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Hybrid approach for 3D base isolation of low damped structures

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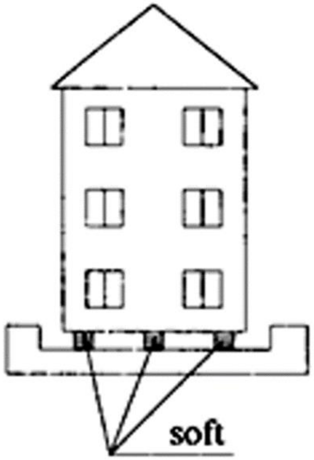
Outline

- Aspects related to the 3-D base isolation of structures are herein presented → numerical approach
- Traditional SI system is coupled with TMD in vertical direction → hybrid approach
- Both massive and lightweight structures → possible benefits
- Findings: TMD is able to control vertical motion → low damping value in the main structure

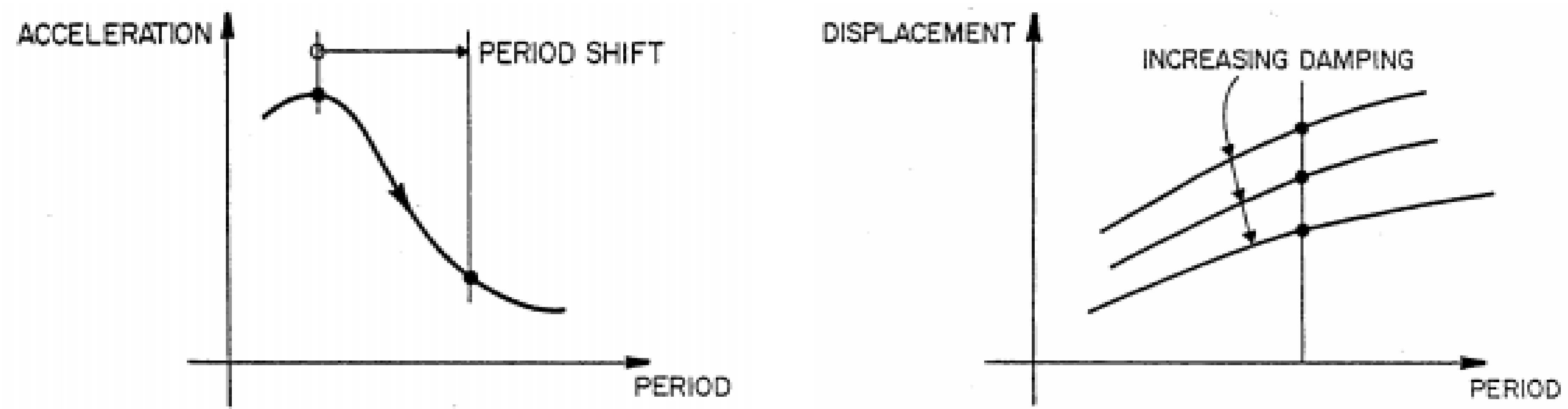


Seismic Base Isolation

TMD

Introduction

- SI → amount of published research → standards
- The concept → move the lateral fundamental period (to about 2-4s) far from the predominant of the ground motion
- Introducing damping to limit rel. displacements

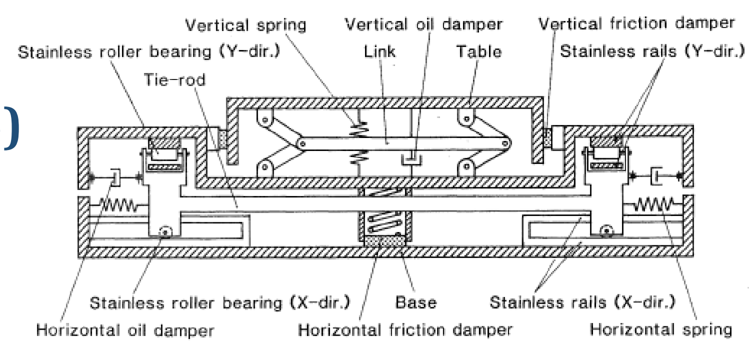


a. reduction in spectral acceleration   b. increase in spectral displacement

Introduction

- SI on the vertical component → received a much more limited attention
- The first proposals were formulated in the late 80s → related to the vertical isolation of part of a floor, to protect valuable light weight equipment

(Fujita 1985)

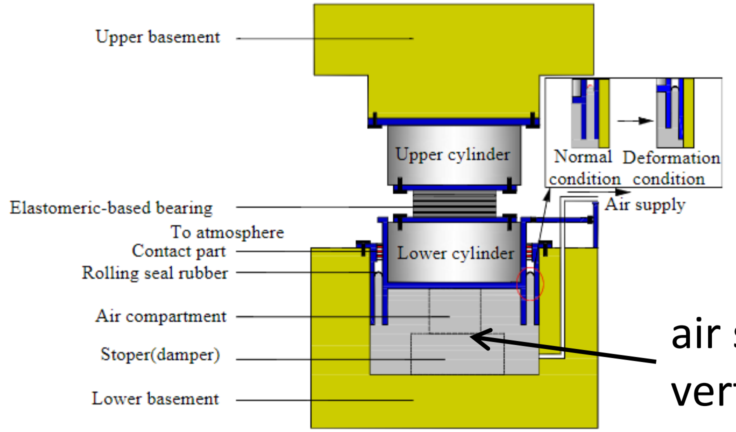


- Lower performance than horizontal isolation

Introduction

- Recently 3D SI emerged in different field → NPP, historical objects & special equipment

(Suhara 2003, Zhou et al. 2016)

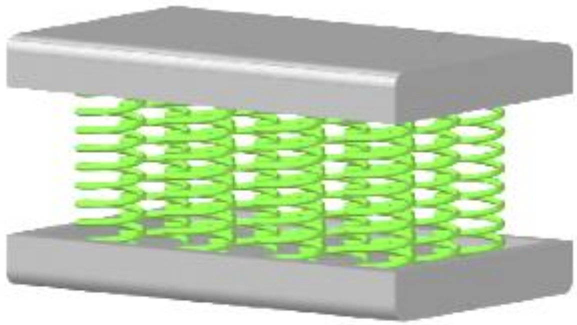


air spring in vertical direction

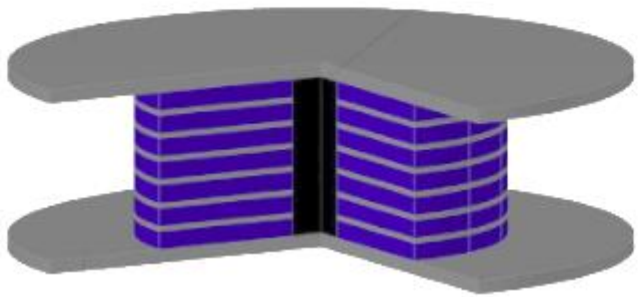
- VBI can be implemented
  A. Combining in series different devices
  B. Using integrated an solution → isolation with respect to all three ground motion components

Methodology

- Two SI solutions in H direction are here considered



(Vertical metallic springs)

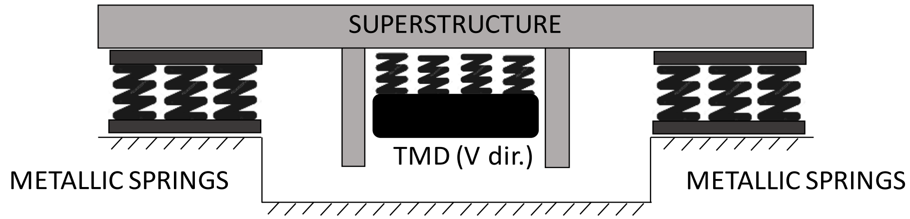


(Elastomeric bearings)

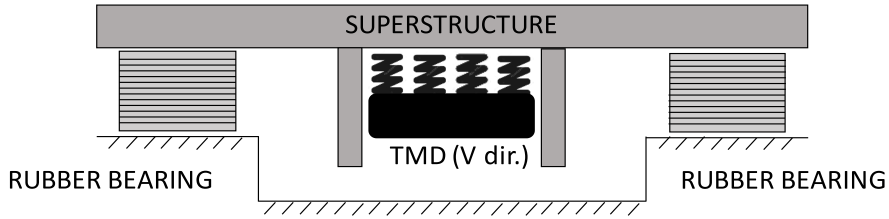
- Metallic springs → very small damping in H and V
- RB may have low (2-5%) or high (10-15%) H damping → lower again in V direction → compound and lead core

Methodology

HYBRID 3D CONTROL SOLUTIONS



Metallic springs + TMD



Rubber bearings + TMD

- In this preliminary work:
- Low damping from metallic springs and Rubber B.
- Damping in V direction is provided by TMD
- Vertical motion only in the performed numerical analysis

Methodology

- TMD operates in a **narrow** frequency band → **quasi-resonance** condition between **TMD** and the **dynamic of the base isolated system**
- The **target frequency** is that one of the **harmonic input** or, for **wide frequency input, the main natural frequency of the structure**

- Den Hartog 1985 (*fixed-points method)* optimal parameters to minimize displacements (vanishing structural damping) are used

- Wider optimization objectives in (Warburton 1982, Ioi & Ikeda 1978)
- Non-vanishing damping in (Asami et al. 2002)

Case Study 1: heavy weight

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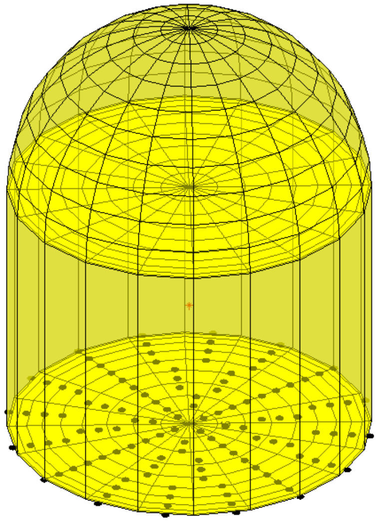
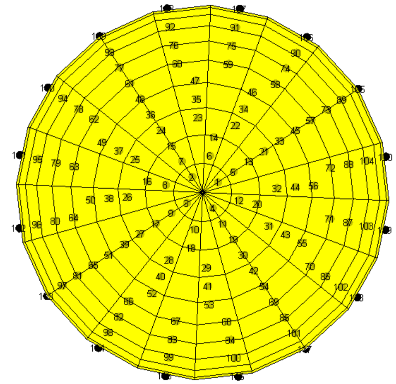
- The considered NPP building is the IRIS medium power pressurized light water reactor (bridging to Gener. IV)



- Preliminary design developed by an international consortium which includes more than 20 partners

- Tentative design isolation system made by 120 HDRB devices (about 1m diam., 0.1m rubber thickness, 10-20% damping, 0.8-1.4 MPa stiff)



Case Study 2: light weight

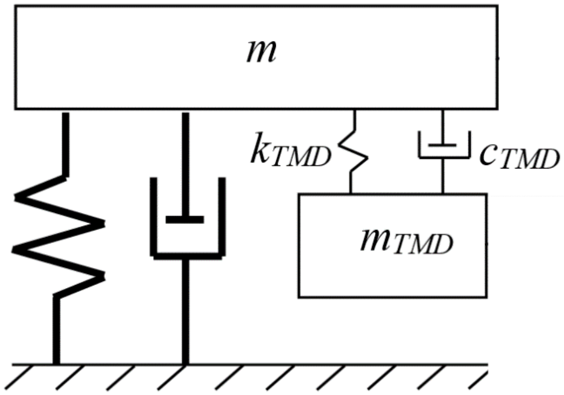
- Real statue case study

Statue Name	Location	Mass [kg]	Footprint [m]		Height [m]	Center of the mass [m]			Photograph	
			x	y		x	y	z	y-z	x-z
Zuccone (Donatello)	Museo dell'Opera del Duomo	576	0.55	0.41	1.99	0.27	0.19	0.91		

- Assumed rigidly connected to the support
- Base isolated on four helicoidal metallic springs with 109 and 122 kN/m as H and V stiffness resp.
- Damping is extremely low (about 0.1% in both HV)

Results

- The preliminary analysis → direct integration of the equation of motion for the 2DOFS
- The seismic input in vertical direction → 1g PGA
- Generalizations due to the intrinsic linearity
- Compatible to the USNRC 1.60 response spectra
- Parametric study of the response (abs. acceleration and rel. displacement, with and w/o TMD)



$$f = \frac{1}{(1+\mu)}$$

$$\xi = \sqrt{\frac{3\mu}{8(1+\mu)}}$$

(Den Hartog 1985)

Generated input

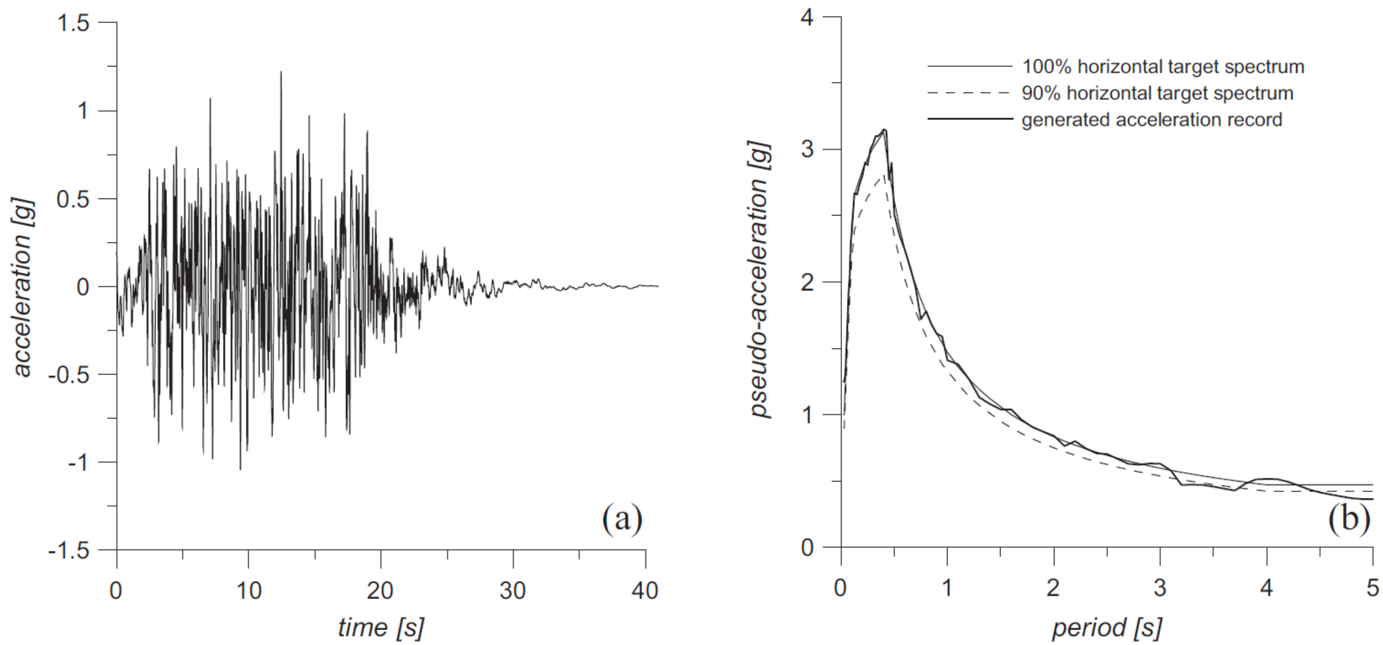


Fig. 6. Example of artificial accelerogram (a) and comparison with the USNRC spectrum (b).

Results: NPP building HDRB

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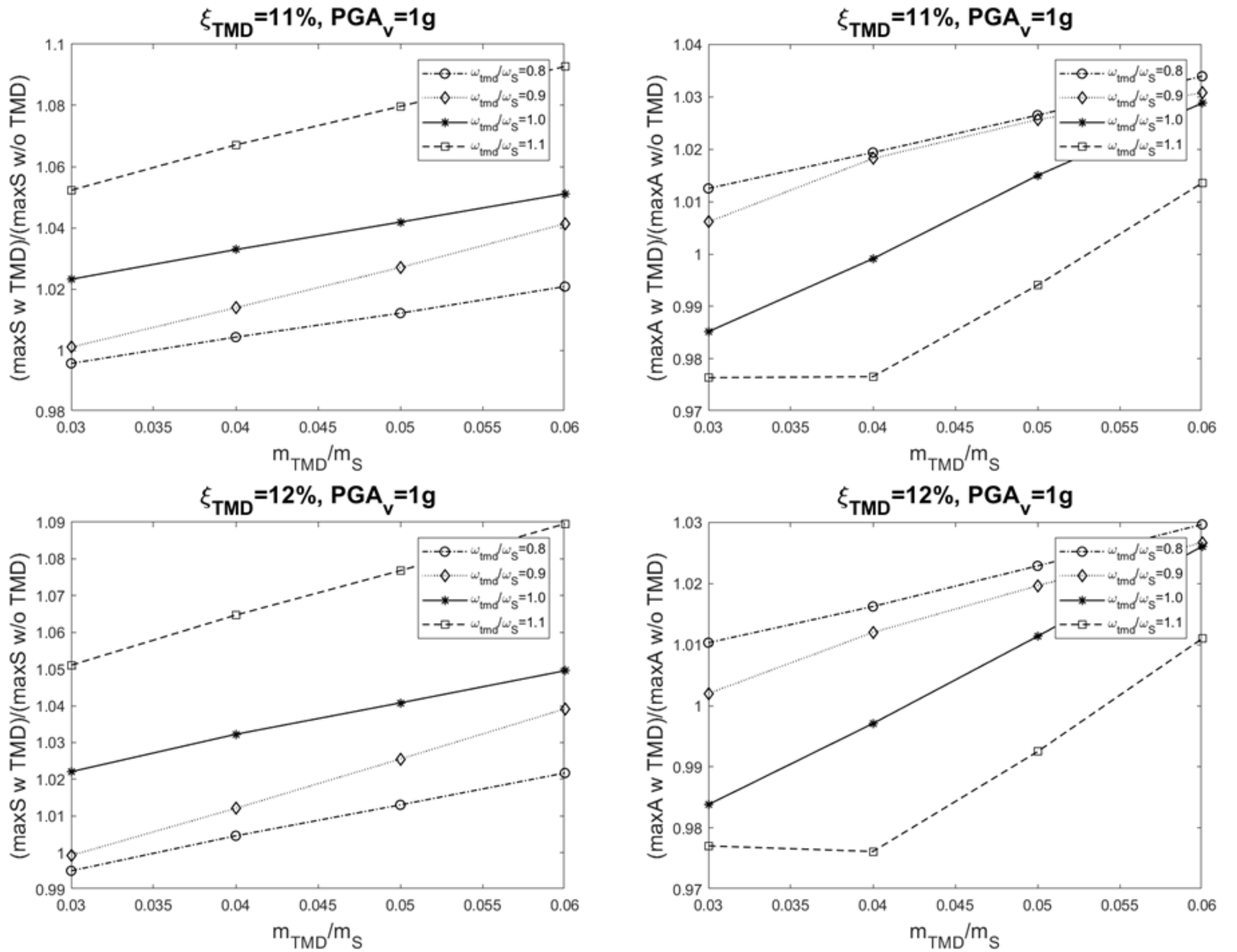
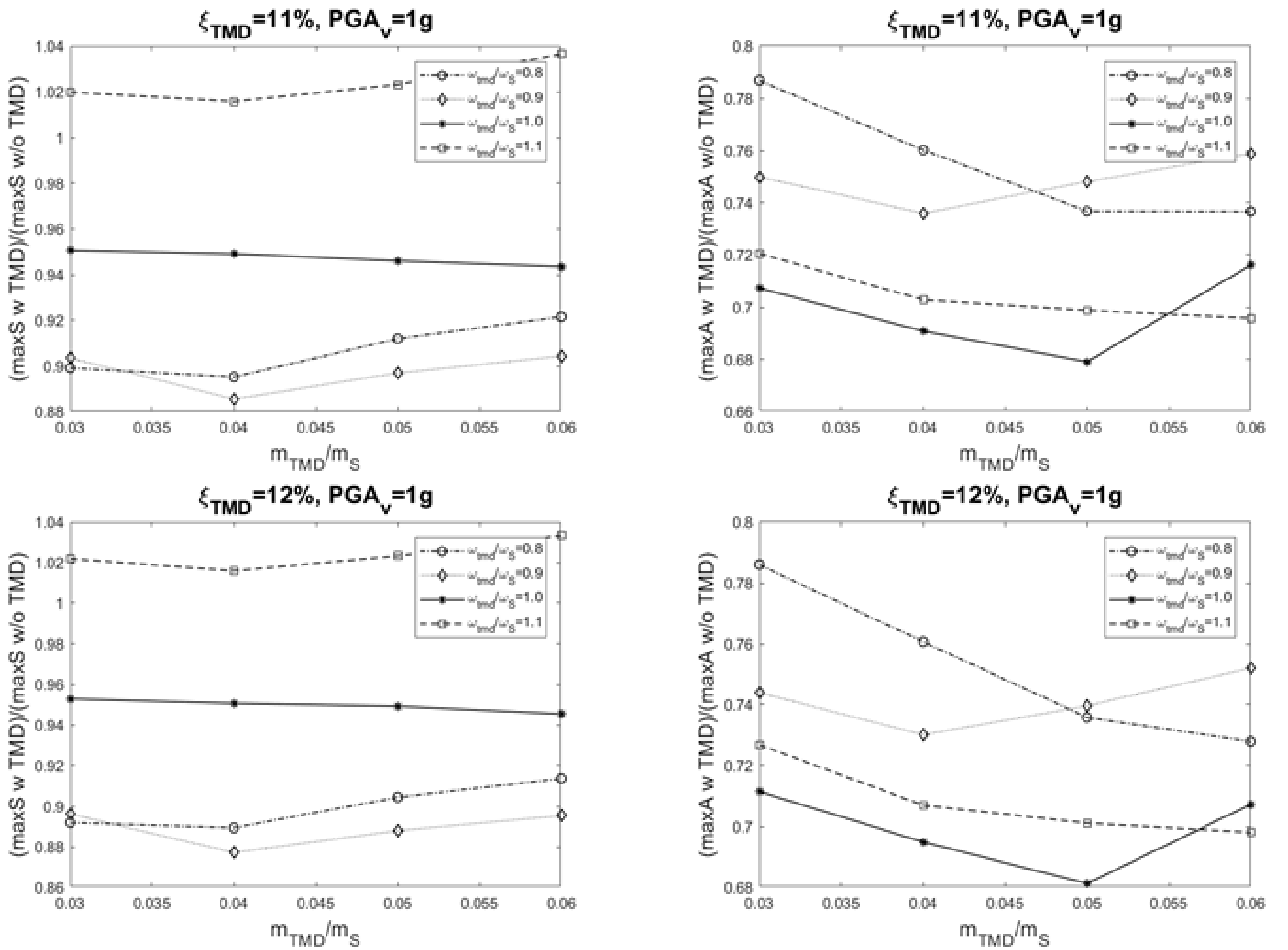
Due to the large amount of damping already provided by HDRBs, the introduction of a TMD deteriorates of the response



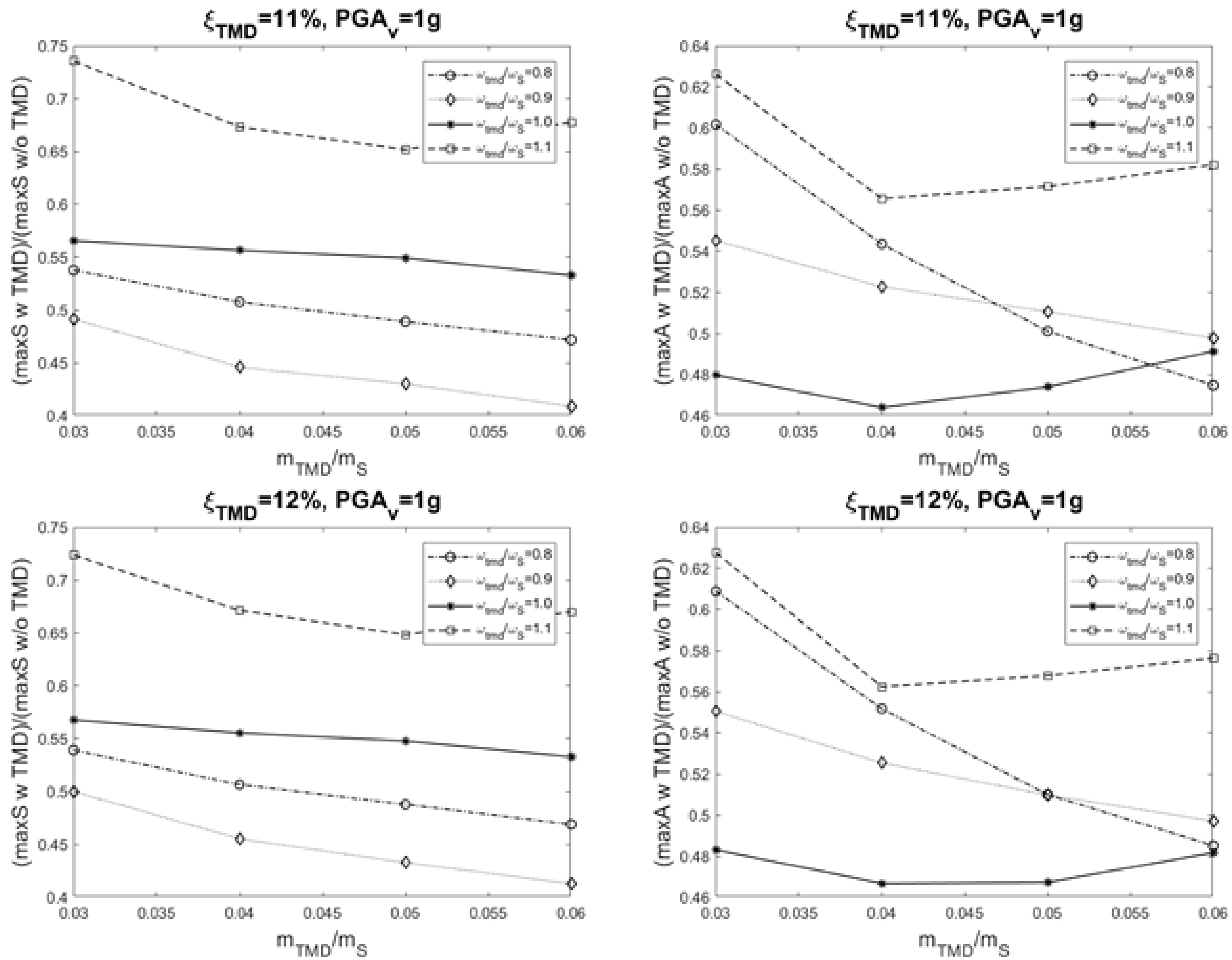
Results: NPP building LDRB

Benefits (abs. A in particular) are highlighted reducing damping of the isolation layer (about 1%)



Results: small statue, metallic springs

Damping is very low. The introduction of a TMS is highly beneficial for both abs. A& rel. S



Conclusions

- Implementation of a TMD in the vertical direction in parallel to traditional SI systems → 3-D base isolation
- Simple heavy and lightweight case studies
- The preliminary results show that the implementation of TMD can be beneficial to reduces the vertical abs. A & rel. S
- Under the condition of low level of the inherent damping in the base isolation bearings

- Further research will be focused on the investigation of more complex structural conditions: coupled H&V nonlinear structural & more general seismic inputs

Thank you for your attention

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