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CHRISTCHURCH NEW ZEALAND

NHERI@UC SAN DIEGO
LARGE-SCALE GEOTECHNICAL SHAKE TABLE TEST
PLANNING WORKSHOP

MAY 31, 2017; SAN DIEGO, CA

Experiences in New Zealand: Geo-structural observations

Waiheke Island, New Zealand, 2015

Alessandro Palermo

Professor in Structural Engineering

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Presentation Outline

- NZ bridge portfolio
- Lesson learnt from recent NZ earthquakes
- Initiatives taken after the NZ earthquakes
- Shift towards repairable connections
- Research questions and opportunities for collaboration

New Zealand Bridge portofolio

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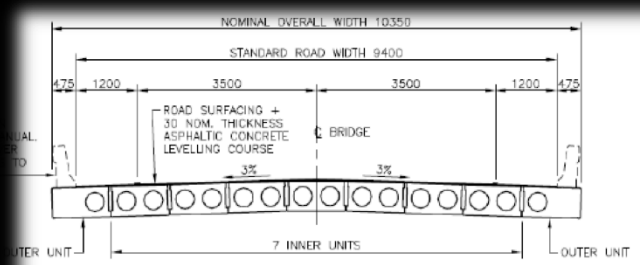
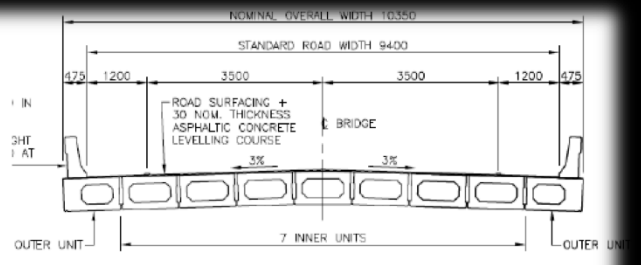
New Zealand Bridge portofolio

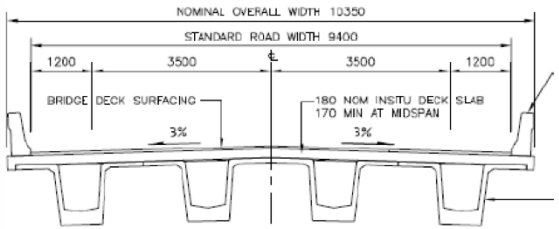
Low-medium span bridges (mainly precast concrete decks



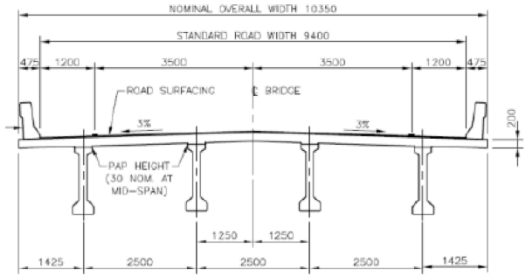
Duo Hollow Core section (up to 14m span length)



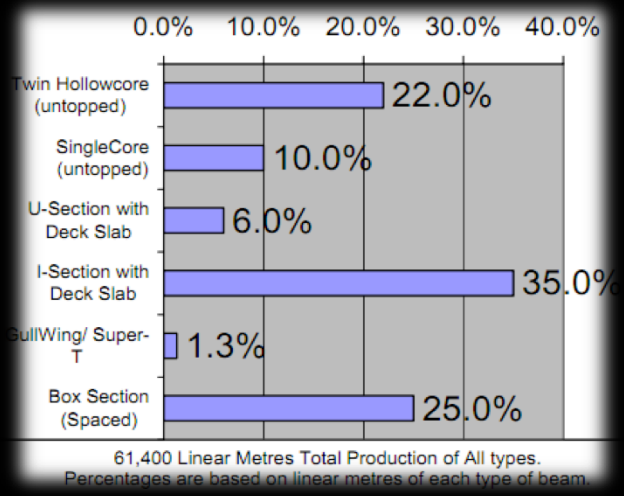
Hollow Core section (up to 22.5/25m span length)



Super T section (up to 30m span length)



I section (up to 24m span length)



NZTA Research report 364, 2008

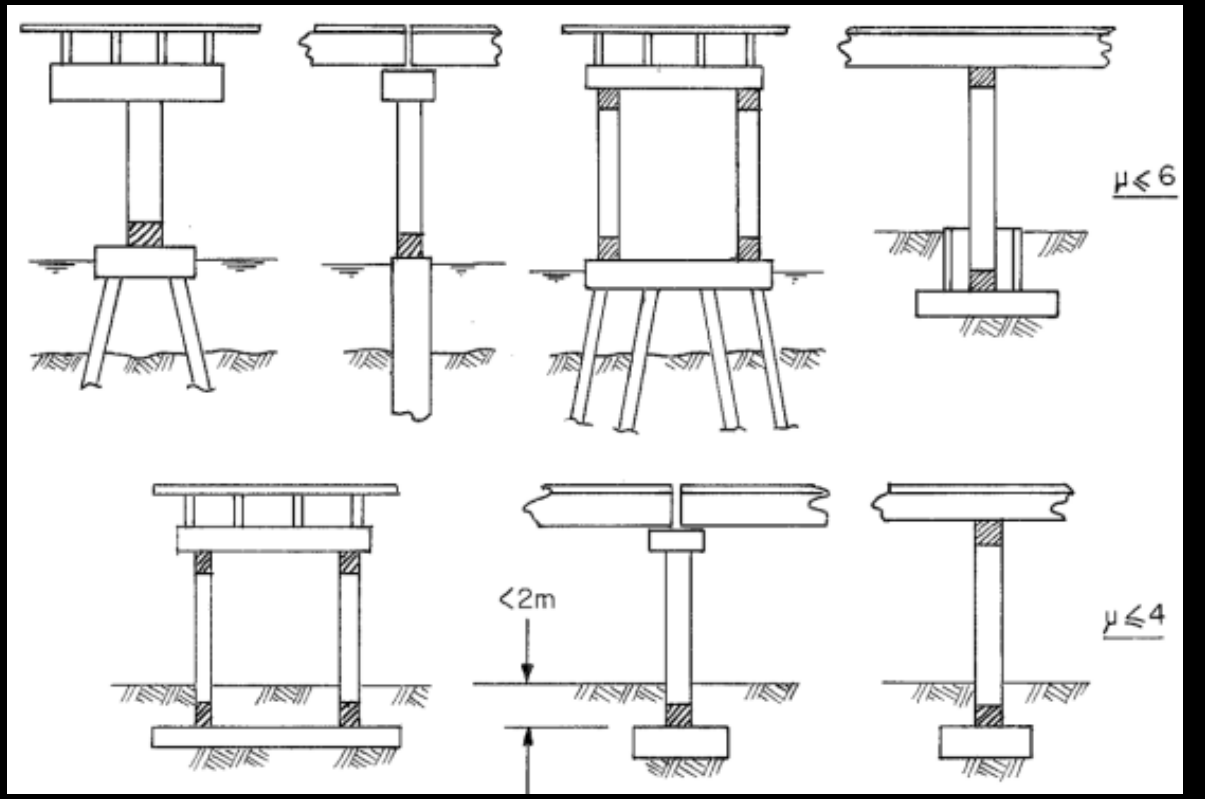
Currently the state highway network in NZ includes about 11-12,000 kilometers of roads, more than 4000 bridges and large number of culverts. The combined length of bridges on the state highway network is over 160 kilometers

New Zealand Bridge portofolio

Current Design Ductility

In the NZTA Bridge Manual the allowable ductility is defined by:

1. Robustness of the structural form
2. Redundancy of the system
3. Predictability of behavior



NZTA Bridge Manual 3rd edition (Figure 5.3)

Preliminary Draft BM limits ductility to 4 rather than 6 (for reasons associated with monolithic connections)

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Lessons Learnt from recent NZ earthquakes

Lessons Learnt from recent NZ earthquakes

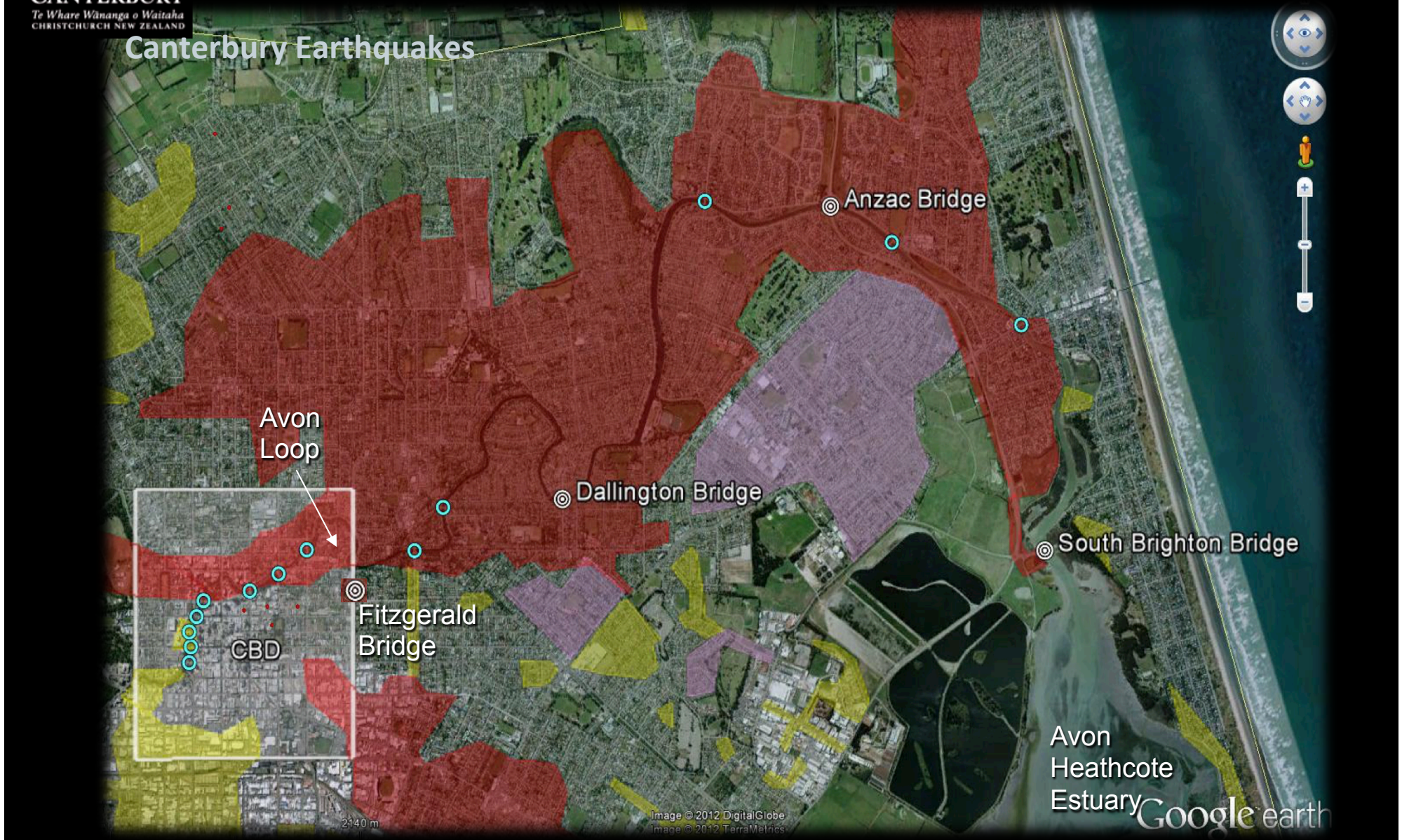
Canterbury Earthquakes (2011)

Cubrinovski et al. (2011)

Kaikoura Earthquake (2016)

Dizhur & Giaretton (2016)

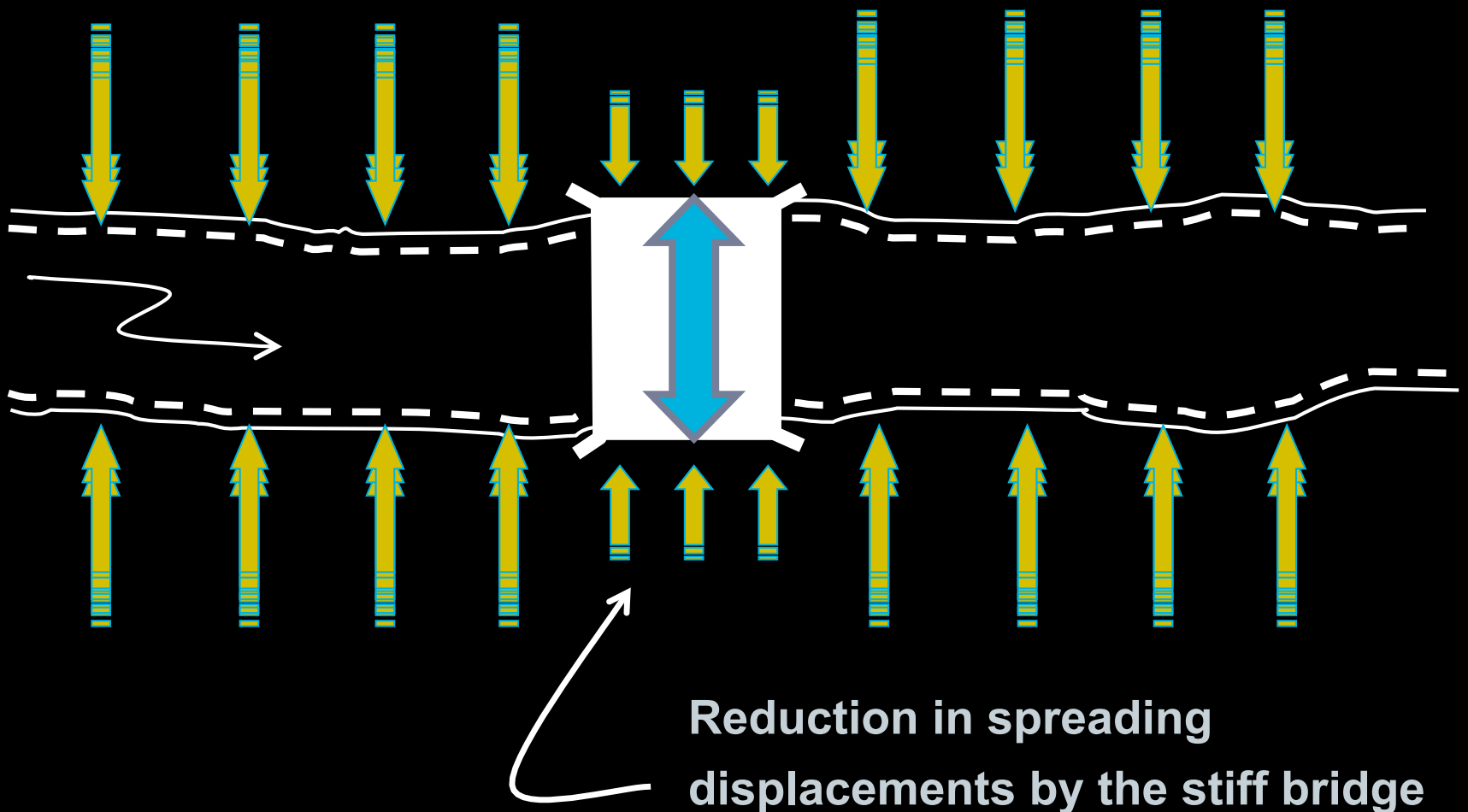
Lessons Learnt from recent NZ earthquakes



Cubrinovski et al. (2014) ASCE J. of Constructed Facilities
Cubrinovski et al. (2014) EQ Spectra

Lessons Learnt from recent NZ earthquakes

Spreading-induced Damage Mechanism



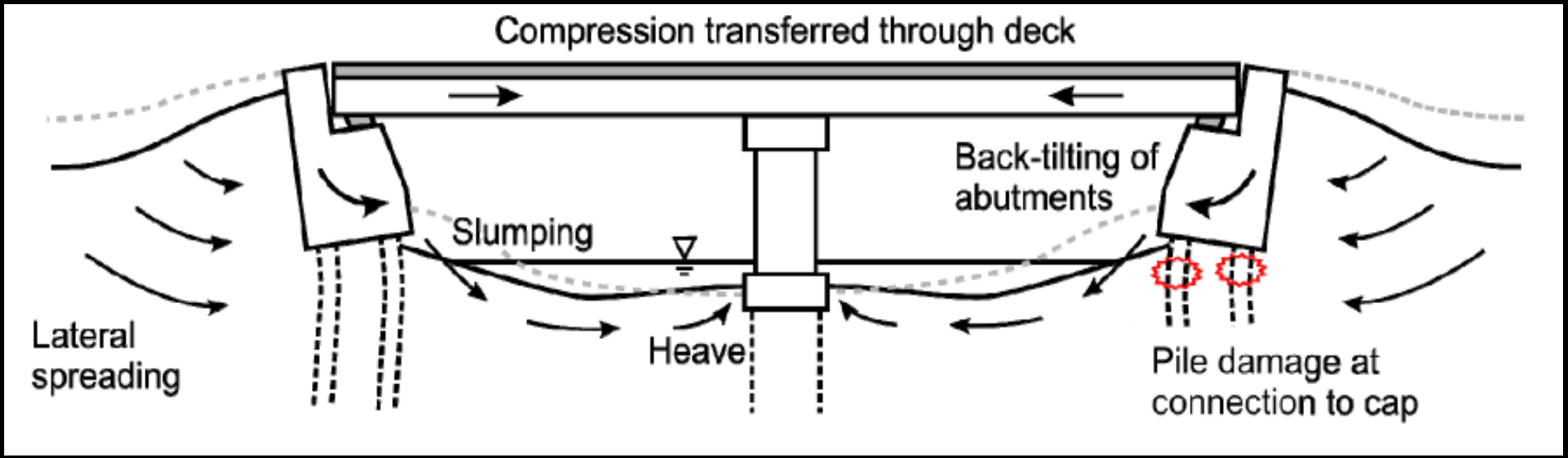
Reduction in spreading displacements by the stiff bridge structure

- short, two or three span bridges, L = 25 – 50 m (65m)

Courtesy of M. Cubrinovski

Lessons Learnt from recent NZ earthquakes

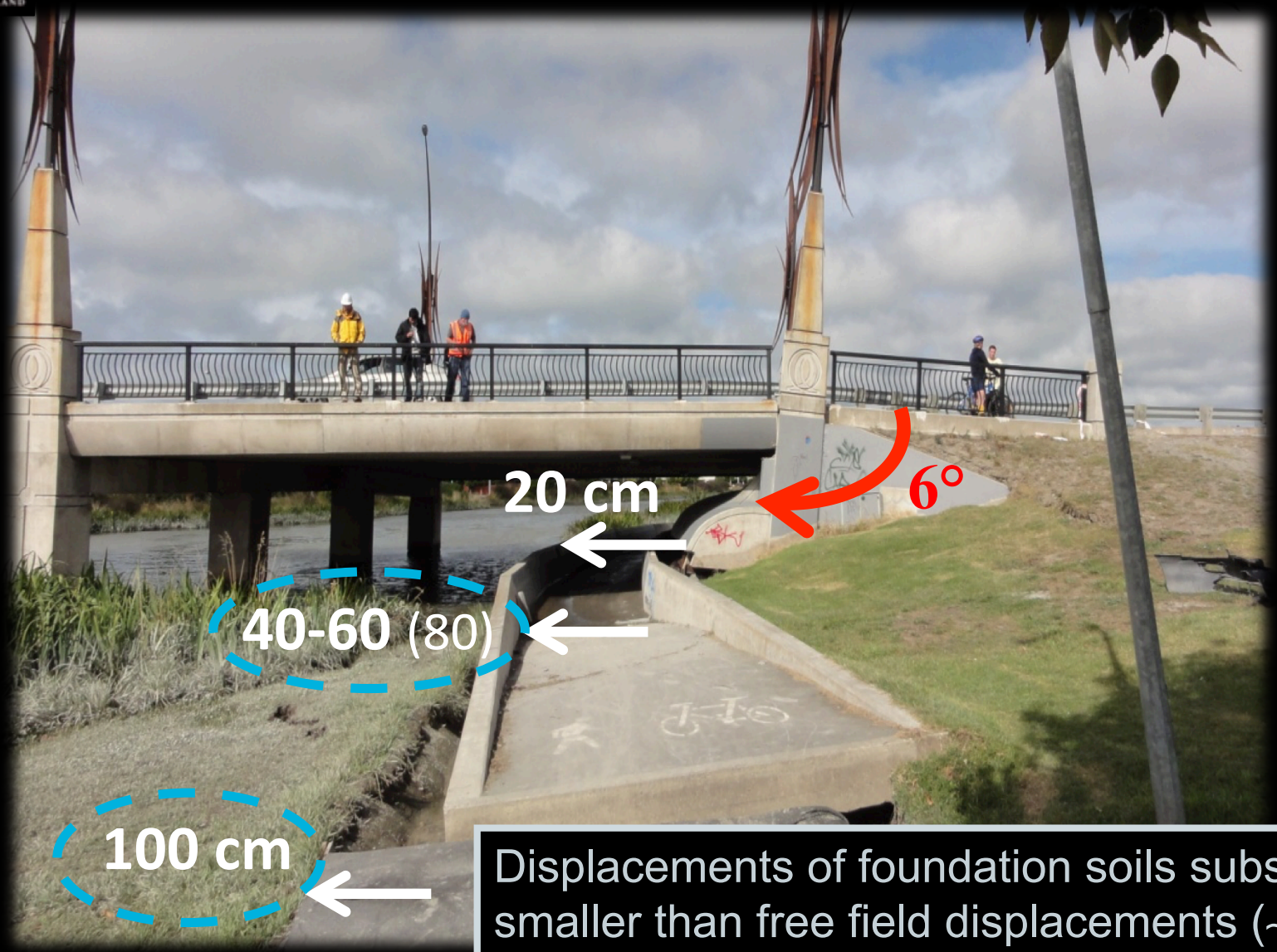
- Short span/length bridges; two or three spans, L = 25 m – 50 m (65m)
- Stiff/robust superstructure with high capacity to resist lateral loads



Deck-strutting → Abutment inward-rotation → Pile displacement → deformation → damage

Courtesy of M. Cubrinovski

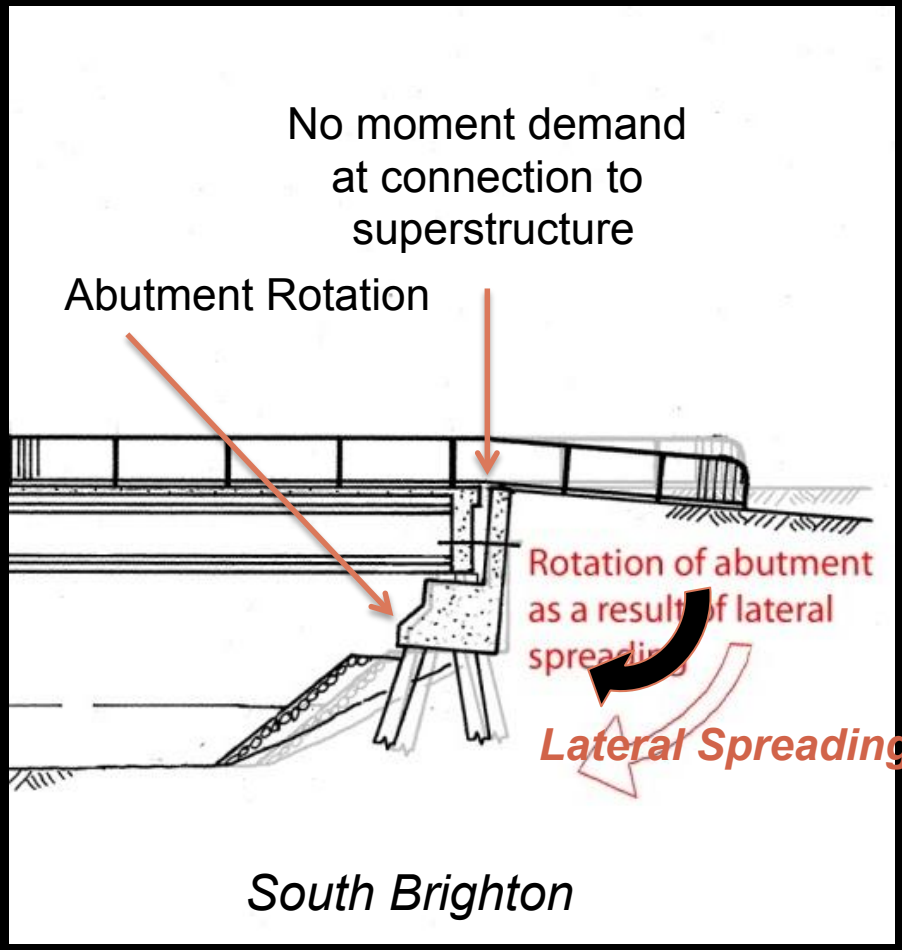
Lessons Learnt from recent NZ earthquakes



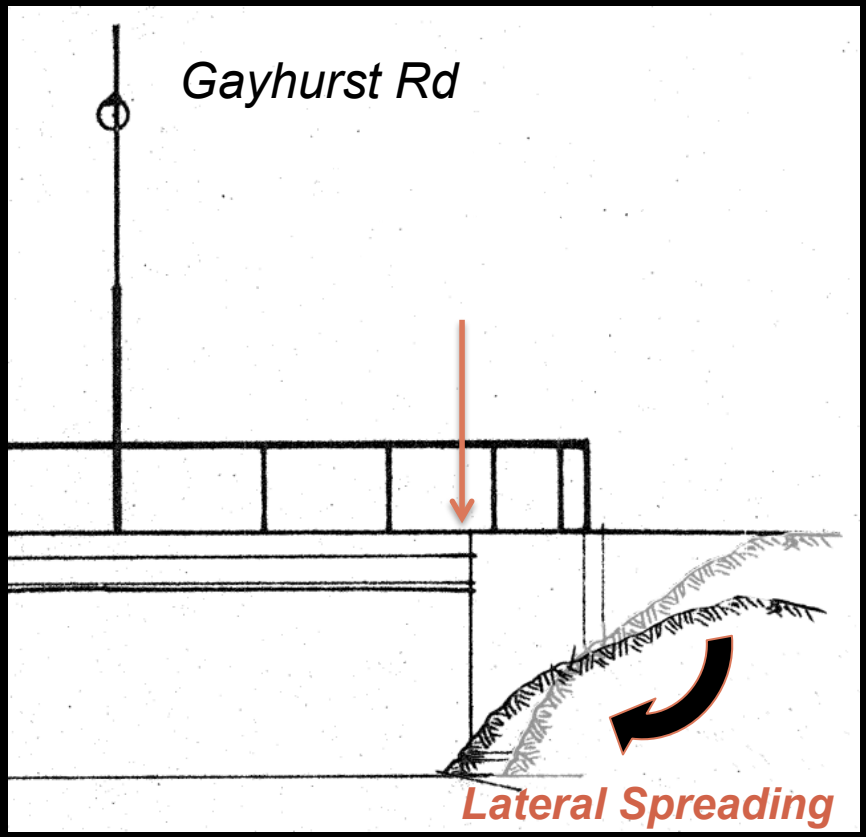
Displacements of foundation soils substantially smaller than free field displacements (~50%)

Cubrinovski et al. (2014) EQ Spectra Special Issue

Lessons Learnt from recent NZ earthquakes



Typical simply supported bridge



Typical integral bridge

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Lessons Learnt from recent NZ earthquakes

BEST PERFORMANCE:

Integral or Precast Bridges?

Pages Road Bridge (Integral)

Anzac Drive Bridge (Precast)

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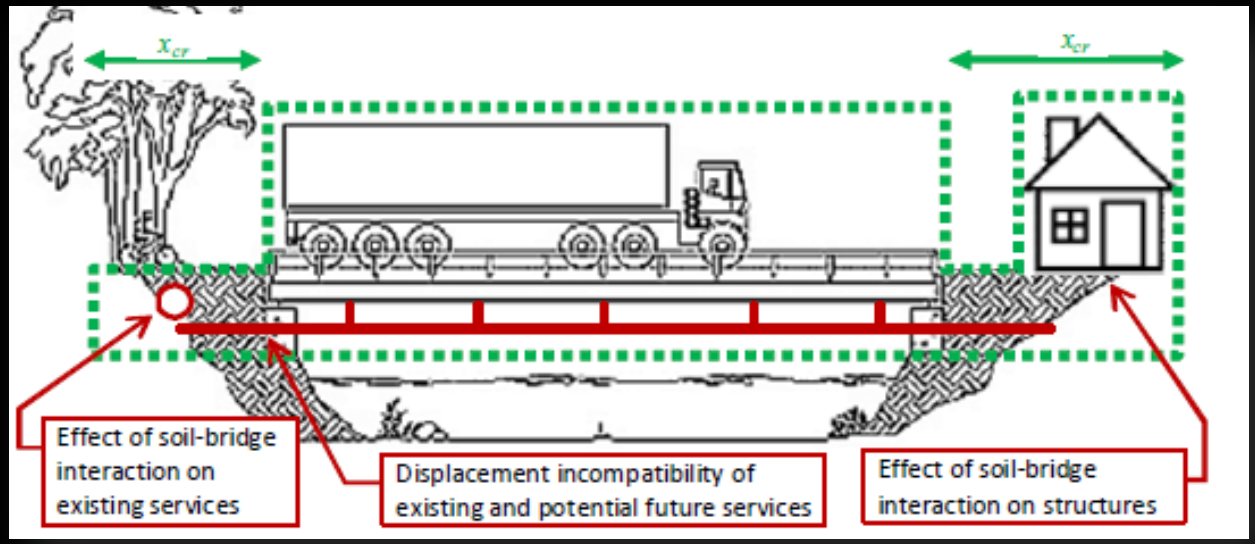
Lessons Learnt from recent NZ earthquakes

South Brighton Road Bridge

02/22/2011 Christchurch earthquake

Lessons Learnt from recent NZ earthquakes

BUS (Bridge Utilities System)



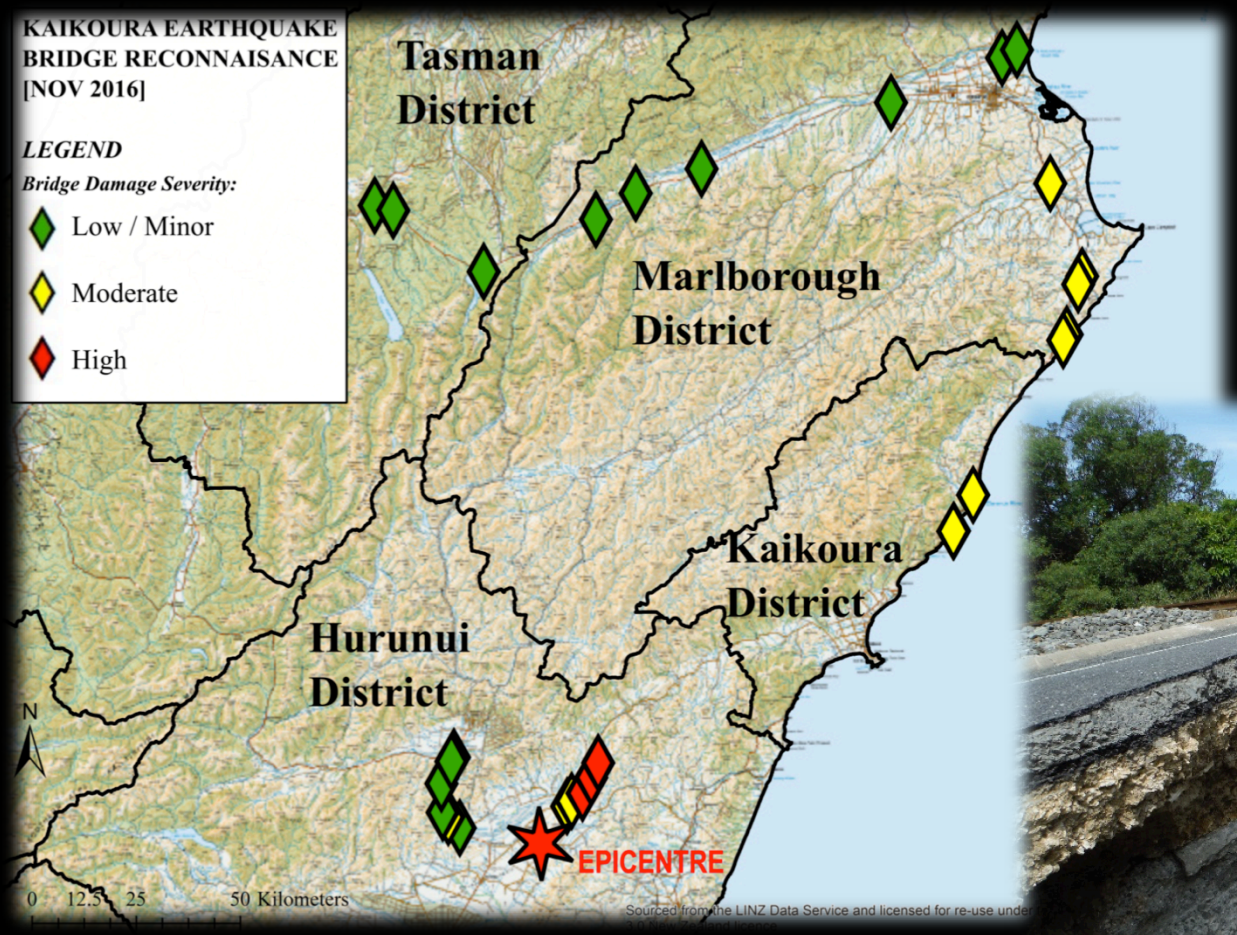
Kainga Road Bridge

Gayhurst Road Bridge

Bridge Street Bridge

Lessons Learnt from recent NZ earthquakes

2016 Kaikoura Earthquake (New Zealand)

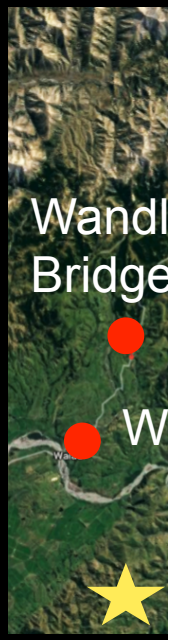


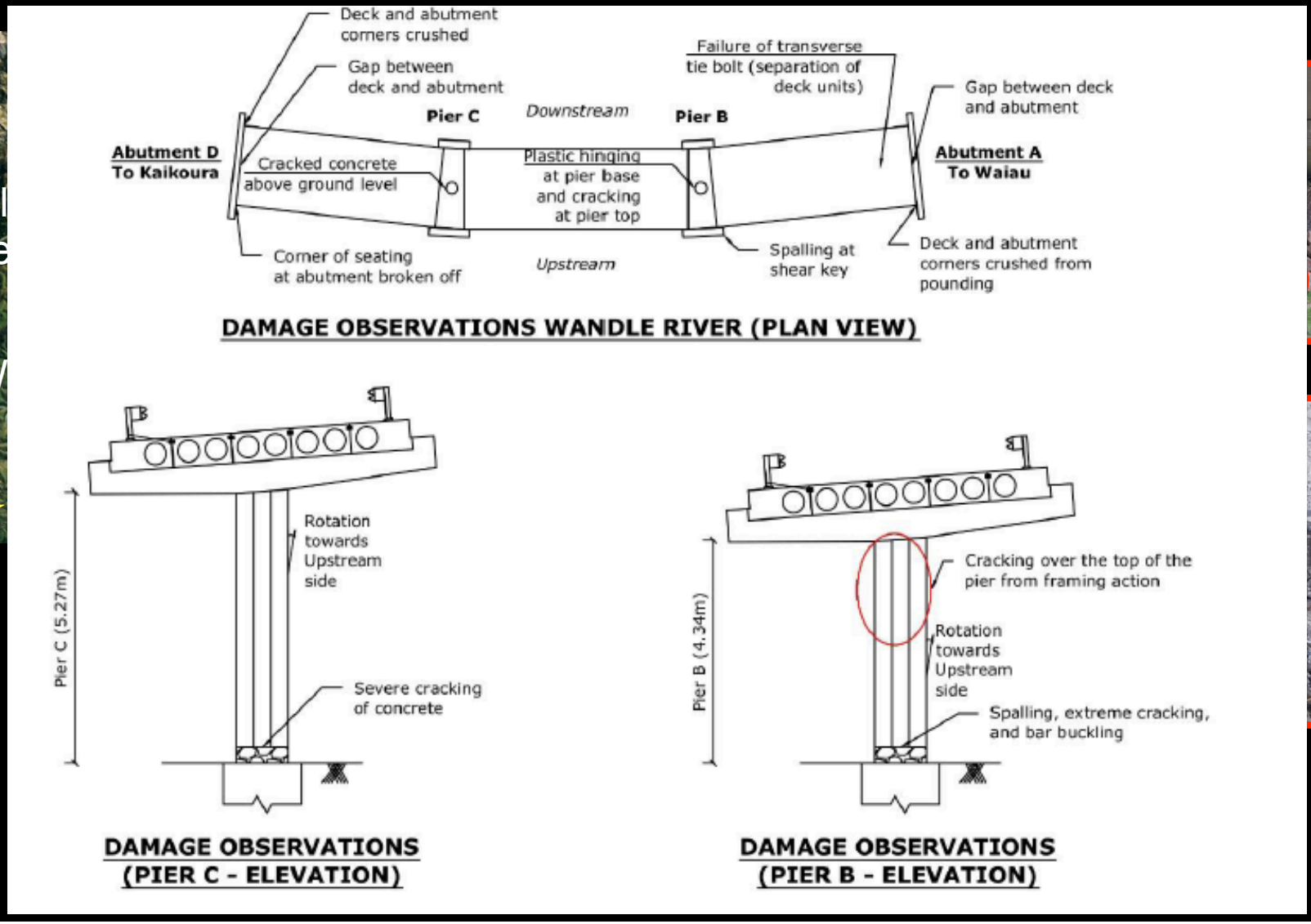
Reconnaisance Survey

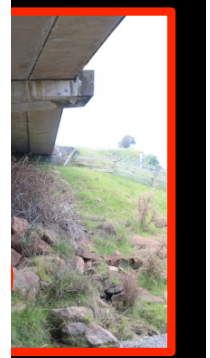
Palermo et al. 2017, Bulletin of NZSEE – Special Kaikoura Eq.

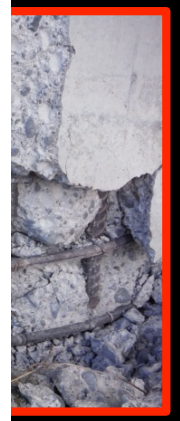
Lessons Learnt from recent NZ earthquakes

Wandle River Bridge









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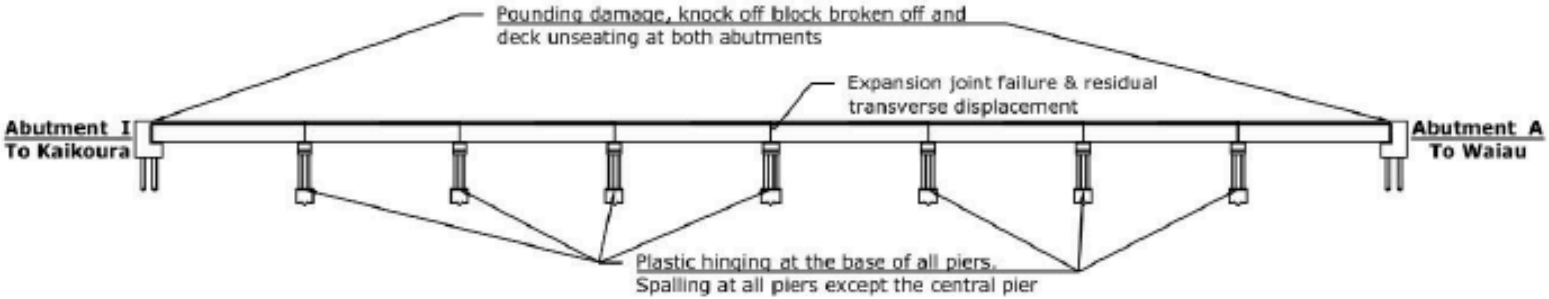
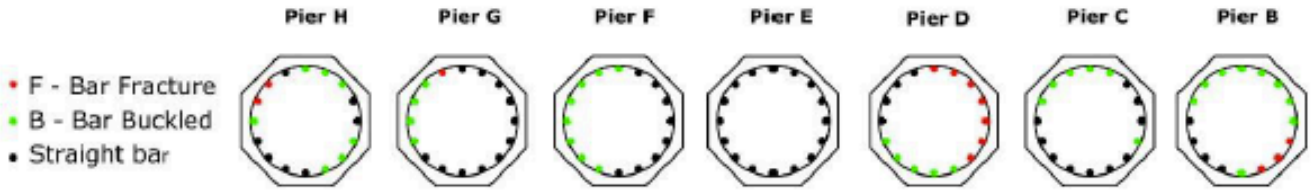
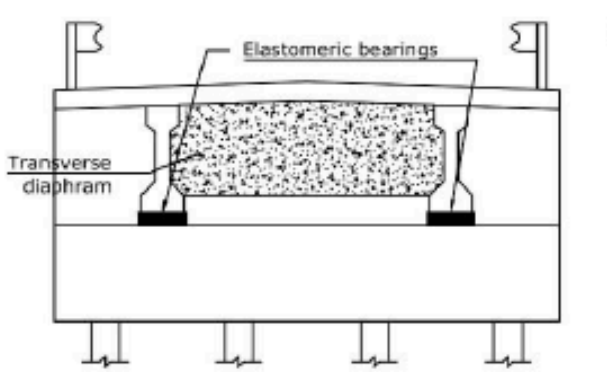
Lessons Learnt from recent NZ earthquakes

Lower Mason River Bridge (1986)

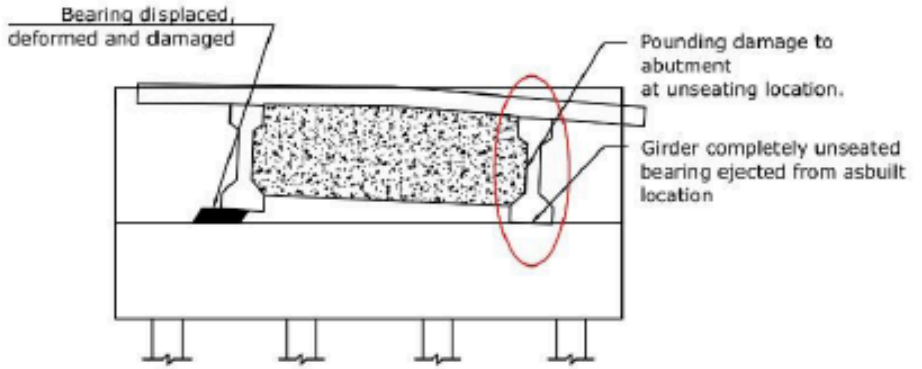




DAMAGE OBSERVATIONS LOWER MASON RIVER (ELEVATION & PIER SECTIONS)

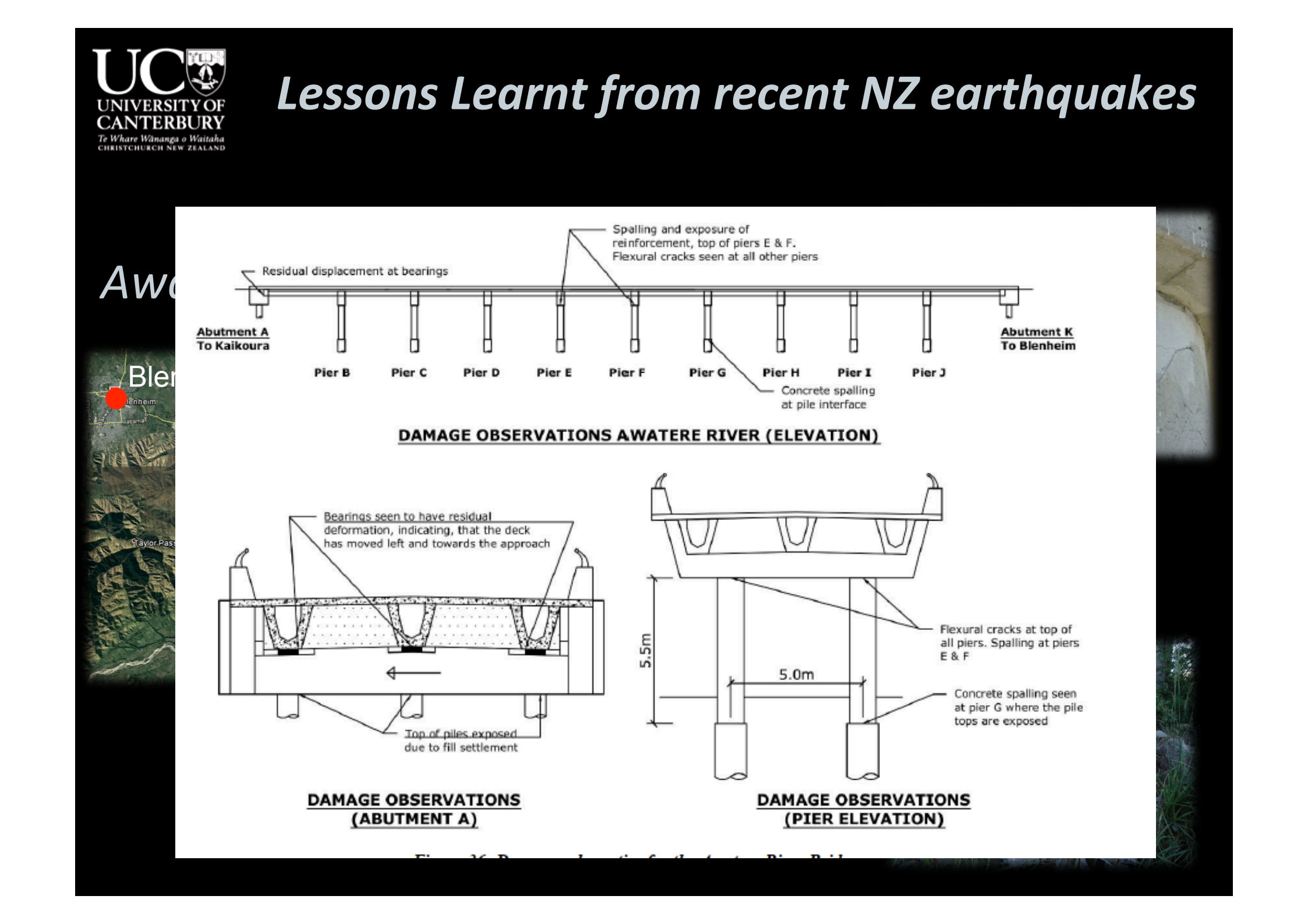


ABUTMENT UNDAMAGED (ELEVATION)



ABUTMENT A DAMAGE (ELEVATION)

Lessons Learnt from recent NZ earthquakes



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Lessons Learnt from recent NZ earthquakes

Slight tilt of South pier

Railway Corrugated steel tunnel

Shear cracking in the piled footing

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Initiatives taken after the New Zealand Earthquakes

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Initiatives taken after the NZ Earthquakes

- NZTA report 553, (2014). The development of design guidance for bridges in New Zealand for liquefaction and lateral spreading effects.

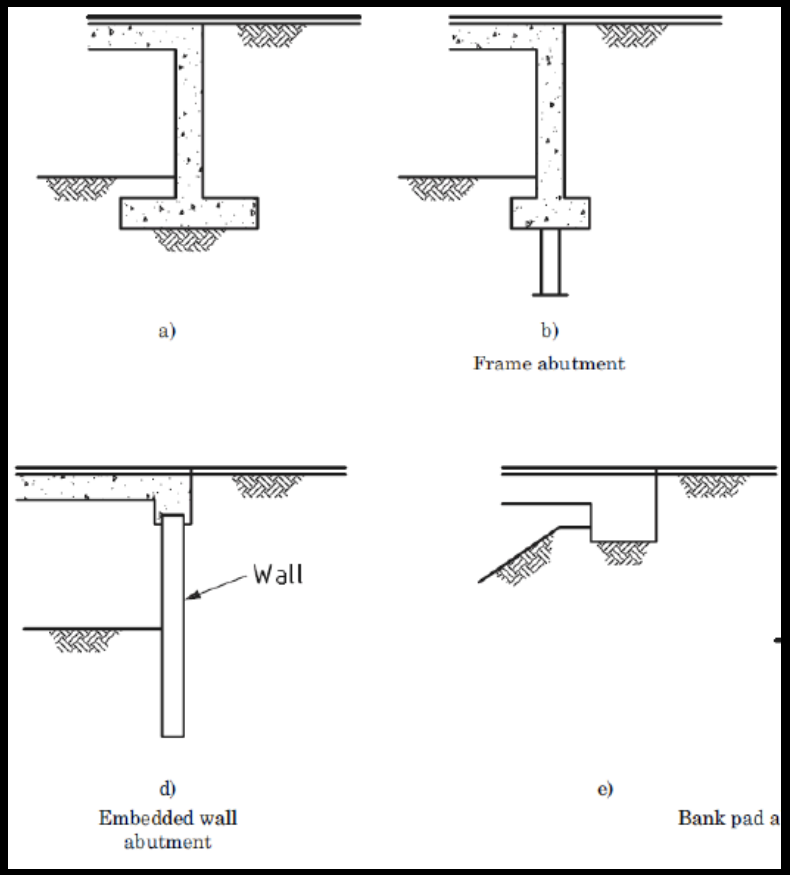
- NZTA (NZ Transportation Agency) Bridge Manual section 5 – Earthquake Resistant Design of Structures: inclusion of Displacement Based Design.

- NZTA (NZ Transportation Agency) Bridge Manual part 6 – Site Stability, foundations, earthworks and retaining walls: variation on the liquefaction part.

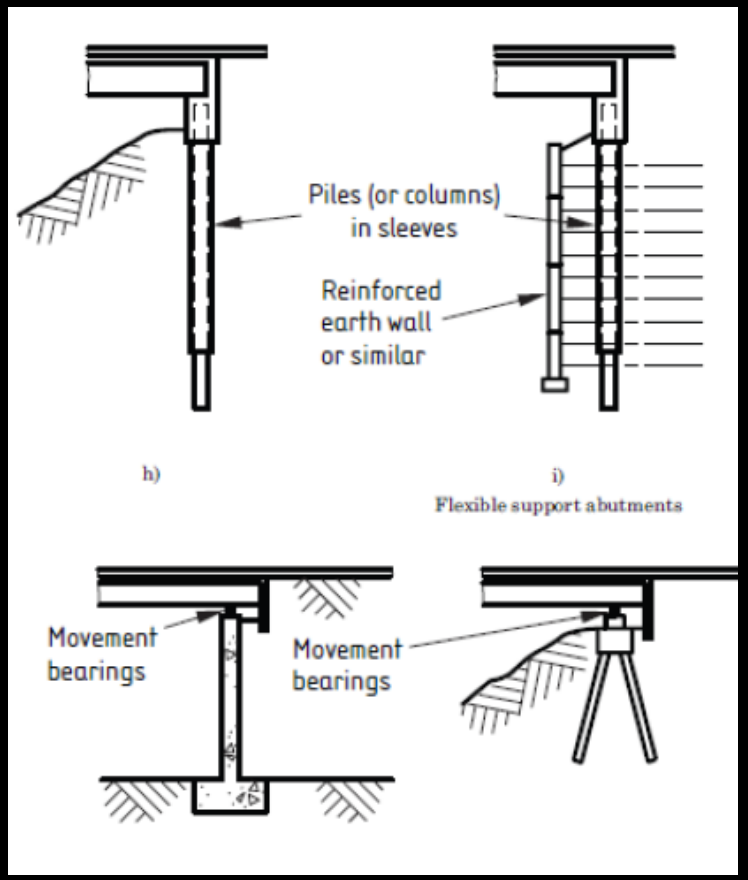
Pdfs all free-dowloadable from NZTA website!

Initiatives taken after the NZ Earthquakes

- **NZTA report 577, (2015). Criteria and guidance for the design of integral bridges in New Zealand .**



Fully integral bridge



Semi-integral bridge

Pdfs all free-dowloadable from NZTA website!

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Shift towards post-earthquake repairabile connections

Shift towards post-earthquake repairabile connections

…In the 80s…

Civil Engineering

Lower Mason (1986)

Mechanical Engineering

Ferrari GTB 308

2017?

?

Can we have higher seismic performance “specs” than Awatere Bridge?

Ferrari 458

New Zealand Natural Hazard Research Platform

University of Canterbury research programme for 4+4 year duration (October 2011-19, $ 900k)

Advanced Bridge Construction and Design for New Zealand (ABCD – New Zealand Bridges)

Scope of the project: develop cost-competitive seismic resistant bridge systems which features aspects such as high-speed of construction and low life-time maintenance.

Obj. 1: Develop earthquake resistant bridge systems which features high speed of construction and/or low post-earthquake repair costs

Obj. 2: Guarantee long term seismic resilience by improving the durability of the materials and the seismic resistant connections

Obj. 3: Build robust modeling techniques and loss-estimation tools for an easier implementation in the Industry

End users: NZ Transport Agency, City Councils, Construction companies, Practitioners

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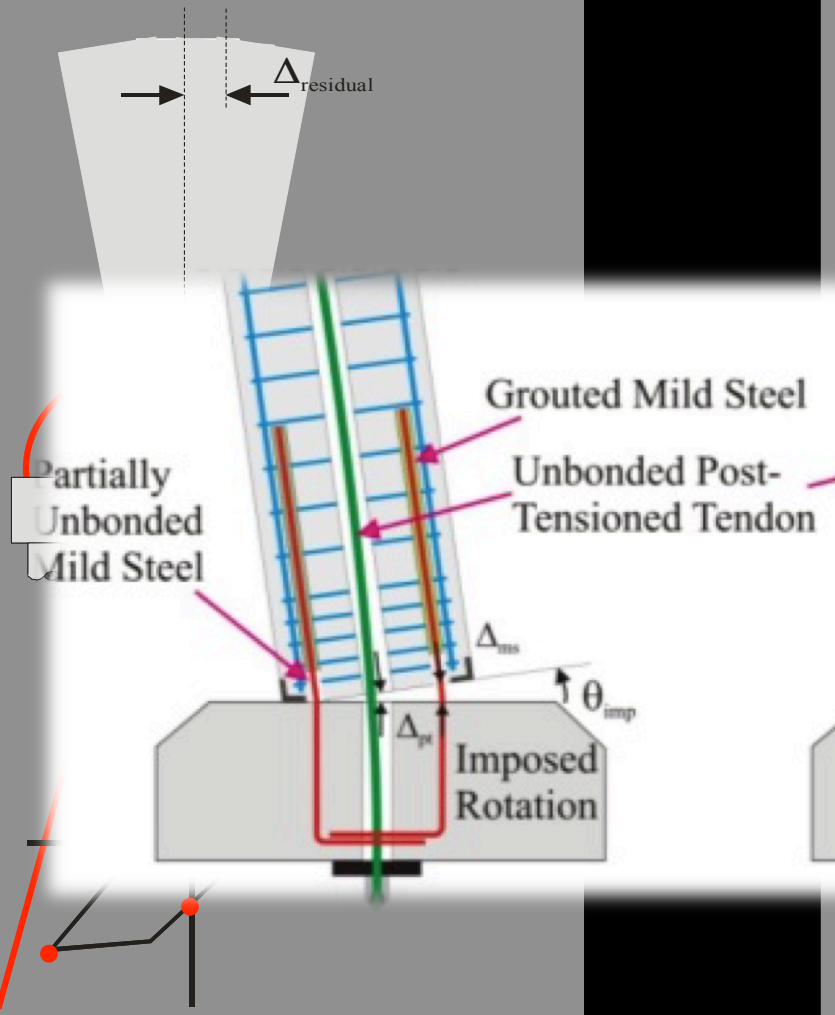
Shift towards post-earthquake repairabile connections

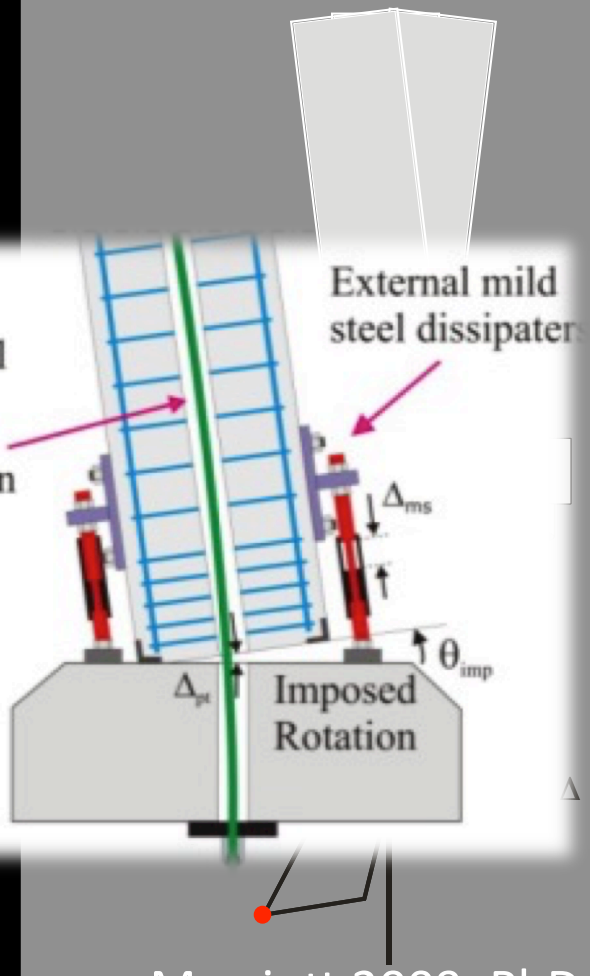
Dissipative Controlled Rocking Design

Traditional (monolithic)



Typically Accepted Damage

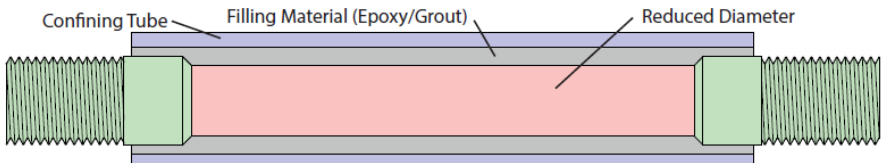
New generation (DCR)



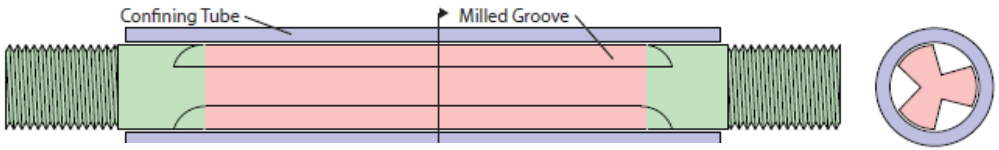
Marriott 2009, PhD Thesis)

DCR rocking design for bridges

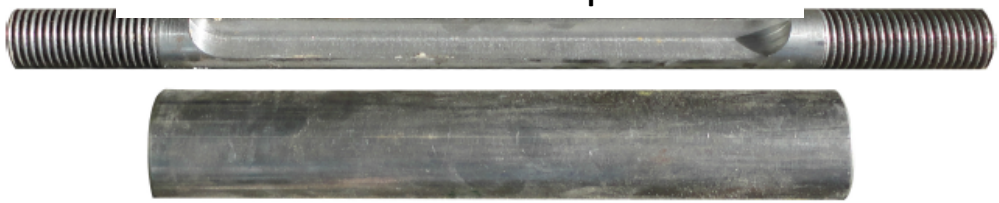
Bar Dissipaters



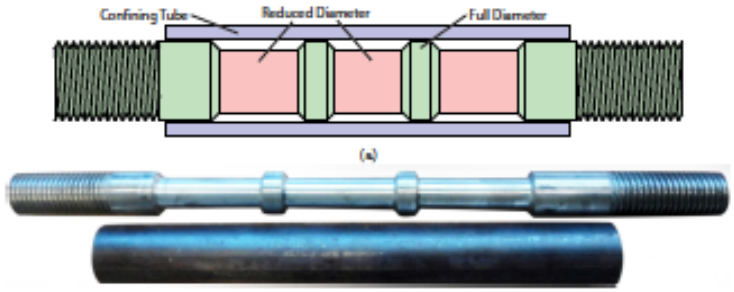
Conventional Buckling-Restrained Fused-type (BRF)



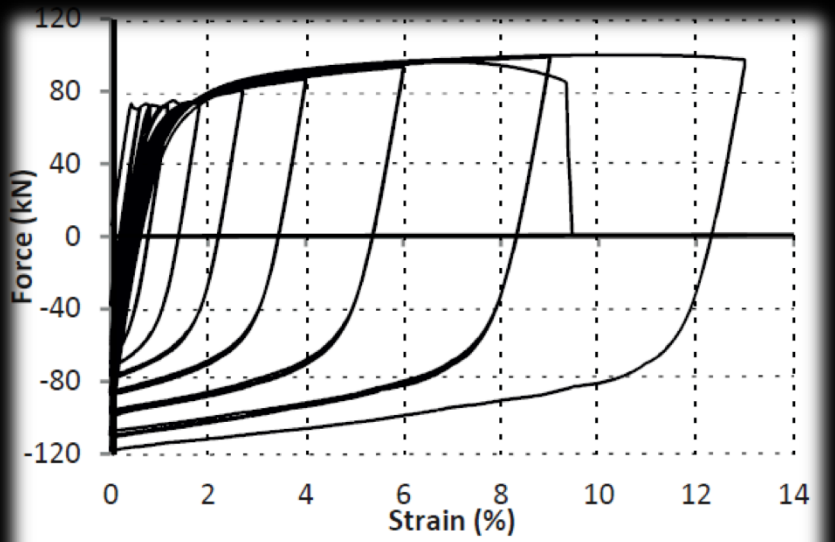
Grooved Bar Dissipater



"Multi-fuse" dissipater



More than 100 tests including bi-axial loading



(a) Force-strain behavior of grooved dissipaters

Sarti et al. 2013, Marriott et al. 2009 Earth. Eng. Structural Dynamics, Kaveh et al. 2017, ASCE journal of bridge engineering (under review).

Shift towards post-earthquake repairabile connections

Dissipative Controlled Rocking (DCR)

100 tons
Damper, built from recycled steel

(Keats/Palermo/ Mashal) patented device

Shift towards post-earthquake repairabile connections

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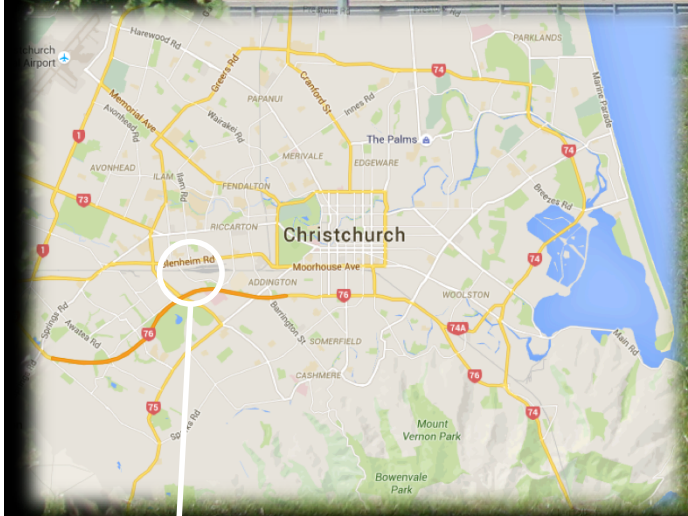
Designer: Opus International Consultants supported by UoC
Owner: Christchurch City Council
Opened: July 2016

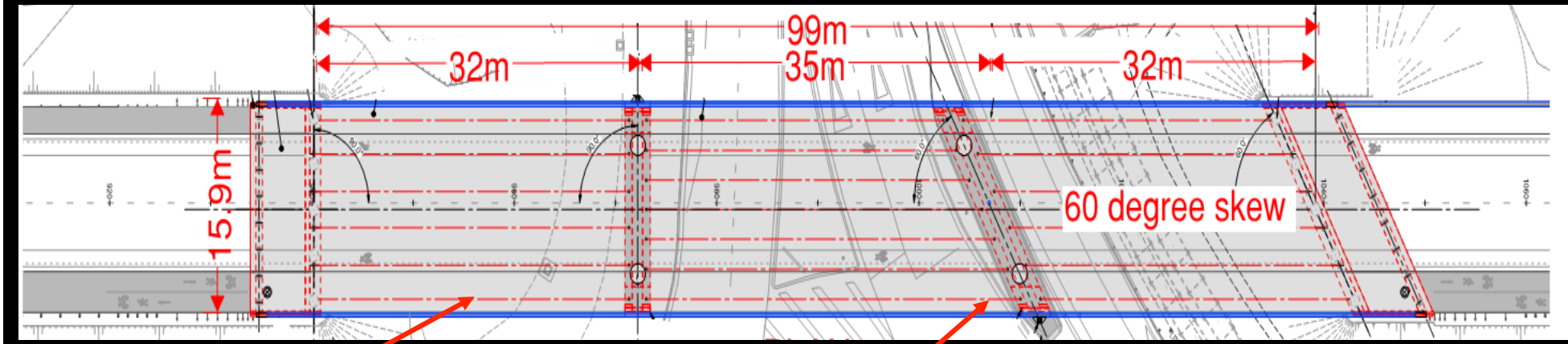


Site Location

Courtesy of Jeremy Kelleher (Dec, 2016)

Shift towards post-earthquake repairabile connections

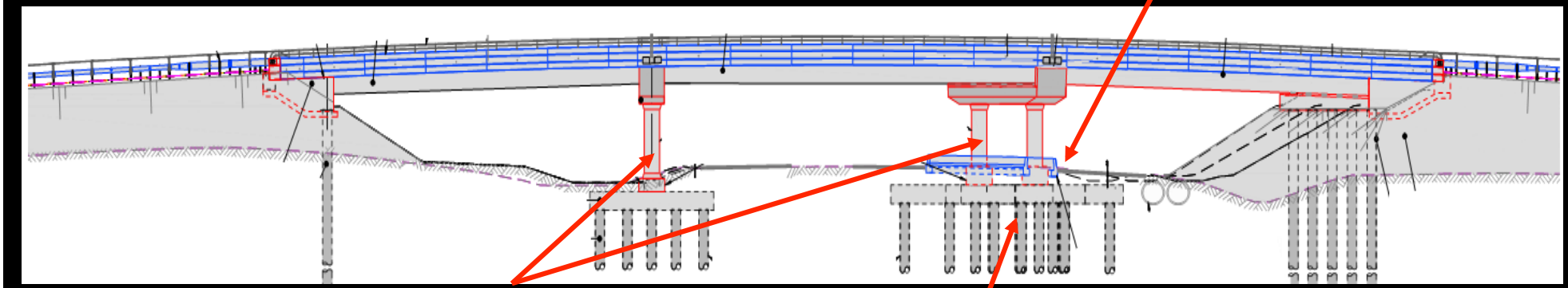
The Wigram-Magdala Bridge Link, Christchurch, NZ



1525mm deep Super-tee beams with 200mm thick slab

In-situ pier headstocks

Concrete plinths

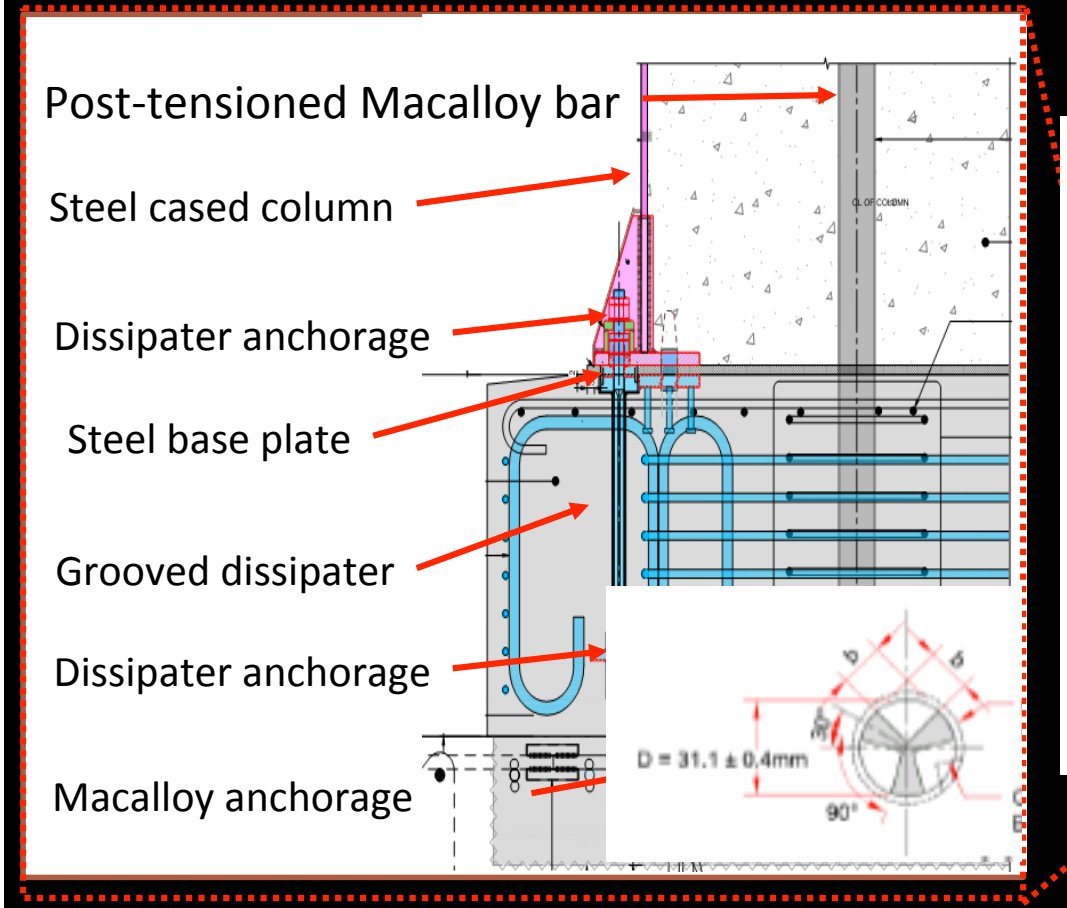


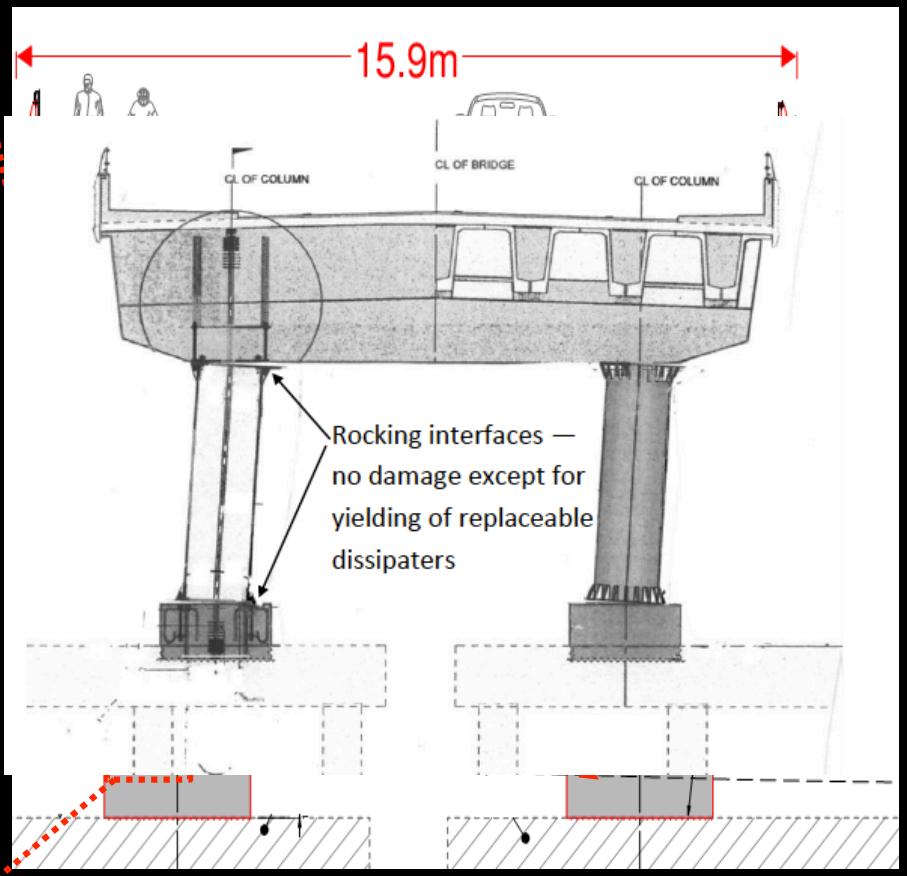
1500mm dia. steel cased columns with low damage connections

900mm diameter piles

Shift towards post-earthquake repairabile connections

Dissipator detailing





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Shift towards post-earthquake repairabile connections

Design detail of bridge piers: steel armoring and dissipators

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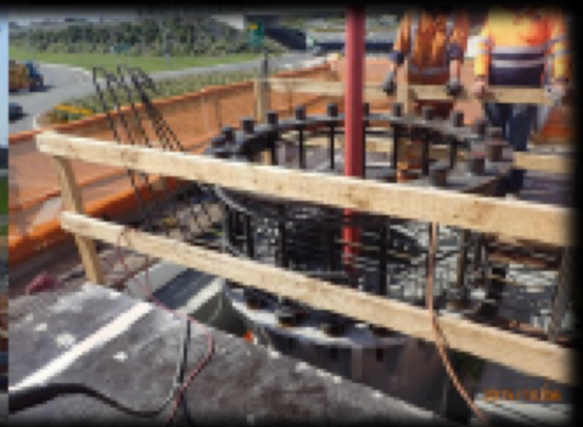
Shift towards post-earthquake repairabile connections



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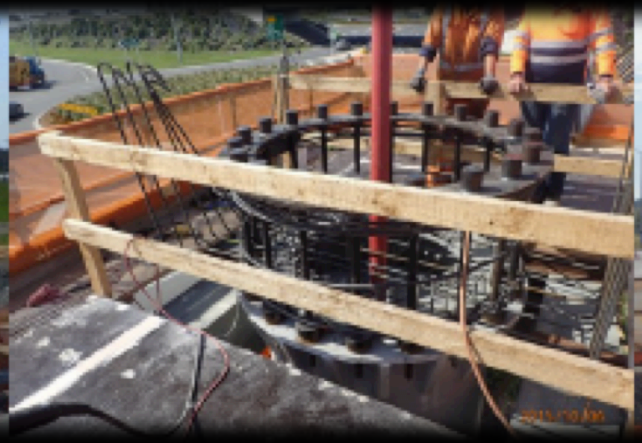
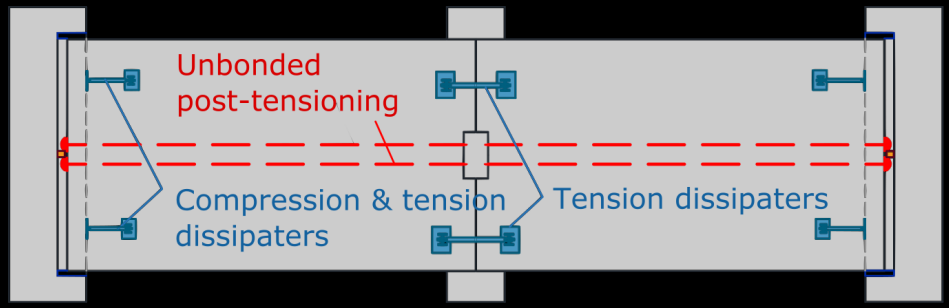
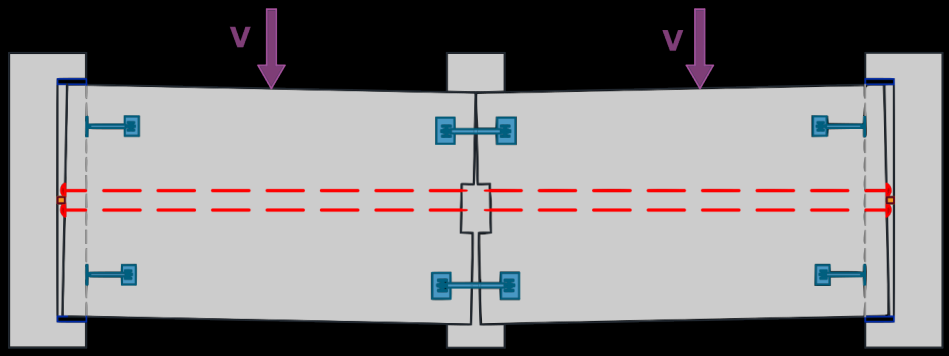
Shift towards post-earthquake repairabile connections



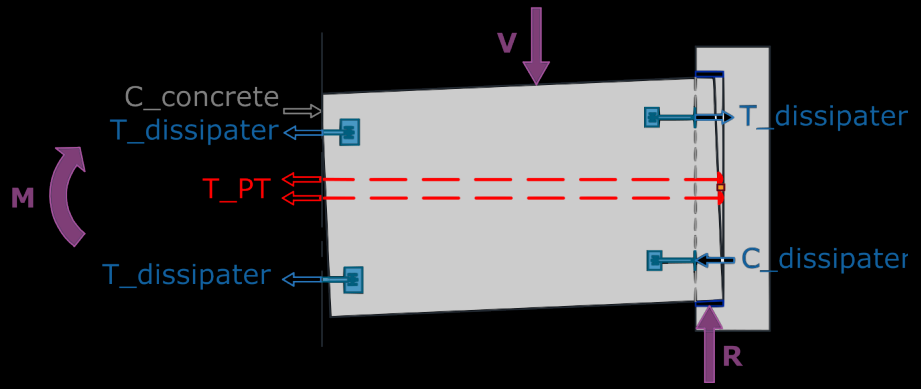
Shift towards post-earthquake repairabile connections

DCR rocking design in the superstructure





NZTA Seismic Strengthening Program



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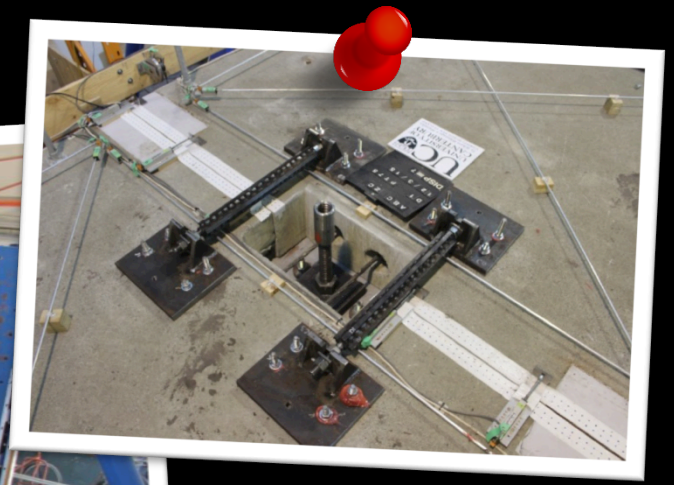
Shift towards post-earthquake repairabile connections

Concept → **Realization**

Testing (will this actually work?)



Quasi static cyclic testing (1:3 scaled prototype)

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Research questions and opportunities for collaboration

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Skew or curved bridges and their interaction with back-fill

Longitudinal seismic response of linked passive soil restraint abutments/flexible pier systems including effect of cyclic soil ratcheting.

Mono column/pile & twin column bent with column/piles: damping and stiffness (transversal response DBD).

Damping and stiffness from interaction at abutments (long response DBD).

DCR bridge piers and interaction with mono-pile and abutment-back-fill

DCR bridge deck and interaction with abutment-back-fill

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Collaborations

- ***Erskine Fellowships offered by University of Canterbury (1-3 months).***

- ***Co-funding with in-kind NSF research programmes:***

  a) EQC research proposal (under scrutiny) Cost-effective low damage piled foundations: A design "shift" for residential low-rise medium density buildings. **Start early 2018.**

  b) NZ Natural Hazard Research Platform: applications open in mid-June 2017. Proposal due by the of July 2017. **Start November 2017.**

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Collaborations

*If you want to go **fast** ... go **alone**!*

*If you want to go **far** ... go **together**!*

(African Proverb)