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16. Abstract

Prestressed concrete box beams incorporated in a bridge project under construction in the Houston District encountered cracking in the notched (dapped) ends during fabrication. Because the members in question are trapezoidal in section and have internal voids, a similar problem could occur in any beam having a voided cross section and dapped ends. As a result, dapped end designs for the section investigated in this study, as well as for similar open-top U-beam members, were reviewed by TxDOT design engineers and by researchers from The University of Texas at Austin.

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TESTING NOTCHED ENDS OF PRESTRESSED CONCRETE BOX BEAMS

by

Michael E. Kreger

Research Report 1479-2F/1340-1F

Research Project 0-1479/1340
Testing Notched Ends of Prestressed Concrete Box Beams

conducted for the

TEXAS DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. Department of Transportation
Federal Highway Administration

by the

CENTER FOR TRANSPORTATION RESEARCH
Bureau of Engineering Research
THE UNIVERSITY OF TEXAS AT AUSTIN

December 1994

IMPLEMENTATION STATEMENT

The findings of these studies can be used by the Texas Department of Transportation in designing stronger notched ends for prestressed concrete box beams. These findings can be immediately implemented on current bridge projects in the Houston District.

Prepared in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration

DISCLAIMERS

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of either the Federal Highway Administration or the Texas Department of Transportation. This report does not constitute a standard, specification, or regulation.

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Research Supervisors

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SUMMARY

Prestressed concrete box beams incorporated in a bridge project under construction in the Houston District encountered cracking in the notched (dapped) ends during fabrication. Because the members in question are trapezoidal in section and have internal voids, a similar problem could occur in any beam having a voided cross section and dapped ends. As a result, dapped end designs for the section investigated in this study, as well as for similar open-top U-beam members, were reviewed by TxDOT design engineers and by researchers from The University of Texas at Austin.

FINAL REPORT ON PROJECT 0-1479

TESTING NOTCHED ENDS OF PRESTRESSED CONCRETE BOX BEAMS

BACKGROUND

Prestressed concrete box beams incorporated in a bridge project under construction in the Houston District encountered cracking in the notched ends (also referred to as dapped ends) during fabrication. Because the members in question are trapezoidal in section and have internal voids, a similar problem could occur in any beam having a voided cross section and dapped ends. As a result, dapped end designs for the section investigated in this study as well as for similar open-top U-beam members were reviewed by TxDOT design engineers and by researchers from The University of Texas.

The analytical prediction of the flow of stresses from the sloped webs in the open portion of the beam to the solid end section and then to the support beneath the dapped end was performed using a strut-and-tie model. Because this plasticity model provides a lower-bound estimate of strength and is quite dependent upon the interpretation of details used to anchor reinforcement, the predicted capacity (which was approximately 25% below factored load levels) was somewhat dubious. As a result, TxDOT designers decided that the most expedient means to verify the strength of the dapped end detail was to perform a test in the casting yard of a girder provided by the fabricator.

DETAILS OF TESTING PROGRAM

A 1.12 m (44-in.) deep, 32.45 m (106-ft., 5.5-in.) trapezoidal beam was placed over a steel support girder as shown in Figure 1. Load was applied to the dapped end by three, 100-ton hydraulic rams through a steel bearing plate and laminated neoprene bearing pad assembly (See Figure 2). The beam was restrained 4.11 m (13.5 ft.) from the end by a steel crosshead (Figure 2). The third point of support was 10.4 m (34 ft.) from the end of the beam. Only a 10.4 m (34-ft.) portion of the beam was loaded during the test so that 1.5 times the factored design shear could be applied at the dapped end without exceeding the flexural capacity of the beam.

Two tests were performed on the beam. First, a "factored load test" was conducted, then the beam was unloaded and reloaded to failure. The maximum load applied at the dapped end during the "factored load test" (FL test) corresponded with the reaction needed to develop the factored moment at midspan of the completed composite girder. Loads beneath the dapped end during the FL test were applied in 130 kN (30-kip) increments up to a maximum of approximately 1340 kN (300 kips). During the test to failure, loads were applied in 270 kN (60-kip) increments up to approximately 1340 kN (300 kips), followed by 130 kN (30-kip) increments up to 1740 kN (390 kips), and finally, load increments as small as 4.4 kN (one kip) were applied until failure occurred.

Response of the beam was monitored using an electronic transducer to measure pressure in the hydraulic rams and vertical displacement transducers to measure the relative movement between the beam and the steel support girder at the end of the dap, at the box section adjacent to the dap, at the location of the crosshead, and at the beam support furthest from the dapped end. Displacement measurements between the ground and steel support girder were made at the crosshead location and at the end furthest removed from the dapped end. Displacement transducers oriented at 45 degrees were also placed across the crack that formed in the corner of the dap, and from the bottom corner of the beam section to the end of the dap. It was hoped that the first of these two inclined gages would provide a qualitative measurement of the crack opening in the corner of the dap. Because the test specimen was an existing beam in the casting yard, it was not possible to attach gages to provide strain measurements in the reinforcement. Data from the transducers were recorded by a Campbell Scientific 21X high-speed data acquisition system every 20 seconds during the testing program.

RESULTS OF TESTS

The response of the beam to loading during the two tests is illustrated in Figures 3 and 4 using plots of load versus dap deflection (beam-end deflection minus deflection of the box end adjacent to the dap). Figure 3 clearly indicates stiffness reductions due to cracking and then yielding of reinforcement at approximately 530 kN (120 kips) and 1500 kN (340 kips). Opening of diagonal cracks at the dap/beam interface is illustrated in Figure 5 for the second test. The displacement transducer was unable to precisely record the small crack width at the dap during the factored load test.

At conclusion of the FL test, the largest crack in the dapped end was approximately 0.25 mm (0.01 in.) wide. Diagonal cracks in the webs of the girder developed during the test and were approximately aligned between the steel crosshead and the bottom corner of the beam. The largest of these was approximately 0.05 mm (0.002 in.) wide. During the test to failure, the largest diagonal crack in the dapped end increased to 2.5 mm (0.1 inches) and the largest diagonal cracks in the beam webs increased to 1.4 mm (0.055 in.) in width. Diagonal web cracks extended into the bottom flange of the box girder near conclusion of the FL test. These cracks extended further and ultimately passed completely through the bottom flange during the second test. Note that the measurements presented in Figure 5 do not agree with the dapped-end crack widths presented above because the gage was not oriented perpendicular to the crack where the crack width measurement was made (using a crack width comparator), and also more than one crack is located within the gage length.

Although the diagonal crack in the dapped-end region was the primary concern at the beginning of this investigation, it is interesting that strength of the beam was ultimately controlled by the diagonal cracks that initiated in the beam webs then propagated into and through the bottom flange. These cracks intersected the prestressing strands inside the required development length and resulted in slip of the strands. Initial slip of the strands was detected at 1600 kN (360 kips). When loading was stopped at a maximum of 1890 kN (425 kips), the top layer of strands had withdrawn approximately 13 mm (0.5 in.) at the end of the beam. At conclusion of the second test, some slip was evident in all four strand layers.

During both tests, University of Texas researchers and TxDOT engineers were exposed to an unexpected occurrence. At a load of approximately 1200 kN (270 kips), water inside the void of the trapezoidal beam began to leak through diagonal web cracks. As cracks continued to grow in width and length, the volume of water escaping from within the beam increased. It is impossible to accurately estimate the quantity of water that escaped from the beam, but based on discussions between the personnel on hand during testing, it was estimated to be 50 to 80 liters (15 to 20 gallons). Because this portion of the beam should remain uncracked in the field (ie. a closed system), corrosion of the reinforcing steel is not believed to be a concern.

In conclusion, the dapped-end detail performed quite adequately during both tests. The detail was capable of resisting at least 1.4 times the strength required at the support to develop the factored flexural strength of the girder. Failure of the girder was controlled by pullout of the prestressing strands, which was aggravated by diagonal cracks propagating through the development length of the strand.

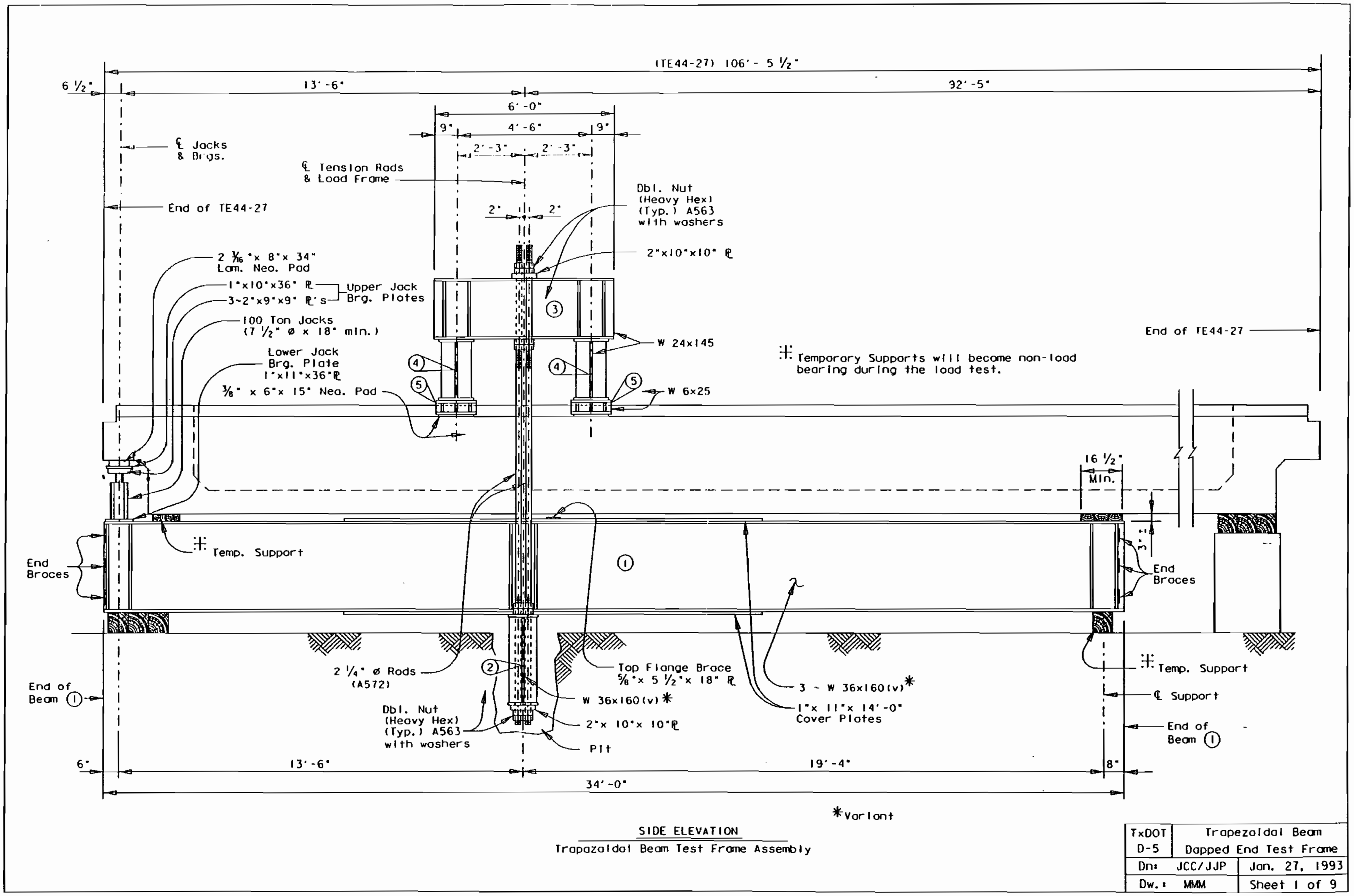

Figure 1 Elevation of Test Setup

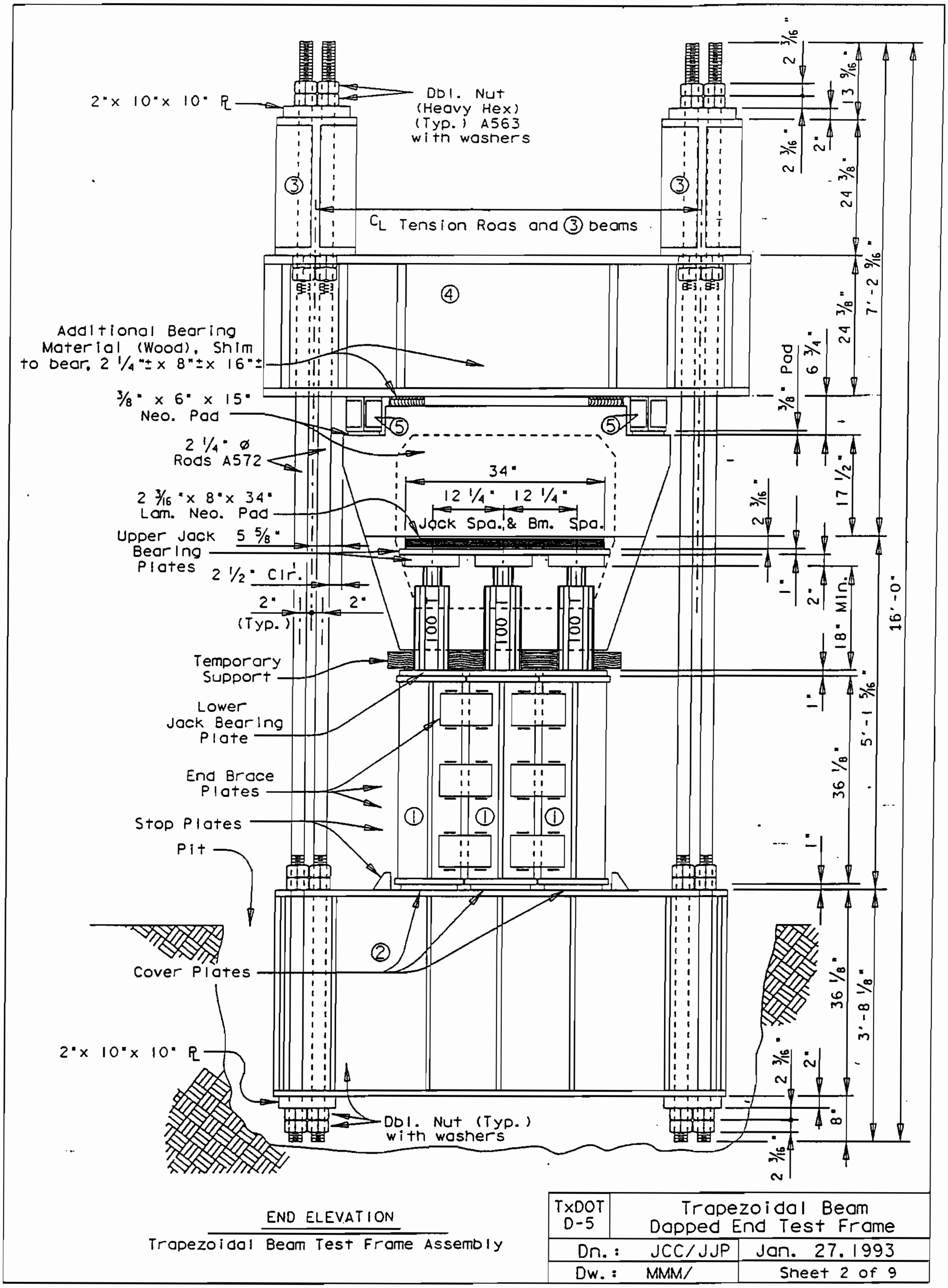

Figure 2 End View of Test Setup

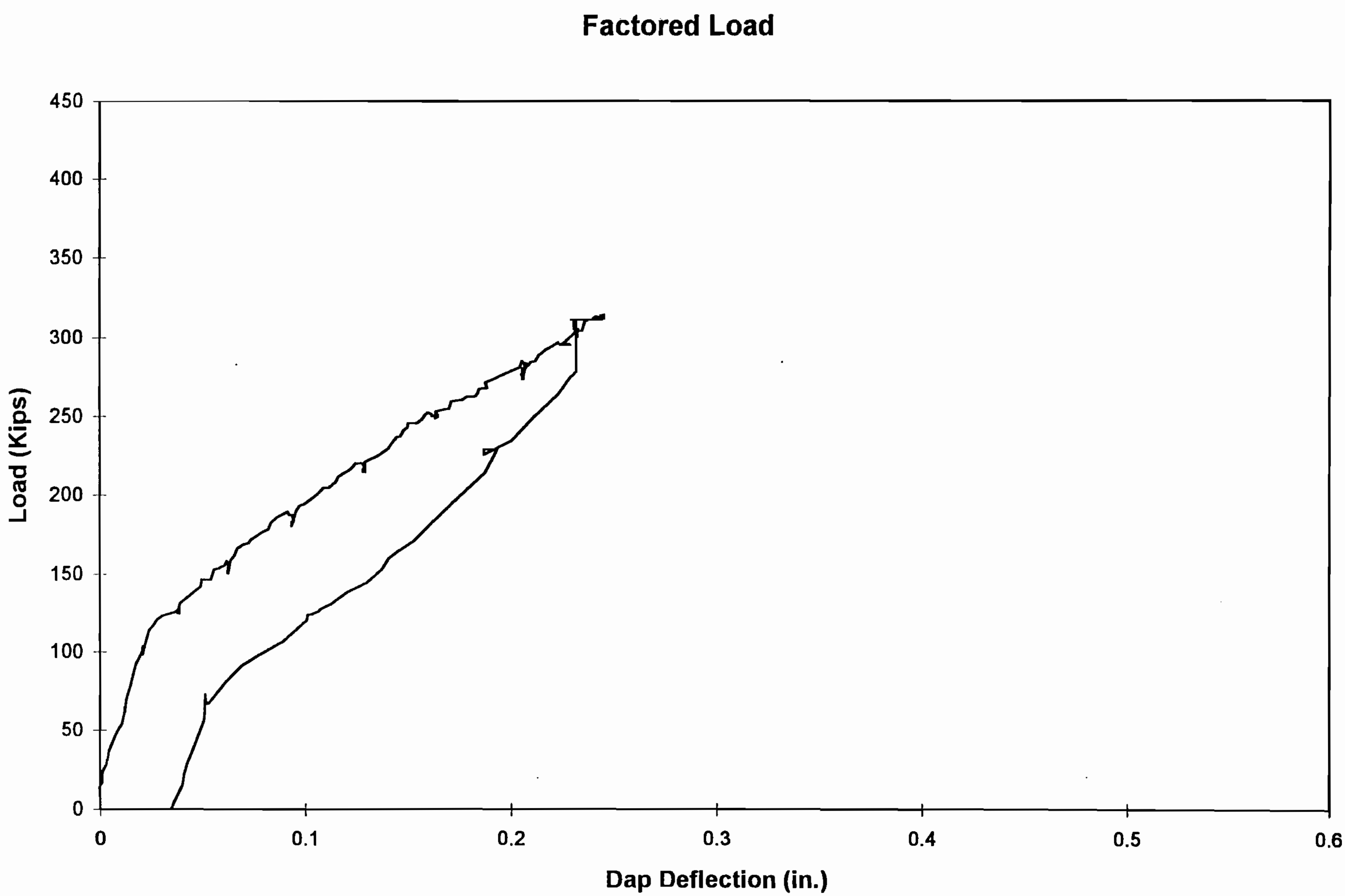

Figure 3 Load vs. Dap Deflection / Factored Load Test

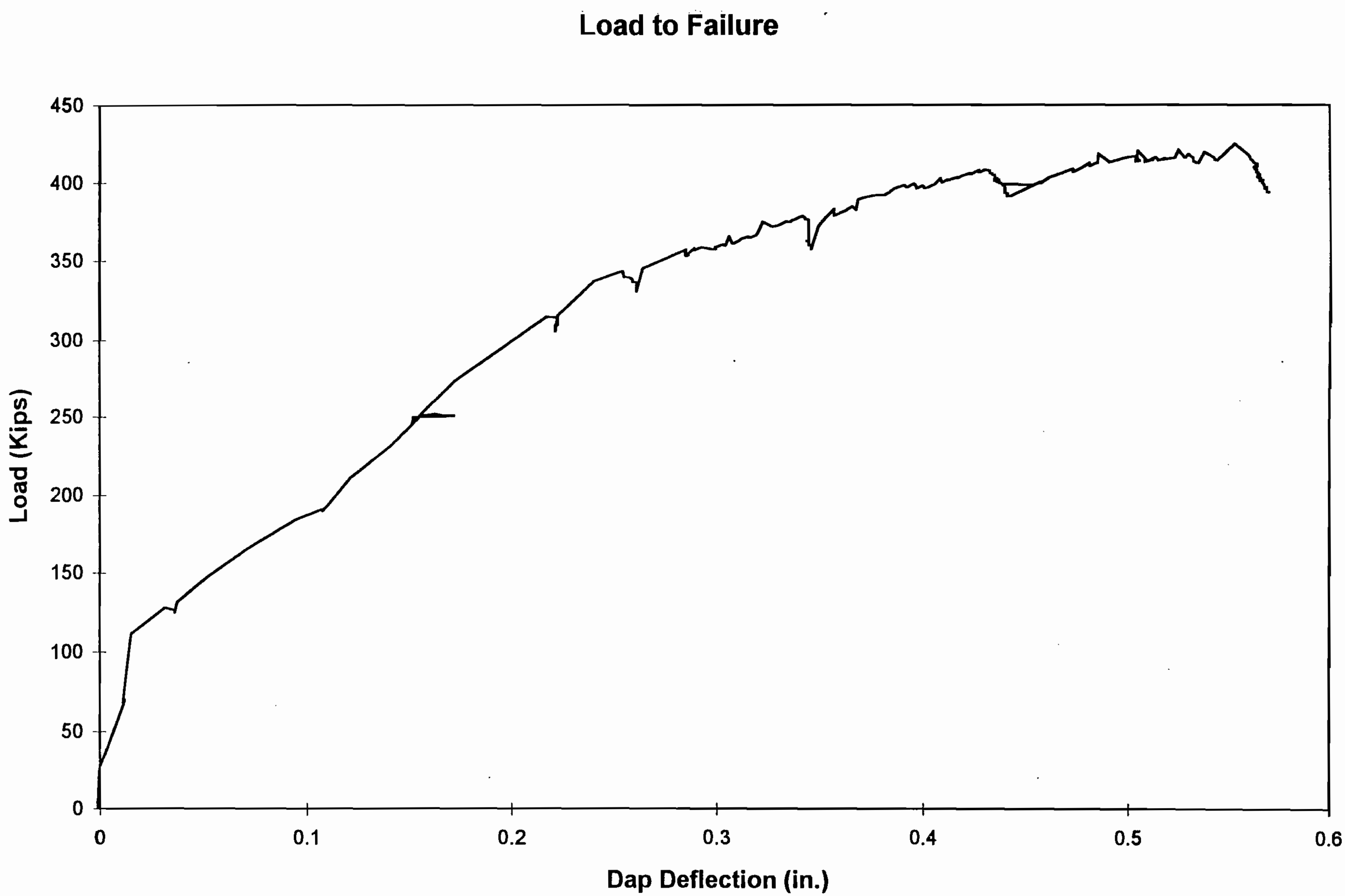

Figure 4 Load vs Dap Deflection / Ultimate Strength Test

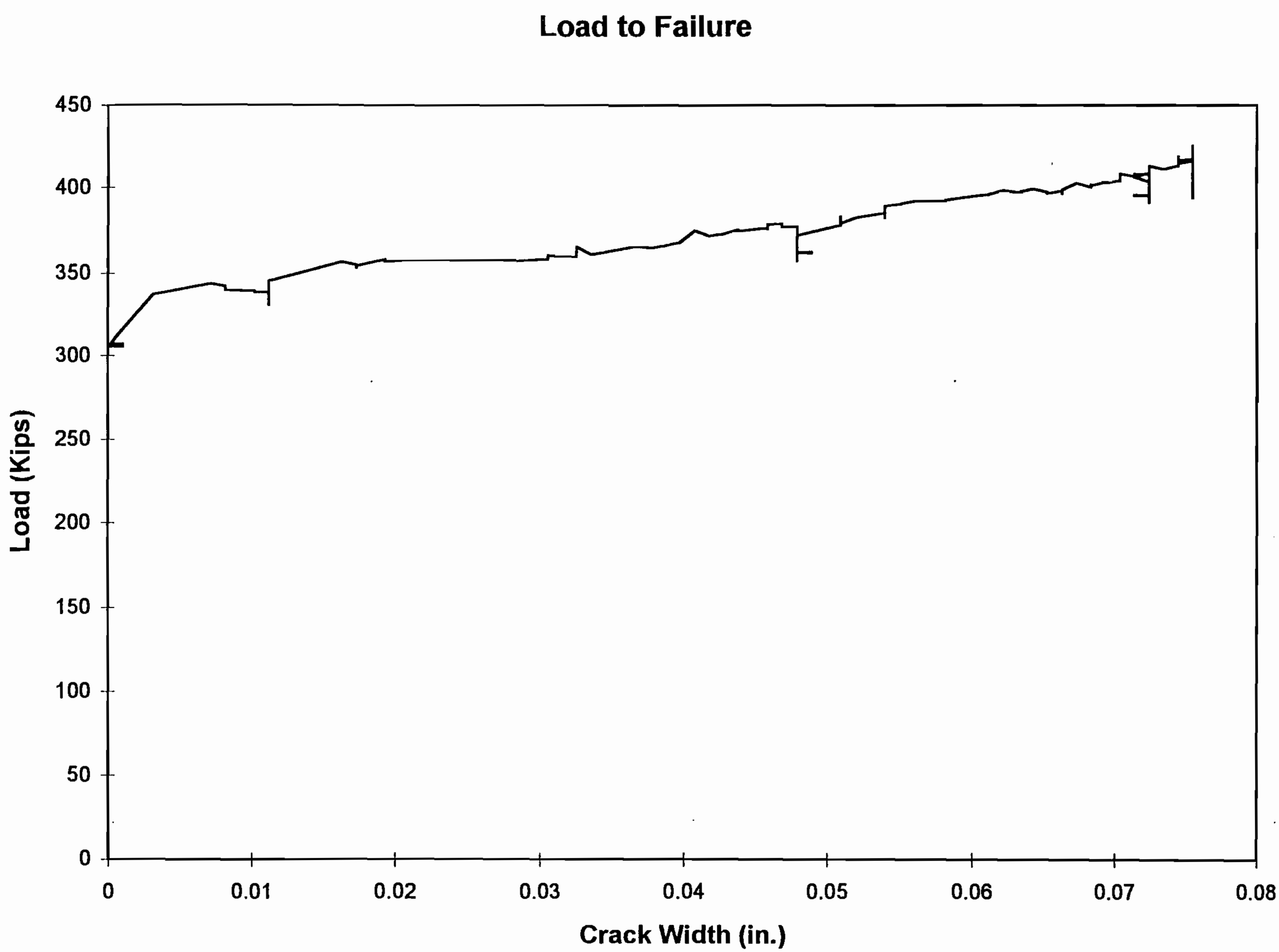

Figure 5 Crack Openings at Beam/Dap Interface for Ultimate Strength Test