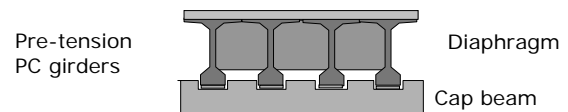


Types of Damage

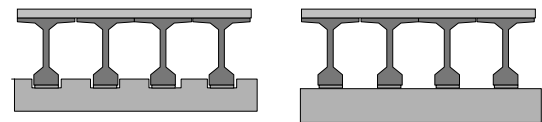
- Damage resulted from insufficient integrity of pre-cast concrete girder bridges due to absence of diaphragms
- Lack of constraint to rotation of deck in skewed bridges
- Damage of piers and foundations in bridges built in the early days
-

Why was damage extensive in bridges built in recent years?

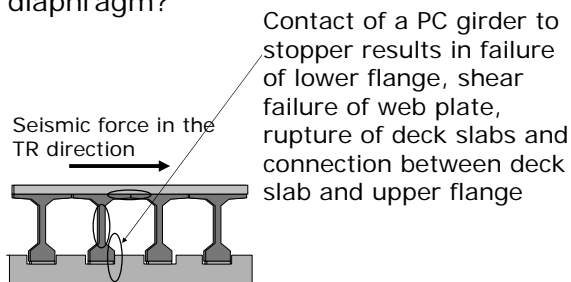
Pre Mid-1990s Typical Chile Bridges



After the Mid 1990s influenced by Spanish practice

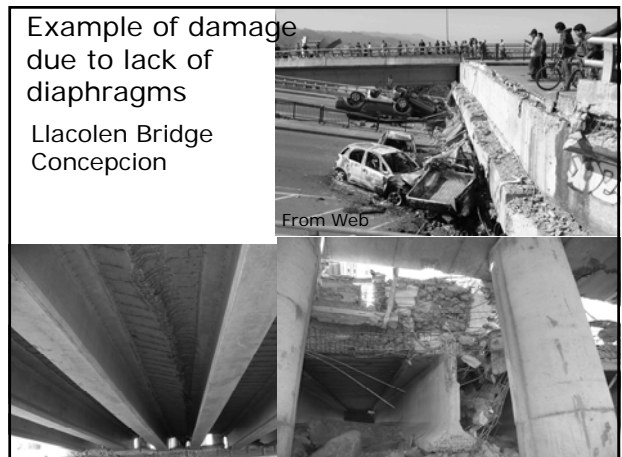


What happened in the bridges with insufficient integrity due to absence of diaphragm?

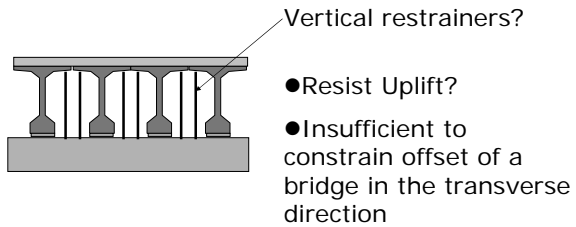


Example of damage due to lack of diaphragms

Llacolen Bridge
Concepcion



What happened if side stoppers on the top of pier cap were removed in addition to removal of diaphragms?



Example of damage due to lack of side stoppers and diaphragms

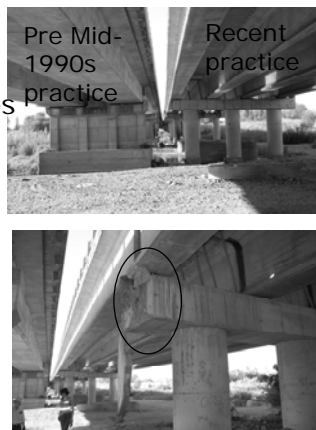
Las Mercedes Bridge
Route 5



Bridges based on recent practice suffered more damage than bridges based on pre mid-1990s practice

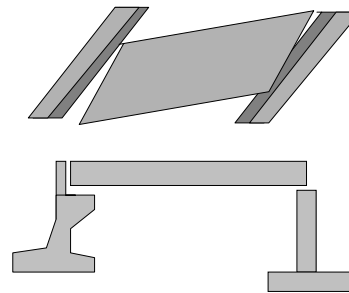
Perquilauquen Bridge
Route 5

Very lucky!
About to collapse



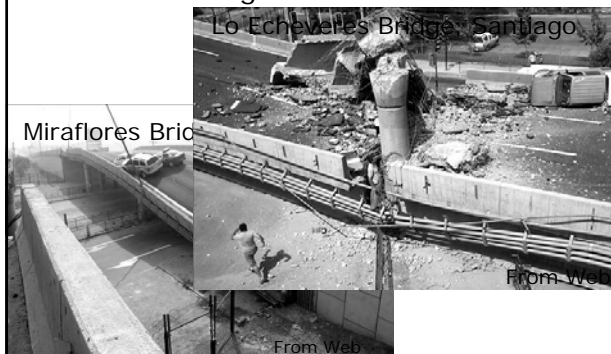
Lack of constraint to rotation of skewed bridges

Skewed bridges tend to rotation under seismic excitation



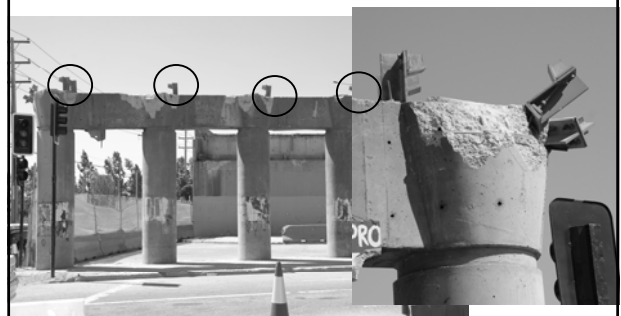
Watanabe, G. and Kawashima, K., Paper No. 789, 13th WCEE, 2004

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



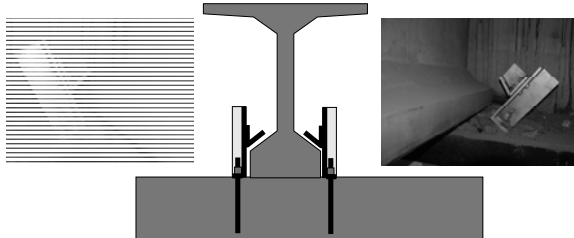
No mechanism to prevent TR and LG offset of bridges

Miraflores Bridge, Santiago



Stoppers for uplift?

- They were set not for preventing TR offset of bridges but for uplift prevention
- They were too weak



Skewed PC girder bridges recently built without diaphragms and effective side stoppers suffered extensive damage

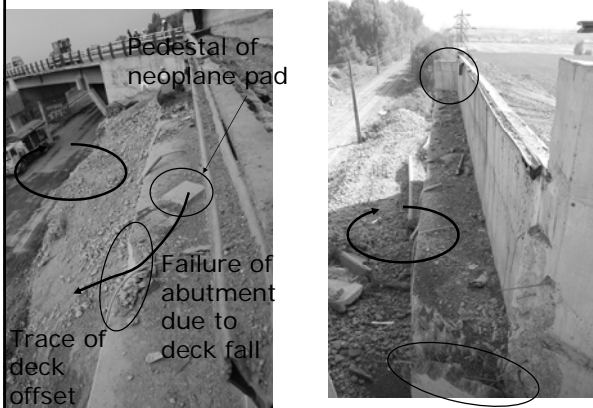
Hospital Bridge
Route 5

Recent practice



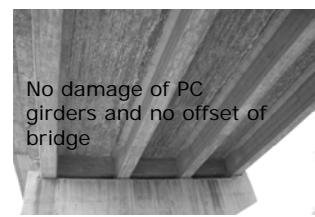
Pre mid-1990s Chile design
practice

Collapse due to rotation of a skew bridge



Older bridge based on Pre Mid-1990s Chile Design Practice performed well

Abutments and piers were built perpendicular to bridge axis (straight bridge)



No damage of PC girders and no offset of bridge

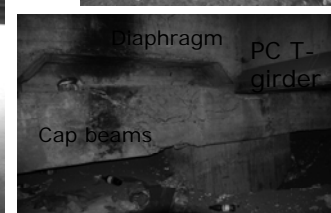


Stable abutments

Juan Pablo II Bridge



Various types of failure of columns and lateral beams



Diaphragm PC T-girder
Cap beams

Thank you for long contribution!

Rio Claro Bridge

A 140 years old unreinforced masonry bridge built in 1870



Claro Bridge
survived heavy
duty for long time

Brittle masonry
easy to remove
clay soil



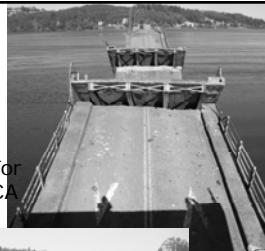
- Arch crown was only 3m thick
- It must be very tough to survive heavy traffic

Thank you for long contribution!

Bio Bio Bridge

● Built in 1930s

● Recognized to be insufficient for traffic since 1990s based on JICA evaluation



Tubul Bridge Arauco

Insufficient performance of foundations



Rupture of Elastomeric Bearing

Las Ballenas Bridge
Local Road, Suburbs of
Consepcion



A 15 cm tall
60cm by 60cm
elastomeric
bearing ruptures
due to shear at
shear strain of
about 70%

A new bridge constructed based on the existing Chile design survived with only very minor damage

- Side stoppers
- Diaphragms



SUMMARY

- Lack of integrity of a bridge due to absence of diaphragms and effective stopper mechanism in the transverse offset resulted in extensive damage in bridges built after the mid 1990s.
- The above deficiency was particularly intensified in skewed bridges resulted from rotation of a whole bridge.
- In contrast to the bridges built after the mid 1990s with insufficient insight to the seismic effects, the bridges which were built based on the original Chile practice did not suffer extensive damage.

SUMMARY (continued)

- Damage of columns/piers and foundations was not extensive except those in bridges built in the early days. However it is suggested to clarify their strength and deformation capacity if Chile practice moves toward higher connection between decks and substructures for limiting relative displacement.

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