Loma Prieta’s Impact on California’s Bridges

Loma Prieta Earthquake Commemorative Symposium
October 17, 2009

Rick Land
Chief Engineer and Deputy Director, Project Delivery
California Department of Transportation
California Roads

State Highways: ~ 15,000 miles
~ 12,000 bridges
Local Roads: ~ 165,000 miles
12,000 local
California Major Seismic Events

1906 San Francisco EQ – M 7.8
1971 San Fernando EQ – M 6.6
1988 Whittier Narrows EQ – M 6.0
1991 Loma Prieta EQ – M 6.9
1994 Northridge EQ – M 6.7
1971 SAN FERNANDO
1987 WHITTIER
1989 LOMA PRIETA

Loss of lives...

Loss of critical routes...

Loma Prieta Earthquake Commemorative Symposium
Governor’s Board of Inquiry

- Existing Structures
- New Construction
- Response and Recovery
Caltrans Seismic Retrofit Program

Seismic Retrofitting Freeway Structures

Previous California earthquakes that devastated highway bridges have prompted a massive renovation program. Older overpasses are vulnerable at their joints and columns and are being retrofitted to help them stand up to a quake.

- Original concrete column
- Cable supports: Keep road beds from separating at joints.
- Hinge restrainers: Cables hold bridge decks to columns.
- Old columns: Vertical rods and 1/2" steel hoops on 12" centers
- Support columns:
  - Older concrete columns lack the tight spiral steel wrapping that better holds the columns together during a quake. These columns are fitted with a steel casing.
  - A thin layer of concrete grout fills in gaps between steel casing and concrete column.
  - Footings are enlarged and pilings driven deep into ground for structures built in soft soil.
- New columns: Continuous 3/4" steel spirals on 3" centers support vertical rods.
- During quake: Columns collapse under lateral motion.

Source: Caltrans rev. 1/95

AP/Karl Gude, Dawn Desilets
1994 NORTHRIDGE
Seismic Retrofit Bond Act of 1996
(Proposition 192)
Caltrans Seismic Retrofit Program

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

Phase 2, 99.7%
Complete 1151 out of 1155 bridges
$1.35 billion

Local: 61% complete
733 out of 1193
$1.96 billion

Toll: 6 out of 7 bridges complete
$8.69 billion

$13.08 billion
East Spans, San Francisco-Oakland Bay Bridge

The New East Span
History in the Making

Image courtesy of Caltrans
Improving Major Bay Area Bridges

Dumbarton

- Typical Main Channel Crossing Bent
- Column
- Footing (under water)
- Bent Cap
- Superstructure
- Substructure
- Piling (under water)
- Column
Improving Major Bay Area Bridges

Antioch
Improving Major Bay Area Bridges

Doyle Drive

- Toll Plaza
- At-Grade
- High Viaduct
- At-Grade
- Low Viaduct

San Francisco Natl. Cemetery

Palace of Fine Arts

Halleck St.
Improving Major Bay Area Bridges

Doyle Drive
Limited research until the mid-1980’s
Then, about $500,000 per year prior to Loma Prieta
By 1991, 35 research projects at $7 million.
Since 1994, averaged $5 million/year
Over $90 million to date with significant focus on implementation of results
Seismic Devices

- Shear Links
- Dampers
- Bearings
- Lockup Devices

Needs:
- Long Term Performance
- Performance Verification
- Maintenance
Caltrans Current Seismic Design Practice

- Current State of the Practice in California
  - Displacement Based
  - Confinement to Develop Ductile Response
  - Continuity or Adequate Support Length
  - Capacity Design Principles
  - Redundancy
  - Proportioning and Balanced Geometry
Caltrans Current Seismic Design Practice

- Expected Performance of Standard Bridges
  - Major Earthquake will result in Major Damage
  - Risk to Loss of Life Minimized

- Expected Performance of Important Bridges
  - Post-EQ operational capacity
Future California Bridges

- Improved Post-Earthquake Serviceability
- Multi-Level Performance Based
- Rapid Post-Earthquake Assessment, Repair and Recovery
- Integrated with Accelerated Modular Bridge Construction Practices

Must be:
- Cost-Effective
- Simple
- Reliable
- Verifiable
- Long Lasting
View Driving West to San Francisco
Structural Fuses

During Large Seismic Events

Linker Beams (shear beams) will deform beyond elastic into plastic range of deformation. As they go plastic, they effectively protect the tower legs and superstructure by serving as a fuse.
Advanced Materials

- High Performance Concrete
- High Performance Steel
- Fiber Reinforced Polymer Composites
- Shape Memory Alloys

Needs:
- Material Performance
- Degradation Models
- Long Term Performance
- Detailing
- Specifications
Precast Segmental Components

- Supports Accelerated Construction
- Needs:
  - Connections
  - Inelastic Performance
  - Predictive Modeling
Improved Analytical Capabilities

- Standardization of Methodologies
- Efficient, Reliable Model Development
- Foundation and Abutment Mathematical Models
- Research System Testing
- Real Event Verification
Monitor Bridge Performance

- Caltrans Strong Motion Instrumentation Program
  - Verification of Predictive Models
  - Archive Analytical Models
- FHWA Long Term Bridge Performance Program
Understanding Seismic Hazards

- Ground Motion
  - Lessons Learned
    - 2004 Parkfield EQ
  - Time History
    - Selection and Site Application
  - Attenuation
  - Near Fault Effects
  - Energy or Duration
Understanding Seismic Hazards

- Other EQ Hazards
  - Fault Rupture
  - Tsunami
  - Liquefaction
  - Landslides
Non-Bridge Structures

- Earth Retaining Structures
- Soundwalls
- Tunnels
Assessment and Recovery

- Assessment
  - Training and Tools
  - Non-Destructive Evaluation
  - Remote Monitoring
  - Determine Remaining Capacity

- Rapid Recovery
  - Repair and Rehabilitation
Conclusions

- Are We Done? - No
- Working to Meet California Goals
  - Mobility
  - Safety
  - Stewardship
- To Meet Goals
  - Requires Innovative Solutions
    - Cost-Effective, Simple, Reliable, Verifiable, Long Lasting
  - Research
  - Pilot Projects
  - Engage with Partners Nationally and Internationally
Competing Against Time
(Maintain Interest)

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

Other Extreme Events

Stay Prepared

Continuing Challenge

International Collaboration

National Code Changes

Challenge / Opportunity Cycle
“Earthquakes measure our actions, not our words.”

- Caltrans Seismic Advisory Board, December 2003