California Roads 2014

State Highways: ~ 15,000 miles
                ~ 13,500 bridges

Local Roads:   ~ 140,000 miles
                ~ 14,200 bridges
Bridge Seismic Safety Program Pre-1994

- **1971 Sylmar Earthquake (M 6.6)**
  - First earthquake to cause significant damage to the State Highway System
  - Generated sweeping changes to the bridge seismic design codes
  - Caltrans initiated the bridge hinge restrainer retrofit program

- **1987 Whittier Earthquake (M 6.0)**
  - Revealed vulnerability of multi-column bridges

- **1989 Loma Prieta Earthquake (M 6.9)**
  - Legislated (SB36x) bridge seismic retrofit program
  - Significantly increase in seismic research
Northridge Impacts – Transportation

### Vehicle Bridge Inventory - 1994

<table>
<thead>
<tr>
<th>Location</th>
<th>Stated Owned</th>
<th>Locally Owned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide</td>
<td>12,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Los Angeles County</td>
<td>2,523</td>
<td>1,500*/800**</td>
</tr>
</tbody>
</table>

* County  ** City

### State Bridges Damaged in Northridge Earthquake

<table>
<thead>
<tr>
<th>Damage State</th>
<th># of Bridges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapse</td>
<td>7</td>
</tr>
<tr>
<td>Major Damage</td>
<td>39</td>
</tr>
<tr>
<td>Moderate/Minor Damage</td>
<td>194</td>
</tr>
</tbody>
</table>
Bridge Collapses During the Northridge Earthquake

<table>
<thead>
<tr>
<th>Bridge Location</th>
<th>Bridge Name</th>
<th>Yr. Built</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gavin Canyon (I-5)</td>
<td>Gavin Canyon Bridge</td>
<td>1967</td>
</tr>
<tr>
<td>14/5 Interchange</td>
<td>Rte. 14 /5 Sep. &amp; OH North. Conn. OC</td>
<td>1971-1974</td>
</tr>
<tr>
<td>118 west of the 405</td>
<td>Mission Gothic UC Bull Creek Cyn. Ch. Br.</td>
<td>1976</td>
</tr>
<tr>
<td>I-10 near downtown</td>
<td>La Cienega-Venice UC Fairfax-Washington UC</td>
<td>1964</td>
</tr>
</tbody>
</table>
Damage-Gavin Canyon UC

- Tall, highly skewed bridge
- Unseated on the obtuse corners during the earthquake.
The 14/5 IC was previously damaged in the 1971 Sylmar EQ

Every connector suffered damage or collapse during Northridge EQ
I-5/SR-14 collapse was due to lack of stiffness and mass “Balance”
I-5/SR-14 Separation and Overhead
Damage SR-118

Woodley Ave UC
53-2207
Approach slab damage

Bull Crk Cyn Ch Br
53-2206
Partial bridge collapse

Mission Gothic UC
53-2205
Partial bridge collapse

Havenhurst UC
53-2204
Approach slab damage

Ruffner Ave OC
53-2396
Major column damage

Balboa Blvd OC
53-2395
Broken water main washed out abutment

Northridge Earthquake Epicenter
SR-118 Roadway Damage
Damage SR-118 Mission-Gothic Undercrossing

- Constructed in 1976-Post Sylmar
- Large and variable skews
- Heavily reinforced column flares
SR-118 Mission-Gothic Undercrossing
SR-118 Bull Creek Canyon Bridge
16 miles south of the Northridge epicenter

This area likely experienced higher shaking because of weak soil deposits

Retrofitted bridges between the two collapsed bridges were undamaged
Santa Monica (I-10) La Cienega-Venice UC
# Impacts of Northridge EQ on Traffic

<table>
<thead>
<tr>
<th>Route</th>
<th>Location</th>
<th>Pre EQ ADT</th>
<th>2/4/94 ADT</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>South of Rte. 170</td>
<td>156,880</td>
<td>149,663</td>
<td>95 %</td>
</tr>
<tr>
<td>10</td>
<td>East of Rte. 405</td>
<td>267,273</td>
<td>113,029</td>
<td>42%</td>
</tr>
<tr>
<td>101</td>
<td>West of Rte. 405</td>
<td>309,049</td>
<td>267,371</td>
<td>87%</td>
</tr>
<tr>
<td>105</td>
<td>East of Rte. 405</td>
<td>171,135</td>
<td>186,234</td>
<td>109%</td>
</tr>
<tr>
<td>118</td>
<td>West of Rte. 405</td>
<td>125,279</td>
<td>48,532</td>
<td>39%</td>
</tr>
<tr>
<td>134</td>
<td>East of 101/170 IC</td>
<td>197,973</td>
<td>264,908</td>
<td>134%</td>
</tr>
<tr>
<td>170</td>
<td>North of the Rte. 101</td>
<td>78,058</td>
<td>76,143</td>
<td>98%</td>
</tr>
<tr>
<td>405</td>
<td>North of Rte. 10</td>
<td>271,940</td>
<td>234,834</td>
<td>86%</td>
</tr>
<tr>
<td>405</td>
<td>South of Rte. 10</td>
<td>321,694</td>
<td>298,851</td>
<td>93%</td>
</tr>
</tbody>
</table>
Northridge Outcomes - Transportation

- Northridge provided a valuable test for the Caltrans design procedures in high intensity moderate magnitude earthquakes
  - Validated that bridges with post 1971 details performed reasonable well
  - Validated that seismically retrofitted bridges performed well
  - The post-Sylmar EQ expansion joint retrofitted bridges performed with mixed results
Northridge Outcomes – Statewide

State Bridges Still in Service by Year Built

Bridges with comprehensive seismic design criteria
Northridge Outcomes—Transportation

- Northridge provided the impetus for the passage of the Seismic Retrofit Bond Act of 1996 (Prop. 192)
  - The damage in Northridge demonstrated the need to expand the program to include multi-column bridges
  - Augmented the bridge seismic retrofit program initiated under emergency legislation (SB36x) after Loma Prieta
  - 1209 additional bridges were added to the program
  - Prop 192 provided $ 2 billion to fund the State owned toll bridges and the Phase II seismic retrofit program
State Bridge Retrofit Program

Non-Toll:
Phase 1, 100% Complete
1039 bridges
$1.08 billion

Phase 2, 99.99% Complete
1155 bridges
$1.35 billion

Local: 73% complete
912 of 1242 bridges
$1.96 billion

Toll: 100% complete
$8.69 billion
## Bridge Seismic Retrofit Program

<table>
<thead>
<tr>
<th>Location</th>
<th>Bridges</th>
<th>Stated Owned</th>
<th>Locally Owned</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statewide</td>
<td>Total Bridges</td>
<td>13,500</td>
<td>14,225</td>
</tr>
<tr>
<td></td>
<td>Retrofitted Bridges</td>
<td>2,200</td>
<td>912</td>
</tr>
<tr>
<td>Los Angeles County</td>
<td>Total Bridges</td>
<td>2,124</td>
<td>2,749</td>
</tr>
<tr>
<td></td>
<td>Retrofitted Bridges</td>
<td>555</td>
<td>282*</td>
</tr>
</tbody>
</table>

* 19 bridges in design or const.
Northridge Outcomes—Transportation

- Caltrans re-examined and modified its seismic screening and prioritization procedures.
- Near fault and thrust fault effects were incorporated into the seismic hazard characterization.
- New design criteria for new bridges and retrofitting bridges were adopted.
- Caltrans successfully employed incentive/disincentive based contracting methods.
Next Steps for Transportation

- Finish the Local Retrofit Program
- Continue seismic research *...in invaluable and indispensable investment...*
  - Advanced Materials
  - Multiple-Hazards
  - Earth Retaining Systems
  - Advanced Computational Techniques
- Improved Post-Earthquake Serviceability
  - Multi-Level Performance Criteria
  - Performance Based Earthquake Engineering
Next Steps for Transportation

- Rapid Repair and Recovery
  - Accelerated Modular Bridge Construction

- Post-Earthquake Assessment
  - Integrated structural instrumentation
  - Post-event investigation (worldwide)
  - Enhance web-based notification and assessment tools
Recommendations for Transportation

- Regularly re-assess the seismic hazard and engineering performance of the State’s bridges including existing, retrofitted, and new structures.

- Regularly review and revise bridge seismic design criteria to reflect the latest seismology, geotechnical, and structural research findings.

- Continue to proactively initiate problem-focused seismic performance research for all transportation structures and systems.
Recommendations for Transportation

- Continue to develop performance based earthquake engineering methods that looks at bridges as part of an interconnected system.

- Continue to develop and implement expedited seismic design and construction techniques that allow for faster recovery from major seismic events.
Seismic Event / Extreme Event

Initial Response “Emergency”

History of Events and Lessons Learned

Action Proposed

Legislative and Programmatic Changes

Get Prepared

Continuing Research and Advance State-of-the-Art Practice

National Code Changes

International Collaboration

Competing Against Time (Maintain Interest)

Stay Prepared

Other Extreme Events

Challenge

Opportunity

Challenge/Opportunity Cycle

Continuing Challenge
Earthquakes measure our actions, not our words.

Caltrans Seismic Advisory Board
“Race to Seismic Safety”
Next Steps for Transportation

- Caltrans is developing new algorithms to prioritize bridges for seismic vulnerabilities.

\[ \text{Score} = (\text{Vulnerability}) \times (\text{Hazard}) \]