Fatigue life of railway bridge welded joints

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ABSTRACT

In the period from 1956 to 1990 the Metal Structures Department of the Technical University of Szczecin conducted X-ray examination of butt welded joints in the mains girders of 155 operated bridges. The most dangerous weld defects, i.e. cracks, were detected in 34 bridges at 437 radiographs. All the cracks but one were found in the bridges built before 1960.

Within the work presented in this paper an analysis of strength of the welded joints with cracks was carried out for 9 plate girder railway bridges of span between 14,5 m and 31,4 m. There were 1408 radiographs taken altogether for those bridges; as much as 67,2% of the radiographs were counted among R4 and/or R5 defectiveness class which are inadmissible for the new bridge structures in the light of the relevant Polish Standard's rules.

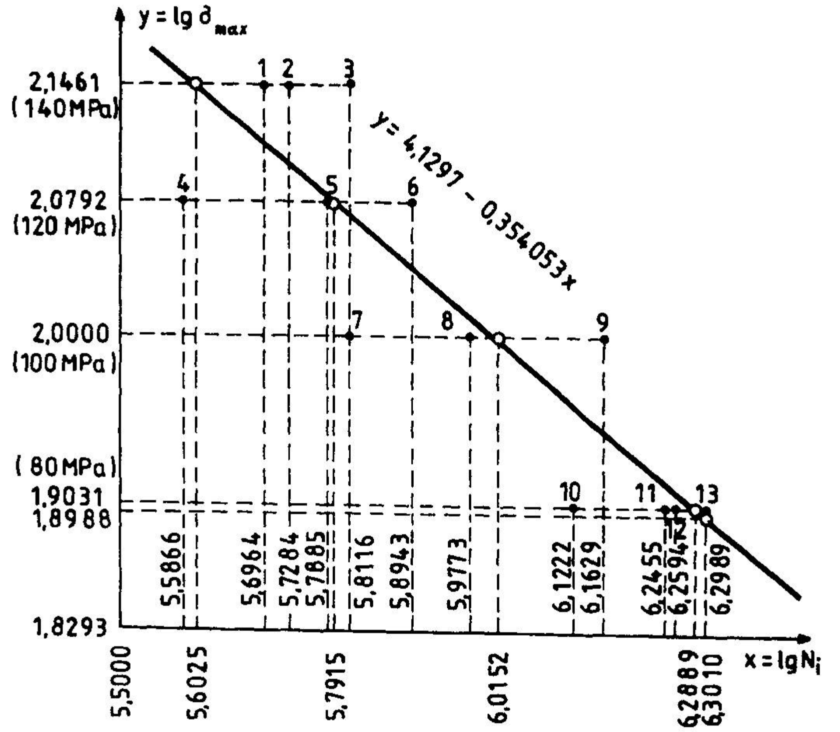
Each flange butt joint was covered one-sidedly with rhomboidal plates situated on the internal surface of the flange. These cover plates had a thickness of 8 mm and they were 80 to 160 mm wide and 160 to 240 mm long.

The maximum global stresses in particular flange joint, calculated from unfactored dead and service load varied from 42,9 MPa to 74,4 MPa whereas within the zone just beyond the straps these figures ranged from 51,9 MPa to 84,2 MPa (design value, without stress concentration effect taken into account).

At the Metal Structures Department of the Technical University of Szczecin, some laboratory tests were carried out on the model of a welded joint that corresponded to the design solution of the bridges flange joints subjected to the strength analysis. The specimens, sized at 180 mm x 12 mm x 720 mm, had the X-type transverse butt weld reinforced one-sidedly with two rhomboidal cover plates (straps) 70 mm x 4 mm x 120 mm. The X-ray examination of the specimen detected a medium continuous lack of penetration in all the welds, as well as numerous medium and small slag inclusions.
The tests were carried out under pulsating tension at 4 levels of the nominal stress: 140, 120, 100 and 80 MPa, by means of a pulsator at frequency of 500 cycles per minute. The cycle stress ratio ($R = \sigma_{nin} / \sigma_{max}$) was equal to $R = 0{,}1$. On the basis of the test results, by means of the least square method, the following regression line equation was formulated:

$$y = 4{,}1297 - 0{,}354053\ x$$

where: $x = \lg N_i$, $y = \lg \sigma_{max}$, N_i - number of cycles to the specimen failure, σ_{max} - maximum value of stress, in MPa.
The value of mean safe fatigue strength derived from the regression line equation for $N_i = 2 \cdot 10^6$ cycles was $Z_{rj} = 79{,}2$ MPa, and for $N_i = 10^5$ cycles was $Z_{rj} = 228{,}8$ MPa.



Regression line derived from fatigue tests

The analysis of the unfactored stresses calculated at joints under the dead and service load as compared to the fatigue limits obtained from the laboratory test as well as from the literature data was a decisive factor in the way of treating the joints with cracks.

4 bridges were reinforced with additional cover plates riveted to the flanges. The welds with cracks in 5 other bridges, though inadmissible in bridge structures, were decided to be left without reinforcement - which was based on the relatively small value of the computed stresses, lower than the safe fatigue strength obtained from the laboratory tests. At the same time a periodical X-ray inspections of the joints were recommended. The subsequent, three-times-repeated inspections of these bridges did not show any changes or development of new cracks, and this despite a great number of train passages which was estimated at $1{,}6 \cdot 10^6$ cycles within a 50-year period of bridge operation.

The following conclusions may be drawn up from the described examination, laboratory tests and calculations:

- The results of X-ray examination conducted in situ have shown that it is economically unjustifiable to evaluate the load capacity of operated bridges making use of the same regulations and standards as in designing new structures. In the standards concerning testing the existing bridges the loads should be close to real weights which actually act on the bridge under consideration. The X-ray inspections also indicated that a defect within a joint, even as sharp as crack, can be admissible if it does not develop during the structure operating.
- All the specimens tested became cracked within parent material at the plane of sharp ends of rhomboidal cover plates which apparently reinforced the joint. The investigations confirmed recommendations applied till now concerning the inexpedience of the use of welded joints with straps in dynamically loaded structures.
- The observations concerning the place of cracks initiation suggest the advisability of conducting periodical external inspection of the welded joints with rhomboidal cover plates.