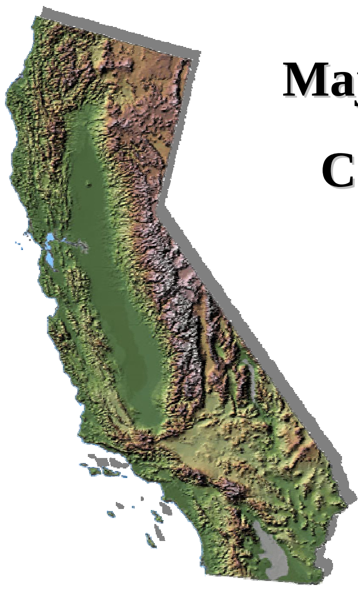
CALIFORNIA DEPARTMENT OF TRANSPORTATION



Major Earthquakes in California and the Development of Seismic Safety in Bridge Design

March 2007

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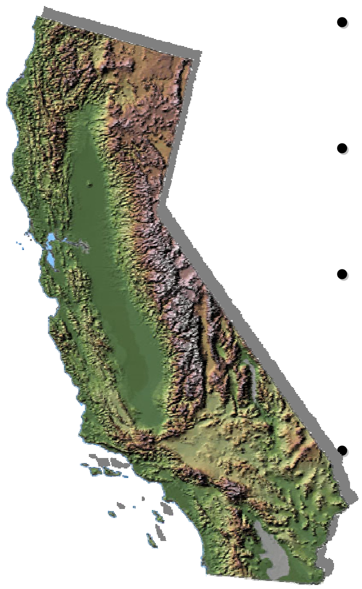
(not a talking slide)

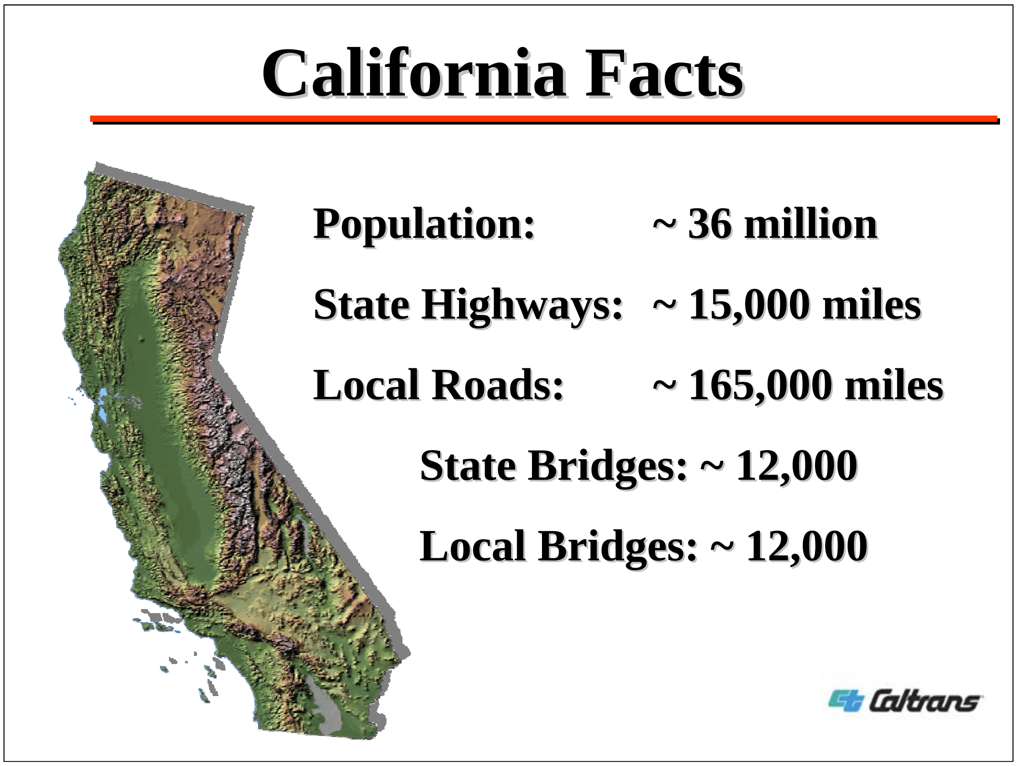
Presentation Overview



- Brief History of California Major Seismic Events
- Seismic Research and Caltrans Retrofit Programs
- Continuing Development of Seismic Design Criteria (SDC) for California Bridges
- Challenge & Opportunity Cycle

Caltrans

1. Will cover the major seismic events beginning with the 1906 San Francisco Earthquake.
2. Will cover the development of seismic design practice in California and AASHTO Specifications.
3. Talk about the challenges and the window of opportunity in getting prepared and staying prepared for a major catastrophic event.



First, let me give you a few facts on California to help put some of our challenges here in California in perspective.

1. California is
   - state with the highest population at 36 million
   - large inventory of bridges
     - 12,000 State Bridges
     - 12,000 Local Bridges

California Major Seismic Events

1906 San Francisco EQ – M 7.8

1971 San Fernando EQ – M 6.6

1987 Whittier Narrows EQ – M 5.9

1989 Loma Prieta EQ – M 7.1

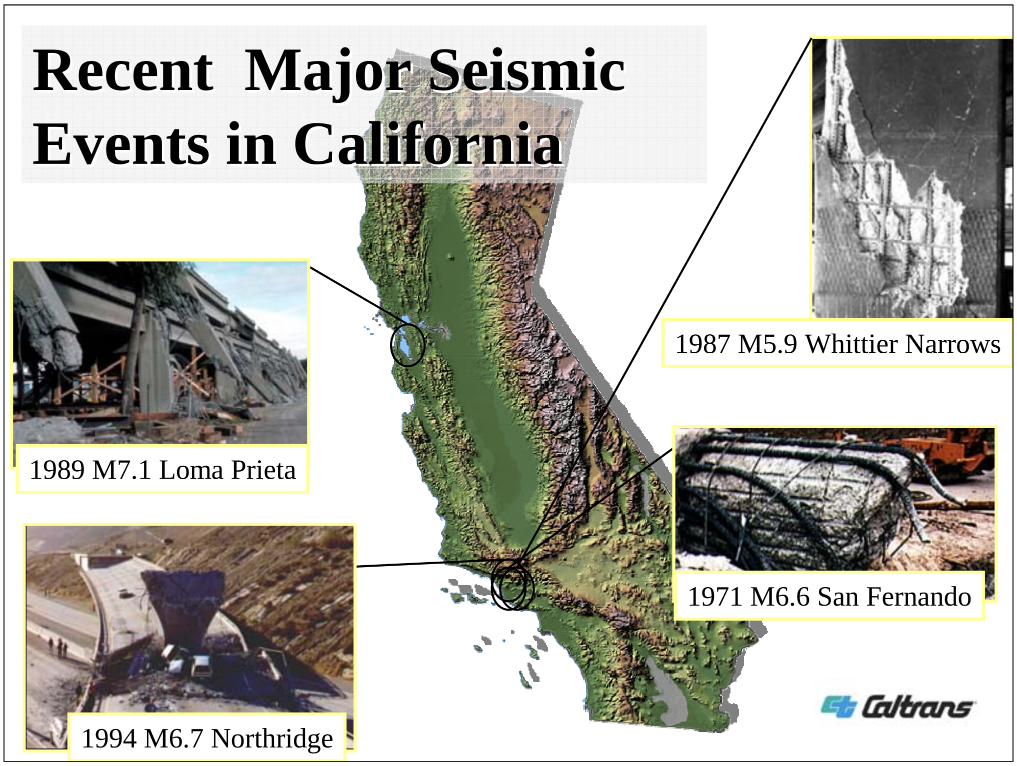
1994 Northridge EQ – M 6.7

Caltrans

1. The 1906 San Francisco Earthquake had a magnitude of 7.8, which was the largest of California's major events shown here.
2. 65 years pass between the San Francisco 1906 Earthquake and the 1971 San Fernando Earthquake.
3. Significant change in seismic design criteria begins with the 1971 San Fernando Earthquake.
4. We will cover the impact of the remaining major seismic events on the development of seismic criteria and the challenges and opportunity cycle that develops with a major event.

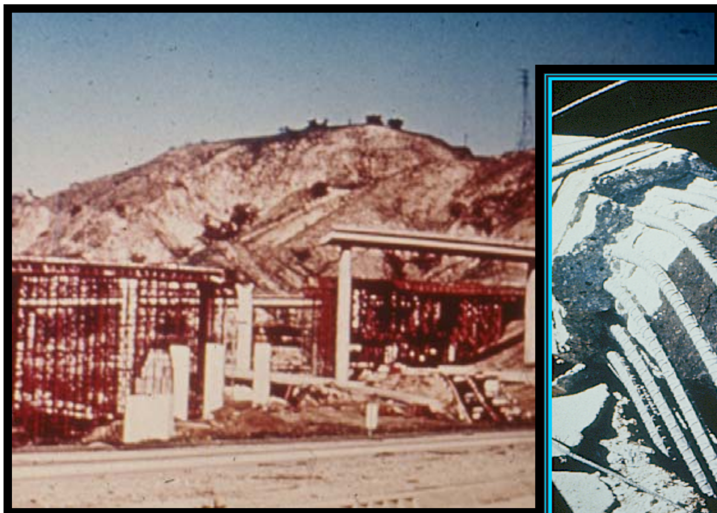
On April 18, 1906 the largest earthquake of the 20th century hit San Francisco

- The earthquake and resulting fires caused an estimated 3,000 deaths
- This earthquake caused the most lengthy rupture of a fault that has been observed in the contiguous United States.



1. 65 years pass between the 1906 San Francisco earthquake and the 1971 San Fernando earthquake.
2. The 1971 San Fernando earthquake is the one “defining event” that changed the focus on seismic safety in transportation.
3. The major events shown here created both challenges and opportunities, to advance seismic safety in transportation.

1971 SAN FERNANDO

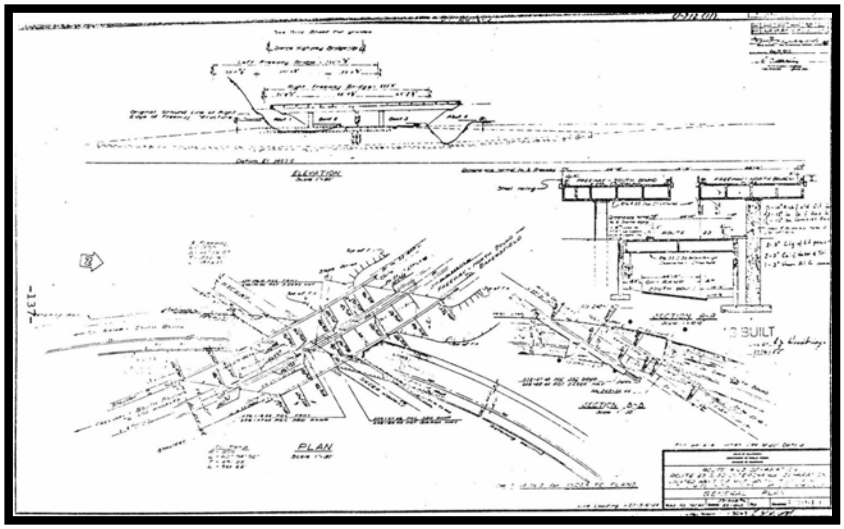


1971 San Fernando, effect was limited w/respect to funding and programmatic change

1. There wasn't a significant Legislative response related to seismic safety of the transportation system.
2. Caltrans initiated revisions in its seismic design criteria within weeks and began development of new criteria for future bridge designs, that eventually came out in 1973.
3. Caltrans initiated a Seismic Retrofit Program focused on mid-span hinges and abutment joints. But budget limitations in the late 1970's really slowed down that program.(Interest waned) It was finally completed in 1989 at a cost of $55 million.
4. There was recognition that columns were the next focus of concern but little work done on columns because we could not secure funding until the mid-1980's and it wasn't until the mid-1980's that we started doing some limited research in the area of seismic design.
5. Focus of this presentation will be on the 5-14 Interchange.

1971 SAN FERNANDO

Route 5/14 Separation



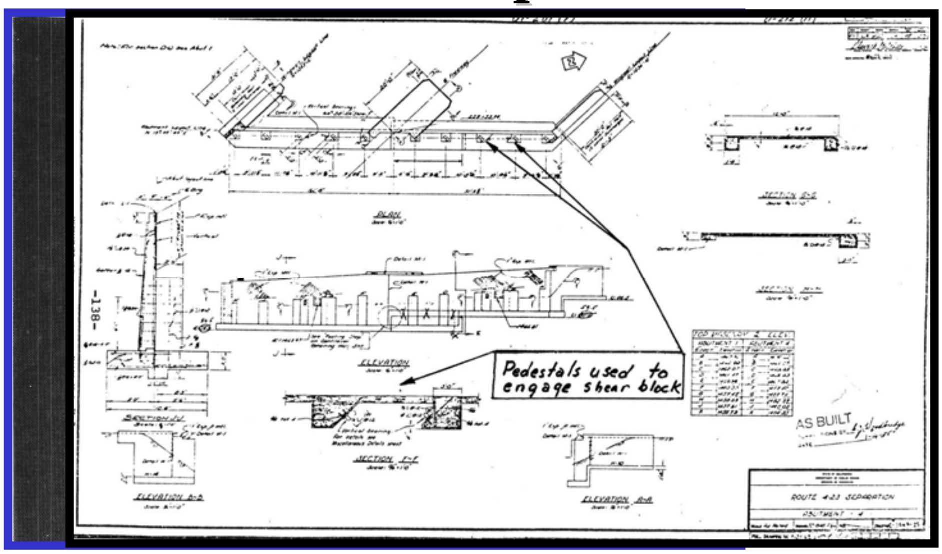
1. Route 5/14 (old 4/23) Separation includes 2 bridges, R/L
2. Three span, single column, box girder type structures that were constructed in 1952.
3. Bents consist of single column 6'0" spirally reinforces columns supported on spread footing

Show photo 37 of pp135 (behind)

Abut plan pp 138 (GB)

1971 SAN FERNANDO

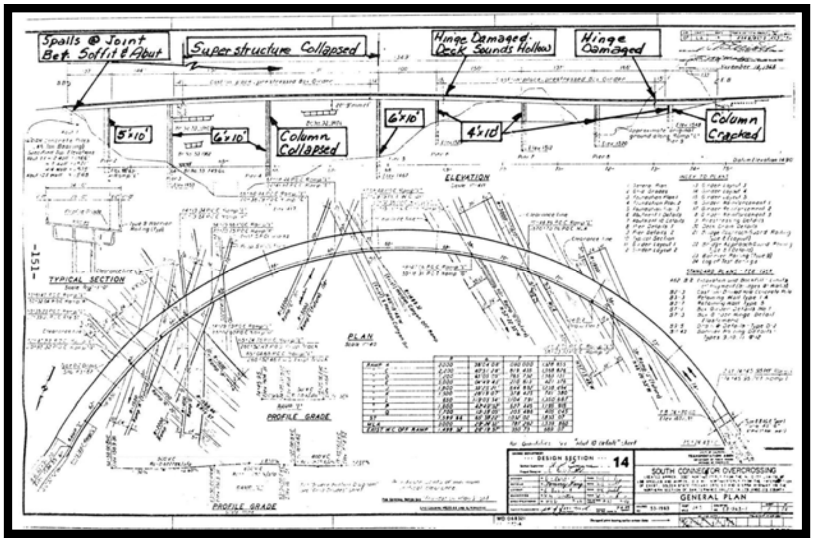
Route 5/14 Separation



1. Damage was limited to the abutment locations.
2. Large transverse forces caused the bearing pedestals to fail as they engaged the shear blocks.
3. Columns were not damaged.
4. Superstructure was not damaged.

1971 SAN FERNANDO

South Connector Overcrossing



1. This structure was completed at the time of the 1971 earthquake.
2. This bridge is a 1349 ft., single column box girder structure; construction complete at time of earthquake.
3. Combination of CIP pre-stressed frames and conventionally reinforced frames
4. Minor damage to abutments.
5. Piers 2, 3, 5, 6, 7 and 8 had no damage. Pier 9 had a longitudinal "X" crack.
6. Column 4 and the superstructure in Span 3 and 4 collapsed. (Collapse due to unseating of the hinge)
7. Note Pier #9 "cracked"! We will talk more about short stiff columns and balanced stiffness later!
8.

Photo 41 pp145 - Photo 46 pp 148 GB

1971 SAN FERNANDO

South Connector Overcrossing

1. The cause of collapse was due to longitudinal displacement of the superstructure and unseating at the hinge locations.
2. Evidence at the site show that Span 4 fell first, then Pier 4 fell on Span 4 and finally, Span 3 fell on pier 4.
3. After superstructure became unseated, the cantilever section drooped and hinged at the top of column 4, then broke off and dropped nearly straight down.

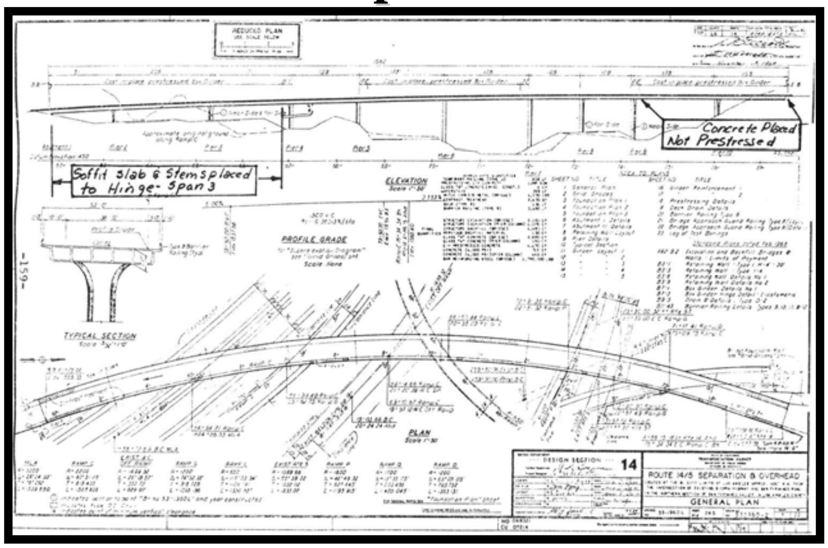
1971 SAN FERNANDO

South Connector Overcrossing

1. This slide shows a close look at column 4.
2. (Bottom Left) shows a view of the superstructure (Span 3) as seen from the top of pier 4 column.
3. (Top Right) shows the top of Pier 4 column. Note fractured #18 Column reinforcement. Also, note the smooth surface on top of the column, this is the construction joint and not the deck.

1971 SAN FERNANDO

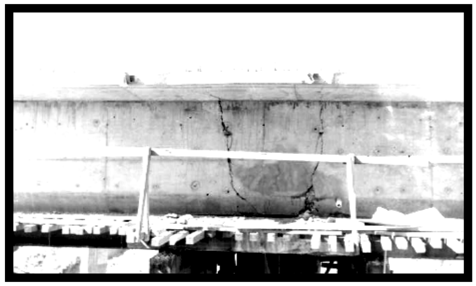
Route 5/14 Separation & O.H.

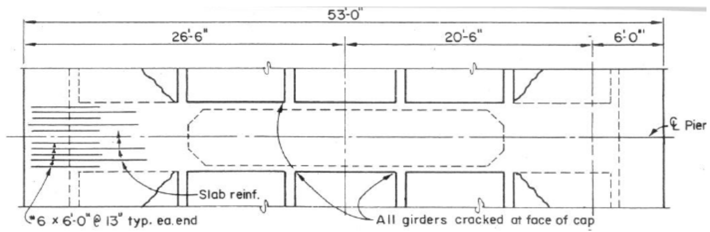


1. The 5/14 separation and OH is a 1582’ single column, box girder type structure with both cast-in-place pre-stressed and conventionally reinforced concrete.
2. At the time of the earthquake, the bottom slab and stem had been placed from Abut 1 to hinge in Span 3.
3. Also, at the time of the earthquake, the concrete from the hinge in Span 9 to Abut had all been placed, but no pre-stressing had been done.
4. At the time of the earthquake, no other superstructure concrete had been placed.
5. Most of the damage to concrete was due to settlement of falsework.
6. This structure later collapsed in the Northridge Earthquake which will be discussed later.

1971 SAN FERNANDO

Route 5/14 Separation & O.H.





1. Note cracking of incomplete caps, which occurred in Piers 2 and 3. The 45º crack extends through the soffit and exterior girders (slab and soffit only)

Photo 53 pp 158 GB

Figure 4-5 pp 28 of the Continuing Challenge

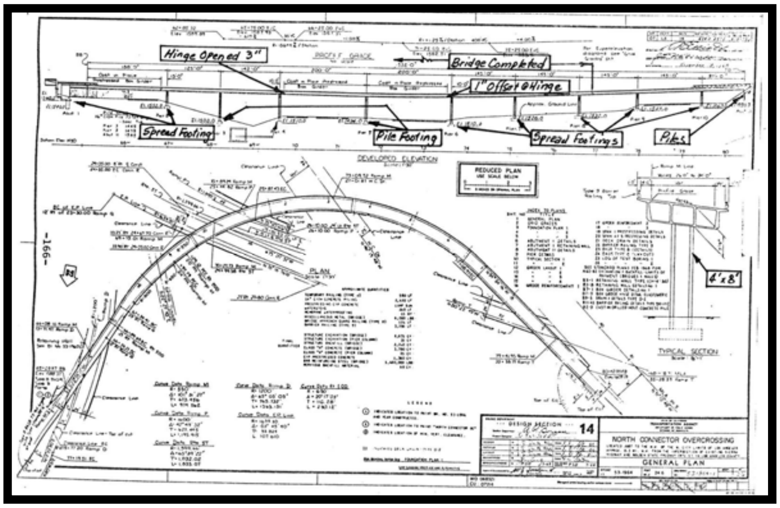
1971 SAN FERNANDO

Route 5/14
Separation & O.H.

1. Note Column 6 damage from south connection.
2. (Top Left) Spans 1, 2, and 3 falsework are visible in the background.
3. (Bottom Right) The structure shown here on falsework will later collapse in the Northridge Earthquake (23 years later).
4. The column visible in the top left with falsework was from 1971. The same column is shown bottom right after Northridge in 1994.

1971 SAN FERNANDO

North Connector Overcrossing



1. The structure is a 1532' single column box girder type structure that was completed up to the hinge of Span 8. Damage to this structure was minor.
2. The structure is oriented similar to the South Connector, only 400' North.
3. Main difference between the South & North Connectors is relative height and substructure type. North Connector is approximately 30' shorter than the South Connector.
4. Substructure Difference:

   North Connector – Columns on footing type supports

   South Connector – CIDH Shafts (more flexible and longer)

5. Note the first two spans of this structure collapsed during the 1994 Northridge Earthquake

   - Pier 2 failed

   - Restrainers at hinge 1 failed

   - Pier 2 was significantly shorter (stiffer) than adjacent piers 3 and 4

Photo 55 pp 165 GB

Figure 4-4 pp 27 Continuing Challenge

1971 SAN FERNANDO

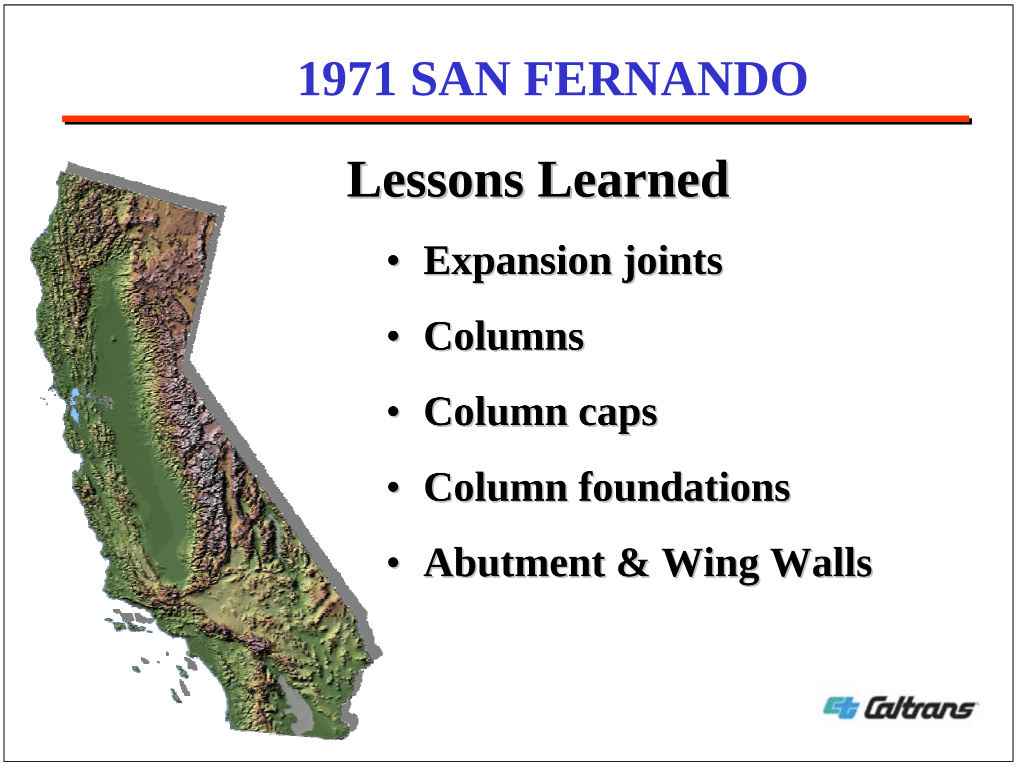
North Connector Overcrossing

1. Left slide shows movement did occur in the North Connector at the time of 1971 San Fernando Earthquake as shown.
2. Right slide shows how this structure later collapsed in the Northridge Earthquake as shown above.

   - Pier 2 failed

   - Restrainers at hinge 1 failed

   - Pier 2 was significantly shorter (stiffer) than adjacent piers 3 and 4



1. Expansion joints – (i.e.extend seat width)
2. Columns – inadequate ties, both in size and spacing (i.e. increase confinement)
3. Column caps – lack of reinforcement tying column caps to the deck/superstructure
4. Column foundation – inadequate anchorage of main reinforcement bars (i.e.
5. Abutment walls & wing walls – need to strengthen these elements to better engage forces transmitted through backfill earth pressures

1987 WHITTIER

1. The 1987 Whittier earthquake again demonstrated the inadequacies of pre-1971 column designs.
2. There were no collapses but the damage observed led to increased emphasis on basic research into practical methods for retrofitting existing columns.

1989 LOMA PRIETA

•1989 Loma Prieta

1. Legislative response was significantly greater than in previous events

    •Loss of life

    •Loss of critical routes

2. Resulted in acceleration of the Bridge Seismic Retrofit Program, and funding for research.

3. The next couple of slides will focus on the Cypress Viaduct and how the structure collapsed.

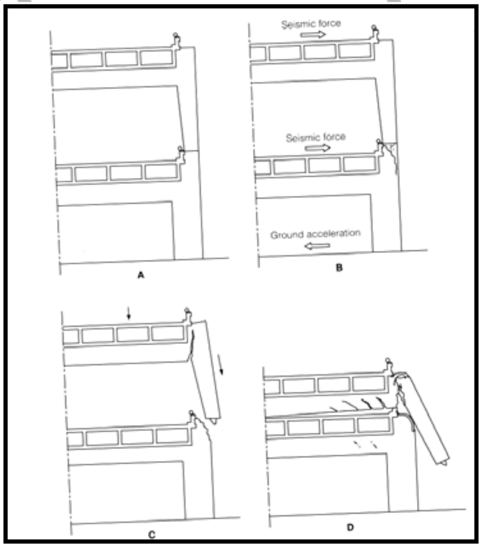
1989 LOMA PRIETA

1. View of several bents that collapsed on the Cypress Viaduct.
2. The Seismic Advisory Board report “Competing Against Time” notes these as Type B1 Bents.

Figure 10-50 pp 174 Competing Against Time

1989 LOMA PRIETA

Typical Failure Sequence

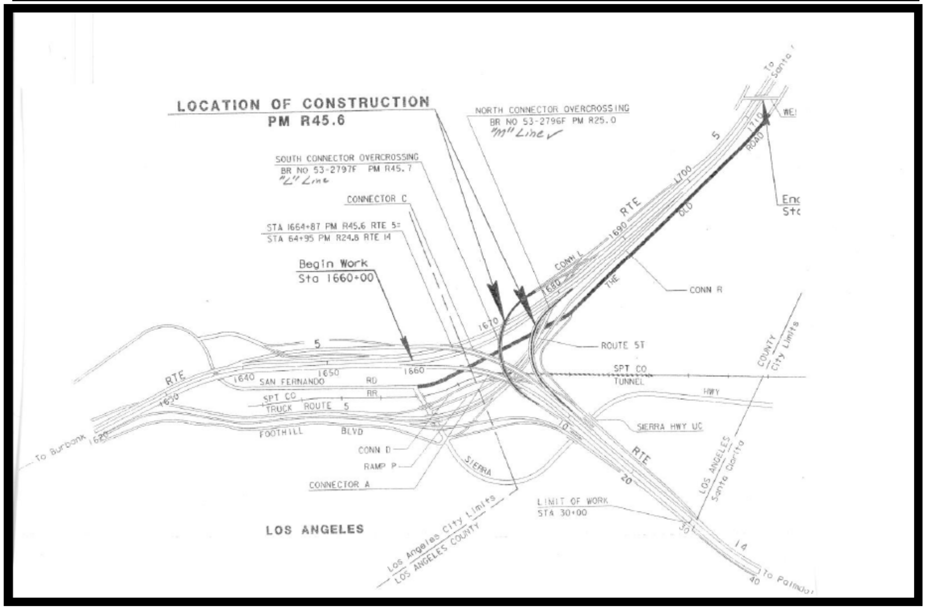


1. This shows the typical failure sequence for a Type B1 Bent.
2. Conclusions (pp 188 Competing Against Time)
    A. Analyses and design of the Cypress Viaduct performed between 1949 and 1954 had little design information available on dynamic effects, realistic ductile design, and ductile details.
    B. Design of the Cypress Viaduct was in conformance at the time, but today, we can identify deficiencies:
        - Structure lacked redundancy
        - Structure lacked ductility (confinement, development, etc.)
        - Lack of capacity to absorb energy
3. Longitudinal restrainers helped, but did not address column ductility.

1994 NORTHRIDGE

1. The Northridge earthquake demonstrated again that there were still many seismic vulnerabilities that needed focus.
2. Retrofitted structures performed well.
3. But questions about;
    a) near fault effects,
    b) unbalanced frames,
    c) vertical ground motions, and
    d) the performance of early retrofit details surfaced and demanded attention.
4. The Phase 2 Retrofit Program, focused on multi-column bents, started in 1995 on the heels of the Phase 1 Retrofit Program.

1994 NORTHRIDGE



1. This is a contract plan view of the replacement structures for:

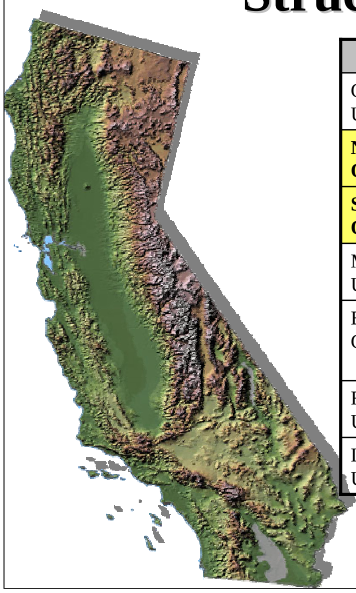
    a. South Connector Overcrossing – damaged in Northridge, but didn’t collapse

    b. North Connector Overcrossing – partial collapse (end spans)

2. This plan view also shows that the 14/I-5 interchange is complex with several connectors in close proximity.

1994 Northridge

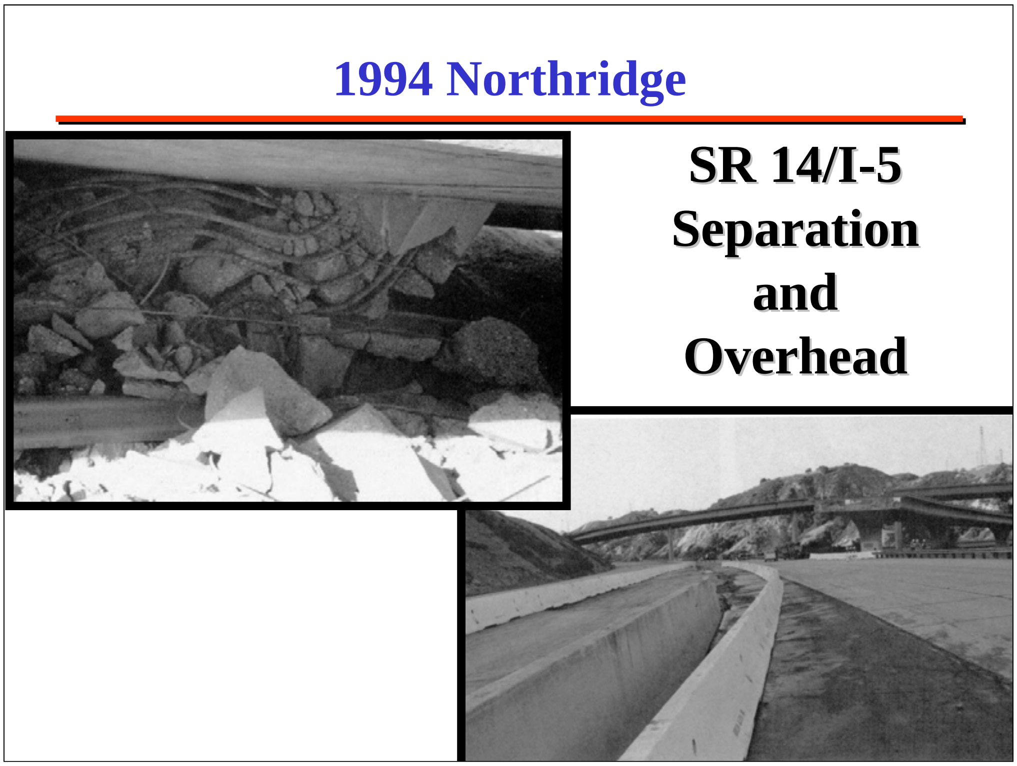
Structures That Collapsed



Bridge	Route	Probable cause of collapse
Gavin Canyon Undercrossing	I-5	Skew geometry and unseating of expansion joints
N. Connector Overcrossing	SR-14/I-5	Short column brittle shear failure
Separation & Overhead	SR-14/I-5	Short column /Long column frames
Mission & Gothic Undercrossing	SR-118	Flexure/shear failure in architectural flared columns at the bottom of flare
Bull Creek Canyon Channel Undercrossing	SR-118	Flexure/shear failure in shortened columns by channel wall and transverse reinforcement ratio
Fairfax & Washington Undercrossing	I-10	Flexure/shear failure of short and stiff columns
La Cienega & Venice Undercrossing	I-10	Brittle shear failure of stiff columns

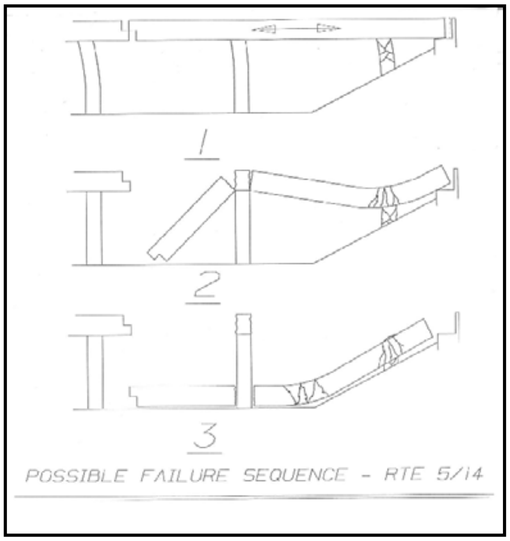
Show a list of structures that collapsed in the Northridge Earthquake - - then focus on 5/14 Interchange.

Figure 4-6 pp 28 - Figure 3-8 pp 20
Continue Challenge



1. Top Left: Short column failure of the 14/I-5 Separation and Overhead. This is Pier #2
2. Bottom Right: Shows completed demolition. (Spans 1, 2, and 3 and piers 2 and 3 removed)

1994 NORTHRIDGE



1. This shows the probable sequence of collapse of the 14/I-5 Separation and Overhead.

   - Short stiff column next to abutment fails

   - Unseating of hinge

   - Spans collapse

Figure 4-5 pp 28 Continue Challenge
Photo 53 pp 158 GB

1994 Northridge

SR 14/I-5 Separation and Overhead

1.Top Right shows the 1994 Northridge collapse of the 14/I-5 Separation and Overhead.

2.Bottom Left - Repeating an earlier slide of 5/14 Separation and Overhead (1971 San Fernando Earthquake).

3.A common misconception following the Northridge Earthquake was that structures that collapsed during the 1971 San Fernando Earthquake collapsed again during the Northridge Earthquake:

- 1971 collapse was in a different separation structure.
- The two bridge sections that collapsed in the Northridge earthquake were under construction during the 1971 San Fernando Earthquake.
- All columns were complete during the 1971 Earthquake and had pre-1971 details (#4 @ 12 transverse column reinforcement)

More – see pp 27, Continuing Challenge

Figure 4-4 pp 27 Continue Challenge

1994 Northridge

SR 14/I-5 North Connector Overcrossing

1. This slide shows the collapse of the North Connector Overcrossing.
2. Both the 14/I-5 Separation and Overhead and the North Connector Overcrossing bridge failures can be attributed to brittle shear failure of short stiff columns.
3. These columns, proportional to their stiffness, attracted more force than their move flexible adjacent bents.
4. Which column failed

   - Pier 2 failed

   - Restrainers at hinge 1 failed

   - Pier 2 was significantly shorter (stiffer) than adjacent piers 3 and 4

1994 Northridge

5/14 Interchange

Shows collapsed end spans of the 14/I-5 Separation and Overhead over I-5 in the Northridge Earthquake.

1994 Northridge

I-5 Interchange Reconstruction

Reconstruction, as shown today of the I-5 Interchange.

1994 Northridge

1. Top: Special Hinge
2. Bottom: Column Isolation

Seismic Research

1906 – 1971 – Significant time between major events.

1971 – Legislative response to San Fernando is limited.

1986 – Secured funding for Seismic Research on columns.

1987 – Whittier Earthquake showed inadequate column details.

1990 – Research tests initiated in 1986 completed.

1991 – Current – Seismic Research is funded at $5 mil per year.

2007 – Focus on continued funding for seismic research.

Show a summary of research trends and impacts of major earthquakes on research.

1906 – 1971 : Not much happened, 65 years pass without a major event.

1971 - Legislative response was limited.

1986 - Funds for limited research on seismic design secured, focus was on columns and column retrofit strategies.

1987 - Whittier Earthquake demonstrated inadequacies of pre – 1971 column designs.

1990 - Research tests initiated in 1986 completed. Annual expenditure for research at $500,000.

1991 – 1994 - By 1991, over 35 research projects are underway under a budget of 7 million, through 1994, Seismic Research is funded at approximately 5 million per year, which is a 10-fold increase over 500,000 per year in 1990.

1995 - Post Northridge Seismic Research continues at approximately 5 million per year. 5 million per year became a separate line item in the budget for continuous research.

2007 - Focus on continued funding for Seismic Research. Articulating the need for continued Seismic Research becoming more important, sustain the level of Seismic Research.

Earthquake Retrofit Program

1971 – Caltrans initiate Seismic Retrofit Program (Phase 1)

1970's – Budget limitations slow Retrofit Funding.

1989 – Phase 1 Retrofit Program initiated in 1971 is completed.

1990 – Column retrofit well underway.

1995 – Phase 2 Retrofit Program focused on multi-column bents.

2001 – 98 percent of bridges in Phase 2 Retrofit Program are completed.

Caltrans

1971 - Caltrans initiated the first "Seismic Retrofit Program" (called Phase 1) which focused on midspans hinges and abutment joints.

Late 70's - Budget limitations "slow progress" on the retrofit program. Interest in funding Seismic Retrofit

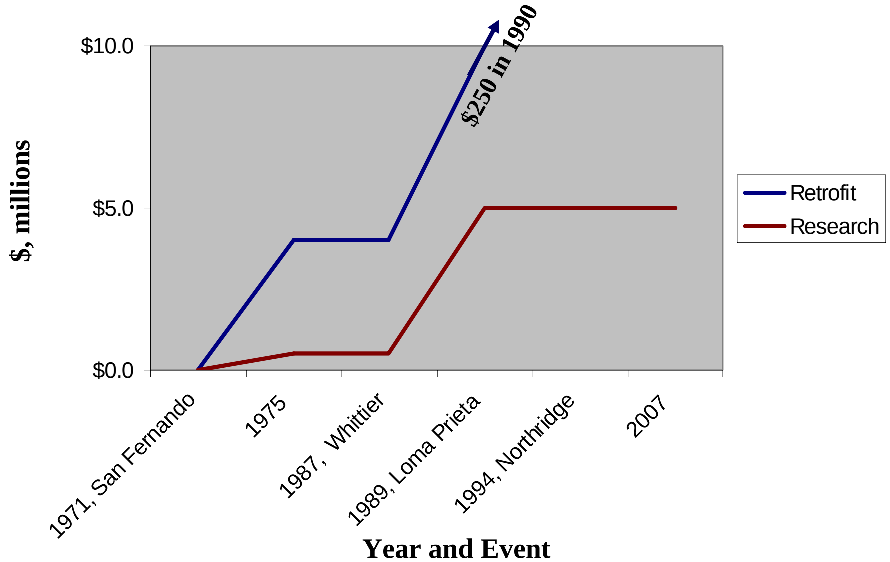
1989 - Phase 1 Seismic Retrofit Program initiated in 1971 is completed. Hinge Retrofit cost was 55 million or 4 million per year, average between 1975 and 1989. Post Loma Prieta Legislative response greatly increased. Seismic Retrofit Program accelerates.

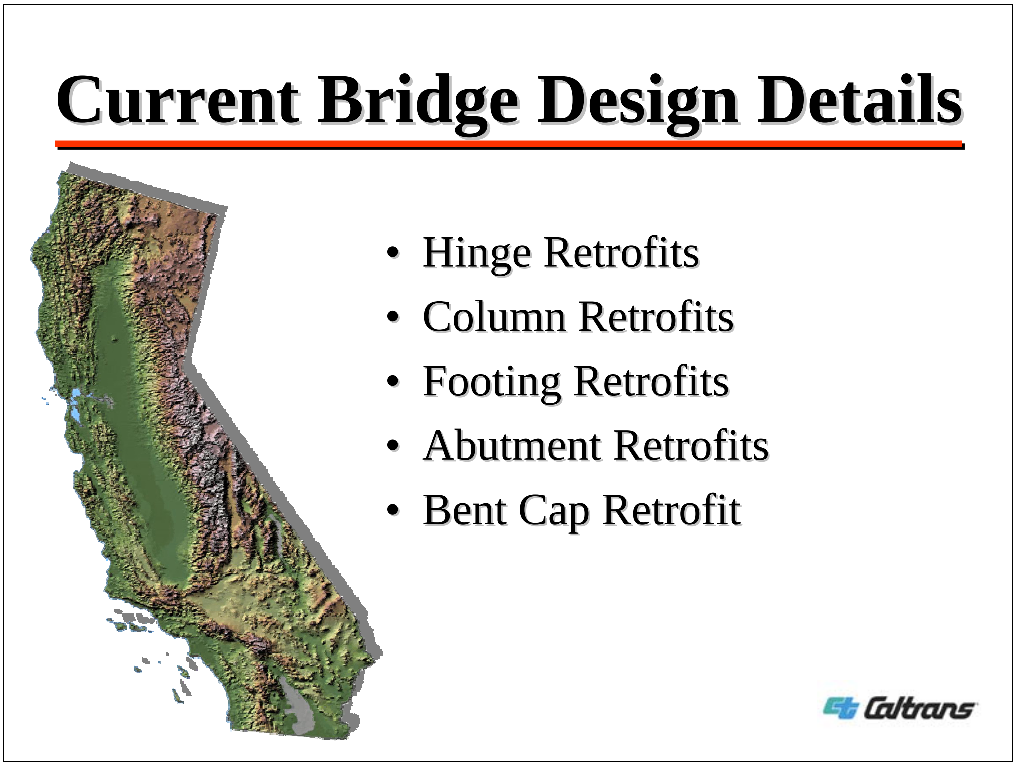
1990 - First 100 bridges were having columns retrofitted. Initial funding for Seismic Retrofitting increases 5-fold, to 16 million per year. Followed by another increase to 250 million per year.

1995 - Phase 2 Retrofit Program focused on multi-column bents.

2001 - 98% of bridges in Phase 2 Retrofit Program are completed.

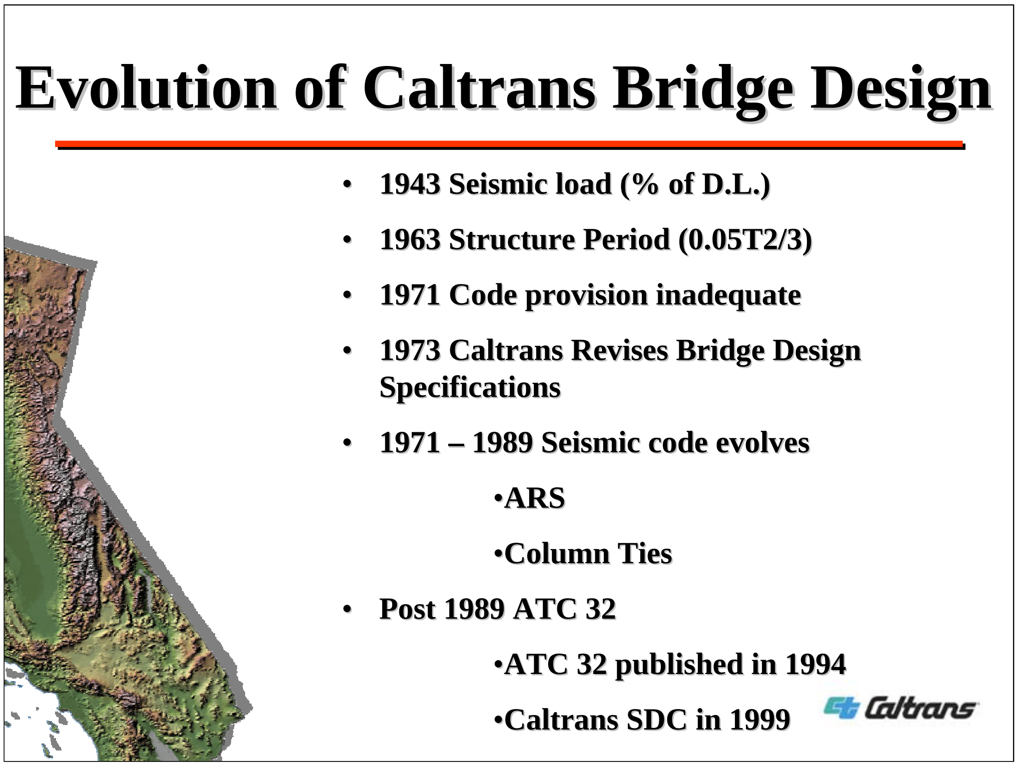
Retrofit & Research Programs





(Consider showing details/slides of presentation given in Taiwan.)

The next few slides show details commonly used in the retrofit of existing structures.



1943 – California State Division of Highways introduced a specific static seismic lateral load requirement into its design seps for the 1st time (% of D.L.)

1963 – Bridge Department adopted the Structural Engineers Association Code EQ = KCD. K = ~,   C = Base sen coefficient, D = Dead Load, = 0.05 $T^{2/3}$ 1971 Earthquake proved this to be inadequate.

1971 – Damages to bridges during the 1971 San Fernando Earthquake made it clear that the 1963 Code provision was inadequate for bridges. Therefore, the California Division of Highways immediately increased the 1963 Code force level by a factor of 2 for bridges on spread footings and 2.5 for bridges on pile foundations.

1971-1989 – Research results from 1971 San Fernando and ATC-6 led to Caltrans implementing a new bridge design criteria. Key changes:

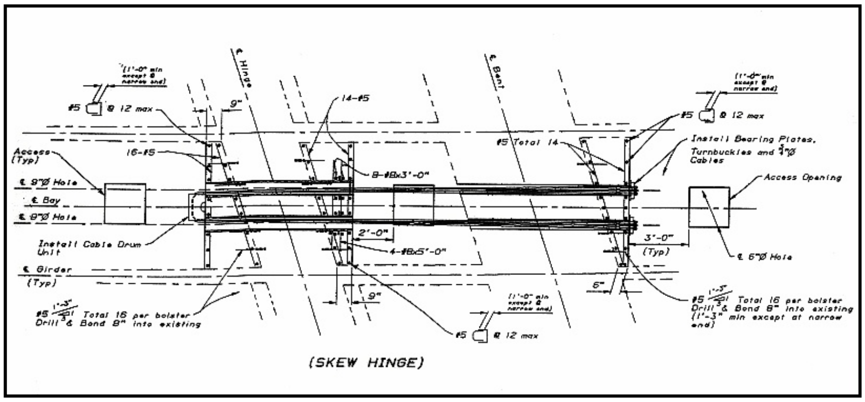
- ARS (Accel. Resp. Spect.) was adopted.
- Specifications of robust spiral ties for columns

Post 1989 – Following Loma Prieta Earthquake, Caltrans accelerated retrofit research:

- SAB Was Appointed
- PEER review panels were selected for the retrofit or replacement of San Francisco Viaducts
- ATC-32 was initiated to revise /improve bridge design criteria. Portions of this have been adopted by Caltrans.

Current Bridge Design Details

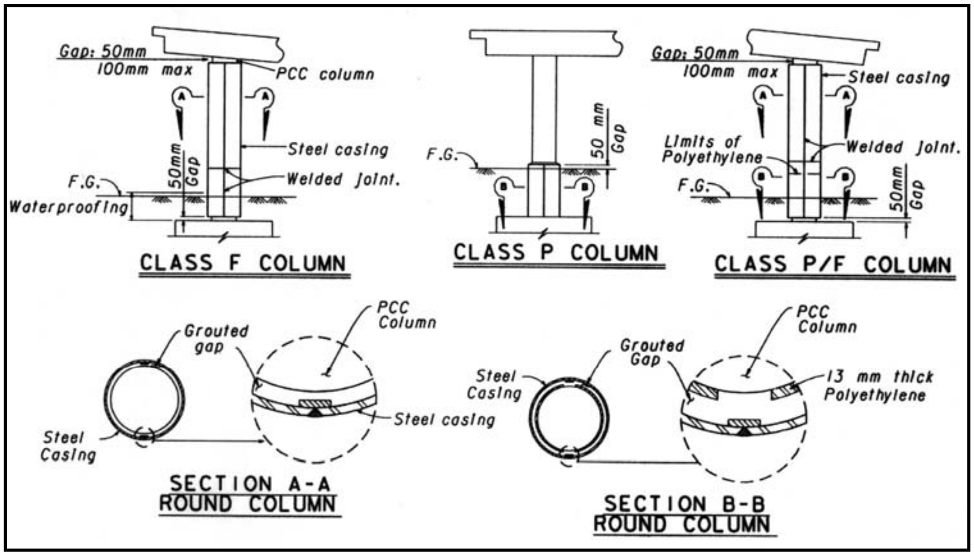
Hinge Retrofit



1. This is a plan view of a hinge retrofit.
2. Cable length allows for an elastic elongation.

Current Bridge Design Details

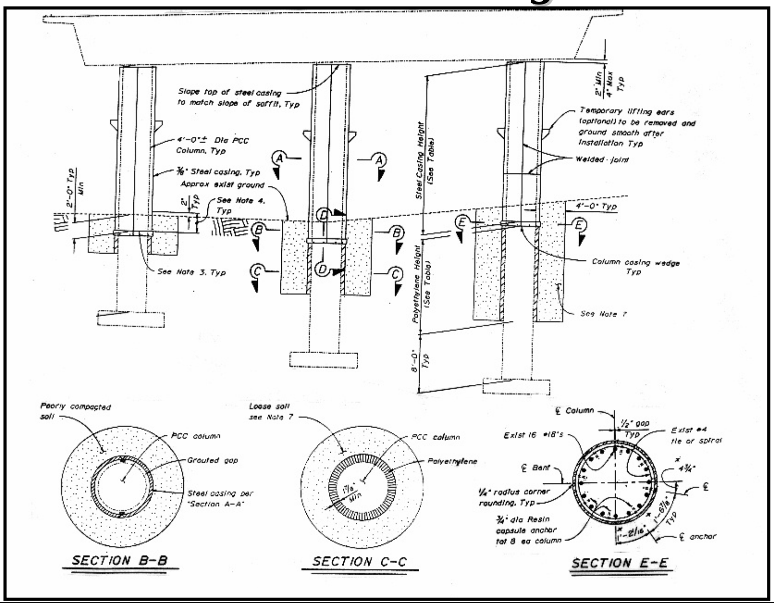
Steel Column Casing



Partial and Full column casing limits.

Current Bridge Design Details

Isolation Casing

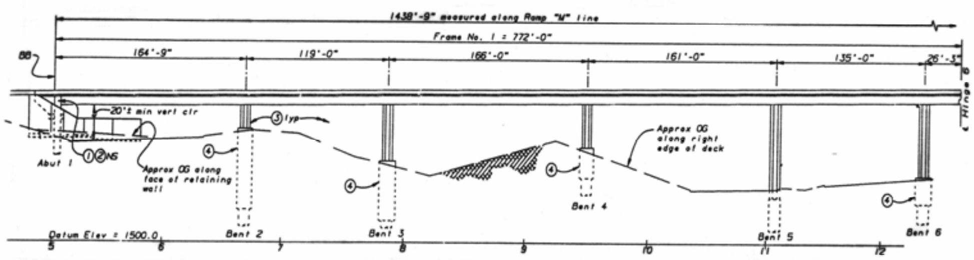


1. Column isolation allows for balance stiffness between columns.
2. This would have been a good detail to eliminate short, brittle column failures experienced in the Northridge Earthquake.

- 14/I-5 North Connector
- 14/I-5 Separation and Overhead

Current Bridge Design Details

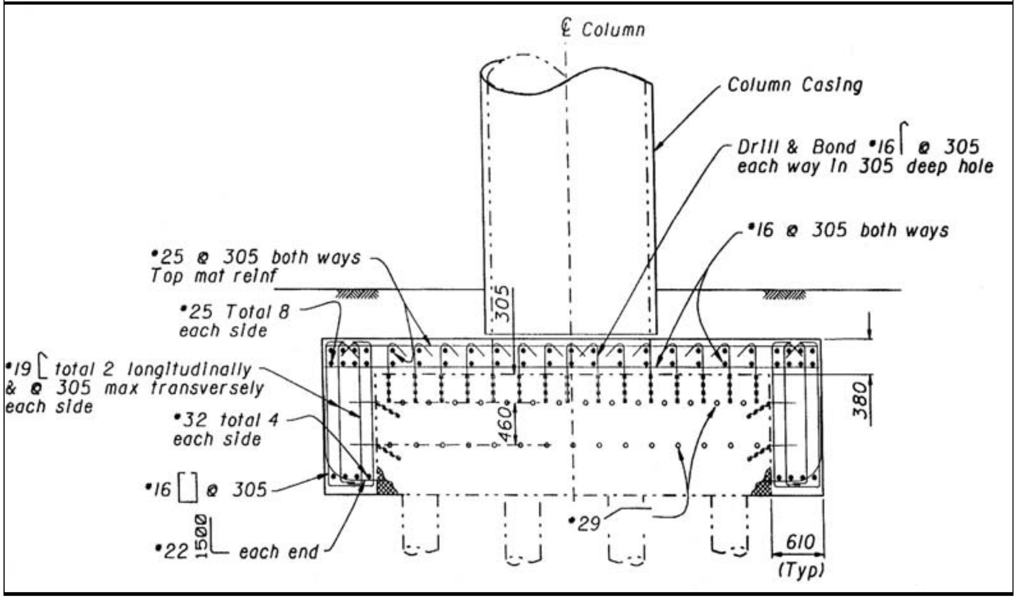
Isolation Casing



1. Balanced column stiffness is important transversely (previous slide) and longitudinally.
2. Longitudinal isolation helps to balance “frame” stiffness.

Current Bridge Design Details

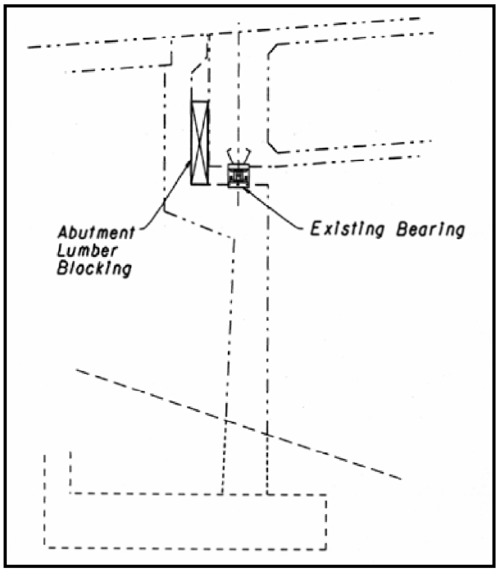
Footing Retrofit



1. This is a typical footing retrofit.
2. The objective is to keep the footing or substructure elastic and force a plastic hinge in a well confined column section.
3. Forcing a plastic hinge in the column as opposed to a footing or superstructure is often referred to as “capacity protected” design.

Current Bridge Design Details

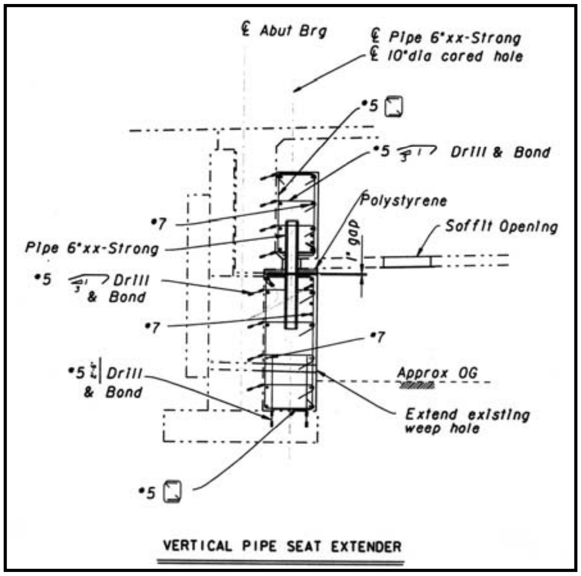
Abutment Retrofit



1. This is an abutment retrofit designed to fully engage the soil behind the superstructure.

Current Bridge Design Details

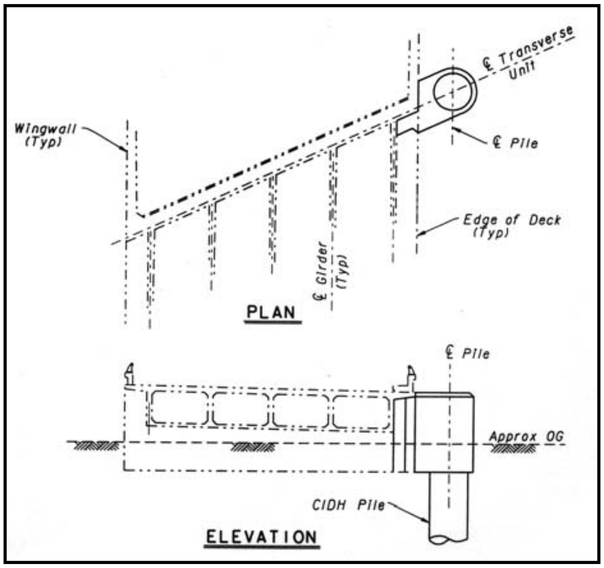
Abutment Retrofit



1. This is an abutment retrofit designed to primarily provide lateral (transverse) restraint during a seismic event.
2. The retrofit mechanism engages the existing foundation to restrain the superstructure both transversely and longitudinally.

Current Bridge Design Details

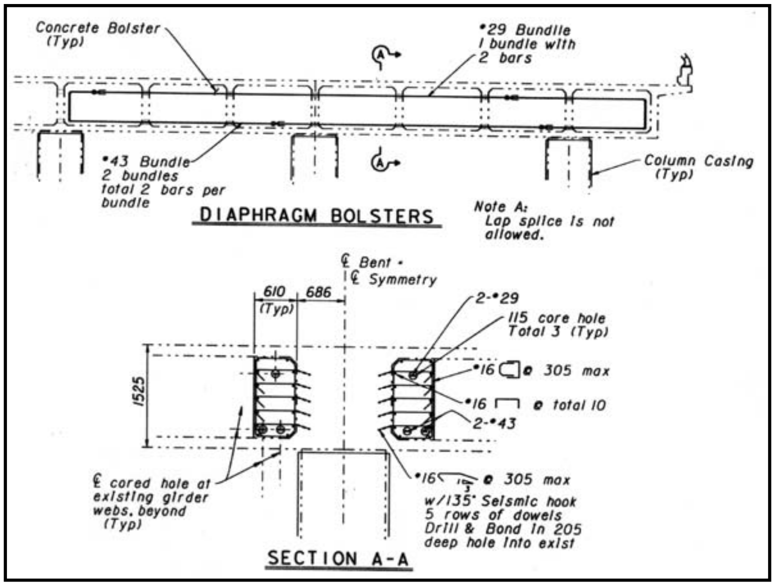
Abutment Retrofit



1. This is an abutment foundation retrofit. The pile primarily provides restraint in the transverse direction.
2. Adding a pile on both sides can also assist in longitudinal restraint as well as in the transverse direction.

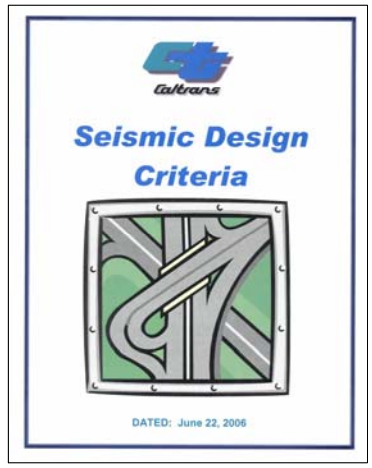
Current Bridge Design Details

Bent Cap Retrofit



1. This is an elevation view and section view (bottom) of a bent cap retrofit.
2. This type of retrofit provides “capacity protection” for the superstructure. It is designed to keep the superstructure in the elastic range, forming a plastic hinge in a well confined column section during a seismic event.

Caltrans Current
Seismic Design Criteria, SDC



•Creates a single comprehensive document outlining Caltrans current seismic design criteria, which has been evolving since the 1989 Loma Prieta Earthquake

•Ensures consistent application of Caltrans seismic design practice

•Performance Based (means optimize strain levels and control damage, to achieve serviceability level required)

•Ductile Response at Predetermined Locations

•Capacity Design Principles

•Redundancy

•Emphasis on Proportioning and Balanced Geometry

Opportunities – Get Prepared
National Seismic Code

1971 San Fernando Earthquake →

1973 Caltrans Seismic Design Criteria (SDC)

1975 AASHTO Interim Specifications for Highway Bridges

1981 ATC-6, Updated Caltrans SDC

1988 AASHTO Std Specs - Division IA

1994 AASHTO LRFD Specs

1996 ATC-32 Published

1999 New Caltrans SDC

2002 NCHRP 12-49; So Carolina SDC

2007 New Guide Specification Ballot

1971 – San Fernando is a "wake-up" call to update seismic design specifications. Caltrans immediately begins work on revising seismic design criteria.

1973 – Caltrans issues new seismic design criteria for bridges.

1975 – AASHTO uses Caltrans criteria to issue new "Interim Specifications for Highway Bridges."

1981 – The Applied Technology Council (ATC) 6 issues seismic design guidelines for bridges, which was sponsored by FHWA. This was adopted immediately by Caltrans and became the basis for Caltrans Seismic Design Specifications.

1988 – AASHTO Std. Specifications – Division 1-A

1994 – AASHTO first edition of LRFD Specifications

1996 – ATC-32 published "Improved Seismic Design Criteria for California Bridges," which formed the basis for new Caltrans SDC.

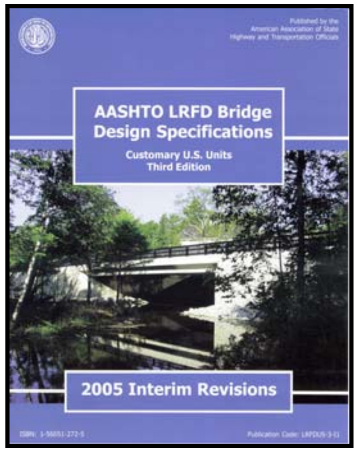
1999 – Caltrans new SDC, based on ATC-32.

2002 – NCHRP 12-4-9 is published

2007 – New specifications proposed

- Guide specifications
- Amended LRFD Specifications (formerly Division A-1)

AASHTO LRFD
Standard Specifications for Highway Bridges



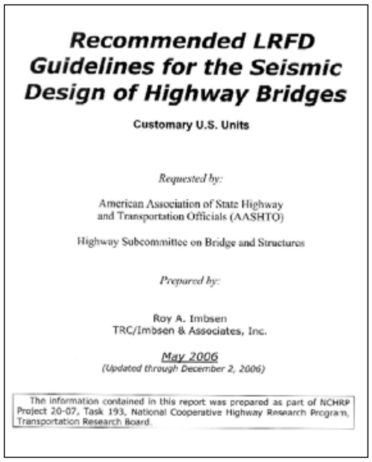
1. Next I will cover how the AASHTO LRFD Bridge Design Specifications are updated.
2. Proposed Ballot for 2007 Annual Meeting for the subcommittee on bridges and structures will be proposed by the technical committee for seismic design of the next annual meeting.
3. The AASHTO Technical Committee for Seismic Design (T-3) will submit one ballot item to adopt both of the following:

a) LRFD Seismic Design Guide Specifications

b) USGS 1000 Year Maps and Accompanying Changes into Current AASHTO LRFD Bridge Design Specifications

4. I will cover how the AASHTO committee is structured later.

Guide Specification "Proposed"



Recommended LRFD Guidelines for the Seismic Design of Highway Bridges

Customary U.S. Units

Requested by:

American Association of State Highway and Transportation Officials (AASHTO)

Highway Subcommittee on Bridge and Structures

Prepared by:

Roy A. Imbsen
TRC/Imbsen & Associates, Inc.

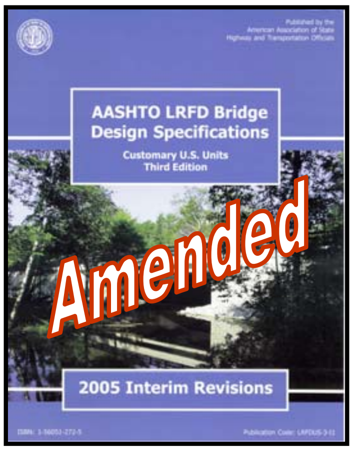
May 2006
(Updated through December 2, 2006)

The information contained in this report was prepared as part of NCHRP Project 20-07, Task 193, National Cooperative Highway Research Program, Transportation Research Board.

- Incorporate Current Best Practices
- USGS 1000 Year Seismic Hazard Maps
- Multiple Zone Criteria including No Analysis
- Displacement Based Approach
- Capacity Design Principles
- Zone-Specific Detailing Requirements

The "Guide Specification for Seismic Design of Highway Bridges" will be a ballot item at this years annual AASHTOO meeting for the Subcommittee on Bridges and Structures in Delaware this July!

Amended LRFD Specifications "Proposed"

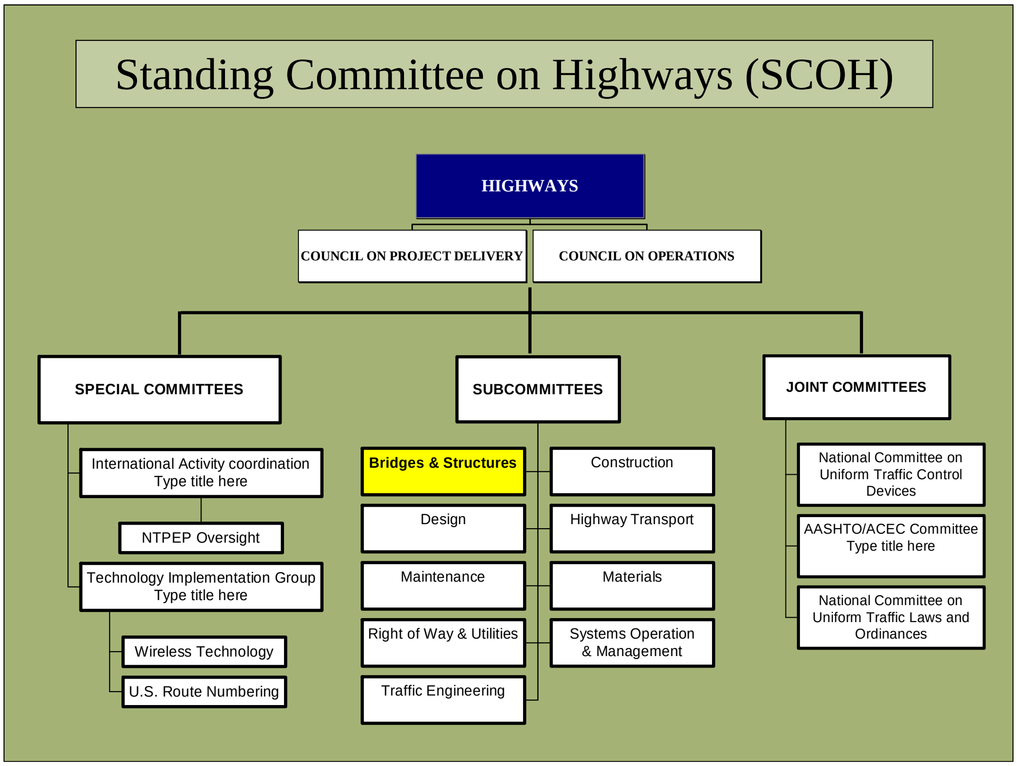


- Modify existing LRFD Specifications
- USGS 1000 year Seismic Hazard Maps
- Allows use of Elastic Design utilizing R Factors

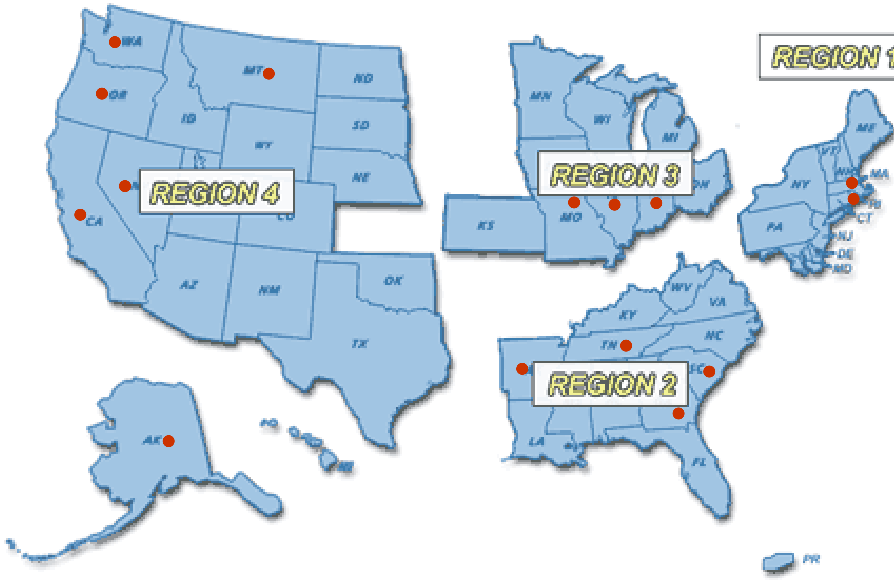
1. The current LRFD Bridge Design Specs plus 1000 year maps will be ready for ballot in 2007
    - Draft presented to T-3 in December 2006
    - T-3 comments to be incorporated into final proposal
2. Incorporates Latest USGS Seismic Hazard Maps, which use a 1000 year return period.
3. Zone 2: Seat Width and Column Flexure, Shear and Confinement Requirements similar to Zones 3 and 4
4. Allows Continued Use of Elastic Design Utilizing R Factors

The membership of the American Association of State Highway and Transportation Officials is composed only of government officials.

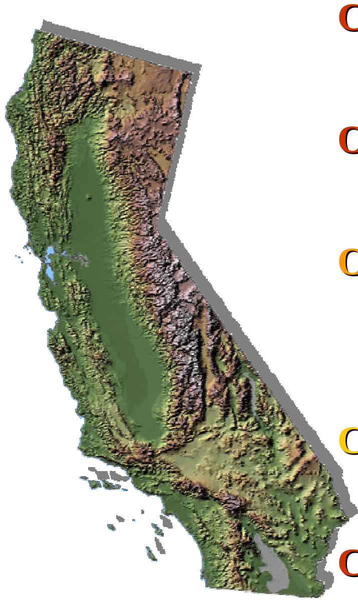
Departments or Agencies of the States of the United States, Puerto Rico, and the District of Columbia, and the United States Department of Transportation, FHWA, which is an ex-officio member.


Standing Committee on Highways (SCOH)
HIGHWAYS
COUNCIL ON PROJECT DELIVERY
COUNCIL ON OPERATIONS
SPECIAL COMMITTEES
SUBCOMMITTEES
JOINT COMMITTEES
International Activity coordination Type title here
NTPEP Oversight
Technology Implementation Group Type title here
Wireless Technology
U.S. Route Numbering
Bridges & Structures
Design
Maintenance
Right of Way & Utilities
Traffic Engineering
Construction
Highway Transport
Materials
Systems Operation & Management
National Committee on Uniform Traffic Control Devices
AASHTO/ACEC Committee Type title here
National Committee on Uniform Traffic Laws and Ordinances

T-3 “Members”



Challenge – Opportunity Cycle



Challenge

- Action Proposed

Opportunity

- Get Prepared

Opportunity

- National Code Changes
- International Collaboration

Continuing Challenge

- Stay Prepared

Challenge (back to the top)

Challenge
Seismic Event / Extreme Event
Initial Response "Emergency"
History of Events and Lessons Learned
Action Proposed
Opportunity
Legislative and Programmatic Changes
Get Prepared
Continuing Research and Advance State-of-the-Art Practice
Opportunity
National Code Changes
International Collaboration
Continuing Challenge
Stay Prepared
Competing Against Time (Maintain Interest)
Other Extreme Events
Challenge / Opportunity Cycle

LANDSLIDE: FERGUSON SLIDE (Hwy 140), CA - April 2006

Rock slide and material began sliding on to State Highway 140 in the Sierra National Forest, approximately 6 miles west of Yosemite National Park. Caltrans temporarily managed to open the road to one lane, but by June 2006 the slide moved even more, closing the road completely.

SCOUR / FLOODING: SHERMAN ISLAND (Route 160), Bay Area, CA

January 2006

Overtopping of a levee adjacent to the San Joaquin River during high winds and Higher High tide.

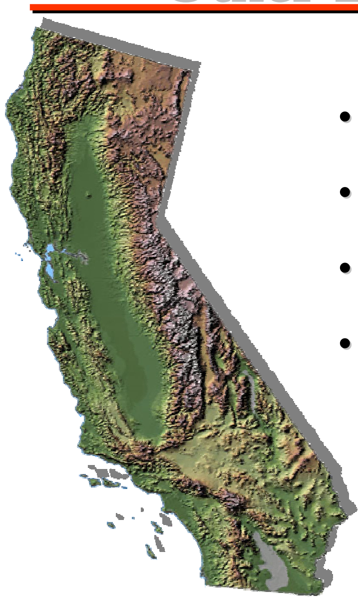
BLAST: CONFIDENTIAL

WIND/HURRICANE: Hurricane Katrina - August 2005

The sixth-strongest Atlantic hurricane ever recorded and the third-strongest hurricane on record that made landfall in the United States.

Damage to the Biloxi-Ocean Springs bridge.

Looking Forward –
Other Extreme Events

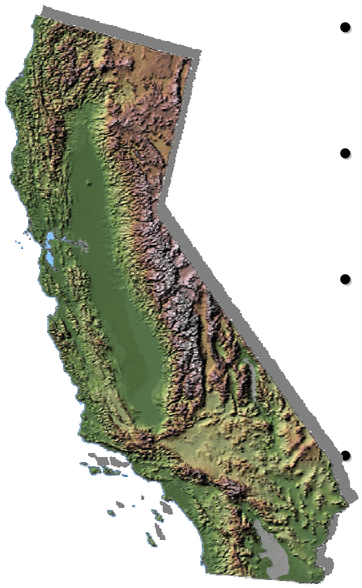


- **Wind / Hurricane**
- **Scour and Flooding**
- **Blast**
- **Applying Seismic Design / Research to Other Events**

Caltrans

- An **Opportunity** from dealing with past **Challenges** is applying new knowledge to other areas
- There are More than Earthquakes
    - Multi-hazard Extreme Events
    - Linking Risk Assessment, Risk Perception and Risk Management
    - California
        - Flooding / Scour
        - Landslides
    - Comparisons of Seismic Design/Research Findings to Other Extreme Events

Summary



- Brief History of California Major Seismic Events
- Seismic Research and Caltrans Retrofit Programs
- Continuing Development of Seismic Design Criteria (SDC) for California Bridges
- Challenge & Opportunity Cycle

Caltrans

References:

All publications may be accessed through the Catalog of the University of California Libraries: **MELVYL web: telnet** database at http://www.lib.berkeley.edu/ITSL/highways.html

1. **The San Fernando Earthquake : Field Investigation of Bridge Damage** / [by] George G. Fung ... [et al.], **Publisher:** Sacramento : California Dept. of Public Works, Division of Highways, 1971.

2. **Competing against time** : report to Governor George Deukmejian / from the Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake ; George W. Housner, chairman ; Charles C. Thiel Jr., editor. **Publisher**[Sacramento, Calif.] : State of California, Office of Planning and Research, 1990.

3. **Northridge earthquake**, 17 January 1994 : **PEQIT report** / Post Earthquake Investigation Team. **Publisher**[Sacramento] : California Department of Transportation, Division of Structures, [1994]

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4. **The continuing challenge : Report on the Northridge, Earthquake of January 17, 1994** / submitted to the director, Dept. of Transportation, State of California by the Seismic Advisory Board. Publisher[Sacramento?] : The Department, c1994

5. **The Race to Seismic Safety : Protecting California's Transportation System** / submitted to the director, California Dept. of Transportation by the Caltrans Seismic Advisory Board, Joseph Penzien, Chairman ; Charles C. Thiel Jr., editor. Publisher[Sacramento : California Dept. of Transportation], 2003.