# Active vibration control with artificial pneumatic muscles for carbon fibre stress-ribbon bridge

**Achim BLEICHER**
Research Assistant
Technische Universität
Berlin, Germany
*www.massivbau.tu-berlin.de*

Achim Bleicher (1977), received his civil engineering degree from the University of Stuttgart.

**Mike SCHLAICH**
Prof. Dr. sc. techn.
Technische Universität
Berlin, Germany
*www.massivbau.tu-berlin.de*

Mike Schlaich (1960), received his civil engineering and Dr. degree from the ETH Zürich. He is Prof. at the TU Berlin and managing director of Schlaich Bergermann und Partner

## Summary

Stress-ribbon bridges are among the lightest and smartest bridges. The lightness of such structures results in low damping properties and at the same time in high vibration sensitivity. These effects increase when stiffness and mass decrease. This is the case when light high-strength CFRP is used for the stress-ribbon and when the weight of the surfacing is small. Then, system properties like the natural mode change as the mass of the bridge varies due to changing pedestrian traffic. Passive dampers to reduce vibrations, which cannot adjust to such changing system properties, lose effectiveness. Consequently, there is a demand for more intelligent solutions, which control a wider range of frequencies and modes. Therefore, an active control system can be installed, which consists of sensors, controller and actuators. The actuators can produce specific forces to influence the structural oscillation. The effectiveness of extremely light actuators like artificial pneumatic muscles is presently being tested on a carbon fibre stress-ribbon bridge at the Technical University of Berlin. This paper describes the first results.

**Keywords:** stress-ribbon bridge; footbridge; CFRP; active vibration control; active damping; artificial pneumatic muscle

## Introduction

High-strength materials such as Carbon Fibre Reinforced Plastics (CFRP) offer great potential for further development of lightweight structures like stress-ribbon bridges. To show this potential, a stress-ribbon bridge with carbon fibre ribbons was recently built in the laboratory hall of the Institute of Conceptual and Structural Design at the Technische Universität of Berlin (Fig. 1), [1]. Instead of steel ribbons or steel cables, very thin CFRP ribbons are anchored at the abutments on both sides. Pedestrians walk directly on the ribbons that are covered and stabilised by open-jointed concrete slabs. Compared with normal structural steel, the tensile strength of this high-strength composite material is ten times higher and the specific weight is five times lower. This allows structures with longer spans and smaller cross sections. The prototype's tensile force of N = 530 kN in the Ultimate Limit State (ULS) has to be carried by 6 straps with a cross section of ≈ 1.1 mm x 50 mm (Fig. 2). Each multilayered strap consists of 10 strips that are only ≈ 0.11 mm thin [2]. The modulus of elasticity of the strip is 170.000 N/mm$^2$. The resulting low extensional stiffness and the lack of bending stiffness have effects on the deformation and vibration behaviour that will be described in the following chapters. A control strategy is shown to reduce the high accelerations from pedestrian induced loads with artificial pneumatic muscles.

https://doi.org/10.2749/222137908796292795

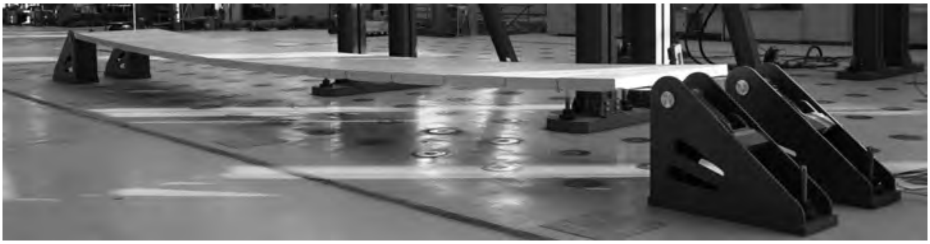

*Fig. 1: Carbon fibre stress-ribbon bridge at the Technische Universität, Berlin*

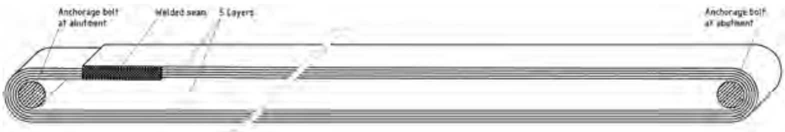


*Fig. 2: CFRP strap*

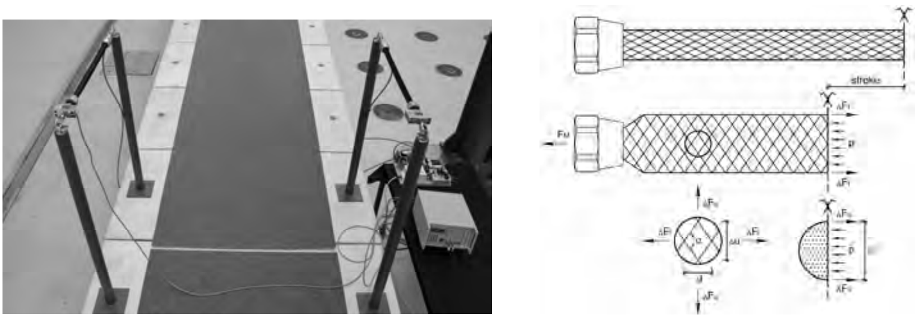


*Fig. 3: First application of artificial pneumatic muscles and their functionality*

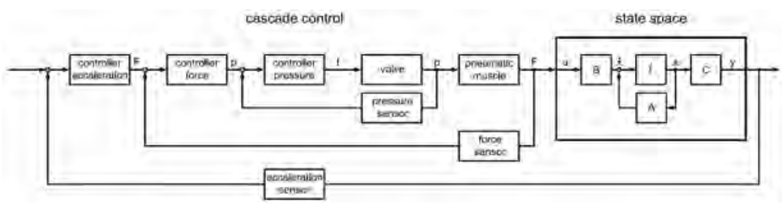


*Fig. 4: Action diagram of a control loop to simulate the active vibration control*

## Conclusion

This paper describes the static and dynamic load bearing behaviour of a new type of stress-ribbon bridge with carbon fibre ribbons. The high vibration sensitivity of the bridge demands new damping or control strategies. Artificial pneumatic muscles in the handrail can calm the rocking bridge. Therefore, several control strategies are presently developed and tested. External energy supply needed to produce compressed air and for controlling is a disadvantage of such an active system especially if built outside the laboratory hall. In the future, by “shifting” compressed air between the muscles and using the pedestrian induced energy a nearly self-sufficient system should be possible.