


American Concrete Institute®
Advancing concrete knowledge

Post-Earthquake Repairs, Part 1

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**REPAIR OF CONCRETE BRIDGES
DAMAGED BY 02/27/2010 M8.8
CHILE EARTHQUAKE**




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Daniel Ortiz, SE Univ. de Chile. CEO, TECNOAV S.A

1.-INTRODUCTION

- During the earthquake and aftershocks, that hit mainly in the central southern regions of the country, many concrete bridges and relatively new overpasses structures were damaged and some others even collapsed.
- The special characteristics of this earthquake combined with deficient connection details between sub and superstructures to transfer both vertical and horizontal forces, produced failures in: decks, basically geometrical distortions; beams; expansion joints and bearings; and in substructures, damages by the effect of shear, torsion, bars buckling because of compression and flexure and inadequate confinement.



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DAMAGE IN BRIDGES

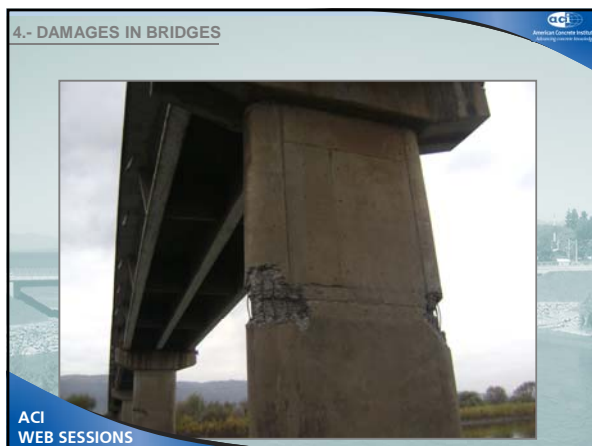
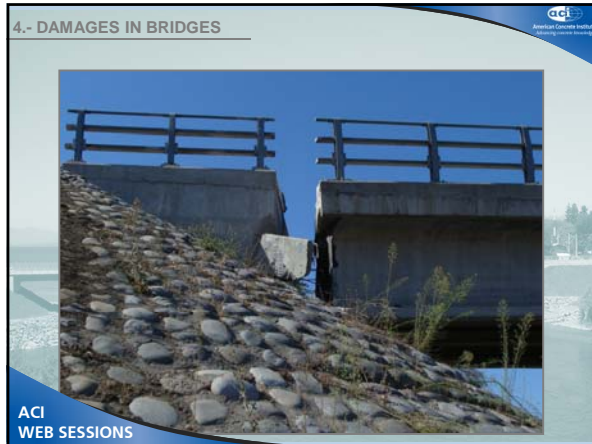


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4.- DAMAGES IN BRIDGES



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5.- WHY DAMAGES HAPPENED?

- Damage resulted from insufficient integrity of pre-cast concrete girder bridges due to absence of diaphragms.
- Lack of constraint to rotation of deck in skewed bridges.
- Damage of piers and foundations in bridges built in the early days.

What happened in the bridges with insufficient integrity due to absence of diaphragm?

Seismic force in the TR direction



Contact of a PC girder to stopper results in failure of lower flange, shear failure of web plate, rupture of deck slabs and connection between deck slab and upper flange

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5.- WHY DAMAGES HAPPENED?

Example of damage due to lack of diaphragms

Las Mercedes Bridge
Route 5



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5.- WHY DAMAGES HAPPENED?

Skewed bridges which lacked diaphragms and effective side stoppers suffered extensive damage

Lo Echevers Bridge
Santiago



Miraflores Bridge
Santiago

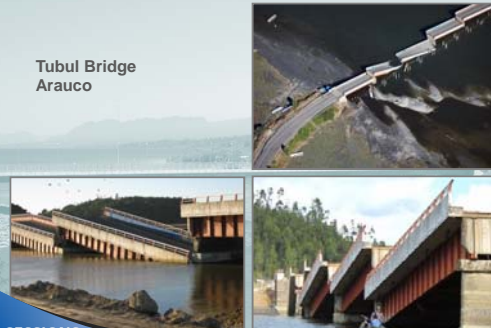


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5.- WHY DAMAGES HAPPENED?

Insufficient performance of foundations

Tubul Bridge
Arauco



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Repairing Procedures

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6.- REPAIRING PROCEDURES CARRIED OUT


- 6.1.-Repairings of deck displacement.
- 6.2.-Repairings of Prestressed beam damages.
- 6.3.-Substructure Repairing.
- 6.4.-Expansion joints replacement.

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6.1.- REPAIRING OF DECK DISPLACEMENTS

SCOPE

To relocate the deck which could suffer vertical and horizontal displacements or twists, to its original position over the piers and abutments. It includes replacing of bearings, expansion joints and vertical connection bars. This situation happened mostly in simple supported span bridges but also in continuous spans.

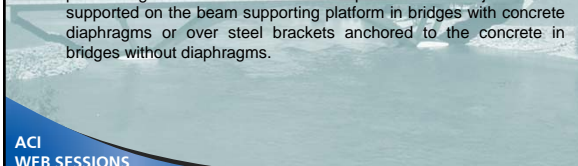


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6.1.- REPAIRING OF DECK DISPLACEMENTS

PROCEDURE

- 1.-Removal of expansion joints, vertical connection bars damaged, damaged concrete, and pavement which interfere with the vertical and horizontal displacement necessary to get the structure back to its original geometry.
- 2.-Vertical jacking procedure to lift the structure in the first support for proceeding later to the horizontal displacement. The jacks were supported on the beam supporting platform in bridges with concrete diaphragms or over steel brackets anchored to the concrete in bridges without diaphragms.



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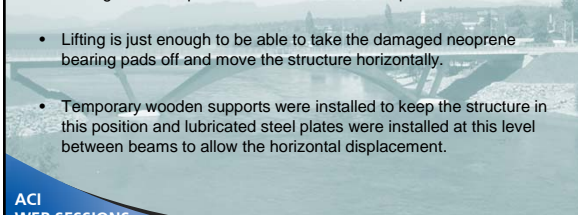
6.1.- REPAIRING OF DECK DISPLACEMENTS



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6.1.- REPAIRING OF DECK DISPLACEMENTS

- It worked with enough 50 Ton capacity jacks, necessary to lift one end of the span.
- They were connected in serial using one or two hydraulic pumps to lift the bridge softly and uniformly, in such a way that any other damage due this procedure could affect the superstructure.
- Lifting is just enough to be able to take the damaged neoprene bearing pads off and move the structure horizontally.
- Temporary wooden supports were installed to keep the structure in this position and lubricated steel plates were installed at this level between beams to allow the horizontal displacement.



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6.1.- REPAIRING OF DECK DISPLACEMENTS



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6.1.- REPAIRING OF DECK DISPLACEMENTS

PROCEDURE

- 3.- Usually 2 horizontal hydraulic 30 ton capacity jacks, were disposed to push the superstructure to its right position sliding over the lubricated surface.
- 4.-Once the superstructure was in its final position, it was supported again on the jacks and all the temporary supports and slide surface were removed. New bearing pads were installed and the deck was finally taken down to its final level.
- 5.-New expansion joints, vertical steel bars and pavement were installed and in most cases, new concrete stoppers were built.
- 6.-Now, the structure was ready to be in service again.

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6.1.- REPAIRING OF DECK DISPLACEMENTS



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6.1.- REPAIRING OF DECK DISPLACEMENTS



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6.2.- REPAIRING OF PRESTRESSED BEAM DAMAGE

SCOPE

- During the earthquake, external prestressed beams hit against the horizontal concrete stoppers suffering damage in webs and bottom flanges close to their support, reducing their shear strength and affecting their support area.
- The idea was to repair them without having to replace them, reestablishing or improving their original properties without interrupting the traffic over the bridge.

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6.2.- REPAIRING OF PRESTRESSED BEAM DAMAGE

PROCEDURE

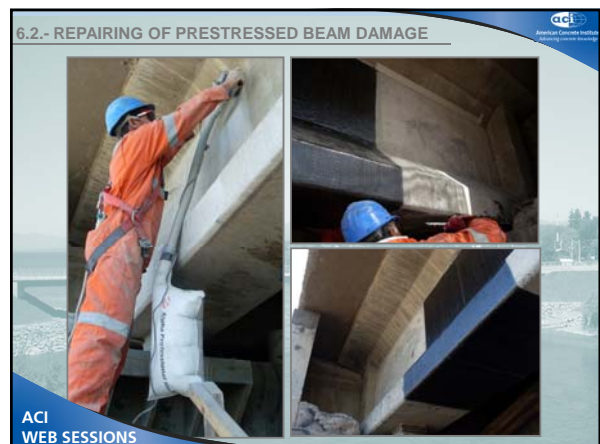
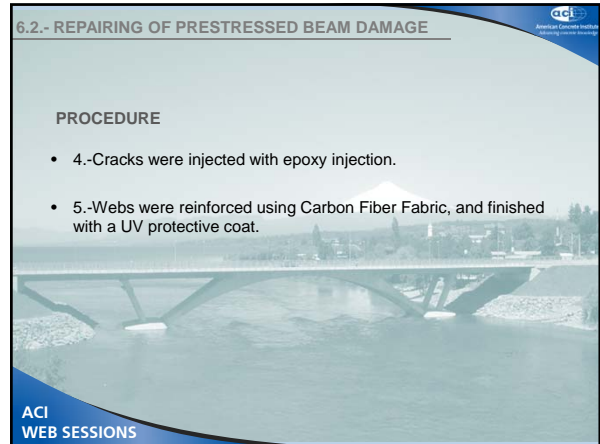
- 1.-Installing a temporary vertical support to the beam as close as possible to the end of the beam.
- 2.-Removing all the concrete and rebars damaged by the distortions or failure and cleaning up all the surfaces.
- 3.-Web and bottom flange concrete repairing were executed using two kinds of concrete depending on the size of the damage:
- -Grout mortar mixed with 25% 10mm gravel, and repairing mortar with fiber for small volumes. In both cases a bonding agent was applied on the old concrete surface.

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6.2.- REPAIRING OF PRESTRESSED BEAM DAMAGE



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6.3.- SUBSTRUCTURE REPAIRING

SCOPE

- Repairing and reinforcing frame columns damaged by shear and torsion.
- Repairing and reinforcing shear wall piers damaged by shear and bars buckling by compression because of deficient or inexistent confinement.

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6.3.- SUBSTRUCTURE REPAIRING

PROCEDURE

1.-COLUMNS

- Cleaning and detection of injectable cracks.
- Injection of cracks using epoxy .
- Reinforcement using Carbon Fiber fabric to improve strength and ductility.
- Finishing using UV protective coat.

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6.3.- SUBSTRUCTURE REPAIRING

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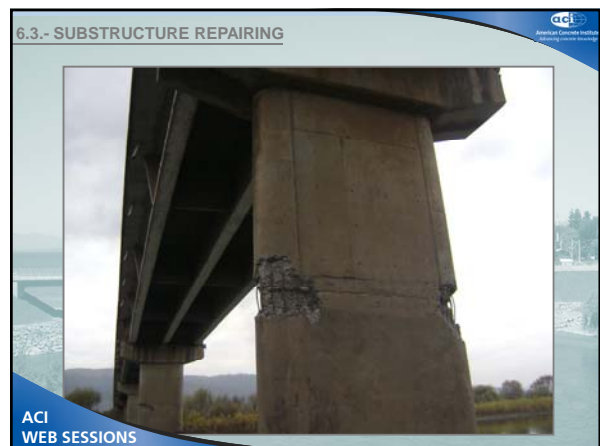


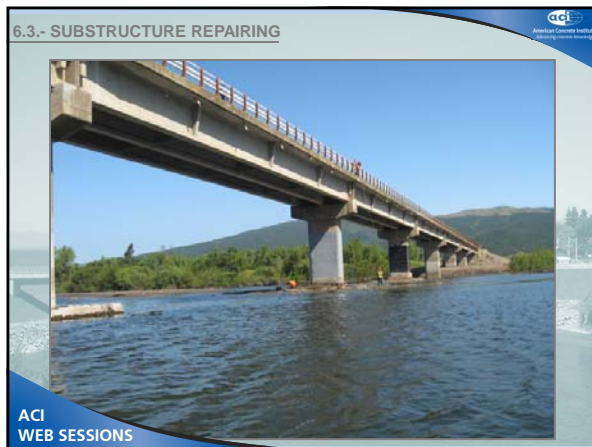
6.3.- SUBSTRUCTURE REPAIRING

2.-SHEAR WALL PIERS

- Cleaning and removal of all damaged concrete and rebars.
- Replacing of vertical rebars spliced with the old bars improving confinement with external horizontal rebars.
- To apply bonding agent in all the old concrete surfaces and to install formworks.(not always)
- Casting of repairing concrete or mortar in +/-1" layers.
- Installing horizontal carbon fiber fabric reinforcement to improve vertical bars confinement to avoid rebars buckling.
- Finishing using UV protective coat.

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6.4.- EXPANSION JOINTS REPLACEMENT

SCOPE

- Replacing of 6.000ft (2.000m) of expansion joints 2" average opening, destroyed by deck movement.
- Most of them were neoprene seal joints from different origins.

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6.4.- EXPANSION JOINTS REPLACEMENT

PROCEDURE

- To repair the expansion joints, the process was divided in 4 steps:
- 1.- Removal of damaged expansion joint .
- 2.- Clearing the area of dust and outside elements. Proceed to cut and demolish the damage surface, creating the space to apply the elastomeric concrete.
- 3.- Elastomeric concrete application with formwork.
- 4.- Installation of the neoprene extruded seal expansion joint.

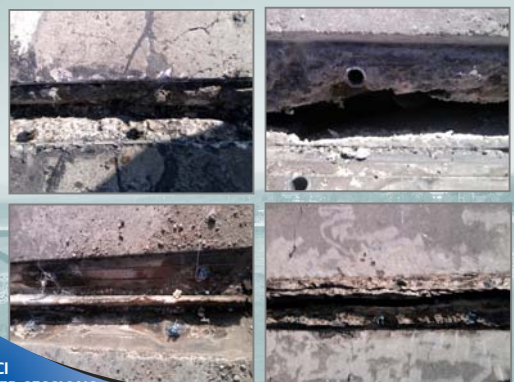
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6.4.- EXPANSION JOINTS REPLACEMENT



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6.4.- EXPANSION JOINTS REPLACEMENT



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6.4.- EXPANSION JOINTS REPLACEMENT



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6.4.- EXPANSION JOINTS REPLACEMENT



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6.4.- EXPANSION JOINTS REPLACEMENT



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