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LONG-TERM RELIABILITY OF CARBON FIBER REINFORCED POLYMERS IN CIVIL CONSTRUCTION

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ABSTRACT

Today the amount of carbon fibres annually used in construction is similar to that in aircraft industry. Applications in aircrafts are based on forty years of practical experiences. How is the situation with Carbon Fibre Reinforced Polymers (CFRP) in the construction industry? Examples of applications in the areas of rehabilitation and new construction are going to be discussed that proof a very high reliability of CFRP components in civil engineering.

Keywords: CFRP tendons, rehabilitation, stay-cables, post-tensioning.

INTRODUCTION

During the 1980ties visions have been developed for very long span lightweight bridges made of CFRP (Meier, 1987). Also since about that time corrosion on suspender-, main- and stay-cables made of steel for suspended bridges are seriously bothering bridge owners. Additionally fatigue is a severe problem in the cases of steel suspender- and stay-cables since such tendons are in use. In many cases also post- and pre-tensioning elements, as well as classical reinforcing bars are concerned. Therefore some institutions in Europe, USA, Canada and Japan proposed the use of non-metallic tendons and reinforcing bars. Some few bridge owners and responsible authorities were willing to support the application of CFRPs under the condition that the long term behavior of concerned structures was going to be conscientiously monitored.

METHODS OF STRUCTURAL HEALTH MONITORING (SHM) APPLIED

The following tools have been used during the described program: strain measurements by a mechanical gauge system, often called “demec gauge”, resistive foil strain gauges (RSG), fiber Bragg grating (FBG) sensors, a CFRP self-sensing system, a coin tapping technique as it is also used extensively at present to detect debonding of honeycomb structures in aircraft industry, and surface monitoring by the means of replica technique and scanning electron microscopy.

REALIBILITY AND STABILITY OF SHM APPLIED

A high stability and reliability of the SHM-tools is the key for the success of any long-term structural monitoring. Within three representative projects 156 demec points have been used during a time period of 14 to 20 years. Only one single point failed. Using the applied configurations all possible kinds of drifts become negligible. The long term reliability of the mechanical strain gauge system used to monitor the behavior of the externally bonded CFRP strips to reinforced concrete structures was instrumental to prove the suitability for use as CFRP post-strengthening system (Fig. 1).

For the safety surveillance of the CFRP stay-cables of the Stork Bridge in Winterthur (Fig. 2) RSG and FBG are redundant in use. The difference between FBG and RSG measurements increases at a rate of about 4µm/m/year. The RSG measurements have a slightly higher resolution, however, the FBG have in this case better stability over time and the increasing difference can be attributed mainly to the RSG system (Meier, 2013). Of fourteen FBG ten are strained and did not fail during sixteen years. No failure occurred in nearly 230 cumulated FBG operation years at the Stork Bridge. In 1996 a total of 22 RSGs were installed. Four of them failed within the first fourteen years. There is a high probability that three of the four RSGs failed due to a lightning strike into the tower of the bridge.

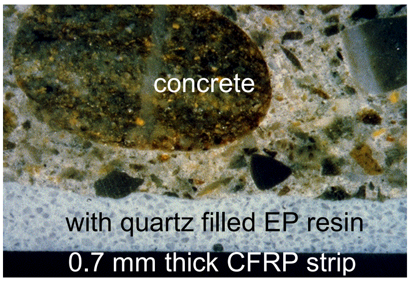

Fig.1 - Longitudinal cross section of a externally bonded CFRP strip

Fig.2 - CFRP cable stayed Stork Bridge in Winterthur crossing 18 tracks of the Swiss Railways

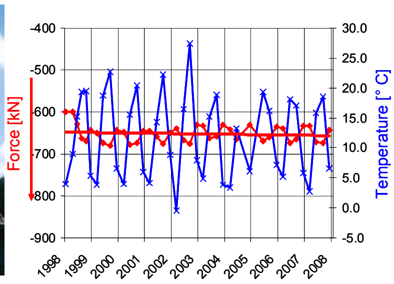

Fig.3 - Cable force and temperature vs. time of post-tensioning CFRP cable of Verdasio Bridge under sustained stress of 1610 MPa

RESULTS AND CONCLUSIONS

Most noticeable in the project of Verdasio Bridge is the very high sustained stress of 1610 MPa on the CFRP post-tensioning tendons. Parallel with the seasonal temperature fluctuation there is a fluctuation of the cable force (Fig. 3). The coefficient of thermal expansion for the CFRP tendons is about zero. In summertime, when the temperature is high, the concrete of the bridge girder expands. Due to that the CFRP cable force is increasing. In winter it is opposite. Most remarkable is that the average of the cable force is constant since 1998 (Fig. 3). That means there is no stress relaxation. This is surprising and unexpected from a “steel cable point of view”, but “no stress relaxation” is a typical property of the carbon fibres.

The application of carbon fibre reinforced polymers (CFRP) in construction, especially in post-strengthening and rehabilitation is well known and mostly accepted today. Without successful long-term performance monitoring on CFRP pilot projects with the means of the structural health monitoring this would not have been possible.

REFERENCES

[1]-Meier U. Proposal for a carbon fibre reinforced composite bridge across the Strait of Gibraltar at its narrowest site, Proc Instn Mech Engrs B2 IMechE, 1987, 201, p. 73-78.

[2]-Meier U, Brönnimann R, Anderegg P, Terrasi G. P. 20 years of experience with structural health monitoring of objects with CFRP components, *in:* Büyüköztürk O, Taşdemir MA, Güneş O, Akkaya Y. (Eds.) Non-destructive Testing of Materials and Structures, Rilem Bookseries 6, Springer, 2013, p. 959-976.