15th World Congress on Computational Mechanics (WCCM-XV)
8th Asian Pacific Congress on Computational Mechanics (APCOM-VIII)
31 July – 5 August 2022, Yokohama, Japan

Numerical Evaluation of Bell-Shaped Proportional Damping Model for Softening Structures

Chin-Long Lee[1*] and Theodore L. Chang[2]

[1] University of Canterbury, 69 Creyke Road, Christchurch 8041, New Zealand, chin-long.lee@canterbury.ac.nz
[2] IRIS Adlershof der Humboldt-Universität zu Berlin, Zum Großen Windkanal 2, Berlin 12489, Germany, tlcfem@gmail.com

Key Words: *Proportional Damping, Bell-Shaped Model, Softening Response, Negative Stiffness*

In the modelling of large-scale structures, energy dissipations not already accounted for using material hysteretic models, often called un-modelled damping, are usually incorporated using viscous damping such as Rayleigh damping due to mathematical convenience and computational efficiency. The use of the Rayleigh damping model during inelastic response after yielding occurs could, however, lead to large spurious damping forces in the order comparable to material constitutive forces. This problem has been well-documented and studied [e.g. 1, 2, 3].

Many remedies have been proposed to address the spurious damping forces. However, most of them are not computationally efficient, and some also deviate from the idea of modal damping ratio due to loss of proportionality, resulting in difficulty for model parameter calibration against experimentally measured modal damping ratios. Most models are also not suitable for structures experiencing softening response due to having negative damping ratio.

A new type of proportional damping models, called bell-shaped proportional damping model, has recently been proposed [4]. This new model has not only addressed the spurious damping forces, but also maintained the same order of computational efficiency as the Rayleigh model. This model has also been further improved such that, by using the tangent stiffness approach, it becomes suitable for structures experiencing softening response with negative stiffness [5]. The improved model, called Type 4, allows users to have flexible control of modal damping ratio for all interested frequency intervals, including those associated with negative stiffness.

In this study, the performance of the Type 4 damping model is evaluated numerically in a response history analysis of a multi-storey building under seismic loading. The results show that, compared to the Rayleigh model, the Type 4 model performs excellently in terms of always giving desirable positive energy dissipation even when the structure is experiencing softening response.

REFERENCES

[1] Bernal, D. Viscous damping in inelastic structural response. *Journal of Structural Engineering.* (1994) **120**: 1240–1254.

[2] Carr, A.J. Damping models for inelastic analyses. *Proceedings of the Asia-Pacific vibration conference*, Kyongju, Korea, (1997), p. 42.

[3] Hall, J.F. Problems encountered from the use (or misuse) of Rayleigh damping. *Earthquake engineering & structural dynamics*. (2006) **35**: 525–545.

[4] Lee, C.-L. Proportional viscous damping model for matching damping ratios. *Engineering Structures.* (2020) **207**: 110178. https://doi.org/10.1016/j.engstruct.2020.110178.

[5] Lee, C.-L. Type 4 bell-shaped proportional damping model and energy dissipation for structures with inelastic and softening response. *Computers and Structures*. (2022) **258**: 106663. http://dx.doi.org/10.1016/j.compstruc.2021.106663.