Safety of California's Transportation Structures

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Dean, Jacobs School of Engineering
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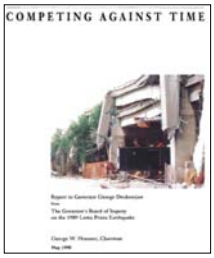
October 17, 1989 – 5:04 PM

Partial collapse of deck roadway above Pier E9 during the Loma Prieta EQ

1 casualty
One month bridge closure
Million $$$ in losses

Loma Prieta EQ
D = 100 km
M = 7.1

Bridge Failures, 89 Loma Prieta



"It is the policy of the State of California that seismic safety shall be given priority consideration in the allocation of resources for transportation construction projects, and in the design and construction of all state structures, including transportation structures and public buildings."

"Establishment of a Seismic Advisory Board"

Governor George Deukmejian
Executive Order D-86-90, June 2, 1990

The ***Board of Inquiry*** has identified three essential challenges that must be addressed by the citizens of California, if they expect a future adequately safe from earthquakes:

1. Ensure that earthquake risks posed by new construction are acceptable.
2. Identify and correct unacceptable seismic safety conditions in existing structures.
3. Develop and implement actions that foster the rapid, effective, and economic response to and recovery from damaging earthquakes.

Competing Against Time
Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake

Caltrans Seismic Advisory Board

Frieder Seible, Chair

Ian Buckle, Vice Chair

Norman Abrahamson

Jack Boda

George Fotinos

Geoffrey Martin

Joe Nicoletti

Ed Wilson

Seismic Advisory Board

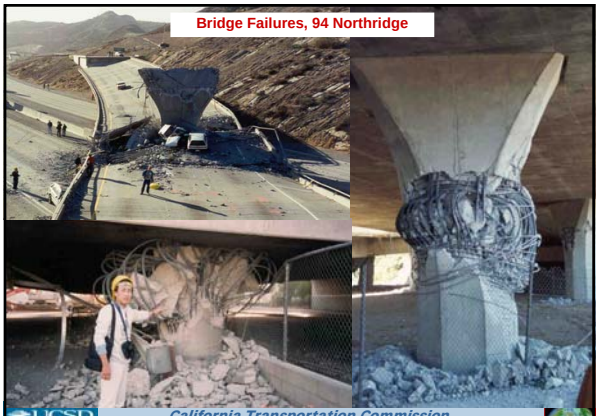
CALTRANS
Seismic Advisory Board

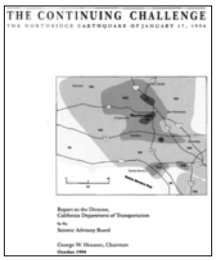
***Mission*:**

The mission of the SAB is to assist Caltrans in its role and obligation to provide seismic safety of California's transportation structures through:

1. **Continued review of earthquake engineering and seismic design as practiced by Caltrans.**
2. **Formulation of recommendations for improvements in Caltrans earthquake engineering and seismic design practices.**
3. **Policy review of seismic hazard definition and mitigation directives.**
4. **Technical review of seismic design guidelines and standards for transportation structures.**
5. **Review and comment on Caltrans seismic research agenda and priorities.**
6. **Being available to provide the general public with explanations regarding Caltrans' seismic safety policies and procedures for maintaining safety and functionality of California's transportation structures.**

Bridge Failures, 94 Northridge

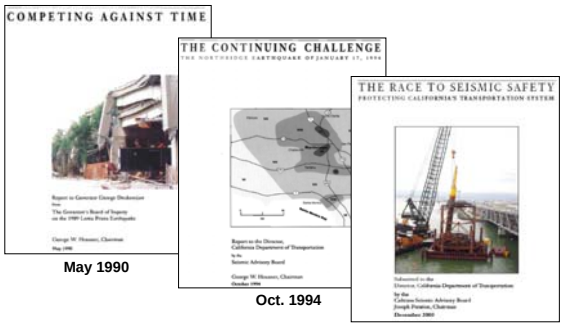




"The safety of every Californian, as well as the economy of our state, dictates that our transportation system be seismically sound. That is why I have assigned top priority to seismic retrofit projects ahead of all other highway spending."

Governor Pete Wilson
Remarks on opening of the repaired Santa Monica Freeway damaged in the 1994 Northridge earthquake, April 11, 1994

Seismic Advisory Board



May 1990

Oct. 1994

Dec. 2003

Seven Recommendations for a Safer Transportation System

1. **SEISMIC SAFTEY POLICY.** Provide an acceptable level of earthquake safety for all transportation structures.
2. **NON-STATE-OWNED BRIDGE RETROFITS.** Retrofitting of all bridges is to be completed within a certain timetable.
3. **DESIGN STANDARDS.** Seismic-related design and construction issues are to be independently reviewed to ensure compliance.
4. **REGULAR SAFETY REASSESSMENT.** Caltrans needs to regularly reassesses the seismic hazard and engineering performances of all bridges.
5. **TOLL BRIDGE SEISMIC SAFETY PROGRAM.** Toll Bridge Safety Program is to be completed without delay.
6. **PROBLEM-FOCUSED INVESTIGATIONS.** Caltrans needs to make a commitment to problem-focused seismic investigations and research funding.
7. **EMERGENCY RESPONSE.** Caltrans needs to maintain a rapid response capability to evaluate, repair, and restore damaged bridges.

The Race to Seismic Safety, Dec. 2003

Caltrans Bridge Seismic Retrofit Program

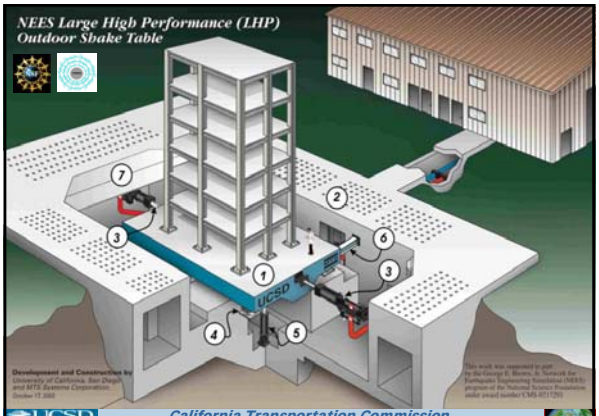
Program		No. of Bridges Identified for Retrofit	Cost ($M)	Completion Date
	Restrainers/Seat Extenders	1,261	54	1989
Phase I	Single Column Bents	1,039	850	2000
Phase II	Multi-Column Bents	1,155	1,350	2010[1]
	Toll Bridges	9	9,685[2]	2013[1]
	Local Agencies	1,235	2,138	2013[1]
	Total	4,699	14,077	

[1] Estimated completion date
[2] Includes a $1B estimate cost for Antioch and Dumbarton

Note, there are ~24,000 bridges in California, half owned by the State and half owned by local agencies such as cities, railroads, or transportation agencies

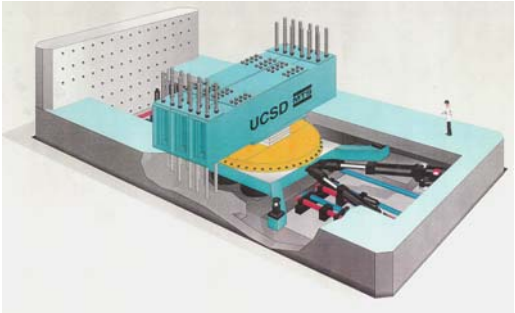
Column Jacketing

a) Research b) Implementation



Seismic Retrofit of the Coronado Bay Bridge

Schematic of the Caltrans SRMD Test System



Caltrans SRMD Technical Specifications

	Vertical	*Longitudinal*	*Transverse*
Force	53,400 kN (12,000 kips)	8,900 kN (2,000 kips)	4,450 kN (1,000 kips)
Displacement	± 0.127 m (5 in.)	± 1.22 m (48 in.)	± 0.61 m (24 in.)
Velocity	± 254 mm/s (10 in./s)	± 1778 mm/s (70 in./sec)	± 762 mm/s (30 in./sec)
Clearance	Up to 1.52 m (5 ft)		~ 4 m (13 ft)
Relative rotation	± 2°	± 2°	± 2°

UCSD Jacobs
California Transportation Commission
January 14, 2009

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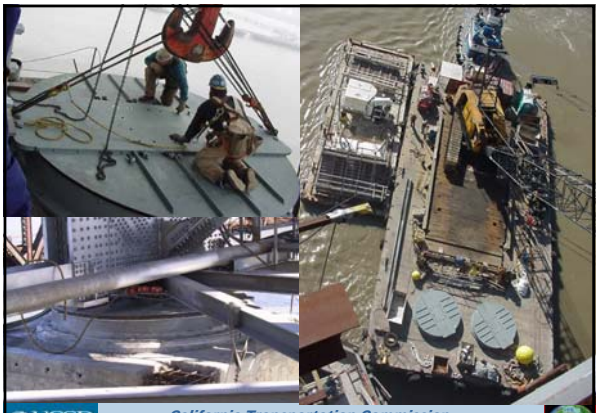

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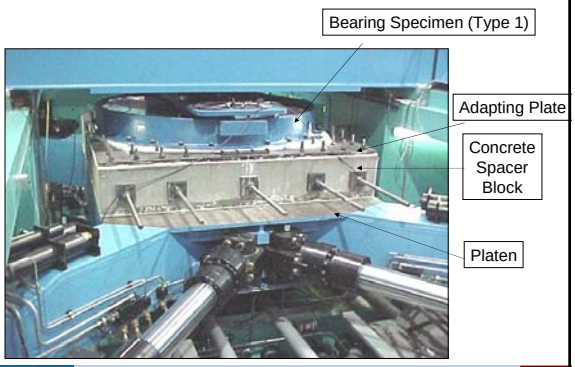


Isolation Bearing Test: Friction Pendulum Bearing

P_z = 6000 kips

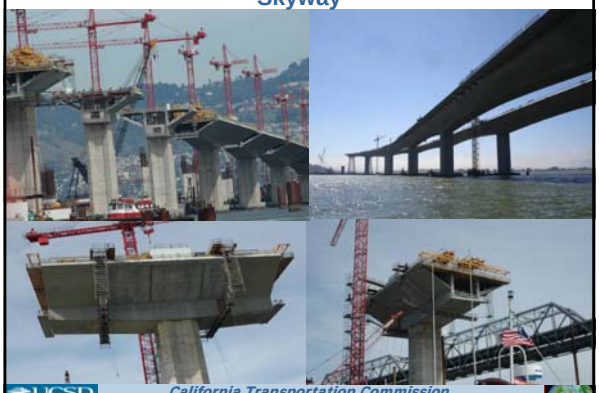
D_x= +/- 29 inches

Vel = 60 in./sec.

The New San Francisco-Oakland Bay Bridge

SFOBB Skyway Precast Segments

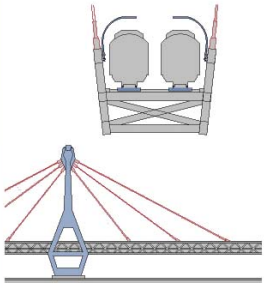
Skyway



High Speed Rail

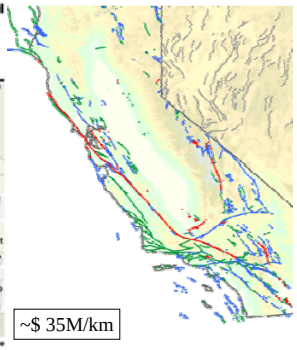
HSR – Erection by Underslung Girder

Taiwan High Speed Rail (HSR) with Earthquake Fault Line



Proposed High Speed Rail

Fault System



California's Proposed High Speed Rail Superimposed with Fault Lines

Unit Cost Index of Beijing to Shanghai High-Speed Railway Construction

High-Speed Rail System

Beijing-Shanghai HSR	L = 1,318 km	$32.3 B	24.5 M/km
CA (Proposed)	L = 800 miles or 1,280 km	$45 B	35.2 M/km

Track System (Beijing-Shanghai)

Elevated Tracks (Bridges)	L = 1,140 km	86.5%	$8.4 B	7.4 M/km
Track in Tunnels	L = 16 km	1.2%	$0.2 B	14.1 M/km
Track At Grade	L = 162 km	12.3%	$0.7 B	4.3 M/km
Total Track System	L = 1,318 km		$9.3 B	7.1 M/km

–> 30% of the total cost is in the track system.
In US, 40% to 50% for track system.
In CA 50% to 60% due to seismic.

Blast Effects and Hardening Technology

Demand Capacity Interaction

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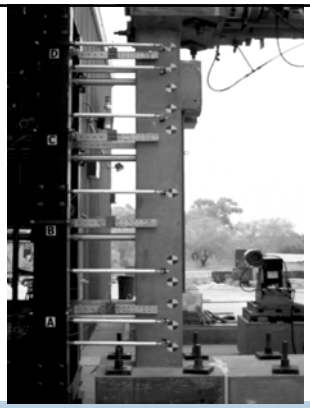
Visualization of Response

↓

Validation of Models and Simulations



As-built column 25 m/s impact.