffic disruption and environmental impact. And of course, an extremely happy motoring public! In the mean time, NJDOT looks forward to more and more innovative and cost-effective prefabricated products that can be selected for the future projects.

References

1. Capers, H. (2005) *Hyperbuild! Rapid Bridge Construction Techniques in New Jersey*, Transportation Research Board 6th International Bridge Engineering Conference, Boston, MA, July, 2005
2. Capers, H., Lopez, J., Lewis, R. and Nassif (2003), H., *Applying The Principals Of Get In, Get Out, And Stay Out Designing And Detailing Of Highway Structures For Rapid Construction In New Jersey*, 2003 NYC Bridge Conference, New York, NY, August, 2003
3. Federal Highway Administration (FHWA) (2005), *Framework for Prefabricated Bridge Elements and Systems (PBME) Decision-Making*, Dec., 2005
4. McGreevey, E. James, Governor, *Executive Order #28*, State Of New Jersey, Trenton, NJ
5. New Jersey Department of Transportation, News Release, *Creek Road Bridge Repairs Move Forward to Allow Reopening on Monday Morning*, Trenton, NJ, June 5, 2002
6. New Jersey Department of Transportation, News Release, *Creek Road Bridge Over I-295 Damaged in Afternoon Accident*, Trenton, NJ, May 30, 2002
7. Ralls, Tang, Bhidé, Brecto, Calvert, Capers, Dorgan, Matsumoto, Napier, Nickas, Russell (2005), *Prefabricated Bridge Elements and Systems in Japan and Europe,* Washington, D.C., March, 2005
8. Roads and Bridges Magazine, November, *Hyperbuild Project,* Scranton Gillette Communications, Inc. Arlington Heights, II, November, 2005