NSBA White Paper

REDUCING TIME FOR STEEL BRIDGE CONSTRUCTION

AMERICA'S aging and deteriorating highway infrastructure sees ongoing significant increases in traffic. The resulting congestion reduces economic efficiency, increasing the costs of goods and services. Constructing and maintaining roads and bridges often disrupts local economies to an extent that overshadows the cost of the construction itself.

Obviously techniques to accelerate construction activity and avoid or minimize traffic disruptions have great value. This white paper discusses four ways used successfully to speed construction of steel bridges: design/build, bridge prefabrication, incremental launching, and steel/elastomer deck panels. The white paper concludes with a summary of advanced, heavy-duty equipment capable of transporting large, prefabricated bridge structures.

Design/Build

FOR LARGE projects, the design/build concept offers an effective approach to speeding the construction of bridges. Traditionally, the bridge design and construction functions occur in two separate successive phases and are the responsibility of two different entities. One firm develops a complete design for a

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bridge. Following approval of the design, contractors use it as the basis for bidding and implementing bridge construction. Design/build, on the other hand, makes these two functions the responsibility of a single entity. This one entity has the responsibility for both designing and constructing the bridge. The design-builder compresses time by fulfilling multiple parallel goals, including those involving aesthetic and functional quality, budget, and schedule for timely completion.

The bridge owner, who hires the design/build firm, can concentrate on defining the scope and requirements of the bridge, along with making timely decisions. Documents specify the owner’s expectations in terms of performance while the design-builder produces results. The owner does not have to warrant to the contractor that the design drawings are complete and accurate. This simplifies the paperwork, language, inspection, and legal requirements of the project.

Because design and construction overlap to some degree, total project time can be significantly reduced. Design and construction personnel, working as a team, can more efficiently and effectively apply value engineering, constructability, and fast-track construction techniques to the project. Procurement and construction work can begin before the drawings and documents are fully completed. The resulting time savings result in lower overall costs and earlier project completion.

Successful large steel design/build project: Cooper River bridge in Charleston, SC—completed within budget one full year ahead of schedule.

The Cooper River (Ravenal) bridge, completed in July of 2005, stands as the first cable-stayed design/build bridge project. This $540 million bridge, with a main span of 1546 feet and a width of eight lanes, is North America’s longest cable-stayed bridge. It replaces aging truss bridges between the cities of Charleston and Mount Pleasant along Highway US 17 in South Carolina.

Bridge engineers stated that the use of structural steel for the main span, high level approaches, and curved ramp structures led to an effective and cost-efficient design in a competitive design-build environment. The Cooper River bridge is subject to both earthquakes and

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hurricanes. Structural steel helped minimize weight, which reduces inertia effects under seismic loading. Steel also minimizes superstructure depth, offering less area exposed to wind than other materials.

The bridge’s two diamond-shaped towers extend 572.5 feet, becoming the tallest concrete structures in the state. The approach superstructures are supported by curved steel plate girder stringers, while the main cable-stayed span has two steel edge girders connected laterally by steel floor beam plate girders.

Engineers for this project noted that the design/build process provided significant opportunities for optimizing both design and construction phases. As with any design/build project, success depended on good cooperation and communication. In addition, a large cable-stayed bridge adds concerns with a structure whose critical characteristics change as construction progresses. Management’s understanding of these complexities required strong and experienced leadership.

Prefabrication advantages

NEW ways to prefabricate superstructures offer opportunities for bridge designers and contractors to significantly reduce construction time. Additionally, they improve worker safety, lessen environmental impact, and cut costs. Through prefabrication, the bulk of the work on a bridge can be performed in a controlled environment prior to on-site construction, with little or no disruption of traffic. Weather becomes less of a factor and quality improves. Workers spend less time on-site, thereby minimizing their risk to traffic and power lines, as well as reducing their time at elevations and over water. Prefabrication also lessens the time that heavy equipment must spend on site, reducing adverse effects on the environment.

In many cases steel beams, being lighter than concrete elements having the same weight-bearing capability, facilitate prefabrication. The prefabricated structure will eventually have to be transported and lifted into place by heavy-duty equipment.

Many job sites impose difficult constraints on the constructibility of bridge designs: heavy traffic on an interstate highway that runs under a neighborhood bridge, difficult elevations, long stretches over water, restricted work areas due to adjacent stores or other facilities. Using prefabricated bridge elements and systems relieves such constructibility pressures.

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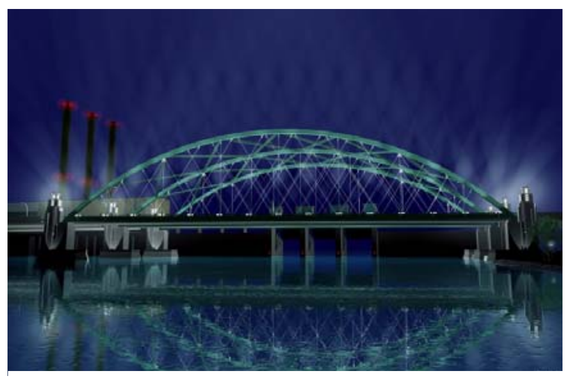
For example, when the Virginia DOT needed to keep I-95 open during the James River Bridge replacement, the department picked a prefabricated superstructure system for most bridge spans. The composite units consisted of an 8.7-inch concrete deck over steel girders fabricated nearby. Crews cut the old bridge spans into segments, removed them, and prepared the resulting gaps for the new composite unit. Lastly, they set the new prefabricated unit in place overnight.

The Wisconsin DOT prefabricated a 475-ft steel tied-arch span as part of a 2,573-ft-long and 50-ft-wide bridge over the Mississippi River. Contractors prefabricated the tied-arch section and floated it into place before connecting it to the permanent bridge piers. They fabricated the bridge segments 90 miles from the site in pieces manageable for shipping and erection. Then they assembled these pieces entirely off-site on barges. The barges floated the center-span steel arch superstructure into place. Prefabrication allowed the contractor to simultaneously work on both the river piers and the arch. It minimized impact on the community, speeding construction of the bridge and limiting disruption of river traffic.

Construction of the proposed Providence River Bridge in Rhode Island will take advantage of prefabrication techniques. This single-span tied-arch bridge for I-95 will be 400 feet long and almost 170 feet wide. The northbound and southbound lanes will be carried on one structure that includes three arches (one in the median, and one at each side). The project contractor will prefabricate the structural steel for the bridge off site on a pier, and then transport the superstructure to a barge, which will float the bridge to its site. Construction of the bridge piers will occur simultaneously, saving a significant amount of time.



Proposed Providence River tied-arch bridge in Rhode Island will take advantage of prefabrication and advanced transportation techniques.

Incremental launching

THE incremental launch represents another prefabrication technique recently adopted for steel bridges. This technique is particularly useful when traffic, site

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conditions, or environmental issues restrict the size and amount of construction equipment permitted below the bridge. The technique also improves safety because crews work close to ground level.

Here the contractor excavates a large launching pit on one or both abutments. Crews preassemble a section of the steel bridge superstructure in the pit atop a system of bearings, and then push or pull the section incrementally across the awaiting piers. Roller bearings positioned at the girder centerlines on the pier caps carry the weight of the bridge sections and facilitate their movement from pier to pier. Push and pull equipment includes hydraulic thrust pistons, motors, cables, and sheaves. The technique applies only to bridges with straight or constant curve profiles.

Since the cantilevered bridge sections may deflect significantly, contractors will usually attach a trussed skid or launching nose to lead the first steel bridge section. The skid will slope upwards a distance somewhat greater than the anticipated deflection. In some cases the launching nose is unnecessary since the successive bridge piers form a continuous downgrade that’s greater than the deflection of the cantilevered section.

Incremental launching has been successfully applied to the construction of a 1630-ft steel bridge for Highway 20 in Iowa, carrying traffic 137 feet above the Iowa River. Each of two parallel steel superstructures consist of four 11.3-ft deep plate girders spaced on 12-ft centers with a deck widths of 37 feet. The bridge has five steel spans measuring 302 feet flanked at each end by a 60-ft precast concrete jump span. The steel superstructure permitted longer spans, reducing the number of required piers in the environmentally sensitive area below. Weathering steel girders blend well with the environment and eliminate the necessity of future painting.

The four-lane Clifford Hollow steel bridge in northern West Virginia represents another highly successful use of the incremental launching technique. This 5-span 2.4-million-pound steel bridge stretches 1700 feet across Clifford Hollow, carrying traffic up to 275 feet above the valley. Crews preassembled 400-ft sections of the steel superstructure, which consisted of steel plate girders, bolts and cross-bracing. Four hydraulic cylinders powered each bridge section across the land-based track rollers on the higher abutment, forming a giant cantilever until the section reached the temporary rollers on the piers. A kingpost frame in the assembly area provided a cable-stay to the end of the bridge section.

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Emergency brakes, consisting of chains at the abutment, allowed the assembly to move back up the track, when necessary.

Prefabricated deck panels

A PATENTED Sandwich Plate System (SPS) shows promise as a way to prefabricate steel decks for bridges to reduce construction time. Typically, a 2-inch thick compact polyurethane elastomer core sits between two steel ¼-inch-thick steel plates, forming a sandwich-like deck structure. To create the deck, workers inject the elastomer as a two-part liquid into closed cavities formed by the steel faceplates and perimeter steel bars.

Section of Sandwich Plate System (SPS) for bridge decks.

SPS decks are similar to stiffened steel plates in structures such as orthotropic decks used for bridges. But compared to a lightweight orthotropic steel deck, the SPS deck is stiffer with reduced deck curvatures and small panel deflections.

Prefabrication of the SPS plates facilitates stricter quality control in the shop and rapid on-site assembly of the deck structure. Fewer fatigue-prone details and improved vibration damping of the SPS deck plate system lead to an increased service life. The SPS bridge deck is lighter than conventional concrete deck structures, resulting in lighter supporting substructures and improved resistance to earthquakes.

In flexure, the plates act as flanges and the core as the web. The flexural stiffness and strength of the sandwich plate can be tailored to meet specific structural requirements by selecting appropriate steel/elastomer thicknesses. The elastomer transfers shear from one steel plate to the other, eliminating the need for fatigue-prone steel-to-steel welds. Also eliminated are closely spaced discrete stiffeners.

Fabricators can create the steel cavities using standard shop welding practices. They can assemble deck units with welds and slip resistant bolted connections for dynamically loaded structures.

The SPS deck has been applied to the two-lane 74-ft-long Shenley Bridge in the municipality of Saint-Martin, Beauce-Sartigan county of Quebec, Canada. In this

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case, deck panels consisted of a prefabricated 1.5-inch-thick elastomer sandwiched between ¼-inch steel plates. To form the deck, eight SPS deck panels, each about 23.3 feet long x 7.9 feet wide, are positioned transversely across three steel plate girders. In addition, the bridge has two end deck panels that measure about 23.3 feet x 5.4 feet. The grade 50 steel plate girders have a 11.8-inch -wide x 0.8-inch-thick top flange, 13.8-inch-wide x 1-inch-thick bottom flange, connected by a web that's 3 ft deep and a half inch in thickness.

The prefabricated deck panel for the Shenley Bridge consists of the SPS sandwich bonded to a cold-formed steel angle at each end of the long side. Slip-critical bolts through the steel angles fasten adjacent panels. In addition, a field v-groove weld joins the top SPS adjacent plates. The angles are bolted to the steel plate girders. A specialized coating on the top plates forming the bridge deck prepares them to receive an asphalt surface.

This bridge has undergone extensive load testing. Under maximum loads the bridge remained linearly elastic, closely matching analytical results. The SPS deck's weight is about 43% of a comparable concrete deck. By using an SPS deck, contractors avoid the common problems associated with corrosion of reinforcing bars in concrete decks. Prefabrication improves quality control and speed of construction.

Heavy-duty equipment

NEW methods for transportation of prefabricated bridge steel superstructures have come into practice on several large projects. The new techniques make use of specialty equipment originally developed by the petrochemical industry. The equipment generally consists of multi-axle trailers and self-propelled transporters that combine high-load capacity and excellent maneuverability. Another technology borrowed from the petrochemical industry is the ability to transfer larger structures from land-based fabrication sites to ocean barges.

Two major types of transporters are in use today. They are designed to distribute large loads both longitudinally and transversely.

Pneumatic Multi-Axle Trailers—These trailers have numerous axle configurations that can be custom tailored for each project. They must be hauled by truck tractors. The trailers have a sophisticated internal load distribution system controlled through an independent onboard hydraulic system. Each axle has two independent four-wheel sets (8 tires per axle) that are interconnected

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through a hydraulic system that can provide equal load to each wheel set. In addition, each axle is also interconnected with the others so that all are equally loaded.

Pneumatic multi-axle trailer pulled by truck tractor.

The entire trailer can be raised or lowered and tilted from end to end and from side to side. In addition, each wheel set can turn independently. This allows the trailer to turn in a pre-programmed fashion where the front and rear axles turn at a different radius than the center axles, minimizing lateral pulling of the tires. This steering system can also be independent of the tractor, which also aids in turning.

The hydraulic load distribution system combined with the turning capabilities allows the transporter to travel over uneven ground and execute turns on normal city streets. The pneumatic trailers have power on board for steering, braking and leveling, however they require the use of pulling and sometimes pushing tractors for movement. Multiple trailers can be bolted together with their hydraulic systems interconnected.

Self-Propelled Transporters—Self-propelled transporters offer more versatility than a multi-axle trailer. Tractors are unnecessary to push or pull these modules. They're similar to the previously described trailers except they are self-powered for forward and backward movement. This means that the vehicles can be tucked under structures and maneuvered into tight spaces.


Self-propelled transporters require no tractor.

Wheel sets of the self-propelled transporter can independently rotate 360 degrees, providing the capability of pivoting in place.

The transporters are also modular and can be aligned in single-wide and double-wide setups. Pivoting in place is possible even when set up in multiple width configurations.

These capabilities have significant ramifications for bridge construction. For instance, an entire bridge overpass superstructure can be placed on these trailers, shipped down the road with the beams parallel to the roadway underneath, and then rotated into position at the bridge site for setting on the substructure. If room is available near a bridge overpass site, the entire superstructure can be prefabricated ahead of time, and installed on the new substructure overnight.

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