Texas A&M Transportation Institute

PROJECT SUMMARY

Texas Department of Transportation

0-6893: Strengthening of Existing Inverted-T Bent Cap

Background

Inverted-T bent caps (Figure 1) are used extensively throughout Texas to economically satisfy geometric constraints and to provide an aesthetically pleasing appearance. With a change in design philosophy, many of the early inverted-T bent caps are deficient when evaluated against the current design approach and future increased traffic demands. When replacement of deficient bent caps is not practical due to cost, interruption to traffic, and/or the acceptable condition of other parts of the structure, robust proven techniques for providing supplemental strength are needed. Because no formal guidance is available in current standards, there is a need to investigate the effectiveness of strengthening solutions that adequately address deficiencies and reduce observed in-service damage of existing inverted-T bent caps.

What the Researchers Did

Field evaluations of inverted-T bent caps on I-35 and US 290 in Austin facilitated development of practical and impactful strengthening solutions. Eighteen retrofit solutions were developed to provide enhanced or alternative load paths for inverted-T bent caps with deficient capacities identified using current design codes. The proposed solutions were evaluated using a weighted sum model in terms of six criteria: strength increase, total cost, constructability, clearance constraints, durability, and ease of monitoring. The top six ranked retrofit solutions were tested in the lab on eight half-scale specimens, with tests designed to target the hanger, ledge, or punching shear capacities.

Figure 1. Inverted-T Bent Cap on I-35 in Austin, Texas.

Experimental results were used to develop recommendations to evaluate capacities of in-service inverted-T bent caps. These recommendations include proposed rational modifications for capacity calculations that are less conservative than present American Association of State Highway and Transportation Officials (AASHTO) *Load and Resistance Factor Design* (LRFD) provisions. Design recommendations were provided for the six tested solutions, with fully worked examples provided to guide future implementation.

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What They Found

Researchers found the following:

- **Service load damage** on the reference specimens was similar to observed damage on in-service bent caps. The measured ledge, hanger, and punching capacities of the specimens were larger than the estimated capacities based on AASHTO LRFD by 40 percent, 21 percent, and 32 percent in average, respectively.

- **End region stiffener retrofit** provided an average of 27 percent strength improvement. The solution was found to be effective in ledge strengthening, but the effectiveness for the hanger and punching strengthening was not clearly identified.

- **Load balancing post-tensioning retrofit** was not tested to ultimate failure. The retrofitted specimens showed substantial reduction in damage at loads expected on in-service bent caps when compared to the reference specimens. The retrofit was effective in strengthening the ledge, hanger, and punching capacities.

- **Larger bearing pad retrofit** increased the exterior capacity by 14 percent, but there was slight or no improvement of the interior capacity. The observed crack angle (35°) was shallower than the 45° assumed in the AASHTO LRFD.

- **Clamped threadbar with channel retrofit** provided an average of 35 percent strength improvement. The solution effectively improved the ledge, hanger, and punching capacities of the specimens. Implementation of the retrofit on damaged specimens was effective in restraining existing cracks.

- **Concrete infill with fiber-reinforced plastics (FRP) retrofits** provided an average strength increase of 44 percent and increased ductility. FRP retrofits were the most effective solutions to strengthening the interior portion of the bent cap. The efficiency of FRP solutions was significantly affected by the wrapping details and order of installation. Both full- and partial-depth FRP retrofits effectively improved the ledge and punching capacities, but only the full depth increased the hanger capacity.

What This Means

The solutions developed by this research are expected to provide increased capacity for existing substructure components on numerous direct connectors and other bridges, including the highly congested I-35 upper deck through downtown Austin. With the increased capacity, the in-service bridges will be able to accommodate higher traffic demand and have an extended service life.

For More Information

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