Longer spans possible

Nebraska professor proposes new standard precast bridge girder shapes

By Grant T. Halvorsen

At the 1993 International Bridge Conference (IBC), held in Pittsburgh June 14-16, University of Nebraska Professor Maher K. Tadros proposed a new generation of I-girder shapes for highway bridges. The presentation was based on K. Lynn Geren's master's thesis, with research partially supported by the Precast/Prestressed Concrete Institute (PCI).

The proposed new girders have varying depths, but the top and bottom flanges don't change from section to section. The section dimensions have been selected in hard metric form. At present, proposed girder depths range from 1600 to 2800 mm in 400-mm increments, but additional sections also may be added. Some states are interested in shallower metric sections for uses like bridge widening where existing construction is AASHTO Types I-IV. The shallowest proposed section is about 63 inches deep, similar to some bulb tees now used. Other current bulb tees are about 72 inches, or 1800 mm, deep. The deeper proposed sections, up to nearly 110 inches, offer the potential for increased load capacity or longer spans. The shapes have a wide, bulky, bottom flange, thin web, and wide, shallow top flange. Rounded corners are provided at the flange tips and flange-web junction to improve bridge esthetics and placement of girder concrete.

Nebraska has adopted the new shapes, and several other states are considering them. The PCI Bridge Committee and the Prestressed Concrete Subcommittee of AASHTO's Committee on Bridges and Structures are evaluating the new shapes, but haven't set a timetable for endorsement.

For producers, there are several implications of these shapes, or others like them. Like the existing AASHTO Type V and Type VI sections, the top and bottom flanges of the proposed new sections have the same size, shape, and web width. Each section could be produced with the same basic set of forms, with insert panels to adjust the section depth. Although new forms will be required, costs should be less than if four completely different sections were specified.

By using the new shapes in conjunction with field splices and full-length post-tensioning, clear spans up to about 250 feet appear feasible. This should increase the ability to market precast/prestressed concrete as a product for longer spans. Requirements for field post-tensioning may require some changes in the plant. Producers will need to become familiar with placing ductwork to the specified profile. They will also need to place and consolidate concrete with the 75-mm diameter duct in the 175-mm girder web (or a 3-inch duct in a 7-inch web).

Current standard I-girder sections

Standard bridge girder shapes in the United States began evolving in the mid-1950s. Early precast/prestressed highway bridge girder shapes often were designed on a job-by-job basis. Designers had preferences for specific shapes, and producers found it expensive to design custom girder forms for each bridge.

Throughout design, production, and construction of precast concrete, standardized shapes are advantageous. Designers can develop plans faster, using design aids and standard details. The producer benefits by repetitive use of formwork and a work force familiar with the products. The contractor can develop lifting hardware and field procedures that can be repeated from one site to another.

The initial set of standard girder shapes was developed by representatives of organizations now known as the Federal Highway Administration (FHWA), American Association of State Highway and Transportation Officials (AASHTO) and the Precast/Prestressed Concrete Institute (PCI). Standard shapes for bridge girders contributed to the rapid and widespread growth of prestressed concrete highway bridge construction.

Figure 1. shows the original four sections (now known as AASHTO Types I-IV), more recent sections, and those just proposed. The first sections were developed to optimize the use of concrete and prestressing steel for design and construction practices of the 1950s and 1960s, 60- to 80-foot simple spans, 5000 psi concrete, and 1/2-inch diameter Grade 250 strand. The I-girders that resulted are stocky, with wide webs and generous chamfers between the flange tip and web (a must for con-

crete placement and consolidation before the day of high-range water reducers). Because of economics, Types I and II are rarely used, and Types V and VI (standardized in the early 1960s), along with the PCI Bulb Tees (recognized by the AASHTO bridge engineers as an industry standard in 1988) are used for longer spans. Girder cross sections change to reflect the relative importance of dead and live loads, as well as bending and shear, as spans increase.

Other girder sections, or variations of the AASHTO sections, are used in some states to reflect regional differences in materials and technology. For example, some states use a 5-inch web in 6-foot-deep girders where the producers are confident of their ability to place and consolidate concrete in the bottom flange. In other parts of the country, a minimum web width of at least 6 inches is required.

Citing the nearly 30-year period needed for the Bulb Tee to be adopted, Geren and Tadros concluded that I-girder evolution had become stagnated. They believe there has been little incentive for significant change, because existing shapes still have a competitive advantage over rolled steel sections.

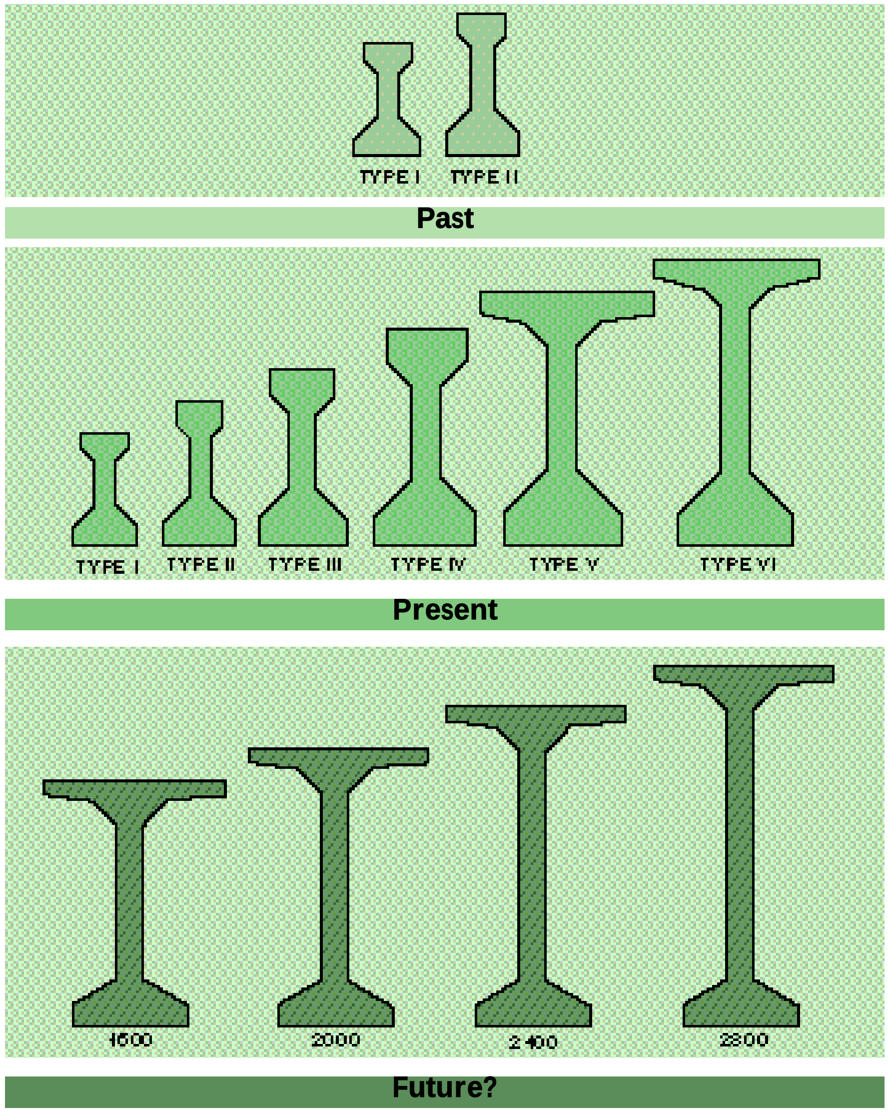

Figure 1. Standard shapes for precast/prestressed I-girders have evolved since the 1950s. Original stocky girder shapes are being replaced with deeper sections for longer spans and heavier loads. University of Nebraska researchers propose a new generation of I-girder shapes with metric dimensions. Differing only in overall depth, these shapes are proportioned to be efficient for the field post-tensioning required to achieve long clear spans.

Changed materials

Functional and structural designs of highway bridges have changed significantly since the early days of the interstate program. These differences lead to new limitations on the most efficient shape for precast I-girders. In the 1950s, typical bridges over interstate highways often consisted of four simple spans, 60 to 80 feet long. A center pier was located in the median between the drive lanes, with additional piers placed between the shoulder and abutment.

Highway safety requirements have eliminated piers between the shoulder and abutment, so it's necessary to span from the abutment to center pier. This long clear span can be provided by making longer members, or field splicing shorter girders. Shipping considerations usually limit single girders to 120 to 140 feet, so longer spans require a field splice.

Simple-span bridges, bridges with joints over each pier, also are less common than they once were. Continuous construction eliminates some high-maintenance bridge joints. Bridges with joints intended to pass water, or joints having failed seals, often have significant substructure corrosion problems. Reducing the number of joints helps with maintenance, but complicates design and construction. Continuous bridges can be made by connecting girders of two adjacent spans over a pier, or by splicing segments within the span. Nonprestressed reinforcement in the cast-in-place bridge deck can be used to make adjacent girders continuous. Full-length field post-tensioning is perhaps more versatile and effective.

Another approach uses cast-in-place girder field splices located at points of relatively low bending moment within the span and post-tensioning coupled at the splice. This construction is suitable when the required girder clear span is greater than the length of girders that can be shipped. Tadros and his associates recently prepared an extensive state-of-the-art report on spliced I-girder bridges. Published as a report of PCI's Bridge Committee, it describes 50 spliced-girder bridges constructed recently and also contains a design example and splice details. The report is available from the Precast/Prestressed Concrete Institute, 175 W. Jackson Blvd., Suite 1859, Chicago, IL 60604 (312-786-0300; fax: 312.786.0353).

Proposed sections

Geren and Tadros reviewed existing standard sections and decided to study new ways to optimize girder cross sections. Nearly 90 state engineers, bridge consultants, precast producers and formwork suppliers provided input early in the study. Although the current generations of standard shapes were selected considering only positive bending moment, the girders resist positive and negative moments when used in continuous construction. The optimization of the girder shape was based on three precast/prestressed concrete girder segments produced with current materials and post-tensioned to make a continuous two-span highway bridge designed for HS-25 truck loading. The bridge girder system consists of a double-cantilever segment placed over the center pier, and one longer segment placed in each span as shown in Figure 2. For a segment length equal to 80% of the clear span, maximum stresses due to transporting and handling the segments are located at about the same place as those due to loads in the final structure. This makes more efficient use of the girder reinforcement.

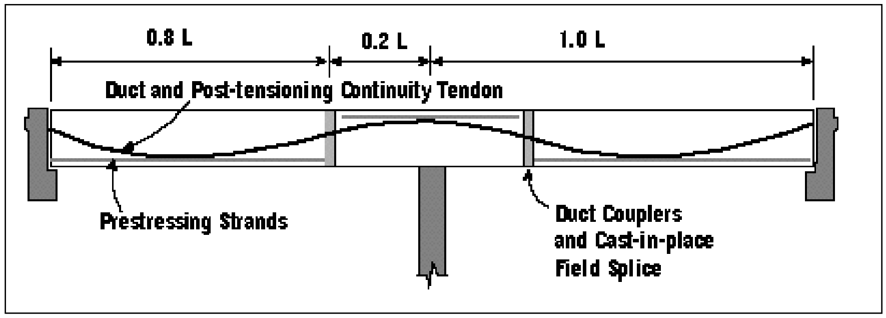

Figure 2. Field post-tensioning of precast/prestressed I-girder segments allows construction of clear spans which are 25% longer than those with single girders. For this configuration, girder reinforcement is very efficient because greatest handling and service load effects occur at the same locations.

The proposed sections were then identified by finding the most efficient concrete cross section with sufficient web space for post-tensioning ducts, and a wide bottom flange to resist compression in negative moment regions. The researchers also discovered that the current 72-inch PCI bulb tee, with its web thickened about an inch, could be a cost-effective girder section for spans up to about 140 feet. Even so, the 1600-mm deep proposed section is about 8 inches shallower and can span farther. For shorter spans the cost premium for the 1600-mm section is estimated as about 50¢ per square foot, or about 1% of the bridge deck cost. In general, the new girders appear able to resist higher loads with shallower sections, an advantage for their use in replacement construction.

Will these sections be the wave of the future? We don't know, but it's a sure bet that development of precast/prestressed girders won't stand still. The Nebraska researchers continue to refine their concept with design aids and reinforcement details. Sponsorship continues from the Nebraska Department of Roads, with advisory participation from several surrounding states.

Geren and Tadros' paper, "The Next Generation of Precast I-Girder Shapes," will be published in the Proceedings of the 10th International Bridge Conference. The $45 volume of conference proceedings will be available from The Engineers' Society of Western Pennsylvania, Pittsburgh Engineers' Building, 337 Fourth Ave., Pittsburgh, PA 15222 (412-261-0710; fax: 412.261.1606) later this year. Meanwhile, for more information, contact Dr. Maher K. Tadros, Center for Infrastructure Research, University of Nebraska, 60th and Dodge Streets, Omaha, NE 68182 (402-554-2980). ■

PUBLICATION #J930801C