Project Summary
Texas Department of Transportation

0-4811: Shear Connector Design for Composite Steel Beams - Strength Limit State

Background

The AASHTO LRFD Bridge Design Specifications provide rules for strength design of shear connectors for steel composite beams. These current rules require that sufficient shear studs be provided to develop the full composite strength of the steel beam. That is, shear studs must be provided to develop the full plastic strength of the cross-section, regardless of the actual loads on the beam. If the full composite flexural capacity of the cross-section is not needed to resist the design loads, then potentially many more studs are provided than actually needed. This is inconsistent with AASHTO rules for composite concrete beams. The current AASHTO rules for composite steel beams may require an excessive number of studs that can be difficult to place without violating current rules for minimum stud spacing, and may pose particular problems for TxDOT standard steel beam spans.

A primary objective of this project is to determine if changes are warranted that would permit shear connectors to be designed based on required strength, rather than based on cross-section properties. Since 1969 the American Institute of Steel Construction (AISC) specification for buildings has permitted composite steel beams to be designed as *partially* composite so the number of shear studs can be chosen based on the actual loading on the beam. For cases where full composite strength is not needed, the use of partial composite design can result in a substantial decrease in the required number of shear studs.

What the Researchers Did

A survey of the literature was conducted to establish the basis for the composite design provisions in the current specifications for bridges and buildings. In order to address the issues and apparent inconsistencies in the AASHTO shear connector design requirements for composite steel beams, four areas of composite beam design were evaluated: stud design philosophy, deflections, stud spacing requirements and stud fatigue behavior. In some cases where the existing research was associated with the elastic stress design approach, the data were reevaluated based on the plastic strength method in the LRFD design provisions.

Research Performed by:

Center for Transportation Research (CTR), The University of Texas System

Research Supervisor:
Joseph Yura, CTR

Researcher:
Michael Engelhardt, CTR

Project Completed:
8-31-04

What They Found

The AISC specification has design recommendations for calculation of both strength and deflections of partial composite beams. As expected, the partial composite design concept has a firm theoretical and experimental research foundation and is accepted in all international codes. Composite stud strength design in AASHTO and other codes is based on plastic design principles that assume the end studs have sufficient ductility to allow a uniform distribution of stud shear capacity in the positive moment region. The maximum span lengths in the experimental data for composite beams is approximately 40 feet, yet composite design is routinely used in bridges with spans that exceed 250 feet. Research should be conducted to investigate the plastic stud design approach for long span bridges. Elastic service load deflections calculated on the basis of a transformed section were found to be slightly underestimated. The effective moment of inertia for partial composite beams, as defined in AISC, is about 25 percent unconservative.

The maximum spacing of shear connectors of 24 inches that was established in the 1940's needs further research. This limit will prevent uplift of the slab and reduce the chances of moisture getting between the slab and steel beam. Moisture between the slab and the steel beam could cause corrosion problems. However, there is no record of non-composite bridges with excessive corrosion. Most codes have a maximum limit that is longer than 25 inches and is a function of slab thickness. The minimum shear connector spacing requirements should remain the same unless experiments are performed on push-out specimens or composite beams with a smaller shear stud spacing. If the minimum spacing requirements are reduced, then the requirements to allow for the proper compaction of the concrete given by ACI 318-02 should be considered, about 3d for a 7/8-inch diameter stud.

When designing a composite beam in accordance with AASHTO, the composite beam must meet strength and fatigue requirements. The fatigue design is based on a fatigue life equation developed in 1967 from push-out tests. This type of test is a conservative estimate of the actual behavior of shear studs in a composite beam. The AASHTO fatigue equation is conservative when compared to the fatigue life equation used in other codes.

What This Means

Current AASHTO bridge specifications require that composite beams have sufficient shear studs to fully yield the steel beam cross-section in tension. The large number of studs required is independent of the loading on the bridge. It is recommended that partial composite design, as used in building specifications, be permitted. It is shown that 85% of the full composite strength can be achieved with 40% fewer studs.

Additional tests are recommended to evaluate the possibility of relaxing the current minimum spacing requirement. The current AASHTO fatigue requirements for stud design are conservative but no change is recommended.

For More Information:
Research Engineer - German Claros, TxDOT, 512-465-7403
Project Director - John Holt, TxDOT, 512-416-2212
Research Supervisor - Joseph Yura, CTR, 512-471-7259

Technical reports when published are available at:
http://library.ctr.utexas.edu/index.html

Texas Department of Transportation
Research and Technology Implementation Office
P.O. Box 5080
Austin, Texas 78763-5080
512-465-7403

www.txdot.gov
keyword: research