2024 PEER - LBNL Workshop
Simulated Ground Motions for the San Francisco Bay Area
January 18-19, 2024

PEER Welcome

Khalid M. Mosalam
Pacific Earthquake Engineering Research Center

Pacific Earthquake Engineering Research (PEER) Center

Berkeley
UNIVERSITY OF CALIFORNIA

Caltech

Oregon State University

Stanford University

UC DAVIS
UNIVERSITY OF CALIFORNIA

UC San Diego

UC Irvine

University of Nevada, Reno

UCLA

UNIVERSITY of WASHINGTON

USC University of Southern California

11 Core Institutions

CAL STATE LA

CSUN
CALIFORNIA STATE UNIVERSITY NORTHRIDGE

CAL POLY
SAN LUIS OBISPO

Carnegie Mellon University

JOHNS HOPKINS
UNIVERSITY

SJSU SAN JOSÉ STATE UNIVERSITY

SMU

UAA
UNIVERSITY of ALASKA ANCHORAGE

UNIVERSITY of HAWAIʻI
MĀNOA

9 Educational Affiliates

Vision: Lead the Resilient Design for Extreme Events

30th/29th Anniversaries of Northridge & Kobe Earthquakes

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From 1/17/2024 (Northridge EQ) to 1/17/2025 (Kobe EQ):
A year of collecting achievements, lessons, research gaps, and data through workshops (**starting with this two-day workshop!**) and web-based data collection platform!

PEER News Digest
PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Dear Khalid Mosalam,

Remembering Northridge and Kobe earthquakes and Call for a Year of Data Collection

Major advances in earthquake engineering have generally occurred because of significant earthquake events. Today marks the anniversary of two such events. At 4:31 am Pacific Time on January 17, 1994, the **Northridge Earthquake**, a magnitude 6.7 event, occurred in the San Fernando Valley with a duration of 10-20 seconds. The death toll was 57, and the property damage was estimated to be as high as nearly $100 billion (in 2024 dollars), making it the costliest natural disaster in US history. The greater Los Angeles area suffered widespread disruptions in the weeks and months following the earthquake.

A year later, at 05:47 am Japan Time, the **[illegible]shin Earthquake**, a magnitude 6.9 event that [illegible] to Kobe, Japan, With over 6,400 lives los[illegible]s second deadliest earthquake of the 20th ce[illegible] Great Kanto earthquake and fire).

Occurring exactly one year [illegible] earthquakes led to paradigm shifts in earthqu[illegible]g, contributed to decades of research, s[illegible]ance-based engineering, advances in design [illegible] codes, reforms in insurance industr[illegible]ents to public policy. **PEER is planning a [illegible]shops, webinars and articles over the ne[illegible]** review the lessons learned and evaluate t[illegible]ahead in a wide range of topics such as seis[illegible]lysis, building performance, bridge performance, code development, public policy, insurance [illegible]r mitigation, risk modeling and seismic retrofit. The first one of these will be the PEER-LBNL w[illegible]uary 18 & 19, 2024, focused on simulated ground motions.

In addition, **PEER is initiating a data collectio[illegible] the coming one-year period** between 1/17/2024 and 1/17/2025. This will leverage PEER's pas[illegible] cosponsoring the Northridge20 Symposium in 2014, and organizing the 2019 Annual Meeting fo[illegible]ridge earthquake. A dedicated page will be developed on the PEER website for this purpose and t[illegible]unity will be invited to contribute. The contributions can be in multiple categories, including, but n[illegible]) policy changes, (b) research motivated by these events in structural engineering, geotechnica[illegible]ground motions, and seismology, (c) achievements in the past 30 years, e.g., the number and type[illegible]structures, and (d) remaining research gaps, needs and problems. The contributions can also be [illegible]alities, including (i) publications with broader impacts, (ii) links to supporting public data from [illegible]nstrumented structures, ground motions, numerical simulations, and available codes, and (iii) [illegible]graphs and videos.

These materials, the develope[illegible]opage, and the database will provide valuable references for researchers, practicing engineers, and policy makers for developing effective solutions to be ready for earthquakes that continue to occur in the U.S., Japan, and other parts of the world. Please monitor the PEER Newsletter for future webinars and articles.

Released yesterday 1/17/2024

PEER

Thanks …

Organizing Committee

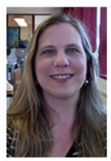

David McCallen
Lawrence Berkeley National Laboratory


Khalid Mosalam
UC Berkeley


Floriana Petrone
University of Nevada, Reno; Lawrence Berkeley National Lab


Amarnath Kasalanati
PEER, UCB


Arben Pitarka
Lawrence Livermore National Laboratory


Christina Bodnar-Anderson
PEER

PEER Staff


Zulema Lara


Erika Donald


Gabriel Vargas

29 speakers
263 participants
(**98** in-person + **165** on-line)
10 posters


Brad Aagaard
U.S. Geological Survey


Pedro Arduino
University of Washington


Domniki Asimaki
California Institute of Technology


Jeff Bachhuber
Pacific Gas & Electric


Brendon Bradley
University of Canterbury, Christchurch, New Zealand


Matt DeJong
UC Berkeley


Joseph Dygert
DOE Office of Cybersecurity Energy Security & Emergency Response


Robert Graves
U.S. Geological Survey


Selim Günay
UC Berkeley


Evan Hirakawa
U.S. Geological Survey


Ken Hudnut
Southern California Edison


Amarnath Kasalanati
PEER, UCB


Maha Kenawy
Oklahoma State University


Albert Kottke
Pacific Gas and Electric Co.


Martin Mai
King Abdullah University of Science and Technology, Saudi Arabia


Brett Maurer
University of Washington


David McCallen
Critical Infrastructure Energy Geosciences Division, LBNL


Khalid Mosalam
UC Berkeley


Rie Nakata
Lawrence Berkeley National Lab


Roberto Paolucci
Politecnico di Milano, Milan, Italy


Floriana Petrone
University of Nevada, Reno; Lawrence Berkeley National Lab


Camilo Pinilla Ramos
Lawence Berkeley National Lab


Arben Pitarka
Lawrence Livermore National Laboratory


Chiara Smerzini
Politecnico di Milano


Kinichi Soga
UC Berkeley


Marco Stupazzini
Munich Re, Geophysical and Parametric Risks


Ricardo Taborda
School of Applied Sciences and Engineering Universidad EAFIT Colombia


Ertugrul Taciroglu
UC Los Angeles


Houjun Tang
Lawrence Berkeley National Lab

Speakers

Program (1/2)

Simulation modeling, validation & use cases

Thursday, January 18, 2024
Day 1 Technology Components for Regional Simulations

Time	Topic/Session
8:00-8:30	Registration / Breakfast
8:30-9:15	**Welcome and DOE program Objectives** PEER Welcome - **Khalid Mosalam, PEER** DOE Interests for energy systems and action items from the PEER June 2021 Pacific Rim International Forum - **David McCallen, LBNL** DOE CESER program on energy systems- **Joseph Dygert, CESER**
9:15-11:15	**S1 - Earthquake source characterization - Arben Pitarka, Moderator** 1. History and current status of rupture modeling - **Martin Mai** 2. Recent developments in kinematic rupture modeling - **Robert Graves** 3. Using sets of realizations of kinematic slip distributions along the Marmara Sea fault to produce site-specific ground motion models of Istanbul - **Roberto Paolucci** **Panel discussion - How many rupture realizations do we need to span the risk space? (Mai, Graves, Paolucci, Smerzini, Taborda, Bradley)**
11:15-11:25	**Break**
11:25-12:45	**S2 - Simulated motions validation and acceptance criteria for ground motion databases - Floriana Petrone, Moderator** 1. Towards the engineering utilization of BB-SPEEDset, a validated dataset of physics-based simulated accelerograms, from multiple seismic regions and faulting styles - **Chiara Smerzini** 2. The Southern California validation experience - **Ricardo Taborda** 3. The link between simulated ground motion intended use and necessary validation/acceptance criteria - **Brendon Bradley**
12:45-2:00	**Lunch, discussion and posters**
2:00-3:20	**S3 - Representation of the near-surface geotechnical layer - Pedro Arduino, Moderator** 1. 1D site response using regional simulated motions - **Brett Mauer** 2. Nonlinear soil model inclusion in regional simulations - **Ertugrul Taciroglu** 3. Empirical models of site effects for simulated ground motions - **Domniki Asimaki**
3:20-3:35	**Break**
3:35-5:00	**S4 - Simulated ground motion use cases I - David McCallen, Moderator** 1. Pacific Gas and Electric perspectives on energy systems - **Albert Kottke** 2. Southern California Edison perspectives on energy systems - **Ken Hudnut** 3. Application of simulated motions to nonlinear building analysis - **Maha Kenawy**

Program (2/2)

Friday, January 19, 2024
Day 2 Focus on the San Francisco Bay Area and the PEER-LBNL Database

Use cases, updates, tools & databases

Time	Topic/Session
8:00-8:30	Registration / Breakfast
8:30-9:50	**S5 - Simulated ground motion use cases II - Floriana Petrone, Moderator** 4. Evaluation of water distribution systems - **Kenichi Soga** 5. Implications of the use of physics-based simulations in the (Re)insurance sector - **Marco Stupazzini** 6. SimCenter tools for simulated ground motion utilization - **Matt DeJong**
9:50-11:10	**S6 - The development of the SFBA regional geologic model and recent updates to the geotechnical layer - Rie Nakata, Moderator** 1. Historical basis for the USGS SFBA velocity model - **Brad Aagaard** 2. Recent SFBA community model updates - **Evan Hirakawa** 3. Evaluating the SFBA velocity structure through simulation comparisons to small SFBA earthquake data - **Camilo Pinilla Ramos**
11:10-11:25	Break
11:25-1:00	**S7 - EQSIM regional framework and large Bay Area simulated earthquake datasets - Khalid Mosalam, Moderator** 1. EQSIM and SFBA large datasets - **David McCallen** 2. Hayward fault rupture model realizations - **Arben Pitarka** 3. EQSIM SFBA ground motion assessment and acceptance - **Floriana Petrone**
1:00-2:00	Lunch, discussion & poster discussion
2:00-3:20	**S8 - PEER-LBNL simulated motion database - Amarnath Kasalanati, Moderator** 1. I/O storage and interrogation of large data - **Houjun Tang** 2. Familiar interface for NGA users - **Khalid Mosalam & Selim Günay** 3. Schedule for data roll-out and beta users - **Khalid Mosalam & Selim Günay**
3:20-3:35	Break
3:35-4:45	**S9 - Community interactions - annual community stakeholder workshops** **Discussion** - Opportunities for system stakeholder, researcher and practitioner community feedback

Open discussion, contemplating a formal annual meeting

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DOE Program Objectives

- Answer the questions:
  - ✓ How do ground motions in scenario earthquakes vary across a region?
  - ✓ How does this variation impact risk to infrastructure?
  - ✓ How do complex incident ground motion waveforms interact with a facility?

- LBNL & LLNL perform intense simulations on DOE's supercomputers working closely with PEER to make the simulated motions available to the earth science & earthquake engineering communities and to the disaster response organizations.

- The simulation-based dataset will facilitate deeper understanding of the hazard, performance, and overall resiliency of California by helping officials to effectively and accurately identify infrastructure systems and structures that pose the largest risk for proper allocation of resources.

Familiar Interface for PEER Recorded Ground Motion Database (NGA) Users

Khalid M. Mosalam
Selim Günay
Pacific Earthquake Engineering Research Center

Development of the PEER-LBNL Simulated Ground Motion Database (SGMD)

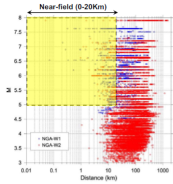
Khalid M. Mosalam & Selim Günay
Pacific Earthquake Engineering Research Center (PEER), University of California, Berkeley

peer.berkeley.edu

BERKELEY LAB

BACKGROUND AND MOTIVATION

- ❑ PEER recorded ground motion (GM) databases (NGA-West2 and NGA-East) are extensively used in the U.S. and around the world.
- ❑ A simulated ground motion database (SGMD) is needed because of:
  - ➢ Scarcity of recorded near-fault GMs from large magnitude earthquakes.
  - ➢ Insufficient recorded GMs to conduct regional scale simulations.
  - ➢ Inability of Ground Motion Models (GMMs) to capture all effects of rupture propagation, e.g., directivity.
  - ➢ Increased number of validated GM simulations from multiple regions.



- ❑ Combining expertise of physics-based GM simulation and database development & maintenance, PEER and the Lawrence Berkeley National Lab (LBNL) are developing the first open-access SGMD.

DATABASE HARDWARE

- ❑ Large storage server (> 90 TB SSD) with regular maintenance & backups (network interface of 10 GB/s) allowing scalability.
- ❑ Ability to accommodate compressed and uncompressed data from many regions and fault rupture realizations.

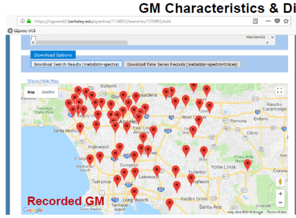
Item	Value
Compressed data per realization (**6.25 m** spacing)	291 GB
# of realizations	30
Total compressed data per region	8.7 TB
# of regions	6
Total compressed data	52.4 TB
Uncompressed data per realization (**2 km** spacing)	2.3 GB
# of realizations	100
Total uncompressed data per region	0.23 TB
# of regions	300
Total compressed data	57.5 TB

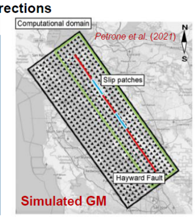
RECORDED vs SIMULATED GROUND MOTION DATABASES

Earthquake & Station Characteristics

Characteristic	Search Item	Recorded GM	Simulated GM
Source	Earthquake	Real Event (e.g., Loma Prieta)	Region/Realization (e.g., SF Bay Area, Realization 1)
	Fault Type	Strike-slip, Normal, Reverse, etc.	
Source to Site	Distance	R_{JB}, R_{rup}	R_{JB}, R_{rup} Latitude, Longitude, Depth
Site	Site Class	Vs30	Vs30
	Location	Depends on station	Grid defined by fault direction & spacing

GM Characteristics & Directions





- ➢ GM data at the **physical stations**
- ➢ **Recorded** 3 components of acceleration, velocity & displacement
- ➢ Horizontal GMs: Depend on **sensor orientation**

- ➢ GM data at the **grid stations**
- ➢ **Computed** 3 components of acc., velocity & displacement
- ➢ Horizontal GMs: **Fault Normal (FN) & Fault Parallel (FP)**

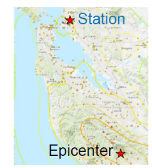
Acknowledgements: The development of SGMD is a joint effort of PEER and LBNL. Authors thank David McCallen, Floriana Petrone, Houjun Tang, Gabriel Vargas & Amarnath Kasalanati for their contributions to this collaborative effort.

RECORDED vs. SIMULATED GROUND MOTION DATABASES

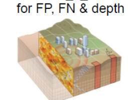
GM Data File Names and Data Format

EQ — GM Direction
RSN750_LOMAP_BRK000.AT2
Record Seq. No. — Berkeley — Acc.

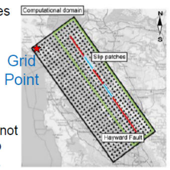
Realization 1 — GM Direction
SFBA_Real1_1_1_1_FP.AT2
Region — Grid loc.* — Acc.

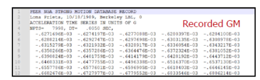


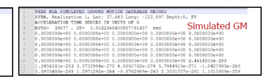
*Grid loc.: 1_1_1: Indices for FP, FN & depth



Simulated GM includes not only surface, but also **subsurface** motions.







Same format (e.g., 5 values/row with data advancing row by row, NPTS & DT locations) such that existing processing codes can be directly used.

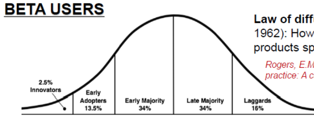
SIMULATED GROUND MOTION DATABASE INTERFACE

Interface supports the two common uses of simulated motions:

1. Regional scale simulations
2. Simulations at a specific location for different realizations

Similar to PEER recorded GM database, in simulated GM database, fault rupture & simulation parameters (unique for each realization) are documented in a **Flatfile**.

BETA USERS



Law of diffusion of innovation (Rogers, 1962): How new ideas, technologies, or products spread through a population.

Rogers, E.M. (1962). How research can improve practice: A case study. Theory into Practice, 89-93.

Potential Beta Users:

1. PEER research (promote use of simulated GMs through Request for Proposals)
2. SimCenter tools
3. Energy providers (PG&E, Southern California Edison, etc.)
4. Government agencies related to infrastructure networks (water, gas, transportation, etc.)
5. Structural engineering firms (using nonlinear dynamic analyses for design & assessment)
6. Simulated GM researchers in various regions in US & worldwide

DATA ROLL-OUT SCHEDULE

Task	Jan.–March	April–May	June–July.	Aug.–Sep.
Complete Server Configuration (Setup & Test)				
Complete User Interface				
Include All Data & Metadata for SFBA Simulations				
Beta Version Roll-out				
Feedback from Beta Users				
Full Version Roll-out				

CONCLUDING REMARKS

- ➢ Simulated GM database is currently under development with a preliminary version in https://sgmd.peer.berkeley.edu/. The interface is to be finalized by June 2024.
- ➢ For seamless integration of the simulated GM database into current research & practice, the developed interface is similar to that of PEER recorded GM databases.
- ➢ The specifics & use cases of simulated GM are considered in the interface.
- ➢ Feedback from potential users is essential to develop the full version of the SGMD.
- ➢ The database development and the full version roll-out will be regularly communicated to the PEER community.

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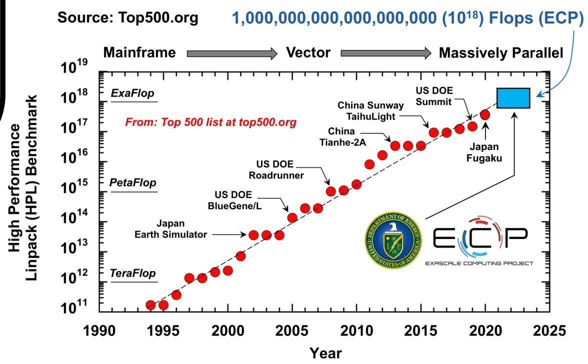
Outline

- Introduction
- Recorded Ground Motion Databases
- Simulated Ground Motion Database

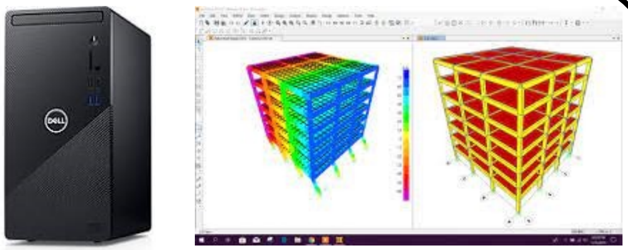
Earthquake Engineering Profession

Future (M)

Functional Recovery + Resilient Communities



Current (H-MC*)



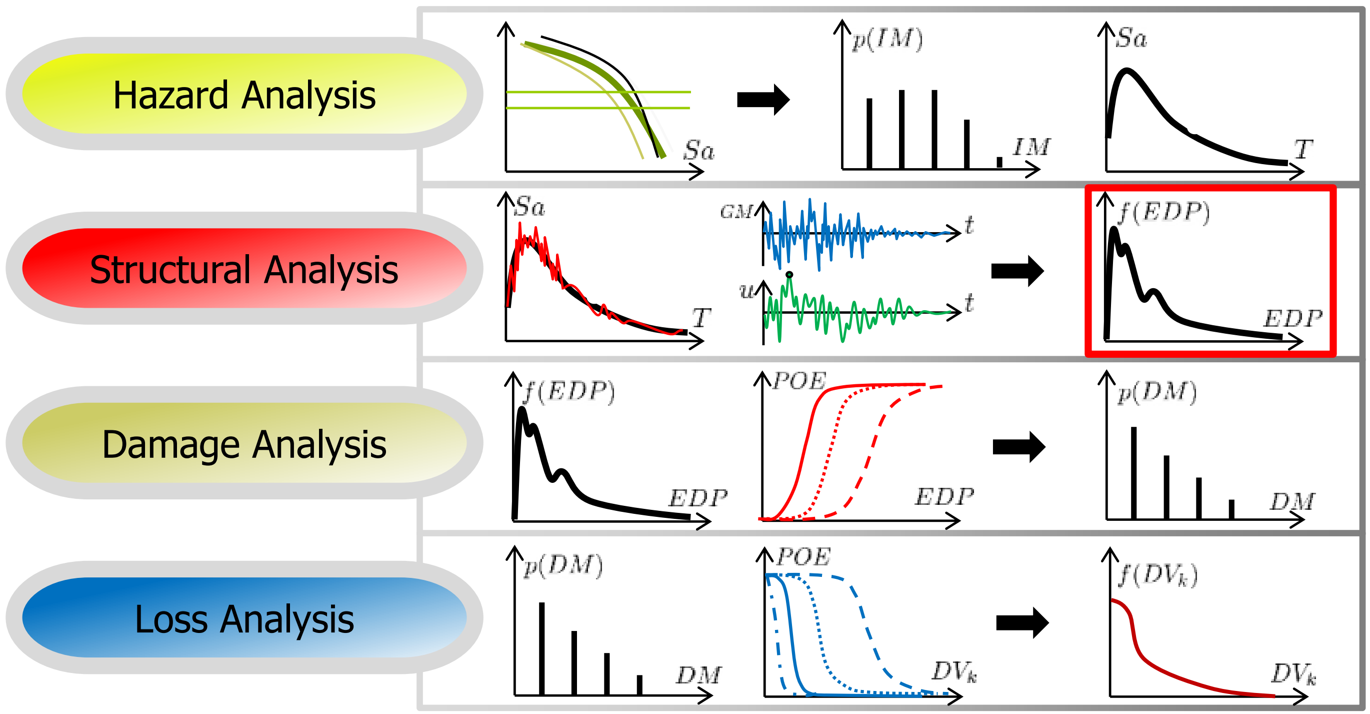
Ductile Response + Collapse Prevention + Saving Lives

***H-MC**: Human-Machine Collaboration

Past (H)

Earthquake Engineering Fundamentals

PEER DNA: Integrated PBEE Methodology



Probabilistic PBEE Framework

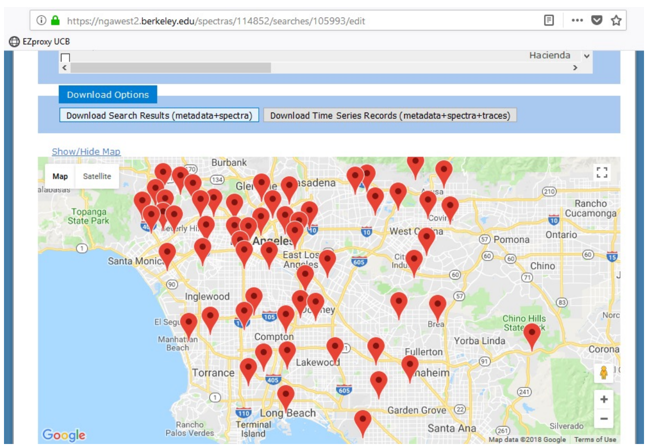
$$\lambda\left(DV > dv\right) = \int_{im}\int_{dm}\int_{edp} G\left(dv \mid dm\right) dG\left(dm \mid edp\right) dG\left(edp \mid im\right) \left| d\lambda\left(im\right)\right|$$

Why Did PEER Develop Recorded Ground Motion (GM) Databases?

- Objective of PBEE: Estimate system performance accounting for uncertainties.
- Defining hazard & select corresponding GMs.
- Access to GMs has been hampered by collecting & manipulating "big data".
- Late 1990s, PEER improved access to strong GM data by creating an accessible web-based searchable database (NGA).

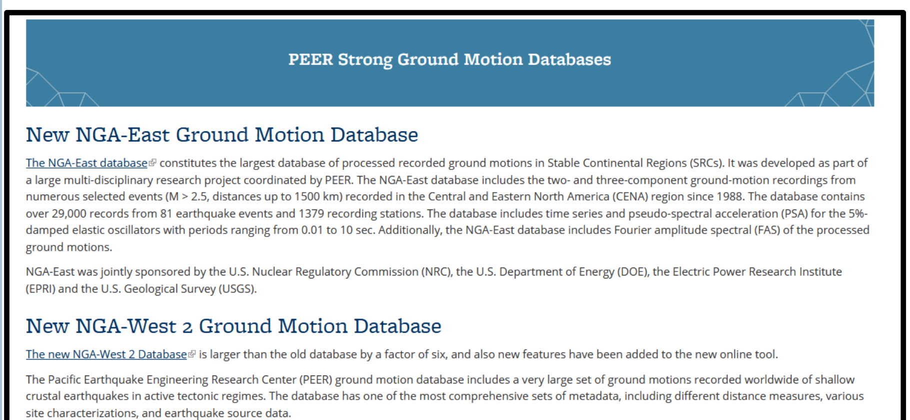
How Did PEER Develop Recorded GM Databases?

1. Collect GM records worldwide.
2. Process all data consistently & reliably.
3. Include metadata (source, site, magnitude, type of faulting, various source-to-site distance measures, local site conditions at recording stations, etc.).



NGA-West Flatfile

	A	B	C	AV	AW	AX	AY	AZ
1	Record Sequence Number	EQID	Earthquake Name	EpiD (km)	HypD (km)	Joyner-Boore Dist. (km)	Campbell R Dist. (km)	RmsD (km)
737	736	0118	Loma Prieta	61.49	63.92	40.85	-999	59.53
738	737	0118	Loma Prieta	40.12	43.76	24.27	-999	39.18
739	738	0118	Loma Prieta	90.77	92.43	70.9	-999	89.24
740	739	0118	Loma Prieta	26.57	31.81	19.9	-999	28.64
741	740	0118	Loma Prieta	26.57	31.81	19.9	-999	28.64
742	741	0118	Loma Prieta	9.01	19.66	3.85	-999	17.46
743	742	0118	Loma Prieta	81.15	83.02	61.15	-999	79.97
744	743	0118	Loma Prieta	86.90	88.64	66.89	-999	85.82
745	744	0118	Loma Prieta	70.71	72.84	50.71	-999	69.24


PEER Strong Ground Motion Databases

New NGA-East Ground Motion Database

The NGA-East database constitutes the largest database of processed recorded ground motions in Stable Continental Regions (SRCs). It was developed as part of a large multi-disciplinary research project coordinated by PEER. The NGA-East database includes the two- and three-component ground-motion recordings from numerous selected events (M > 2.5, distances up to 1500 km) recorded in the Central and Eastern North America (CENA) region since 1988. The database contains over 29,000 records from 81 earthquake events and 1379 recording stations. The database includes time series and pseudo-spectral acceleration (PSA) for the 5%-damped elastic oscillators with periods ranging from 0.01 to 10 sec. Additionally, the NGA-East database includes Fourier amplitude spectral (FAS) of the processed ground motions.

NGA-East was jointly sponsored by the U.S. Nuclear Regulatory Commission (NRC), the U.S. Department of Energy (DOE), the Electric Power Research Institute (EPRI) and the U.S. Geological Survey (USGS).

New NGA-West 2 Ground Motion Database

The new NGA-West 2 Database is larger than the old database by a factor of six, and also new features have been added to the new online tool.

The Pacific Earthquake Engineering Research Center (PEER) ground motion database includes a very large set of ground motions recorded worldwide of shallow crustal earthquakes in active tectonic regimes. The database has one of the most comprehensive sets of metadata, including different distance measures, various site characterizations, and earthquake source data.

https://peer.berkeley.edu/peer-strong-ground-motion-databases

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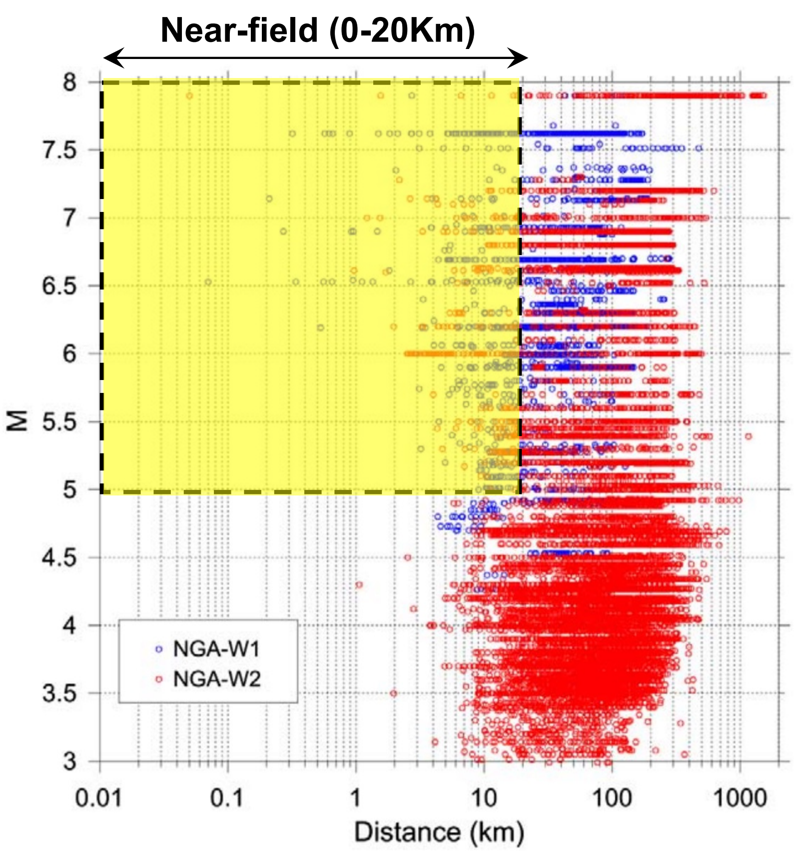
Need for Simulated GM Database



- ✓ Scarcity of recorded near-fault GMs from large magnitude earthquakes.
- ✓ Insufficient recorded GMs to conduct regional scale simulations.
- ✓ Lack of the ability of most GM Models (GMMs) to capture effects of rupture propagation, e.g., directivity.
- ✓ Increased number of validated GM simulations from multiple regions.

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Requirements of a Successful Database

✓ Scalability, i.e., large storage server (**up to 95 TB SSD**) with regular maintenance & backups (**network interface of 10 GB/s**).

✓ Procedure to expand the database with new data including an effective web interface with well-defined search options.

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# of regions	6
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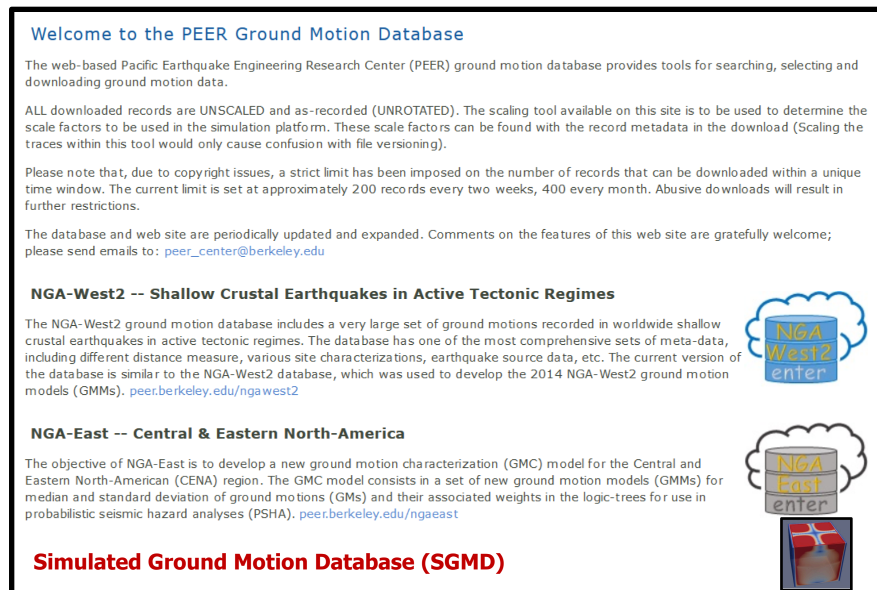

Welcome to the PEER Ground Motion Database

The web-based Pacific Earthquake Engineering Research Center (PEER) ground motion database provides tools for searching, selecting and downloading ground motion data.

ALL downloaded records are UNSCALED and as-recorded (UNROTATED). The scaling tool available on this site is to be used to determine the scale factors to be used in the simulation platform. These scale factors can be found with the record metadata in the download (Scaling the traces within this tool would only cause confusion with file versioning).

Please note that, due to copyright issues, a strict limit has been imposed on the number of records that can be downloaded within a unique time window. The current limit is set at approximately 200 records every two weeks, 400 every month. Abusive downloads will result in further restrictions.

The database and web site are periodically updated and expanded. Comments on the features of this web site are gratefully welcome; please send emails to: peer_center@berkeley.edu

NGA-West2 -- Shallow Crustal Earthquakes in Active Tectonic Regimes

The NGA-West2 ground motion database includes a very large set of ground motions recorded in worldwide shallow crustal earthquakes in active tectonic regimes. The database has one of the most comprehensive sets of meta-data, including different distance measure, various site characterizations, earthquake source data, etc. The current version of the database is similar to the NGA-West2 database, which was used to develop the 2014 NGA-West2 ground motion models (GMMs). peer.berkeley.edu/ngawest2

NGA-East -- Central & Eastern North-America

The objective of NGA-East is to develop a new ground motion characterization (GMC) model for the Central and Eastern North-American (CENA) region. The GMC model consists in a set of new ground motion models (GMMs) for median and standard deviation of ground motions (GMs) and their associated weights in the logic-trees for use in probabilistic seismic hazard analyses (PSHA). peer.berkeley.edu/ngaeast

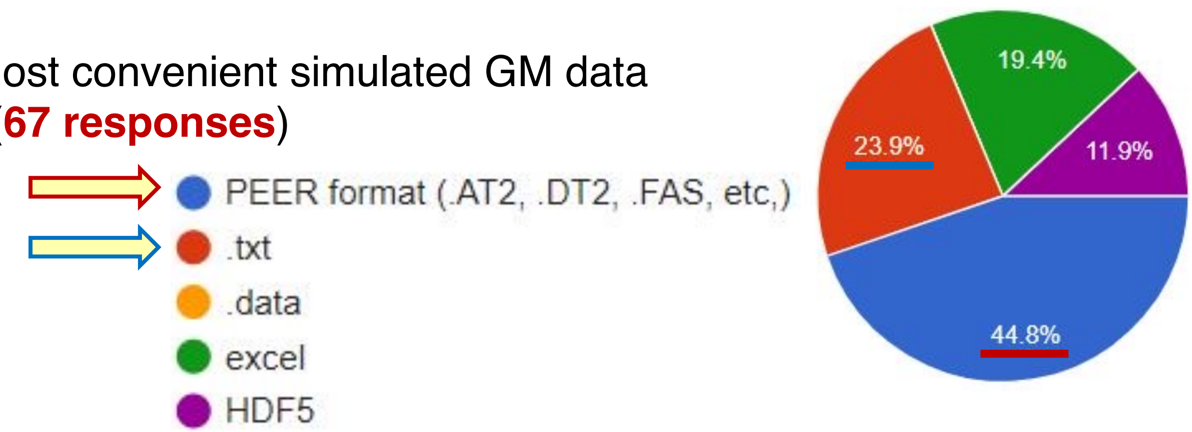
Simulated Ground Motion Database (SGMD)

Use the well-known NGA interface with added specifics & use cases of the simulated GMs.

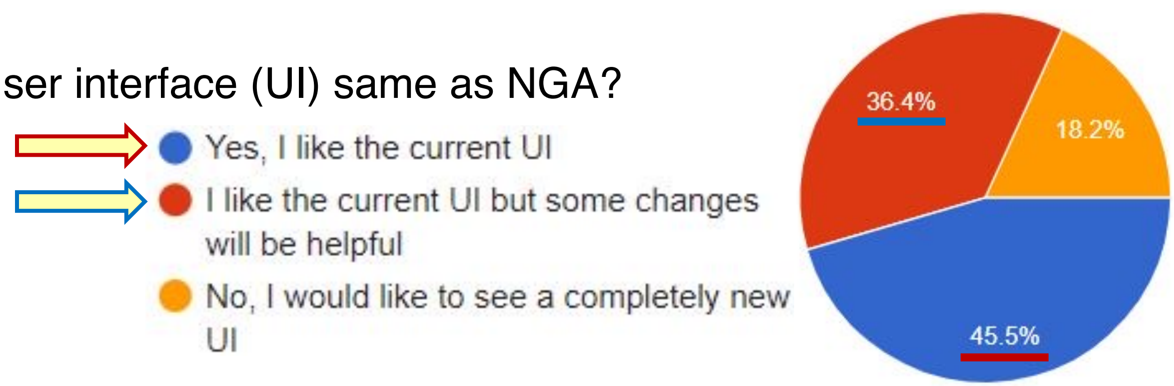
Survey About Simulated GM Database Interface (March 2022)

What simulated GM data products would you like to have readily available? (**71 responses**)

What would be the most convenient simulated GM data & metadata format? (**67 responses**)

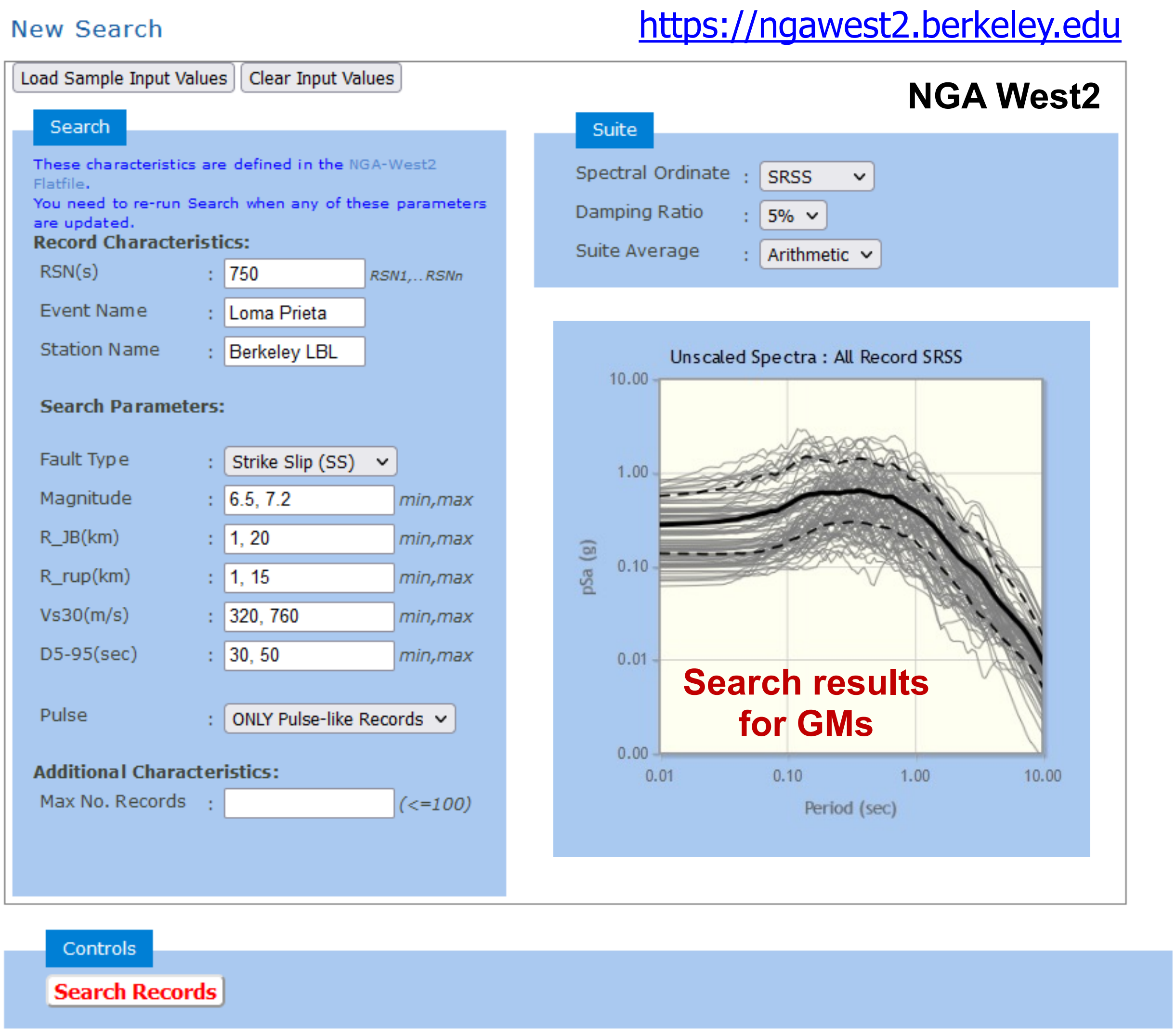


Would you want the user interface (UI) same as NGA? (**66 responses**)



PEER

PEER Recorded GM Database Interface



PEER

Recorded vs. Simulated GM Databases (1/3)

Earthquake & Station Characteristics

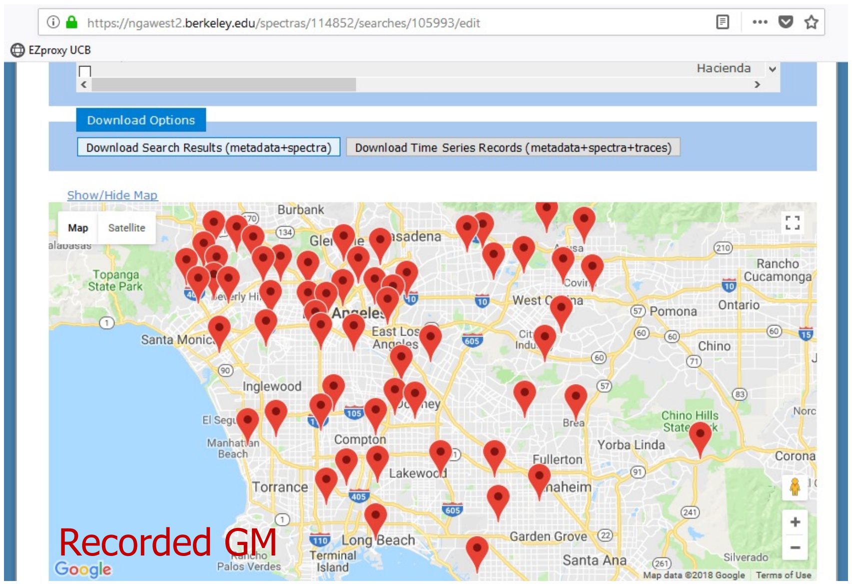
Characteristic	Search Item	Recorded GM Dataset	Simulated GM Dataset
Source	Earthquake	Real Event (e.g., Loma Prieta)	Region/Realization (e.g., SF Bay Area, Realization 1)
	Fault Type	Strike-slip, Normal, Reverse, etc.	
Source to Site	Distance	R_{JB}*, R_{rup}**	R_{JB}, R_{rup}
			Latitude, Longitude, Depth
Site	Site Class	Vs30	Vs30
	Location	Depends on station	Grid defined by fault direction & spacing

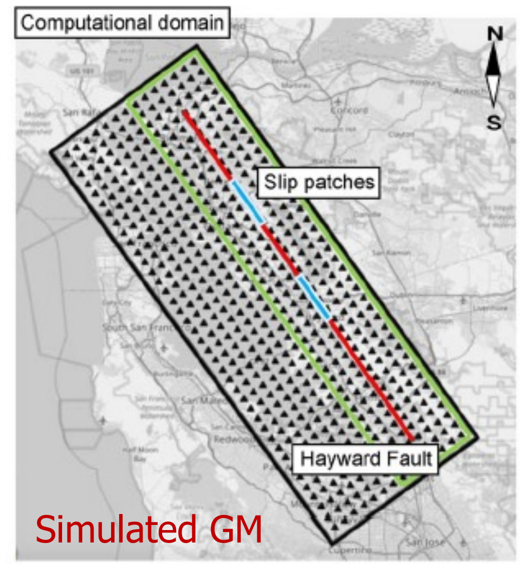
*R_{JB}: Joyner-Boore Distance; shortest horizontal distance from recording site to vertical projection of rupture

**R_{rup}: Closest distance from recording site to rupture surface

Recorded vs. Simulated GM Databases (2/3)

GM Characteristics & Directions





Petrone et al. (2021)

- GM data at the **physical stations**
- **Recorded** 3 components of acceleration, velocity & displacement
- Horizontal motions depend on **sensor orientation**

- GM data at the **grid stations**
- **Computed** 3 components of acceleration, velocity & displacement
- Horizontal motions are **Fault Normal & Fault Parallel**

PEER

Recorded vs. Simulated GM Databases (3/3)

Same format (e.g., 5 values/row with data advancing row by row) such that existing processing codes can be directly used.

Recorded GM

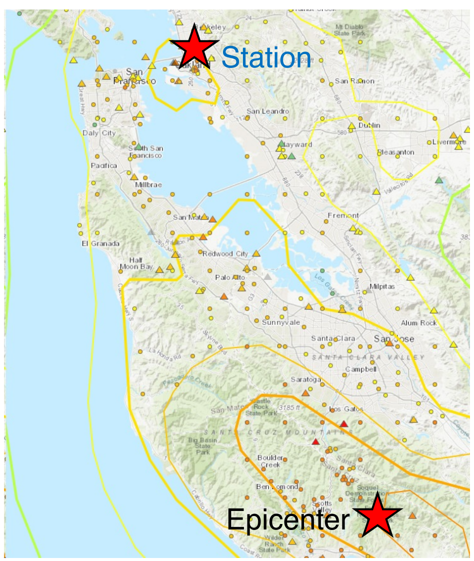
```
PEER NGA STRONG MOTION DATABASE RECORD
Loma Prieta, 10/18/1989, Berkeley LBL, 0
ACCELERATION TIME SERIES IN UNITS OF G
NPTS=   7998, DT=   .0050 SEC,
  -.6271696E-03  -.6274197E-03  -.6277088E-03  -.6280397E-03  -.6284100E-03
  -.6288214E-03  -.6292747E-03  -.6297698E-03  -.6303135E-03  -.6308978E-03
  -.6315279E-03  -.6321932E-03  -.6328917E-03  -.6336054E-03  -.6343217E-03
  -.6350266E-03  -.6357286E-03  -.6364476E-03  -.6372324E-03  -.6381052E-03
  -.6390824E-03  -.6401759E-03  -.6414179E-03  -.6428192E-03  -.6443712E-03
  -.6460331E-03  -.6477755E-03  -.6496338E-03  -.6516370E-03  -.6537130E-03
  -.6557786E-03  -.6577601E-03  -.6596905E-03  -.6618403E-03  -.6646145E-03
  -.6682676E-03  -.6727977E-03  -.6779552E-03  -.6833546E-03  -.6886214E-03
```

Simulated GM

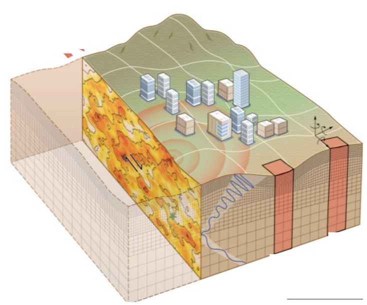
```
PEER NGA SIMULATED GROUND MOTION DATABASE RECORD
SFBA, Realization 1, Lat: 37.643 Long: -122.697 Depth:0, FP
ACCELERATION TIME SERIES IN UNITS OF G
NPTS=  39877 , DT=  0.0022569400907791457  sec
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00
0.0000000e+00 0.0000000e+00 0.0000000e+00 0.0000000e+00 2.4614500e-299
1.2456181e-283 3.3732994e-278 4.5950762e-274 5.7944915e-271 -1.8427990e-268
3.6903480e-268 1.2971291e-264 -9.8762989e-263 2.3031557e-261 1.1810689e-259
```

RSN750_LOMAP_BRK000.AT2
- RSN750: Record Sequence No.
- LOMAP: Loma Prieta EQ
- BRK: Berkeley
- 000: GM Direction
- AT2: Acceleration

SFBA_Real1_1_1_1_FP.AT2
- SFBA: Region
- Real1: Realization 1
- 1_1_1: Grid location*
- FP: GM Direction
- AT2: Acceleration

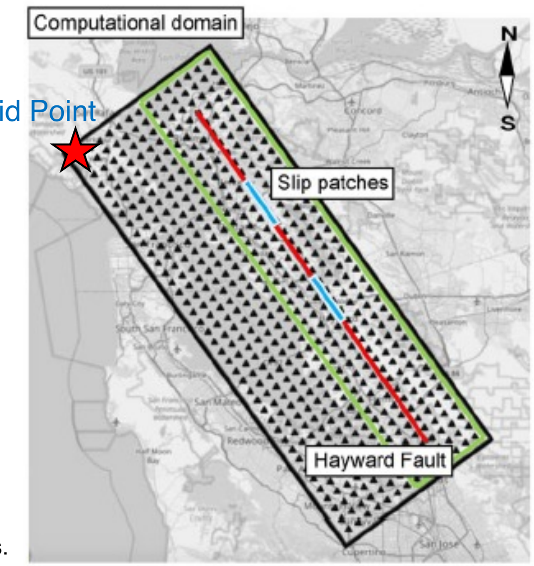


*Grid location: 1_1_1 indices for Parallel to fault_Normal to fault_Depth



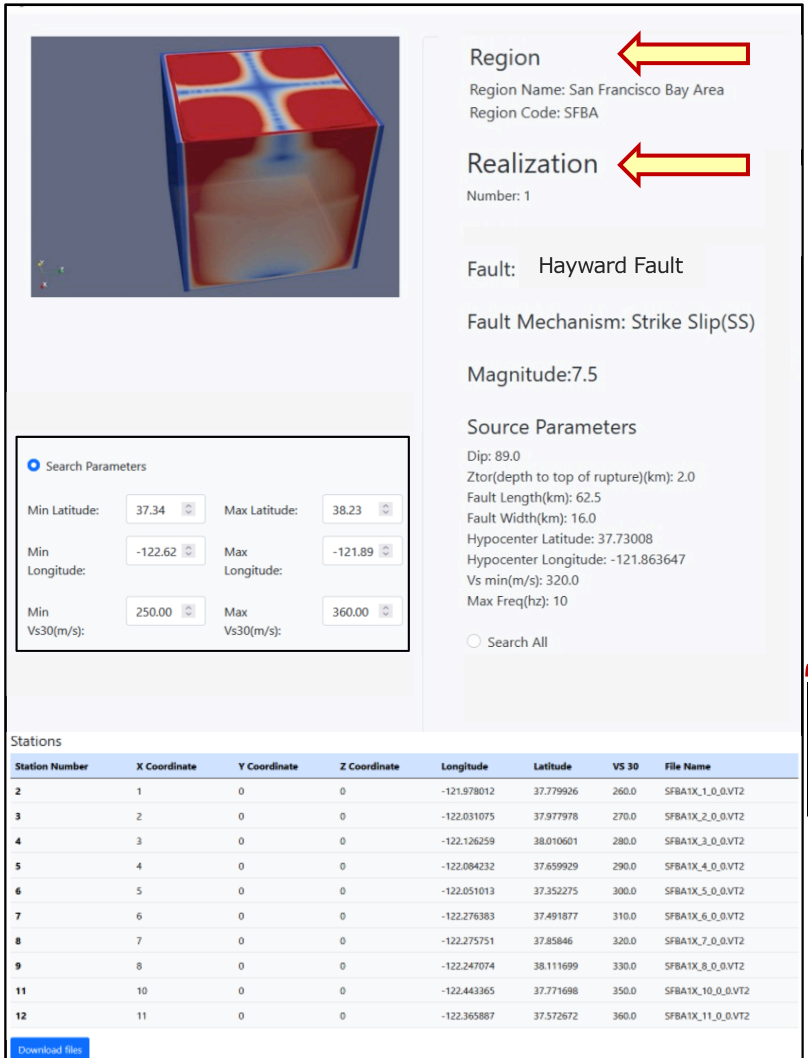
Simulated GM includes not only surface, but also **subsurface** motions.

Grid Point



PEER

Simulated GM Database Interface



1. Regional scale simulations
2. Simulations at a specific location (different realizations)

Similar to PEER recorded GM, in simulated GM, fault rupture & simulation parameters (unique for each realization) are documented in a **Flatfile**.

Region | Realization

Region Name	Region Code	Realization #	Fault Name	Magnitude	Fault Mechanis	Dip (˚)	Strike (˚)	ztor (Depth to top of rupture) (km)	Fault Length	Fault Width	Hyp_lon	Hyp_lat	Vs_min (m/s)	Max freq (Hz)	Grid spacing (km)
San Francisco Bay Area	SFBA	1	Hayward	7.0	Strike slip	90	30	0.2	62.5	16	-121.86	37.7301	320	10	2
San Francisco Bay Area	SFBA	2	Hayward	7.2	Strike slip	90	30	0.1	100	20	-121.86	37.7301	320	10	2
San Francisco Bay Area	SFBA	3	Hayward	7.1	Strike slip	90	30	0.5	60	16	-121.86	37.7301	320	10	2
San Francisco Bay Area	SFBA	4	Calaveras	7.2	Strike slip	90	35	0.2	62.5	16	-124.91	37.7301	320	10	2
San Francisco Bay Area	SFBA	5	Calaveras	7.0	Strike slip	90	35	0.2	62.5	16	-125.93	37.7301	320	10	2
San Francisco Bay Area	SFBA	6	Calaveras	6.8	Strike slip	90	35	0.2	62.5	16	-126.95	37.7301	320	10	2

Fault rupture parameters | Simulation parameters

Concluding Remarks

- Simulated GM database is currently under development with a preliminary version in https://sgmd.peer.berkeley.edu/. The interface is to be finalized by June 2024.
- For seamless integration of the simulated GM database into current research & practice, the developed interface is similar to that of PEER recorded GM databases.
- The specifics & use cases of simulated GM are considered in the interface as search options.

Schedule for Data Roll-Out & Beta Users

Khalid M. Mosalam
Selim Günay
Pacific Earthquake Engineering Research Center

Outline

- Engaging the Earthquake Engineering Community
- Transition to Practice
- Beta Users
- Schedule for Data Roll-Out

Engaging the Earthquake Engineering Community (1/2)

- Value Proposition of PEER to develop the simulated GM database:
  - ✓ Earthquake Engineering Center "11 core institutions, 9 educational affiliates & many participants"
  - ✓ Culture of creating/maintaining enabling technology (e.g., PBEE, OpenSees & NGA databases)
  - ✓ Active connection to the Earthquake Engineering profession in California and elsewhere

- PEER will facilitate broader use and impact of the simulated GM database (e.g., research in transportation systems, links to OpenSees/OpenSRA & SimCenter tools).

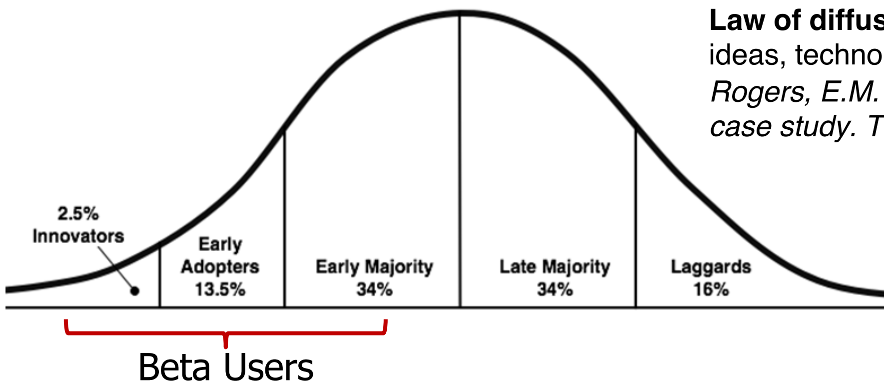
- The simulated GM database is timely to engage the Earthquake Engineering community by leveraging DOE resources.

- *Simulated GMs are expected to facilitate regional scale evaluation of energy systems.*

Engaging the Earthquake Engineering Community (2/2)

- Database interface will include a feedback feature for users to provide suggestions to be considered in future updates.
- The Earthquake Engineering community input will facilitate future design standard guidance using simulated GMs and realizing their benefits.
- We plan to hold an annual SGMD Forum similar to this event "every April?"

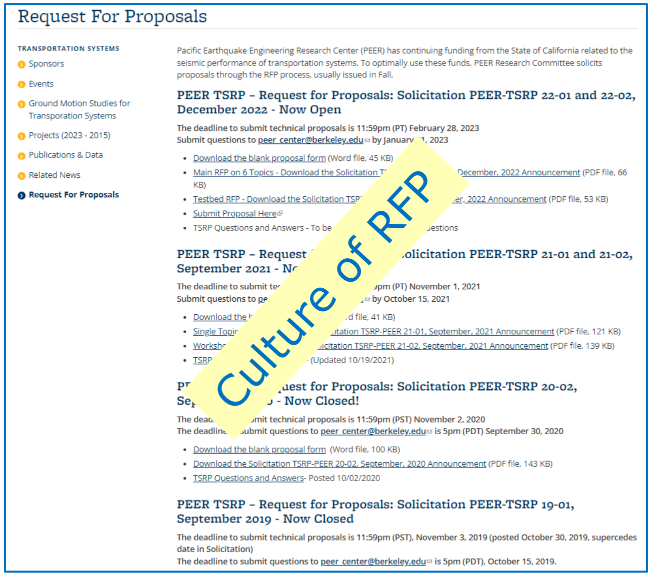
Beta Users



Law of diffusion of innovation (Rogers, 1962): How new ideas, technologies, or products spread through a population. *Rogers, E.M. (1962). How research can improve practice: A case study. Theory into Practice, 89-93.*

Potential Beta Users:

1. PEER research (promote use of simulated GMs through "**PEER Requests for Proposals (RFP)**")
2. Users of SimCenter tools
3. Energy providers (PG&E, Southern California Edison, etc.)
4. Government agencies related to infrastructure networks (water, gas, transportation, etc.)
5. Structural engineering firms (using nonlinear dynamic analyses for building design & assessment)
6. Simulated GM researchers in various regions in US & worldwide


Request For Proposals

TRANSPORTATION SYSTEMS
- Sponsors
- Events
- Ground Motion Studies for Transporation Systems
- Projects (2023 - 2015)
- Publications & Data
- Related News
- **Request For Proposals**

Pacific Earthquake Engineering Research Center (PEER) has continuing funding from the State of California related to the seismic performance of transportation systems. To optimally use these funds, PEER Research Committee solicits proposals through the RFP process, usually issued in Fall.

PEER TSRP – Request for Proposals: Solicitation PEER-TSRP 22-01 and 22-02, December 2022 - Now Open

The deadline to submit technical proposals is 11:59pm (PT) February 28, 2023
Submit questions to peer_center@berkeley.edu by January [illegible], 2023

- Download the blank proposal form (Word file, 45 KB)
- Main RFP on 6 Topics - Download the Solicitation T[illegible] December, 2022 Announcement (PDF file, 66 KB)
- Testbed RFP - Download the Solicitation TSR[illegible]er, 2022 Announcement (PDF file, 53 KB)
- Submit Proposal Here
- TSRP Questions and Answers - To be [illegible]uestions

PEER TSRP – Request [illegible]olicitation PEER-TSRP 21-01 and 21-02, September 2021 - N[illegible]

The deadline to submit te[illegible]pm (PT) November 1, 2021
Submit questions to pe[illegible] by October 15, 2021

- Download the [illegible]d file, 41 KB)
- Single Topic[illegible]itation TSRP-PEER 21-01, September, 2021 Announcement (PDF file, 121 KB)
- Worksh[illegible]icitation TSRP-PEER 21-02, September, 2021 Announcement (PDF file, 139 KB)
- TSRP[illegible] (Updated 10/19/2021)

P[illegible]uest for Proposals: Solicitation PEER-TSRP 20-02, Se[illegible] - Now Closed!

The dead[illegible]mit technical proposals is 11:59pm (PST) November 2, 2020
The deadline[illegible] submit questions to peer_center@berkeley.edu is 5pm (PDT) September 30, 2020

- Download the blank proposal form (Word file, 100 KB)
- Download the Solicitation TSRP-PEER 20-02, September, 2020 Announcement (PDF file, 143 KB)
- TSRP Questions and Answers- Posted 10/02/2020

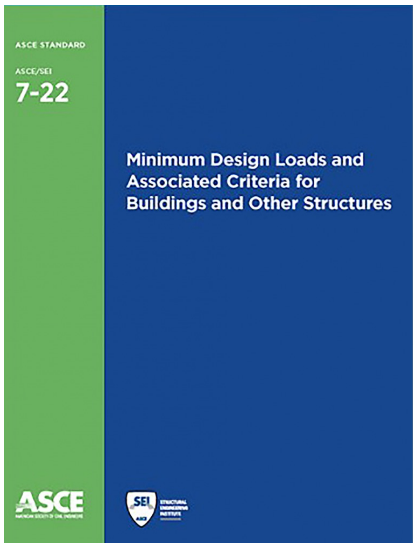
PEER TSRP – Request for Proposals: Solicitation PEER-TSRP 19-01, September 2019 - Now Closed

The deadline to submit technical proposals is 11:59pm (PST), November 3, 2019 (posted October 30, 2019, supercedes date in Solicitation)
The deadline to submit questions to peer_center@berkeley.edu is 5pm (PDT), October 15, 2019.

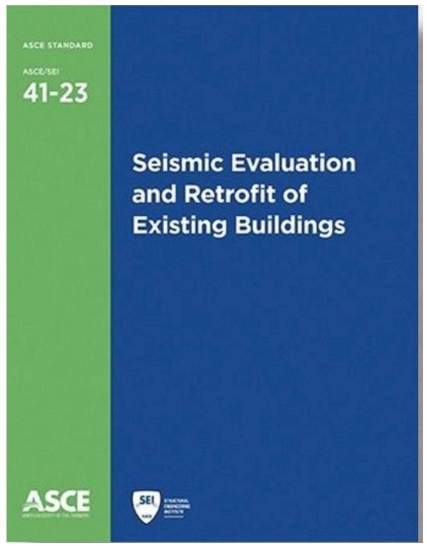
Culture of RFP

PEER

Transition to Practice

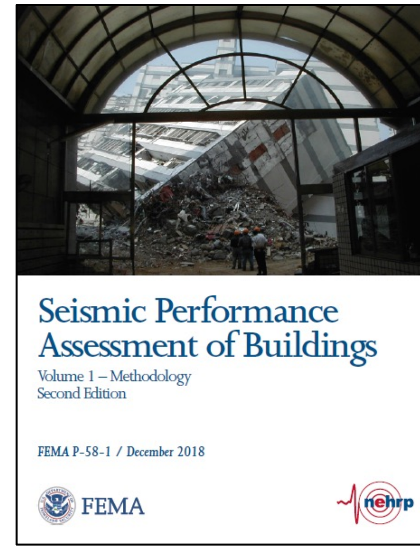


ASCE 7-22



ASCE 41-23

Tall Buildings Initiative

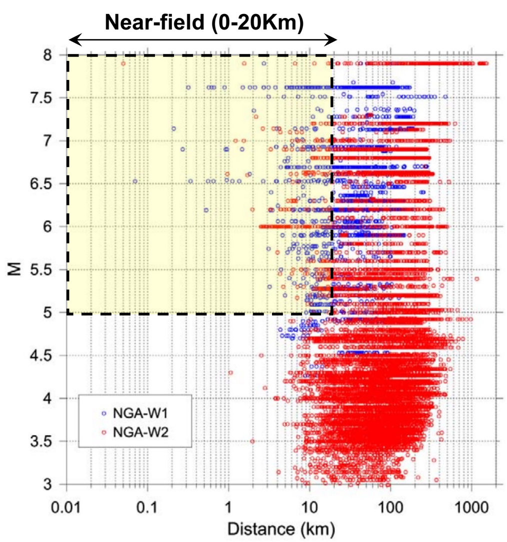


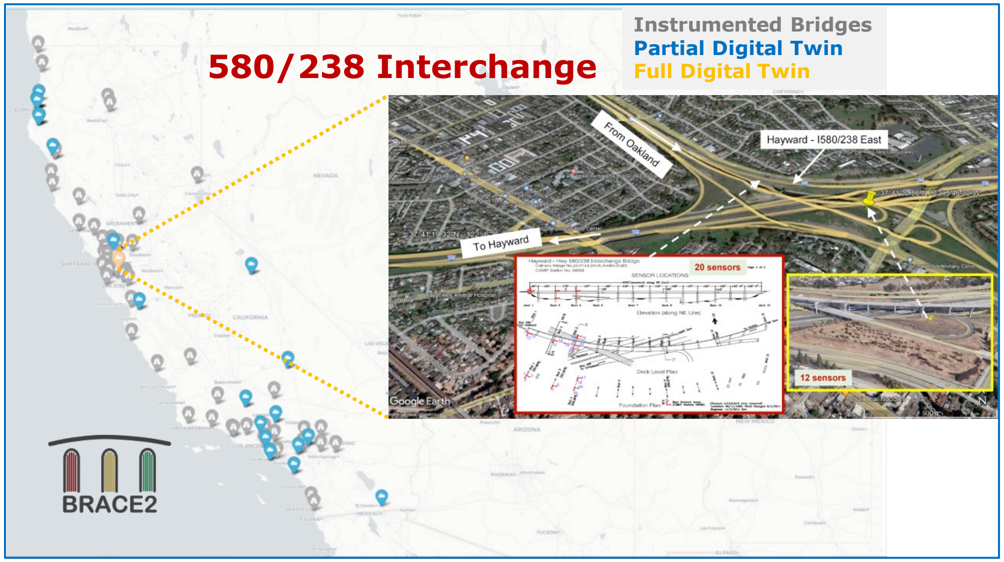
FEMA P-58

- ➢ ASCE 7-22 requires a minimum of 11 GM time histories for each target spectrum.
- ➢ ASCE 7-22 Section 16.2.3: "*Where the required number of recorded ground motions is not available, it shall be permitted to supplement the available records with simulated GMs.*"
- ➢ In PBEE, even more GMs are preferred to:
  - ✓ Quantify the uncertainty in structural/foundation response
  - ✓ Estimate probability of collapse

Advantages of the Simulated GM Database in Practice

- Availability of subsurface motions where recorded GMs are generally at the surface with limited number of geotechnical arrays (typically hard to maintain)
- Suitable for scenario-based regional-scale simulations
- Recorded motions not available for significantly large earthquakes (NGA West2 database only has records for moment magnitudes Mw ≤ 7.9 & mostly distances ≥ 5 km)
- Realistic GM input to long span structures having insufficient number of recorded GMs for multi-support excitation input

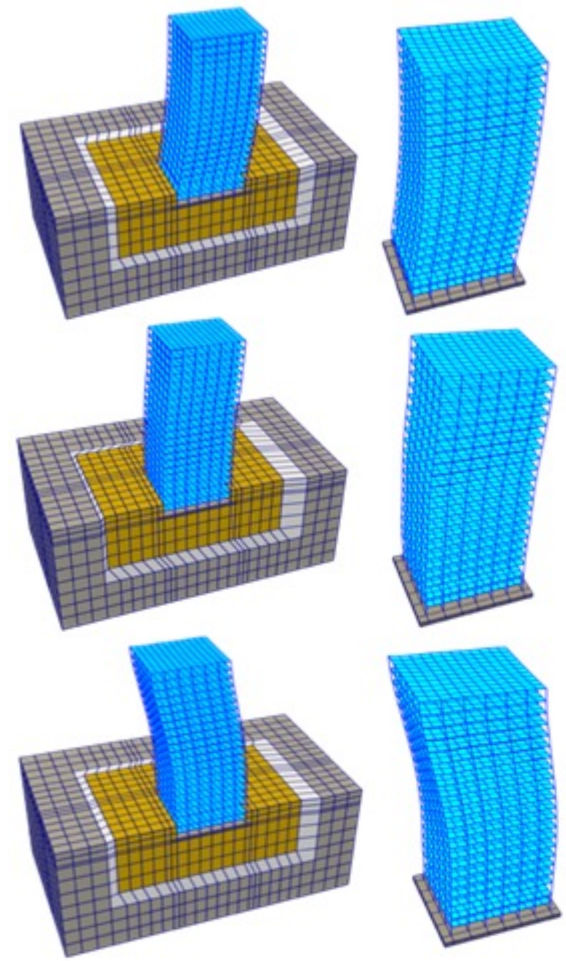




PEER

Potential Uses for Engineering Research & Practice: **Structural**

- **Probabilistic Performance-based design optimization**: Minimize lifecycle costs; Achieve resilience objectives
- **Floor Motions**: Response of nonstructural components
- **Comparisons**: Structural response with recorded & simulated motions for validation & acceptance
- **Instrumented Buildings**: More confidence in use of simulated GMs

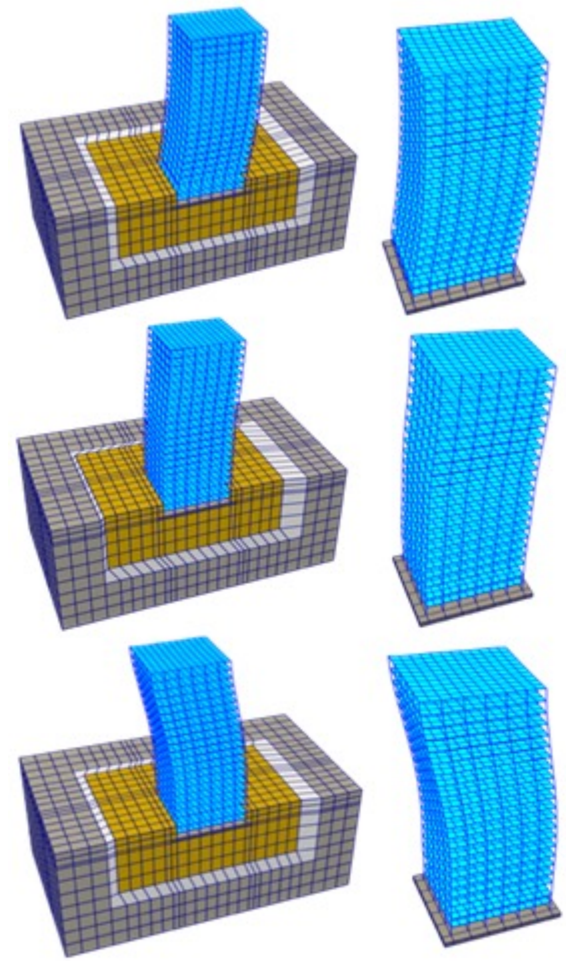


Courtesy of D. McCallen

PEER

Potential Uses for Engineering Research & Practice: **Geotechnical**

- **Free Field vs. Motions at the Base of the Structure**: Identify needs for Soil-Foundation-Structure Interaction (SFSI) modeling
- **Bedrock Motions**: Use in complete SFSI modeling
- **Geotechnical Arrays**: Validation of subsurface motions; Characterizing soil layers
- **Simulated Motions**: Coupling with liquefaction (e.g., NGL), landslide analysis, etc.

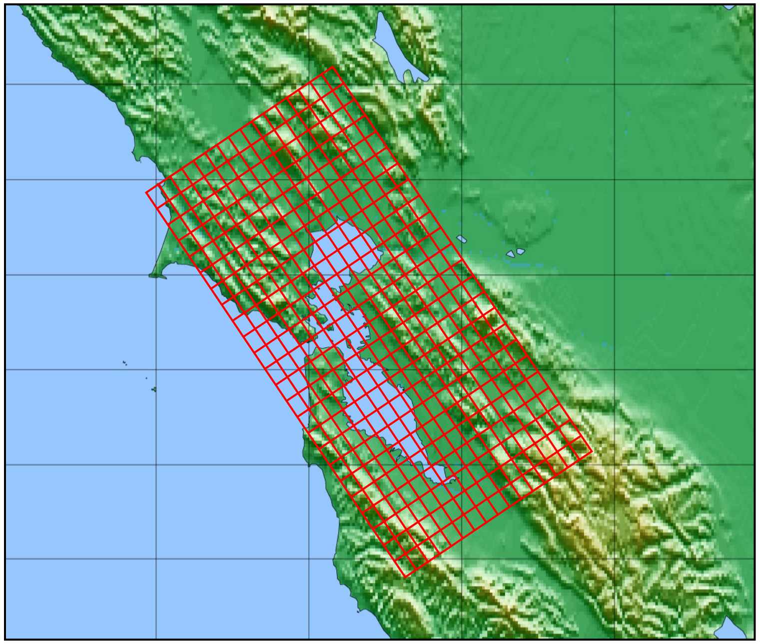


Courtesy of D. McCallen

PEER

Potential Uses for Engineering Research & Practice: **Regional Sim.**

- **Coupling Simulated Motions with Fragilities and Consequence Functions**: Scenario-based loss assessments
- **Identification of Weakest Links of a System**: Prioritization of structures to be retrofitted or need for further detailed analysis
- **Machine Learning Models Using Results for Training from Many Simulations**: Potential updating of ShakeAlert's location & magnitude estimations for Earthquake Early Warning (EEW)

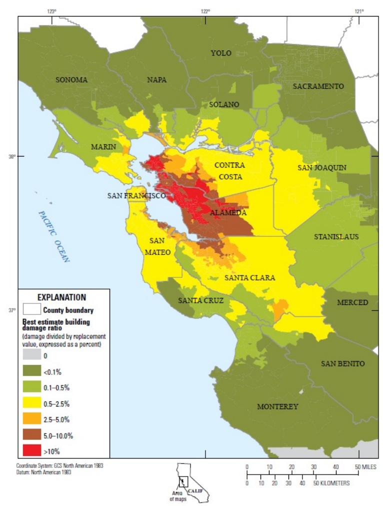


Courtesy of D. McCallen

Regional PBEE Simulations Using Simulated GMs

- With advances of computational technologies & availability of efficient methods to extract information, application of PBEE for regional scale simulations is possible.
- Simulated GMs are essential for accurate regional quantification of shaking in hazard analysis, to develop GMs for structural analysis, and for better city planning.

ShakeMap of a M 7.3 scenario earthquake on the Hayward fault



Example building damage maps from the HayWired study (2018)

- Regions with high seismicity in US (e.g., Cascadia Subduction Zone, Humboldt Region, San Francisco Bay Area, Greater Los Angeles Area & New Madrid Zone) and worldwide with available simulated GM studies (e.g., Chile, Colombia, Italy, Japan & Türkiye) can be added later to the database.

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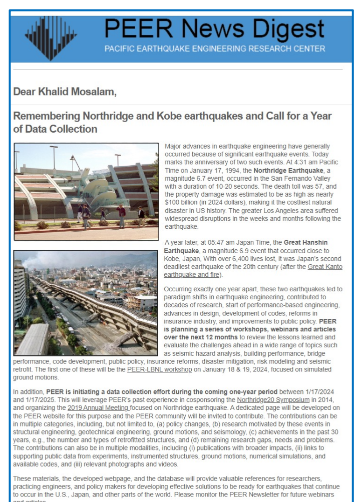
Schedule for Data Roll-Out

Task	Jan.–March	April–May	June–July.	Aug.–Sep.
Complete Server Configuration (Setup & Test)	■			
Complete User Interface	■	■		
Include All Data & Metadata for SFBA Simulations	■	■		
Beta Version Roll-out			■	
Feedback from Beta Users			■	■
Full Version Roll-out				■

Concluding Remarks

- PEER hosting & maintaining the database adds a value to the broader use and impact of the simulated motions, which are expected to facilitate the regional scale evaluation of energy and other infrastructure networks.
- The motions in the database have many potential uses in structural, geotechnical, and regional scale applications including transition to practice.
- Feedback from potential users is essential to develop the full version of the database.
- There are current and future physics-based GM simulation studies in the US and around the world from which new data can be added to the database in the future.
- The database development and the full version roll-out will be regularly communicated to the PEER community (Website + Social Media + News Digest + Annual SGMD PEER-LBNL-DOE Forum).



PEER News Digest

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Dear Khalid Mosalam,

Remembering Northridge and Kobe earthquakes and Call for a Year of Data Collection

Major advances in earthquake engineering have generally occurred because of significant earthquake events. Today marks the anniversary of two such events. At 4:31 am Pacific Time on January 17, 1994, the **Northridge Earthquake**, a magnitude 6.7 event, occurred in the San Fernando Valley with a duration of 10-20 seconds. The death toll was 57, and the property damage was estimated to be as high as nearly $100 billion (in 2024 dollars), making it the costliest natural disaster in US history. The greater Los Angeles area suffered widespread disruptions in the weeks and months following the earthquake.

A year later, at 05:47 am Japan Time, the **Great Hanshin Earthquake**, a magnitude 6.9 event that occurred close to Kobe, Japan, With over 6,400 lives lost, it was Japan's second deadliest earthquake of the 20th century (after the Great Kanto earthquake and fire).

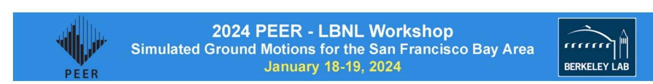
Occurring exactly one year apart, these two earthquakes led to paradigm shifts in earthquake engineering, contributed to decades of research, start of performance-based engineering, advances in design, development of codes, reforms in insurance industry, and improvements to public policy. **PEER is planning a series of workshops, webinars and articles over the next 12 months** to review the lessons learned and evaluate the challenges ahead in a wide range of topics such as seismic hazard analysis, building performance, bridge performance, code development, public policy, insurance reforms, disaster mitigation, risk modeling and seismic retrofit. The first one of these will be the PEER-LBNL workshop on January 18 & 19, 2024, focused on simulated ground motions.

In addition, **PEER is initiating a data collection effort during the coming one-year period** between 1/17/2024 and 1/17/2025. This will leverage PEER's past experience in cosponsoring the Northridge20 Symposium in 2014, and organizing the 2019 Annual Meeting focused on Northridge earthquake. A dedicated page will be developed on the PEER website for this purpose and the PEER community will be invited to contribute. The contributions can be in multiple categories, including, but not limited to, (a) policy changes, (b) research motivated by these events in structural engineering, geotechnical engineering, ground motions, and seismology, (c) achievements in the past 30 years, e.g., the number and types of retrofitted structures, and (d) remaining research gaps, needs and problems. The contributions can also be in multiple modalities, including (i) publications with broader impacts, (ii) links to supporting public data from experiments, instrumented structures, ground motions, numerical simulations, and available codes, and (iii) relevant photographs and videos.

These materials, the developed webpage, and the database will provide valuable references for researchers, practicing engineers, and policy makers for developing effective solutions to be ready for earthquakes that continue to occur in the U.S., Japan, and other parts of the world. Please monitor the PEER Newsletter for future webinars and articles.

Subscribe to the PEER News Digest
https://peer.berkeley.edu/

FOLLOW PEER ON SOCIAL MEDIA



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