



## TEXAS TECH UNIVERSITY CENTER FOR MULTIDISCIPLINARY RESEARCH IN TRANSPORTATION

Project Summary Report O-1853-S

Project O-1853

Authors: W.R. Burkett, W.P. Vann, R. Cedeno-Rosete & S. Turkeyilmaz

# Alternate Vertical Shear Reinforcement In Prestressed Concrete Beams: Summary

The use of precast, prestressed concrete I-beams with cast-in-place concrete deck slabs in highway bridge construction is a common practice in the United States. Efficient material utilization and cost effectiveness have led to the popularity of this construction technique and its widespread use. One innovative improvement is the use of Welded Wire Fabric (WWF) in lieu of traditional reinforcing bars to control tensile and shear stresses in the concrete. Using WWF allows a large number of bars to be prefabricated into a single unit and set into place at one time. This saves time and labor during the fabrication of the prestressed I-beam, which is a time-critical process.

Current Texas Department of Transportation (TxDOT) policy permits the substitution of, "An equal area of welded wire fabric for Bars R, V, S, or X if approved by the engineer." The R-bars and the S-bars were of primary and secondary interest in this project, respectively. The R-bars are bent stirrups that help carry the shear forces. The S-bars are straight bars that are placed in pairs between the R-bars only in

each end region of the I-beam (the first 38 inches) and are used to control tensile stresses and horizontal cracks in the thin web of the I-beam. The R-bar must remain fully anchored at its ends to function properly at ultimate load. The anchorage detail changes significantly when WWF is substituted for the standard TxDOT R-bar and S-bar details, thus the need for this project.

### What We Did...

This project consisted of 43 full-scale load tests conducted on 18 test specimens with multiple load tests on each specimen using some combination of the four load/support configurations shown in Figure 1. Load tests were conducted at the Civil Engineering Structural Test Laboratory at Texas Tech University in Lubbock, Texas. The basis of each test specimen was a 36-foot long, TxDOT Type A prestressed concrete I-beam. An 8-inch thick, 72-inch wide reinforced concrete deck slab was then cast-in-place to complete the test specimens and provide composite action. The slab was reinforced per TxDOT standards and was cast using 5,000-psi concrete. Both flexural

tests and shear tests were conducted on the specimens. During the flexural tests, the specimens were subjected to loads that caused internal moments that only slightly exceeded the theoretical ultimate moment capacity of the specimens. This was done to preserve the specimens and allow additional shear tests to be completed on the basically unaffected end regions of the specimens. During the shear tests, the specimens were loaded to complete failure.

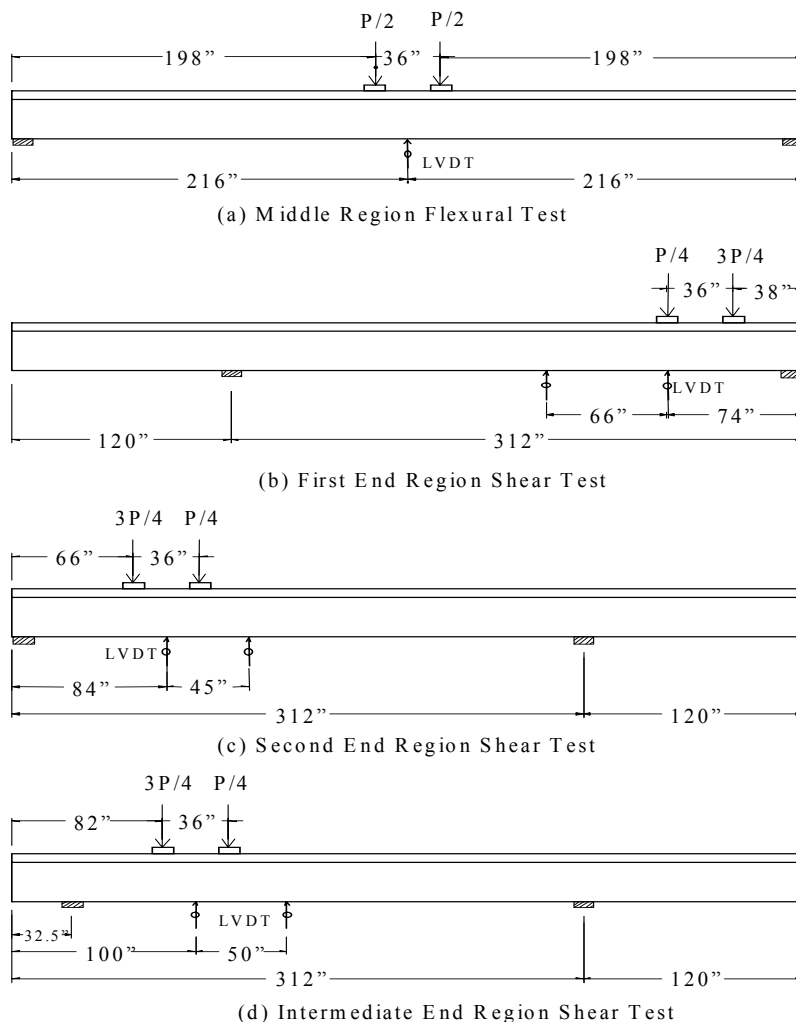
The I-beams were fabricated using combinations of five different shear reinforcing steel details, two shear steel design yield strengths, and two beam concrete strengths. For comparative purposes, TxDOT's standard deformed bar detail was used where #4 R-bars and #5 S-bars are alternately placed on 2-inch c/c spacings in the first 38 inches (first end region) of the beam, followed by #4 R-bars at 8-inch c/c spacings in the next 112 inches (second end region) of the beam. During this project, an 8-inch c/c R-bar spacing was used everywhere except for the first 38-inches on each end of the



beams to account for the expected higher than normal shear forces caused by the modified load/support configurations used during testing.

A “Matching WWF” detail was used, which used a one-for-one, size-for-size substitution of wires for bars. A “Simplified WWF” detail was used by substituting D26 wires spaced at 2-inch c/c in lieu of #4 R-bars and #5 S-bars spaced alternately at 2-inch c/c in the first end regions of the beam. This detail was developed to provide better economy in the fabrication of the WWF cage. An “Equal Strength” WWF detail was used and consisted of the simplified detail concept of a single wire size in a given region of the beam but used proportionately smaller areas of wires as the steel design yield stress was increased from 60-ksi to 80-ksi. An “Alternate R-bar” detail was used that used the “Standard Bar” sizes and spacing but the 90-degree hook on the bottom of each R-bar leg was rotated 90-degrees and oriented parallel to the axis of the beam in an effort to alleviate the bottom concrete cover problem sometimes associated with TxDOT’s standard R-bar detail.

The two shear steel design yield strengths that were used were 60 and 80-ksi, where 60-ksi is the maximum value allowed by AASHTO specifications and 80-ksi is the more common value of the wire material. The two beam concrete strengths that were used were normal strength concrete (NSC) in the 5,000 to 7,000-psi range and high strength concrete (HSC) in the 10,000 to 12,000-psi range. The prestressing strands were 270-ksi, one-half-inch diameter, low relaxation, seven-wire strands, stressed to 75% of guts, and were placed on a 2-inch c/c grid. The NSC beams were fabricated using 10 strands, six straight and four harped, and the HSC beams were fabricated using 14 strands, eight straight and six harped.

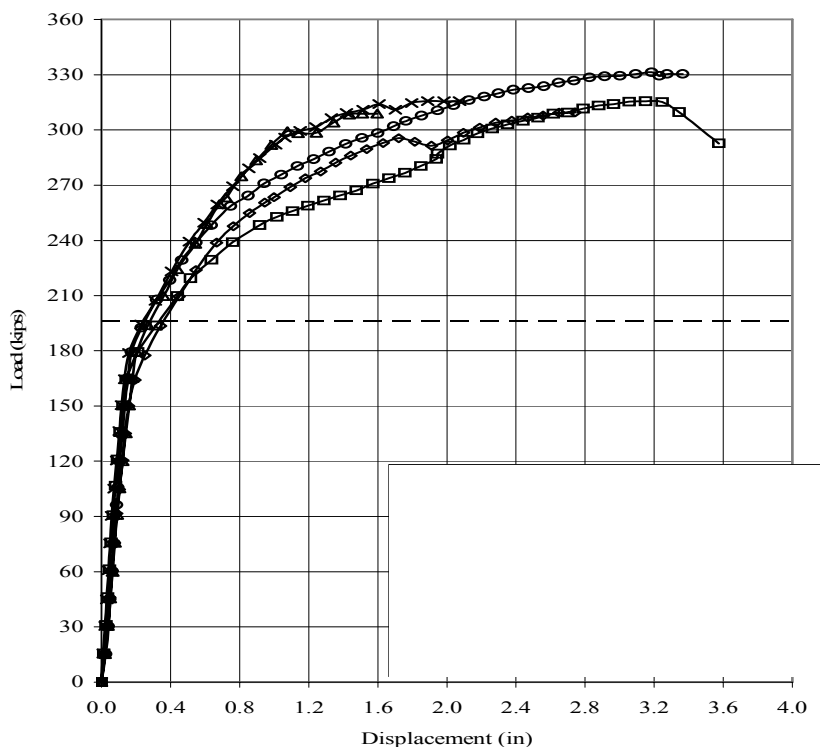


**Figure 1: Load and Support Test Configurations**

The four load and support test configurations shown in Figure 1 were developed for specific purposes. Part (a), the “middle region flexural test,” was developed to test the specimens in flexure and verify the primary design response of the specimens. Part (b), the “first end region shear test,” was developed to force a shear failure in the heavily reinforced, first end region of the specimen. The failure mode associated with this type of test was not shear but was either crushing of the beam’s web concrete due to the development of a compression strut between the near load point and support or splitting off of part of the lower flange due to slippage of one or more of the strands at the end of the beam. Part (c), the “second end region shear test,” was developed to

force a shear failure just inside the second end region where the stirrups were spaced at 8-inch c/c. In all of the specimens except the “equal strength” WWF specimens, the failure mode in this type of test was either a flexural or a shear-flexural failure mode, in spite of a 40% margin of safety against a flexural failure when using AASHTO values. Only the equal strength WWF specimens failed in shear when loaded using the second end region shear test configuration. Part (d), the “intermediate end region shear test,” was developed, as an artificial load configuration, to force a shear failure in the second end region of the beam after the second end region shear tests were not fully successful in doing so. The typical failure mode in this type of test was shear.





**Figure 2: Load-Deflection Curves for NSC Second End Region Shear tests, Second Beam of Pair**

The specimens were loaded incrementally and data recorded at each load increment. In all tests, 15-kip increments were used while the specimens were in their elastic ranges. Once the specimens moved beyond their elastic ranges, a second load increment was used. During the middle region flexural tests, a second load increment of 5 kips was used until the tests were stopped when the extreme concrete fiber strain reached a value of 0.002. During the three other types of shear tests, a second load increment of 10 kips was used. The 10-kip increment was continued during the first end regions shear tests until failure occurred. The 10-kip increment was continued during the second and intermediate end region shear test until the 10-kip increment produced an associated deflection greater than 1/10th of an inch. Thereafter, a 1/10th of an inch deflection increment controlled

load application until failure. Data collected at the increments of the various tests included applied load, specimen deflection, maximum strain in the concrete deck, strains in selected stirrups during selected tests, and strand end-slip in selected strands during selected tests. In addition, conventional and digital photographs were taken to document crack patterns and distributions at selected load levels. The digital images were processed using a technique developed during this project and used to evaluate and compare crack patterns, sizes, and distributions between specimens at common load values near failure.

### What We Found...

The specimens in this test program all performed up to expectations in that, the

capacity of the beam met or exceeded the AASHTO design capacity, in flexure and shear. In comparing the performance of the beams with WWF details or the alternate R-bar detail to those with the standard TxDOT detail, the specimens had similar or improved responses when comparing ductility ratios, elastic and plastic stiffnesses, and loads at first cracking. This generally comparable behavior was true for specimens using normal strength and high strength concrete. Typical load-deflection curves are provided in Figure 2 for the second end region shear tests for all five of the specimens with different shear reinforcement details and normal strength concrete.

Cracking in all the specimens was also comparable at comparable loads near failure. Crack areas and widths, as quantified by the newly developed digital imaging technique, were almost the same for the WWF and alternate R-bar specimens when compared to standard TxDOT specimens. Good crack width and crack area results were obtained by digital imaging for cracks of small to large width, but limitations were encountered in attempting to use the method on very narrow (hairline) cracks.

### The Researchers Recommend...

The primary recommendation from this report is the use of the simplified WWF detail and the two cross-wire anchorage detail at the bottom of each leg of the WWF stirrups. Other test parameters that proved to be effective during this project include: the use of the matching WWF detail, the use of 80-ksi wire, the use of the alternate R-bar detail, and the use of high strength concrete.

## *For More Details...*

The research is documented in the following reports:

Report No. 1853 - Alternate Vertical Shear Reinforcement In Prestressed Concrete Beams

Research Supervisor: W.R. Burkett, P.E.

Project Director: Tom Rummel, P.E., TxDOT Bridge Division

To obtain copies of the reports, contact the Center for Transportation Research Library at (512) 332-3126.

## **TXDOT IMPLEMENTATION STATUS December 2003...**

This project validated the common practice of substituting WWF for plain reinforcing bar shear reinforcement in pre-stressed concrete beams. The results are already being implemented through TxDOT review and approval of fabricator-submitted shop drawings proposing this substitution. The use of a simplified WWF standard detail developed as part of this project should result in fabrication efficiencies and standardization that create a better final product and a potential for some possible cost savings over conventional reinforcing bars.

For more information, contact; W.R. Burkett, P.E., (806) 742-3538.

## **Your Involvement Is Welcome...**

## **Disclaimer**

This research was performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration. The content of this report reflects the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. Trade names were used solely for information and not for product endorsement.



US Postage Paid  
Permit No. 391  
Austin, TX