Damage of Transportation Facility due to 2010 Chile Earthquake

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Bridge Team Dispatched by Japan Society of Civil Engineers
45 bridges located at 30 sites were investigated.

**Suburbs of Concepción**
- 27. App. bridge
- 28. Las Ballenas
- 29. Lirquen
- 30. Itata

**Concepción**
- 19. Jan Pablo II
- 20. Llacolen
- 22. La Mochita
- 23. Laraquete

**Arauco**
- 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. Augustura
- 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.
Example of damage due to lack of diaphragms

Llacolen Bridge
Conception

From Web
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

Vertical restrainers?
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

Pre Mid-1990s practice
Recent practice
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

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

Recent practice

Pre mid-1990s Chile design practice

From Web
Collapse due to rotation of a skew bridge

Pedestal of neoplane pad

Trace of deck offset

Failure of abutment due to deck fall
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
Jan Pablo II Bridge
Various types of failure of columns and lateral beams

Cap 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 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 Conception

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.
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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