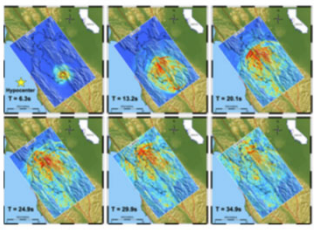
2025 PEER LBNL Workshop on the Regional Scale Simulated Ground Motion Database (SGMD) for the San Francisco Bay Area

Selection of Input Motions from Validated Datasets of Regional Simulated Accelerograms

Roberto Paolucci & Chiara Smerzini

POLITECNICO MILANO 1863



Banatao Auditorium, UC Berkeley
March 24, 2025

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SPEED @PoliMI: software for physics-based ground motion simulations (PBS)

SPEED

OPEN-SOURCE

http://speed.mox.polimi.it/

SPEED – SPectral Elements in Elastodynamics with Discontinuous Galerkin

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SPEED – SPectral Elements in Elastodynamics with Discontinuous Galerkin

SPEED is an open-source code designed with the aim of simulating large-scale seismic events in three-dimensional complex media: from far-field to near-field including soil-structure interaction effects.

SPEED combines the flexibility of discontinuous Galerkin methods to connect together, through a domain decomposition paradigm, Spectral Element blocks where high-order polynomials are used. SPEED heavily exploits parallelism in the framework of explicit time integration and features optimal scalability properties making use of the open-source libraries METIS and MPI for mesh partitioning and message passing.

SPEED is jointly developed at Politecnico di Milano by The Laboratory for Modeling and Scientific Computing MOX of the Department of Mathematics and by the Department of Civil and Environmental Engineering

MOX | POLITECNICO MILANO 1863 | Dipartimento di Ingegneria Civile e Ambientale

Antonietti et al. (2012), Mazzieri et al. (2013) 2

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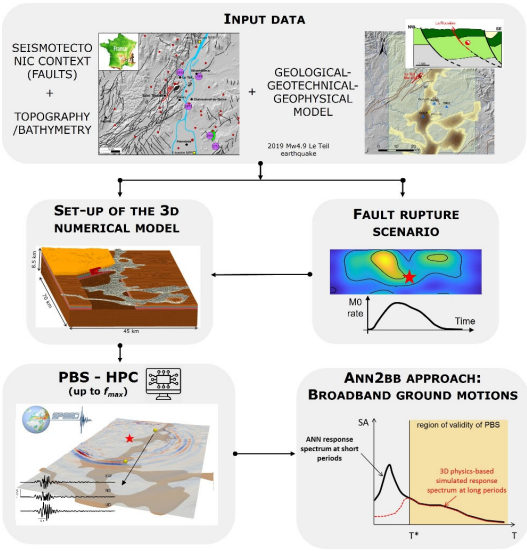
Workflow for the generation of broadband earthquake ground motions from 3D PBS by SPEED



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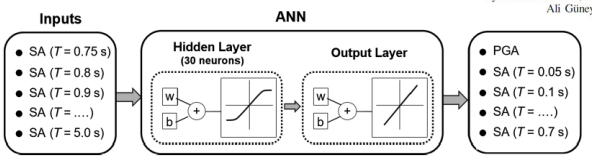
ANN2BB: BB ground motions using Artificial Neural Networks

Bulletin of the Seismological Society of America, Vol. 108, No. 3A, pp. 1272–1286, June 2018, doi: 10.1785/0120170293

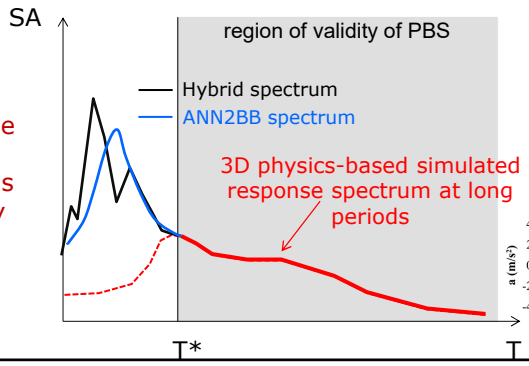
Broadband Ground Motions from 3D Physics-Based Numerical Simulations Using Artificial Neural Networks

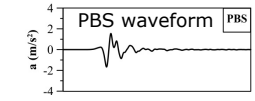
by Roberto Paolucci, Filippo Gatti, Maria Infantino, Chiara Smerzini, Ali Güney Özcebe, and Marco Stupazzini

(1) Training of an ANN (*una tantum*) based on a strong motion database (e.g., NGA)

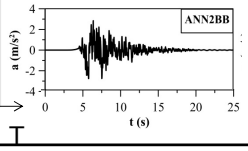


(2) Response spectrum at short periods predicted by the ANN





(3) Scaling the PBS waveform in order to match (within a tolerance) the ANN spectrum → ANN2BB



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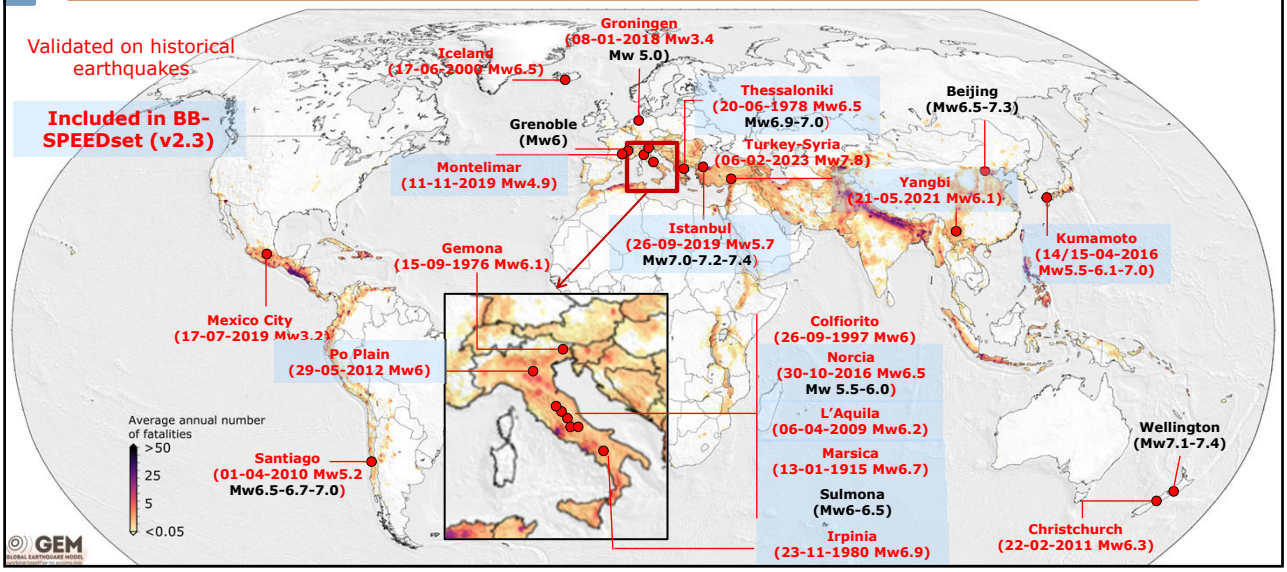
Case studies of PBS by SPEED



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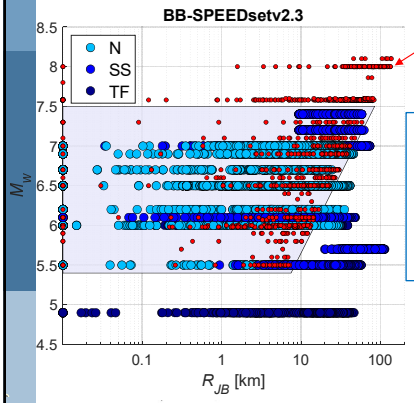
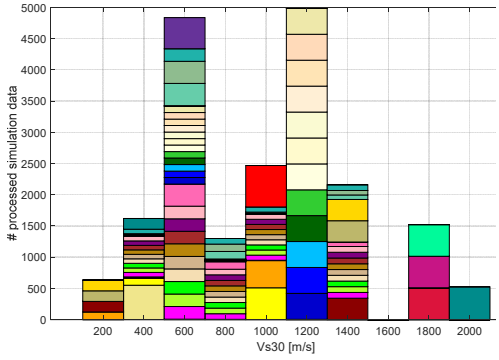
BB-SPEEDset (v2.3): a dataset of near-source accelerograms from PBS

M_w- R_{jb} and V_{S30} distribution of BB-SPEEDset



NESS2.0 (Sgobba et al. 2021)

BB-SPEEDset v2.3:
- 37 scenarios (12 validations + 25 scenarios)
- 55% N; 38% SS; 6% TF
- 75% VS30 > 600 m/s; 1% VS30 < 200 m/s



BB-SPEEDset: A Validated Dataset of Broadband Near-Source Earthquake Ground Motions from 3D Physics-Based Numerical Simulations

Roberto Paolucci; Chiara Smerzini; Manuela Vanini

Bulletin of the Seismological Society of America (2021) 111 (5): 2527–2545.

Open-source (*available soon v2.3*):
http://speed.mox.polimi.it/bb-speedset/
- Flatfile
- 3-component broadband accelerograms (20'046)

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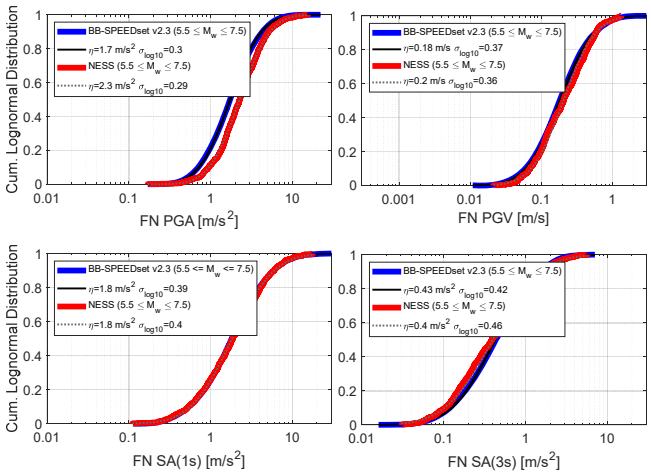
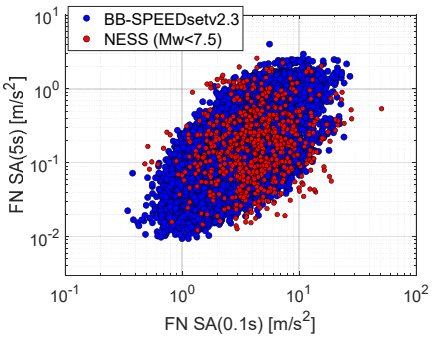
BB-SPEEDset: consistency checks with recorded near-source dataset (NESS2 @INGV)

Cumulative distributions of horizontal (FN) PGA, PGV, SA(1s), SA(3s) from BB-SPEEDset and from NESS2



Fault Normal SA(0.1s)-SA(5s) correlation



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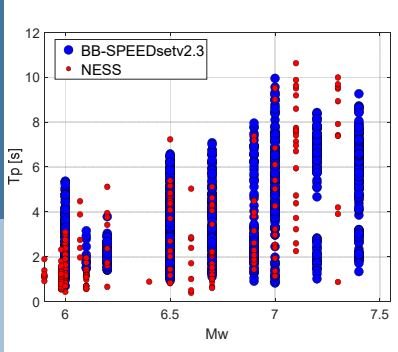
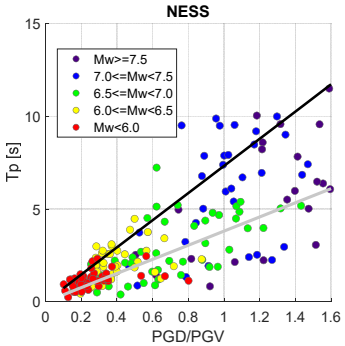
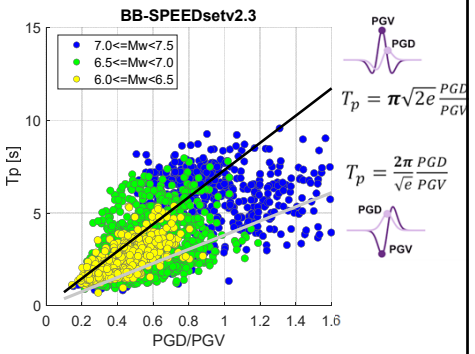
BB-SPEEDset: consistency checks with recorded near-source dataset (NESS2 @INGV)

Identification of pulse-like waveforms and of corresponding pulse period Tp according to Shahi and Baker (2014)







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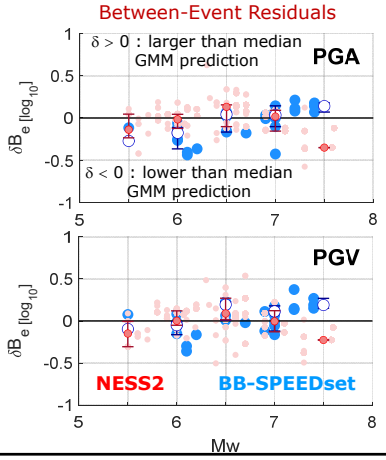
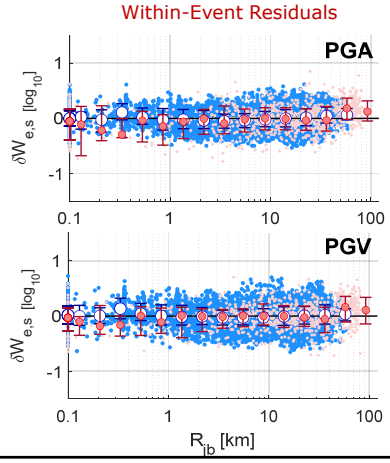
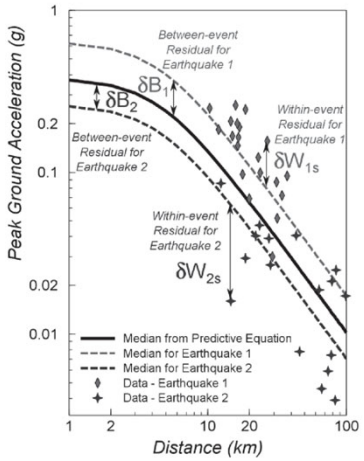
BB-SPEEDset: consistency checks with recorded near-source dataset (NESS2 @INGV)

Between- and within-event residuals of **BB-SPEEDset** and **NESS2** with respect to the ITA18 GMM (Lanzano et al. 2019, adjusted by near-source effects)







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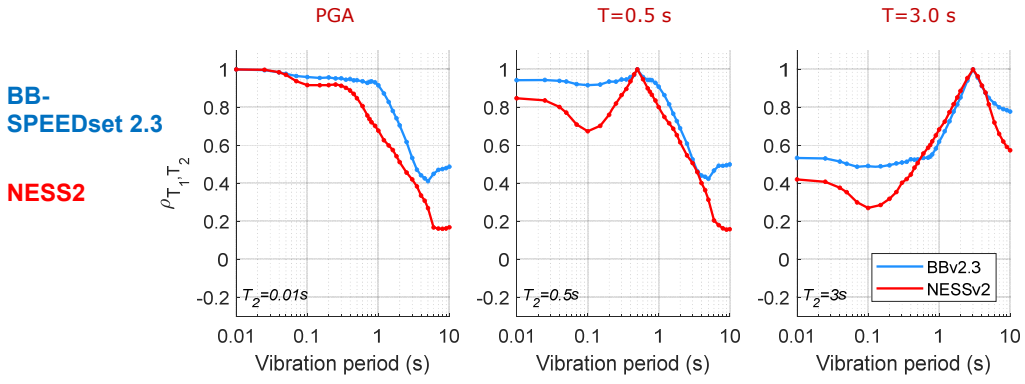
BB-SPEEDset: consistency checks with recorded near-source dataset (NESS2 @INGV)

Period-to-Period (P2P) correlations

residuals with respect to Lanzano et al. (ITA18corr) GMM



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Software tool for ground motion selection enhanced by PBS

Bulletin of Earthquake Engineering (2022) 20:4961–4987
https://doi.org/10.1007/s10518-022-01393-0
REVIEW ARTICLE

Selection and spectral matching of recorded ground motions for seismic fragility analyses

Vincenzo Manfredi[1] · Angelo Masi[1] · Ali Güney Özcebe[2] · Roberto Paolucci[3] · Chiara Smerzini[2]

GM DATABASES
- NGA-WEST2, SIMBAD
- BB-SPEED SET

TARGET SPECTRUM
- USER-DEFINED
- NORMS (EC8, ASCE)

SELECTION CRITERIA
- NUM. ACCELEROGRAMS
- M, PERIOD RANGE
- MAX/AVG PERMIS. MISMATCH
- SITE-CONDITIONS
- PULSE-LIKE SELECTION
- 3-COMPONENT
- RANKING WEIGHTS

SELECTION OF A SET OF N MULTI-COMPONENT ACCELEROGRAMS APPROACHING A TARGET SPECTRUM

SPECTRAL MATCHING OF THE N SELECTED ACCELEROGRAMS

MATCHING CRITERIA
- PERIOD RANGE
- VARIABILITY BAND
- PGA CONSISTENCY

SET OF N **UNSCALED OR SPECTRALLY-MATCHED REAL/SIMULATED ACCELEROGRAMS** COMPATIBLE WITH A TARGET SPECTRUM

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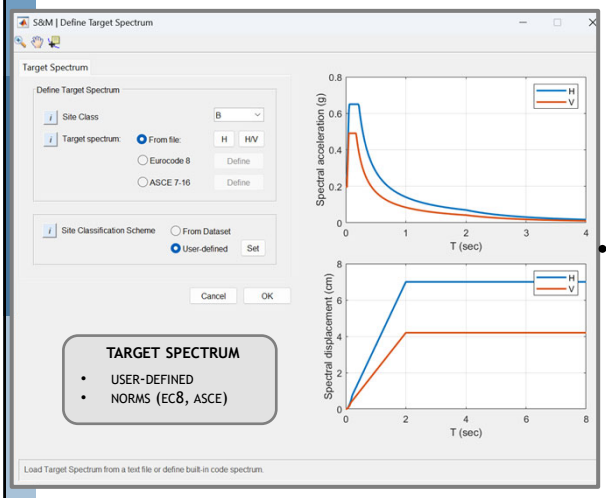
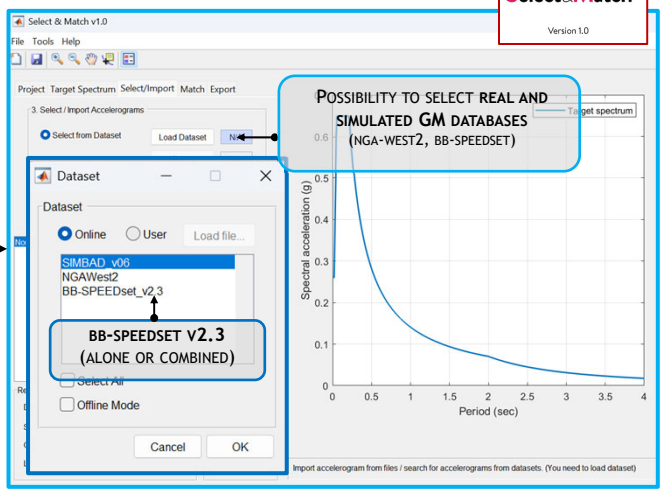
Software tool for ground motion selection enhanced by PBS



TARGET SPECTRUM
- USER-DEFINED
- NORMS (EC8, ASCE)



POSSIBILITY TO SELECT REAL AND SIMULATED GM DATABASES (NGA-WEST2, BB-SPEEDSET)

BB-SPEEDSET V2.3 (ALONE OR COMBINED)

Select&Match
Version 1.0

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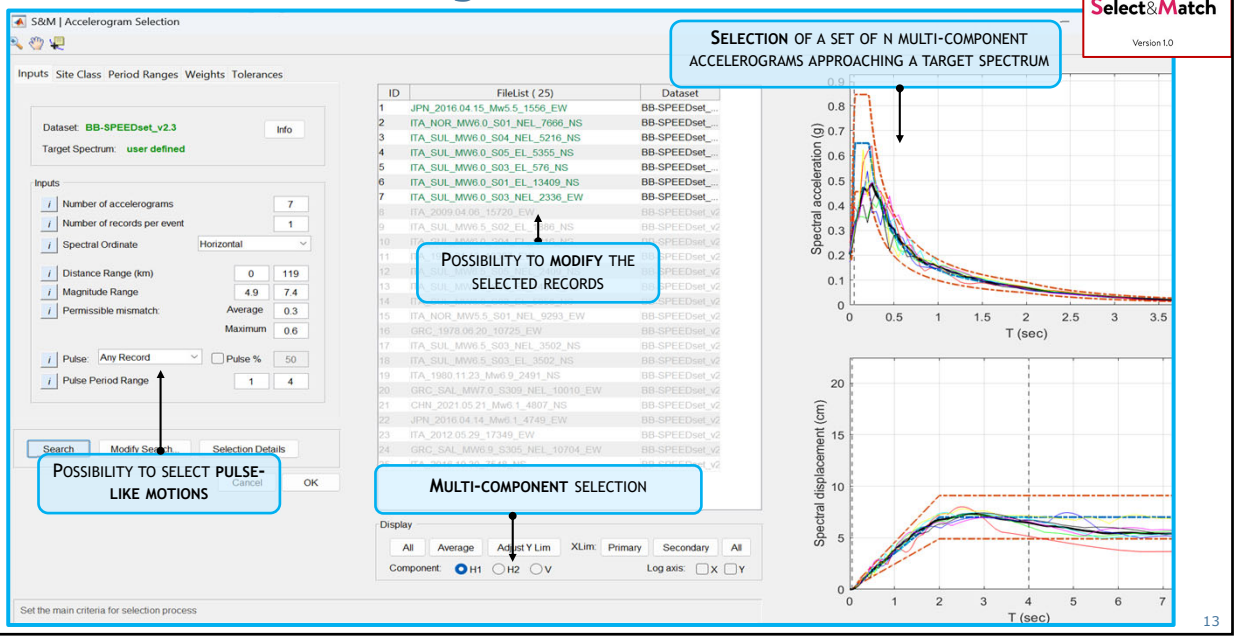
Software tool for ground motion selection



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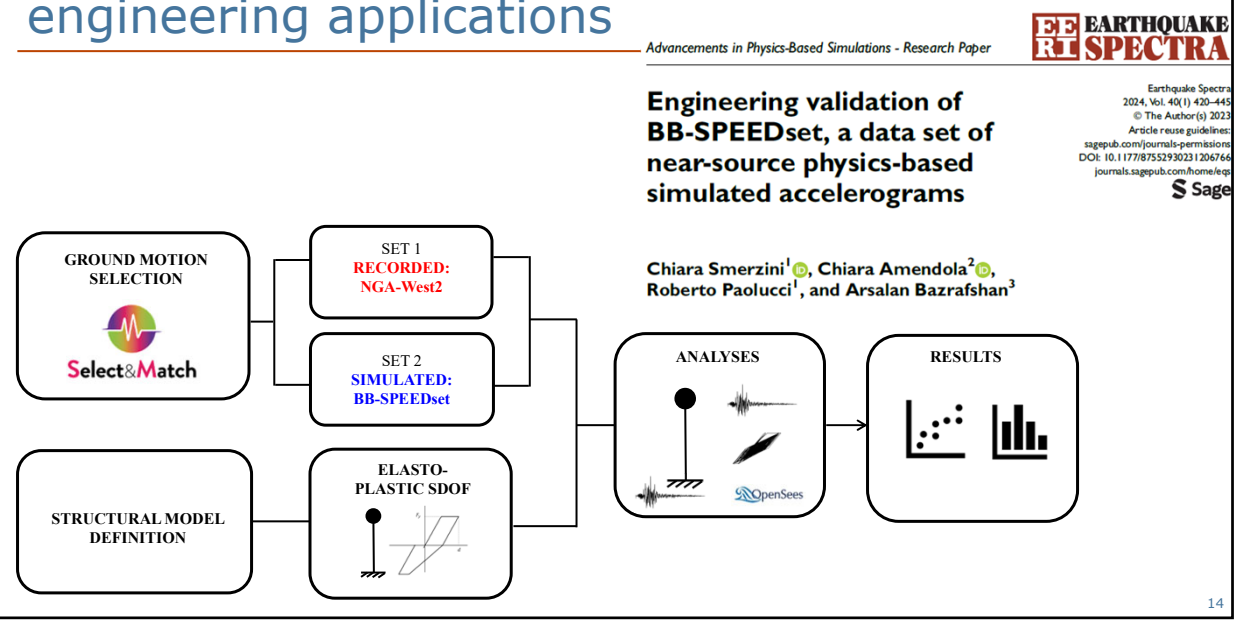
Validation of simulated ground motions for engineering applications



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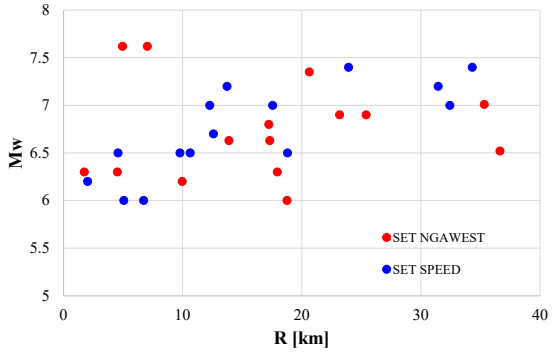
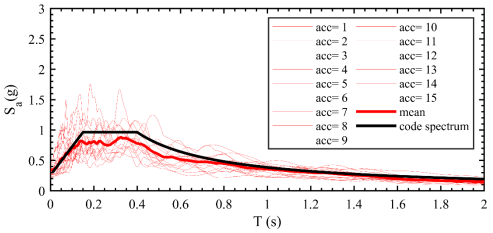
Software tool for ground motion selection enhanced by simulated datasets

Consistent selection criteria:

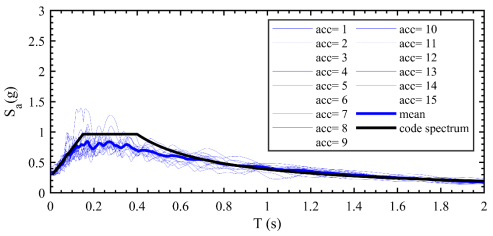
- 975 yrs return period elastic design spectrum (Central Italy)
- Reference rock site
- T=0.1-4 s within prescribed upper and lower tolerances
- Unscaled accelerograms



RECORDED SET: NGA-West2



SIMULATED SET: BB-SPEEDset



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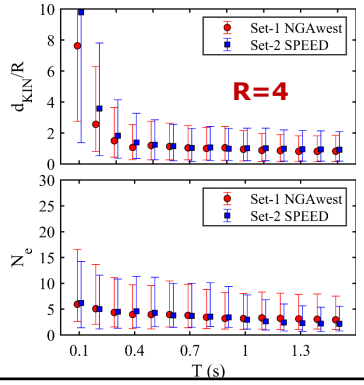
Structural model and inelastic EDPs

Inelastic SDOF systems with:

- Elasto-plastic backbone curve (EPP)
- Vibration period from T=0.1 to 1.5 s
- Strength reduction factors R=2, 4, 6
- Constant-strength systems

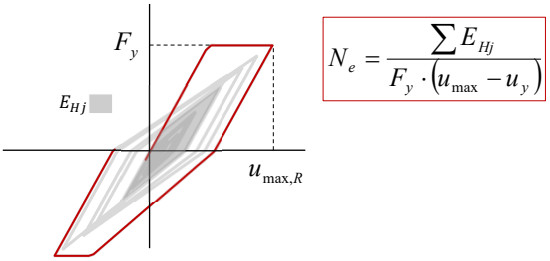
PEAK RESPONSE

CYCLIC RESPONSE



- Peak Response: displacement ductility over strength reduction factor

- Cyclic Response: equivalent number of hysteresis cycles



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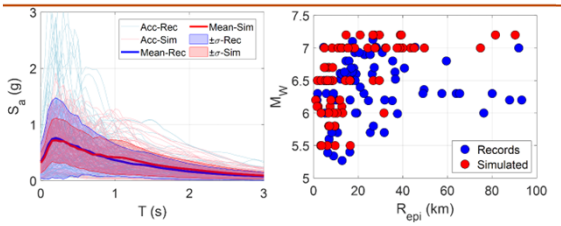
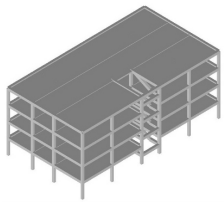
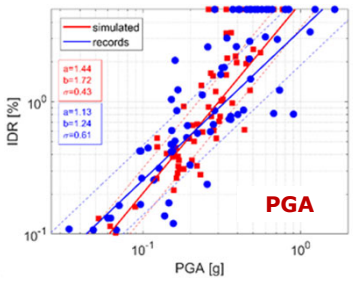
Fragility curves from recorded and simulated ground-motion sets

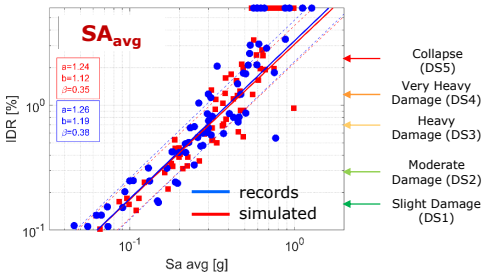


RC building
4s|IF|70s
T_0=0.54s

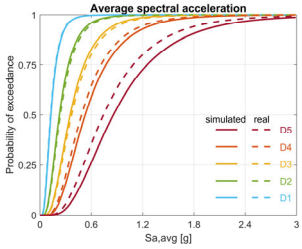




insufficient IM



sufficient IM



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Concluding remarks

- Building confidence in utilization of datasets of regional-scale PBS for earthquake engineering applications requires extensive validations of simulated ground motions, in a broad frequency range.
- Validation should involve checks on both ground-motion IMs and EDPs, from both historical and datasets of scenario earthquakes in a sufficiently wide (M,R) range.
- Availability and dissemination of simulated ground motion datasets, such as BB-SPEEDset, preferably embedded in ground-motion selection tools, is a key step for this purpose.
- Efforts are still needed towards the definition of common acceptance criteria and standards for the validation checks on simulated ground motions.

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Thank you!

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