Seismic Isolation and Mass Damping

3 CFU - 24 ore

Lecturers

Prof. Elena Mele, PhD Diana Faiella, PhD Francesco Esposito

Summary

The course aims to provide doctoral students with the theoretical foundations and application criteria of seismic isolation and mass damping systems, offering a unified dynamic perspective.

The concepts and operating principles of base isolation and tuned mass damping are introduced, along with the analytical formulation of the dynamic problem applied to two-degree-of-freedom models. Intermediate-level seismic isolation is presented using simplified lumped-mass models, highlighting the dual functionality that combines isolation and mass damping strategies.

Classical modal analysis is initially employed to derive modal shapes, periods, and participating masses, while discussing the vibrational characteristics of the models. Subsequently, considering non-proportional damping, a state-space formulation is adopted to solve the eigenvalue problem in the complex domain.

The vibrational characteristics are analysed as system parameters vary, identifying the ones governing the dynamic behaviour of different configurations and determining design criteria for achieving optimal performance. The frequency response of the systems is also examined, and possible optimization procedures are defined.

Design procedures for both new and existing buildings are discussed, also accounting for possible inelasticity arising in existing building structures. Case studies and recent applications are illustrated and examined, including RSA (Response Spectrum Analysis) and NTHA (Nonlinear Time History Analysis) of simplified lumped-mass models and three-dimensional finite element models.

Considering the unified dynamic perspective, a design strategy based on a similarly “unified” approach is finally proposed, applicable to both new and existing buildings.

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COURSE PROGRAM 3 CFU - 24 hours

Lecture 1 (February 10, 2025, 10:00-13:00): Base Seismic Isolation (Mele, Faiella) [3 hours]

- Introduction and Course Content: base seismic isolation, tuned mass damping, intermediate seismic isolation (Mele)
- Kelly's formulation for base-isolated structures (Faiella)
- Effectiveness of base-isolated structures: some examples (Faiella)

Lecture 2 (February 12, 2025, 10:00-13:00): Tuned Mass Dampers (Esposito) [3 hours]

- Den Hartog's formulation for tuned mass damper systems
- Comparison of optimal formulations for tuned mass damper systems
- Influence of design parameters on the structural response of mass-damping systems

Lecture 3 (February 13, 2025, 10:00-13:00): Intermediate Seismic Isolation (Faiella) [3 hours]

- Introduction to intermediate seismic isolation
- Problem formulation and simplified models with two, three, and multiple degrees of freedom
- Non-proportional damping

Lecture 4 (February 17, 2025, 10:00-13:00): Intermediate Seismic Isolation for New and Existing Buildings (Mele) [3 hours]

- Examples of intermediate seismic isolation for new and existing buildings (Mele)
- Dynamic behavior of existing buildings with intermediate isolation systems (parametric analyses on simplified three-degree-of-freedom models) (Mele)

Lecture 5 (February 18, 2025, 10:00-13:00): Intermediate Seismic Isolation for Retrofitting Existing Buildings – Part 1 (Esposito) [3 hours]

- Design procedure for existing buildings with nonlinear behavior equipped with intermediate isolation
- Influence of damping modeling on the nonlinear response of existing buildings with intermediate isolation
- Comparison of three-dimensional finite element models: linear and nonlinear time-history analyses

Lecture 6 (February 19, 2025, 10:00-14:00): Intermediate Seismic Isolation for Retrofitting Existing Buildings – Part 2 (Esposito, Faiella) [4 hours]

- Pole allocation method for intermediate-level isolated buildings (Esposito)
- Closed-form relationship for the design spectrum for intermediate isolation systems (Esposito)
- Regularization of the dynamic response of irregular existing buildings with intermediate isolation (Faiella)

Lecture 7 (February 20, 2025, 09:00-14:00): Motion-Based Design (Mele, Faiella) [5 hours]

- Innovative mass damping approaches based on seismic isolation (Mele)
- Introduction to mega-sub configurations and problem formulation (Mele)
- Dynamic response of two and multi-degree-of-freedom models (Faiella)

Final Test