Vibration-Based Monitoring Of External Post-Tensioning Tendons: Tension Estimation

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External prestressing is commonly used in case of new bridge designs and in the framework of rehabilitations of old structures due to its ease of monitoring, re-stressing and substitution in case of failure. Hence, there is a need for reliable methods for estimating the actual tensile force and to assess its structural performance by means of damage predictors. Several methods for estimating prestressing forces can be found in the literature. These methods are based on indirectly monitoring the prestressing force through monitoring of another relevant parameter. Thus, vibration-based monitoring methods (based on acceleration) may be employed to assess the structural performance of external posttensioning tendons and estimate their effective tension. The authors are carrying out an intensive dynamic analysis of a12-span continuous concrete bridge, with a total length of 558 m, of a high-speed railway line. The bridge has two families of prestressing tendons, a first one of internal and bonded tendons for the launching and a second one of external and unbounded tendons for providing continuity between spans once the bridge is launched. This work focuses on the external tendons, formed by 25 strands of 7 wires each, contained inside a polyethylene duct where a grout is injected to protect the cable. The detection of corrosion in several tendons made that some of them are being substituted. Thus, the authors have carried out the continuous vibration–based monitoring of the tensioning process of one of the new tendons, amongst other works. During the tensioning, the tendon has been instrumented with 18 high sensitivity accelerometers attached through ad doc designed flanges. The tensioning process was carried out in 7 stages and, for each stage, an operational modal analysis was conducted. The first four natural frequencies, and their ratios were tracked during the process. For each tensioning stage, the effective tensile force is estimated through a model updating including up to the four vibration modes. The taut string approach including bending stiffness is adopted assuming semi-rigid connections to deviators or anchorages. This model is particularly interesting in term of accuracy for short cables with neglected sag and complex boundaries. The linear mass density is assumed to be known and the bending stiffness, the effective length and the effective tensile force are estimated by minimizing a cost function defined from the error in frequency estimation and from the modal assurance criterion computed for experimental and theoretical mode shapes. Finally, the tensile force applied by the hydraulic unit to control the prestressing jacks and the estimated one are critically compared. Additionally, the evolution of the frequency ratios as damage predictor are also analyzed for all the stages. Keywords: External prestressing, Model updating, Tensile force estimation, Cable dynamics