Performance of Precast Girder Bridges During Recent Earthquakes

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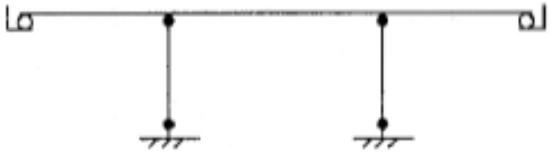
Longitudinal Response

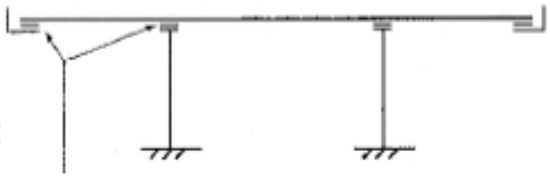
1



- Plastic hinges in inspectable locations or elastic design of columns.
- Abutment resistance not required as part of ERS
- Knock-off backwalls permissible

Longitudinal Response

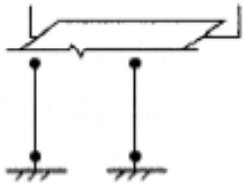
2



- Isolation bearings accommodate full displacement
- Abutment not required as part of ERS

Transverse Response

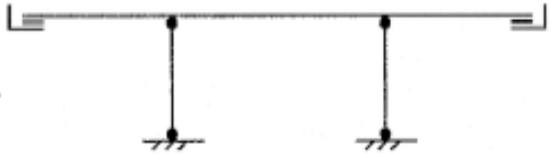
3



- Plastic hinges in inspectable locations or elastic design of columns
- Abutment not required in ERS, breakaway shear keys permissible

Transverse or Longitudinal Response

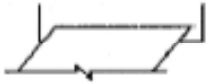
4



- Plastic hinges in inspectable locations or elastic design of columns
- Isolation bearings with or without energy dissipaters to limit overall displacements

Transverse or Longitudinal Response

5



- Abutment required to resist the design earthquake elastically
- Longitudinal passive soil pressure shall be less than 0.70 of the value obtained using the procedure given in Article 5.2.3

Longitudinal Response

6

- Multiple simply-supported spans with adequate support lengths
- Plastic hinges in inspectable locations or elastic design of columns

Caltrans Office of Earthquake Engineering is working to develop Earthquake Resisting Systems (ERS) for precast girder bridges that will have little damage for smaller earthquakes and prevent collapse for unexpectedly large earthquakes.

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	*<.17*	*.17-1.4*	*1.4-3.9*	*3.9-9.2*	*9.2-18*	18-34	34-65	65-124	>124
PEAK VEL.(cm/s)	<0.1	0.1-1.1	1.1-3.4	3.4-8.1	*8.1-16*	*16-31*	*31-60*	*60-116*	*>116*
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Magnitude 8.8

Saturday, February 27, 2010 at 03:34:14 AM at epicenter

Location 35.909°S, 72.733°W

Depth 35 km (21.7 miles)

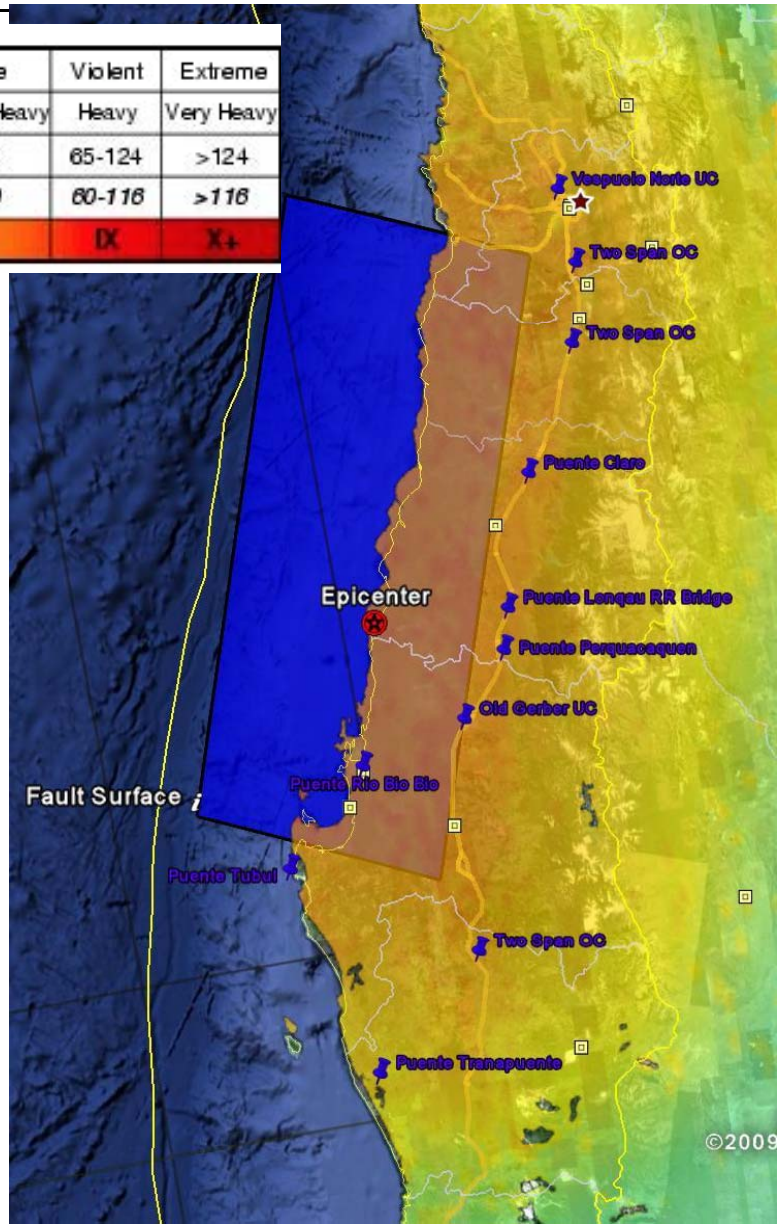
Offshore Maule Earthquake

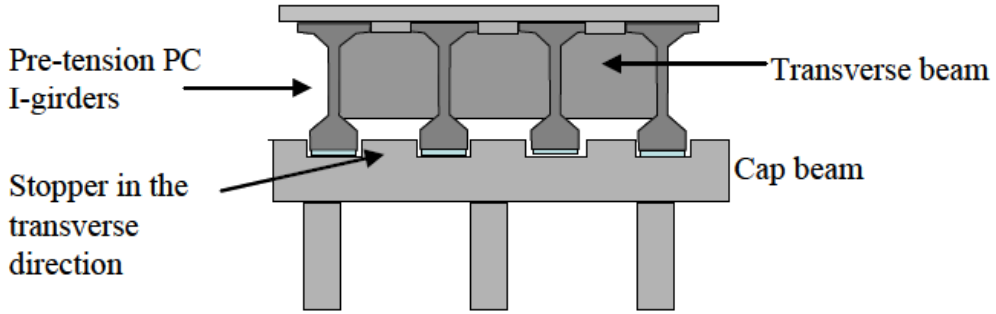
Epicenter 105km (65 miles) NE of Concepcion, Chile

115 km (70 miles) SW of Talca, Chile

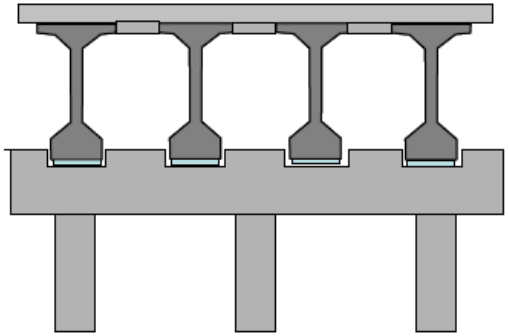
335 km (210 miles) SW of SANTIAGO, Chile

Source USGS

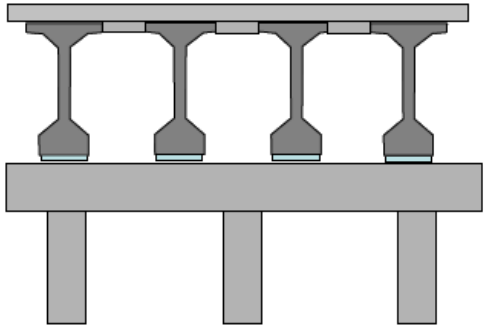




(a) Original Chile Design

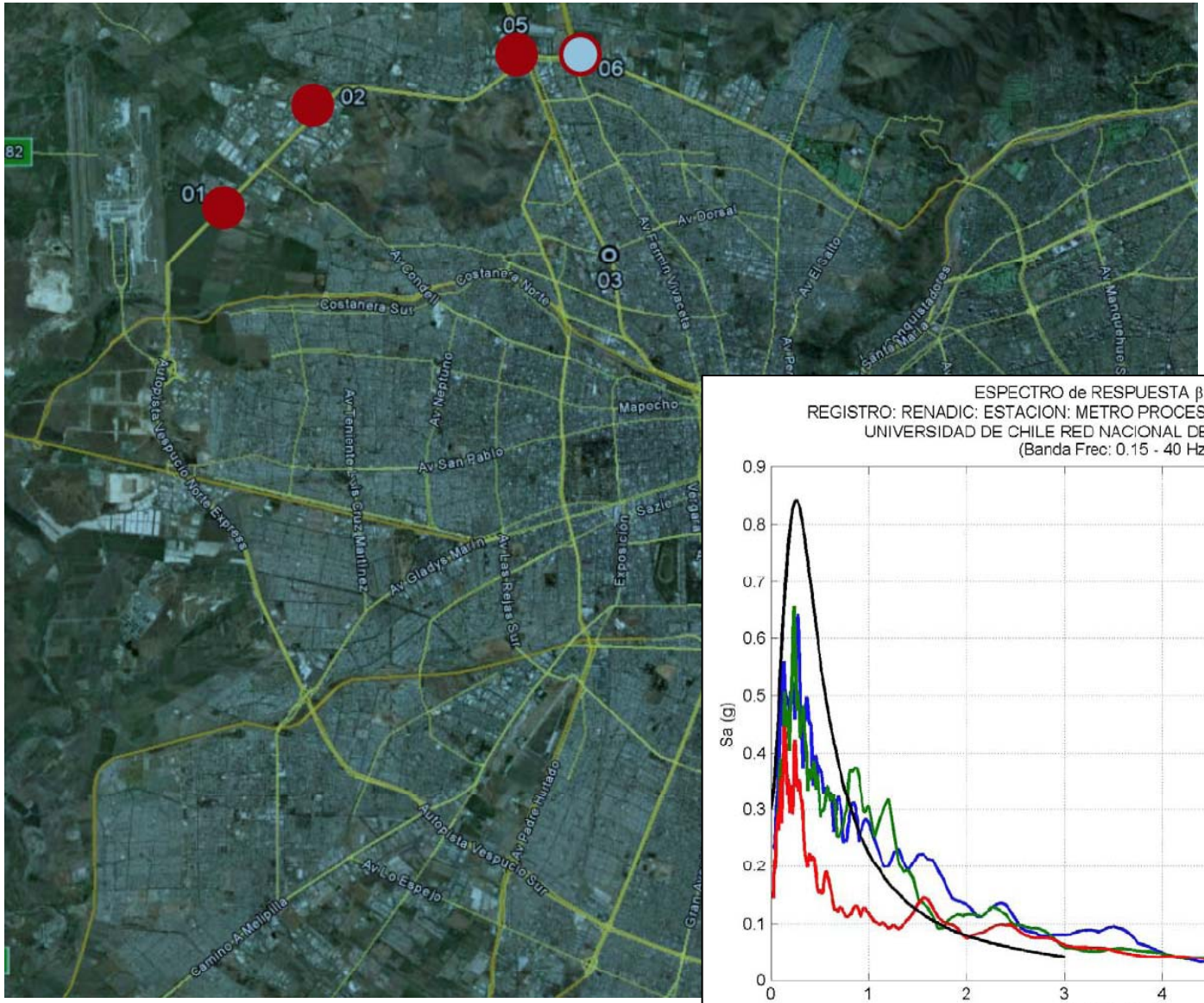


(b) Interim Design



(c) Design by Concessions

- Federal Bridges **6,800(MOP) 103Damaged-10Collapsed**
- Bridges in Concessions **450-100Damaged-8Collapsed**


05
06
02
01
03
82
Av. Dorsal
Av. Condell
Costanera Norte
Costanera Sur
Av. Neptuno
Mapocho
Av. San Pablo
Autopista Vespucio Norte Expres
Av. Teniente Cruz Martinez
Av. Gladys Marin
Av. Las Rejas Sur
Exposicion
Sazie
Autopista Vespucio Sur
Av. Padre Hurtado
Av. Lo Espejo
Camino A Melipilla

ESPECTRO de RESPUESTA β = 5%
REGISTRO: RENADIC: ESTACION: METRO PROCESA P. SOTO R. BOROSCHEK
UNIVERSIDAD DE CHILE RED NACIONAL DE ACELEROGRAFOS
(Banda Frec: 0.15 - 40 Hz)
NS
EW
UD
NCh433
Sa (g)
Periodo (seg)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
2
3
4
5
6
7

Santiago

1: Vespucio Norte Expressway –Miraflores Bridge

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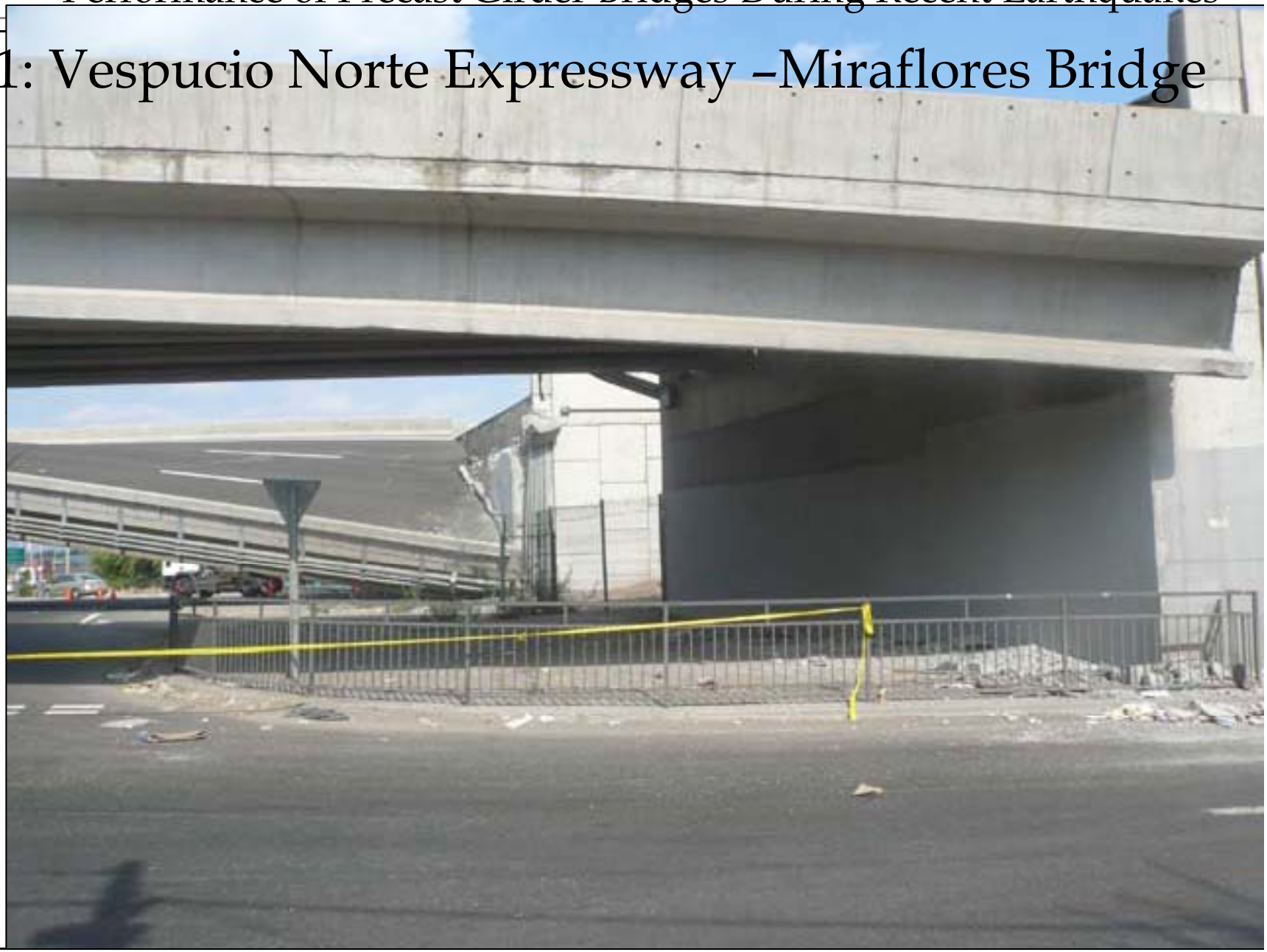
1: Vespucio Norte Expressway –Miraflores Bridge



1: Vespucio Norte Expressway –Miraflores Bridge

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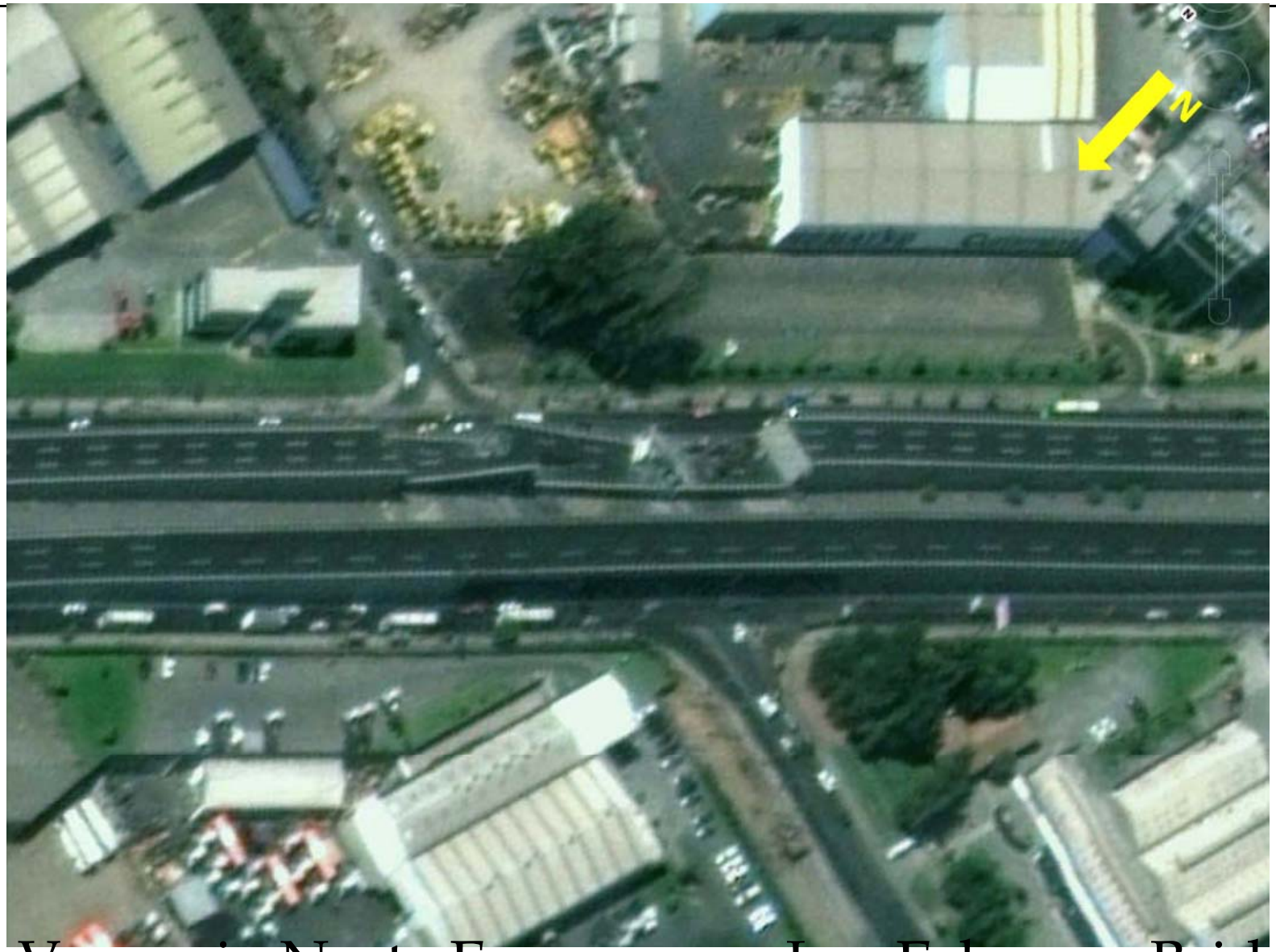

2: Vespucio Norte Expressway Los Echevers Bridge

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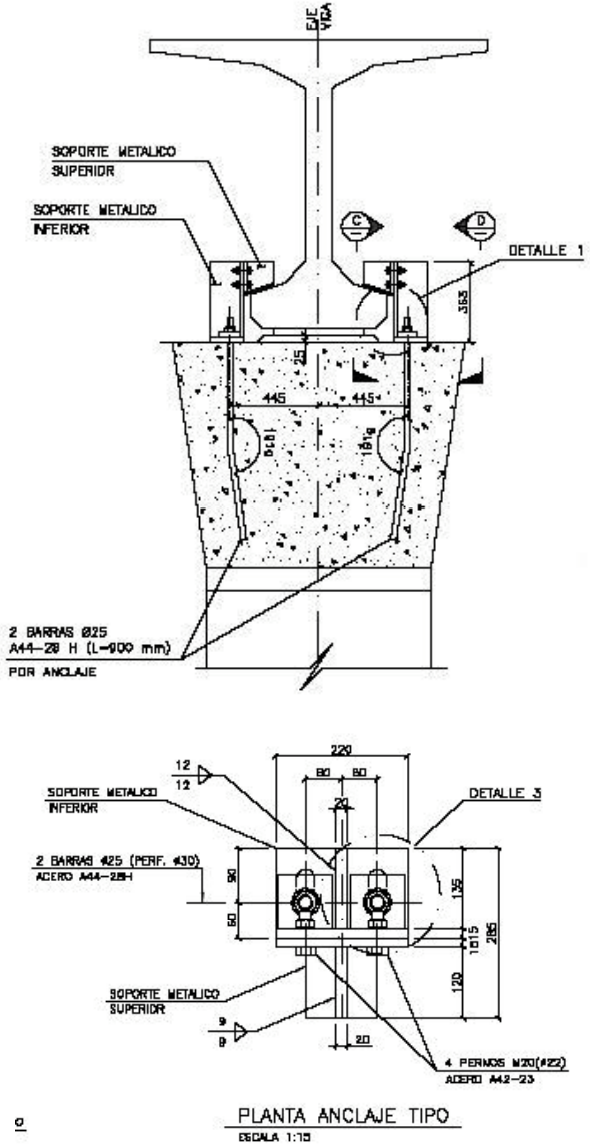

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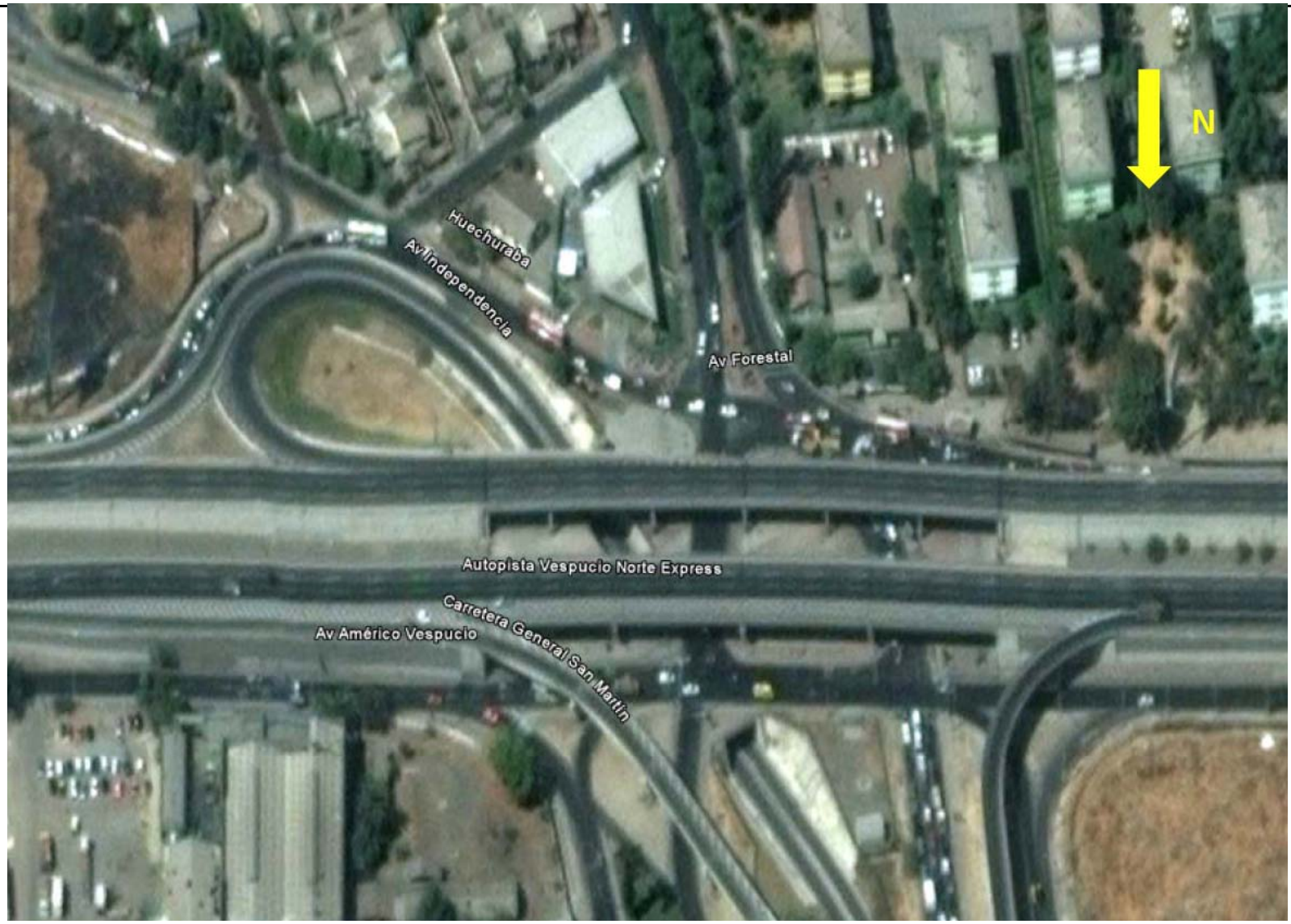

6: Vespucio Norte Expressway Independencia Bridge

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6: Vespucio Norte Expressway Independencia Bridge

6: Vespucio Norte Expressway Independencia Bridge

6: Vespucio Norte Expressway Independencia Bridge

7: Route 5: Avenue Romero Bridge

7: Route 5: Avenue Romero Bridge

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7: Route 5: Avenue Romero Bridge

7: Route 5: Avenue Romero Bridge

8: Route 5: Avenue Chada Bridge

8: Route 5: Avenue Chada Bridge

8: Route 5: Avenue Chada Bridge

12: Route 5: Las Mercedes Bridge

12: Route 5: Las Mercedes Bridge

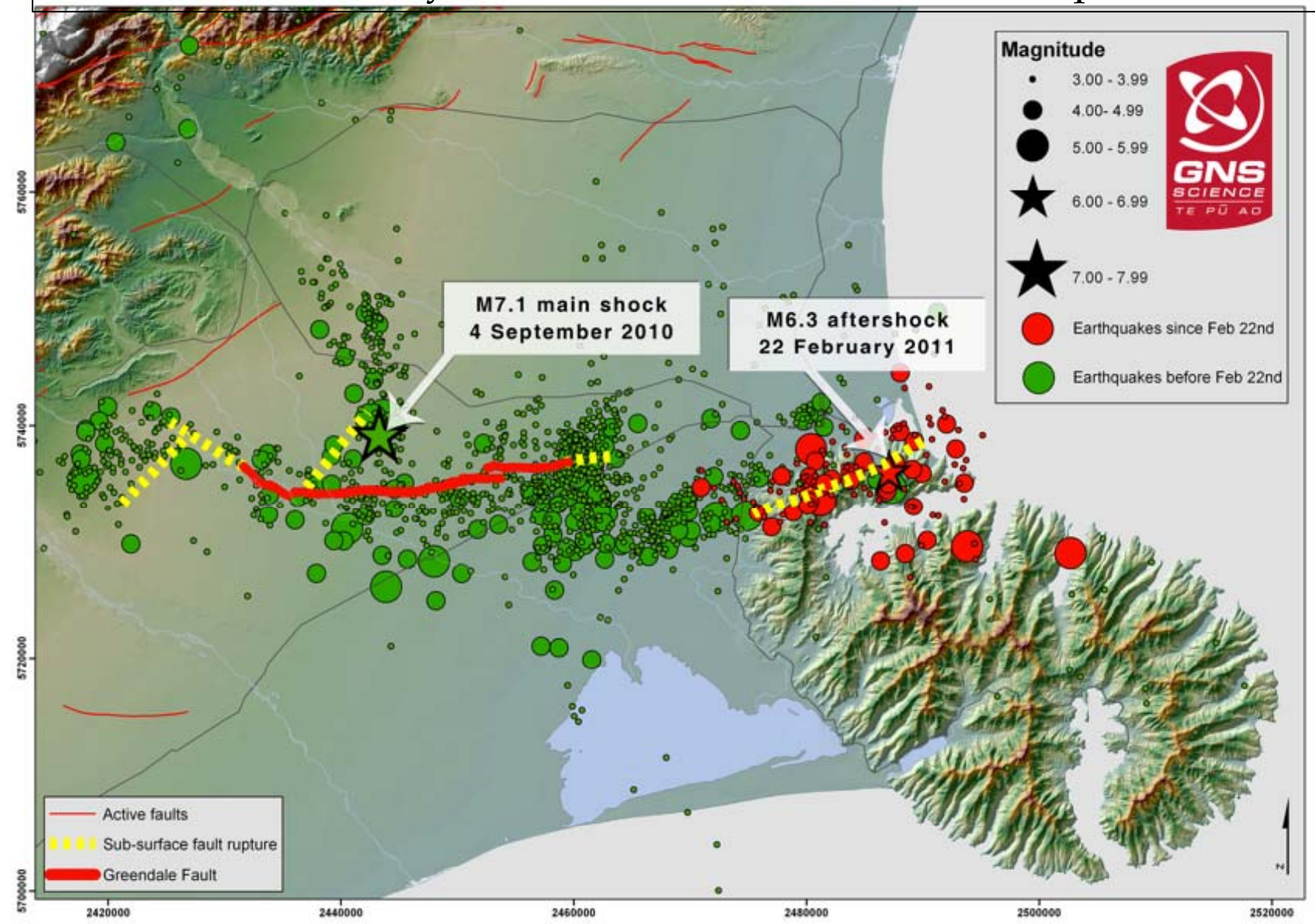
12: Route 5: Las Mercedes Bridge

12: Route 5: Las Mercedes Bridge

13: Route 5: Rancagua Overcrossing

14: Puente Llacolen in Concepcion

The February 22, 2011 M6.3 Christchurch Earthquake



Christchurch Earthquake – Comparison of Recorded and Design Ground Motions

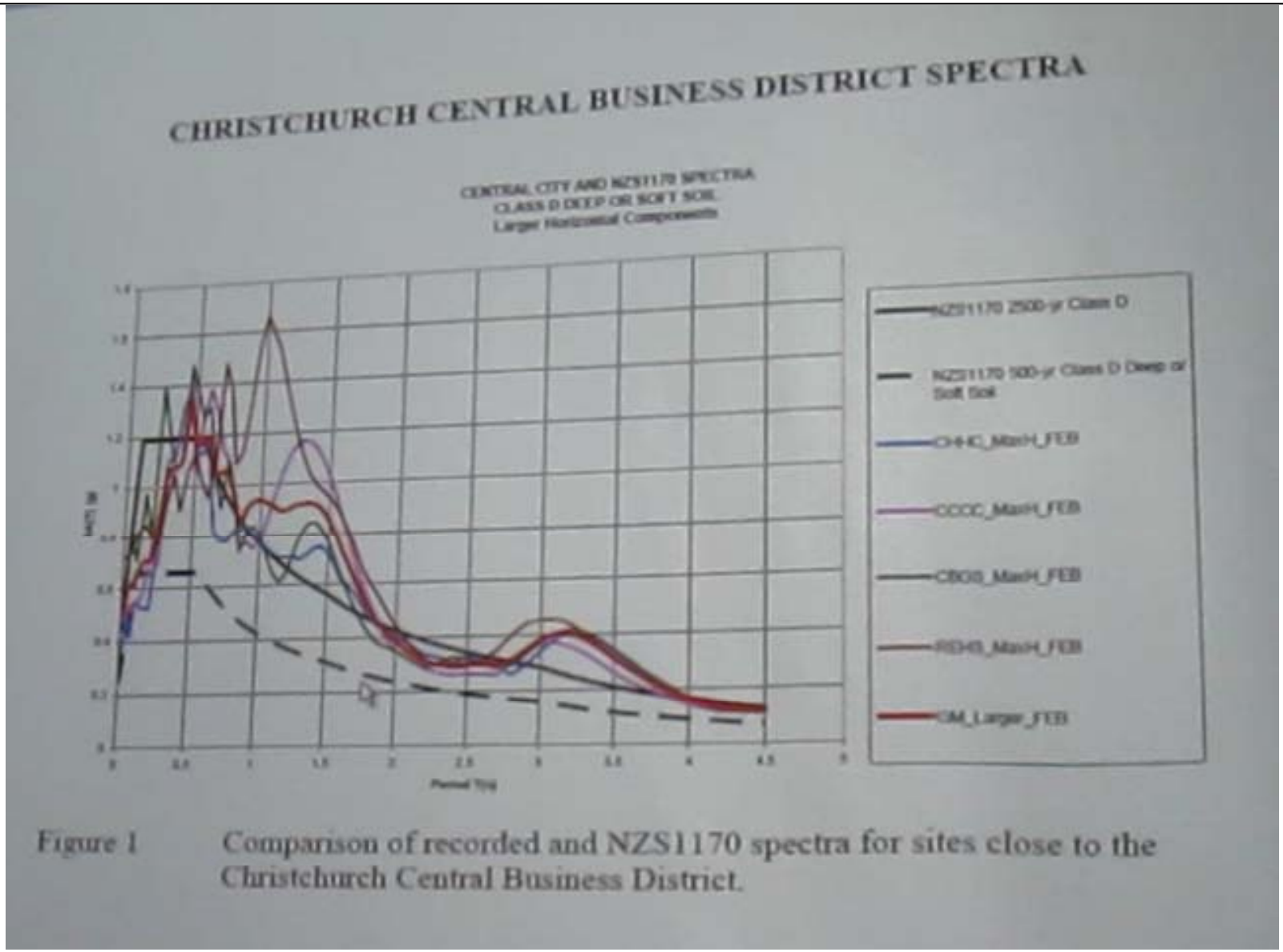
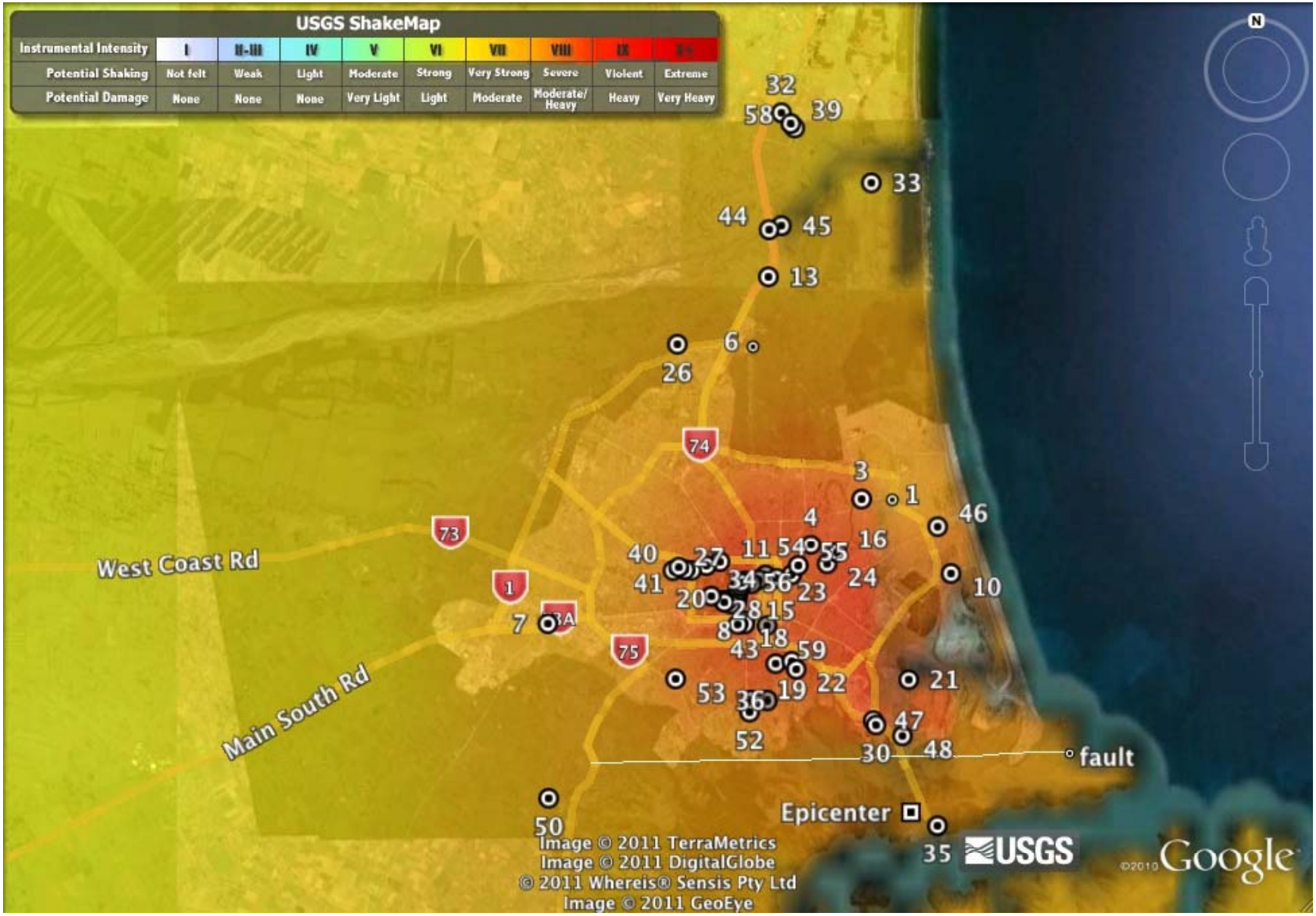


Figure 1 Comparison of recorded and NZS1170 spectra for sites close to the Christchurch Central Business District.


USGS ShakeMap
Instrumental Intensity | I | II-III | IV | V | VI | VII | VIII | IX | X+
Potential Shaking | Not felt | Weak | Light | Moderate | Strong | Very Strong | Severe | Violent | Extreme
Potential Damage | None | None | None | Very Light | Light | Moderate | Moderate/ Heavy | Heavy | Very Heavy
West Coast Rd
Main South Rd
fault
Epicenter
Image © 2011 TerraMetrics
Image © 2011 DigitalGlobe
© 2011 Whereis® Sensis Pty Ltd
Image © 2011 GeoEye
USGS
©2010 Google

New Zealand Bridge Seismic Criteria

Design for three earthquakes

100 yr – no damage

500 year – can be repaired

1000 year – no collapse

Use R-factor < 6

Almost all precast girder (Park and Pauley)

NZ Transit privatized – OPUS taken most functions

Retrofits just tie everything together

NZ seismic code has fallen behind

The Basic Facts

No highways and almost no modern bridges.

Almost all precast girders.

Deep liquefiable soil.

No bridges instrumented.

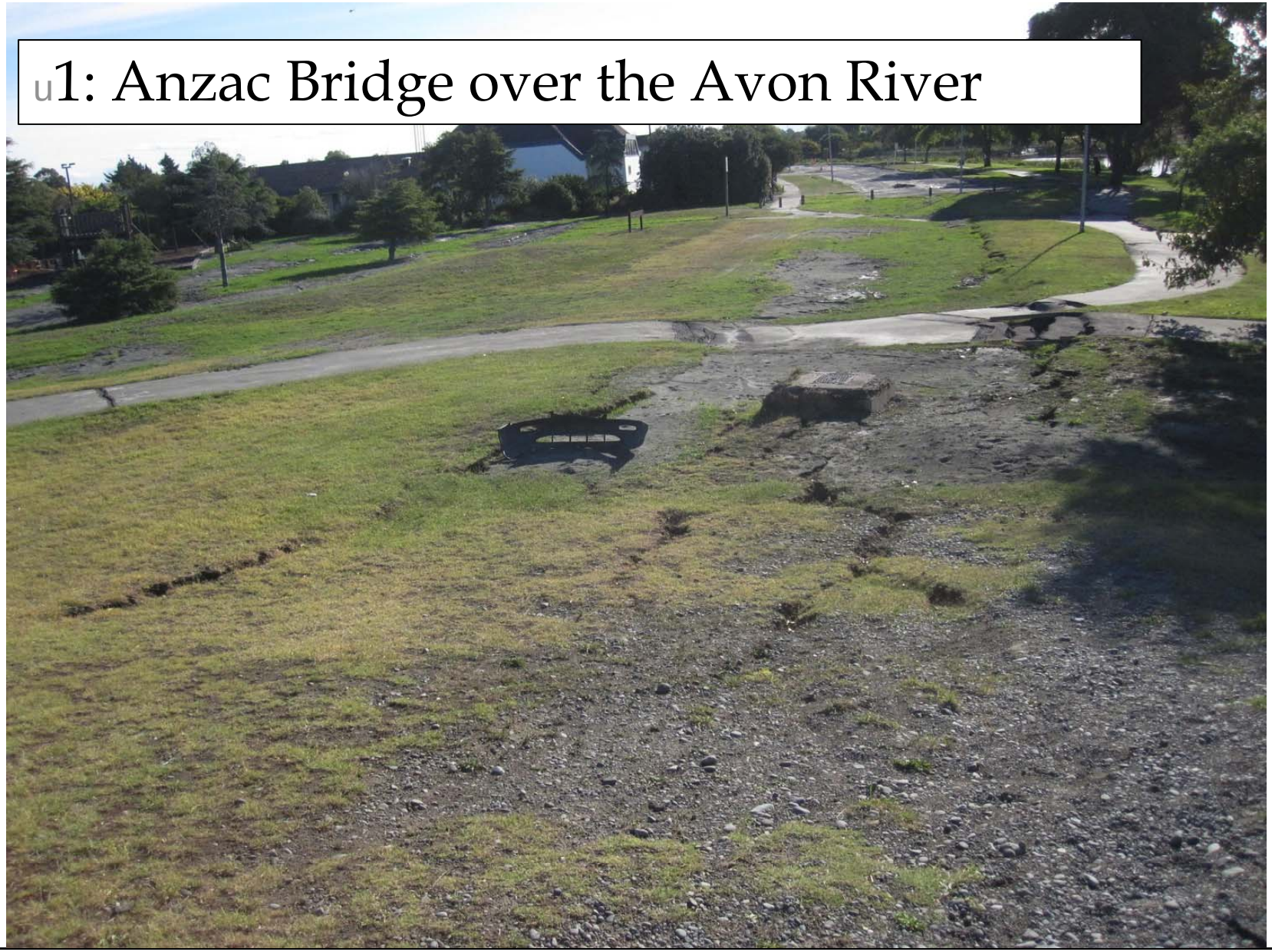
Seismic code hasn't been updated in years.

Two earthquakes, six months apart.

A small crack shows where damage begins.

Think about displacement and load path to picture how damage occurred.

u1: Anzac Bridge over the Avon River



u1: Anzac Bridge over the Avon River

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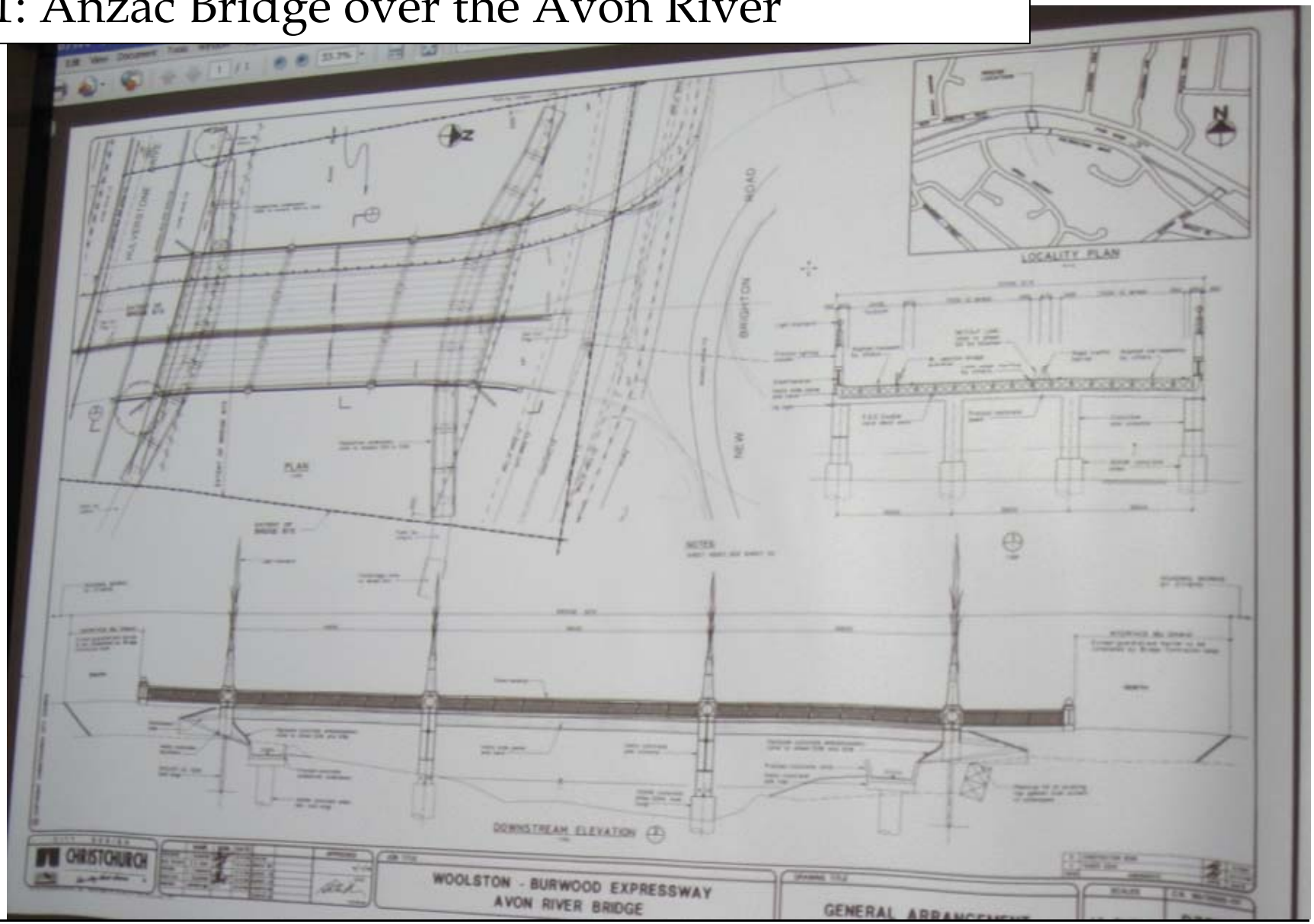

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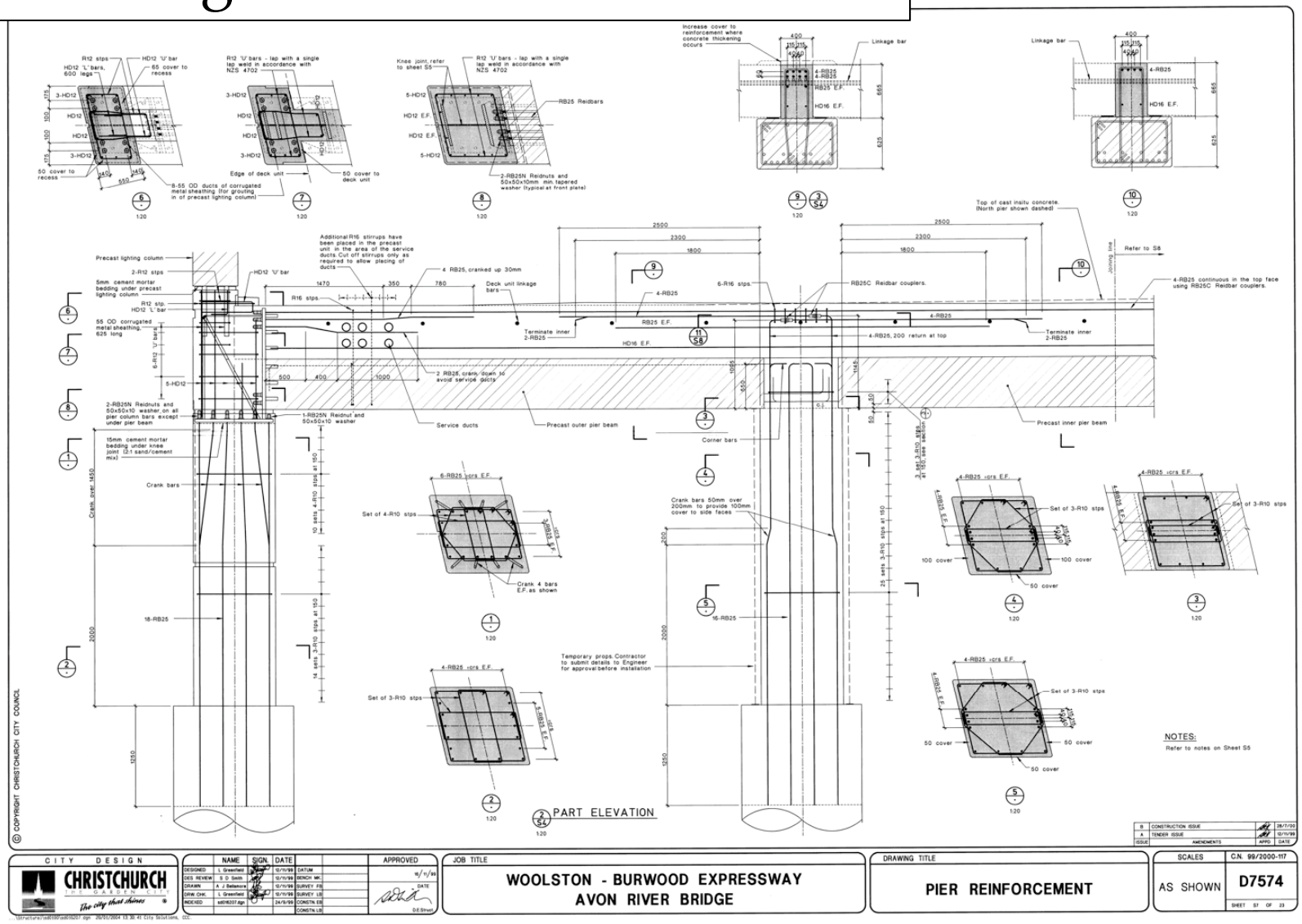
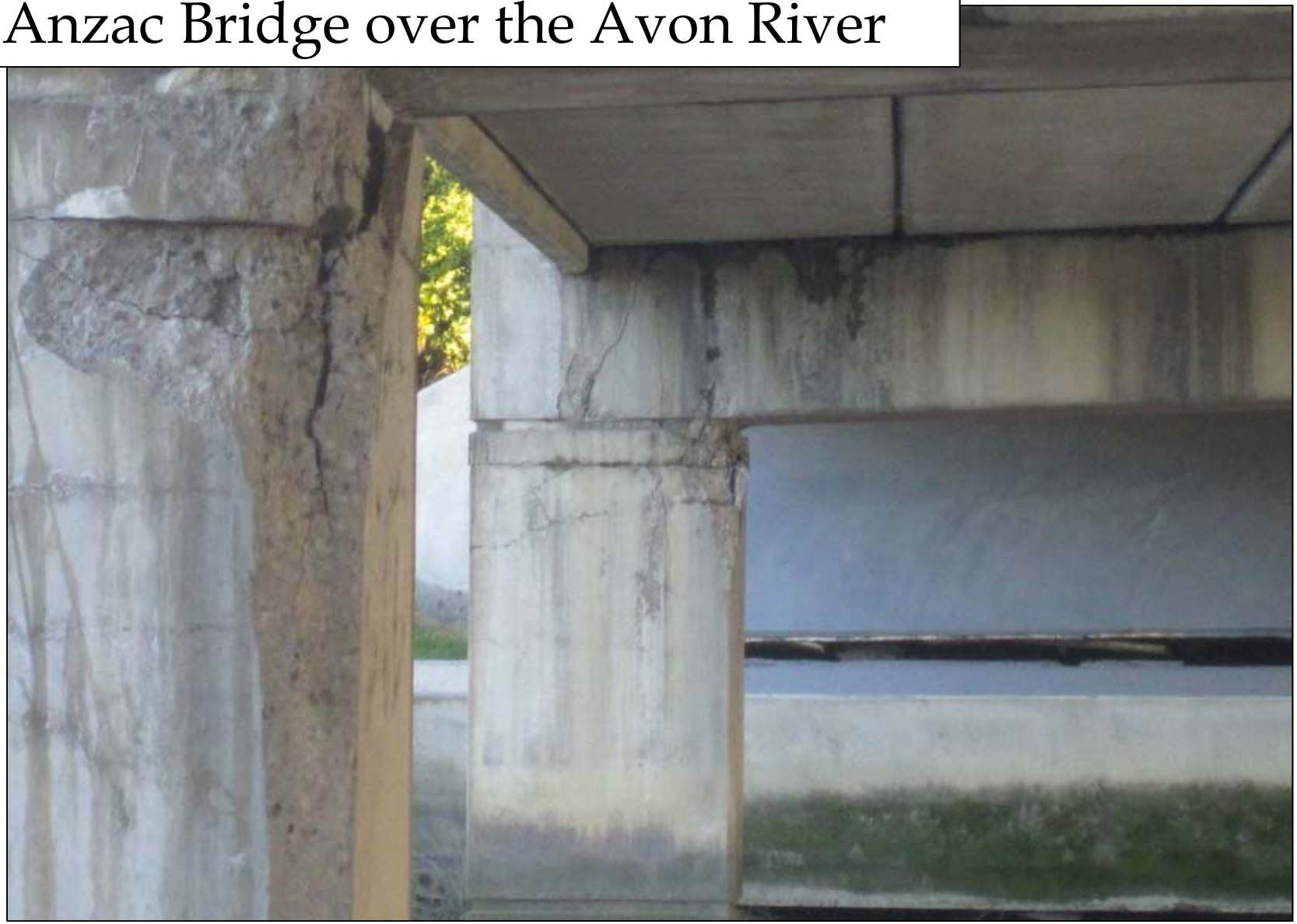


u1: Anzac Bridge over the Avon River



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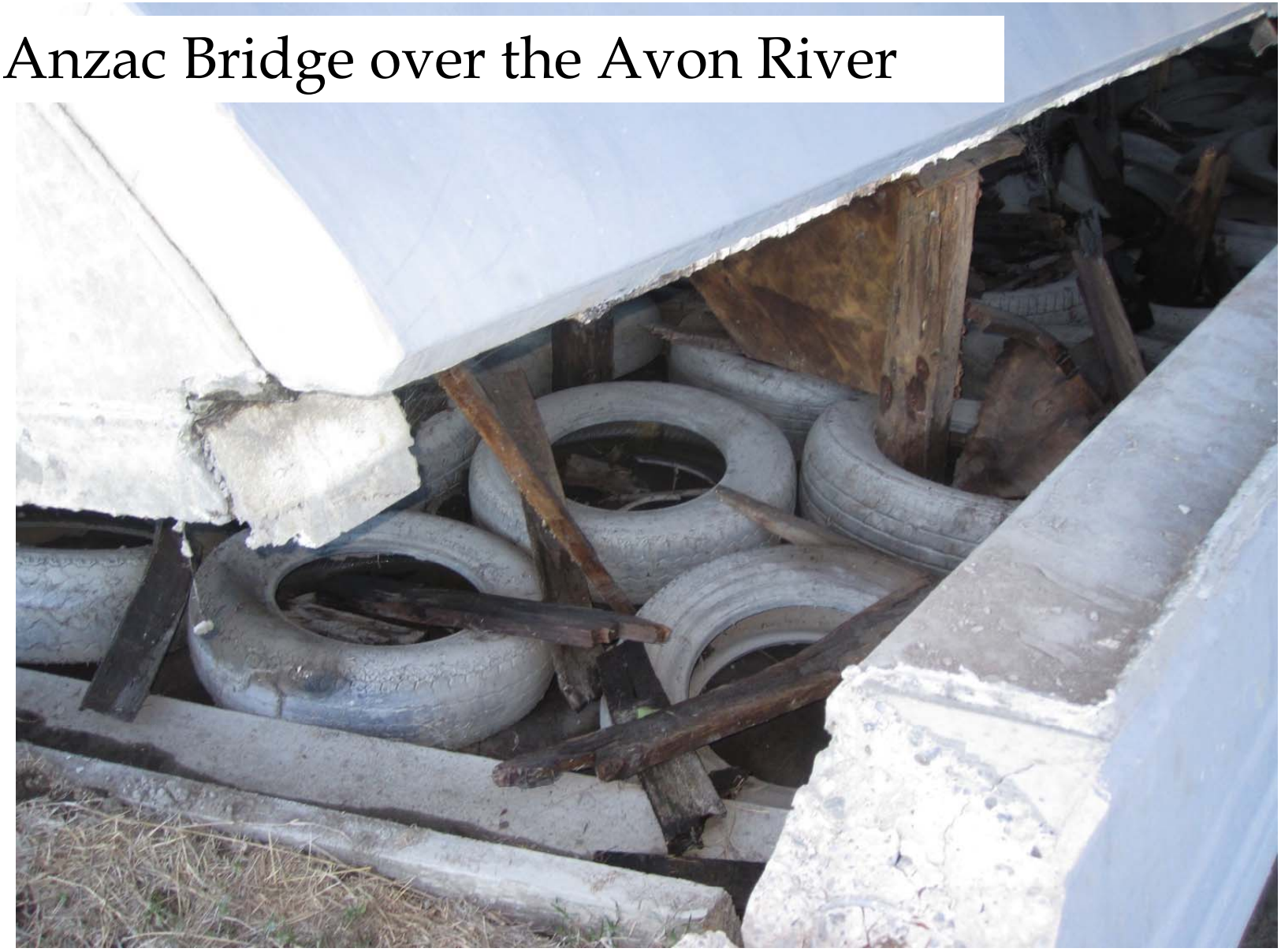


7: Brand New Blenheim Bridge in Christchurch CBD

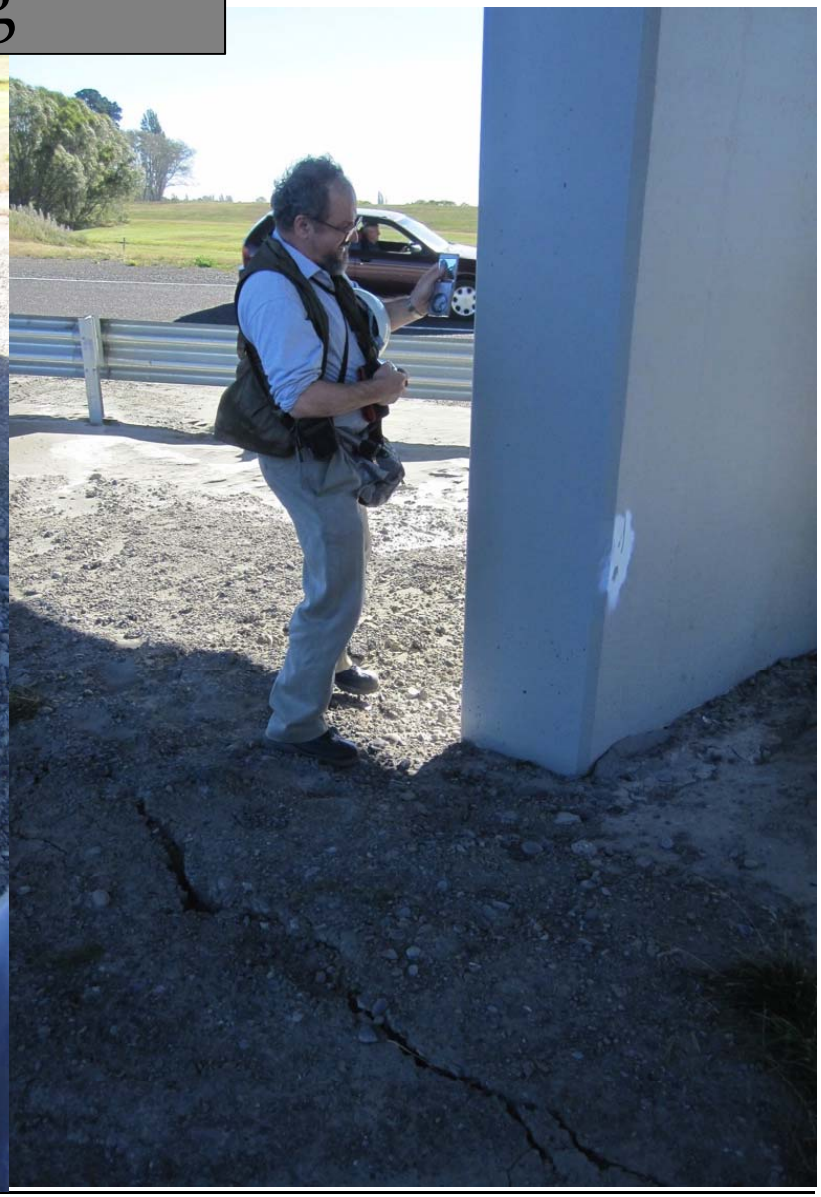
13: Chaney's Overcrossing (1972) has a three-span precast box superstructure, pier walls, its north of town (1.0 sec SA = .2g) and it was slightly damaged by both earthquakes.

13: Chaney's Overcrossing was one of the few highway (Route 1) bridges in Chrisgtchurch.

13: Chaney's OC carries Route 1 north of Christchurch.

13: Chaney's Overcrossing

13: Chaney's Overcrossing



13: Chaney's Overcrossing.

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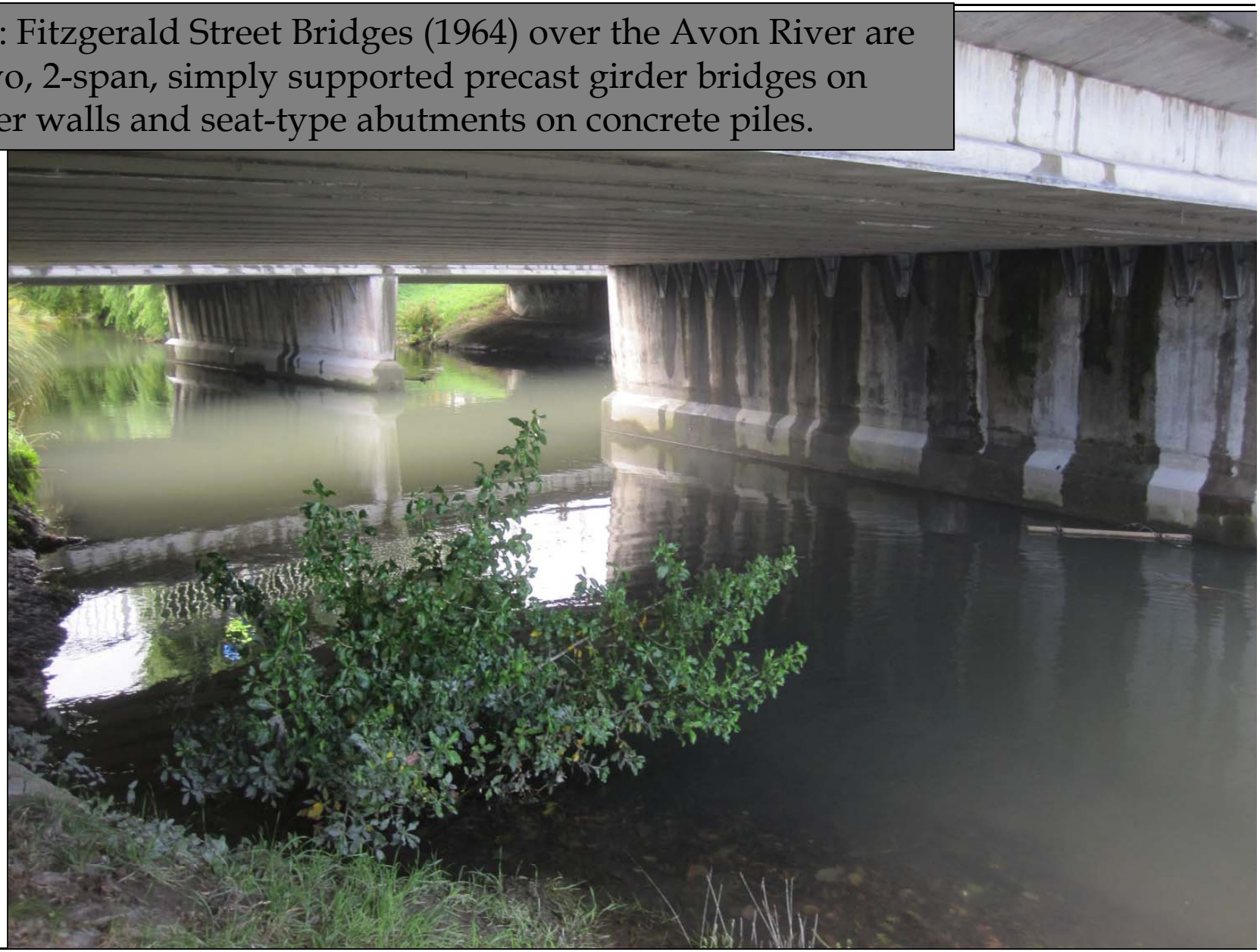
23: Fitzgerald Street Bridges (1964) over the Avon River are two, 2-span, simply supported precast girder bridges on pier walls and seat-type abutments on concrete piles.



23: Fitzgerald Street Bridges (1964) over the Avon River

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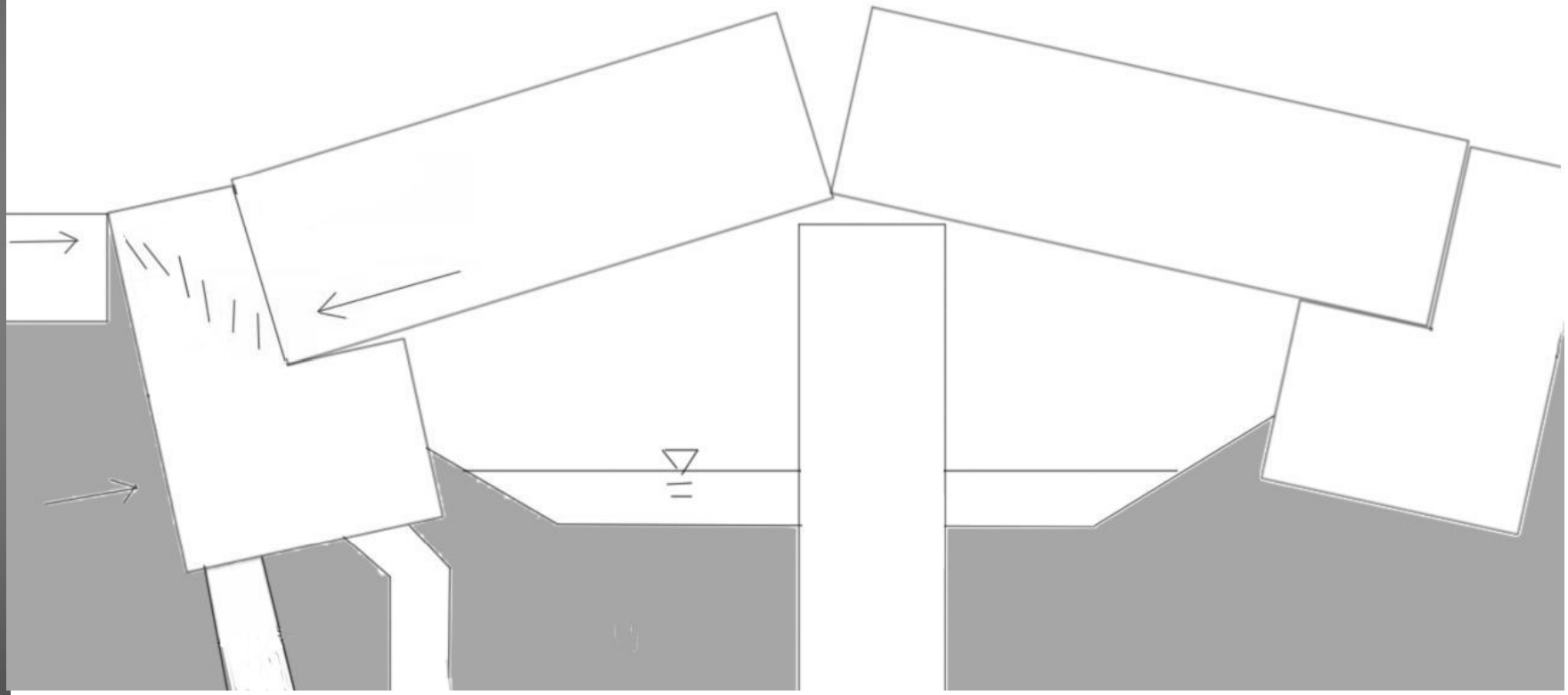

47: Port Hills Overbridge (1970) over Route 73

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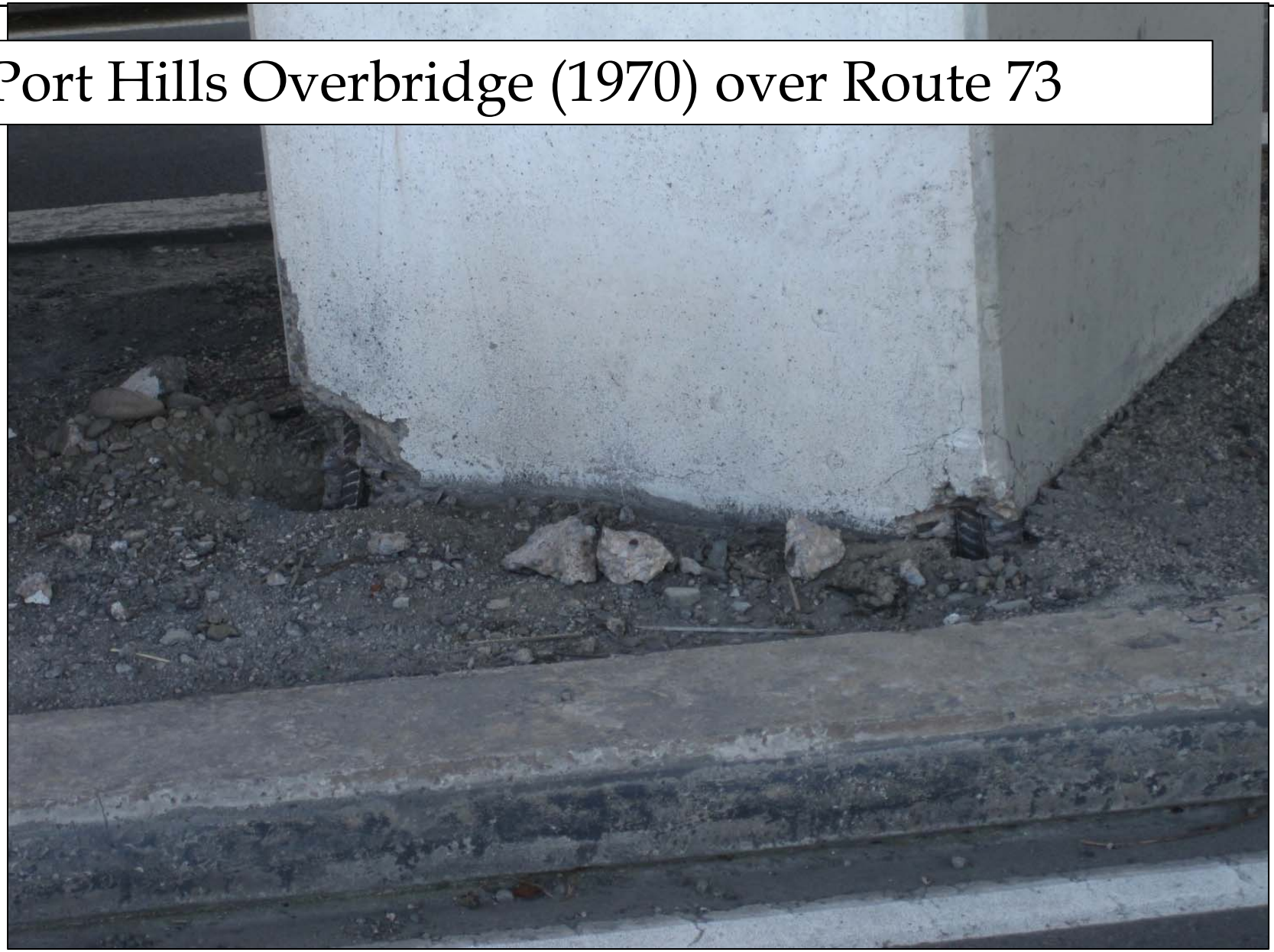

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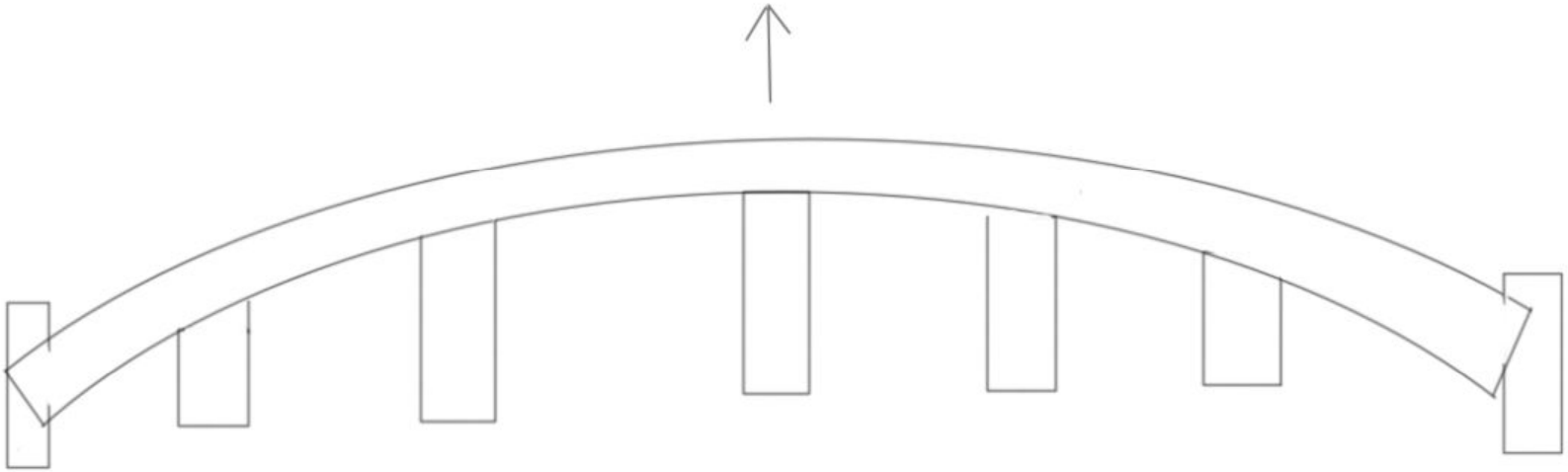
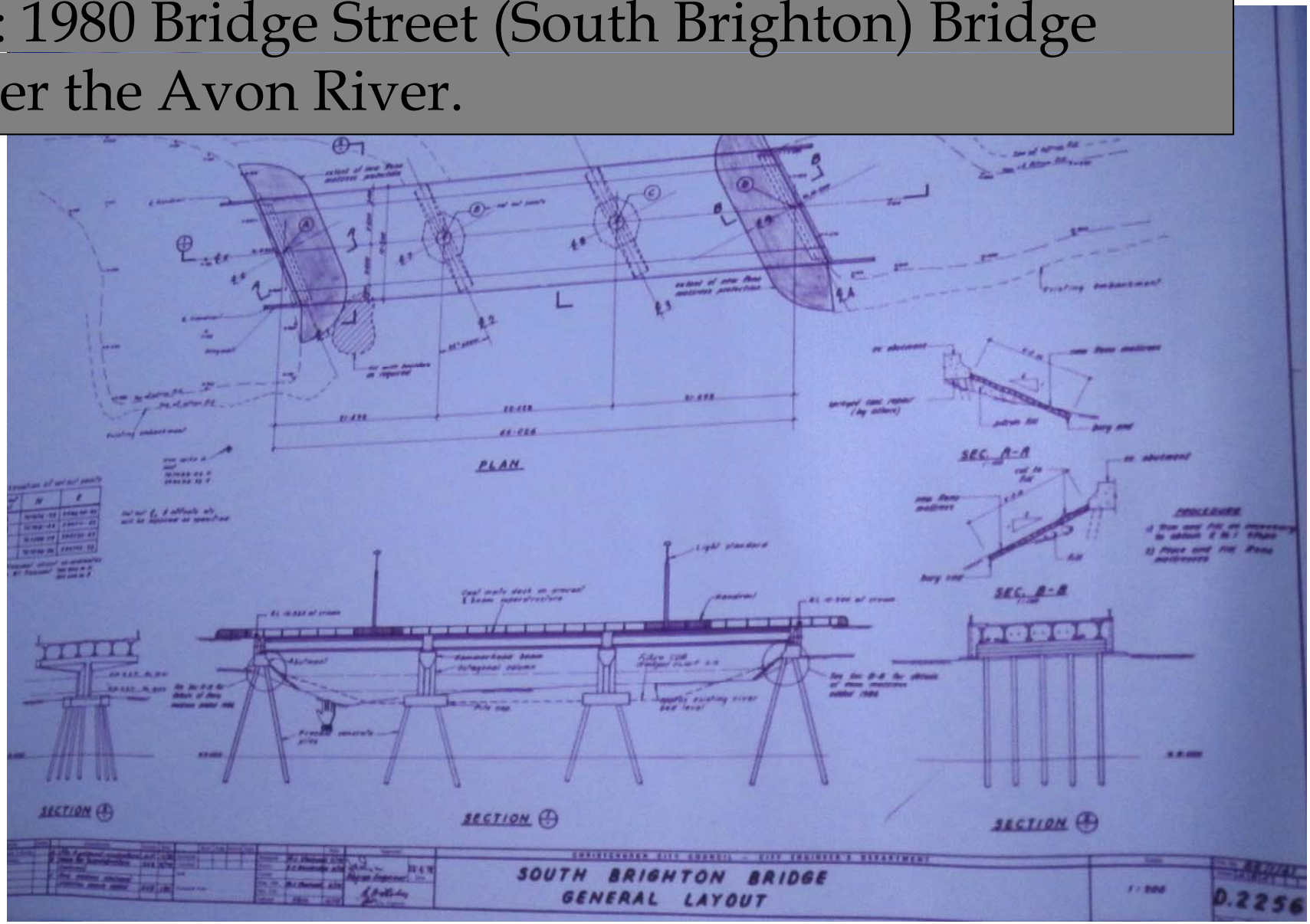
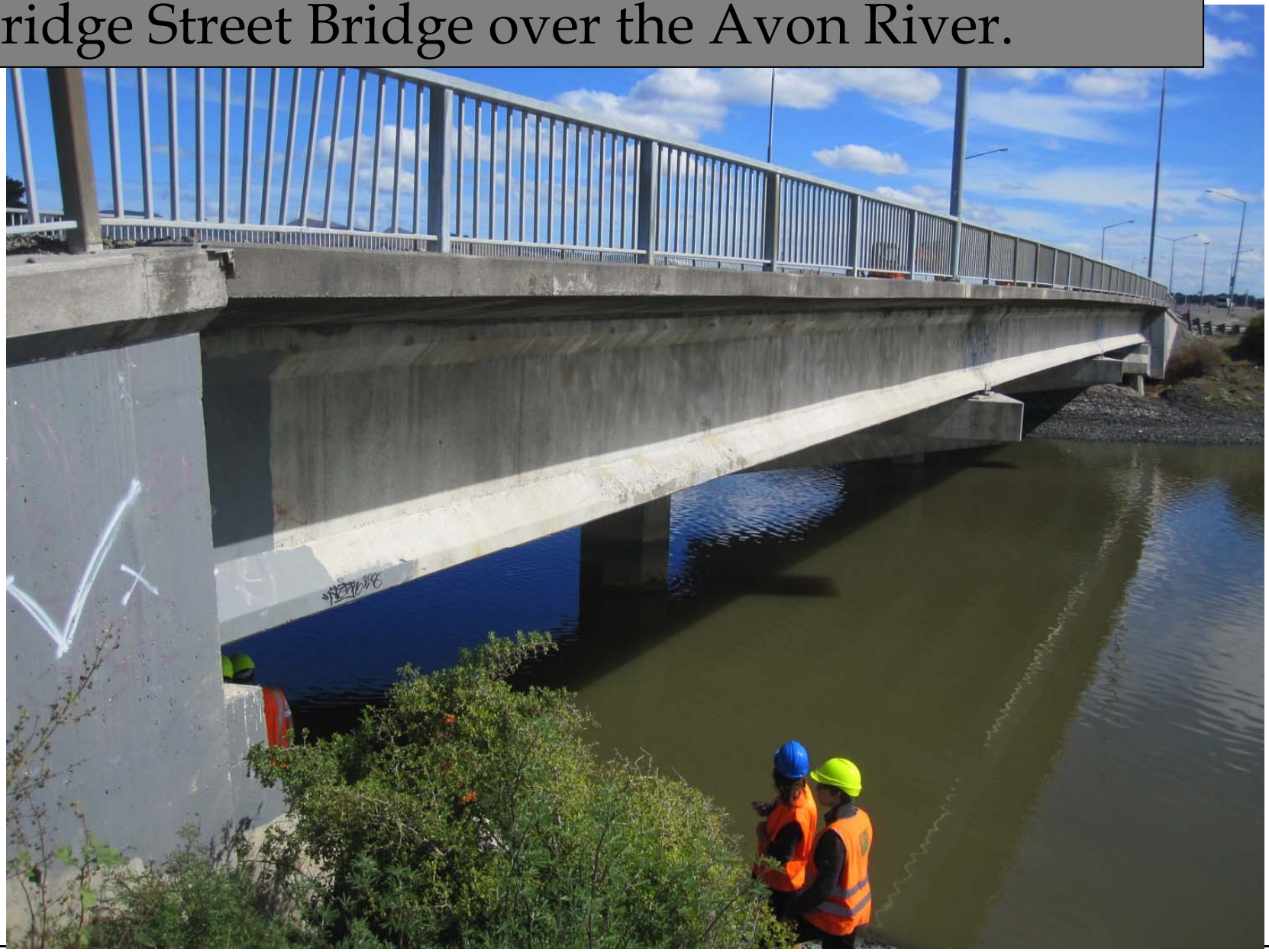


Plan View

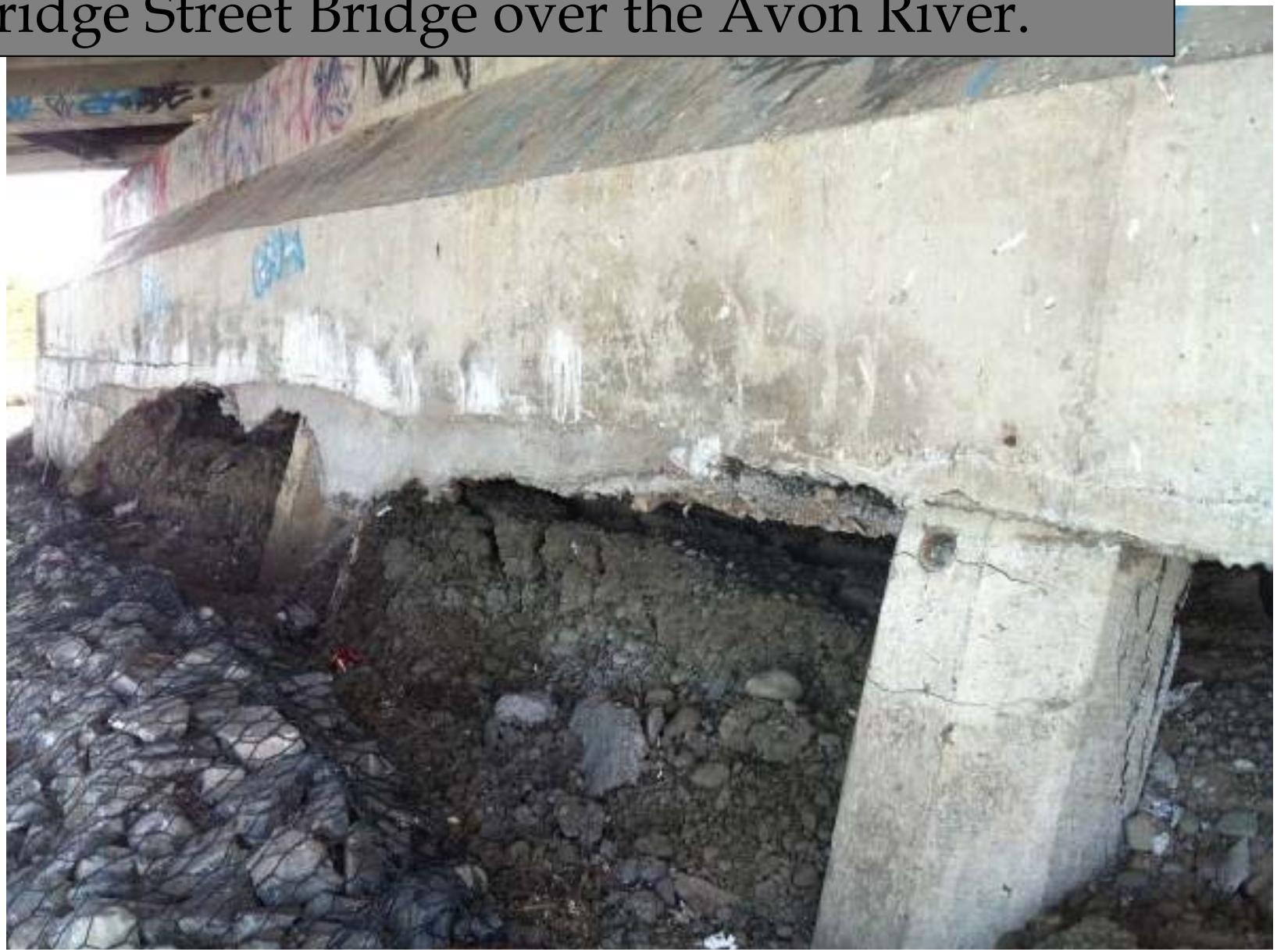
10: 1980 Bridge Street (South Brighton) Bridge over the Avon River.



10: Bridge Street Bridge over the Avon River.



10: Bridge Street Bridge over the Avon River.



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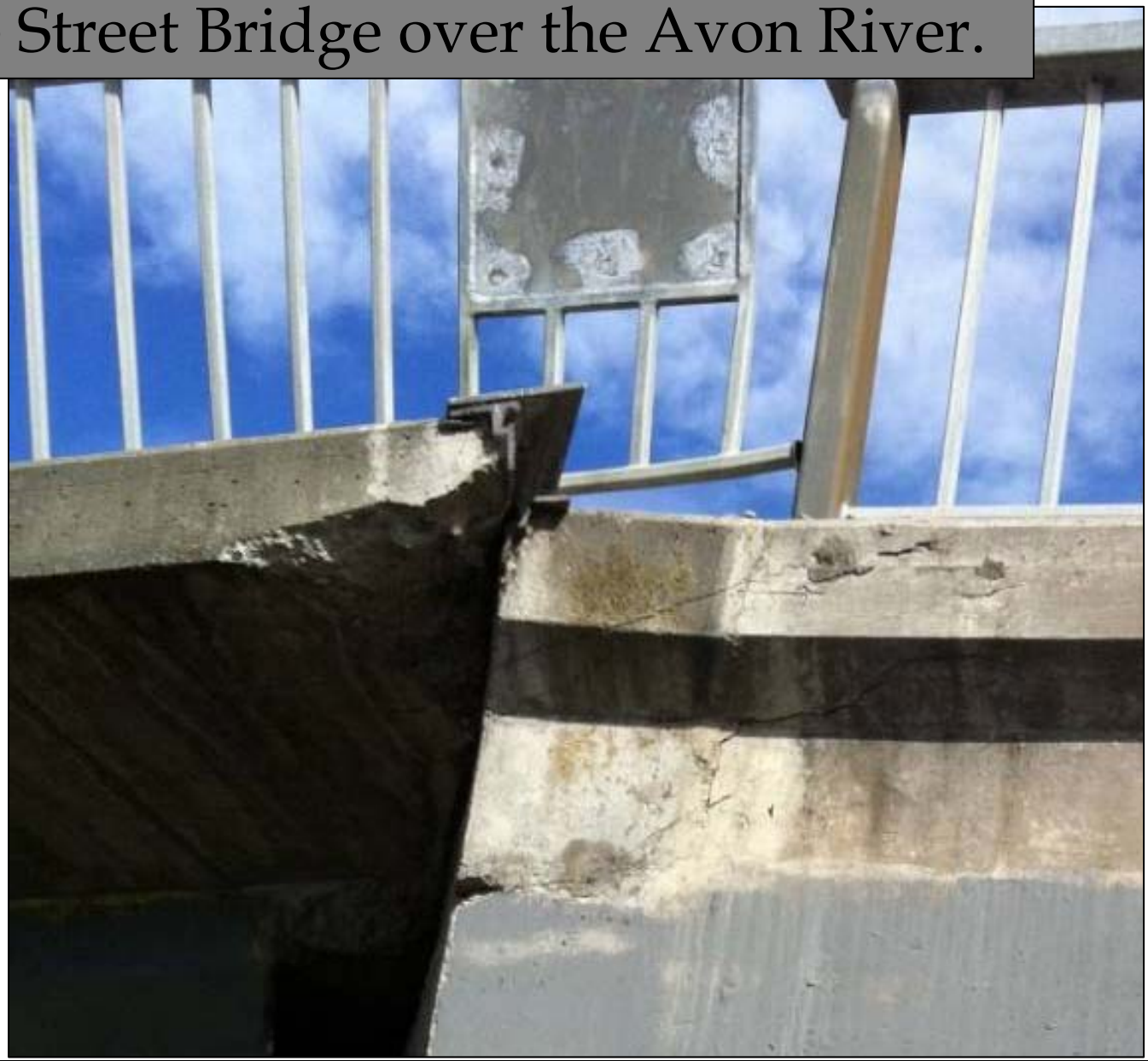

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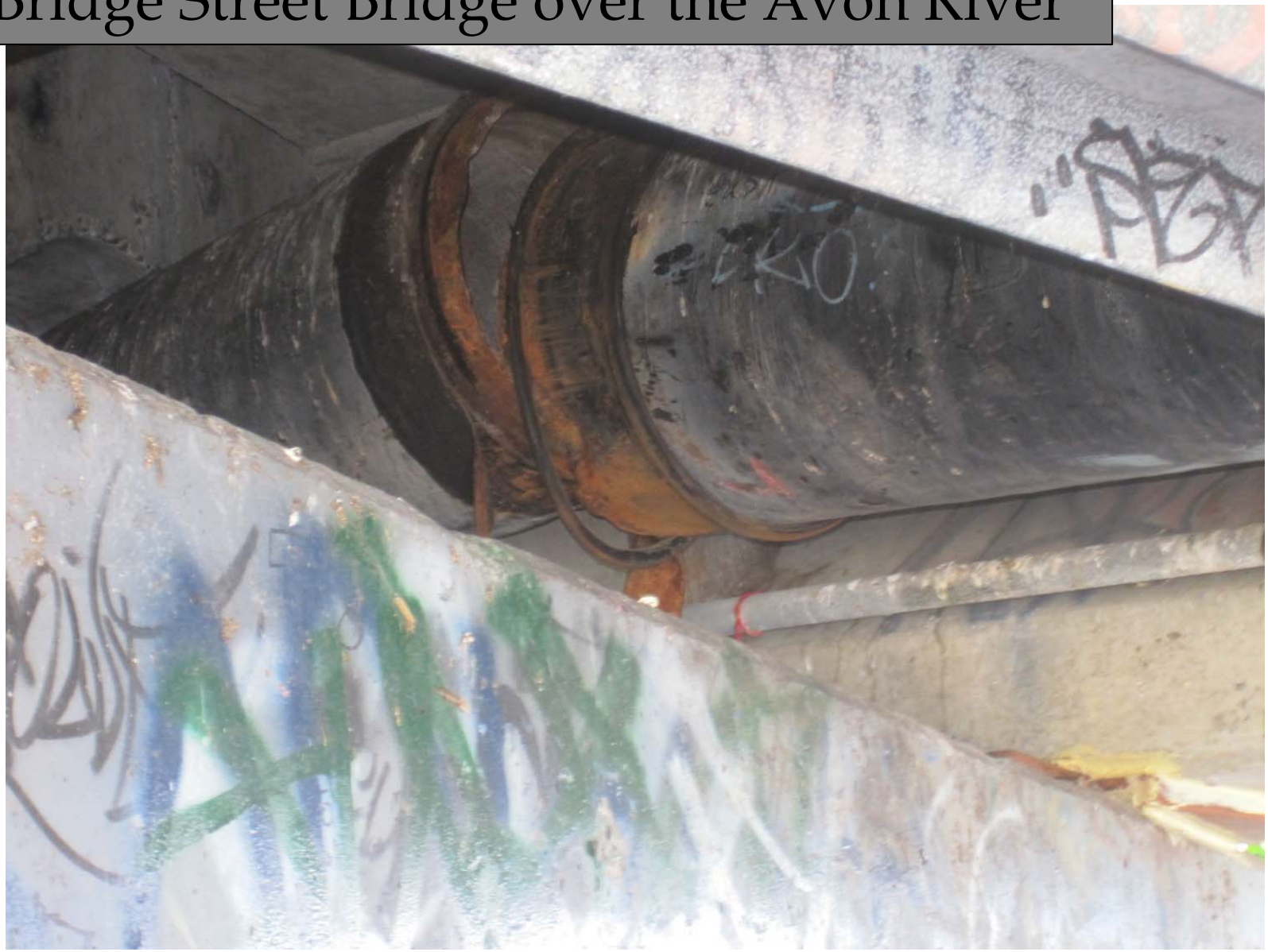

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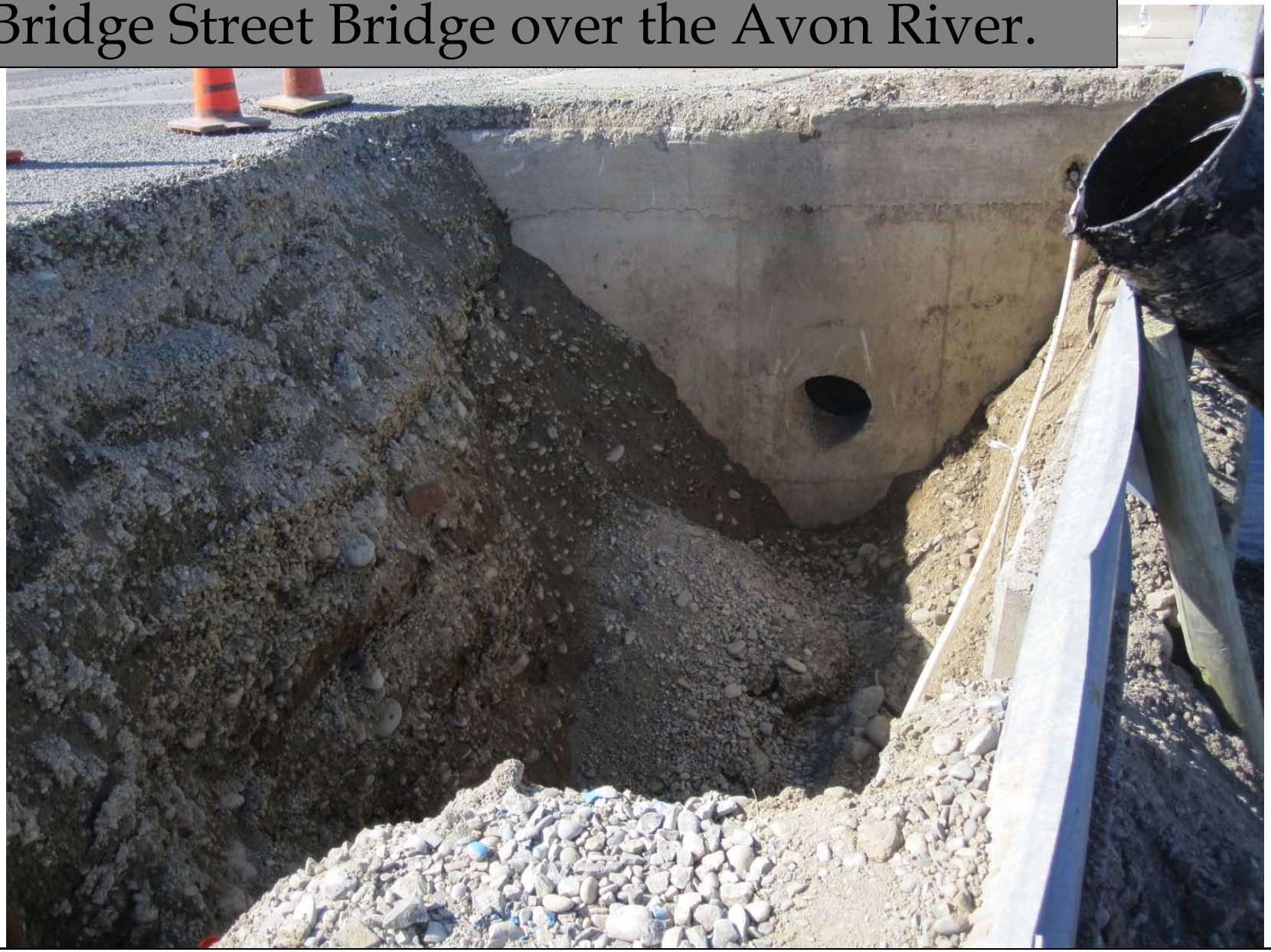

10: Bridge Street Bridge over the Avon River.

Caltrans Office of Earthquake Engineering has developed seismic criteria for precast girder bridges.

Shorter bridges are designed to have a rigid superstructure that engages the abutments during an earthquake.

Longer bridges are designed to have fixed connections to the bents to force plastic hinging of the columns.

Research is ongoing to consider isolation devices and other techniques for precast girder bridges to speed construction while maintaining seismic safety.