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Longer Bridge Spans with Nebraska's NU I-Girders

Nebraska Department of Roads

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Bridge designers are continually being challenged to design long-span structures with low initial costs. While precast prestressed concrete I-girder bridge systems are economical and versatile, they can be made more efficient through the use of new material technologies. The University of Nebraska's I-girder series uses a unique cross section and high-strength concrete to achieve longer spans. To address concerns related to the transportation and erection of long, heavy I-girder segments, the university developed a segmented girder system that is spliced in the field using post-tensioning techniques. A haunched variable-depth segment enhances aesthetic appeal and structural efficiency. These innovative features allow for spans up to 90 m (300 ft).

Problem

Increasingly, precast prestressed concrete bridges are being constructed as continuous-span structures to increase span length and achieve greater economy. Nevertheless, bridge designers are severely constrained by the standard girders of the American Association of State Highway and Transportation Officials, which were developed for simple-span structures and are designed to accommodate tensile stresses that occur only in the lower portion of the girder. In contrast, continuous-span structures must resist tensile stresses throughout the girder. Longer continuous spans are also difficult to achieve with the AASHTO girders because of insufficient compression area in the bottom of the girder and web widths too small to accommodate continuity post-tensioning.

While several states have developed new standard girders to increase structural efficiency and span length, the transportation and erection of long spans remain challenging. To optimize the financial savings to highway departments, the girders should be easy and inexpensive to manufacture, transport, and erect.

Solution

The NU I-girder series, developed by the University of Nebraska's Center for Infrastructure Research in cooperation with the Nebraska Department of Roads, spans farther than any other standard I-girder shape available today. The new girders have depths ranging from 750 to 2400 mm (30 to 95 in.), with constant top and bottom flange dimensions. The girder's cross section, shown in Figure 1, provides several advantages. The wide top flange allows for better worker-platform and shorter deck-slab spans. The wide and thick bottom flange enables increased strand capacity for simple spans and provides increased negative moment capacity for continuous spans. The bottom flange is also designed for

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increased stability in shipping and handling. Curved fillets reduce stress concentration and aid the flow of concrete during fabrication.

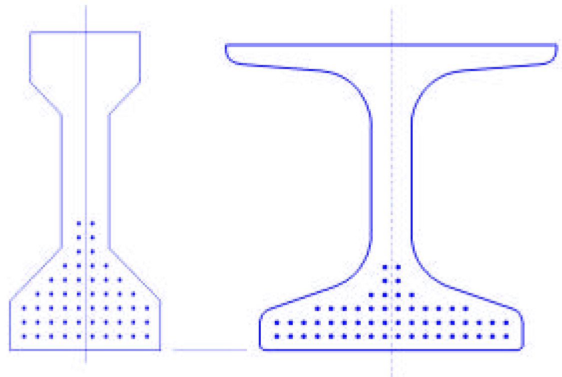

FIGURE 1 NU (*right*) and standard I-girder's bottom flange is much larger than its top flange. This design accommodates more prestressing strands and enables the girder to withstand increased loads of longer spans.

To address fabrication, transportation, and erection challenges, the NU I-girders have the following features:

- A haunched girder shape that provides an increase in depth of 1 m (3.3 ft) over a distance of 5 m (16.4 ft) to allow the use of one set of forms for all girder sizes and all bridge spans. The NU2000 I-girder can span up to 90 m (300 ft), twice the length of a girder without a haunched segment.
- Standard prefabricated welded wire reinforcement cages, with wire diameters as large as 9 mm (0.33 in.), to expedite fabrication while providing excellent quality control.
- An anchorage block that weighs only 2 tons (about 20 percent of the weight of the standard block) and provides for less reinforcement congestion. Reinforcement details are standardized such that the same reinforcement is used irrespective of the amount of post-tensioning, girder span, or girder spacing.

Application

Since 1994 more than 40 bridges have been constructed in Nebraska using the NU I-girder. The Nebraska Department of Roads has adopted the NU I-girder as a standard for all prestressed concrete bridges. Mexico has also elected to use the new girder, and several other U.S. states and Canadian provinces have adopted similar sections.

Benefits

The NU I-girder series uses an economical precast prestressed concrete system for longer girder spans. The new haunched girder shape allows the NU2000 I-girder to span up to 90 m (300 ft), maintaining structural efficiency while improving aesthetics. In comparison with all types of standard I-girders used in bridge systems, the NU2000 I-girder offers the advantage of allowing longer spans while maintaining the same depth. The Nebraska Department of Roads has used the new girder to develop concrete systems as an alternative to structural steel for spans of up to 67 m (220 ft); the standard I-girders were limited to spans of 43 m (140 ft). The girders' large span-to-depth ratio allows their use as alternatives to steel plate girders without the need to increase the superstructure depth; the result is a simplified design and reduced embankment cost.

Specific features of the NU I-girders provide additional benefits. Standardization of welded wire fabric sizes simplifies the design and production of the girders and reduces fabrication time by as much as 40 percent. The reduced anchorage block weight contributes to a reduction in fabrication and transportation costs.

The construction of two similar bridges near Omaha, Nebraska, in the mid-1990s illustrates the savings that can be realized from the use of the new design. The bridges were 67 m (225 ft) long and 26 m (85 ft) wide, and each consisted of three 23 m (75 ft) spans. The first, conventional bridge required 11 Nebraska Type 3 girders per span at a spacing of 2.4 m (7 ft, 11 in.); the other bridge required 7 NU I-girders per span at a spacing of 3.8 m (12 ft, 5 in.). Girder heights were similar---1.14 m (45 in.) and 1.09 m (43 in.) for the Nebraska Type 3 girders and NU I-girders, respectively. The cost of both girders was about \$492/m (\$150/ft). The cost saving is calculated as 4 girders/span x 23 m/girder x \$492/m x 3 spans = \$135,000/bridge or \$76/m^2 = (\$7/ft^2).

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Suggestions for "Research Pays Off" topics are welcome. Contact G. P. Jayaprakash, Transportation Research Board, 2101 Constitution Avenue, N.W., Washington, D.C. 20418 (telephone 202-334-2952, e-mail gjayapra@nas.edu).