Nebraska's Inverted Tee SHORT-SPAN Bridge System

IT system proves quick and efficient

by Fouad Jaber, Nebraska Department of Roads

A significant number of bridges in Nebraska must cross waterways or railroads where vertical clearance is critical and the span length required is less than 80 ft. The sparsely populated area located outside of the Omaha-Lincoln metropolitan area has a flat terrain and many small streams that have to be crossed, which requires shallow superstructures.

Inverted Tee System

First introduced in 1996, the inverted-tee (IT) system is structurally efficient, rapid to build, and economically competitive. Over 100 IT bridges have been designed and constructed by Nebraska Department of Roads (NDOR) and other agencies.

The IT system consists of precast, prestressed concrete inverted-tee beams with a 6-in.-thick, cast-in-place (CIP) concrete deck. IT beams are extremely simple to produce and light to handle. The topping reinforcement is a single layer of welded-wire or mild-steel reinforcement located at mid-depth. The system can be used for a span-to-depth ratio of up to 35, making it shallower than other available precast concrete products.

The Nebraska IT series was designed in SI units and ranges from 12 to 32 in. deep (designated IT300 to IT800) in increments of 4 in. The IT beams are set at a standard 37-in. spacing, center to center, and can span up to 80 ft.

This bridge system is cost-effective for short-span bridges, despite the use of what appears to be "too many" girder lines. The IT beams are extremely simple to fabricate with standard strand and welded-wire reinforcement (WWR), and no tied reinforcing bars. The deck is formed with 32-in.-wide, ¾-in.-thick plywood sheets, which are placed into ¾-in.-wide, 1-¼ in.-deep ledges notched on each side of the web, requiring few field labor skills.

The IT shape has no top flange and has a constant web width, and its simple shape allows the use of only one set of forms for various beam depths.

Applications

The IT beam system has various applications, such as:

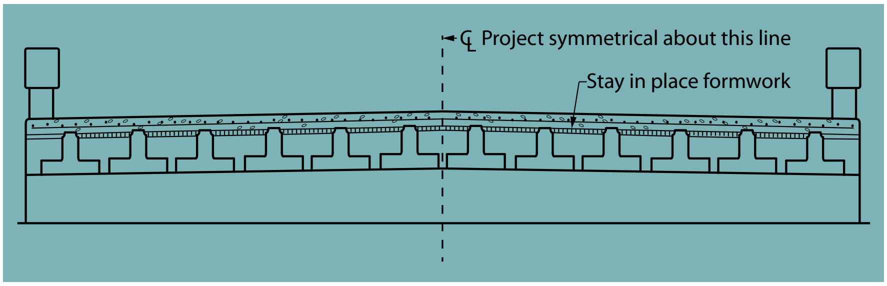
- New construction, where the superstructure depth must be kept to a minimum. This may include high flood-elevation areas and nearly flat road overpasses over flat terrain.
- New construction, where conventional on-site formwork cannot be used due to existing restrictions.
- Bridge superstructure replacement, where a greater load capacity is required for the same superstructure depth.
- Bridges where structural continuity over the support is required.

Fabrication

The two components of the concrete beam shape—bottom flange and web—are standardized such that the bottom flange width is the same for all beam depths. The web height is easily adjustable within the standardized design at 4 in. increments. Self-consolidating concrete makes this small and efficient shape relatively easy to cast. The only types of reinforcement used in the section are straight, ½-in.-diameter strands and WWR. The beams are relatively lightweight reducing some of the heavy lifting and transportation requirements typically associated with AASHTO or bulb-tee beams. The standardized element shape, with a range of beam heights and only two types of reinforcement—combined with high-quality concrete mix designs and fabrication specifications required by NDOR—provide a superior beam system for the bridges that is both efficient to manufacture and lightweight to install.

Reinforcement details of inverted-tee beam. Photo: Nebraska Department of Roads.

Typical inverted-tee in the casting yard. Photo: Concrete Industries.



General cross section of roadway. Figure: Nebraska Department of Roads.

Design

Because the IT beams are not connected in the transverse direction, except at the diaphragms and at abutment turndowns, they should behave similar to a composite I-girder system with relatively narrow spacing. After extensive grid analysis and field-testing, the NDOR policy is to use a distribution factor of S/11 per lane for shear, where S is the beam spacing, and use the flexure equations in the *AASHTO LRFD Bridge Design Specifications* for I-girders.

The single layer of slab reinforcement located at mid-slab thickness is typically No. 5 bars at 6 in. centers for transverse reinforcement and No. 5 bars at 10 in. centers for longitudinal reinforcement. Additional reinforcement is provided in the slab on structures made continuous over the piers. NDOR also requires interstate bridges to have a slab thickness of 8 in. with two layers of reinforcment and designed using the empirical method in the *AASHTO LRFD Specifications*.

The two criteria that often control the design of the IT system are the top-fiber compressive concrete stress at service load at midspan and member deflection. Bridges are designed as simple span for dead load and 100% continuous for live load. Longer spans can be achieved by providing continuity in the IT system for deck weight plus all superimposed loads.

The NDOR policy is to provide at least one alternate CIP slab or steel girder design whenever an IT system is proposed. Recently it has been the trend that the IT system is the choice of the contractor.

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The IT system is designed to be especially efficient for construction by small contractors in sparsely populated areas. IT beams can be handled with the same equipment used for precast concrete pile handling. Installation of formwork for the overhang is the most time consuming part of the deck forming, and is typically left up to the contractor to decide on the best method of construction.

Typical inverted-tee bridge. Photo: Nebraska Department of Roads.

Inverted-tee and NU I–girder used on the same bridge in Omaha, Neb. Photo: Nebraska Department of Roads.

Cost

The unit prices of the CIP slab system per square foot, as taken from records of similar projects by the NDOR, is $\$23.50/ft^2$. This average cost per square foot does not include the cost of bridge rails or substructures.

Summary

Since their introduction by Nebraska in 1996, precast, prestressed concrete IT-beam bridges have become the most dominant system in Nebraska. Developed for short to medium-span bridges, the IT beams are more cost efficient (on average) and are advantageous when spanning greater distances where depth of the structure is critical. In addition, the IT system requires no temporary field forming and is constructed quicker than CIP slab bridges. This type of bridge is excellent for projects where the construction areas are limited and where superstructure forming should be minimized.

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For additional photographs or information on this or other projects, visit www.aspirebridge.org and open Current Issue.

EDITOR'S NOTE

More information about the development of the IT System is available in Kamel, M. R. and Tadros, M. K., "The Inverted Tee Shallow Bridge System for Rural Areas," PCI Journal, *September-October 1996, pp. 28-43.*