ANALYTICAL STUDY OF THE FATIGUE BEHAVIOR OF A LONGITUDINAL TRANSVERSE STIFFENER INTERSECTION

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Purpose

The analytical study contained in this report was performed to determine the estimated fatigue life at the location of the intersection of longitudinal and transverse stiffeners. At this location, an extremely poor fatigue detail may occur. This detail occurs repeatedly throughout a bridge being examined in this study at locations of longitudinal girder-to-floor beam connections. Figure 1 shows the floor beam-to-plate girder connections in greater detail.

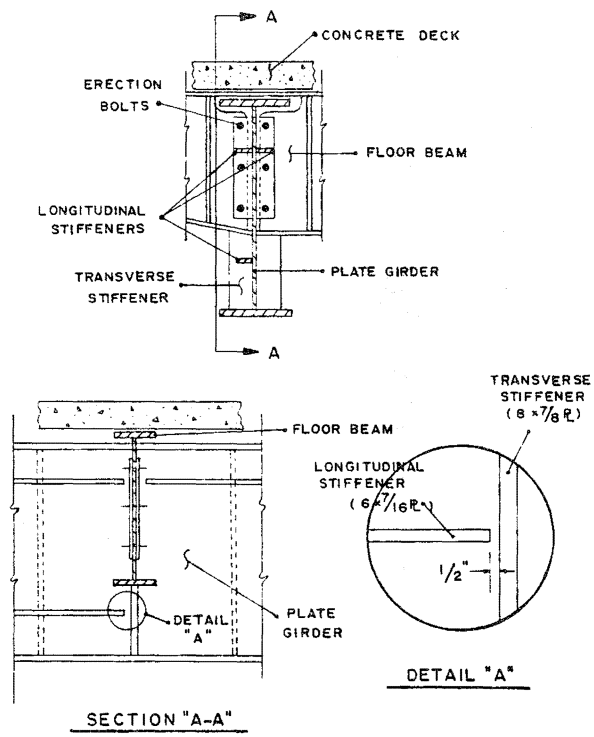

Fig. 1. Floor beam-to-plate girder connection.

When transverse and longitudinal stiffeners are used, each results in a weld termination. Since the transverse stiffener can be considered a short attachment in the direction of applied stress, it is governed by the Category C design condition. However, the longitudinal stiffener is a long attachment, the end of which is governed by the Category E design condition. A more desirable condition is achieved if the transverse stiffener is placed on one side of the web and the longitudinal stiffener on the other. Category C still applies to the transverse stiffener, but the longitudinal stiffener welds are now continuous, in which case Category B is applicable. For the detail being considered, however, the presence of the floor beams on both sides of the girder web forced the undesirable situation depicted in Fig. 1, resulting in a longitudinal transverse stiffener intersection. As can be seen in Fig. 1, the clear distance between the transverse stiffener and the longitudinal stiffener end is only 1/2 in. Considering the presence of the 5/16 in. web-to-transverse stiffener fillet weld and the 5/16 in. web-to-longitudinal stiffener fillet weld, it is observed that a weld overlap exists in the gap between the transverse and longitudinal stiffeners. This situation results in a possible stress concentration greater than that of a Category E detail. If this were the case, the existing bridge detail could exhibit a very low fatigue life. Clearly, the proximity of the longitudinal transverse stiffener intersection raises a question with respect to the fatigue severity of the detail.

The analytical finite element study contained in the report was undertaken to determine the influence of various geometric parameters upon the intersection detail fatigue performance. The results were used to design the specimen for the experimental fatigue tests performed as part of the project.

Objectives

The primary objective of this study is to establish an analytical estimate of the fatigue life of a longitudinal transverse stiffener intersection bridge detail. A finite element model of the detail in question is utilized to determine the influence of geometry on the stress at the end of the longitudinal stiffener weld. Fracture mechanics principles are employed to achieve an estimate of the fatigue life of the structural steel bridge detail.

In addition to the primary objective, several secondary objectives are given significant consideration. Specifically, the current study strives to aid in the development of an experimental test specimen, to determine the adequacy of current fatigue design specifications, and to propose recommended design details for future use.

The following geometric variables were included in the study of the fatigue behavior of the stiffener intersection detail:

(1) Web thickness
(2) Longitudinal stiffener size
(3) Gap between stiffeners
(4) Welding the longitudinal stiffener to the transverse stiffener

Conclusions

The results indicate that due to the close proximity of the weld toes of the two stiffeners, 1/2 in. in the girder studies, the fatigue life of this detail is lower than the E′ detail of the AASHTO Specifications. The estimated fatigue strength of the stiffener intersection detail is shown in Fig. 2 for three different values of the assumed initial crack size at the weld toe. The detail has an extremely poor estimated fatigue performance. Very low nominal stresses in the web at the location of the detail can lead to fatigue cracking. The fatigue performance of the detail can be improved if the gap between the stiffeners is increased, the longitudinal stiffener is coped and welded to the transverse stiffener, the web thickness is increased, or the longitudinal stiffener area is decreased. The most practical means of increasing the fatigue life of this detail is increasing the gap to a minimum of 4 and a maximum of 6 times the web thickness. These are the same requirements for the end of a transverse stiffener.

Implementation

The results of this analytical study indicate that the longitudinal transverse stiffener intersection produces a severe fatigue detail. The cause of the poor fatigue performance is the interaction of the stress concentration associated with the weld toes of the two stiffeners. The interaction can be reduced by increasing the gap between the welds to a minimum of 4 and a maximum of 6 times the web thickness or by welding the longitudinal stiffener to the transverse stiffener.

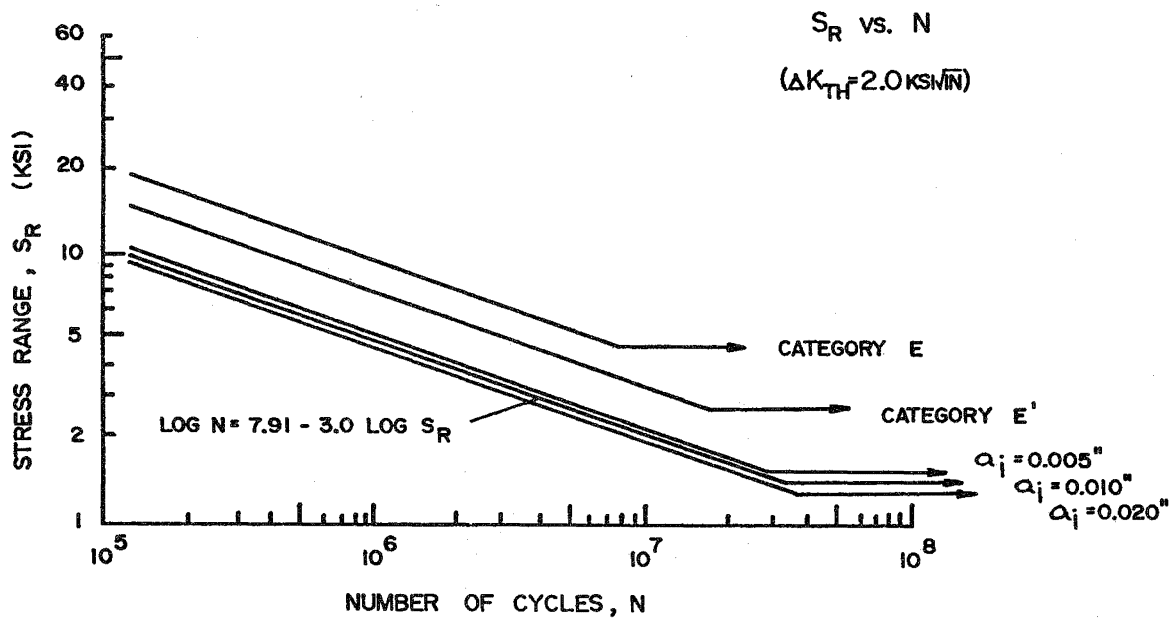

Fig. 2. S-N relationship for the longitudinal transverse stiffener intersection detail assuming no bending.

Fatigue tests to determine the improvement of the fatigue strength using a larger gap and welding the longitudinal stiffener are underway. These tests will be used to verify the results of this analytical study and to produce design fatigue recommendations. However, for current designs, the results of this analytical study are sufficient to recommend either the use of the larger gap or welding the longitudinal to the transverse stiffener to avoid the severe fatigue detail which occurs with a small gap.

KEY WORDS: fatigue behavior, longitudinal transverse stiffener intersection, fracture mechanics, finite element, two-dimensional mesh, stress distribution.

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The full text of Research Report 247-1 can be obtained from Mr. Phillip L. Wilson, State Transportation Planning Engineer; Transportation Planning Division, File D-10R; State Department of Highways and Public Transportation; P. O. Box 5051; Austin, Texas 78763.