SYNTHETIC ACCELEROGRAMS FOR HAZARD EVALUATION AND RESPONSE-HISTORY ANALYSIS OF BUILDINGS

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Outline

- *introduction;*
- *hazard assessment – MCSI;*
- *natural vs synthetic accelerograms in NLTHA – a code based comparison;*
- *MCSI and NLTHA – a case study in Norcia*

Introduction

In NLTHA accelerograms should be chosen among those representative of the seismological conditions at the site of interest.
Their selection for nonlinear dynamic analysis must be made considering, at least, the following parameters:

- *the target response spectrum;*
- *the period range for spectrum compatibility check;*
- *the minimum number of analyses to perform;*
- *source and site effects;*
- *the availability of accelerograms*

It is difficult to find real records that meet these requirements

Can we use physics-based accelerograms for hazard assessment and perform NLTHAs?

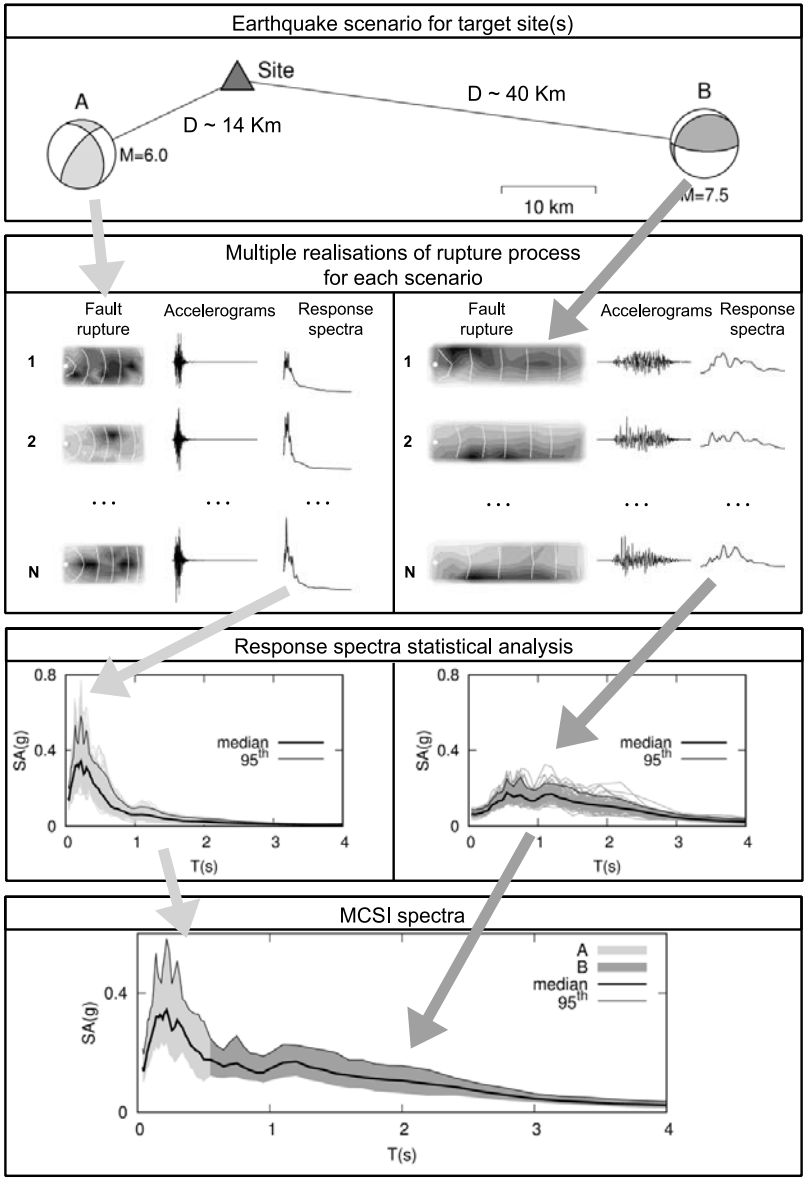
Hazard assessment

MCSI – Maximum Credible Seismic Input (***Fasan et al. 2015, 2016, 2017***)

- *based on the Neo-Deterministic approach for the evaluation of the seismic hazard (**NDSHA**) (Panza et al. 2001, 2012);*
- It is based on the **modelling of the propagation of seismic waves** starting from the knowledge of the sources and the structural properties of the Earth;

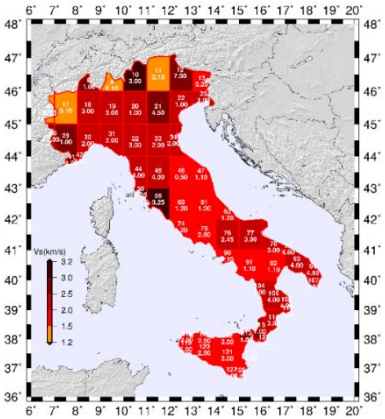
Mainly consists in:

- **Identifying all the sources** that may affect the site of interest;
- each source is **assigned** the **maximum** plausible **magnitude;**
- **uncertainty** about the future **location** of the earthquake considered using **multiple scenarios;**
- **variability** taken into account by simulating different **directivity, rupture velocity; distribution of slip** on the fault plane and **soil layers;**
- as a rule, the method allows to consider **uncertainty on physical parameters** by modelling them with multi-realization.

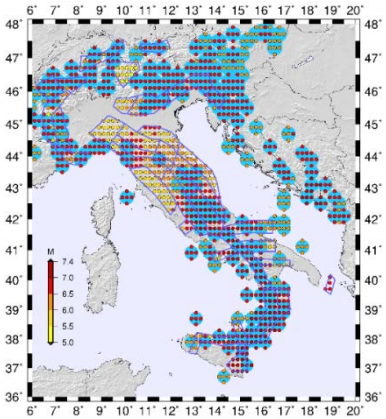


Hazard assessment

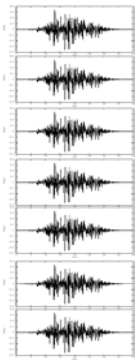
MCSI – computation at bedrock for Trieste



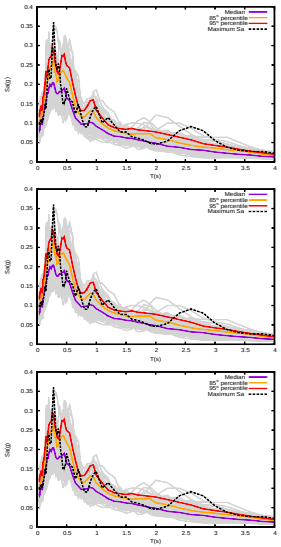
Definitions of the structural model



Definitions of the seismic sources



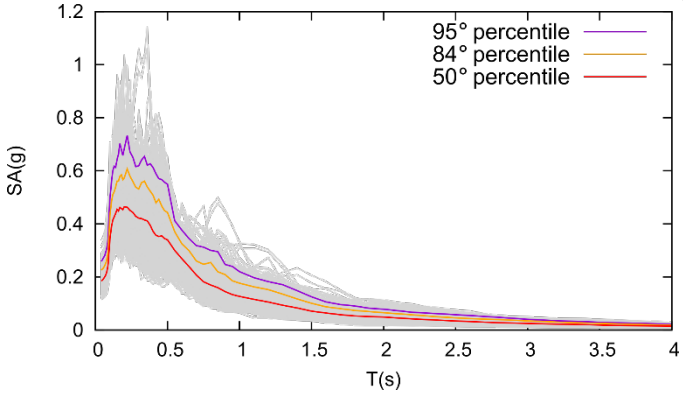
Computation of synthetic seismograms



Develop statistics for each source

Accelerograms are computed at 10Hz using

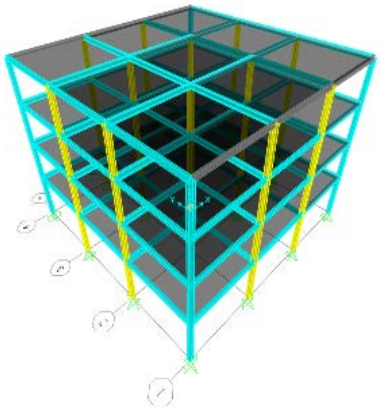
- a 1D model;
- the Modal Summation (MS) technique for epicentral distance R_{epi} >20kM (Panza et al. 2001, Panza et al. 2012);
- the Discrete wavenumber (DWN) technique for epincentral distance R_{epi} ≤20kM (Pavlov 2009);
- a maximum distance R_{max}= 150km

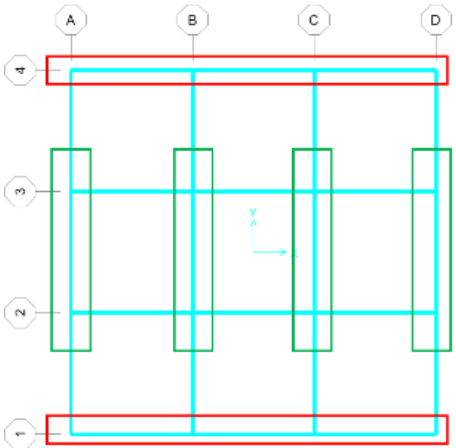


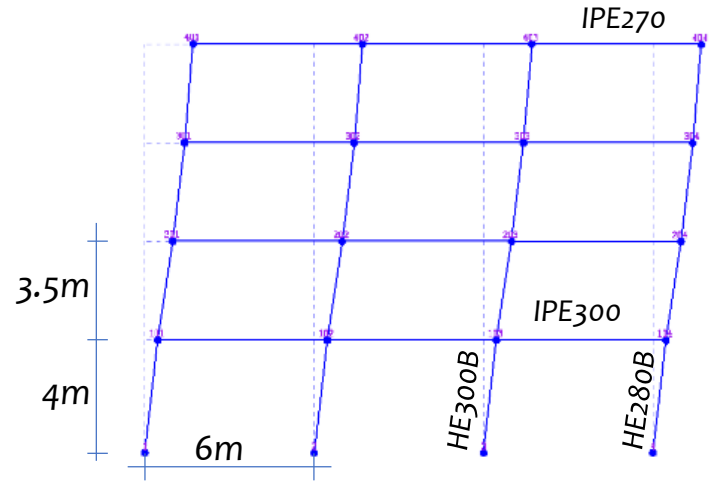
$MCSI_{BD}$

Envelope of the median response spectra, and the associated 84th and 95th percentile, of the sources within a distance of 150 km from the site (at each periods he source with highest median spectral acceleration is selected)

NLTHA - Natural and synthetic accelerograms: A code based comparison







Building properties and modelling:

- *4 storeys Steel Moment Resisting Frame – class S235;*
- *1st vibrational period of 1.5 s with 85% of mass participation;*
- *non-linear fibres model including large displacements effects (ADAPTIC software);*
- *steel material is modelled as bilinear with kinematic hardening;*
- *Newmark-β method is used to resolve the equation of motion;*
- *Rayleigh proportional damping matrix with constants α and β chosen to have a critical damping ratio of 1% at $2T_1$ (3 s) and T_4(0.17 s).*

Comparison between results of NLTHAs of:

- *5 sets of 11 natural records each;*
- *5 sets of 11 synthetic accelerograms each.*

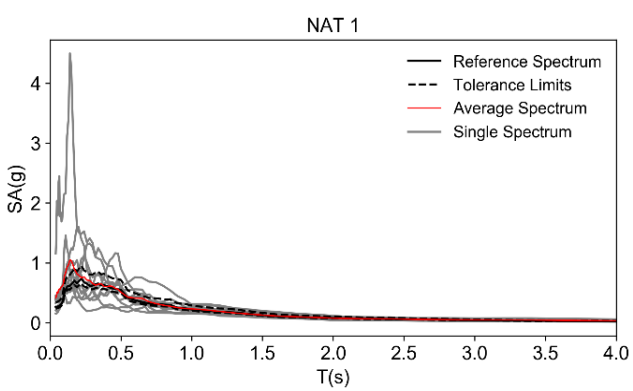
Natural vs synthetic accelerograms in NLTHA: A code based comparison

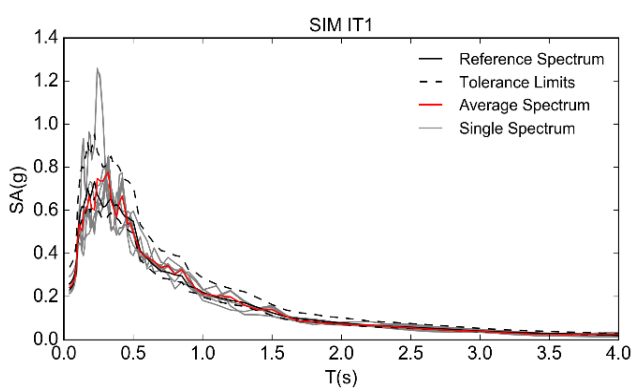
The following criteria are used to search the ESM database (Luzi et al., 2016):

- *a magnitude range from 6 to 7;*
- *an epicentral distance range from 10 km to 30 km;*
- *site class A and B, as per EC8;*
- *a period range for compatibility from 2 times the fundamental vibrational period T1 to 0.2T1;*
- *a maximum deviation of spectral accelerations from the target spectrum ranging from 90% to 130% of the target value.*

To be consistent with these features:

- *A database of simulations with magnitudes ranging from 6 to 7 and distances ranging from 10 to 30 is compiled for the Italian territory at the bedrock;*





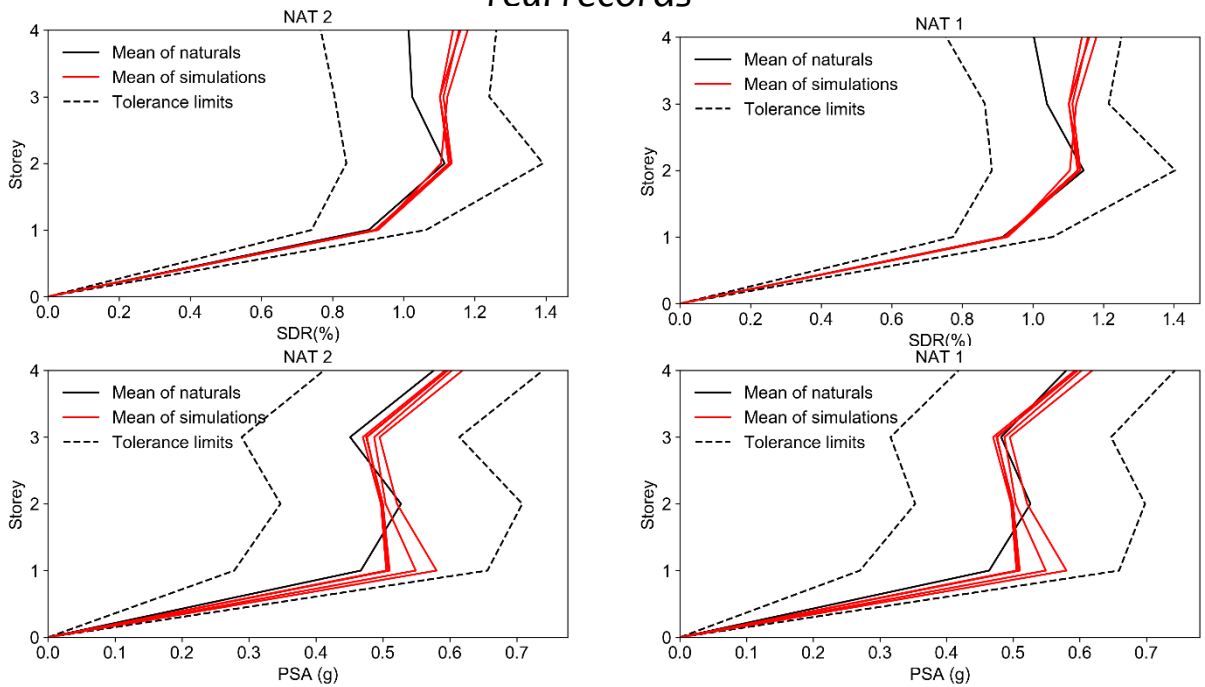
examples

Natural vs synthetic accelerograms in NLTHA: A code based comparison

Select Engineering Demand Parameters (EDPs):

- *Peak Storey Accelerations (PSA);*
- *Peak Interstorey Drift Ratio (SDR).*

The difference between the values is considered significant if the mean of a set of simulated accelerograms falls outside the range from 16th to 84th percentile of the value of a set composed by real records



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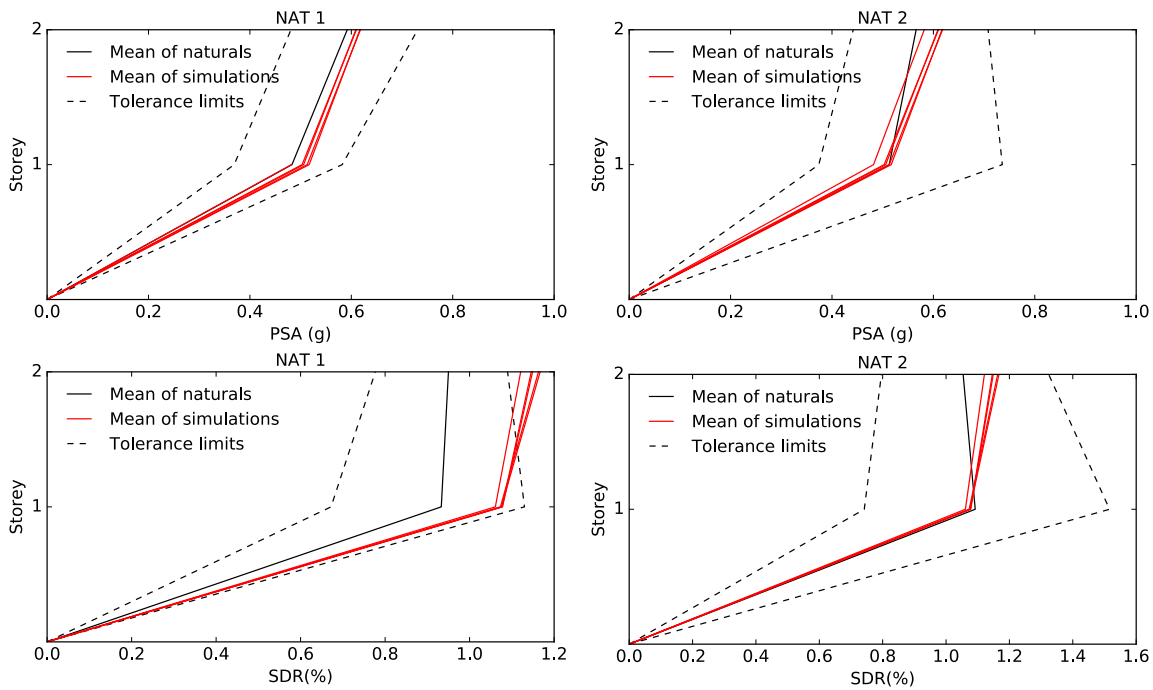
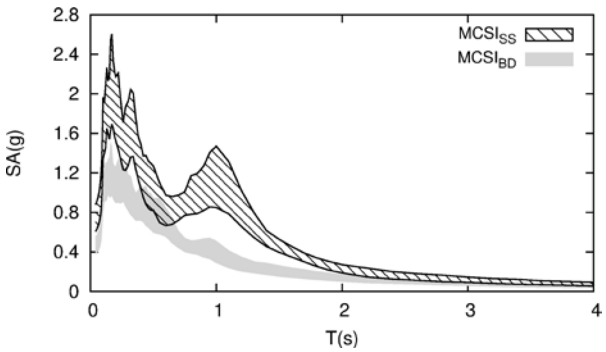
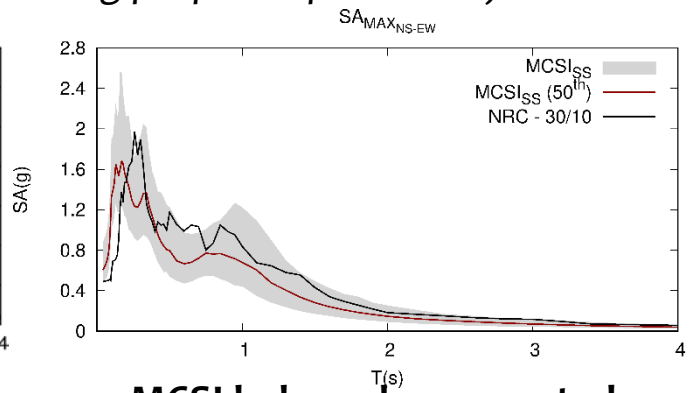


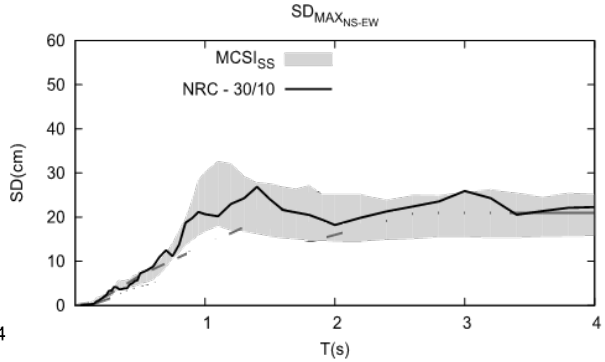
2-storeys MRF
T_1=0.83s

MCSI and NLTHA – a case study in Norcia

Bedrock and Site Specific MCSI are computed for the site of Norcia (NRC station) and compared with spectral accelerations recorded during the seismic even of the 30th of October 2016 (computed before the event, following proposed procedure)

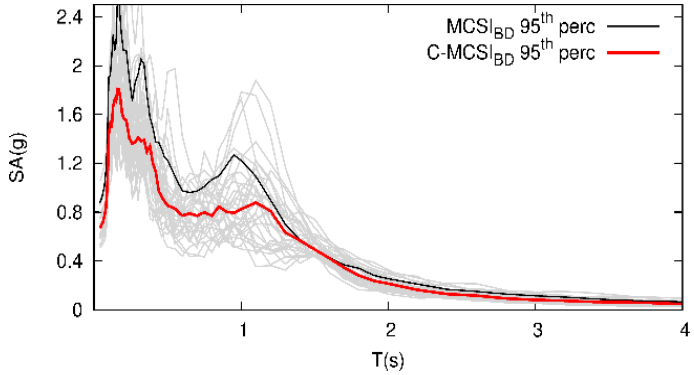






MCSI behaved as expected

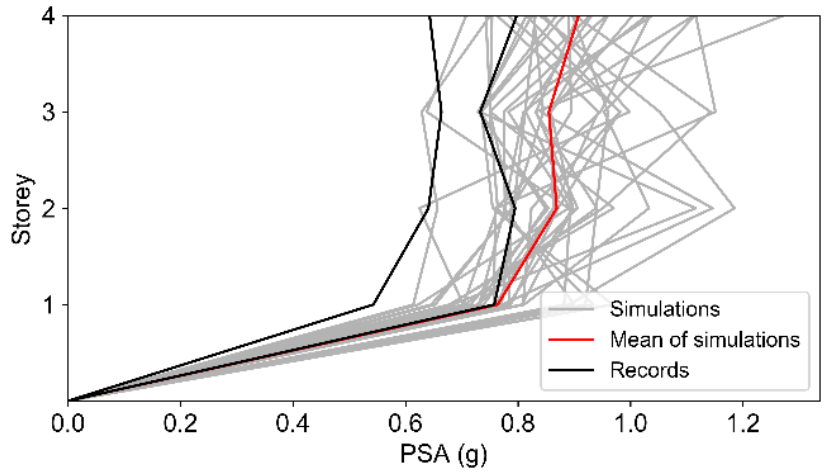
A set of synthetic accelerograms is selected following the C-MCSI procedure proposed by Fasan (2017):

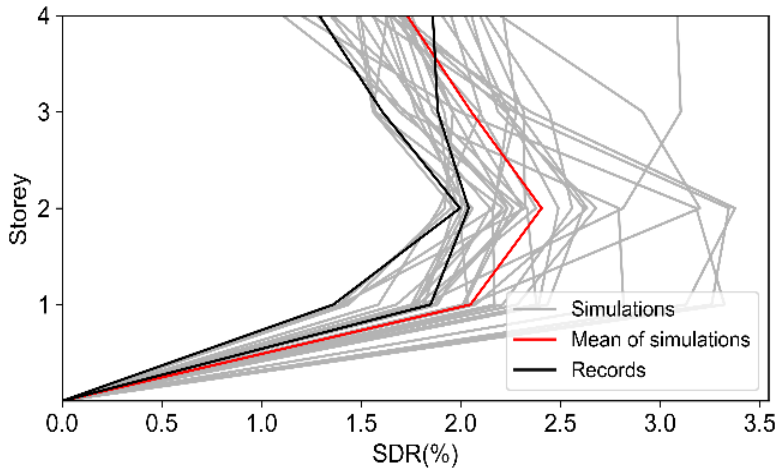


Not a priori selection Based on MCSI values

MCSI and NLTHA – a case study in Norcia

Using the FEM model used at point 2, structural demands obtained with synthetic records are compared with those obtained with the real records





MCSI behaved as expected

Conclusions

- *Results of NLTHAs obtained with natural accelerograms are compared with those obtained with different sets of NDSHA synthetic records:*

synthetic accelerograms selected to match any target response spectrum (both deterministic and probabilistic) provide similar structural demands (at least when looking for maximum parameters)

- *synthetic accelerograms are used to evaluate the Maximum Credible Seismic Input at the site of Norcia in the framework of the NDSHA method:*

MCSI acceleration response spectrum and the recorded spectral acceleration during the event of the 30th of October 2016 are very similar.

- *structural demands due to synthetic records selected on MCSI and the demands due to the record of the 30th of October are compared:*

MCSI accelerograms effectively predicted the structural demand

Future developments:

- *Tests with more stations and earthquakes (need for adequate knowledge of soil profiles);*
- *take into account the cumulative non-linear structural demands.*

Thank for your attention

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