Fatigue Evaluation of Pre-Tensioned Concrete Girders

Bewertung des Ermüdungsverhaltens von Spannbettbindern

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Abstract

Prestressed precast concrete beams are increasingly used in bridge construction. Due to the cyclic loading of bridges caused by high and heavy traffic, the fatigue design and construction of prestressed bridge beams is of special interest. Based on an evaluation of previous fatigue test results on prestressed concrete beams, compiled in a database, the cyclic load level could be identified as a decisive parameter with regard to the fatigue life and failure mode of prestressed concrete beams under cyclic loading. At common cyclic load levels the fatigue failure of the embedded strands was found to be critical.

1. Introduction

When pre-tensioned precast concrete girders are used as bridge girders, like in the USA, many Asian and European countries and also increasingly in Germany, they are subjected to cyclic loads caused by high and heavy traffic. Consequently, the fatigue resistance of these girders is of major importance within the design and construction of such bridges.

In order to evaluate the fatigue behaviour of pre-tensioned concrete girders, international fatigue test results of pre-tensioned concrete girders have been analysed with regard to fatigue life, failure mode as well as different influencing parameters. In addition, further systematic fatigue tests have been carried out at iBMB, Division of Concrete Construction of TU Braunschweig.

2. Fatigue of pre-tensioned concrete girders

2.1 Code provisions

In current code provisions, such as Eurocode 2 /1/, the design against fatigue failure is regulated separately for concrete and prestressing steel. The fatigue strength of concrete is basically described by the maximum cyclic stress level (referred to the concrete compressive strength) as a function of fatigue life (number of load cycles to failure). The fatigue strength of prestressing steel is defined by S-N curves describing the relationship between the stress range and the fatigue life. The fatigue failure of girders follows as the minimum of the both.

2.2 Fatigue behaviour

Based on international fatigue test results on pre-tensioned concrete girders, summarised in a database at iBMB, the fatigue behaviour of girders has been evaluated initially with regard to the type of failure, which substantially depends on the maximum fatigue load level (maximum fatigue moment $M_{fat,max}$ referred to experimental/calculated static moment capacity M_u, Fig. 1).

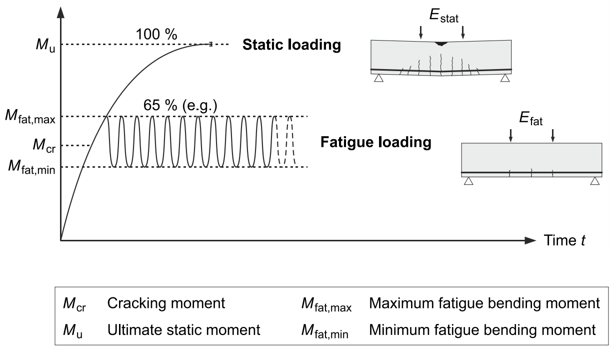

Fig. 1: Definition of fatigue load level $M_{fat,max}/M_u$

The evaluation of this load level in Fig. 2 indicates the typical fatigue failure differentiated in concrete compression failure and prestressing steel failure:

$$M_{fat,max}/M_u \geq 0.70 \qquad \text{Concrete failure} \qquad (1)$$

$$M_{fat,max}/M_u < 0.70 \qquad \text{Prestressing steel failure} \qquad (2)$$

Due to the fact that in bridges the stress levels are usually below this distinctive value, the fatigue of prestressing strands is considered to be critical to the fatigue life of pre-tensioned concrete girders. In order to quantify the fatigue life of prestressing strands, additional fatigue tests on both prestressed concrete girders (Fig. 3, cf. /2/) and single strands have been performed and evaluated in relation to international fatigue test results from the database (Fig. 4).

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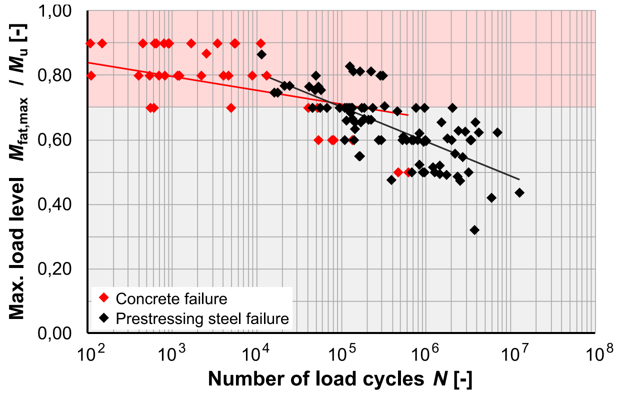

Fig. 2: Fatigue test results of girders

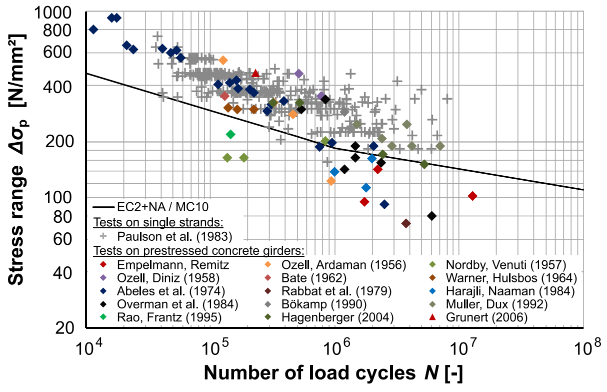

Fig. 4: Fatigue test results of girders in comparison to single strands

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The fatigue strength of embedded strands in prestressed concrete girders is influenced primarily by the stress range and the applied number of load cycles (Fig. 4). However, the fatigue life of embedded strands is also affected by structural parameters (e.g. prestressing and reinforcement ratio) and by fatigue processes (e.g. the friction between strands and concrete), leading to a reduction in the fatigue strength compared to fatigue tests on single prestressing strands /3/. The aim of current experimental and theoretical investigations is to identify, quantify, model and describe the individual parameters and mechanisms.

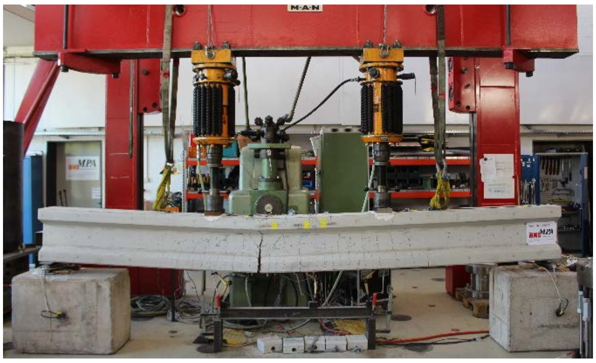

Fig. 3: Fatigue test at iBMB (after failure)

3. Conclusions

In general, the fatigue strength of pre-tensioned concrete girders is influenced primarily by the maximum cyclic load level that allows a prediction of failure mode, differentiated in a concrete compression failure for $M_{fat,max}/M_u \geq 0.70$ and a prestressing steel failure for $M_{fat,max}/M_u < 0.70$. Based on an evaluation of international test results and additional own fatigue tests on pre-tensioned concrete girders the fatigue life, the typical fatigue failure mode and the related specific influences are presented.

4. Literatur

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