Rayleigh with viscoelasticity applied to a highly slender 40-m-high concrete mast

Alexandre de M. Wahrhaftig*

*Federal University of Bahia (UFBa), Polytechnic School, Department of Construction and Structures, Rua Aristides Novís, Nº 02, 5º andar, Federação, Salvador – BA, Brazil, CEP: 40210-910
e-mail: alixa@ufba.br, web page: http://lattes.cnpq.br/7971716903240686

ABSTRACT

For a complete vibration analysis, the stiffness of a structure is composed of two characteristics: one corresponding to conventional stiffness and the other to the geometric stiffness. Thus, the total stiffness takes the form where the rheological model that one wants to use to represent any viscoelastic behaviour of the material is introduced to the first part via the modulus of elasticity. The second is the geometric, function of the normal effort that includes the self-weight of the structural element. In this study, an analytical approach based on the Rayleigh method is adopted to calculate the first resonant frequency of a highly slender, actual 40-m-high concrete mobile phone mast system by considering the geometric stiffness, which is a geometric nonlinear consideration. The mast is done in concrete, so that its nonlinear behaviour is linearised by reducing the flexural stiffness. The creep, an important aspect for that structure, defined as the increase of deformation on time for a constant level of stress, is taken into account by a rheological model of three parameters. The section of reinforced concrete is treated from the theory of the homogenised section in order to consider the presence of the steel. Under geometric and material nonlinearity, with creep, the vibration frequency of the fundamental mode is calculated analytically and an evaluation of the structural collapse is performed. The process is built step-by-step, as the integrals of the method are resolved into the limits established for each interval according to the geometry. Finally, the structural stiffness is evaluated.

REFERENCES

[1] W.N. Findley, J. S. Lai, K. Onaran, *Creep and Relaxation of Nonlinear Viscoelastic Materials, Whit an Introduction to Linear Viscoelasticity*, Dover Publications, Inc, New York, (1989).

[2] F. Leohard, E. Mong, *Constructions of concrete – Basic principles for dimensioning of concrete structures*, 1. ed., v.1, Livraria Interciência, Rio de Janeiro, (1977).

[3] P.K. Mehta, P.J.M. Monteiro, *Concrete: structure, proprieties and materials*. São Paulo: PINI, (1994).

[4] R.W. Clough e J. Penzien, *Dynamic of Structures*, Taiwan: McGraw Hill International Editions, Second Edition, (1993).

[5] A.M. Wahrhaftig, R. M. L.R. F. Brasil, "Ensaio sobre a fluência na vibração de colunas", Paper ID 002, Congress on Numerical Methods in Engineering CMN2015, Lisboa, 2015.

[6] A.M. Wahrhaftig, R. M. L. R. F. Brasil, J.M. Balthazar, *The first frequency of cantilever bars with geometric effect: a mathematical and experimental evaluation*, J. Braz. Soc. Mech. Sci. Eng., 35 (2013) 457-467, doi:10.1007/s40430-013-0043-9.

[7] A.M. Wahrhaftig, R.M.L.R.F. Brasil, *Initial undamped resonant frequency of slender structures considering nonlinear geometric effects: the case of a 60.8 m-high mobile phone mast*, Soc. Mech. Sci. Eng. (2016), 1-11, doi:10.1007/s40430-016-0547-1.

[8] A.M. Wahrhaftig, *Analysis of the first modal shape using case studies*, Proceedings of the 6th International Conference on Computational Methods, 1st–4th August 2016, Berkeley, ScienTech Publisher, Paper ID 1378 (ISSN 2374-3948, online).

[9] J. Awrejcewicz, A.V. Krysko, N.A. Zagniboroda, V.V. Dobriyan, V.A. Krysko, *On the general theory of chaotic dynamics of flexible curvilinear Euler–Bernoulli beams*, Nonlinear Dyn. 79 (2015) 11–29, doi: 10.1007/s11071-014-1641-5.