Project Summary

Texas Department of Transportation

0-5253: D-Region Strength and Serviceability Design

Background

Since the inclusion of Strut-and-Tie Modeling (STM) provisions in the AASHTO LRFD specifications in 1994, TxDOT engineers have been examining the impact that the provisions have on the design of their bent caps. In general, it has been difficult to implement the STM provisions due to their seemingly complicated nature. In addition, bents in the state of Texas are experiencing diagonal cracking problems with increasing frequency. These field-related issues and the difficulty in implementing the AASHTO LRFD provisions in their design practice were the impetus for TxDOT to fund the current project. The overall objective for the project was to develop safe and consistent design guidelines in regards to both strength and serviceability of bent caps and other deep beams.

What the Researchers Did

To achieve the primary research objective stated above, a database of test results from the literature was compiled; and an experimental program was conducted. The total number of deep beam tests ($a/d \leq 2.5$) in the database, including the specimens of the current project, was 904. The data from the literature was generally insufficient to address the objectives of the current project for two reasons. First, very little serviceability information (primarily diagonal crack width data) existed in the literature. Second, the cross-sectional dimensions of deep beams, particularly the beam width, tested in the past were drastically smaller than those of members in service. It was determined that the best means to improve the design and performance of actual bent caps was to examine specimens that were as representative as possible. As a result, filtering criteria were established based primarily off of cross-sectional dimensions, quantity of web reinforcement, and sufficient bearing plate details to remove specimens from the database that were exceptionally un-representative of actual members. The final evaluation database consisted of 178 tests—including the specimens of the current project.

For the reasons stated above, 36 tests were conducted consisting on some of the largest reinforced concrete deep beams ever tested in the history of shear research. The cross-sectional dimensions of the test specimens included the following sizes: 21”x23”, 21”x42”, 21”x44”, 21”x75”, and 36”x48”. During the tests, measurements of the applied loads, the deflections along the beam, the strains at various locations throughout the section and along the member, and the maximum diagonal crack widths in the test spans were recorded. With the data from these tests and from the database, the primary objective of the current project was addressed.

Research Performed by:

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What They Found

A new STM design procedure was developed for the design of deep beams. The new method was formulated based on the methodology published by the International Federation for Structural Concrete (fib, 1999) while maintaining consistency with ACI 318-08 and AASHTO LRFD (2008). In addition, the proposed method was calibrated based on beams that were considered more representative of beams designed in practice—in terms of their size and reinforcement details. The newly proposed STM procedure is: 1) simpler, and 2) more accurate than the ACI 318-08 and AASHTO LRFD (2008) STM design provisions. The procedure is based on the fundamental principles of STM and on the procedures established in ACI 318-08, AASHTO LRFD (2008), and fib (1999). Thus, it has been derived based on theoretical principles, tests of D-regions, and by maintaining consistency with current design provisions. The procedure is practical, yields conservative strength estimates, and has been derived in a comprehensive and transparent manner. Implementation of the new design provisions into AASHTO LRFD Bridge Design Specifications (2008) is recommended.

A simple and conservative equation to estimate the diagonal cracking load of deep beams was developed that was a function of the shear area, the square root of the compressive strength of concrete, and the a/d ratio.

A simple chart was developed to correlate the maximum diagonal crack width in a deep beam to the load acting on the member, quantified as a percent of its ultimate capacity.

What This Means

New strut-and-tie model design provisions for strength were developed. These provisions are simpler and more accurate than those in AASHTO LRFD (2008) and ACI 318-08, and they are just as conservative. These design provisions were calibrated to improve the serviceability performance of bent caps. Improved serviceability performance will reduce the cost of bridge maintenance in Texas. In addition, the knowledge obtained from this study was also used to develop tools to simplify the structural evaluation of bent caps in the field. The use of these evaluation tools will reduce bridge inspection costs and improve safety by more accurately assessing which elements are in need of repair.

For More Information:
0-5253-1 Strength and Serviceability Design of Reinforced Concrete Deep Beams

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