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Innovative experimental technologies and numerical simulation methods:

Future directions

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Innovative Experimental Technologies

- Improving Shake Table Performance
  - Large loads can impact the ability of the shake table to recreate the desired motions – improvements in control
  - Higher velocities and larger displacements to recreate more complex motions
  - Handle impact loads
    - Rocking
    - Abutment pounding
- Instrumentation that captures the complete motion of the experiment
  - Non-contact sensors
  - Ability to process video data
    - Global movements
    - Local strains and displacements

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Innovative Experimental Technologies

- Striving to work at larger scale
  - While not innovative, the larger the scale the more confidence we have in the results
- Working to address more complex issues
  - Soil-structure interaction
    - Difficulties with boundary conditions, soil conditions
    - Removing and replacing soil
  - Tsunamis
  - Large fault ruptures
- New innovative materials
  - Ultra High Performance Concrete (UHPC)
  - Engineered Cementious Composites (ECC)
  - High Strength Steel Reinforcement and High Ductile Steel
  - Shape Memory Alloys

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Innovative Numerical Simulation Method

- Global and material models are good
  - Need improvements in model building, can be very time consuming
  - Computational speed needs improvement. The speed improvement could be enhanced by finding ways to more easily tie programs into High Performance/Super Computers.

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Impact of Earthquake Duration on Structural Performance

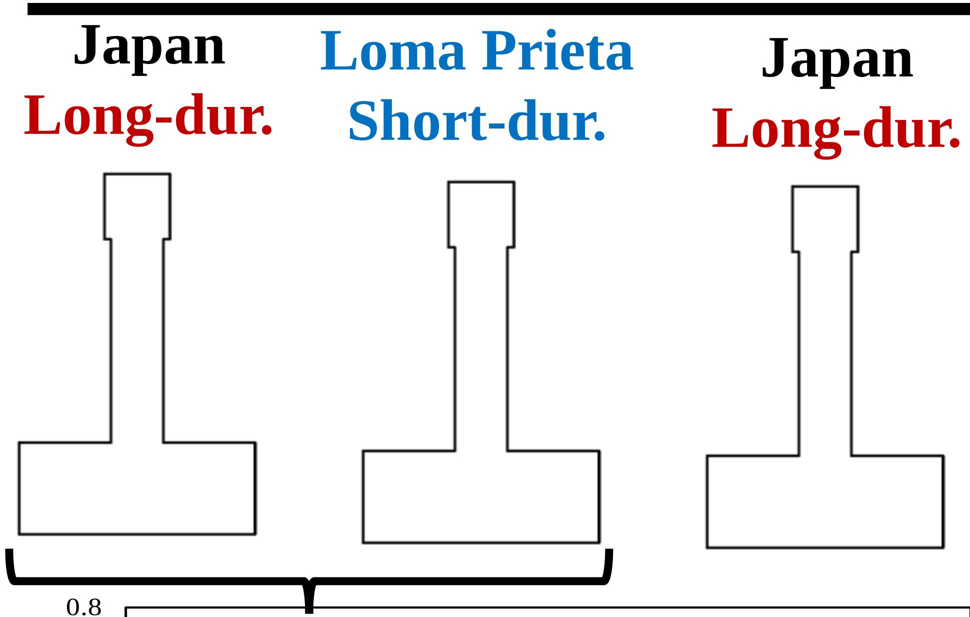
- **Chile Earthquake (2015, 2014, 2010) – Ruptured over ~ 500 km – 20 to 90 seconds**

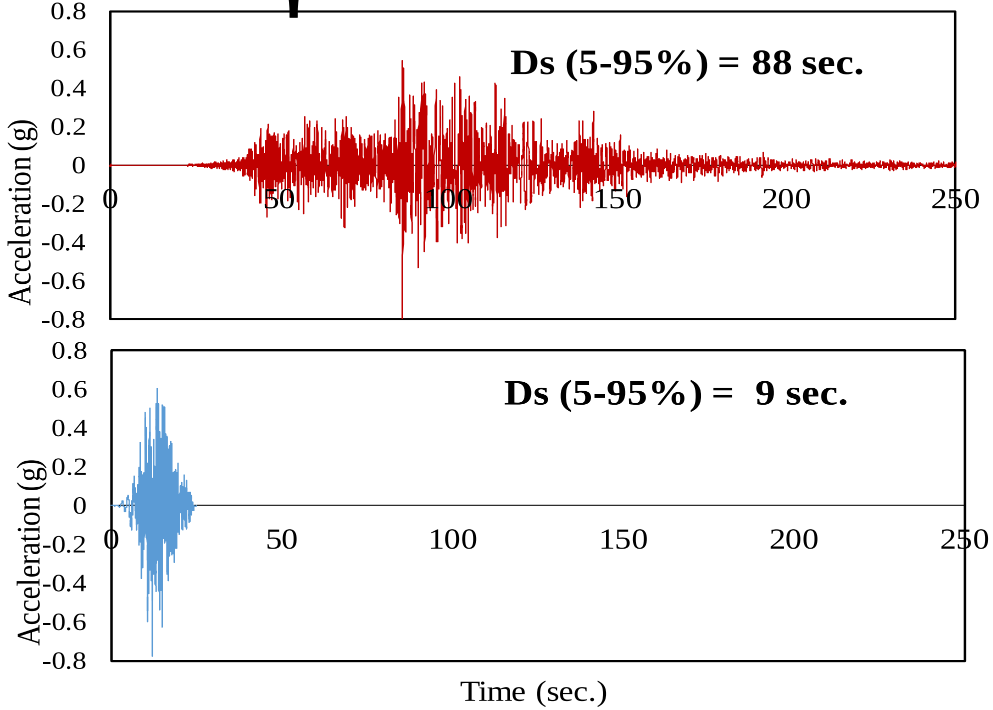
- **Tohoku Earthquake (Japan, 2011) - Ruptured over ~ 500 km**

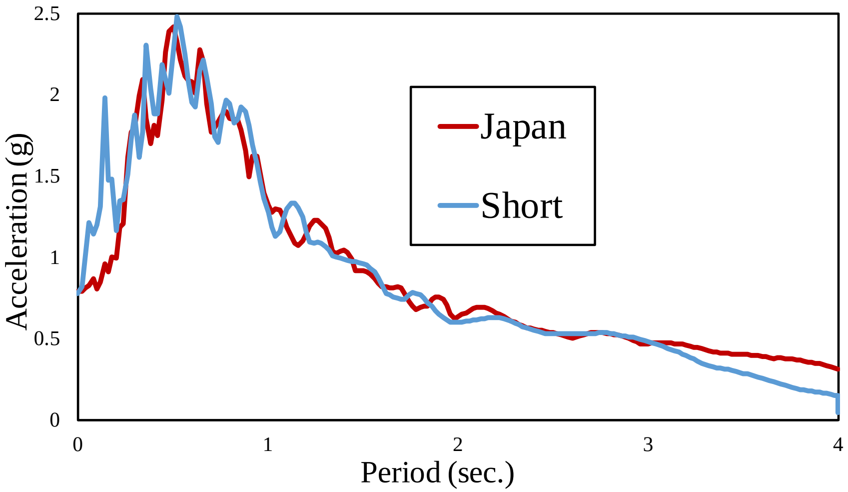
- **California earthquakes are less than 30 seconds**

- **Cascadia Subduction is longer than Tohoku**

Shake Table Tests



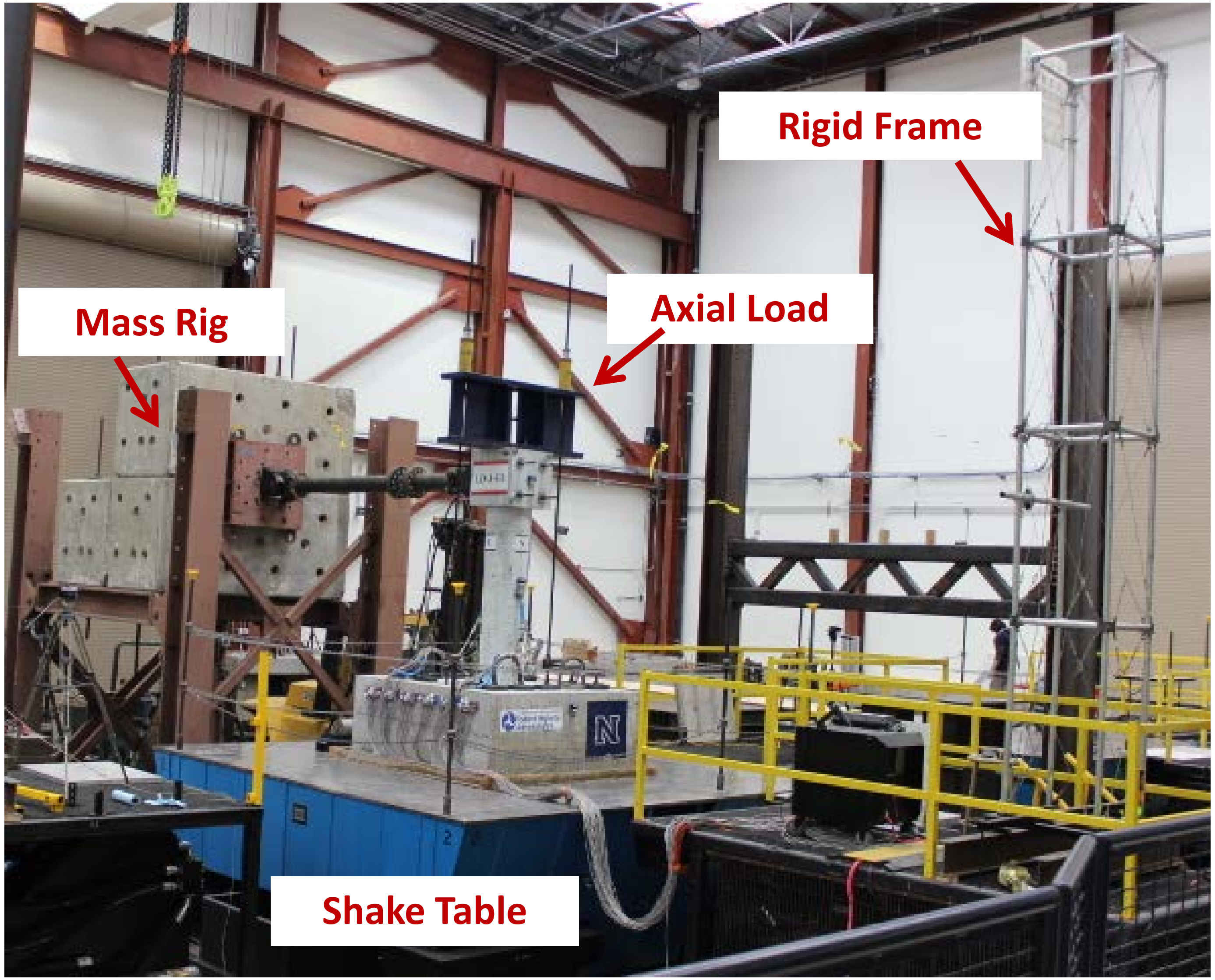




Design codes→

These motions are the same

Test Setup



Test Results

100 % of the Ground Motion

Column 1 (Japan- Long Dur.)

Max. Disp.= 4.5”

South

- **4.4” spalling**
- **Spirals Exposed**

North

- **3.0” spalling**
- **Spirals Exposed**

Column 2 (Short-duration)

Max. Disp.= 3.88”

South

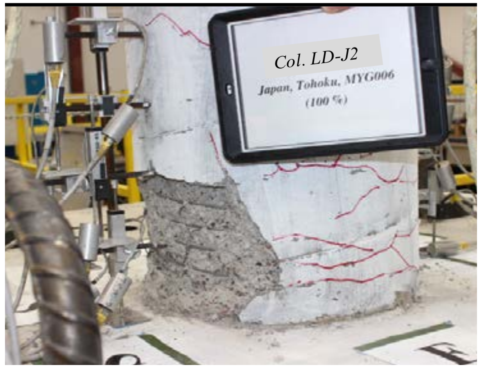
- **Cracks (max width= 0.4mm)**

North

- **4.5” spalling**
- **No RFT. Exposed**

Column 3 (Japan – Long Dur.)

Max. Disp.= 4.7”



South

- **7.5” spalling**
- **Spirals Exposed**

North

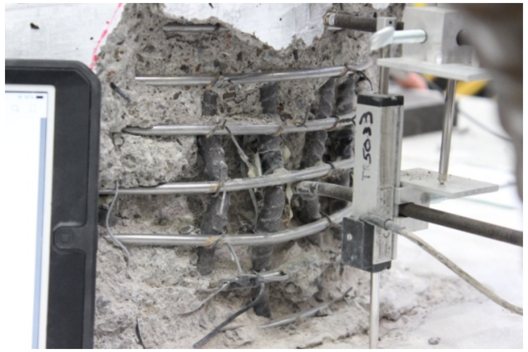
- **Minor spalling**
- **No RFT. Exposed**

Test Results

125 % of the Ground Motion

Column 1 (Japan- Long Dur.)

Max. Disp.= 4.98”



South

- **8.5” spalling**
- **4 Bars fractured**

North

- **6.4” spalling**
- **Core Damage**

Column 2 (Short-duration)

Max. Disp.= 4.8”

South

- **4.5” spalling**
- **Spirals exposed**

North

- **4.5” spalling**
- **Spirals exposed**

Column 3 (Japan – Long Dur.)

Max. Disp.= 7.38”

South

- **8.0” spalling**
- **3 Bars buckled**

North

- **5” spalling**
- **1 Bar fractured**

Test Results

175 % of the Ground Motion

Column 1 (Japan- Long Dur.)	Column 2 (Short-duration)	Column 4 (Japan – Long Dur.)
Max. Disp.= 4.98”	Max. Disp.= 9.22”	Max. Disp.= 7.38”

Column 1: Not Applicable

Bars Fractured at 125%

Column 2:

South

- **4 bars buckled**

North

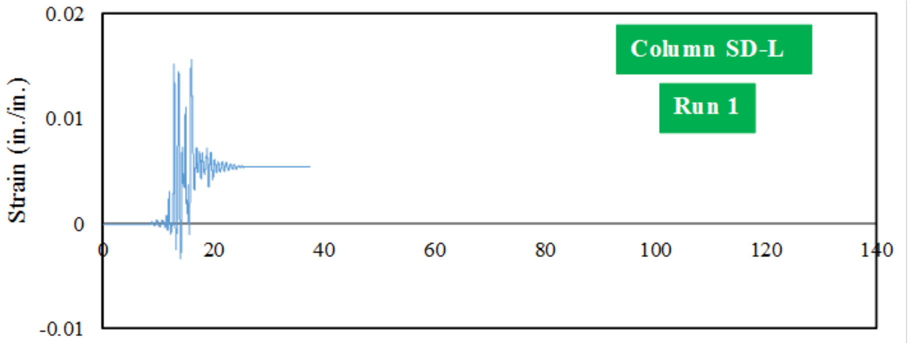
- **1 bar fractured**
- **2 bars buckled**

Column 4: Not Applicable

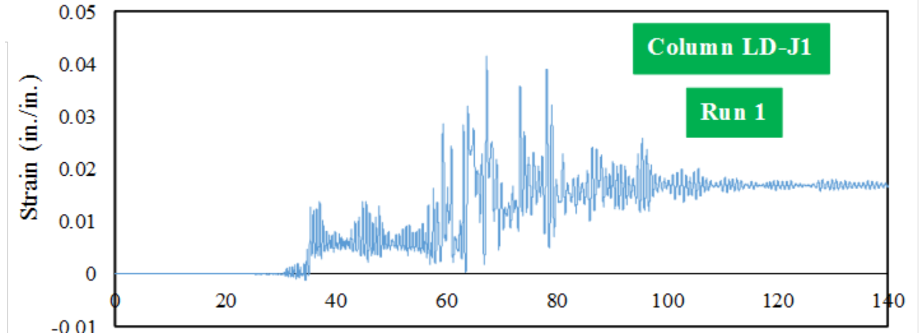
Bars Fractured at 125%

Test Results

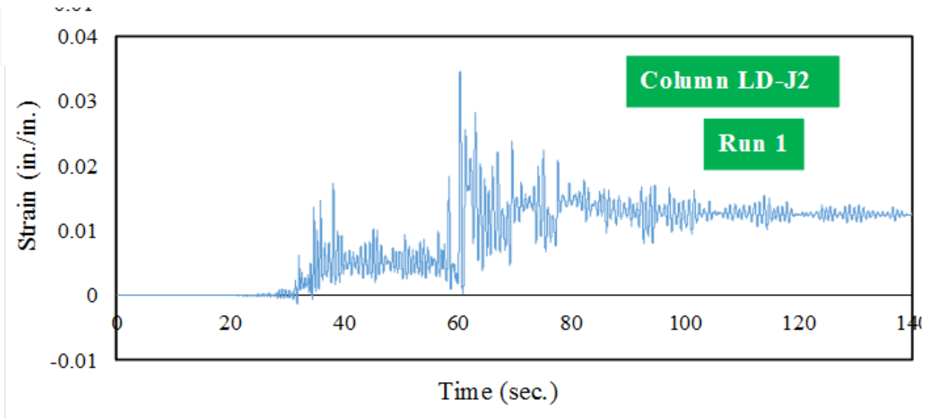
Strain History



Short-Duration



Long-Duration (Japan-1)



Long-Duration (Japan 2)

Existing analytical models still struggle with overall displacements
and residual displacement,
But certainly capture trends in displacements and strain.

Straw-bale Housing in Pakistan

Straw-bale House - Lifted onto Shake Table

Straw-bale House after 2 x Northridge Earthquake

Develop models for non traditional structures and system both structural and non-structural