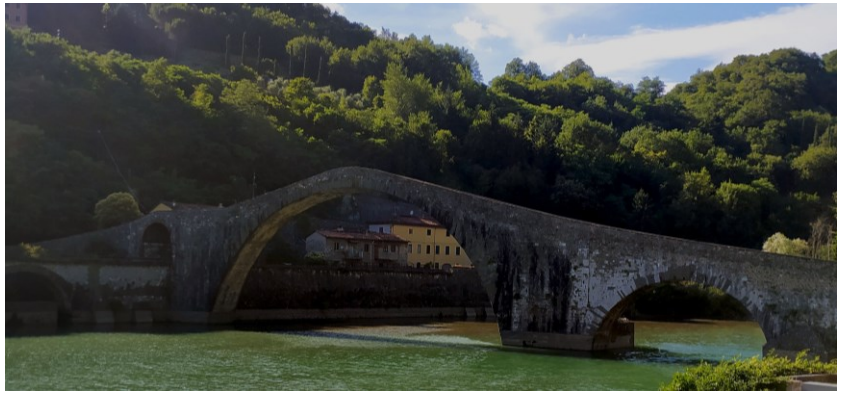
FABRE – Consorzio di ricerca per la valutazione di ponti viadotti e altre strutture
Ponti, viadotti e gallerie esistenti: ricerca, innovazione e applicazioni
2- 4 Febbraio 2022, Lucca



Risposta sismica di ponti con pile alte e snelle

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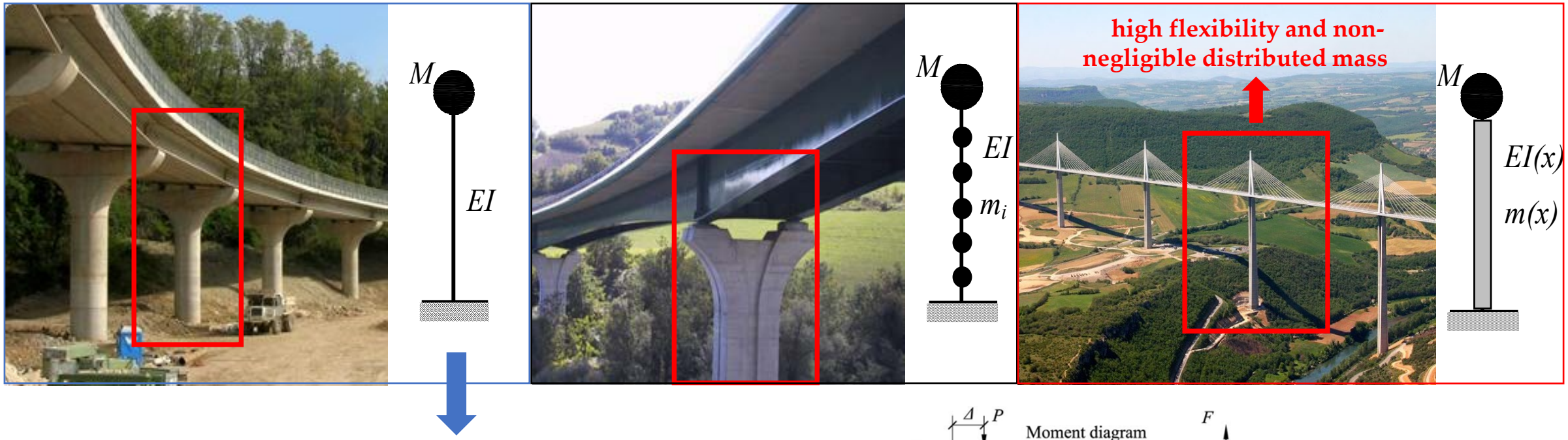
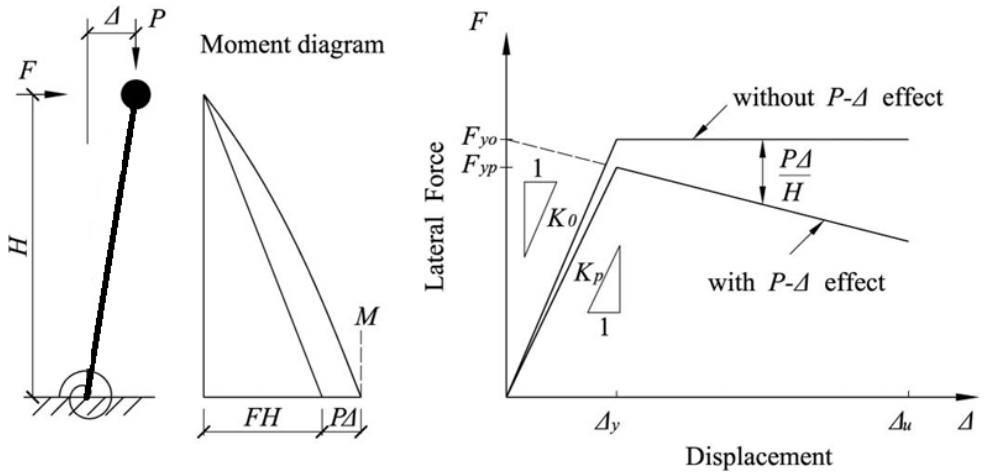
Tall (slender) piers



- Dynamic problem treated with simplified formulas (static case) derived adopting SDOF models (*Pauley 1978; Bernal 1987; Priesley 2007; Li 2012*)
- EC8-part 2 (moment magnification factor evaluated on SDOF models)

$$\Delta M = \frac{1+q}{2} d_{Ed} N_{Ed}$$



Study aims

- Characteristic parameters governing the dynamic response of tall piers
- Influence of higher order modes and axial load effects on the seismic response of tall piers for different values of the characteristic parameters
- Assessment of simplified approaches suggested by the EC 8

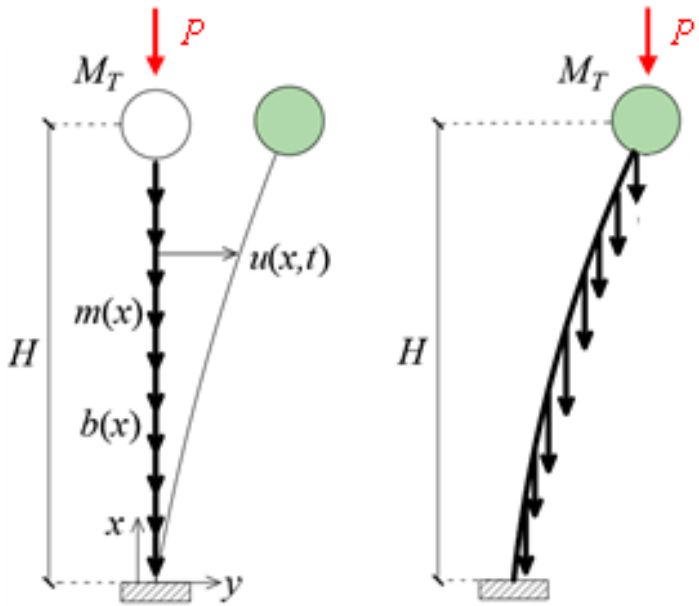
Method

Analytical problem formulation: continuous linear-elastic Euler-Bernoulli cantilever beam (homogeneous EJ and m)

$$\left[b(x)u''(x,t)\right]'' + \left[N(x)u'(x,t)\right]' + m(x)\ddot{u}(x,t) = -m(x)\ddot{u}_g(t)$$ Equation of motion

$$\left[b(x)u''(x,t)\right]'' + u(0,t) = u'(0,t) = b(H)u''(H,t) = 0$$
$$b(H)u'''(H,t) + Pu'(H,t) - M_T\ddot{u}(H,t) = M_T\ddot{u}_g(t)$$ BCs

$$u(x,t_0) = \dot{u}(x,t_0) = 0$$ ICs



Characteristic parameters

Characteristic non-dimensional parameters controlling the system's dynamic

$$\alpha^2 = \frac{P}{P_{cr}} = \frac{P \cdot 4H^2}{\pi^2 EI}, \quad \beta = \frac{\bar{m}H}{M_T}, \quad \gamma = \frac{\bar{m}gH}{P_{cr}} = \frac{\bar{m}gH \cdot 4H^2}{\pi^2 EI}$$

$\alpha^2 + \gamma$ = non-dimensional measure of the total vertical loads acting on the pier in relation to the buckling load

- $\alpha^2 + \gamma >> 0$ → slender piers
- $\alpha^2 + \gamma \cong 0$ → stocky piers

β = ratio between the distributed pier mass and the top concentrated mass M_T

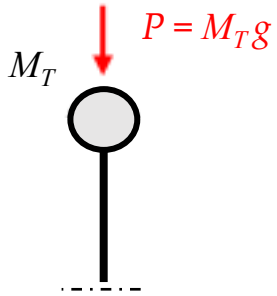
Parametric analysis

$\alpha^2 \in [0.01;\ 0.4]$

$\beta \in [0.01;\ 3.00]$

$P = M_T g$ → $\gamma = \beta \alpha^2$ (2 parameters)

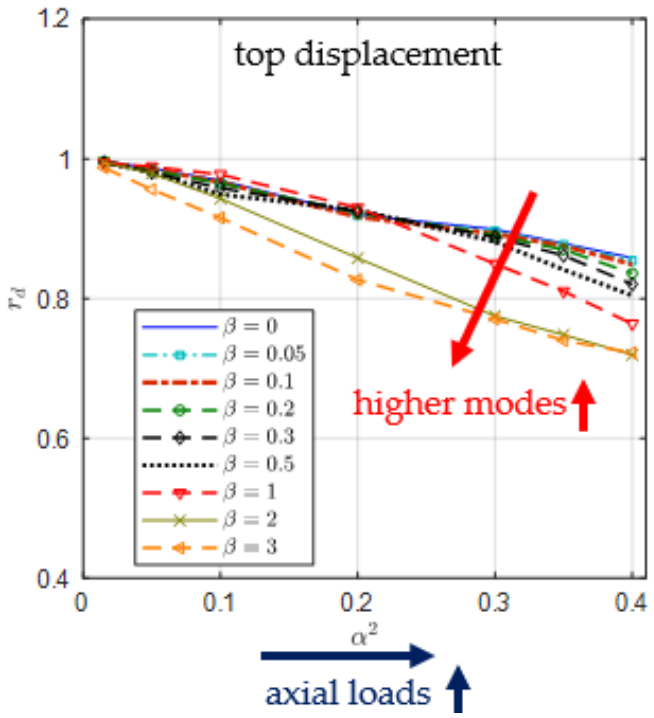
$T_0 \in [3; 8]$ s

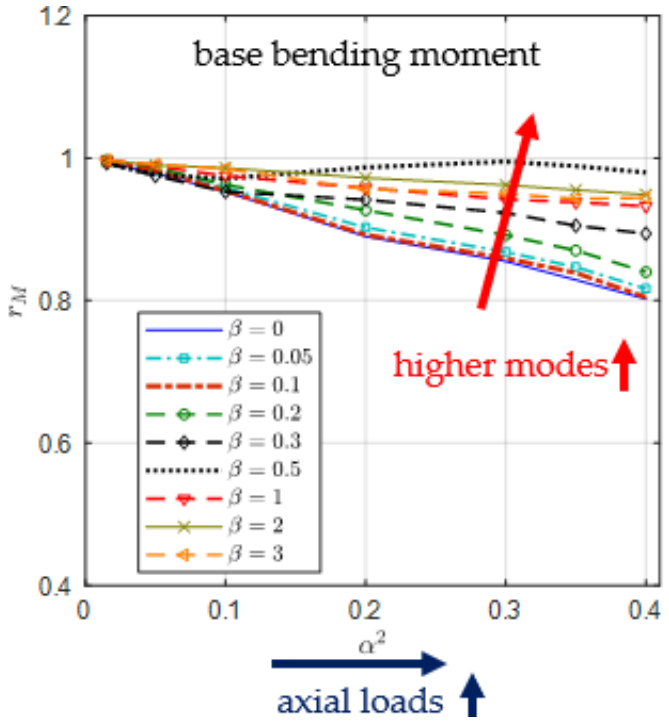


Parametric analysis

- **Seismic response**

$$r = \frac{\text{response quantity } \mathbf{w/} \text{ axial loads}}{\text{response quantity } \mathbf{w/o} \text{ axial loads}}$$





- **EC8 approach assessment**

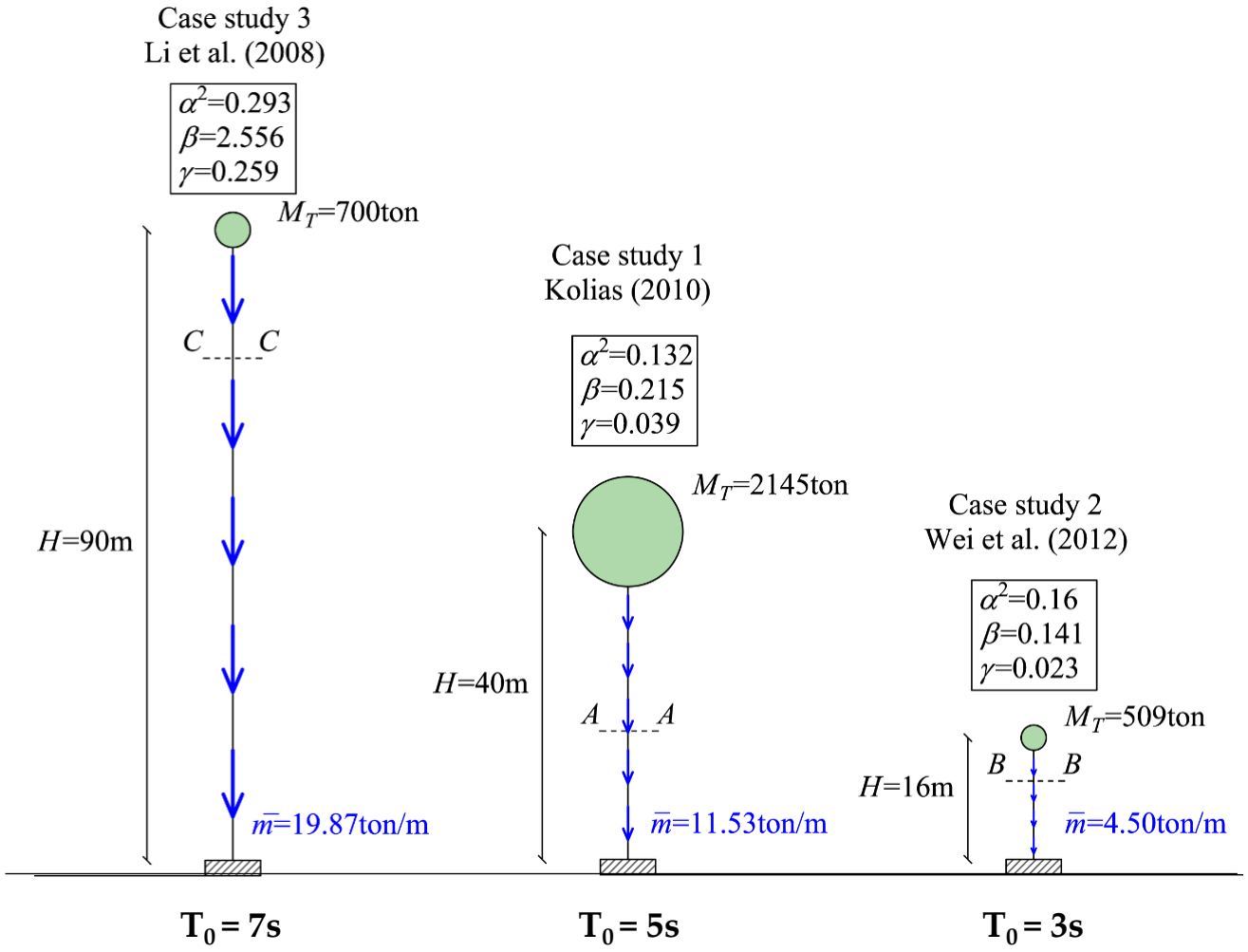
EC8-Part 2 → moment magnification factor: increase bending moment from first-order analysis (no axial force contribution)

$$\Delta M = \frac{1+q}{2} d_{Ed} N_{Ed}$$

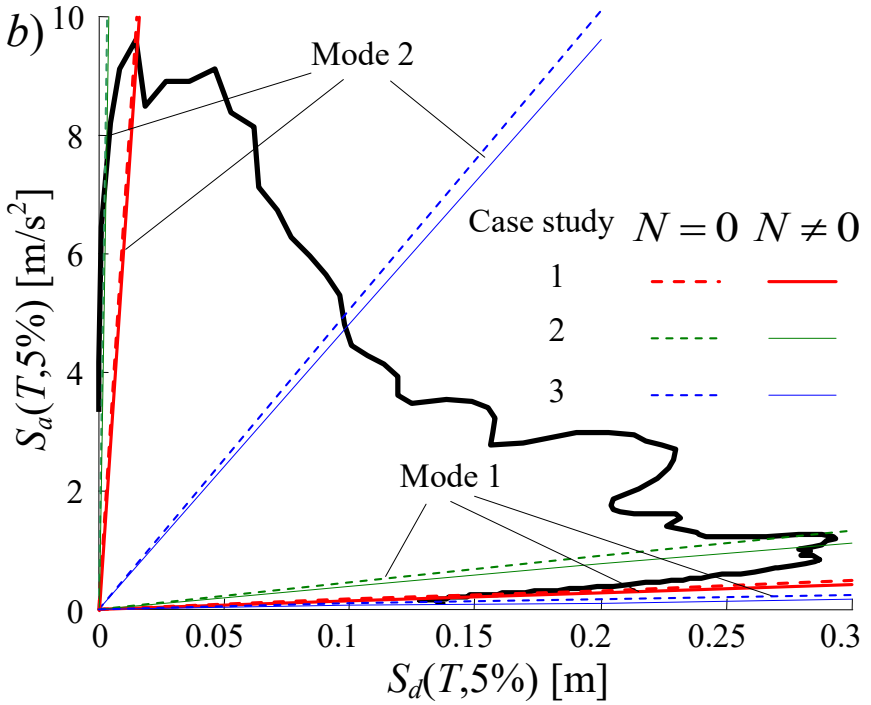
EC8 bending moment overestimation: The highest overestimation is observed for structural systems with high top loads and negligible distributed mass. Overestimation also increases in piers with higher fundamental periods.

Case studies

Seismic analysis of three real case studies



Axial loads effect → periods elongation



Acceleration-Displacement response spectrum (ADRS)

Main Conclusions

- The performed study aims to quantify the influence of both axial loads and higher order modes on the seismic response of slender piers, which are the most important components of the earthquake resisting system of bridges.
- Higher modes' contribution becomes more important for higher ratios between the distributed pier mass and the top concentrated mass.
- The **EC8 design procedure** applied to piers with low distributed mass brings to **results extremely conservative** and this trend increases with the pier top load intensity and system fundamental periods.

Further details can be found here

Tubaldi, E., Scozzese, F., De Domenico, D., & Dall'Asta, A. (2021). Effects of axial loads and higher order modes on the seismic response of tall bridge piers. *Engineering Structures*, *247*, 113134.

Tubaldi, E., Tassotti, L., Dall'Asta, A., & Dezi, L. (2014). Seismic response analysis of slender bridge piers. *Earthquake engineering & structural dynamics*, *43*(10), 1503-1519.

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