Student assistant position (HiWi 40 h/month)

Adaptive Bridge Structures

The bridge stock in the Trans-European Transport Network (TEN-T) is aging and it has been estimated that approximately 40-50% of the bridges in Germany, Netherlands and Denmark and Portugal will soon approach the end of service (older than 40 years) [7]. In addition, given the increased traffic demand, the majority of bridges built before 1980 typically experience significantly stronger solicitations than the loads they were designed to withstand.

External post-tensioning can be used effectively to improve the serviceability performance of a bridge and to delay or prevent the onset of damage (e.g., cracking) [1]. Since typical post-tensioning increases flexural stiffness, it has been successfully employed to reduce in-service deflections and vibrations of short-span bridges [1]. Post-tensioning has been primarily implemented using unbonded tendons that run through the bridge cross-section and are anchored at the bridge ends. The tendons can be straight or draped using deviators. In either case, the tension force from the external cables is applied eccentrically to the neutral axis of the bridge cross-section. The resulting system of forces induces a bending moment that counteracts the effect of the external load. However, conventional external post-tensioning systems can only be effective against one loading condition, which is usually the permanent load. In scenarios where the live load is commensurate with the dead load and strict criteria for safety and serviceability apply, e.g. for high-speed railway bridges, conventional post-tensioning does not perform optimally.

Previous work has shown that structural adaptation can be employed to significantly improve structural capacity through stress homogenization by redirecting the force flow from critically stressed elements to lower-stressed elements [2]–[4]. In addition, adaptation can be employed to improve serviceability performance by reducing deflections and vibrations[5], [6]. Most bridges typically retain a significant reserve capacity [7] that could be unlocked through optimal retrofitting of control systems (e.g., sensors, actuators, and processing units) thus avoiding costly decommission and replacement by extending their service life.

External adaptive tensioning (EAT) systems can be retrofitted to existing bridges and employed for the design of new bridges [8]. A type of external adaptive post-tensioning system that is well-suited for retrofitting on different bridge types comprises cables deviated by variable-length compressive struts that are fixed below the bridge deck, as shown in Figure *1*. Linear actuators adjust the length of the structs, which changes the tension in the cables allowing manipulation of the bending moment as the load changes. Simulations have been carried out on high-speed railway bridges modeled with simply supported steel-composite beams. Active control performed by the EAT system enables satisfying required vertical acceleration limits without the need to increase flexural stiffness by adding more material.

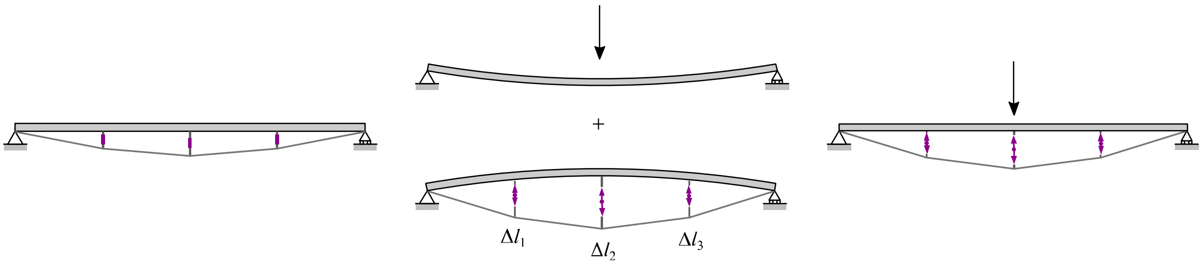

Figure 1 External adaptive tensioning system

This work will investigate several bridge configurations and evaluate the potential of active control through EAT systems. The student assistant will be involved in:

- Analysis of the adaptation potential of beam, frame, truss, arch, suspension and cable-stayed bridges. This task involves modeling and simulation to evaluate how the structural capacity and serviceability performance can be improved through different actuation systems.
- Development of actuation strategies to extend the service life of existing and new bridges by mitigating the effect of heavy crossing to reduce the cyclic stress range.

For short- to medium-span highway and railway bridges, the main objective is to reduce vibrations and stresses caused by heavy loading to extend the service life by mitigating fatigue effects. The potential of adaptation on the performance of lightweight (e.g., pedestrian), as well as stiffness-dominated bridges including long-span cable-stay and suspension configurations, will also be considered. For new bridges, the main objective is to improve the structural performance by reducing significantly material mass requirements and in parallel increasing the span.

Supervision

Dr. Eng. habil. Gennaro Senatore, gennaro.senatore@ilek.uni-stuttgart.de
Dr. ès sc. Arka P. Reksowardojo, arka.reksowardojo@ilek.uni-stuttgart.de
Institute for Lightweight Structures and Conceptual Design (ILEK)

Supervision will be carried out in English.

Key requirements

Bachelor’s degree in civil engineering, architecture and/or computer science.
Good knowledge of structural mechanics including dynamic analysis.
Knowledge of (or strong interest to learn) control theory and implementation.
Knowledge of (or strong interest to learn) MATLAB/Python programming language.
Advanced spoken and written English.

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