Energy harvesting from bridge vibrations with piezoelectric devices – Analysis of a case study bridge

Jacopo Bonari[1], Davide Colonna[2], Paolo S. Valvo[2]
[1] *IMT School for Advanced Studies, Lucca, Italy*
E-mail: jacopo.bonari@imtlucca.it

[2] *Department of Civil and Industrial Engineering, University of Pisa, Italy*
E-mail: davicolo10@hotmail.it, p.valvo@ing.unipi.it

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The use of piezoelectric devices to harvest the energy connected to the vibrations induced on road bridges by travelling vehicles has been proposed in the recent literature, albeit with application limited to an idealised bridge modelled as a simply supported beam [1].

In a previous work, we started a feasibility study on the application of the above-mentioned technique to a real bridge. To this aim, we selected an existing urban bridge in Pisa as a case study and collected the available documentation about its original design. The results of a past experimental campaign provided the natural frequencies and mode shapes of the structure [2].

Besides, we developed a mechanical model of a laminated cantilever beam with a top piezoelectric layer and a concentrated mass on its free end. The eigenfrequencies of the cantilever beam were determined in both short- and open-circuit electrical boundary conditions. Then, the partial differential equations were deduced for the coupled electro-mechanical problem and solved in terms of the cantilever displacement and voltage output, in the case of vehicle-induced vibrations and with a finite electrical resistance connected to the device [3].

In this work, we develop a three-dimensional finite element model of the case study bridge. The model is first calibrated to match the results of the experimental dynamic acquisitions. Next, the dynamic response of the bridge under travelling vehicles is simulated. To this aim, the data of real cars and busses allowed to cross the bridge are considered. The outcomes of the simulations in terms of acceleration time histories are used as input for the model of the piezoelectric cantilever beam, suitably designed to feature the same first natural frequency of the case study bridge. Neglecting electrical damping, a close relation between voltage output and vehicle speed is obtained. In the practical range of vehicle speed, a maximum power output in the order of $100\,\mathrm{mW}$ is predicted [4].

References:

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