Static and Dynamic Fatigue Strength of Textile Reinforced Concrete

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Summary

The application of textile reinforced concrete (TRC) is an effective way to strengthen reinforced concrete structures, as already demonstrated in numerous studies, pilot projects and practice-oriented applications. In order to allow the application of TRC for bridge strengthening, further investigations regarding the static and dynamic fatigue strength of the composite material are necessary. To obtain results in those fields first experimental investigations have been conducted. We tested the long term strength for specific periods under defined permanent loads and varying climatic conditions. Subsequently the residual strength of the specimen was determined. Additionally dynamic tests were carried out to prove the fatigue strength of TRC. This paper shows test setups and results of these investigations and provides some perspective to future developments.

Keywords: Textile Reinforced Concrete; TRC; carbon; static fatigue strength; sustained load; long-term load; dynamic fatigue strength; dynamic load.

1. Introduction

With the increase of traffic over the last decades and a considerable part of the German infrastructure dating back to the post-WWII period of reconstruction, a great number of German bridges is functionally obsolete or structurally deficient ([1]). While many of them will have to be replaced, a number of bridges can be preserved through maintenance, repair and rehabilitation. Thus, the market for repair and strengthening measures is steadily growing.

The application of the innovative composite material textile reinforced concrete (TRC) for strengthening of structural elements presents a new approach to this problem area. TRC consists of a fine-grained concrete and a high-performance carbon-textile as flexible reinforcement with high tensile strength (e.g. [2]). Over the last two decades numerous studies have shown that, due to its versatility and high load-bearing capacity paired with low dead weight, TRC is an efficient material for strengthening purposes ([2] to [6]). While during the early years of research mostly alkali-resistant glass fibres were used as a basis for the textile reinforcement, by now the material of choice is carbon, due to its excellent durability and high tensile strength.

In practice, TRC is used increasingly ever since 2005 for strengthening purposes as well as for construction of new elements ([7], [8]). To enable a widespread industrial application, an important step was to obtain a first General Type Approval for the application of TRC for enhancing the bending strength of reinforced concrete structures in June 2014 ([7], [9]).

So far research has concentrated mostly on material behaviour under predominantly static and short time loads. However there are two major aspects that have to be considered for an application of TRC to bridges: the material behaviour under sustained static loads (static fatigue) and under cyclic loads (dynamic fatigue). In order to confirm and expand findings from the few studies, that have been conducted for textile reinforced concrete under these load types, further investigations of the material properties of carbon textile reinforced concrete under sustained and dynamic tensile load have been conducted, the results of which are shown in the full paper and summed up below.

2. Experimental investigations and conclusions

For the experimental investigations shown in this paper, small-format strain specimens were prepared with two layers of an open-mesh carbon fabric consisting of multifilament yarns embedded in a fine grained concrete matrix. In order to evaluate the results of static and dynamic fatigue tests, static uniaxial tensile test have been conducted, aiming to find the reference strength of the textile reinforced concrete system at ambient temperatures of 20 °C and 40 °C.

For the static fatigue tests long-term loads at a level of 70 % of the 5 % fractile of the short-term tensile strengths were applied to the specimens at ambient temperatures of 20 °C and 40 °C for various periods of time reaching from 100 h to 4000 h at most. The load was applied in two steps, as shown in Fig. 1. In these tests none of the specimens showed tensile failure. Subsequently the specimens were unloaded and then tested again in short-term tensile tests in order to obtain their residual strength. Fig. 2 shows that the residual strength values were on or slightly above the level of short-term strength, with the linear trend line slightly rising. Consequently, at the long-term load level tested no reduction of the tensile strength of TRC could be found.

In order to demonstrate the fatigue strength of TRC under non predominantly static loading, dynamic fatigue tests were carried out on the strain specimens with 2×10^6 load cycles, at a frequency of 25 Hz, a top load of 60 % and a load range of 10 %, both in regard to the reference tensile strength. None of the specimens failed. For the load path see Fig. 3. The static tensile tests following the dynamic loading and the unloading showed no decrease in strength due to damage resulting from the cyclic load (Fig. 4).

Although test results have shown the composite material's general capability of coping with both long-term and cyclic loads, further investigations regarding different load levels will have to be conducted.

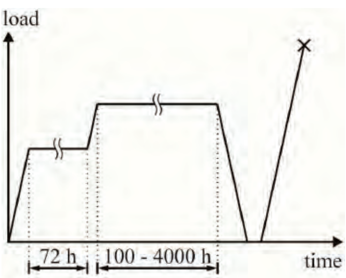

Fig. 1: Load path for static fatigue test

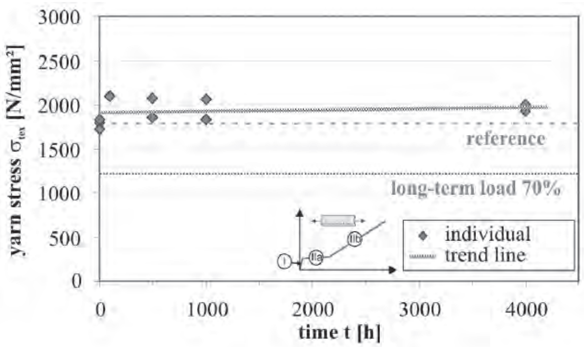

Fig. 2: Results of the residual strength tests after long-term load at 40 °C

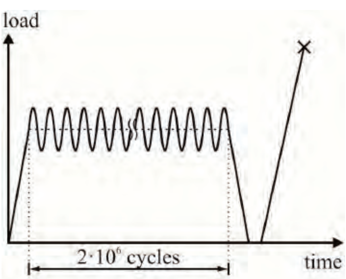

Fig. 3: Load path for dynamic fatigue test

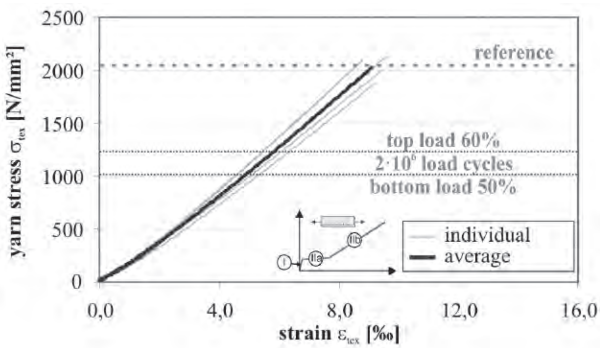

Fig. 4: Results of the residual strength tests after cyclic load