Shear-torsional nonlinear galloping of base-isolated continuous beams

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Abstract. An equivalent one-dimensional visco-elastic beam model is proposed to study the aeroelastic behaviour of base-isolated tower buildings, subjected to a steady wind flow. The beam is internally constrained, so that it is capable to experience shear strains and torsion only. The system is constrained at the bottom end by a nonlinear visco-elastic device and free at the top end. The aeroelastic effects, responsible for self-excitation, are evaluated via the quasi-static theory, and the occurrence of Hopf bifurcation is detected. Critical and post-critical behaviour is analysed by applying a perturbation scheme. The influence of mechanical and aerodynamic coupling (between torsional and transversal vibrations) on the critical galloping conditions is investigated. Furthermore, the visco-elastic insulation system is calibrated to optimize the aeroelastic performances of the structure.

Introduction

Tall buildings are very sensitive to dynamic actions induced by wind, which causes a variety of instability phenomena. The aeroelastic analysis of multi-story buildings, when they are made of a sufficiently large number of floors, can be carried out by means of equivalent beam models, derived by suitable homogenization techniques (e.g., [1-3]). In particular, in [1] a shear–shear torsional beam model is formulated, by focusing the attention on the torsional and transversal coupling in galloping of fixed-free beams. In [2, 3], an insulation device is applied to the base of a planar (shear [2] or Euler-Bernoulli [3]) beam, to passively control galloping phenomena. Here, a continuous visco-elastic shear-torsional beam model, subjected to uniformly distributed steady wind flow, is formulated. A suitable visco-elastic device is interposed between the ground and the bottom of the beam, with the aim to mitigate the aeroelastic instability effects.

Model and results

An equivalent linear continuous shear-torsional beam model is used to describe the behavior of multi-story frame buildings. Aerodynamic forces and couples, distributed along the beam axis, are modeled in the framework of the quasi-steady theory. A passive control system is applied to the base of the beam, consisting of a viscoelastic device, made of a linear elastic spring and a nonlinear dashpot, assembled in parallel (Figure 1). Kinematics of the beam is assumed linear, and nonlinearities accounted for both in the aerodynamic forces and dashpot damping. Critical and post-critical behavior is analyzed by applying a perturbation scheme. In particular, the roto-translational galloping is investigated, with focus on the influence of the coupling between shear and torsion, according to the eccentricity between the torsional center and the centroid as well as the torsional-to-shear frequency ratio. Abrupt changes of the modal shape (torsional, translational or mixed) are observed when the torsional frequency is varied, together with a general increment of the critical wind velocity (when far from the resonant value). Finally, the parameters of the insulation system are properly calibrated to optimize the aeroelastic performances of the structure. The asymptotic results are validated via numerical time-integration of ordinary differential equations, derived via in-space finite differences.

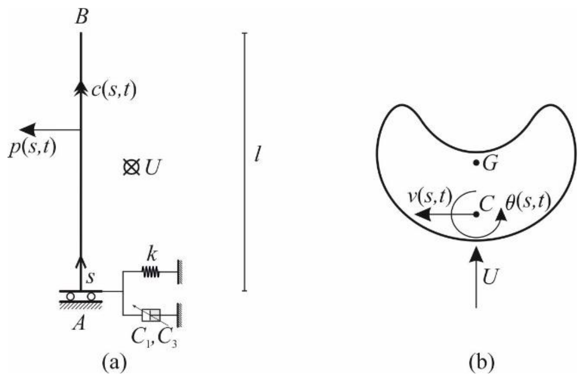

Figure 1: Base-isolated tall building under uniform steady wind flow: (a) beam model and external loading; (b) cross-section.

References

[1] Piccardo G., Tubino F., Luongo A. (2015) A shear–shear torsional beam model for nonlinear aeroelastic analysis of tower buildings. *Z. Angew Math Phys* **66**: 1895–1913.

[2] Di Nino S., Luongo A. (2020) Nonlinear aeroelastic behavior of a base-isolated beam under steady wind flow. *Int. J. Non-Linear Mech* **119**:103340.

[3] Di Nino S., Luongo A. (2022) Nonlinear dynamics of a base-isolated beam under turbulent wind flow. *Nonlinear Dyn* **107(2)**: 1529-1544.