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Universidad de los Andes

Dirección de Vialidad
Ministerio de Obras Públicas

First Applications Of Structural Redundancy In Chilean Bridges

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1. Introduction

Ministerio de Obras Públicas
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1. Introduction

- ➢ Redundancy in structural design ➔ higher degrees of structural safety.

(Frangopol & Curley 1987)	• Defined it as in case of absence of one or more critical components the structure will eventually collapse.
(Ghosn & Moses 1998)	• Studied bridge type structures and defined the redundancy as the capability to keep sustaining loads after the failure of one of its members.
(Kanno & Ben-Haim 2010).	• The extent of degradation that a structure can suffer without losing functionality

- ➢ Chilean proposal Definition

(Figueroa 2015)	• The structural property of being able to redistribute loads off members that exceeded their design limit state.

2. Chilean experience

Design of traditional bridges: Manual de Carreteras + AASHTO Standard
New codes application ➔ AASHTO LRFD 2012 (redundancy)

Relation between seismic loads and scour ➔ Seismic scour hazard (PSS)

Figure 1. Eroded soil around the pier of the Curacavi Bridge, in Metropolitan Region, Chile.

2. Chilean experience

2010 earthquake in Chile → Many cases of soil liquefaction which reduces the bearing capacity

Study Justification

Structural redundancy in bridges with special focus in pier failure to make sure that designs have enough of it to prevent loss of functionality

No experience in the Chilean design

Figure 2. Loncomilla Bridge collapsed due to scour. (Fisco deberá pagar. 2011)

3. Redundancy Indices

Liu et al. 2000 : Deterministic and non linear incremental

“A bridge substructure is considered as safe if it provides a reasonable safety margin against ultimate failure(whether due to excessive component damage or overall system collapse) and it does not exhibit excessive displacements that render the bridge inadequate for use”

- Ultimate Limite State (LFu)
- Ultimate limit state for damaged condition (LFd)
- Reserve ratios (1.2<Ru, 0.5<Rd)
- Redundancy factor, 1.0<φs

4. Case Study

Ramadillas 2 Bridge

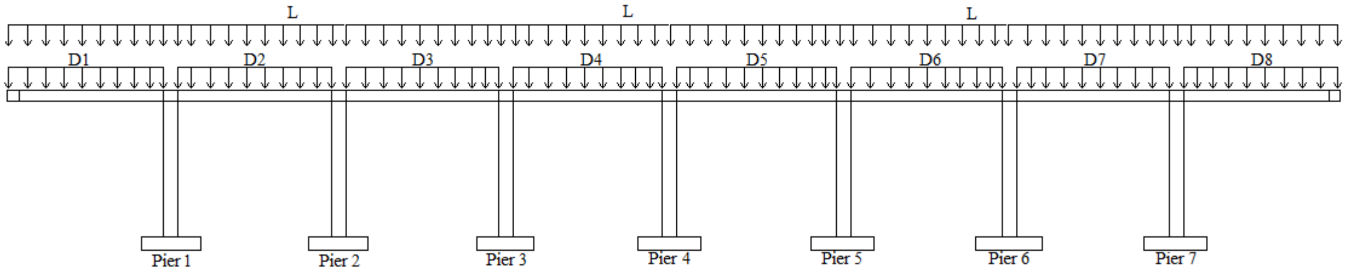


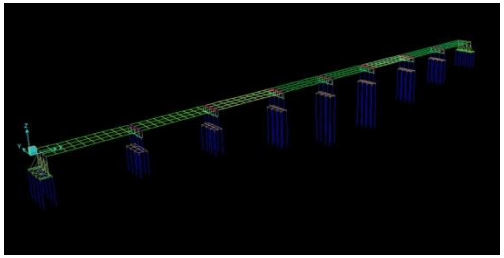
Figure 5. Load distribution in the case study.

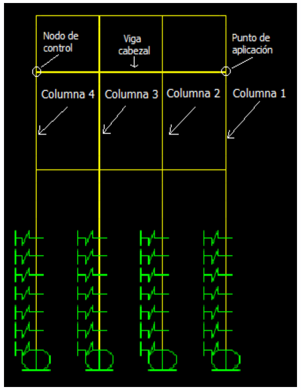
- Route 160 Concepción – Lebu
- Carampangue river
- Concrete slab. Semi-continuos span
- 4 concrete precast beam
- Total length 280 [m]

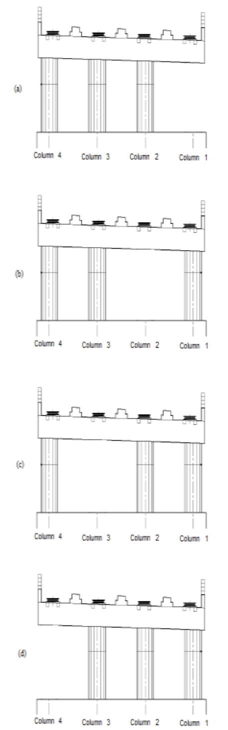
- Concrete column piers
- Foudation: Piles (1.2 – 9.5 m)
- width of the deck 12.85 m
- Loads: DD- LL 4000 kgf

5. Application Methodology

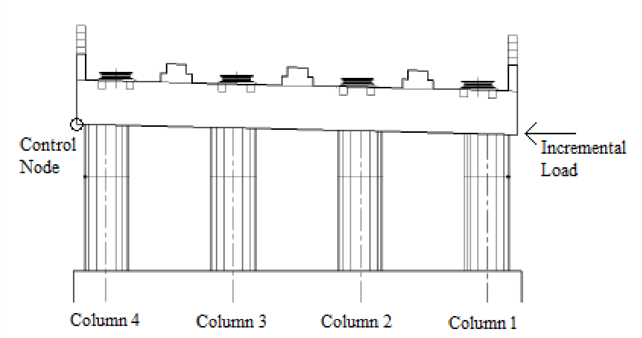
- 1) FEM model.
- 2) Damage scenarios. Five different damage scenarios.
- 3) Enumerate piers, main members and damage scenario.
- 4) Non-linear pushover analysis.
- 5) Collect and analyze results.







- Load application point is located on the cap beam
- Load increases perpendicular to the longitudinal axis of the structure.
- Control node is located on the opposite side of the cap beam
- Plastic hinges were located on every column at 5% and 95% of the column height.



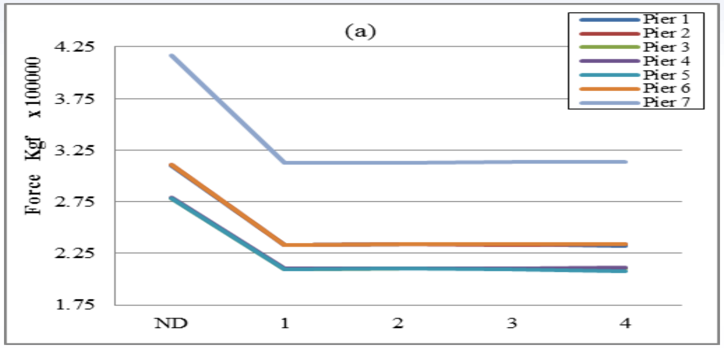
6. Results

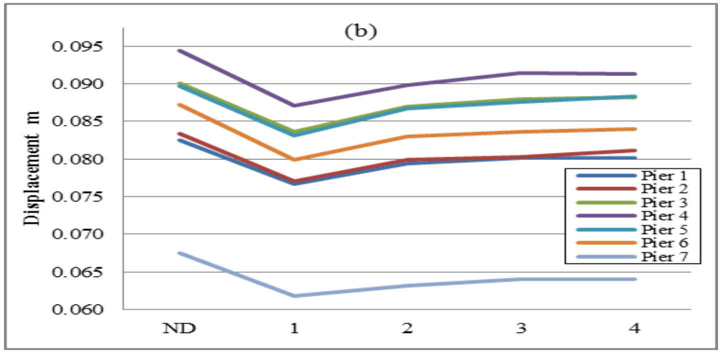
	Redundancy Factors ND
Pier 1	1.3404
Pier 2	1.3895
Pier 3	1.3316
Pier 4	1.3437
Pier 5	1.3332
Pier 6	1.3548
Pier 7	1.3835

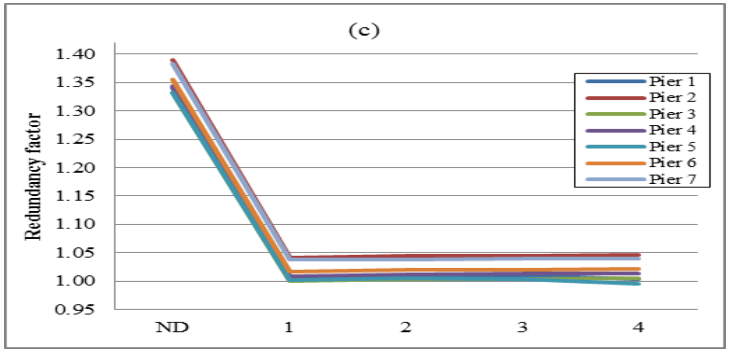
Maximum variation of 4.3%

	1	2	3	4
Pier 1	1.005	1.009	1.009	1.004
Pier 2	1.042	1.045	1.044	1.046
Pier 3	1.000	1.004	1.003	1.005
Pier 4	1.009	1.012	1.013	1.014
Pier 5	1.001	1.005	1.004	0.995
Pier 6	1.016	1.020	1.020	1.021
Pier 7	1.037	1.038	1.040	1.040

Pier 7 Critical (near abutment)!!







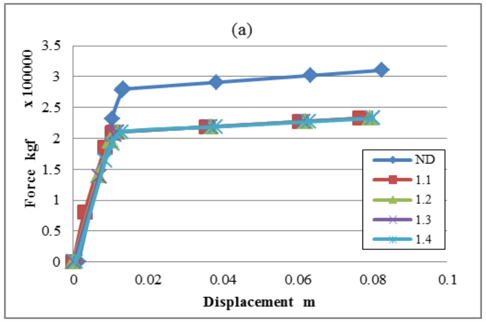
Figueroa & Valenzuela (2016), First Applications Of Structural Redundancy In Chilean Bridges

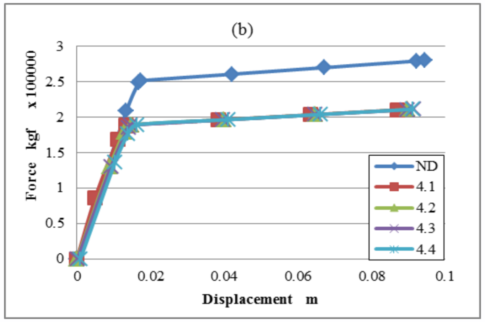
6. Results

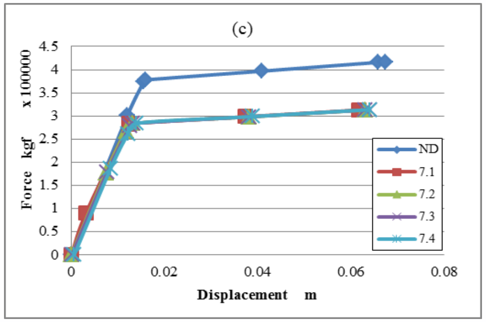
Damage Scenario	Ru/1.2	Rd/0.5
Pier 7		
Collapse ND	1.1529	
Collapse 7.1		2.0750
Collapse 7.2		2.0750
Collapse 7.3		2.0798
Collapse 7.4		2.0805

The Pile Soft property (similar to the case study)
Failure of first member 0.05 m
Mechanism state before reaching 0.1 m,

Solid structural redundancy.







6. Final Comments

1. Redundancy of the traditional Chilean bridge, Ramadillas 2, were evaluated
2. Incremental lateral loads emulate the plastification at the piers due to seismic loads and scour.
3. 2010 earthquake. Bridges withstand the damage because of their redundancy
4. Transition Manual de Carreteras / AASHTO LRFD
5. Identified different alternatives to increase this capacity.
6. Future research ongoing (superestructure)

Santiago – CHILE
18 al 20 de Octubre de 2017
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Venue – Santiago Chile

Technical Visit – Puerto Montt, Chile
Chacao Bridge Project

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Thank you

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