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Research on changes in properties of steel from the old road bridge

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A B S T R A C T

This paper deals with problems stemming from the long service of steel bridges, in particular with the changes in the mechanical and strength properties of their steel over time. The considerations are of special relevance for bridges (including historic bridges) which have been in service for a long time, in the case of which it is vital to determine the actual operational strength of their main structural steel components. Operational load capacity reserves are evaluated as part of a technical condition assessment to determine the remaining service life.

In this research an attempt was made to evaluate changes in the properties of the steel in the main girders of a heavily deteriorated steel road bridge (designated for dismantling) built in 1908. For this purpose tests were carried out on steel specimens taken from the most stressed places near the middle of a steel girder's span. The specimens were taken along the entire height of the girder's web. Analyses were carried out to determine whether the long service of the steel spans and their cyclic stressing resulted in changes in the properties of the steel and how significant the changes are.

In order to reliably evaluate the changes laboratory chemical tests, metallographic examinations and strength tests were carried out on the structural steel. On the basis of the test results the changes in the properties of the steel as a function of time were determined. It was found which parameters were critical and to what degree.

1. Introduction

Knowledge of the operational durability of old steel bridges is essential for assessing their condition and remaining service life [1–3]. The aim of this research was to determine if the mechanical and strength properties of the steel in bridge spans change as a result of the latter's long service and if this is the case, how significant the changes are. So far no steel testing method for determining the operating stress of the structural elements of bridges has been developed. Studies of the effect of long service on some mechanical properties of the steel in the girders of railway bridges, based on the analysis of specimens taken from different cross sections along the span's length, were presented in [4].

As part of the present research an attempt was made to evaluate changes in the material properties of the main girders of an old heavily deteriorated steel road bridge scheduled to be dismantled. The results of tests carried out on steel specimens taken from more stressed and less stressed places in the same cross section were compared. Obviously it would have been more proper to compare the test results with the properties of the same steel not incorporated into the bridge, but that was impossible in this case.

2. Investigated bridge specifications and service loads

As mentioned above, a heavily deteriorated bridge was selected for the tests. The bridge had been built over the Biała Lądecka River in Stronie Śląskie in 1908. After about 100 years it was designated for dismantling because it did not meet the modern transport needs, mainly it was too narrow. The bridge was a through road bridge with an effective span of 16.50 m, with a 4.00 m wide roadway without walkways. The bridge deck was made up of 20 × 15 cm wooden planks laid on the steel stringers and cross beams.

Fig. 1 shows the basic dimensions of the bridge. Two riveted plate girders with an axial spacing of 4.20 m, with a 950 × 10 mm web and the top and bottom flanges made of 100 × 100 × 10 mm angles constituted the load-bearing structure. The stiffener rib was made of 75 × 75 × 10 mm angles to which transverse beams made of I-bars I 260, spaced at every 1.65 m, were attached.

2.1. Determination of bridge service loads

A model of the service loads of the bridges on the roads in Poland, developed by the author on the basis of the studies described in [5–7] (Table 1), was used to determine the service loads of the investigated bridge.

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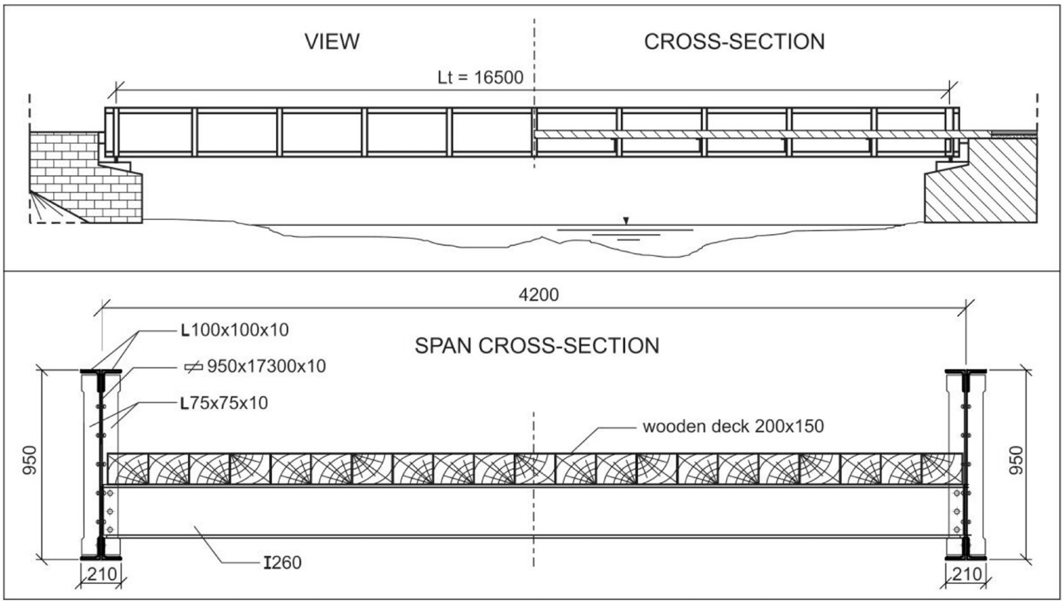


Fig. 1. Basic geometric parameters of investigated bridge.

Considering the type of the road on which the investigated bridge was situated, average daily truck traffic density $N_d = 1000$ in both traffic directions was assumed. Hence the number of operating stress cycles for the whole lifetime of the bridge amounted to $N_e^r \approx 36.5 \times 10^6$ cycles.

In order to determine the actual stresses in the of the main bridge girders, the static analysis based on Polish bridge standards has been performed. Individual maximum stresses have been identified, for the load for the schemas listed in Table 1, and for common used type of lorries. Table 2 summarizes the maximum calculated stresses in girders of the bridge.

3. Description of tests

Test specimens were taken from the upper, middle and lower part of the main girder's web. The main girder's middle part in the neutral axis region was deemed to be the least stressed in service (as opposed to [4], where the girder's parts near the supports were deemed to be the least stressed, despite the fact that the greatest shear forces occur there).

Three series of test specimens, denoted respectively A, B and C, were taken. Series B specimens were taken from the middle cross section of the span. Cross sections A and C were shifted by a specimen length, i.e. about 0.40 m, to the left and right of the span's vertical axis. The places from which the test specimens were taken are shown in Fig. 2.

The total number of test specimens was 34, including 13 series A specimens, 8 series B specimens and 13 series C specimens. The specimens were denoted with consecutive numbers depending on the cross section and the geometric position along the web height, i.e. from the girder top flange level. The test specimens were machined in accordance with the applicable standards. They were wholly machined flat 10d gauge length specimens with heads, having an overall length of 365 mm, a width of 40 mm and a thickness of 9 mm. Moreover, specimen B9 was taken from a place adjoining a rivet.

4. Test results

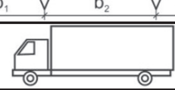
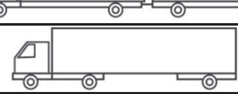
In order to reliably determine the changes in the parameters of the structural steel of the bridge's main girders over its long time of service the following tests were carried out:

- a chemical analysis of the steel,
- metallographic examinations,
- strength tests of the structural steel.

Table 2
The results of the static analysis of stresses in girders of the bridge for workloads.

Type of vehicle according to Table 1	Maximal bending moment [kNm]	Maximal stresses in girder [MPa]
2	856,60	50,58
2P2	1109,80	65,53
2 N1	1062,70	62,75
Star 266 vehicle	922,10	54,45
Class “C” vehicle (according to Polish standard)	1468,40	86,70

Table 1
Model of service loads for Polish road bridges [5].

Type of vehicle	Scheme of load: q_1Q_e b_1 q_2Q_e b_2 q_3Q_e b_3 q_4Q_e	a_i [%]	Q_e [kN]	q_1 -	q_2 -	q_3 -	q_4 -	b_1 [m]	b_2 [m]	b_3 [m]
2		65,90	129,6	0,348	0,652	-	-	3,71	-	-
2P2		20,60	291,0	0,211	0,377	0,206	0,206	3,92	4,96	3,63
2N1		13,50	262,6	0,218	0,356	0,426	-	3,56	5,89	-