Texas Department of Transportation

UNIVERSITY of HOUSTON

PROJECT SUMMARY REPORT

# 0-6905-01: Performance of Skewed Reinforcing in Inverted-T Bridge Caps

## Background

The inverted-T bridge caps (ITBCs) are widely adopted in Texas for increased bridge clearance, reduced bridge elevation, lower abutments, and larger spans with increased clearance and aesthetics. The traditional method of transverse reinforcing involves flaring out the transverse rebars, which has significant drawbacks in design and construction that compromise the structural performance of the ITBC in the long term. ITBCs in Texas are designed using the traditional empirical procedure outlined in the TxDOT Bridge Design Manual that conforms to the AASHTO. However, no precise methods or guidelines are given in the AASHTO-Load and Resistance Factor Design (LRFD) or TxDOT LRFD to design skew ITBCs. According to the results of lab tests from TxDOT Project 0-6905 (Phase 1, Initial Investigation of Performance of Skewed Reinforcing in Inverted-T Bridge Caps), using skewed transverse reinforcement throughout ITBCs will have the same load capacity as the traditional design. In addition, it is found that using skewed transverse reinforcement throughout ITBCs will have a fewer number of cracks and smaller crack widths compared to the traditional design. Further, Phase 2 of TxDOT Project 0-6905 performed a parametric study on the ITBC that found better structural performance of the ITBC with skewed transverse reinforcing than traditional transverse reinforcement with notably reduced construction cost. This project investigates the implementation of skew reinforcing in ITBCs of the Donigan Road Bridge at Katy, Texas.

## What the Researchers Did

In this research, two significant ITBCs are selected to investigate the structural performance of skew reinforcing. The global models for ITBC 2 (skew angle 430) and ITBC 7 (skew angle 330) are established with four columns, I-girders in the forward and backward span, and a deck. Each ITBC is simulated in 15 cases of Static Test-1. Further, two critical cases of Static Test-1 were simulated in five positions in Static Test-2. The nonlinear finite element (FE) simulations of 50 full-scale bent caps are performed to identify sensor installation locations and critical cases for load tests. Each bent cap was tested in Static Test-1, Static Test-2, Dynamic Test-1, and one case of Dynamic Test-2 (see Figure 1). The experimental investigation on the ITBC focused on (1) skew angle, (2) skew reinforcing of transverse rebars, (3) location of exterior loading pads, and (4) loading cases. The parametric study is conducted to further investigate the effects of the skew angle and the location of exterior loading pads on the ITBC. The parametric study examined the strain on transverse rebars, torsional effects, higher-end face displacements, and magnified compressive stress on the exterior loading pads of ITBC.

(a) Bent Cap 2

(b) Bent Cap 7

Figure 1. Load Test on Inverted-T Bridge Caps of Donigan Road Bridge


**Research Performed by:**
University of Houston

**Research Supervisor:**
Dr. Y. L. Mo

**Researchers:**
Bhagirath Joshi
Nagesh Ramaswamy
Priyanka Shrestha
Jiaji Wang
Xiaonan Shan
Thomas T.C. Hsu



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## What They Found

Based on the load tests and finite element analysis (FEA) on ITBC 2 and ITBC 7 of Donigan Road Bridge over I-10, the following main conclusions are presented:

- Tensile strains on the S bars (south side, near end face) and M bars (at the interface of ledge and stem) are higher in critical loading cases, particularly with truckloads positioned in two lanes or closer to the parapet. Torsion affects strain patterns, with higher compressive strain observed in the north side S bars.
- The location of exterior loading pads influences strain distribution, with the fourth and fifth G bars experiencing higher tensile strains. Diagonal G bars at the end faces reduce strains in transverse bars near these pads.
- Loading scenarios with truckloads concentrated in one lane (near the parapet) produce higher transverse rebar strains and displacements, while two-lane truckloads reduce these effects.
- Concrete tensile strains at the stem and ledge interface are higher in all loading cases, but remain below the cracking strain. This indicates that skew reinforcement ensures the structural resilience of the ITBCs.
- The stem and ledge interface at the cantilever portion and the projected end face of the bent caps are identified as critical areas with higher tensile stresses and displacements.
- Static tests result in higher strains and displacements compared to dynamic tests, as static loading allows stress transfer to the ledge over time.
- Higher skew angles amplify tensile strains on transverse reinforcement, torsional effects on bent caps, and compressive stresses on exterior pads, while increasing end face displacements and tensile strain on concrete.

## What This Means

The following design recommendations are proposed for the design and construction of resilient inverted-T bridge caps:

- The S bars on the extended cantilever portion experience higher tensile strains, validating the TxDOT Project 0-6905 Phase-1 findings. Double S bars should be used throughout the bent cap, with spacing at column support areas not exceeding 12 inches to manage longitudinal rebar strains effectively.
- The inclusion of #6 U1, U2, and U3 end bars reduces crack width and ensures resilience. Skew reinforcement and end bars are critical for managing tensile strains at the stem and ledge interface, with calibrated models confirming strains remain below cracking levels.
- Diagonal G bars at the end faces delay cracking and reduce transverse bar strains near exterior loading pads. Providing #7 G bars up to the exterior loading pad location, at a maximum spacing of 6 inches, ensures optimal performance.
- A minimum compressive strength (f'c) of 5 ksi is recommended to increase ITBC stiffness and reduce cracking. To maintain performance consistency, the distance from the centerline of exterior girders to the end face of ITBCs should be at least 24 inches.
- Despite a smaller skew angle, the compressive stresses on exterior loading pads for Bent Cap 7 are comparable to those for Bent Cap 2, attributed to differences in loading pad distances. Proper geometric considerations should be integrated to balance stress distribution and displacement effects.

### For More Information

**Project Manager:**
Jade Adediwura, RTI Jade.Adediwura@txdot.gov

**Research Supervisor:**
Y.L. Mo, UH yilungmo@Central.UH.EDU

**Project Monitoring Committee Members:**
Michael Carlson, Walter Fisher, Courtney Holle, Abraham Ramirez

Research and Technology Implementation Division
Texas Department of Transportation
125 E. 11th Street
Austin, TX 78701-2483

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