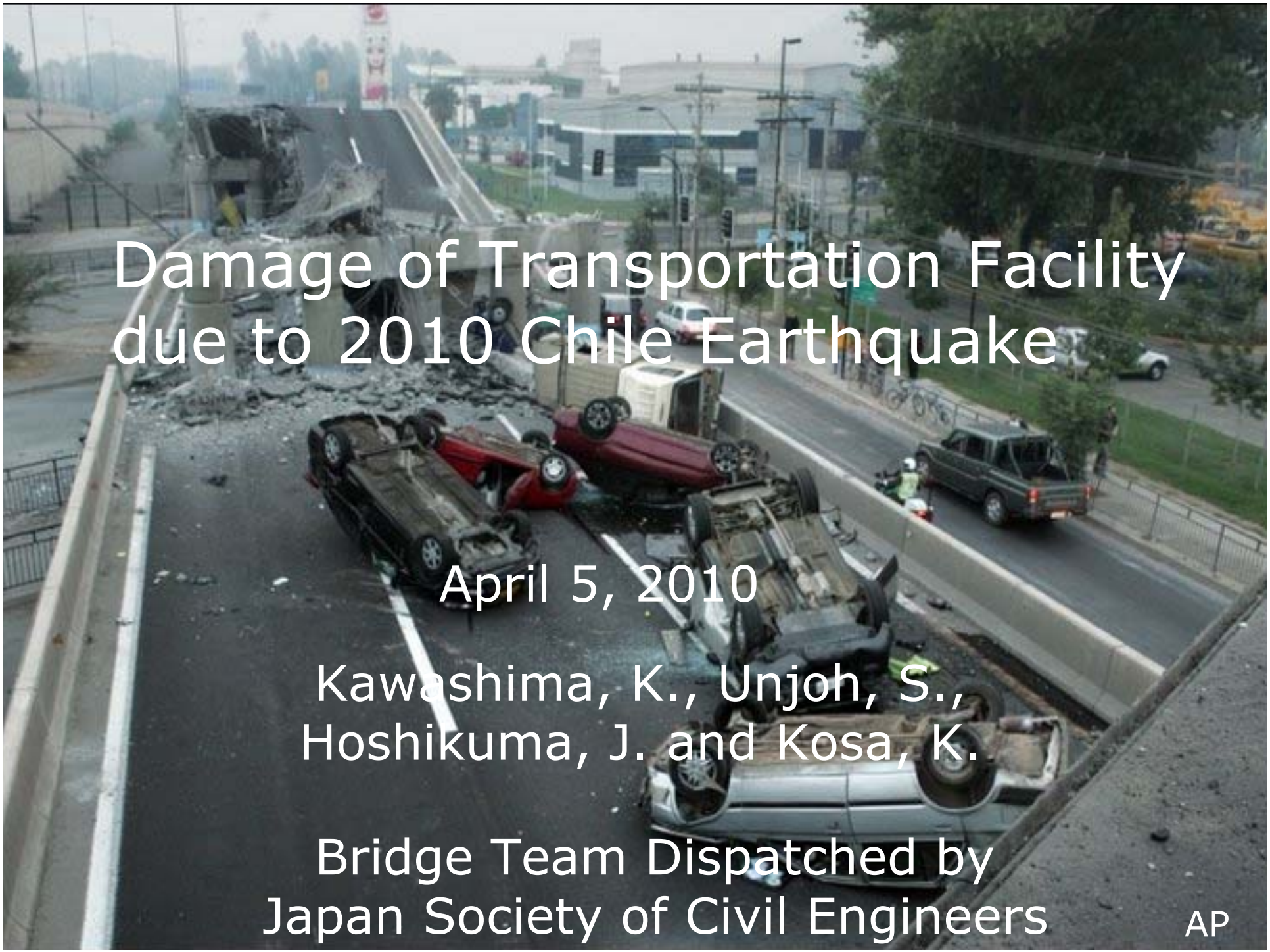


Damage of Transportation Facility due to 2010 Chile Earthquake

April 5, 2010

Kawashima, K., Unjoh, S.,
Hoshikuma, J. and Kosa, K.

Bridge Team Dispatched by
Japan Society of Civil Engineers

AP

45 bridges located at 30 sites were investigated

Suburbs of Cenception

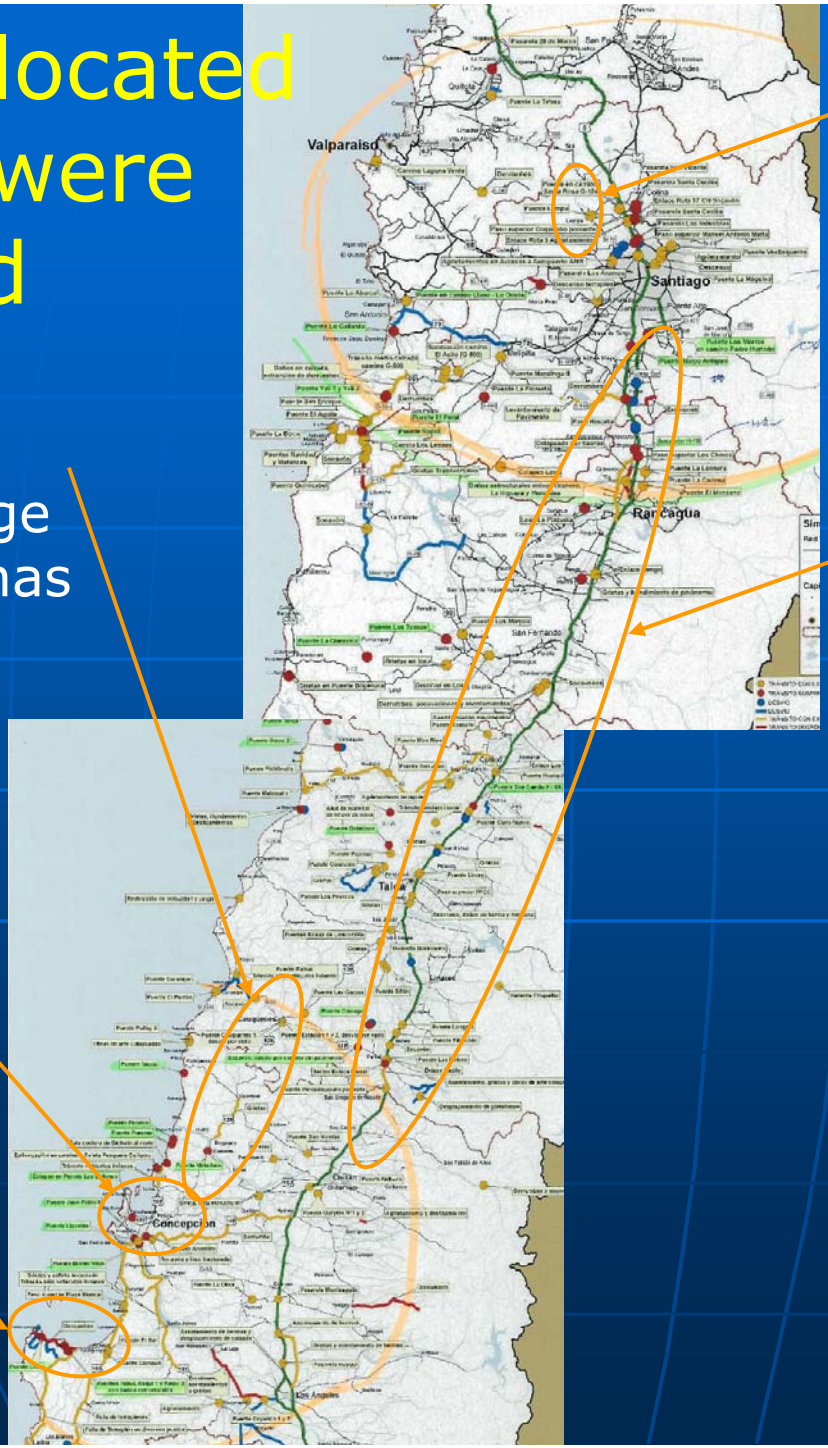
27. App. bridge
28. Las Ballenas
29. Lirquen
30. Itata

Conception

19. Jan Pablo II
20. Llacolen
21. Bio Bio
22. La Mochita
23. Laraquete

Arauko

24. Raqui I
25. Raqui II
26. Tubul



Santiago

1. Mira Flores
2. Lo Echeveres
3. Americo ves Pusio
4. San Martin
5. Emanuel Antonio

Route 5

6. Maipo
7. Hospital
8. Pedestrian bridge
9. Augostura
10. Graneros
11. Les Mercedez
12. Rio Claro
13. Rio Maule
14. Longavi
15. Copihue
16. Parval
17. Perqui Lauquen
18. ? (Gerbar hinge)

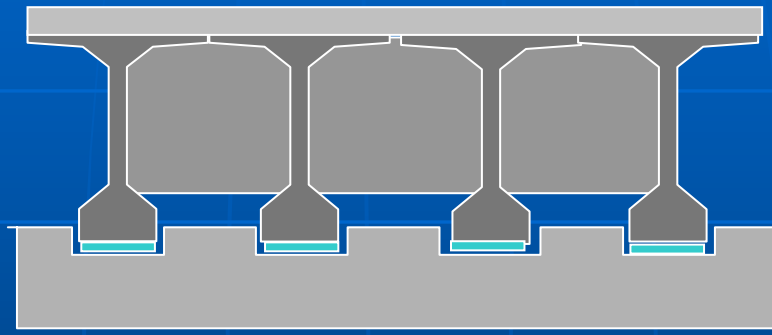
Types of Damage

- 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

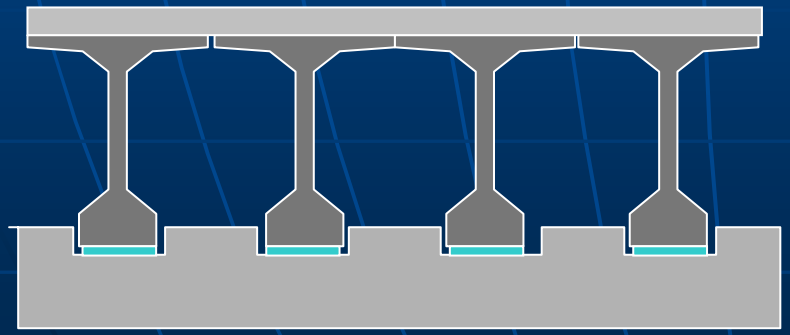
Pre-tension
PC girders

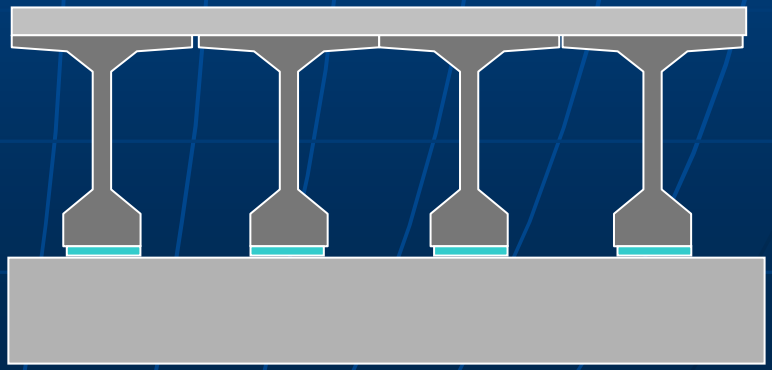


Diaphragm

Cap beam

After the Mid 1990s influenced by Spanish practice

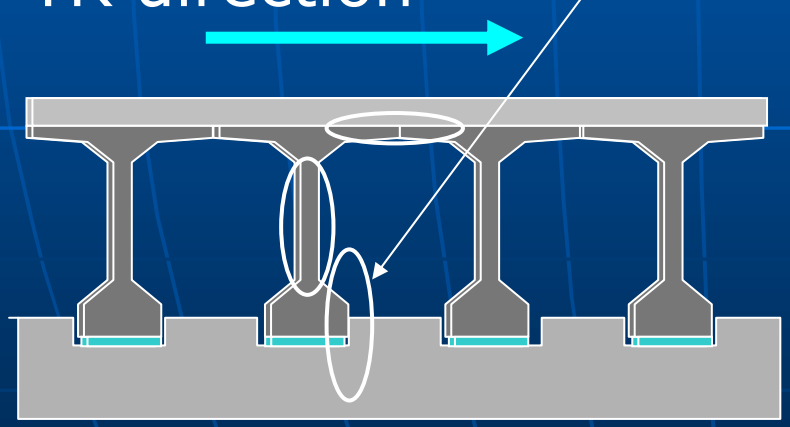




What happened in the bridges with insufficient integrity due to absence of diaphragm?

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

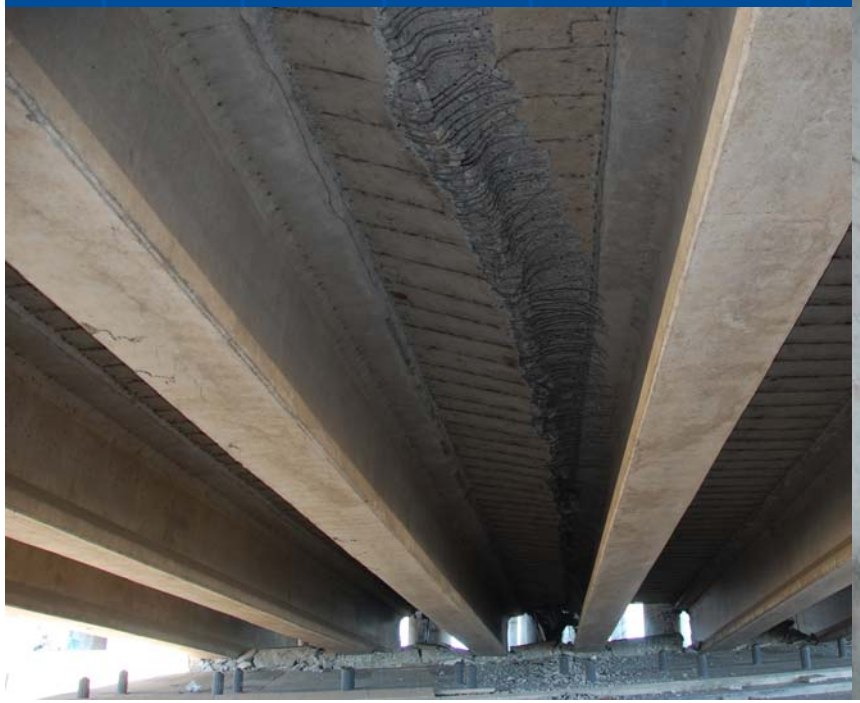
Seismic force in the TR direction



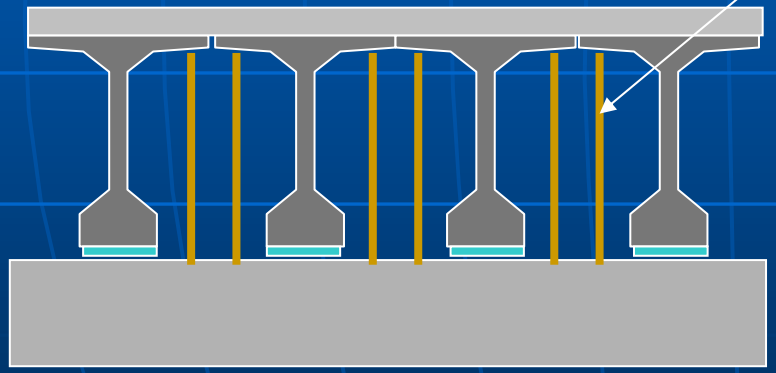
Example of damage due to lack of diaphragms

Llacolen Bridge

Conception



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



- Resist Uplift?
- Insufficient to constrain offset of a bridge in the transverse direction

Example of damage due to lack of side stoppers and diaphragms

Las Mercedes Bridge

Route 5

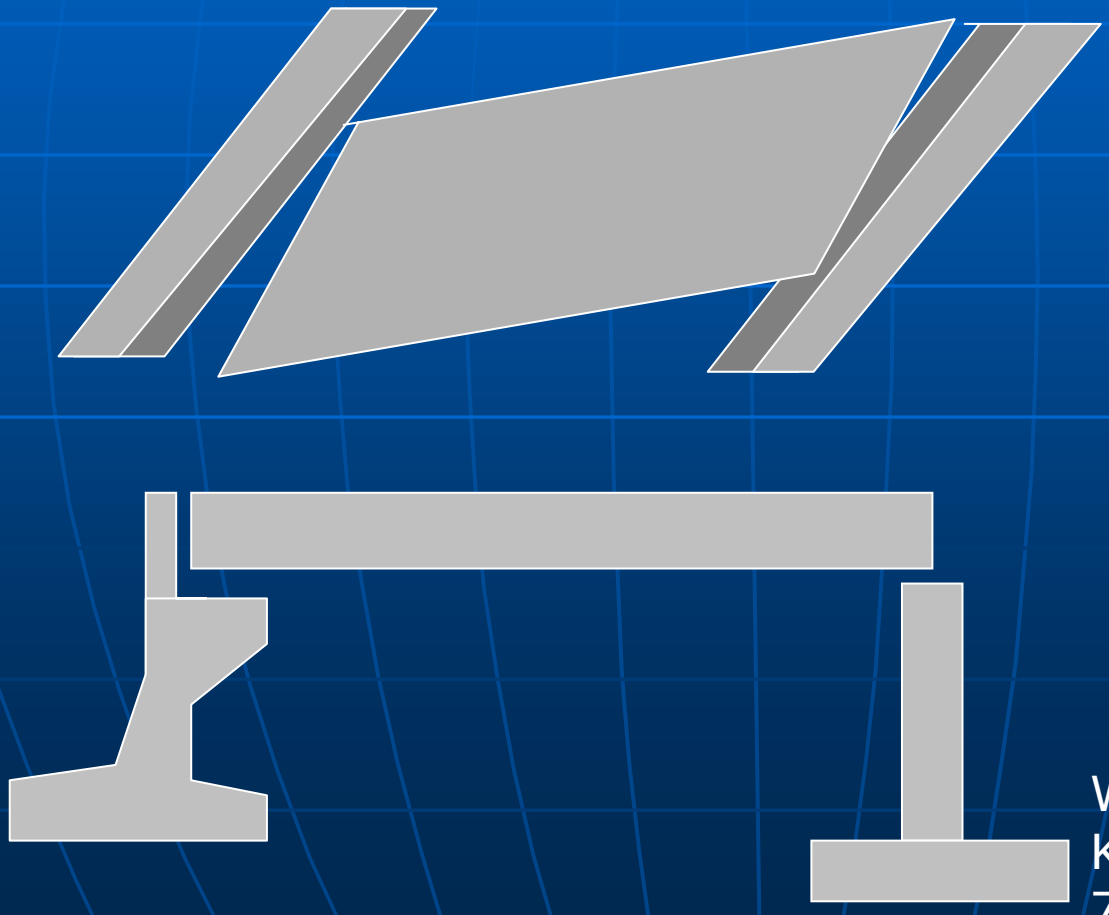
Bridges based on recent practice suffered more damage than bridges based on pre mid-1990s practice

Perqui Lauquen Bridge
Route 5

Very lucky!
About to collapse

Lack of constraint to rotation of skewed bridges

Skewed bridges tend to rotation under seismic excitation



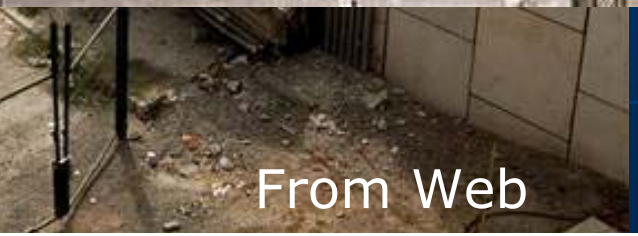
Watanabe, G. and Kawashima, K., Paper No. 789, 13th WCEE, 2004

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

Lo Echeveres Bridge, Santiago

From Web

Mira Flores Bri



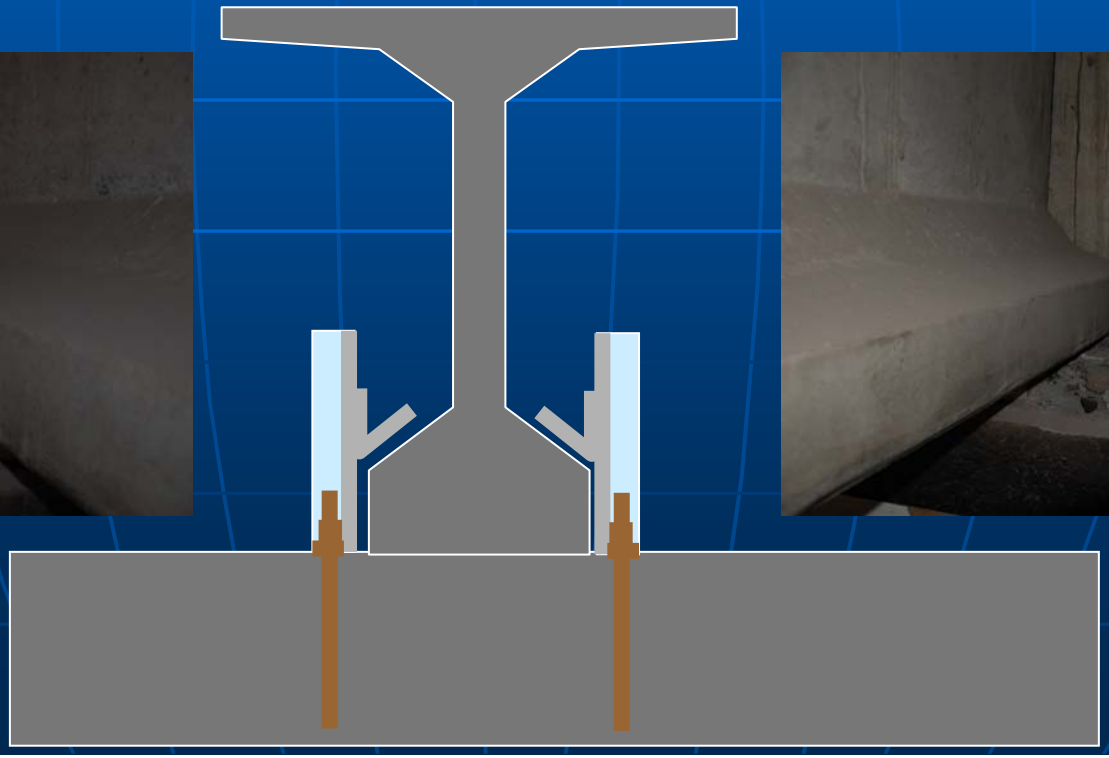
From Web

No mechanism to prevent TR and LG offset of bridges

Mira Flores 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

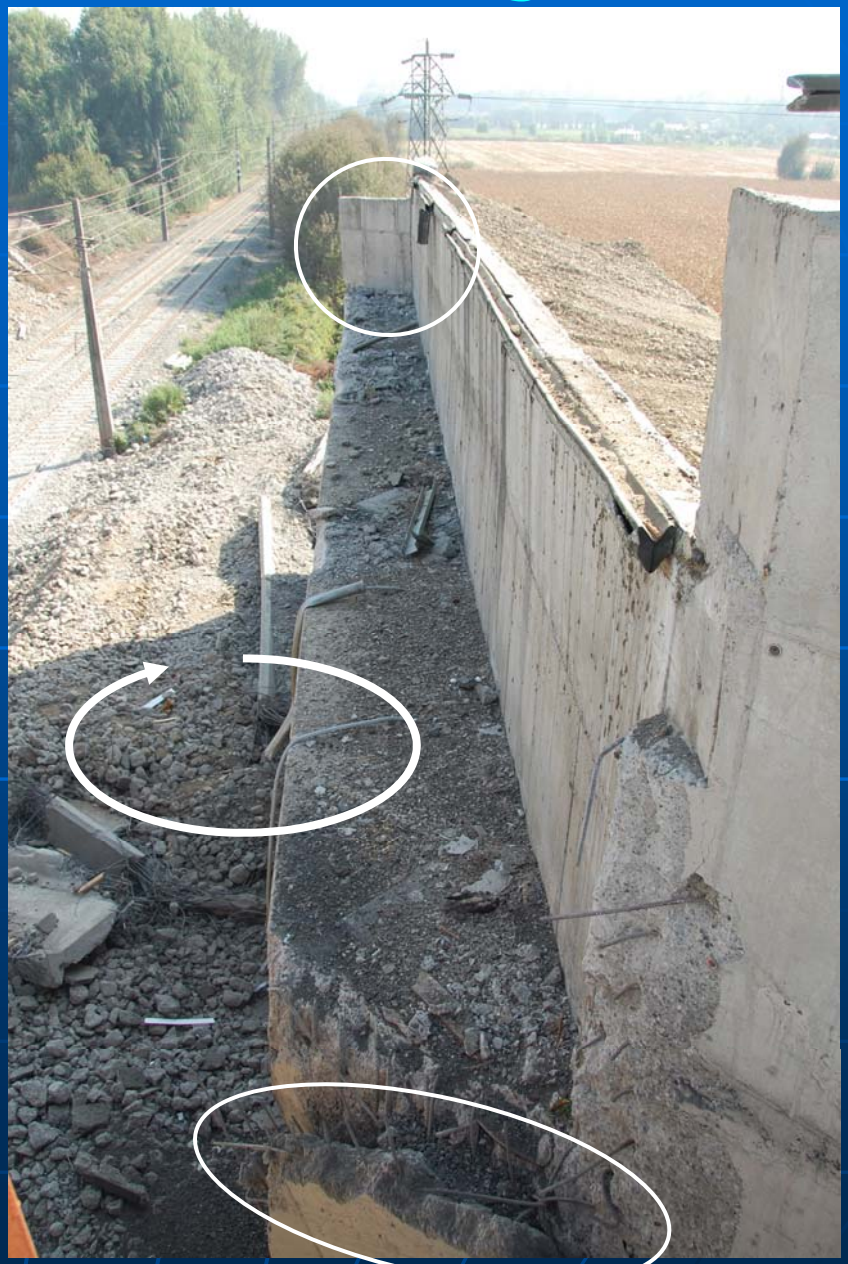
Hospital Bridge
Route 5

From Web

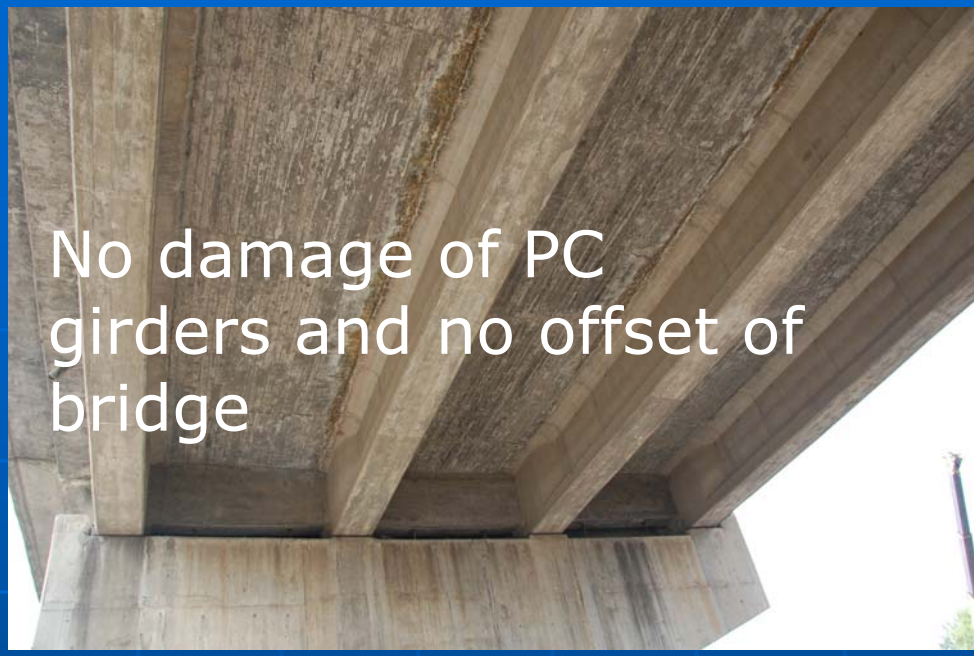
Recent practice

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

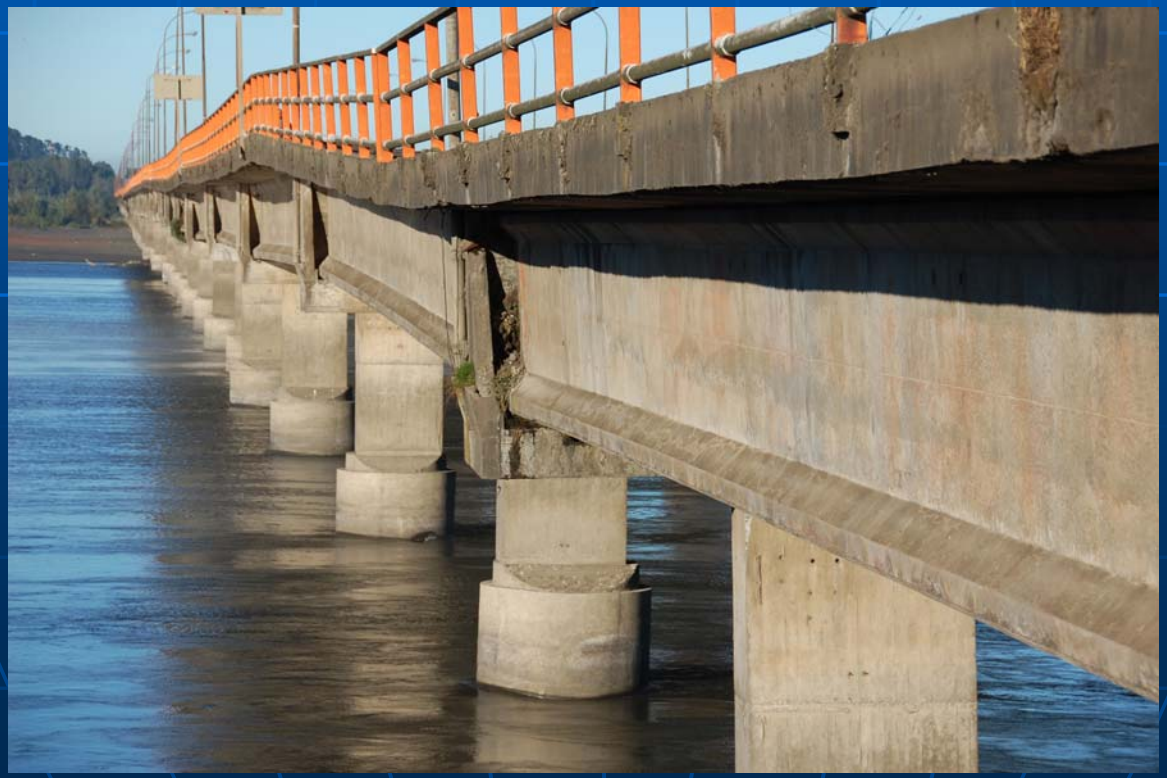


No damage of PC girders and no offset of bridge

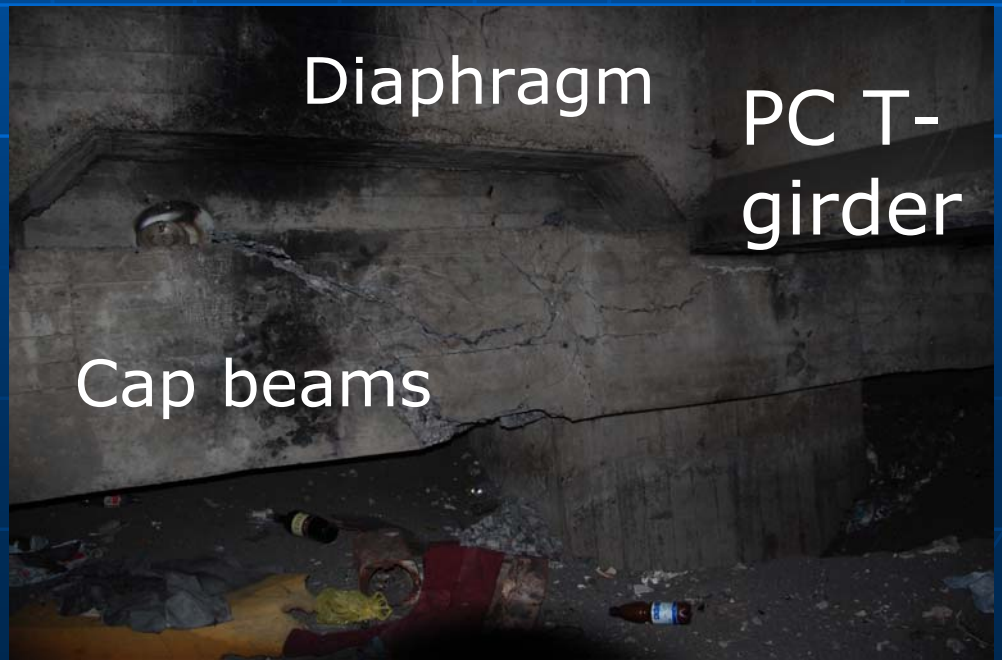
Abutments and piers were built perpendicular to bridge axis (straight bridge)

Stable abutments

Jan Pablo II Bridge



Various types of failure of columns and lateral 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 tuff to survive heavy traffic

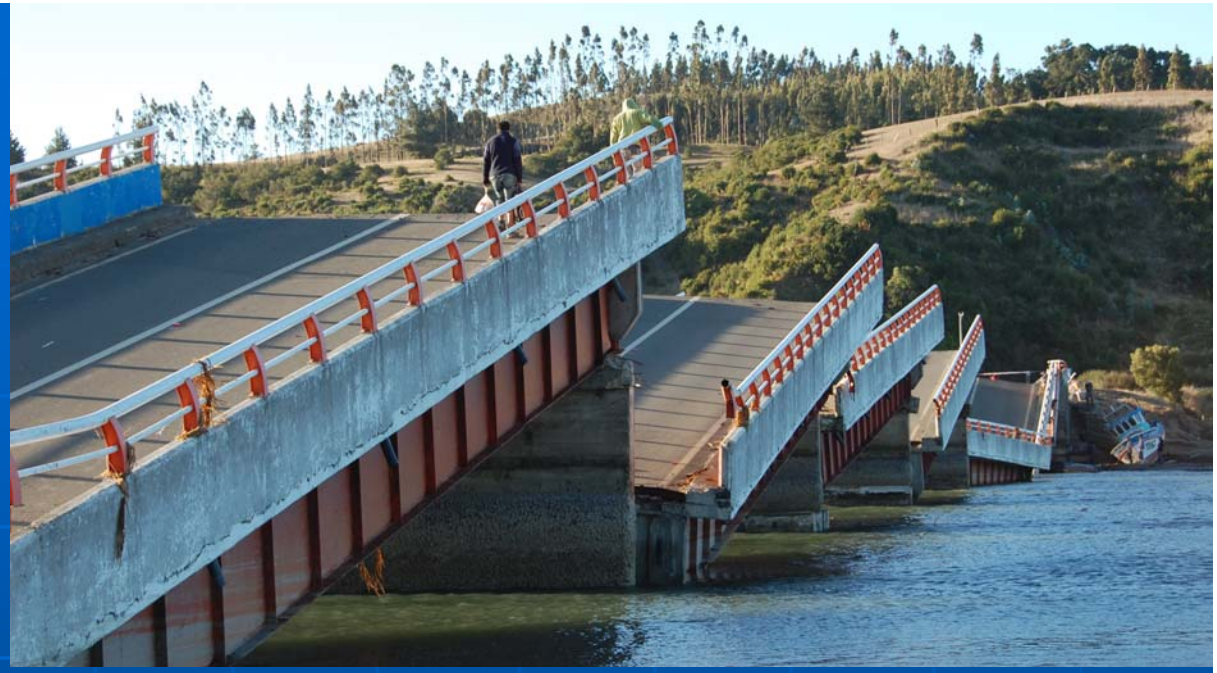
Thank you for long contribution!

Bio Bio Bridge

- Built in 1930s
- Recognized to be insufficient for traffic since 1990s based on JICA evaluation

Tubul Bridge
Apauco

Insufficient performance of foundations



Rupture of Elastomeric Bearing

Las Balenas Bridge

Local Road, Suburbs of Conseption

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.

ACKNOWLEDGEMENTS

Damage investigation of bridges was supported by number of personals. Special appreciation is extended to Ing. Fernandez, M., Ing. Ortega, J.M., Ing. Carracedo, M., Ing. Guzman, M., Ing. Achvrra, S., Ing. Concha, A., Ing. Valdebenito, R. (Ministry of Public Works), Dr. Celebi, M. (USGS), Professor Saragoni, G.R. (Univ. Chile), Professor Alvarado, R.V. (Catholica Univ.), Professor Fishinger, M. (Univ. Lubujana), Professor Omer, A. (Tokai Univ.) and Ing. Furukawa, K. (Interpreter).