Experimental Investigations on the Fatigue Behavior of Concrete Bridges

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Summary

Due to the rising demands existing bridges have to meet, periodical inspections are necessary. Decisions on the necessity of costly maintenance to guarantee structural safety and serviceability have to be made. Increasing traffic loads and frequencies may cause a strength reduction of structural materials which is also known as fatigue. In reinforced concrete structures the reinforcement is particularly subject to fatigue.

To shed light on the load bearing behavior under service conditions, large-scale tests with frames under cyclic loading are performed. Emphasis is placed on the recording of crack patterns and the detection of single rebar breaks by non-destructive methods. The specimens on a scale of 1:2 are designed to match dimensions and detailing of frame bridges of the 1960ies and 70ies, which are very common on Swiss motorways. The tests shall show whether fatigue has to be taken into account when inspecting these bridges and how fatigue damages can be detected at an early stage.

Keywords: Fatigue, Reinforcement Breaks, Bridge Assessment, Non Destructive Testing

1. Introduction

Since the establishment of Switzerland's motorway system in the nineteen-sixties there has been a considerable increase in heavy traffic [1]. Railway bridges are subjected to heavier loads and more load cycles as well [2]. Recently, discussions about new load models for heavier railway cars and trucks have re-established the discussions about fatigue behavior of reinforced concrete bridges. Compared to other structural engineering domains, there is a great lack of knowledge in the domain of fatigue in reinforced concrete.

Especially heavy truck crossings cause large stress variations in the reinforcement of corners and midspan of frame bridges. Additionally, the repair of some of these bridges revealed that the reinforcement in the frame corners was placed lower than indicated in the drawings, which shortens the fatigue life due to higher stress levels in the reinforcement.

2. Experimental Work

The planned test series contains two identical specimens but different load histories. Fig. 1 shows the test setup. Two single loads are applied by 400 kN-cylinders. The test procedure contains continuous gaging under cyclic loading as well as periodical measurements under static loading. Additionally, an attempt is made to detect breaks in reinforcement bars with acoustic emission. Furthermore, the research group of the authors develops a device to localize breaks in single reinforcement bars by use of remanent magnetism.

Approaches for calculation of the reinforcement's fatigue life in present codes are based on

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Basquin's law [3]. By following the code procedures, stress differences for the reinforcement of the specimen were calculated in a first step. Secondly, a more detailed analysis for the calculation of the load effects was performed. A simple strut-and-tie-model with struts of variable stiffness was used. Fatigue life of the reinforcement has been calculated with the values given by the Swiss code SIA 262:2003 [4] and the calculated stress differences.

Due to the fact that the frame is hyperstatic, the detailed analysis that takes the cracking into account leads to a different distribution of the internal forces. Thus, the results produced by the two methods differ a lot.

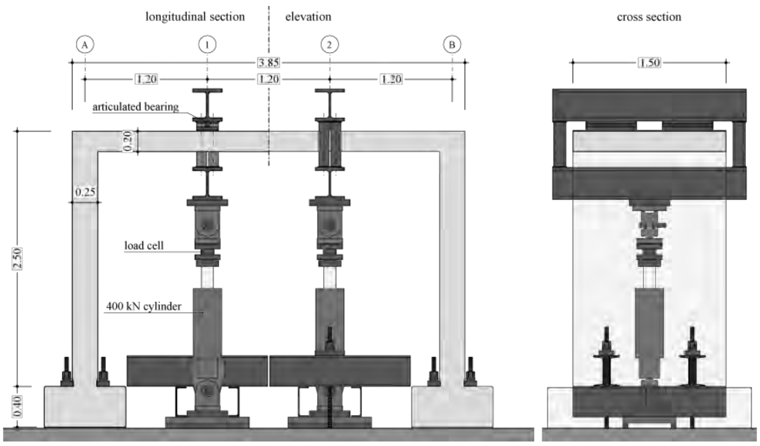

Fig. 1: Test setup

3. Discussion and conclusions

In order to obtain reasonable results for the fatigue life of the reinforcement, stress differences should be calculated exactly. It must be pointed out that a 10% higher stress difference results in a 30% shorter fatigue life. The method proposed in the codes to calculate fatigue life of the reinforcement is easy to apply and therefore interesting for practical engineers who are designing new bridges. However, the application of this method for the assessment of existing bridges is very limited, especially because assumptions about the stress history, from which the reinforcement has suffered in the past, have to be made.

It has been seen that even in a test with clear boundary conditions - on the action side as well as on the resistance side - fatigue life of the reinforcement is difficult to predict. The appliance of current code provisions is simple but must be questioned and adapted for the particular structure. However, these code provisions seem to be conservative because they rely on a small range of knowledge. The mechanisms which lead to fatigue damage are not completely investigated yet.

It is thus necessary to find out more about the fatigue damage mechanisms in reinforced concrete and to explore or adapt methods which enable the detection of endangered or already damaged bridges. Furthermore, new methods to evaluate the accumulated fatigue damage and the residual service life of concrete bridges have to be developed to avoid costly reconstruction or strengthening. As public funds for infrastructure are limited today, it is necessary to extent the service life of the existing bridges by adequate measures in order to create a sustainable infrastructure.

References

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