Rapid Replacement

Turning Overnight Bridge Replacement Upside Down

By Peter J. Smith

As our nation's heavily traveled bridges continue to age and deteriorate at an alarming rate, the need for rapidly replacing them is becoming more important. And while the search for rapid replacement techniques continues, the Inverset™ system has been used in the Northeast for the last 16 years to replace entire bridges, or portions thereof, during overnight, over-the-weekend or similarly abbreviated work closures (*Figure 1*).

Figure 1

Speed of installation and quality of the completed structure are two important attributes that are desperately needed when it comes to replacing vital bridges. Because the system delivers both, it behooves the practicing bridge engineer to know the basics, the potential as well as the limitations of the system.

What is the Inverset™ System?

Inverset is a trademark for a precast composite bridge system that was initially developed and patented (now expired) by Mr. Stan Grossman of Norman, Oklahoma in the early 1980's. The system features a unique up-side-down casting method of prefabricating full-span superstructure units, each typically consisting of two steel beams cast compositely with a concrete deck of shippable width (10- to 12-feet).

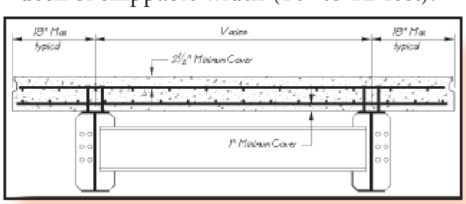

Figure 2

At time of erection, completed units are shipped to the job site and placed in position next to each other to make up the total width of bridge. The structure is completed by installing diaphragms and grout between units. After railings

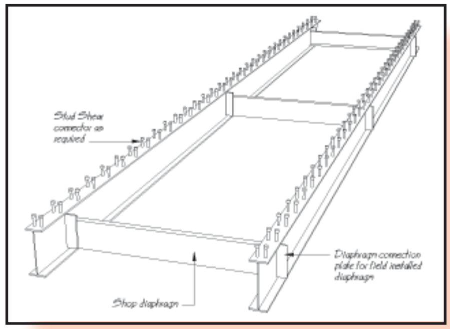

Figure 3

and approaches are installed the structure is ready for traffic. The amount of field work required for a typical installation is usually minimal.

Design and the Casting Process

The design and casting processes go hand in hand. Generally following AASHTO guidelines, the design process is similar to that used for conventional composite bridges except that beams are designed in pairs composite with the deck.

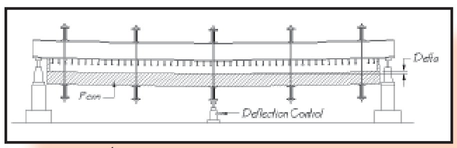

Figure 4

The iterative design process starts by assuming a beam size. Deflection and stresses in the beams are computed and tabulated for the first step of the casting process in which a steel beam pair, complete with stud shear connectors (*Figure 3*), is placed up-side-down in the casting position (*Figure 4*). The stresses in this position, shown conceptually in *Figure 5*, are "locked" in the beams as soon as the concrete is cured.

Next determine the dead load stresses in the beams **and** the deck of the newly composite section in the right-side-up position. Dead load stresses imposed on the section in this position are added to the "locked in" stresses calculated in step 1 (*Figure 6*). Notice the stresses are very small in the bottom flange, about the same (tension) in the top flange (because it is near the neutral axis) and significant (compression) in the concrete deck - under its own dead load.

Finally, stresses and deflection of the composite unit are determined under design live load conditions. If they exceed or fall too far short of the allowable, the process is repeated until the optimum beam size is determined.

Benefits of the System

The benefits of casting composite units in this manner include:

1. Beams up to 25% smaller may be used because the section is composite under its own dead load.
2. The deck is under a state of ambient compression, rendering it crack resistant during handling and more durable over the long term.
3. The concrete that is at the bottom of the deck, is the densest and therefore the most durable. Turned right-side-up, it ends up as the riding surface.
4. Precise deflection control during casting makes the units match each other within ¼-inch ± eliminating the need for an overlay.
5. Units are essentially ready for use as soon as they are erected

Joining Units Together

After the units are erected, diaphragms are installed between units to make the steel framework continuous. The deck is made continuous by filling the longitudinal joints with high strength non-shrink shear grout. For decks that are not overlaid, the top 1-inch of the joint is filled with an elastic joint sealing material. For decks overlaid with a waterproof membrane and asphalt wearing course, the entire joint is filled with non-shrink grout.

Alternatively, the deck may be made structurally continuous with a narrow steel-reinforced closure pour, eliminating longitudinal joints. This detail extends installation time to allow for closure concrete to cure and may not be suitable, therefore, for rapid installation projects.

Dispelling a Myth

Some engineers are concerned that bridge decks, as described above, can not be replaced using conventional cast in place techniques since the beams are sized for the up-side-down casting method. This is a valid concern but one that is easily addressed. If the engineer chooses to design for future conventional cast-in- place rehabilitation, beams for that purpose are used in the design. When these beams are used in the Inverset process, the benefits described above are retained.

While this strategy can provide the

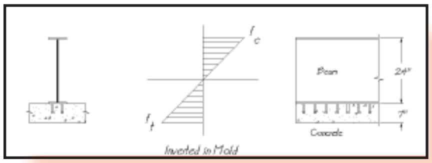

Figure 5

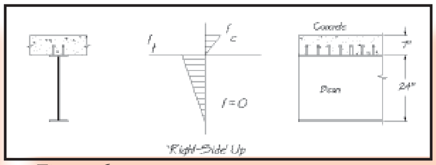

Figure 6

“best of both worlds,” most engineers take full advantage of the steel-saving Inverset design process.

Other Factors to Consider in the Design Process

Apart from satisfying AASHTO’s structural criteria, other factors that need to be considered include:

1. The maximum weight and length of a unit that can be fabricated, shipped and erected.
2. If reconstruction is done in stages, the width (and therefore the design) of the units may be different in each stage.
3. Utility requirements may determine the width and design of particular units.
4. Severe vertical curves may require beams to be precambered. If rolled beams cannot be cambered enough, plate girders may be required.
5. The maximum “practical” skew is about 45-degrees, although bridges with larger skews have been built.
6. Span-to-span continuity can be accomplished with Inverset units, but details of that design are driven by the time allowed for installation.
7. Horizontal and vertical alignment.

If the issues in the foregoing list are properly considered and treated, even a complex structure can be built in a much abbreviated time frame.

Beyond the Inverset Span Range

The maximum “practical” span is about 100-feet ±, primarily due to the maximum weight of a unit that can be cast in the upside-down position. Precast concrete/steel (non-Inverset) composite units longer than that can be built and shipped, but they must be fabricated in the right-side-up position. In so doing, some of the listed benefits derived from the upside-down casting method are lost because of the difficulty of achieving the same level of prestress in the composite section. However, the major benefit required for rapid bridge construction is still realized because the fully cured precast unit is essentially ready for use as soon as it is erected.

Variations and Improvements

Numerous variations and improvements have been made to the original Inverset concept. Very shallow plate girders with wide bottom flanges have been used to accomplish shallow, vertically curved bridges over railroads. Bridges have been built with semi-integral, fully integral, and load bearing backwalls, precast parapets and balustrades and even precast approach slabs, all to facilitate installation and accommodate special project conditions.

The privately-developed formerly patented precast composite bridge system that was once regarded as clever, but not taken seriously, has come a long way. Its use in over 13 states is now approaching nearly one million square feet and growing. It is a system that is here to stay, and the concepts that have been developed and used successfully on past projects may well have valuable application on future rapid bridge replacement projects.▪

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