APPENDIX B
FRACTURE CRITICAL MEMBERS

The U.S. Army Corps of Engineers (USACE) has adapted American Association of State Highway and Transportation Officials (AASHTO) guidelines for fracture critical members (FCMs) on all steel bridges stated in the "Manual for Condition Evaluation of Bridges" (reference 4*p*).

> *"Fracture critical members or member components are tension members or tension components of members whose failure would be expected to result in collapse of a bridge."*

Tension components of a bridge member consist of components of tension members and those portions of a flexural member that are subject to tension stress. Any attachment having a length in the direction of the tension stress greater than 100 mm (4 inches) that is welded to the tension area of a component of a "fracture critical" member shall be considered part of the tension component and, therefore, shall be considered "fracture critical."

Not all tension members are FCMs. Redundant tension members are not FCMs. Redundancy means that should a tension member or its component fail, the load carried by the failed member could be redistributed to other members that have reserve capacity to temporarily carry additional load, and avoid catastrophic collapse of the structure. See reference 4*n* for recommended procedures for identification of FCMs.

FCMs have all or part of their cross section in tension. Most cracks in steel members occur in the tension zones, generally at a flaw or defect in the base material. Frequently the crack is a result of fatigue, occurring near a weld, a material flaw, and/or changes in member cross section.

After the crack occurs, failure of the member could be sudden and would lead to the collapse of the bridge. For this reason, steel bridges with the following structural characteristics or components should receive special attention during inspection:

- One- or two-girder systems, including single boxes with welding.
- Suspension systems with two eyebar components.
- Steel pier caps and cross girders.
- Two-truss systems.
- Suspended spans with two girders.
- Welded tied arches.
- Pin and hanger connections on two or three girder systems.

Inspection of steel bridges should include the identification of FCMs and the development of a plan for inspecting such members. The FCM inspection plan should identify the inspection frequency and procedures to be used. A very detailed close visual "hands-on" inspection in the field is the primary method of detecting cracks. This inspection requires that critical areas be specially cleaned prior to the inspection and additional lighting and magnification be used. Other nondestructive testing procedures (see reference 4*n* and Chapter 18 of reference 4*f*) should be used for the members that are not accessible for close visual contact or for examination of suspected cracks or flaws on welded members. Photographs and sketches should be made of the conditions found, and onsite comparisons of photographs and sketches should be made at follow-up inspections.

The FCM inspection plan for each bridge shall be developed by a qualified bridge inspector who should decide the frequency, methods, and procedures of the inspection. Inspection procedures shall follow guidelines of reference 4*n*. The FCM shall receive an independent technical review and shall be subject to the approval process required for bridge inspections.

Initial inspection of FCMs should be conducted thoroughly for each welded, bolted, or riveted joint and connection. The condition of the inspected members should be recorded clearly in the report. The report should include assessment and recommendation for follow-up inspections of the members. The recommendation should include the frequency, methods, and procedures of the inspection. Maximum inspection intervals of 6 years for Public Highway/Roadway bridges are permitted if the inspected and assessed FCMs are in good condition and an evaluation of fatigue life shows that the member is not approaching its useful limit. See reference 4*f*, Chapter 18, and reference 4*n* for more detailed information on FCM inspection and evaluation. For routine biennial inspection, FCMs should be inspected and reported not less than other structural members.

Inspection intervals for FCM inspections on bridges other than Public Highway/Roadway bridges shall be determined based on number and magnitude of load cycles, condition of bridge, and internal redundancy. Inspection intervals generally should not exceed 6 years. Longer intervals may be proposed if, in the judgment of the engineer in charge of the bridge inspection program, longer intervals are justified. Justification for increased intervals should be based on condition of bridge, amount of internal redundancy, potential for fracture, and length of remaining life determined from a fatigue analysis. Proposals for longer intervals shall be submitted to the Major Subordinate Command for review and approval.

When cracks are detected in an FCM, or when bridge and traffic conditions warrant it, the inspection should be supplemented by a fatigue and/or fracture evaluation of the member. The evaluation should be used to determine the remaining useful life and the critical crack size. Procedures may follow those outlined in reference 4*n* and applicable USACE publications. The computer program, NASGRO, developed by the National Aeronautics and Space Administration, may be used for fracture analysis. The program is available at http://mmptdpublic.jsc.nasa.gov/nasgro/nasgromain.html. Whenever the fracture toughness of the steel is not documented, some testing will be necessary to determine the threat of brittle fracture at low temperatures.