Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 52 (1986)

Artikel: Fatigue damage and repair of steel railway bridges in Japan

Autor: Abe, Hidehiko / Sakamoto, Kenji / Abe, Makoto

DOI: https://doi.org/10.5169/seals-40343

FATIGUE DAMAGE AND REPAIR OF STEEL RAILWAY BRIDGES IN JAPAN

H.Abe ;Univ.of Utsunomiya
K.Sakamoto ; Japan National
M.Abe ; Railways

Fatigue damages have been occasionally experienced in structural details of railway bridges, because relatively large train loading is repeated in many cycles. Fig. 1 shows a schematic of the through type steel railway bridge and locations of fatigue cracks, as an example.

(A) COPED CROSS BEAM

Failure Mode : A crack is originated at the cope corner or the toe of fillet weld at the cope formed for connection with the main girder. It develops diagonally in the web plate, as shown in Fig. 2. It occurs even in case the lower flange of the main girder and that of the cross beam are connected with each other.

Cause : Both insufficiency of resisting moment of the beam due to the coping and local stress concentration are the causes of crack.

Repair : The web plate of the cross beam is locally reinforced by bolting additional plates, as shown in Fig. 3.

(B) COPED STRINGER

Failure Mode : A crack develops at the cope corner of stringer web, where the lower flange is cut short for connection with the cross beam, as shown in Fig. 4.

Cause : The lower flange of a stringer tends to be displaced sideways during train passage and a stress concentration takes place at the cope corner.

Repair : In case the crack is small, the lower flange is connected with the web, as shown in Fig. 5. But in case the damage is significant, the whole stringer is replaced by a new one.

(C) WEB PLATE NEAR VERTICAL STIFFENER END

Failure Mode : A crack develops in the web plate at the toe of fillet weld around the lower scalloped end of an intermediate stiffener, as shown in Fig. 6.

Cause : In addition to the in-plane-deformation due to the bending moment, the out-of-plane deformation due to vibration of the web plate or due to relative lateral displacement between the web and the lower flange causes this kind of crack.

Repair : Local reinforcing plates are bolted, as shown in Fig. 7.

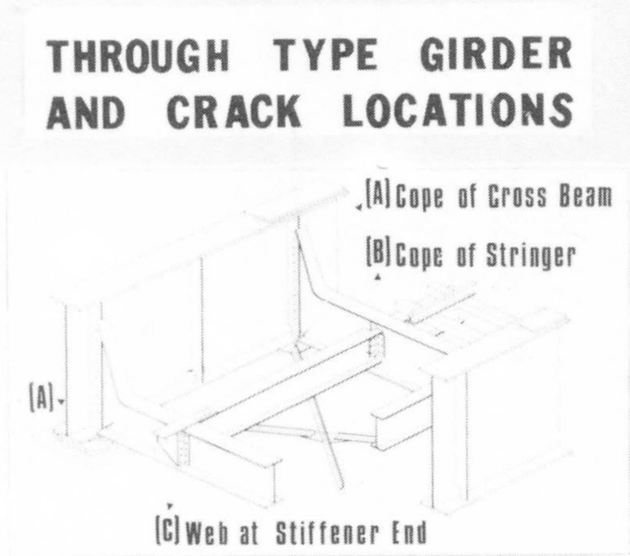


Fig. 1

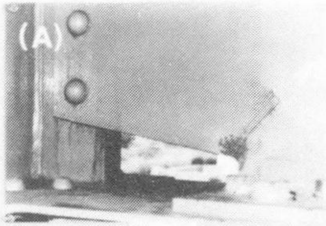


Fig. 2.

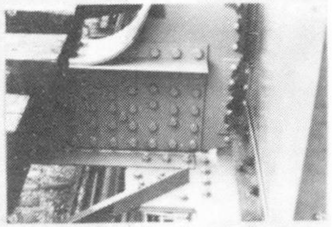


Fig. 3.

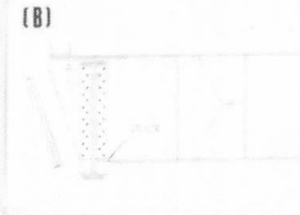


Fig. 4.

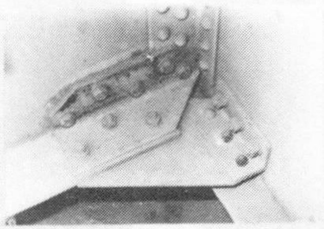


Fig. 5.

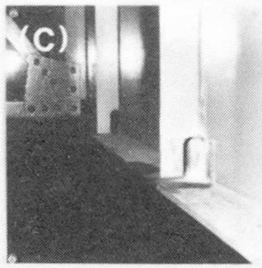


Fig. 6.

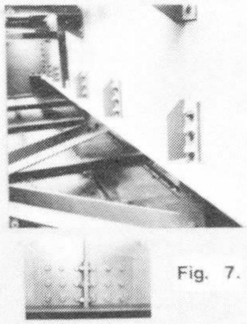


Fig. 7.

Fatigue Damage and Repair of Steel Railway Bridges in Japan

Hidehiko ABE
Professor
University of Utsunomiya
Tokyo, Japan

Kenji SAKAMOTO
Senior Engineer
Structure Design Office, JNR
Tokyo, Japan

Makoto ABE
Design Engineer
Structure Design Office, JNR
Tokyo, Japan

1. Introduction

In general, railway bridges are actually subjected to repeated train loading of a magnitude comparable to that assumed in design. In result, some inadequately designed or manufactured structural details have suffered fatigue cracks. In this poster three representative types of fatigue damages shown in Fig. 1 in Poster are dealt with.

2. Cope of Floor Beam Web

As seen in Fig. 2 in Poster, a crack initiated from the cope at the lower corner of floor beam of a through girder bridge. Such cracks have occurred in a few end floor beams and one intermediate floor beam. Their lower flanges were connected by gusset plates with those of the main girders. Fig. I shows an example of the stress variation during passage of a train in the vicinity of the cope. Then, half-scale models, in which the horizontal lengths

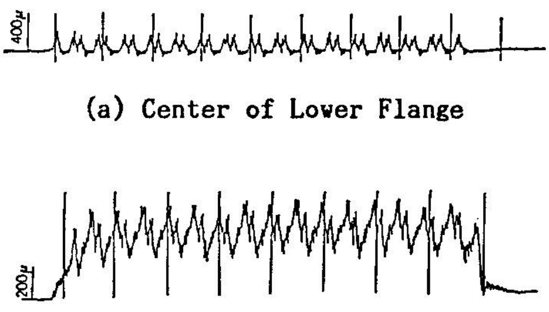


Fig.I Observed Stress Variations at End Floor Beam

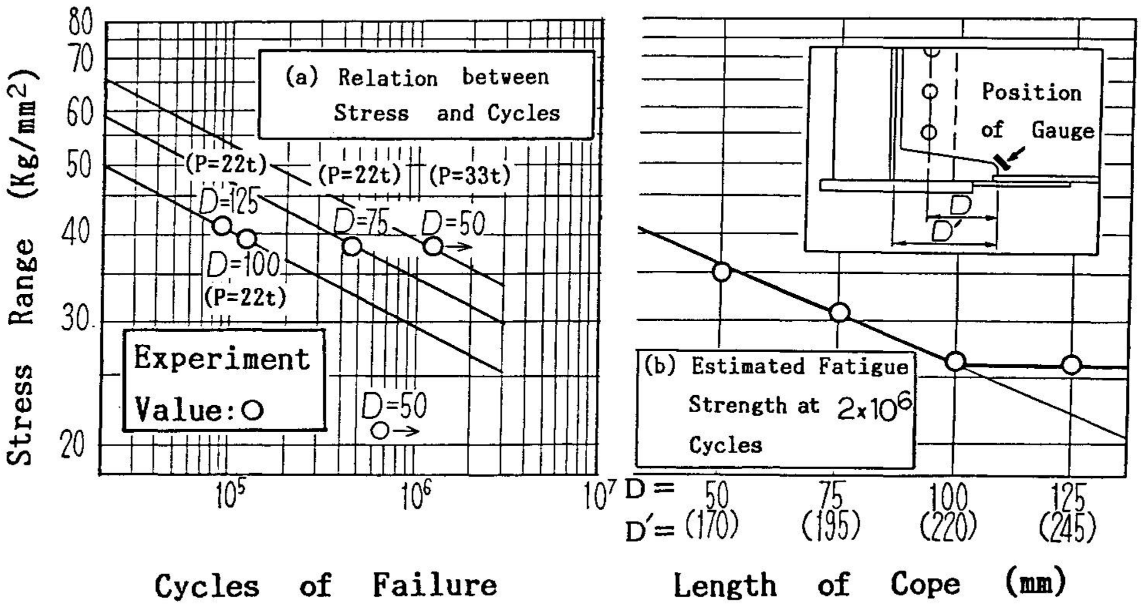
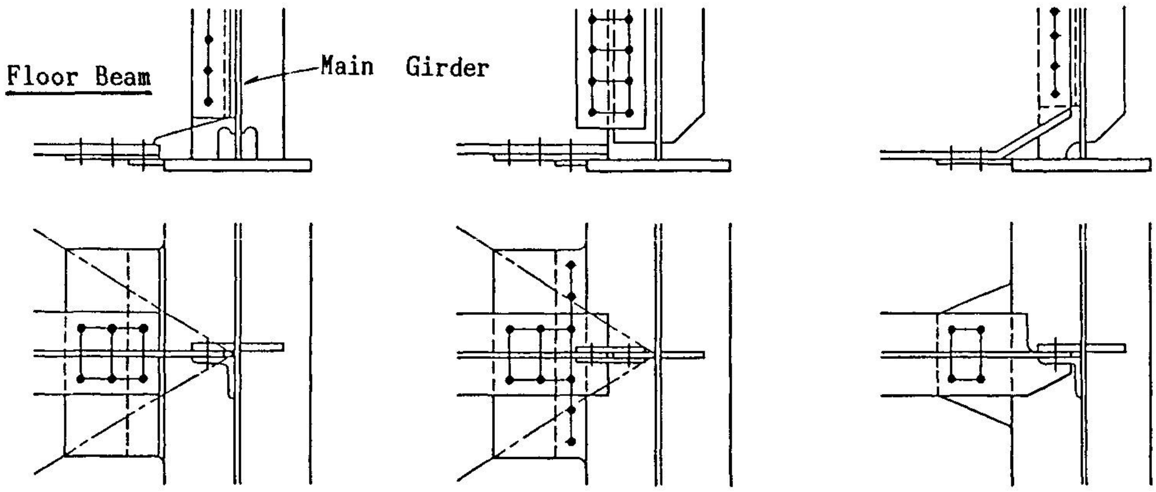


Fig. II Fatigue Strength of Coped Portion of Floor Beam of the copes were varied, were tested under repeated loading and developed the same kind of crack as seen in the actual bridges. Both the FEM analysis and the model test revealed that the local tensile stress along the periphery of the cope became greater and consequently the fatigue strength decreased, as the cope length increased, as shown in Fig. II .

In the damaged floor beams holes were drilled at the tips of fatigue cracks in order to releave the stress and steel plates were attached by high-strength-bolts , as shown in Fig. 3 in Poster. The details of currently designed bridges have been improved as illustrated in Fig. III. The whole width of at least a half width of the lower flange of floor beam is extended to its end.



(a) Defective Details (b) Examples of Improved Details

Fig. III Details of Floor Beam

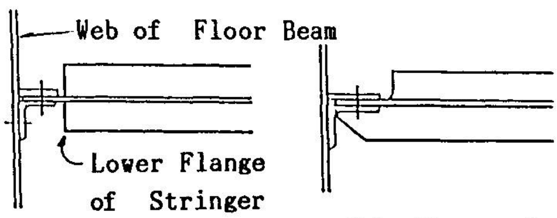
3. Cope of Stringer Web

In a stringer where the lower flange was cut short as shown in Fig. IV (a), and only the web plate was connected with the web of floor beam, a crack started from the cope , as shown in Fig. 4 in Poster. According to the observation of an actual bridge, the coped part was subjected to a high local tensile stress, because of the loss of flanges and, moreover, the lower flange moved sideways by a small amount. It is supposed, then, that the combined effect developed a crack from the cope.

In case the damage was signifficant, a small hole was drilled at the tip of the crack and the lower flange was fixed to the web of floor beam, as shown in Fig. 5 in Poster and, if necessary, additional plates were attached to the end portion of the web. In case the lower flanges of adjacent stringers are connected with each other, or a half width of the lower flange is extended to the end of the web, as shown in Fig. IV (b), there has been no instance of this kind of crack.

4. Crack in Web at Scallop of Vertical Stiffener of Web Plate

An intermediate vertical stiffener is provided with a scallop-cut at its upper and lower ends, in order to allow the longitudinal weld between the flange and the web to pass continuously and the lower end of the stiffener is not welded usually, so that fatigue strength of the lower flange may not be reduced. For the same purpose, a rather high scallop is



(a) Crack occurred (b) No crack occurred

Fig. IV Details of Stringer

often provided at the lower end of stiffener. A crack developed in the plate from the web-side toe of the fillet weld deposited between the stiffener and the web around the scallop at the lower end, as shown in Fig. 6 in Poster. After it grew in the web along the toe of corner fillet weld to some extent, it turned to the horizontal direction, extending as far as 10 cm at most, penetrating the web plate. The observation of actual bridges revealed a relative transverse displacement between the web and the lower flange due to various causes. The web plate may be forcibly subjected to repetition of out-of-plane bending of less than 10 Hz. in frequency due to the train axle loading on the girder, and also the web plate vibrates in its natural frequency of 20 to 50 Hz. as seen in Fig.V.

Based on an analysis it was found that the latter relatively more contributed to the fatigue effect on the critical part than the former. Because this kind of crack grows very slowly, not exceeding 10 cm or so in length, and the direction of the crack is parallel to the primary stress of the girder, it seems practically harmless.

For the repair work, usually, a holes were drilled at the tips of cracks and plates or angle steels were attached to that part by high-strength bolts, as shown in Fig. 7 in Poster. It will be effective that the lower end of the vertical stiffener is fixed by some means such as high-strength bolts, which will not so much reduce the fatigue strength of the tension flange.

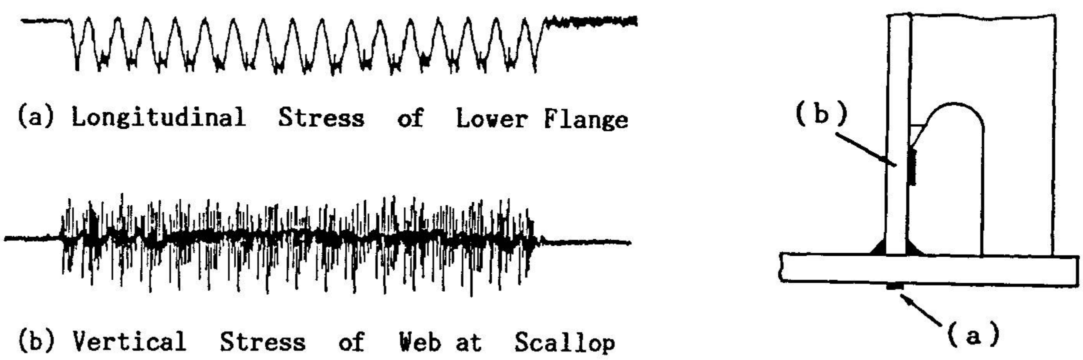


Fig. V Stress Variations of Lower Flange and Web at Scallop

5. Conclusions

The number of occurrence of actual fatigue cracks is rather small and no fatal accident has yet taken place, because important parts of primary members of railway bridges have been designed and manufactured according to specifications where fatigue is taken into account, and fatigue cracks have been discovered before it grew to a serious extent by a well-organized inspection system and proper measures have been taken. However, careful inspection should be continued because new kinds of fatigue cracks may appear in the future.

By Hidehiko Abe, Professor, University of Utsunomiya, JAPAN
Kenji Sakamoto, Senior Engineer, Structure Design Office, Japanese National Railways
Makoto Abe, Design Engineer, Ditto.