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6. Ohara Bridge Fatigue Crack Repair (Japan)

Owner: Toyama Prefecture
 Engineer & Contractor: Kawada Industries
 Work's duration: 6 months
 Date of repair: 1984 – 1985

The Ohara Bridge is a two-hinged arch bridge with the bridge span of 106.5 m and the roadway width of 6.0 m, completed in 1963 (Fig. 1). This bridge was designed with the longitudinal support condition as being movable at both ends and had a single box construction with arch ribs having a very small depth. After the elapse of more than 20 years since its erection, fatigue cracks occurred in parts of the members of this bridge, mainly due to increased traffic volume in recent years and frequent passage of heavy motor vehicles associated with dam construction work. Therefore, this bridge was repaired to reinforce the members against loads.

The fatigue cracks occurred at the connecting gusset plates to each panel of intermediate post, which connects the stiffening girder to arch rib (Fig. 2, 3), and also at the web of stiffening girder above end post, which is the joint between center span and side span (Fig. 4, 5). These cracks were found by visual inspection during patrol in 1982.

According to the results of liquid penetrant tests conducted immediately after finding them, the maximum length of the cracks was 65 mm at the gusset plate of intermediate post, respectively 185 mm at the web of stiffening girder.

Among these cracks, a temporary repair was made for the cracks in the web of stiffening girder immediately after finding them in order to prevent a rapid breakdown as explained below. That is, stop holes were drilled at the end of all cracks in the web. Moreover, steel brackets were installed on all end posts and were used as temporary supports for stiffening girders in side span and center span.

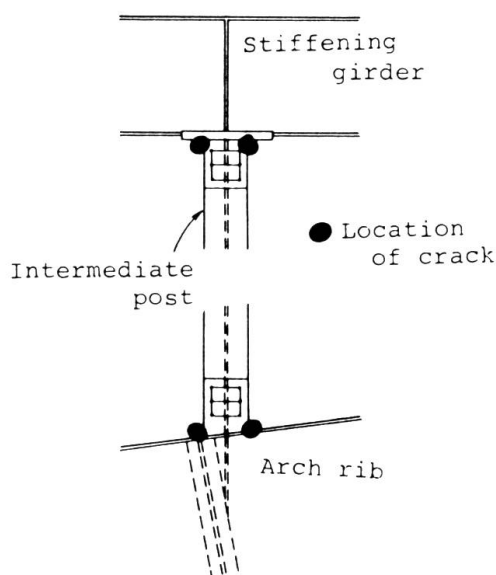


Fig. 2 Location of crack

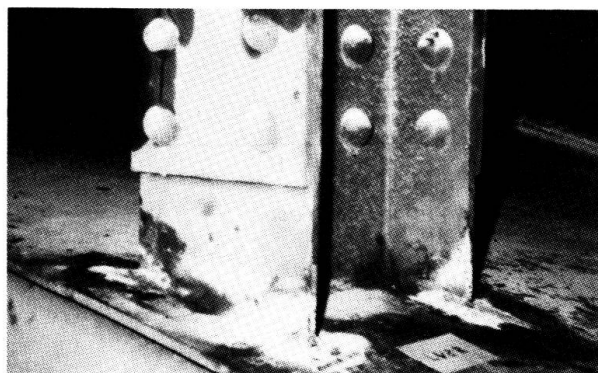


Fig. 3 Crack at gusset

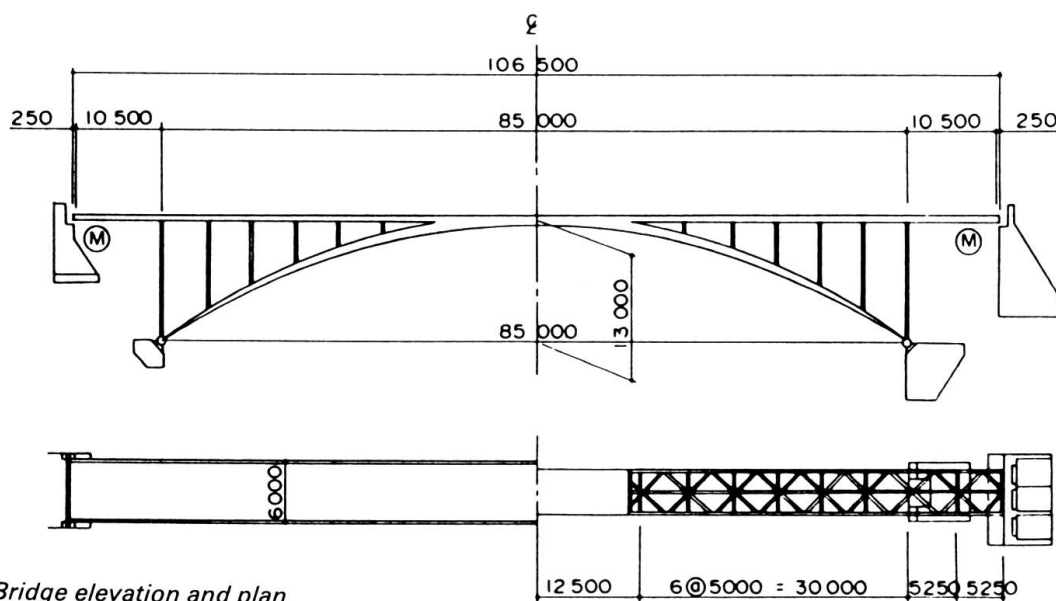


Fig. 1 Bridge elevation and plan

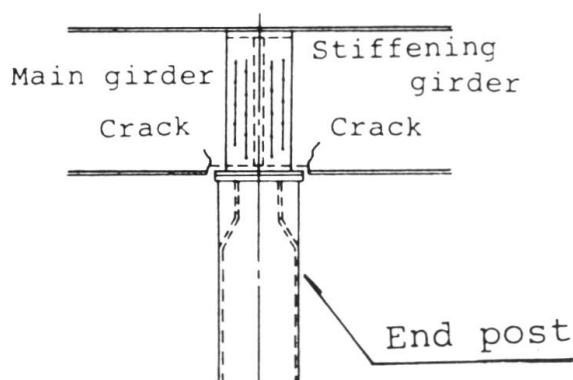


Fig. 4 Location of crack

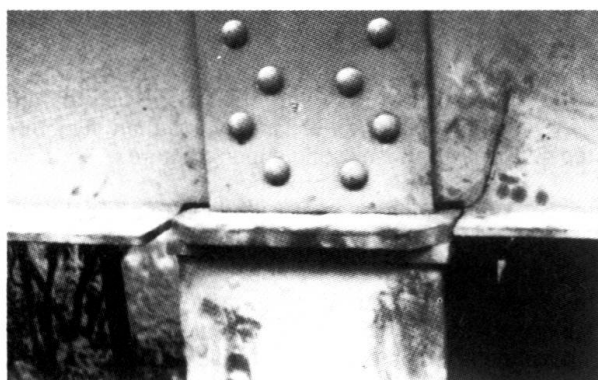


Fig. 5 Crack at stiffening girder web

The fatigue cracks in the gusset plates of intermediate posts were mainly caused by excessive stress concentration at the corner section. This stress concentration was caused by a relatively large longitudinal displacement between stiffening girder and arch rib, which was created by the movability of both end supports. This was confirmed from displacement obtained in a loading test on the actual bridge, results from stress measurements, and the results of 3-dimensional finite element method analysis (Fig. 6). Therefore, as repairing method, new damper bearings were installed on the top of both abutments for reducing the relative longitudinal displacement (Fig. 7). This damper bearing comprised a rubber bearing, return spring and special hydraulic damping system. The supporting condition provides movability at both support bearings for static movement such as temperature effect and resists only to vertical movement caused by live load, giving elastic restraint toward longitudinal movements. Moreover, improvement schemes by making rigid joints or by providing hinges at the gusset plates of intermediate posts were reviewed, but the former indicated an adverse influence upon arch rib and the latter was found to be uneasy to work with. In addition, the compression stress was found to be primary, and the relief of residual stress by the outbreak of cracks was found to be expectable, so both improvement schemes were not adopted this time.

With respect to the fatigue cracks in the web of stiffening girder above the end post, the stress concentration by secondary bending stress at the notches, which also resulted from out-of-plane displacement, was found to

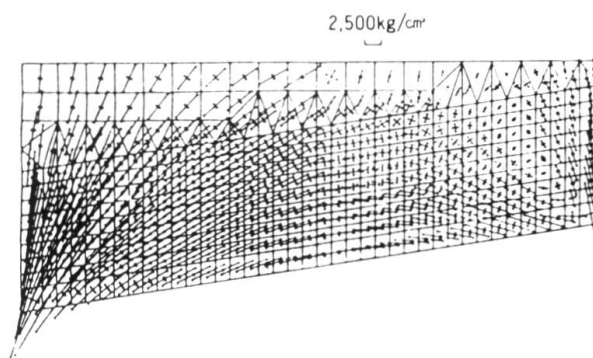


Fig. 6 F.E.M. analysis stress diagram

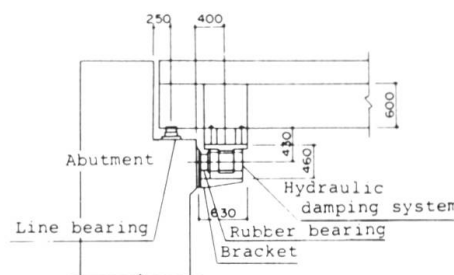


Fig. 7 Damper bearing

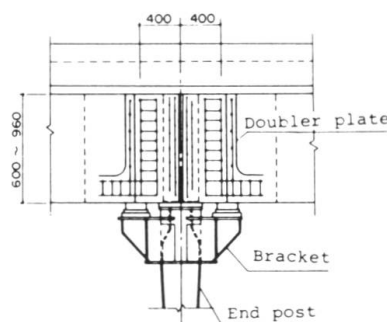


Fig. 8 Doubler plate added to web

be the main cause of the fatigue cracks. This was also confirmed by the loading test on the actual bridge. In the repairing method adopted, it was first necessary to reduce the out-of-plane displacement of web and thus lateral bracings were added near the location of web. As repairing measures against the cracks in web, three schemes were reviewed: making rigid connections or hinged connections at the joints, or repairing cracked portion by double plates. In consequence, the scheme of repairing the cracked portion by double plates was adopted from the viewpoint of easier work and appearance (Fig. 8). It was decided to leave the steel brackets, installed during temporary repair, as they were.

Effect of repair was checked by a loading test on the actual bridge. As a result, the relative longitudinal displacement and out-of-plane displacement of the stiffening girder and arch rib were reduced by 60 to 70% compared to the values measured before the repair, by which it was possible to confirm a sufficient effect of this repair.

Moreover, a liquid penetrant test was conducted two years later, and it was confirmed from the results that cracks were not progressing.

(Shoji Miyazaki)