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Problems of Lamella Flanges in Steel Bridge Construction

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Abstract: As the plate elements of ordinary lamella flanges always exhibit unavoidable initial geometrical imperfections, a gap always occurs between them, into which the loaded lamella is pressed under load. Given the fact that the loading is many times repeated, the above phenomenon is also many times repeated, a pronounced cumulative damage process being thereby generated. This leads, as it became manifest during the authors´ tests, to the initiation and propagation of fatigue cracks in the longitudinal fillet welds connecting the individual lamellas, which can, of course, imperil the safety and useful lifetime of the bridge structure concerned.

Introduction

Lamella flanges have lately grown popular with the designers of steel bridges, because – in their belief – they provide us with the possibility of avoiding very thick flange plates in steel bridge structures. This belief is based on the assumption that the lamellas are perfectly plane and, therefore, in perfect contact everywhere, so that the loading from one lamella is transmitted into the other via pure compression, and that the perfect interaction of both lamellas is materialized by means of boundary fillet welds connecting both of the two lamellas. This simple assumption is, however, far from reality: it is not in the means of steel fabricators, not even in the means of those which are very progressively equipped, to produce perfectly plane flange lamellas. Then both lamellas exhibit unavoidable initial curvatures, which in combination form a gap between the lamellas, and consequently the directly loaded lamella are pressed into this gap. As the loading acting on every bridge is many times repeated, the aforesaid phenomenon is also many times repeated, (we can say that the lamellas „breathe“), and then an unavoidable cumulative damage process in the lamellas comes to being.

Experimental investigation

The aim of this investigation was to examine whether, due to the breathing of the lamellas, significant cumulative damage was generated such as to endanger the whole structural system.

The corresponding test specimens were materialised as a transverse cut-out from the lamella flange of a bridge in the neighbourhood of Prague, the width of the specimen being 250 mm, and the specimen acting compositely with a concrete slab (this again being compatible with the situation in the bridge concerned). The whole model was tested in the upside-down position, so that the plate elements of the lamella flange were above the concrete slab. The top plate element was repeatedly loaded by a force modelling the reactions of the inclined webs in the system of the whole box girder. The related test set-up is shown in Fig. 1.

In the course of the investigation, two models were tested, and therefore two tests carried out. The first of them started by a static, one-cycle loading experiment (which also provided the authors with useful information), and then was continued by a typical cyclic loading test, during which the model was subjected to many times repeated cycles of loading. The objective of this repeated loading test, which played the role of a pilot test for the whole examination, was to prove that the phenomenon of lamella breathing could significantly affect the performance of a lamella flange system. Therefore the gap between the two lamella plates in this first test was chosen large, namely as 12mm.

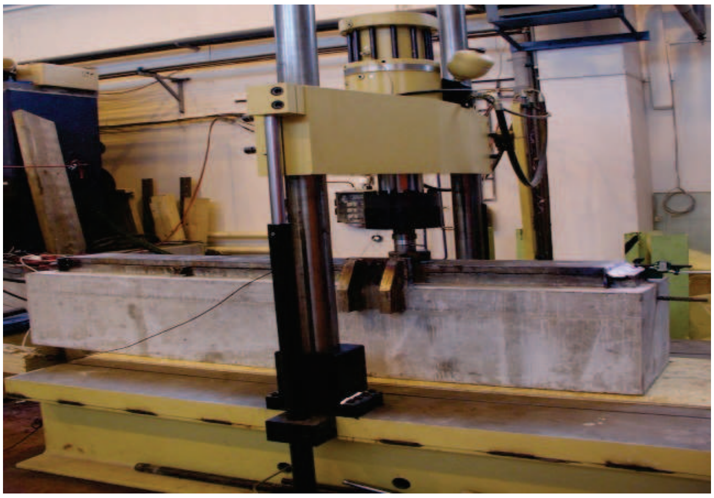

Fig. 1: The test set-up used

The other experiment already had quantitative objectives and was tailored to the real situation in an ordinary lamella-flange system. That is why the gap between the lamella plates was chosen much smaller (as 5.5 mm), with the view to reflect a possible combination of manufacture tolerances of the lamella plates in question.

The results of the static test were also used to determine the maximum amplitude to be safely applied during the cyclic loading experiment. A sinusoidal frequency of 2 Hz was used, and the cyclic loading was continued until the fatigue crack, generated by the cumulative damage process induced by the repeated loading, reached the whole length of the fillet weld connecting both of the two lamellas.

The welds of the first model cracked completely after 129 353 loading cycles, i.e. already after a few hours of testing. The importance of a real danger of lamella flange breathing, and of its impact on the limit state of the whole bridge structure, was therefore already demonstrated by this pilot test.

Of course, the results of, and the conclusions drawn from, the second test , where the gap between the flange lamellas realistically depicted the situation occurring in ordinary lamella flanges currently used in steel bridge construction, are of a much greater practical importance. There the fatigue crack initiated at 578 558 loading cycles, then propagated under further repeated loading, and covered the whole length of the weld (and thereby heralded a complete failure of the weld) after 1 256 293 loading cycles.

The experiments clearly demonstrated that the performance of the lamella flanges at the limit state is significantly influenced by a phenomenon which is still not taken into account. The authors´ experimental investigation proved the possibility of threats to the reliability and safety of the bridge due to the failure of the longitudinal boundary fillet welds connecting the plates of the lamella flanges, and consequently due to the disruption of their primary function necessary to ensure the desired action of the plates of the lamella flanges as a composite system.

The fatigue phenomenon studied, whose probability increases with the increasing number of heavy vehicles crossing the bridge, can result in very severe problems that may occur after many years of service of the bridge.

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