CENTER FOR TRANSPORTATION RESEARCH

PROJECT SUMMARY

Texas Department of Transportation

0-6831: End-Region Behavior of Pretensioned Concrete Beams with 0.7-inch Prestressing Strands

Background

The majority of pretensioned concrete elements currently fabricated use 0.5- or 0.6-in. diameter strands as the prestressing steel. However, in recent years, there has been interest in using 0.7-in. diameter strands in pretensioning applications. The use of these larger-diameter strands is believed to improve the efficiency of pretensioned concrete elements by reducing the number of required strands and making it possible to concentrate a greater steel area near the bottom of the cross section. However, the effects of using 0.7-in. strands on the serviceability and strength of pretensioned girders need to be identified and addressed before potential implementation of girders that employ these larger-diameter strands in bridge applications. Greater transverse tensile stresses are expected to develop, which may lead to excessive cracking and diminished serviceability of girders. Moreover, use of 0.7-in. diameter strands may increase the likelihood of atypical shear failure modes such as anchorage-induced shear failure and horizontal shear failure.

This project was initiated to address the discrepancies and limitations of previous studies and fill some of the gaps in knowledge concerning the use of 0.7-in. strands in pretensioned concrete girders, with a focus on Texas bulb-tee girders (Tx-girders).

What the Researchers Did

We completed the following major tasks:

1. A parametric investigation was conducted to examine the benefits and limitations of using 0.7-in. prestressing strands in more than 10,000 bridge configurations. The main parameters of interest were strand diameter, girder cross section type, compressive release strength, span length, and spacing between the girders.

2. Seven full-scale Tx-girder specimens (two Tx70 and five Tx46 girders) were fabricated at Ferguson Structural Engineering Laboratory using typical industry practices. The specimens employed 0.7-in. diameter strands on the standard 2- by 2-in. grid that is commonly used for pretensioned girders with smaller-diameter strands. All specimens were extensively instrumented to determine the transfer length, end-region stresses, and prestress losses.

3. All specimens were tested as simply supported elements under shear-critical loading until failure. A symmetric loading configuration was used for testing the specimens, with shear span-depth ratios of 3 and 2.3 for Tx46 and Tx70 specimens, respectively. During the shear tests, the specimens were monitored for load-deflection response, stresses within transverse reinforcement, strand slip, and patterns of cracking and damage. The specimens' nominal load-carrying capacities were calculated using AASHTO LRFD specifications.

4. A series of finite element simulations was conducted in ATENA 3D to supplement the experimental program. Data from both previous experimental studies and the current research project were used to validate the modeling assumptions.

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What They Found

1. The parametric investigation showed that the use of 0.7-in. diameter strands results in a considerable reduction in the number of strands required compared to smaller-diameter strands, which may lead to notable savings in the time and cost of precast fabrication. Benefits other than the reduction in the number of strands were found to be highly dependent on increasing the compressive release strength of concrete above the commonly used values.

2. The transfer lengths immediately after prestress transfer were generally shorter than 42 in., which is the estimate obtained from AASHTO LRFD bridge design specifications, but slightly exceeded this estimate after 24 hours. However, this project's findings do not reveal any concerns regarding the use of 42 in. as the transfer length for 0.7-in. diameter strands in the calculations for Tx-girders.

3. All specimens developed cracks within their end-regions after prestress transfer, which continued to grow in length, width, and number over time. However, the patterns of end-region cracking were similar to those observed in Tx-girders currently fabricated using 0.6-in. diameter strands. All specimens were deemed acceptable for exposure to deicing chemicals according to ACI 224R-01 guidelines.

4. The greatest stresses in the end-region reinforcement at the time of prestress transfer were detected at the interface between the web and the bottom flange. However, these stresses were found to diminish very quickly with the increase in distance from the end face. As a result, large stresses were generated only in the end-region reinforcement that was located within the overhang region or directly over the support.

5. Results from the shear tests showed that the use of 0.7-in. diameter prestressing strands increases the likelihood of atypical failure modes in Tx-girders. Almost all specimens showed clear signs of anchorage-zone distress. The atypical failure mechanisms did not prohibit the specimens from achieving the shear-tension failure, which is the basis for calculations of shear strength in AASHTO LRFD general method.

6. Increasing the diameter of vertical end-region reinforcement bars or adding horizontal end-region reinforcement in the web were found to be ineffective in reducing the widths of end-region cracks. However, the addition of a series of "cap bars" resulted in noticeably smaller strand slip and greater load-carrying and deformation capacities.

What This Means

The findings of this research project showed that 0.7-in. diameter strands can be used on a 2- by 2-in. grid in Tx-girders. The observed cracking patterns and damage in the specimens did not reveal a critical need to modify the end-region reinforcement in Tx-girders for incorporating 0.7-in. diameter strands. Moreover, no concerns were identified regarding the conservativeness of AASHTO LRFD bridge design specifications in predicting the load-carrying capacities of such girders under shear-critical loading conditions. However, the use of cap bars, which was found to be very effective in controlling the strand slip under applied loads, is recommended for incorporation in the standard drawings of Tx-girders employing 0.7- or 0.6-in. diameter prestressing strands.

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