National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 101 - APRIL 1978

Retrofitting Procedures for Fatigue-Damaged Full-Scale Welded Bridge Beams

A digest of interim findings from NCHRP Project 12-15(2), "Retrofitting Procedures for Fatigue-Damaged Full-Scale Welded Bridge Beams," by John W. Fisher, Fritz Engineering Laboratory, Lehigh University

THE PROBLEM AND ITS SOLUTION

Project 12-15(2), "Retrofitting Procedures for Fatigue-Damaged Full-Scale Welded Bridge Beams," is comprised of three tasks. Task 1 had as its objective a detailed inspection and retrofit of the east- and westbound bridges of span No. 10 at Yellow Mill Pond in Bridgeport, Conn. This task was carried out during the summer of 1976 and additional inspections were made in 1977.

Task 2 has as its purpose the testing of 15 full-size coverplated bridge beams. These beams were the same size as many beams at Yellow Mill Pond. They were tested to determine the fatigue strength of these as-welded members and to further assess the merits of retrofitting fatigue-damaged details by peening the weld toe or applying gas tungsten arc remelt to the cracks at the weld toe. Thirteen of these beams were tested as of March 31, 1978.

Task 3, still in progress, will provide information on the effects of out-of-plane displacements at the ends of transverse stiffeners.

FINDINGS

In June 1976, 40 coverplate details in the east- and westbound bridges of span No. 10 at Yellow Mill Pond were inspected for fatigue cracking using visual, magnetic particle, dye penetrant, and ultrasonic procedures prior to retrofitting these girders. Twenty-two of these details were found to be cracked by visual inspection. The smallest visual crack indication was 6.4 mm (0.25 in.) long. Fifteen of these cracks had propagated deep enough to be detected by ultrasonic inspection.

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To inspect for cracks it was first necessary to blast clean and remove paint, dirt, and oxide that had accumulated in the weld toe region. The visual (10X magnification), magnetic particle, and dye penetrant inspection provided data regarding the length of the surface cracks. The magnetic particle inspection was discontinued after examining several cover plates, due to difficulty in working with the probe in the overhand position.

The ultrasonic inspection provided data regarding both the length and depth of cracks. Cracks at the weld toe smaller than approximately 2.5 mm (0.1 in.) deep could not be reliably detected by the ultrasonic probe. The deepest crack depth indications of 13 mm (0.5 in.) were found at the west end of the eastbound bridge of span No. 10 in Beams 3 and 7 (see Fig. 1). Comparisons of estimated crack depths from ultrasonic inspection and actual measured crack depths after a fracture surface was exposed indicate that deviations of 1.6 mm (± 0.06 in.) are possible. Figure 1 shows the approximate location of the details that were inspected in span No. 10 and summarizes the findings.

Peening and gas tungsten arc remelting procedures(1) were used to retrofit fatigue-damaged beams in span No. 10 of the Yellow Mill Pond Bridge. Peening was performed with a small pneumatic hammer operated at 0.17 N/mm^2 (25 psi) air pressure. The end of the peening tool was shaped with a 19-mm (3/4 in.) radius about one axis and a 3-mm (1/8 in.) radius about the other axis (see Figure 2). All sharp edges were ground smooth. Several minutes were required to peen the weld toe. Peening was continued until the weld toe became smooth. The depth of indentation due to peening was approximately 0.8 mm (0.03 in.).

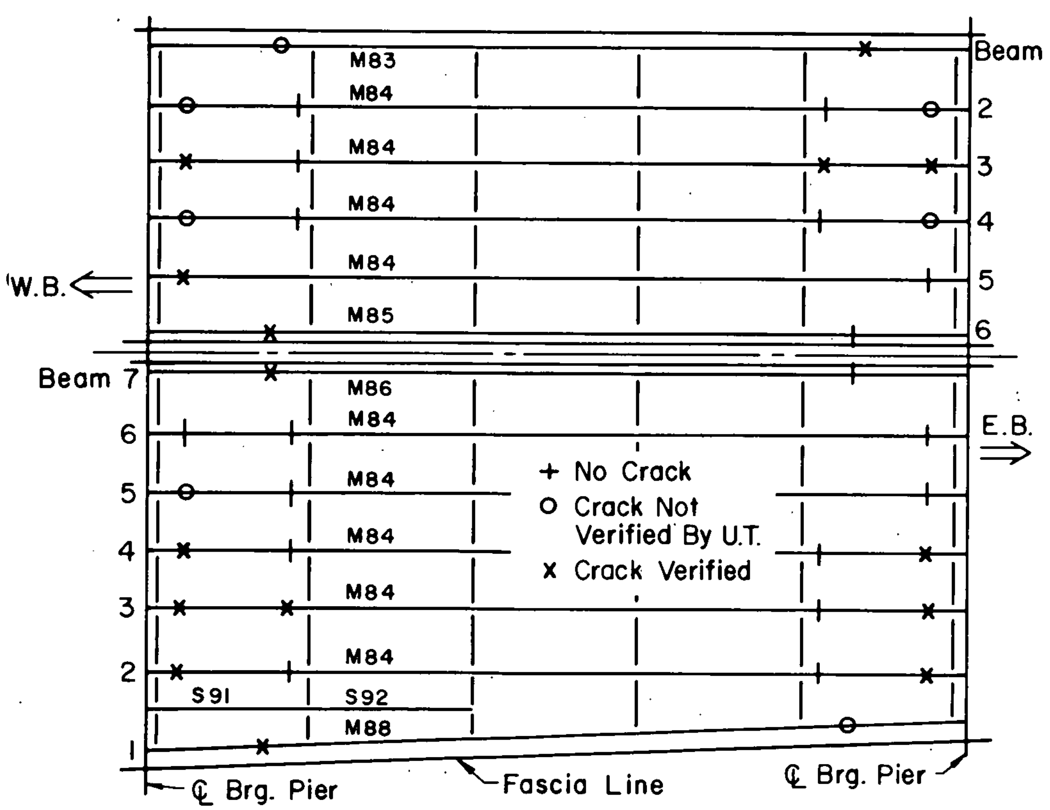

Figure 1. Plan of inspected details in span No. 10, Yellow Mill Pond Bridge.

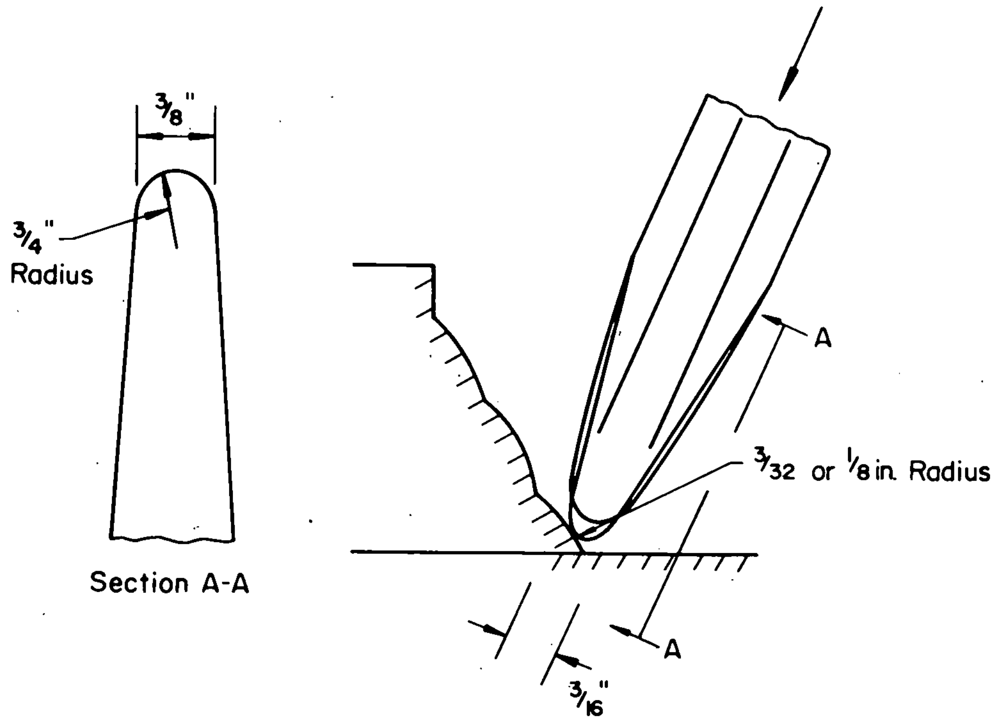

Figure 2. Schematic of peening tool (from British Naval Construction Research Establishment).

The gas tungsten arc process (GTA) removes the nonmetallic intrusions at the weld toe and reduces the magnitude of the stress concentration by smoothing the weld termination. The tungsten electrode is manually moved along the toe of the fillet weld, melting a small amount of the fillet weld and base metal. Provided the cracks are not too deep, the metal around the cracks can be sufficiently melted so that after solidification the cracks will have been removed.

Welding equipment consisted of a 200-amp DC power source with drooping V-I characteristics; a high-frequency source was used to start the arc. The electrode was 4.0 mm (0.156 in.) in diameter with a 4.8-mm (0.188 in.) stick out and composed of 2 percent thoriated tungsten. A Linde HW-18 water-cooled torch was used. The entire welding unit was mounted on a Bernard portable carriage, which also contained the water supply and a recirculating pump to cool the torch. The portable carriage was mounted on the rear of a truck with the portable gasoline power supply. A 15-m (50 ft) line from the welding unit to the torch permitted the welder access to the girder.

All retrofit welds on span No. 10 were performed in the overhead position. The areas to be welded were sandblasted to remove mill scale that might cause undercutting. A shielding gas of helium and argon mixture and a cathode vertex angle between 30 and 60 degrees were used as the mixture provided about the same penetration as helium alone. Travel speed was approximately 1.3 mm/sec (3 in./min). The retrofit weld was started on the longitudinal weld toe and continued along the transverse weld toe.

The weld finally terminated at the opposite longitudinal weld toe. Intermediate terminations were made at approximately 100-mm (4 in.) intervals because of the duty cycle of the portable welding unit. Each of these terminations was carried up to the weld face to prevent cratering at the weld toe.

Twenty-five of the coverplate details in span No. 10 were repaired after being inspected; 14 were peened and 11 were gas tungsten arc remelted. Figure 3 shows the type of repair made at each coverplate weld toe.

The 13 beams with coverplates tested during Task 2 of this study and 6 beams tested earlier (2) provided data on 34 coverplate details. The beams were W36X230 or W36X260 A36 and A588 steel rolled sections with 1-1/4 x 12-in. or 1 x 12-in. coverplates welded to each flange.

The test data for the untreated coverplate details are plotted in Figure 4. Also shown is the Category E design line for current specifications, which is based on the 95 percent confidence limits for 95 percent survival of earlier tests on smaller beams (3). It is apparent that nearly all test data indicate less fatigue resistance.

A new lower-bound fatigue resistance was constructed based on the test data and estimates from a mathematical model developed for coverplated beams (4, 5).

Of the two details (one on each end) on each beam, one was retrofitted after cracks were detected and had grown to a length of 1 to 3 in. The crack depth was estimated to be less than 1/4 in. prior to retrofitting. Both peening and gas tungsten arc remelting were used to treat the cracked details. Only the gas tungsten arc remelt process was used if the crack depth exceeded 1/8 in.

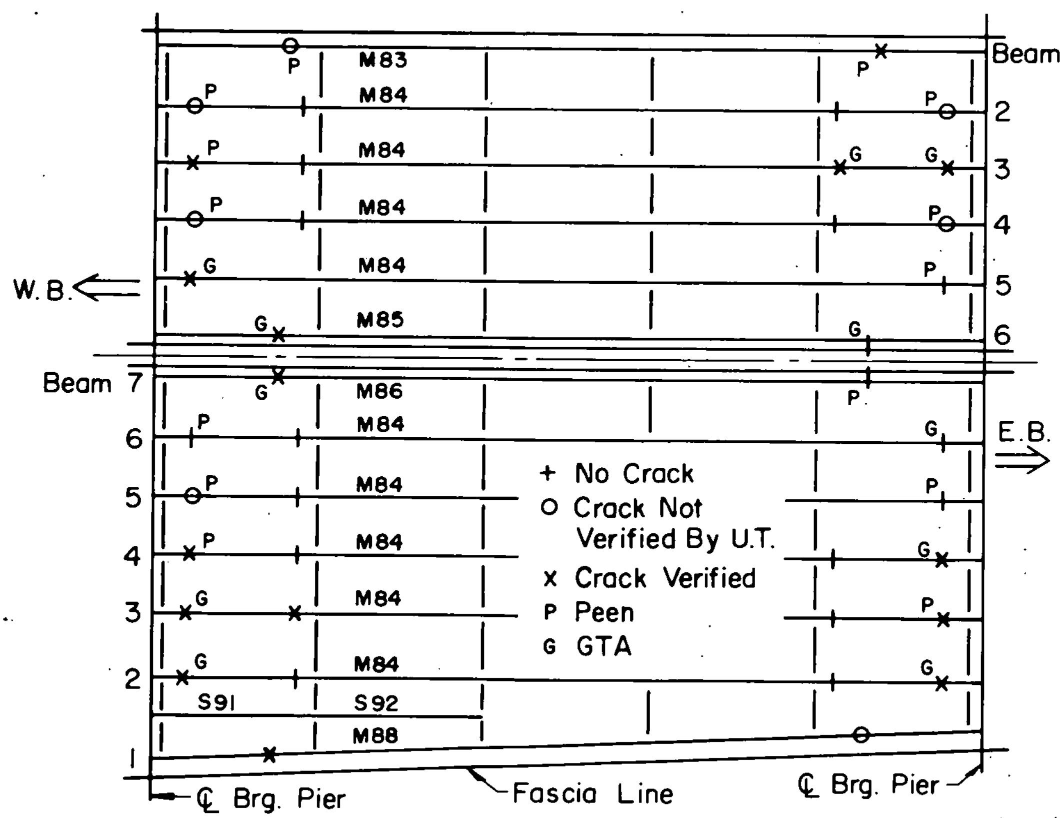

Figure 3. Repair methods as applied to span No. 10, Yellow Mill Pond Bridge

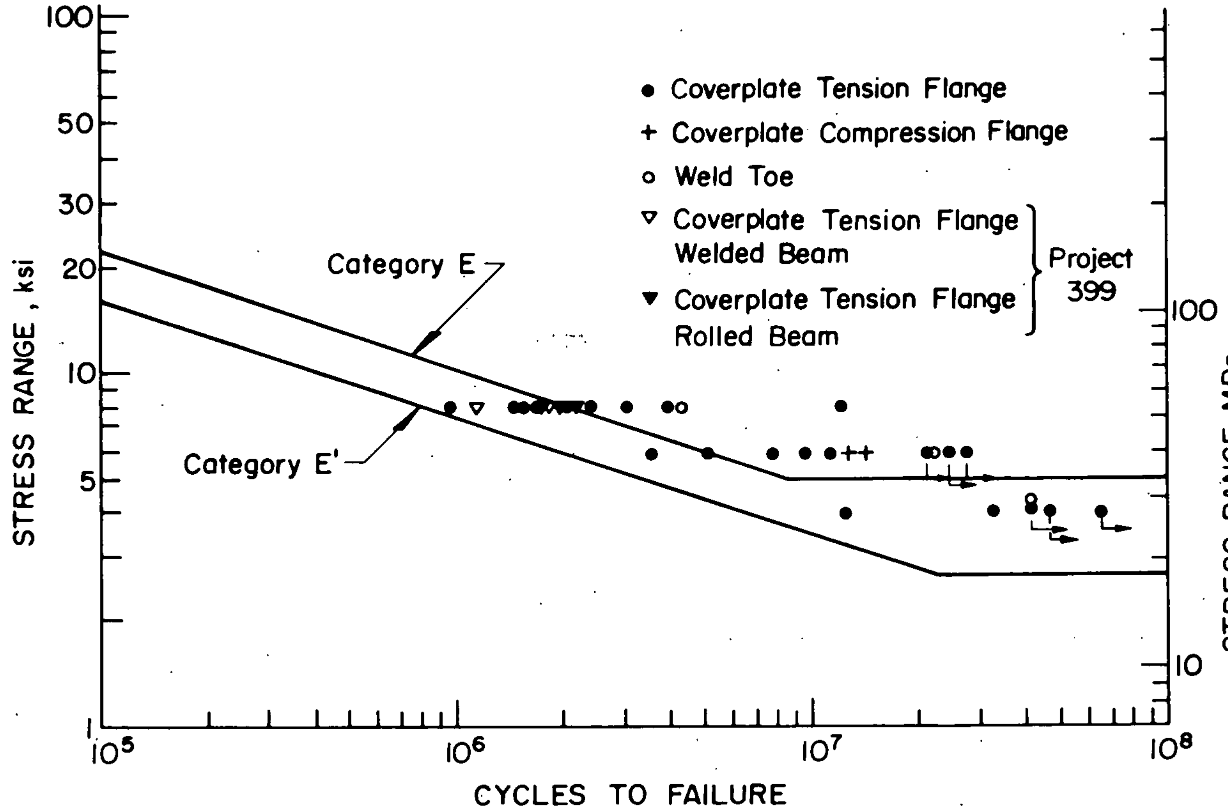

Figure 4. Fatigue strength of full-size coverplated beams.

The results of the tests are shown in Figure 5. Because of time limitations, all but one of the retrofitted beams were tested at either 6- or 8-ksi stress range. The results indicated that both procedures could be used to successfully extend the fatigue life and prevent further crack growth. Only details with initial crack depths greater than 1/8 in. did not achieve the desired life increments.

For details with very small or no visible crack, the peening procedure appears to provide a reliable and the most economical means of retrofitting fatigue damage; for details with slightly larger cracks (up to 3/16 in. deep) the gas tungsten arc remelt process is preferred.

APPLICATIONS

The findings from this study should be of value to structural engineers involved in the design of welded steel beams, researchers working in the subject area, and, perhaps most of all, members of specification writing bodies. The suggested revisions to the *AASHTO Specifications for Highway Bridges* included here warrant consideration. Further, the suggested revisions can also be applied to other specifications, such as those of the American Institute of Steel Construction and the American Railway Engineering Association. The findings result from a meticulously designed and executed experimental effort verified by analyses of crack propagation and fracture mechanics and appear to warrant serious consideration for immediate inclusion in design specifications.

Table 1 gives suggested allowable ranges of stress for a new fatigue category, E' which is applicable to coverplated beams with flange thickness greater than 0.8 in. (20 mm). It is intended for application with redundant load-path struc-

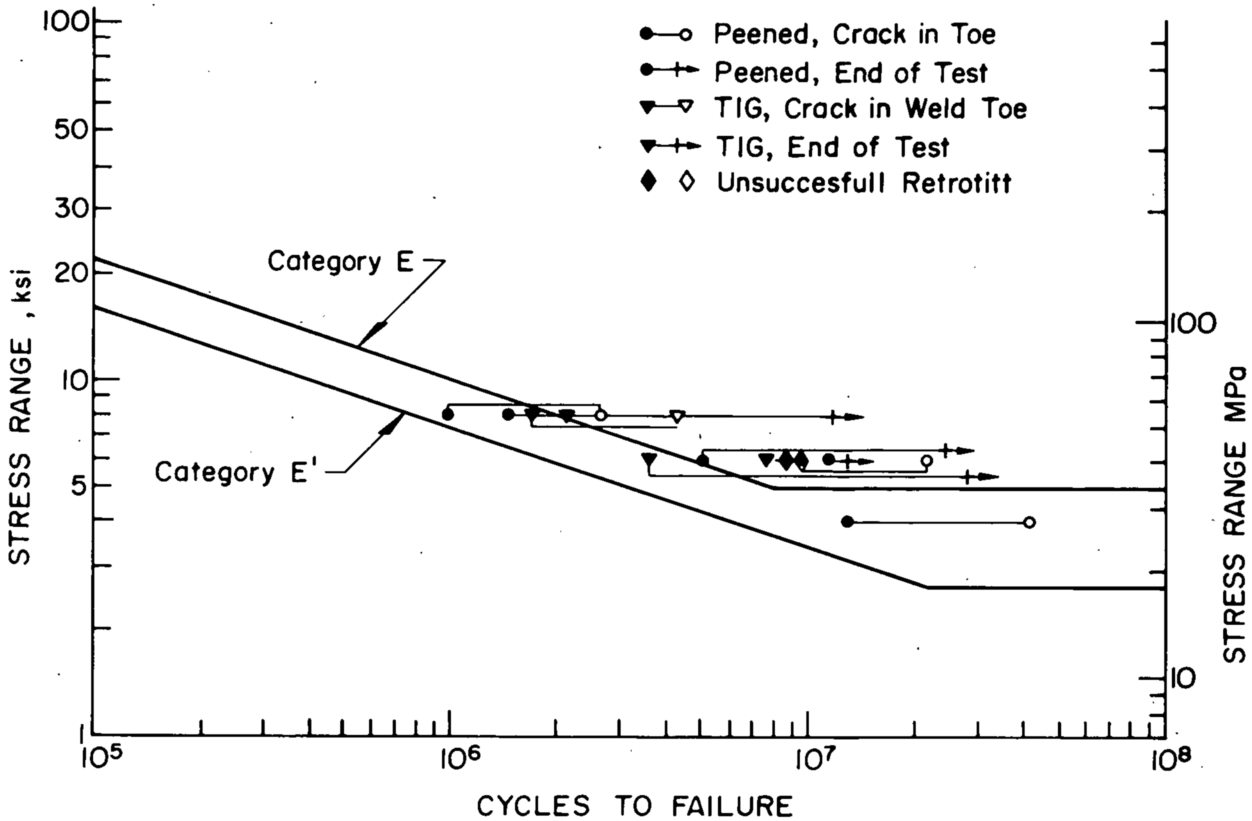

Figure 5. Fatigue resistance of retrofitted fatigue-damaged details.

tures. This category can be inserted as an addendum into the appropriate tables of the AISC, AASHTO, and AREA specifications.

Table 2 describes the situation intended to be covered by category E'. A comparison of fatigue data on various details, including coverplated beams with thinner flanges, shows that existing category E is applicable. However, additional NCHRP research is planned to assess this condition for other details.

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TABLE 1

ALLOWABLE STRESS RANGE

Category	For 100,000 Cycles		For 500,000 Cycles		For 2,000,000 Cycles		For 20,000,000 Cycles	
	(ksi)	(Mpa)	(ksi)	(Mpa)	(ksi)	(Mpa)	(ksi)	(Mpa)
E'	16	110	9.4	65	5.8	40	2.6	18

TABLE 2

DETAIL CLASSIFICATION

Situation	Kind of Stress	Stress Category	Ex. No.
Base metal at end of partial-length welded coverplates having square or tapered ends, with or without welds across the ends:			
Flange thickness ≤ 0.8 in. (20 mm)	T or Rev	E	7
Flange thickness > 0.8 in. (20 mm)	T or Rev	E'	7

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