Post-Earthquake Bridge Inspection

Cypress Viaduct on Route 880 after the 6.9 Loma Prieta EQ, 1989

Ching Chao, PE, MS; Vinh Dang, PE
Office of Structure Maintenance & Investigations, Caltrans
Provide a safe, sustainable, integrated and efficient transportation system to enhance California’s economy and livability
EOC Emergency Operation Centers

LA Regional Transportation Management Center
ShakeCast

A post-earthquake decision-making and rapid-response tool
**ShakeCast**

- Retrieves measured shaking data within minutes after an earthquake.
- Compares shaking distribution with unique bridge vulnerabilities.
- Provides hierarchical lists and maps of bridges most likely impacted.
- Emails bridge and facility location and inspection priority information to responders within 15 minutes following events with a magnitude greater than 4.0.
- Automatically generates products for direct use in Google Earth, ArcGIS, and Excel
- Provides a suite of tools on ShakeCast website

**USGS ShakeCast website:**

http://earthquake.usgs.gov/research/software/shakecast/
ShakeCast

Caltrans ShakeCast Preliminary Earthquake Bridge Impact Report

Event Summary
Name: (Unnamed Event), Version 1
Magnitude: 6.9
ID: Loma_Prieta_scte-1
Location: 7 km NNE of Apts, CA
Latitude: 37.04
Longitude: -121.88
Time: 1989-10-18 00:04:00 GMT

Bridges Assessment Summary

<table>
<thead>
<tr>
<th>Priority</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>High priority for full engineering assessment</td>
</tr>
<tr>
<td>Medium-High</td>
<td>Medium priority for full engineering assessment</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium priority for full engineering assessment, quick visual inspection likely sufficient</td>
</tr>
<tr>
<td>Low</td>
<td>Low priority for full engineering assessment</td>
</tr>
</tbody>
</table>

Bridges Assessment Details

[Table with bridge names, numbers, descriptions, priorities, and inspection methods]

Downloads & Resources

Caltrans Intranet Links:
- Caltrans ShakeCast Intranet
- Caltrans ShakeMap Products

GoogleEarth KML files:
- (save to your computer as a KML file and open with GoogleEarth)

ShakeCast Bridge Assessment
- Statewide Bridge Inventory
- Caltrans Real-time Traffic
- USGS Real-time Earthquakes
ShakeCast Preliminary Earthquake Bridge Impact Report

**Event Summary**

- Name: (Unassigned Event)
- Version: 1
- Magnitude: 7.5
- Location: San Jose, CA
- Location Long/lat: 37.3413, -122.0779
- Time: 21:40:00 GMT

**Bridge Assessment Summary**

- Maximum Peak 1 sec Spectral Acceleration: 5.0 g
- Maximum Acceleration: 1.3 g
- Total Number of Bridges Assessed: 108

<table>
<thead>
<tr>
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<th>Description</th>
</tr>
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<tbody>
<tr>
<td>High</td>
<td>High Priority for full engineering assessment</td>
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<tr>
<td>Medium-High</td>
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</tr>
<tr>
<td>Medium</td>
<td>Medium Priority for full engineering assessment</td>
</tr>
<tr>
<td>Low</td>
<td>Low Priority for full engineering assessment</td>
</tr>
</tbody>
</table>

**Bridge Assessment Details**

<table>
<thead>
<tr>
<th>Bridge Name</th>
<th>Bridge Number</th>
<th>Dist-City-Rte-PM</th>
<th>Inspection Priority</th>
<th>1sec Peak Spectral Acceleration (g)</th>
<th>Exceedance Ratio</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>raise Avenue OC</td>
<td>58 0114</td>
<td>04-SW-1019.55-BUT</td>
<td>High</td>
<td>106.3003</td>
<td>2.934</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Via Del Oro</td>
<td>37 0471</td>
<td>04-SV-009.1-71-SU</td>
<td>Medium-High</td>
<td>49.5111</td>
<td>2.472</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Constitution Way OC</td>
<td>33 5519</td>
<td>04-AL-A10.8-6.6-A</td>
<td>High</td>
<td>86.2755</td>
<td>1.416</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Median Road Underpass</td>
<td>37 0258</td>
<td>04-SL-020-R3.9-S</td>
<td>Medium-High</td>
<td>59.9229</td>
<td>1.222</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Campbell Underpass</td>
<td>37 0135</td>
<td>04-SL-017.12-CMB</td>
<td>High</td>
<td>70.2112</td>
<td>1.087</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Redwood Creek</td>
<td>35 0145</td>
<td>04-SV-016.2-RDVC</td>
<td>Medium-High</td>
<td>61.0924</td>
<td>1.064</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Stobb-Approach Lower Deck</td>
<td>34 0119</td>
<td>04-SF-080-1.46-SF</td>
<td>High</td>
<td>33.2578</td>
<td>1.657</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Holly Street OC</td>
<td>35 0307</td>
<td>04-SV-009.1-71-SU</td>
<td>High</td>
<td>65.904</td>
<td>1.048</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Route 1380 Separation (South)</td>
<td>33 0191</td>
<td>04-AL-A15.13-92-BER</td>
<td>Medium-High</td>
<td>59.9229</td>
<td>1.222</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Race Street Overflowing</td>
<td>37 0260</td>
<td>04-SL-020-R3.75-S</td>
<td>High</td>
<td>59.9229</td>
<td>1.222</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Pinole Parkway</td>
<td>34 0119</td>
<td>04-SF-080-1.46-SF</td>
<td>Medium-High</td>
<td>65.904</td>
<td>1.048</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>South Delaware Street UC</td>
<td>35 0158</td>
<td>04-SM-092-R11.51-S</td>
<td>High</td>
<td>35.1822</td>
<td>1.030</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>South Delaware Street UC</td>
<td>35 0158</td>
<td>04-SM-092-R11.51-S</td>
<td>High</td>
<td>35.1822</td>
<td>1.030</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Powell Street UC</td>
<td>33 0020</td>
<td>04-AL-A10.8-3.79-EMV</td>
<td>Medium-High</td>
<td>66.7668</td>
<td>1.020</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Redwood Harbor Overpass</td>
<td>35 0656</td>
<td>04-SV-010-1.5-RDVC</td>
<td>High</td>
<td>56.8606</td>
<td>1.018</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>MacArthur Avenue OC</td>
<td>37 0100</td>
<td>04-SL-020-L5.18-S</td>
<td>High</td>
<td>54.4613</td>
<td>1.012</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>N17-210 Connector</td>
<td>37 0516</td>
<td>04-SL-017.24-LGTS</td>
<td>High</td>
<td>86.2137</td>
<td>1.068</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>San Francisco Creek</td>
<td>35 0913</td>
<td>04-SM-092-R11.51-S</td>
<td>High</td>
<td>55.3670</td>
<td>1.007</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>N1287-520 Connector Separation</td>
<td>37 0396</td>
<td>04-SL-087-6.1-S</td>
<td>Medium-High</td>
<td>50.5654</td>
<td>1.001</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Blossom Hill Road OC</td>
<td>37 0343</td>
<td>04-SL-020-R3.55-S</td>
<td>Medium-High</td>
<td>49.4996</td>
<td>0.951</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Hawkins Slough Road OC</td>
<td>36 0899</td>
<td>05-SC-001-R2.27-WAT</td>
<td>Medium-High</td>
<td>56.8606</td>
<td>0.938</td>
<td>Limited view of bridge approaches.</td>
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<tr>
<td>Sun dissatisfaction</td>
<td>37 0263</td>
<td>04-SL-020-R3.41-S</td>
<td>High</td>
<td>52.8878</td>
<td>0.909</td>
<td>Limited view of bridge approaches.</td>
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<tr>
<td>Sunshine Road</td>
<td>37 0263</td>
<td>04-SL-020-R3.41-S</td>
<td>High</td>
<td>52.8878</td>
<td>0.909</td>
<td>Limited view of bridge approaches.</td>
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<tr>
<td>Winchester Boulevard OC</td>
<td>37 0195</td>
<td>04-SL-020-R3.41-S</td>
<td>Medium-High</td>
<td>55.327</td>
<td>0.898</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>Lincoln Avenue UC</td>
<td>37 0262</td>
<td>04-SL-020-R3.51-S</td>
<td>Medium-High</td>
<td>52.8878</td>
<td>0.898</td>
<td>Limited view of bridge approaches.</td>
</tr>
<tr>
<td>South Shore Glh</td>
<td>37 0360</td>
<td>04-SL-020-R3.51-S</td>
<td>Medium-High</td>
<td>42.3770</td>
<td>0.896</td>
<td>Limited view of bridge approaches.</td>
</tr>
</tbody>
</table>
## SM&I Earthquake Field Damage Report

**SM&I Disaster Command Center - Email: smidcc@dot.ca.gov Phone: (888) 893-9974**

<table>
<thead>
<tr>
<th>Bridge Number:</th>
<th>Date:</th>
<th>Time (24hr):</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bridge Name:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inspector 1:</strong></td>
<td><strong>Inspector 2:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Unit:</strong></td>
<td><strong>Unit:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Phone No.:</strong></td>
<td><strong>Phone No.:</strong></td>
<td></td>
</tr>
</tbody>
</table>

### Current Status:
- Open [ ]
- Open with Shoring [ ]
- Closed / Can Be Open [ ]
- Closed [ ]

### Restrictions:
- No Restrictions [ ]
- Operational [ ]
- Structural [ ]
- Investigate / Repair Prior to Open [ ]

### Damage:
- Damage [ ]
- No Damage [ ]
- No Additional Damage [ ]

### 15 Damage Summary:

### Repair Cost Estimates:
- None [ ]
- Low <$5K [ ]
- Medium $5K-$50K [ ]
- Medium-High $50K-$100K [ ]
- High >$100K [ ]

### Detailed Cost Estimates:

### Feature Damage (Detailed Damage):

- Approach Roadway:
- Approach Slabs:
- Superstructure:
- Wingwalls and Rails:
- Abutments:
- Expansion Joints:
- Hinges:
- Shear Keys:
- Bearings:
- Column/Path Caps:
- Foundation/Files:
- Retrofit:
- Other: 

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*Structure Maintenance & Investigations 1801 30th Streeet, Sacramento, CA, 95818 Phone: (916) 227-8831 Fax: (916) 227-8357*
EMERGENCY RESPONSE INSPECTION
Affix this sticker to the RIGHT BRIDGE RAILING next to the BRIDGE NAME(NUMBER LOCATION
DATE: _______ TIME: _____ BY: _______ PH#: _______
DATE: _______ TIME: _____ BY: _______ PH#: _______
DATE: _______ TIME: _____ BY: _______ PH#: _______
ANY BRIDGE CONCERNS CONTACT:
STRUCTURE MAINTENANCE AND INVESTIGATIONS (888) 893-9974
Structures Maintenance Automated Report Transmittal System

- Integrated Oracle Form Application database
- Compatible with NBIS, National Bridge Inspection Standards, coding guides & data reporting requirements
- Consistent with the design of the AASHTOWare® Pontis® Bridge Management System database
- Supports the entire cycle of bridge management, including Inventory, Inspection and Project and Program Development
- Used on Bridge Routine Inspection, Specialized Inspections, Hydraulics, Load Rating & Project Development
Bridge Inspection Records Information System

Provides an interface to as-built plans, inspection reports, and other documents pertaining to transportation structures in the state of California. The system currently contains over 950,000 documents.

RECORD TYPE AND SEARCH CRITERIA

![Diagram of record type and search criteria interface]
San Fernando Earthquake, 1971
Route 210/5 Interchange
San Fernando Earthquake, 1971

Route 14/5 Interchange
San Fernando Earthquake
Rte. 210/5 Separation & OH

Anchorage Failure at Base of Column

Lap Splices at Base or Lack of Development into the Footing
Non-ductile failure: Lack of Confinement Resulted in Rapid Loss of Section and Consequently, Rapid Loss of Strength.
San Fernando Earthquake
San Fernando Road OH (Route 210)

Lack of Confinement
San Fernando Earthquake, 1971

San Fernando Rd. OH, Loss of Girder Support
San Fernando Earthquake, 1971

Balboa Blvd. OC, South Abut Failure in Shear of Superstructure and End Diaphragm at Soffit
210 Interchange

Wingwall Damage at Abutment
Non-ductile details built by Caltrans had four main structural problems:

- Lack of confinement. (#4 @ 12” ties)
- Lap splice at the base of the column
- No top mat in footing
- Inadequate rebar development into the superstructure
Earthquake Damage to Bridge

- **Superstructure**
  - Loss of Girder Support
  - Rotation due to High Skew
- **Substructure**
  - Column Flexural Failure
  - Column Shear Failure
  - Column Anchorage Failure
- **Abutments**
  - Abutment Movement/Failure
  - Approach Settlement
- **Foundations**
  - Ground Movements
  - Liquefaction
Retrofit Approach

• **Collapse prevention by:**
  • *providing sufficient seat for displacement*
  • *allowing max ductility in the supporting members (columns)*
Column Retrofit

- Most common type of retrofit
- Previous design approach relies heavily on column’s inelastic capacity for ductile response
Steel Column Casings

- **Most Common Type of Column Retrofit**
- **Increase Flexural Ductility Capacity**
- **Develop Flexural Capacity of Existing Lap Splices**
- **Increase Shear Capacity**
Steel Shell Encased Around Existing Column-Filled With Grout
Column Retrofit - Steel Column Casings

- Thickness 5/8” min-1” max
- 2” Gap-Prevent Bearing on Soffit and Footing
- Weld Seams

Common Shapes are Circular and Elliptical
Column Addition
Additional Columns are Added to Strengthen Transverse Response

Originally a Single Column Bent
In-Fill Wall

Acts Like a Shear Wall

Improves Stability in Transverse Direction

RC Wall Securing Two Adjacent Columns Together
Not all bents are retrofitted-
Minimum one bent per frame
Link Beam Retrofit

Applicable to Tall Multicolumn Bents

Control Distribution of Transverse Forces

Beam Element Connected to Columns Within a Bent
Link Beam Retrofit

(a) Retrofit for reduced displacements.

(b) Retrofit for reduced cap beam forces.

(c) Retrofit for reduced footing forces.
Link Beam Retrofit

Retrofitted for Reduced Cap Beam Forces
Bent Cap Retrofit

Additional Strength to Ensure Elastic Response of Bent Cap
Bent Cap Retrofit in Progress

- Uses High Strength Threaded Bars
- Access Openings at All Bays Indicates Retrofit Work
Prevent girders from falling off their supports
Cable Restrainer

Preferred detail

- Tied into bent cap
- Each girder is tied independently
Unseating of Hinge Seat Leads to Collapse

Northridge Earthquake 1994, M 6.8
Gavin Canyon Undercrossing – Year Designed: 1965
Hinge Retrofit-Cable Restrainer

Uses Cables Anchored to One Side to Prevent Hinge From Unseating
Hinge Retrofit-Pipe Seat Extender

Allows Hinge Joint to Open and Close in Longitudinal Direction

Uses Steel Pipe Anchored to One Side of Hinge
Old way-seat width ~8-12”
New way-Seat width=24” min
Footing Retrofit

Enlarge Footing to Ensure Elastic Response and Prevent Overturning

Add Top Mat and Shear Reinforcements

Add Piles if Needed for Lateral/Tension/Compression Capacity
Footing Retrofit

Generally, Footing Retrofits are the Most Expensive

Cored Holes for Tiedowns

Generally, Footing Retrofits are the Most Expensive
Footing Retrofit-Tiedown Anchors

Uses Prestressed Anchors to Prevent Footing from Uplifting
Abutment Retrofit-Fill up Gap Behind Superstructure

Superstructure Should Engage and Break Backwall Before Damage to Columns

Gap-Preferred 2” or Less

Soil Behind Abutment is Mobilized and Absorbs Earthquake Loads Away From the Bents
Abutment Seat

New Design-30” Min
Abutment Retrofit

For Existing Bridge, Addition Seat Width May be Required

Seat Extender
Abutment Retrofit
Abutment Retrofit - Vertical Pipe Seat Extender

- Prevents Unseating at Abutment
- Additional Restraint to Abutment
Abutment Retrofit - High Skew Bridges

Tendency to Rotate Could Lead to Excessive Displacements at Abutments

- Unseating at the Abutment
  Leads to Collapse
Abutment Retrofit-High Skew Bridges

Excessive Displacement Due to Rotation

Collapse of Superstructure
Abutment Retrofit-High Skew Bridges

Provide External CIDH Pile at the Acute Corner of the Bridge
Abutment Retrofit-High Skew Bridges
Abutment Retrofit-High Skew Bridges
Shear Keys - New Bridge

Accept Transverse Seismic Loads at Abutments

Shear Keys Must Break Before Piles

External Shear Key

Internal Shear Key

Not Preferred - Difficult to Repair
Approach Slabs

For important bridges on lifeline highways, emergency vehicles must be able to get across.

San Fernando Earthquake Rte. 5/210
Approach Slab-New Bridge

Tie bars to backwall are provided to prevent approach slab settlement.
Approach Slab-Existing Bridge

Paving Notch Extension and Ties
Applicable to New Approach Slabs on Existing Bridge
Column Isolation Casing

Balance frame stiffness is necessary to efficiently distribute earthquake loads.

Isolation casings are provided to control columns stiffnesses across uneven grounds.
Loose Soils are Placed in the Casing to Allow Movement and Plastic Hinging Below Ground
Column Isolation Casing

External Debris and Dirt Should Be Prevented From Entering the Casing to Allow the Column to Move
Questions???