

Simulated Ground Motions as Synthetic Data for Infrastructure Assessment

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The *BRACE*² Project is Made Possible Through the Support of:

- **Caltrans:** Chris Traina & Sharon Yen
- **California Geological Survey:** Hamid Haddadi & staff
- **PEER Center:** Amarnath Kasalanati & Gabriel Vargas
- **STAIRlab:** Chrystal Chern, Selim Günay & many students



U.S. DEPARTMENT
of **ENERGY**



- 1 Overview
- 2 Context: The *BRACE*² Project
- 3 Simulated Assessment
- 4 Closure

The Bridge Rapid Assessment Center for Extreme Events

Networks

Options

show

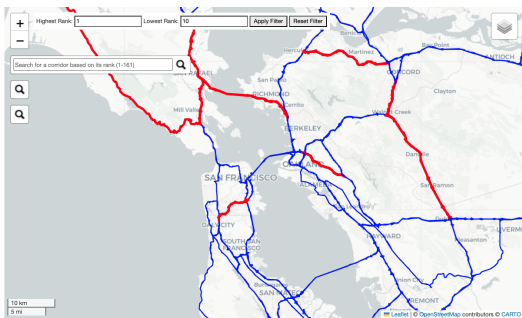
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26	04-MRN-101-2	10.0
57	04-SOL-008-6	10.0
122	04-SCL-101-6	10.0
69	04-CC-004-1	10.0
9	04-SH-001-2	11.0
23	04-SF/MRN-001	11.0
38	04-SON-001	12.0
72	04-CC-160	12.0

Previous 1 2 3 Next

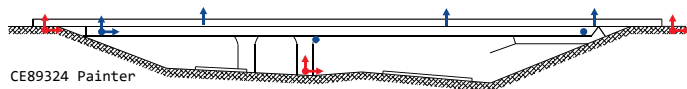
All

Corridor 37 X



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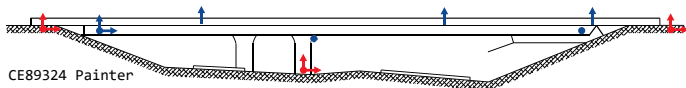
Instrumented Bridges



*Figure source: CESMD with modifications

- **inputs**: response measured at the ground level
- **outputs**: response measured at the superstructure

Instrumented Bridges



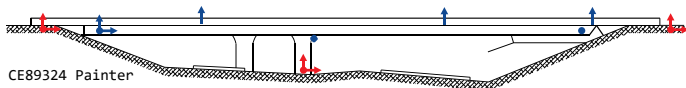
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Objectives:

- Taking advantage of the bridge sensors to evaluate the bridge conditions following earthquakes.

Instrumented Bridges



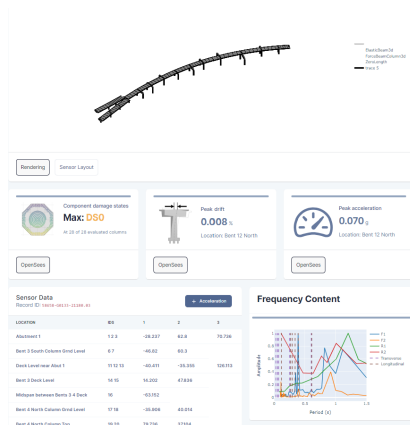
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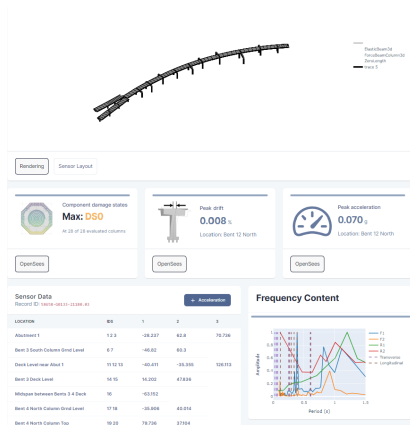
Objectives:

- Taking advantage of the bridge sensors to evaluate the bridge conditions following earthquakes.
- Realize rapid and comprehensive assessments of instrumented bridges in California.

Objective: Health Evaluations

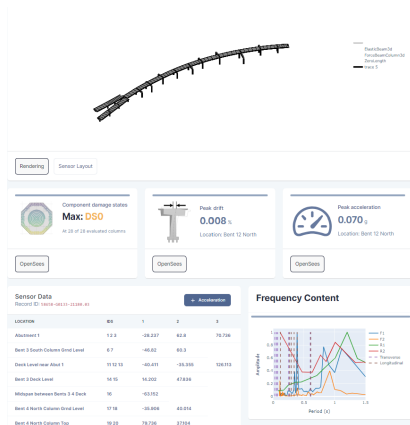


Objective: Health Evaluations



$$m\ddot{u} = f^{\text{ext}} - f^{\text{int}}(u, \dot{u})$$

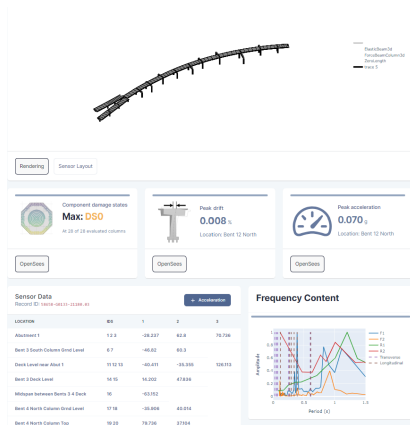
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Two approaches:

Objective: Health Evaluations

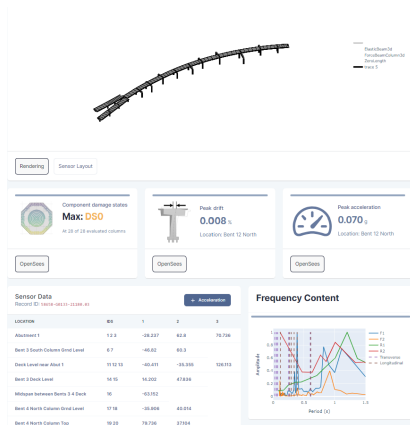


$$m\ddot{u} = \boldsymbol{f}^{\text{ext}} - \boldsymbol{f}^{\text{int}}(\boldsymbol{u}, \dot{\boldsymbol{u}})$$

Two approaches:

1 Conventional Analysis

Objective: Health Evaluations



$$m\ddot{u} = f^{\text{ext}} - f^{\text{int}}(u, \dot{u})$$

Two approaches:

- 1 Conventional Analysis
- 2 Data-driven Analysis

Conventional Modeling



Overpass modeled with χ ara.

Conventional Modeling



Overpass modeled with χ ara.

- High fidelity

Bent 9 South	Minor damage: flexural cracks
Bent 10 North	Minor damage: flexural cracks
Bent 10 South	Minor damage: flexural cracks
Bent 11 North	Minor damage: flexural cracks
Bent 11 South	Minor damage: flexural cracks
Bent 12 North	Core edge failure
Bent 12 South	Minor spalling
Bent 12 Center	Visible reinforcing bars
Bent 13 South, NE Line	Visible reinforcing bars
Bent 13 North, NE Line	Extensive cracks and spalling
Bent 14 South, NE Line	Visible reinforcing bars
Bent 14 North, NE Line	Visible reinforcing bars

- High fidelity
- Large workforce

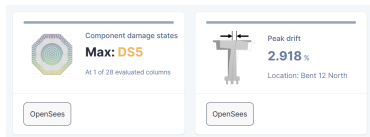
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Conventional Modeling



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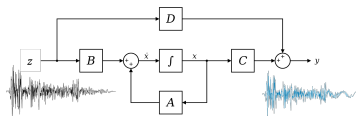
- High fidelity
- Large workforce
- Intuitive metrics



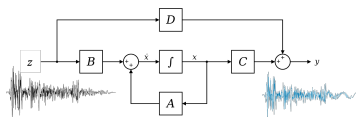
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Data-Driven Methods

- Minimal setup and deployment effort

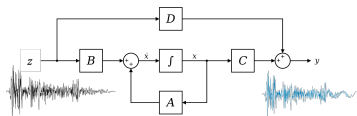


Data-Driven Methods



- Minimal setup and deployment effort
- High computational efficiency, enabling rapid analysis

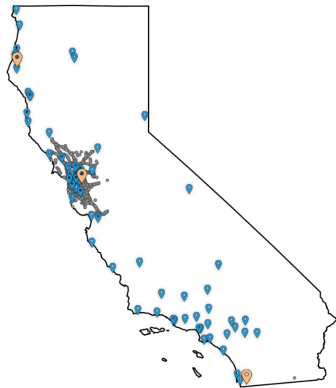
Data-Driven Methods



- Minimal setup and deployment effort
- High computational efficiency, enabling rapid analysis
- Learns and improves continuously as more data becomes available

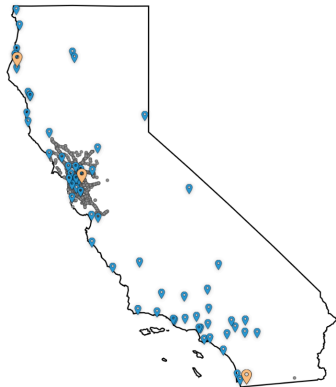
Bridges

- Over **2400** bridges cataloged



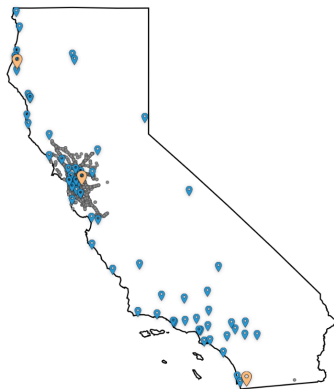
Bridges

- Over **2400** bridges cataloged
- Over **70** bridges instrumented



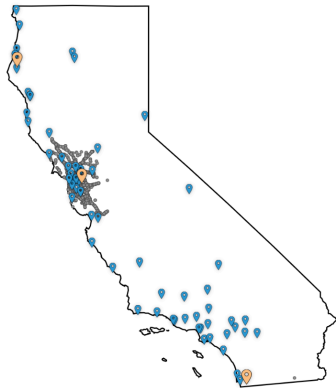
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- **3 bridges with models**



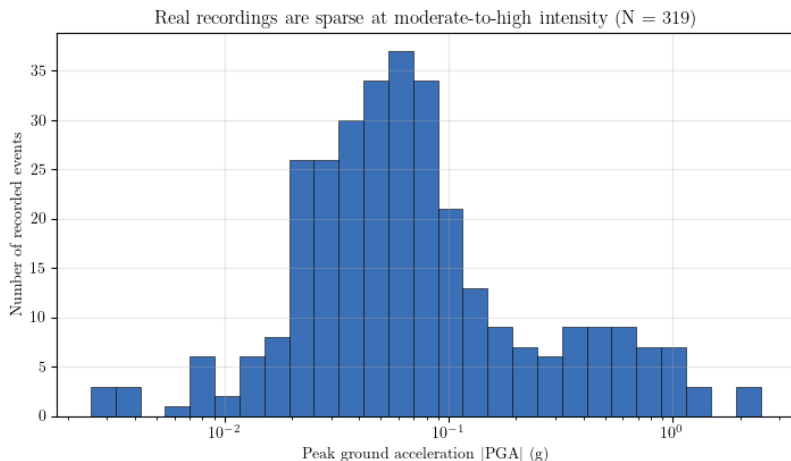
Bridges

- Over **2400** bridges cataloged
- Over **70** bridges instrumented
- **3** bridges with models
- **2** bridges with data streaming



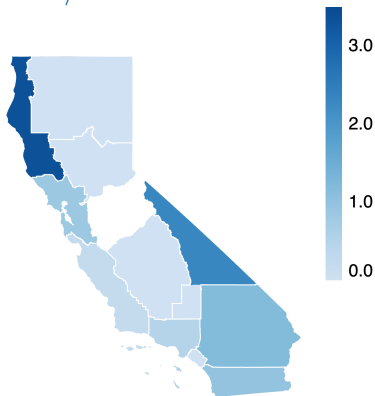
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As it happens, strong events are rare



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Events/Asset¹



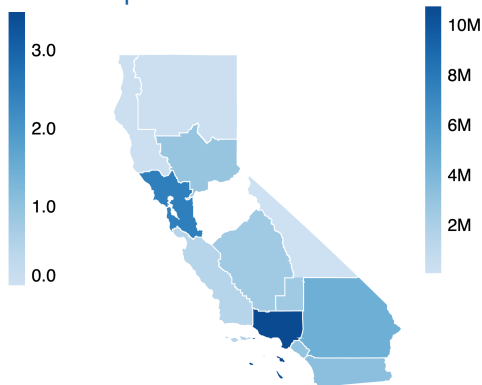
¹ Number of events with $\text{PGA} \geq 0.1 \text{ g}$ per asset in district.

As it happens, strong events are rare

Events/Asset¹



Population



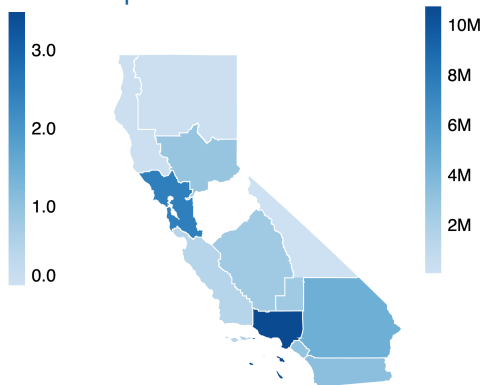
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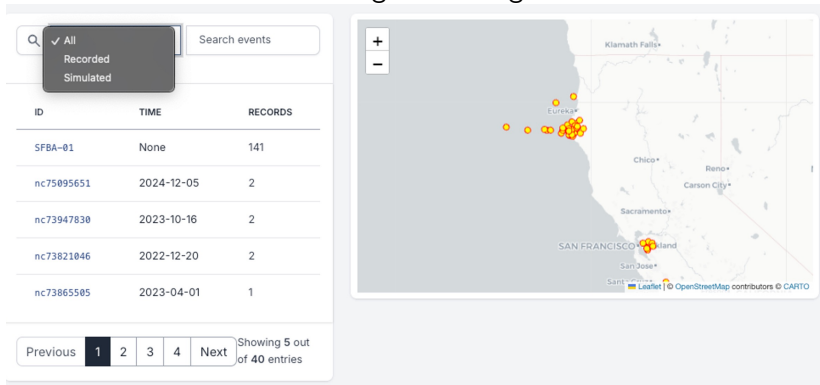
Population



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Implementation of Simulated Events

Simulated events are now integrated alongside recorded events.



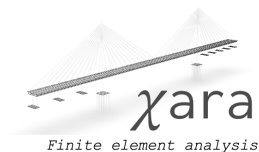
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Conclusions

- Synthetic ground motions address the scarcity of strong recorded events at the asset scale.
- Conventional high-fidelity modeling is indispensable, particularly for complex structures.
- Data-driven methods can reduce assessment cost and runtime when supported by high-quality sensor data and validated analysis procedures.
- High-quality data & robust analysis methods can significantly reduce cost; for simple structures, this trend is already evident.

Open Source Software

Several open-source programs are available, accessible at:
<http://stairlab.berkeley.edu/software>



Thanks!

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