FULL-SPAN PRECASTING OF RAILWAY BRIDGES

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Span stacking on support frames. Photo: Systra.

In recent years, more than 35,000 spans of high-speed railway (HSR) bridges have been built in China and large investments in HSR infrastructure have been made in Europe, Japan, Korea, and Taiwan. Long prestressed concrete (PC) bridges are the typical solution for HSR infrastructure on poor soil. The combination of long bridges and short spans results in a large number of modular spans. This allows for investments in large precasting facilities and special means for beam transportation and erection.

Light-rail transit (LRT) projects also include miles of PC elevated guideways. Many HSR bridges and the first new-generation LRT bridges have been built with precast concrete beams. Precasting offers rapid construction and repetitive casting processes in factory-like conditions. The beams can be erected all year round in almost any weather conditions. This article illustrates the application, transportation, and erection of full-span precast concrete beams for LRT and HSR bridges.

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U-beams for LRT Bridges

Dual-track precast concrete segmental box girders have been used intensively for LRT bridges. Single-track, precast concrete U-beams, however, are being used more frequently because of their higher quality and faster erection rate.

Single-track U-beams include two edge girders and a bottom slab that supports the track via ballast or direct fixation. The edge girders keep the train on the bridge in case of derailment, and the top flanges are used as walkways for passenger evacuation. Precast concrete beams offer simple casting operations, rapid and inexpensive erection with ground-based cranes, optimal integration with the urban environment, built-in sound barrier and system functions, and the possibility of lowering the vertical profile by 5 to 6½ ft.[1]

A single-track U-beam is 15 to 18 ft wide, weighs from 340 kips for 82-ft-long spans to 500 kips for 115-ft-long spans, and is typically transported on the ground with trucks and rear steering trolleys. Different proportions of pre- and post-tensioning are possible. Pretensioning simplifies forming and diminishes the cost of prestressing, but requires anchor bulkheads and reaction beams designed for the prestressing force of many strands.

The fabrication process is consistent with the speed of erection. Storage for completion of curing is necessary only when the beams are delivered on the completed deck. Ground transportation and crane erection require two to three days of curing, and the beams can complete curing on the piers. A small storage area may be needed to provide some flexibility in case of delivery delays or defective beams. In typical conditions, the beams are picked up from the

Span transfer to the storage platform with a portal carrier with pivoted tractors. Photo: Marco Rosignoli.

casting bed and loaded onto the truck for just-in-time delivery.

HSR Bridges

The precast concrete beams for HSR bridges are too heavy for ground transportation and need to be delivered on the completed deck and positioned with dedicated machines.[1] The productivity of the precasting facility matches the productivity of the erection lines. The size of the storage area and the number of storage platforms are based on the curing time required prior to delivery, which depends on the type of beam transporter.

The beams are often designed for post-tensioning to facilitate handling of prefabricated cages and to shorten the curing time in the casting bed. Combinations of pre- and post-tensioning are also possible. Partial post-tensioning is applied after 12 to 18 hours of curing to make the beam self-supporting for transfer to the storage area. Parallel casting lines are separated by transportation routes for cage delivery and removal of the beams. Three casting beds may be used in the casting lines for single-track U-beams in combination with an inner form that shuttles back and forth along the casting line.[1] Alternatively, the inner tunnel forms for box girders are more complex to operate and may be stored between two casting beds to serve them. Casting beds and handling equipment for dual-track box girders are more expensive than for single-track U-beams, but the number of units is halved.

Portal cranes on rails or steering wheels are used to move the beams around the precasting facility. Portal cranes with transverse tractors and steering wheels facilitate access to casting beds and storage platforms. Portal cranes with pivoted tractors are also used for beam delivery and placement.

Tire Trolleys

Tire trolleys are used to transport the beams along the access embankment and completed superstructure to the rear end of the launcher. The tire trolleys have 135- to 200-kip capacity and the speed varies significantly from machine to machine. The main beam of the trolley is supported by multiple transverse beams. Each transverse beam has a pivot for 360-degree rotation of two paired wheels controlled by a steering computer. Long transverse beams ensure lateral stability and align the wheels of the trolley with the superstructure webs for direct loading. The load in the wheels is equalized electronically.

An articulated saddle supports the rear end of the beam and rolls along the main beam during beam extraction. Two fixed blocks support the front end of the beam and provide the torsional restraint during transportation.

Span Launchers

The typical configuration of a span launcher includes a rear main frame and a front underbridge. The underbridge is supported at the leading pier of the span to be erected and at the next pier. The front end of the main frame is supported on the underbridge during launching and on the leading pier cap during beam placement. A C-frame supports the rear end of the main frame and allows the precast concrete beam to pass through. The main frame cantilevers out behind the rear C-frame to store two winch trolleys for beam removal from the tire trolley.

Tire trolley for 900-kip, single-track box girders. Photo: BWM.

Telescopic span launcher for 107-ft-long, 2023-kip, dual-track beams. Photo: BWM.

Portal carrier positioned for span lowering. Photo: Marco Rosignoli.

Repositioning of the underbridge. Photo: Marco Rosignoli.

Loading the launcher is relatively simple. The tire trolley is driven under the rear overhang of the main frame, the front winch-trolley picks up the front end of the beam and moves forward, and when the rear support saddle reaches the front end of the tire trolley, the rear winch-trolley picks up the beam to release the tire trolley.

The beam is moved out and lowered to the deck level. Load cells and stainless steel shims are used to adjust the support reactions. Placing the beam takes two to three hours and repositioning the launcher takes another two to three hours, so two to three beams can be placed every day when crossover embankments exist along the delivery route and the precasting facility is designed for such production.

Beam launchers fed by tire trolleys are preferred for very long bridges, as the launcher is not used for beam transportation and the trolleys are stable and fast. Multiple shorter bridges are better handled with portal carriers.

Portal Carriers with Underbridge

A portal carrier comprises two wheeled tractors connected by a box girder that supports two hoists. The tractors have motorized steering wheels controlled by steering computers.[1] In some machines, the tractors rotate by 90 degrees for the lateral movements of the carrier; in other machines the wheels turn by ±90 degrees individually.

To pick up the beam from the casting bed, the carrier is moved alongside the beam and the tractors are rotated by 90 degrees; rotation is not necessary when the carrier has ±90 degree steering wheels. The carrier is driven laterally over the beam, lifts the beam, is driven back to the transportation route, and is realigned with a reverse sequence of operations. The same operations are repeated to release the beam into the storage area and to pick it up for final delivery.

At the leading end of the erection line, the carrier reaches a two-span underbridge. The underbridge is a stiff box girder supported on self-launching pier frames at the two piers of the span to be erected and at the next pier. A motorized saddle rolls along the underbridge and carries vertical support cylinders for the front tractor of the carrier.

The saddle is moved to the rear end of the underbridge, the carrier is driven forward until the front tractor is over the saddle, and the vertical cylinders of the saddle are activated to lift the tractor from the deck. The hydraulic motors of saddle and rear tractor are synchronized, and the carrier is moved along the underbridge until the front tractor is beyond the leading pier.

After reaching the span lowering position, the saddle pushes the underbridge forward to clear the area under the carrier for span lowering. After positioning the beam, the underbridge is moved back to release the front tractor onto the new span for a new placement cycle.[1]

Beam lifting takes one to two hours, placement takes three to four hours, and transportation may take an entire day when the delivery route is long. When the precasting facility has two casting lines, each carrier serves a casting line. Two carriers and two underbridges may be used to erect two bridges simultaneously. Two carriers may also work with a common underbridge to double the erection rate of one bridge when crossover embankments exist along the delivery route.

Portal carriers are the first-choice solution for construction of multiple HSR bridges separated by embankments or tunnels. The carrier picks up the underbridge from the landing embankment and moves it to the next abutment without dismantling. Immediate restart of beam placement minimizes disruption of precasting facilities designed for just-in-time delivery.

Reference

1. Rosignoli, M. 2013. *Bridge Construction Equipment*, 496 pp., ICE Publishing, ISBN: 978-07277-5808-8.

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EDITOR'S NOTE

This article is an abbreviated version of a paper published in the Spring issue of the PCI Journal. *The full version is available at www.aspirebridge.org and click on Resources.*