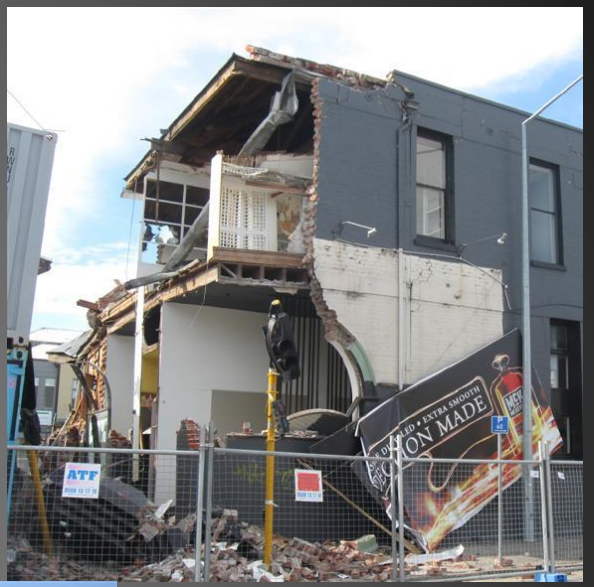
Retrofitting: improving the seismic performance of masonry buildings

by Andrew Charleson
Adjunct Professor,
Victoria University of Wellington

Introduction

Damage to Christchurch Buildings after M7.1 2011

Christchurch: consequences of a passive approach

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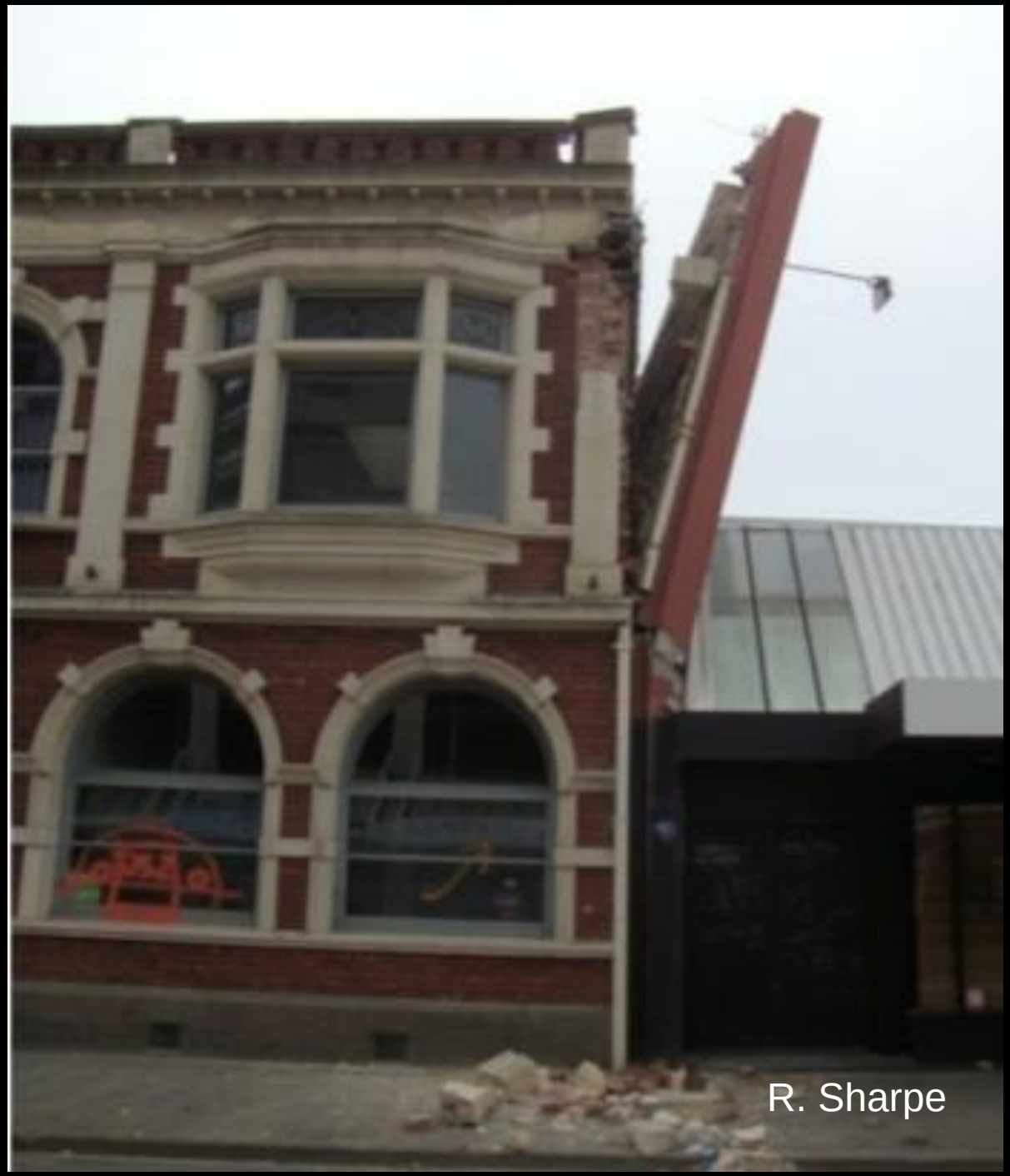
Community of the Sacred Name, Barbadoes Street, Christchurch

PERFORMANCE OF MASONRY BUILDINGS AND CHURCHES IN THE 22 FEBRUARY 2011 CHRISTCHURCH EARTHQUAKE Dmytro Dizhur et al., Bulletin of the NZ Society for Earthquake Engineering, 44:4,pp 279-96.

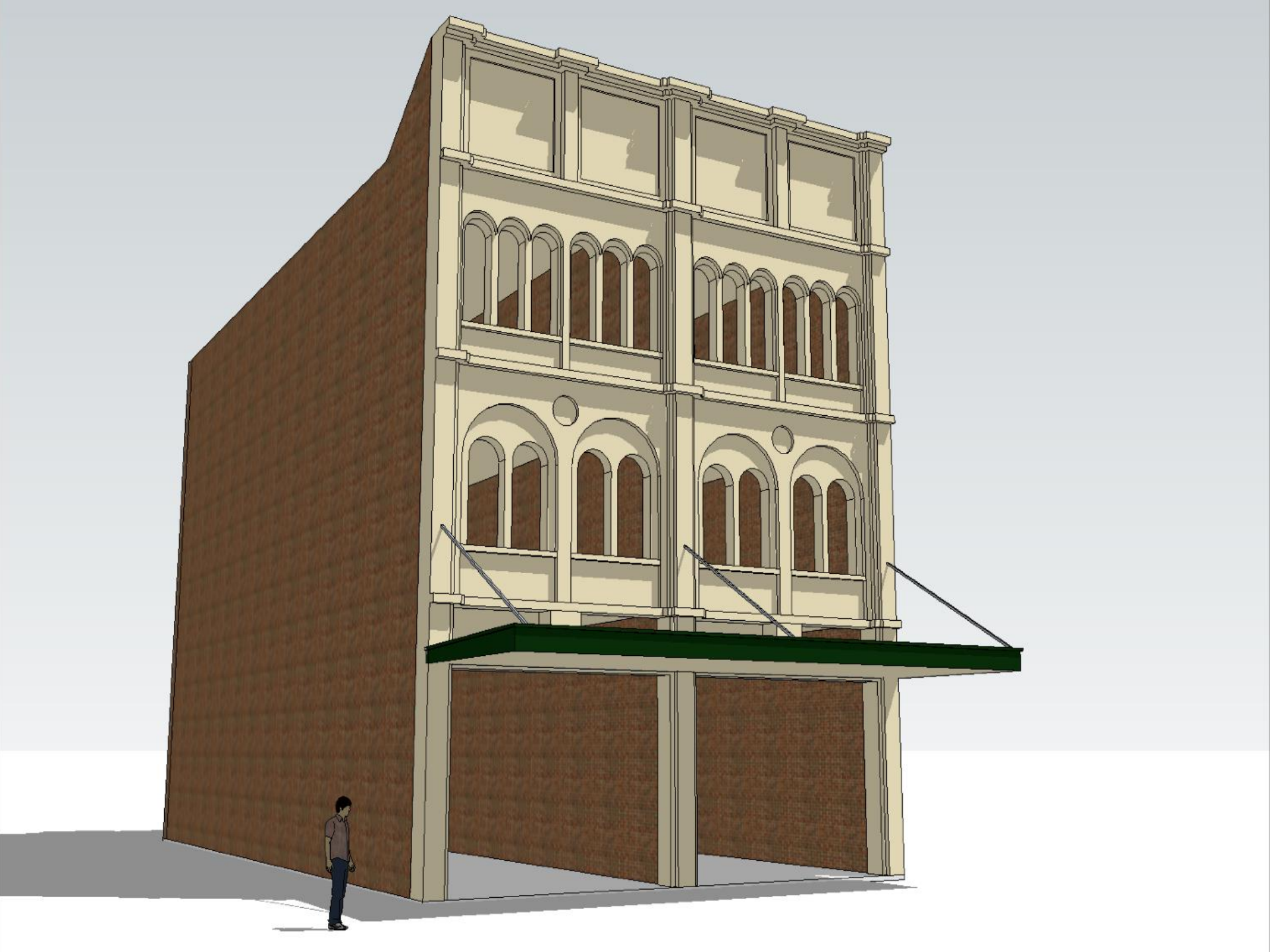

R. Sharpe

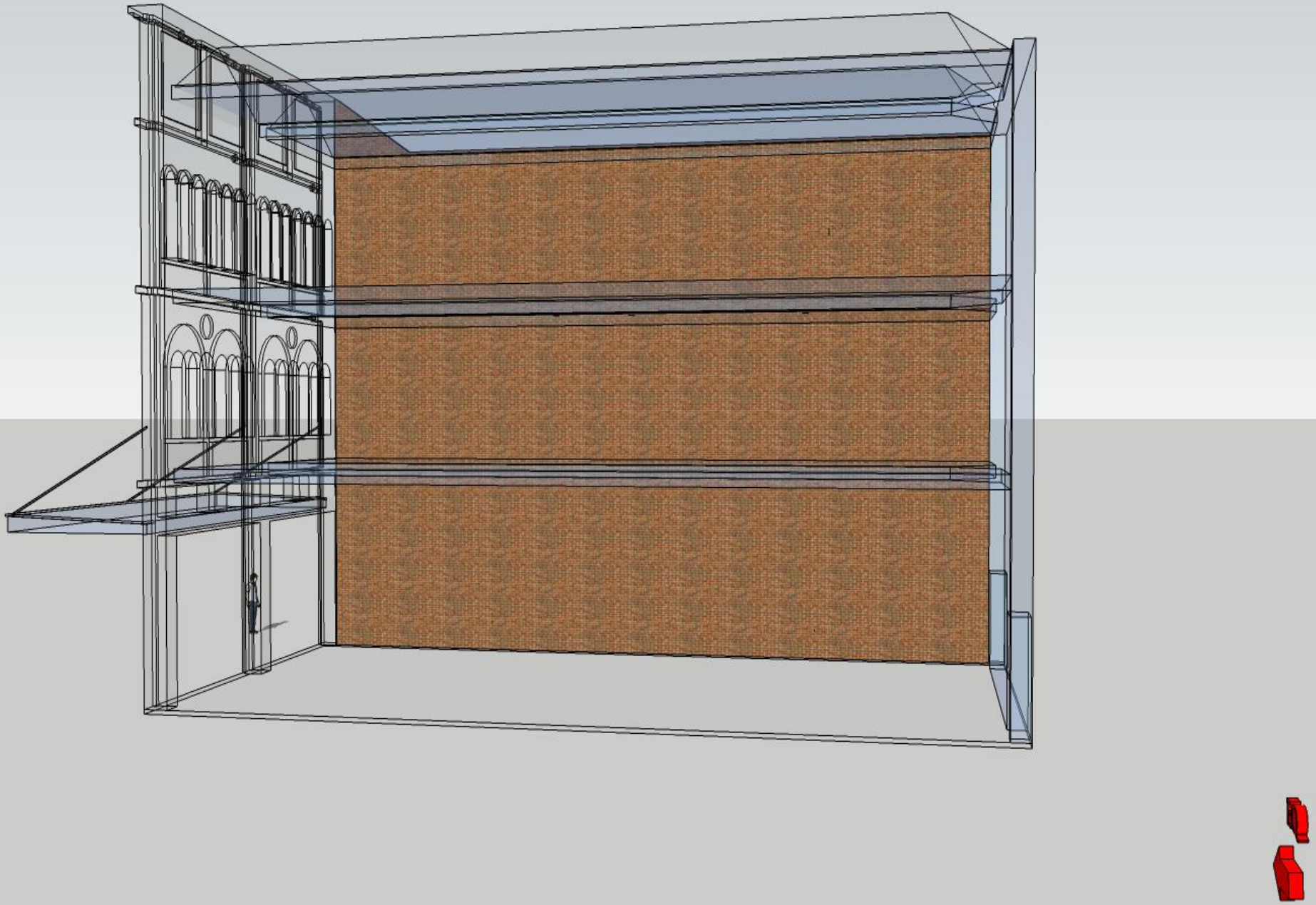

AVONMORE HOUSE
Hereford St
AVONMORE
AVONMORE
arches Cafe & Bar

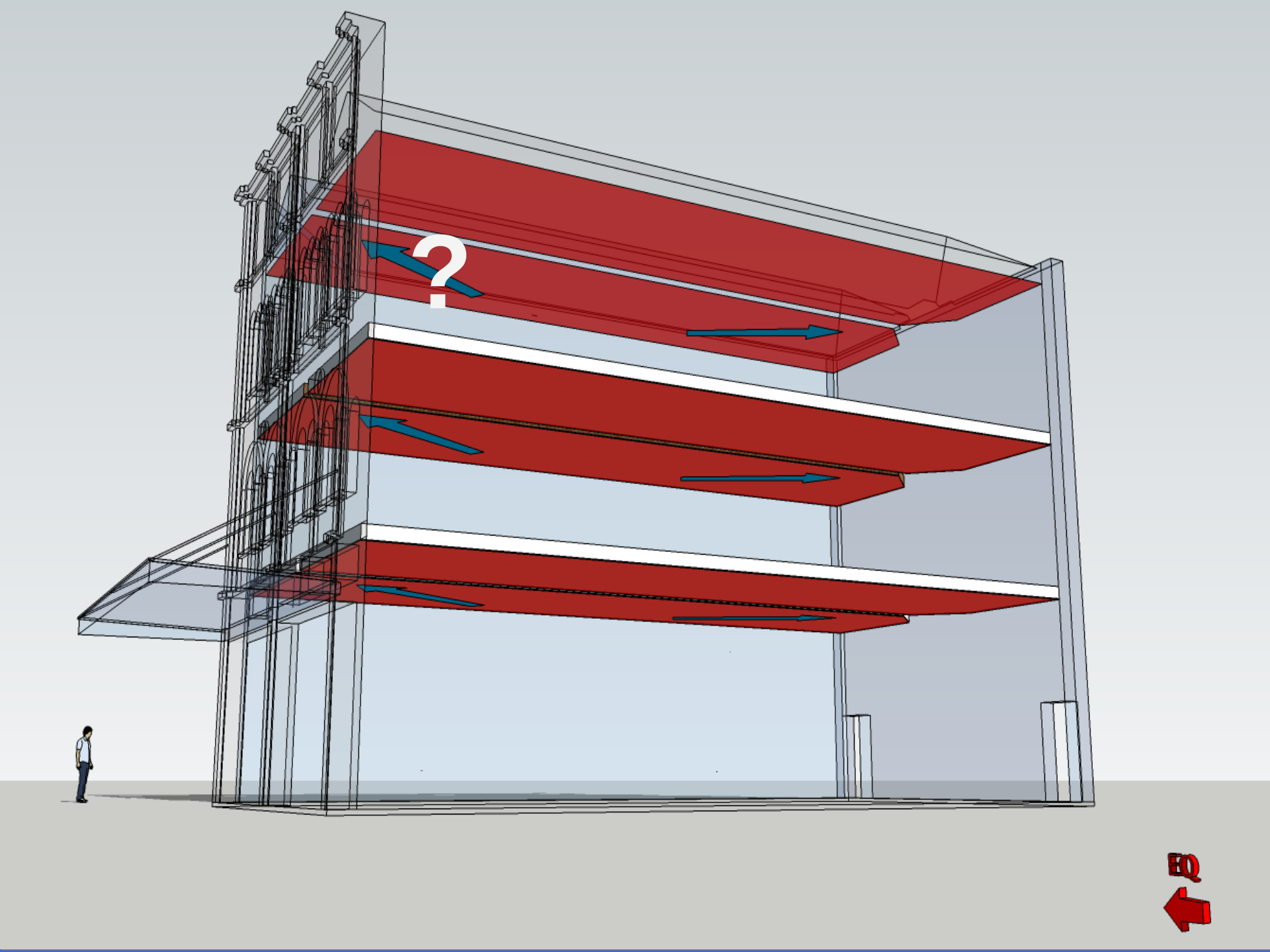
Force paths in a simple building

Basic considerations

- Source of inertia loads
- Face-loaded walls
- Supporting floor/roof diaphragms
- In-plane loaded walls
- Foundations



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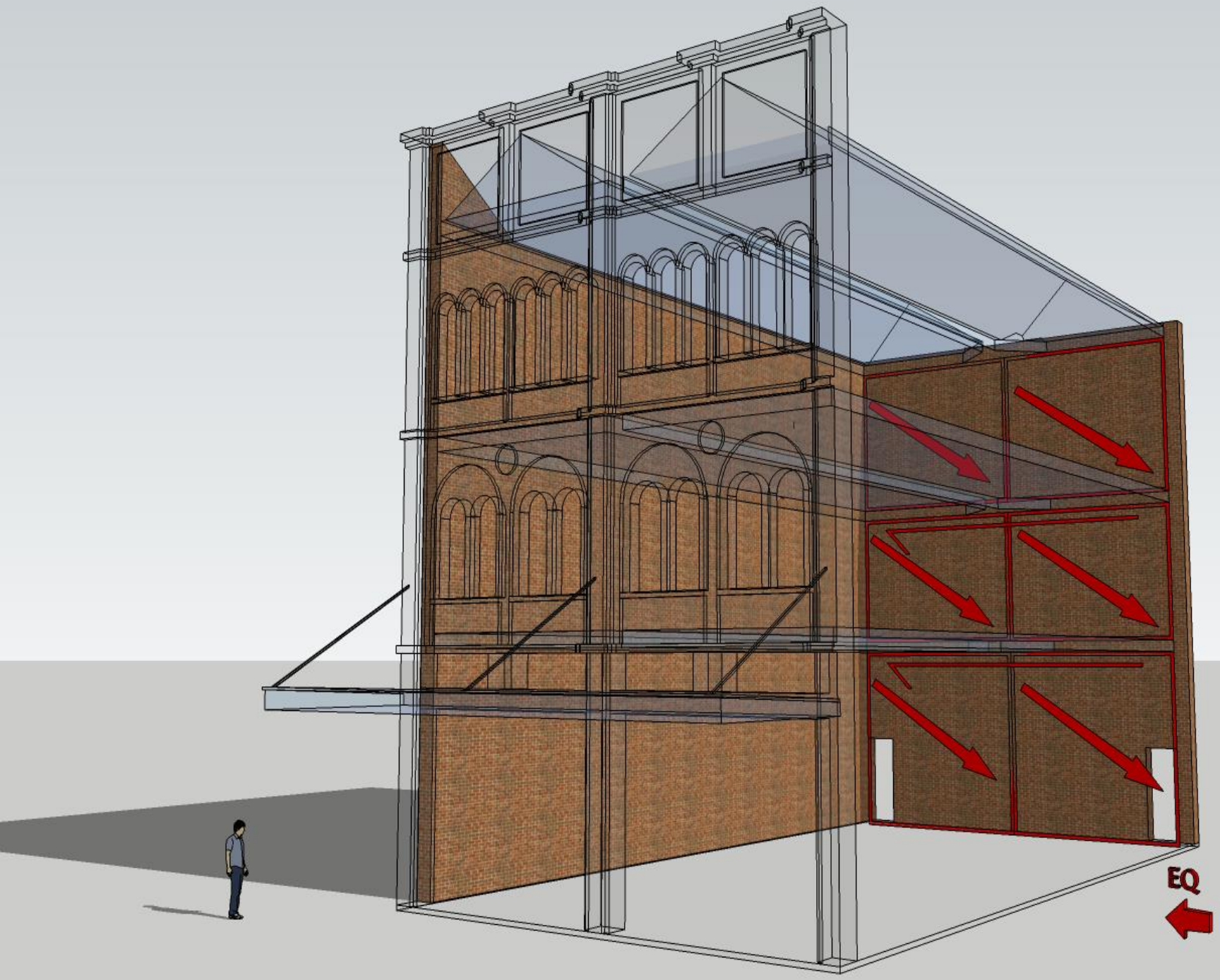
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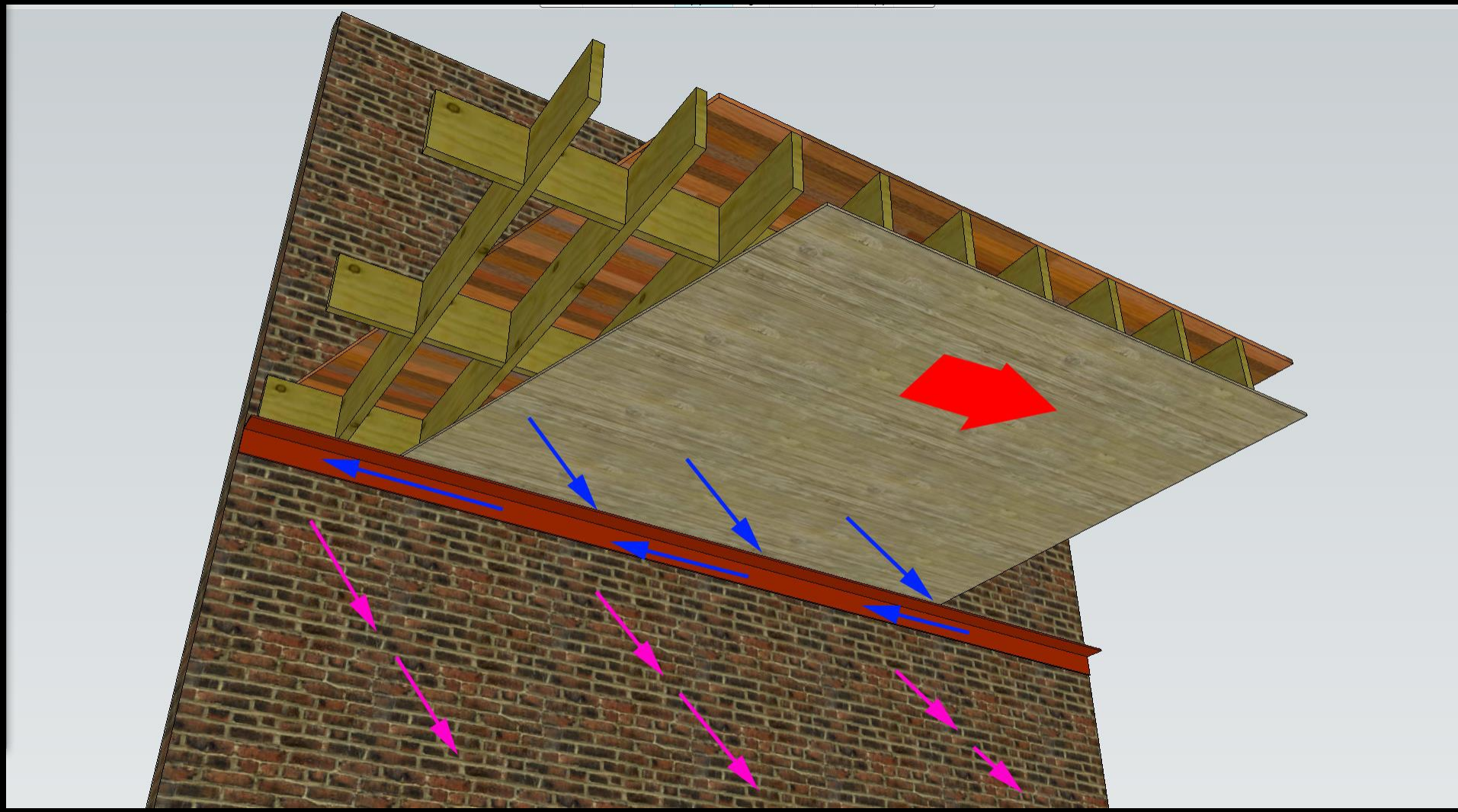

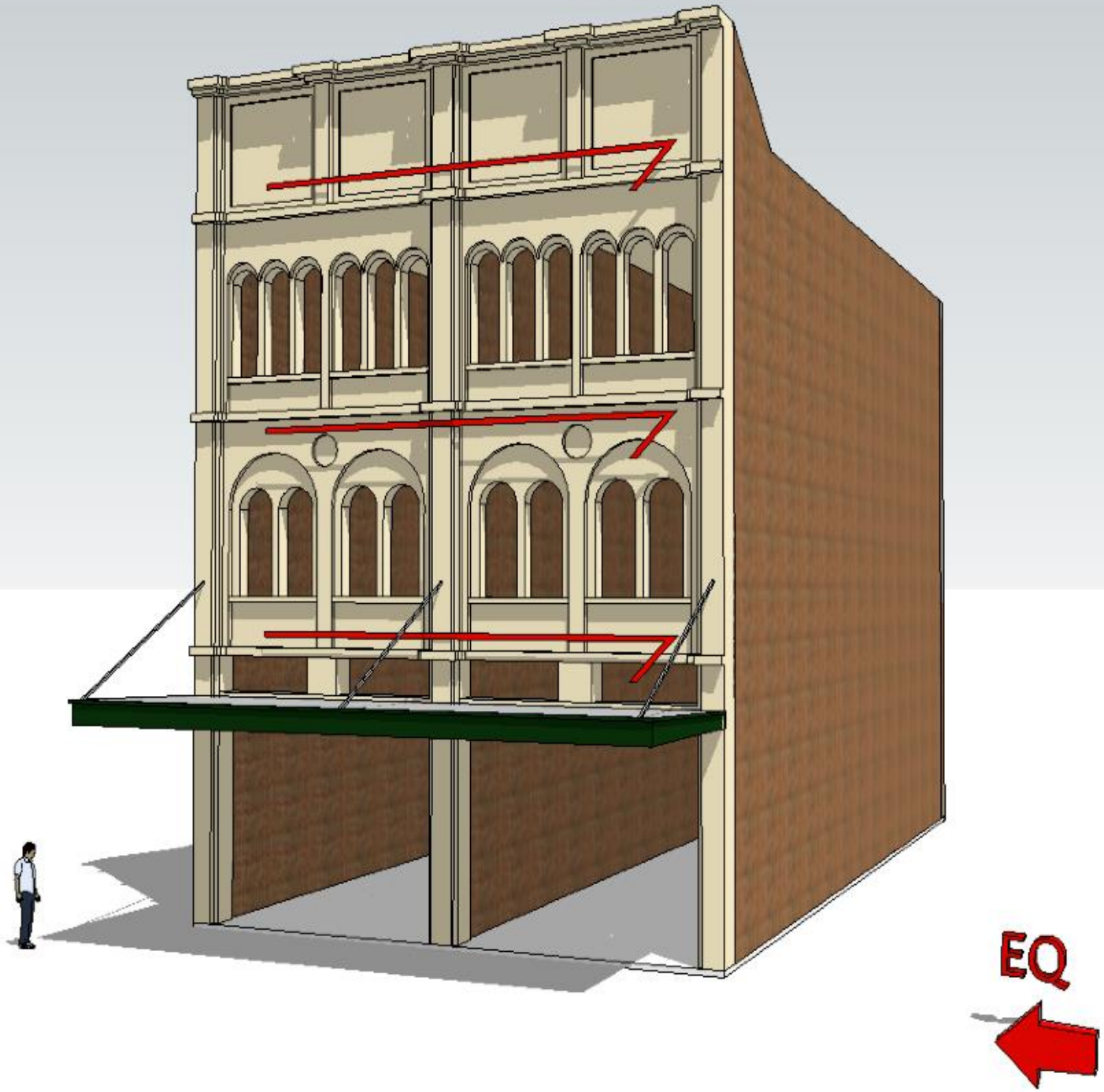
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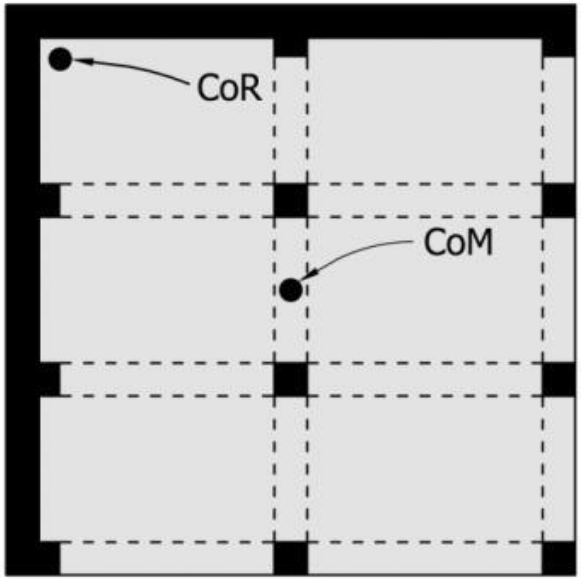
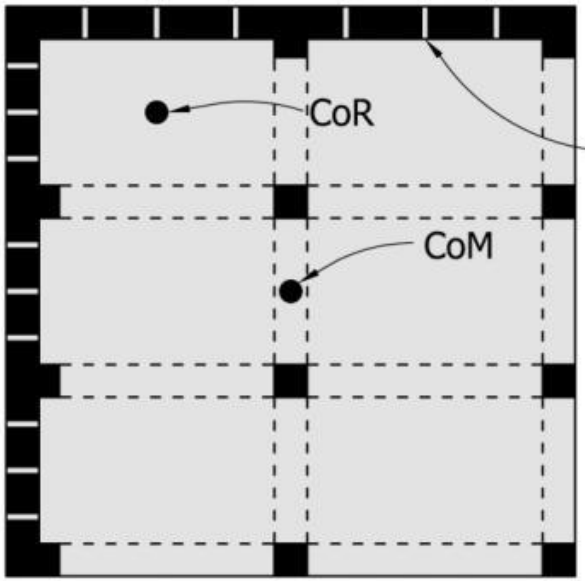
Retrofitting approaches

Retrofit Approaches

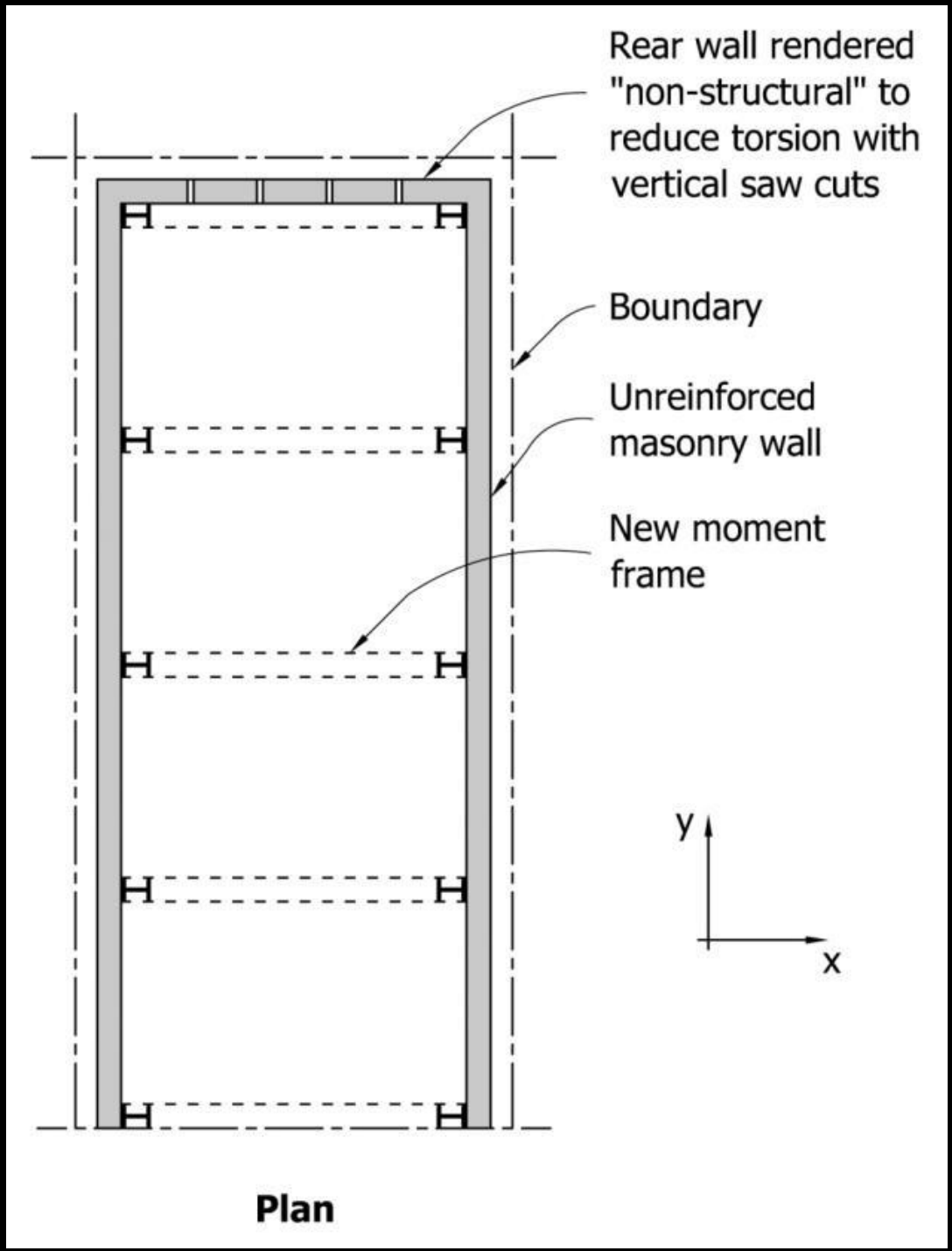
1. Improving seismic performance



Plan

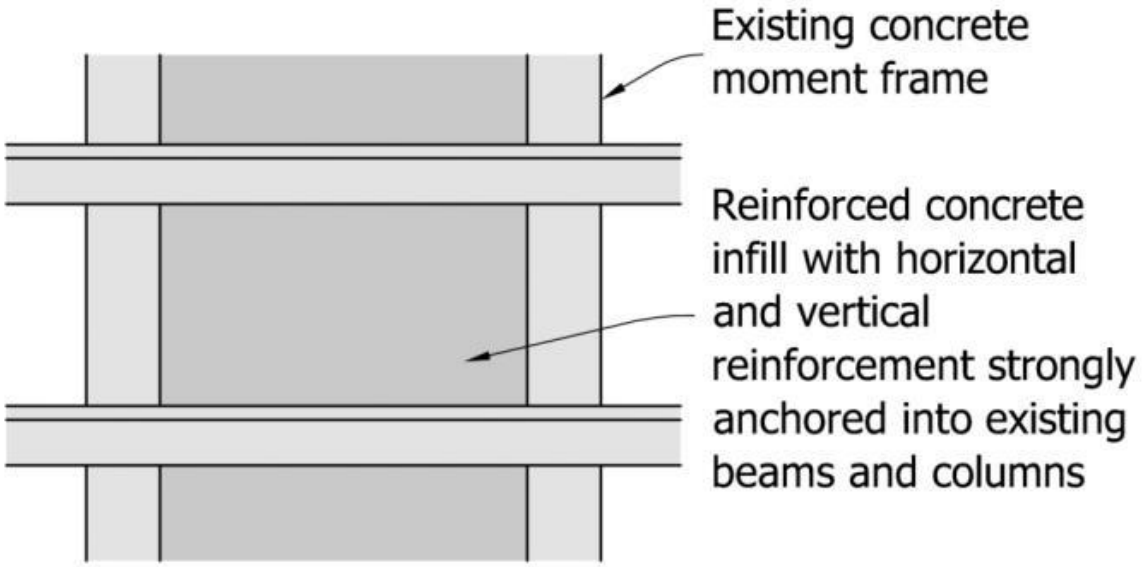


Plan

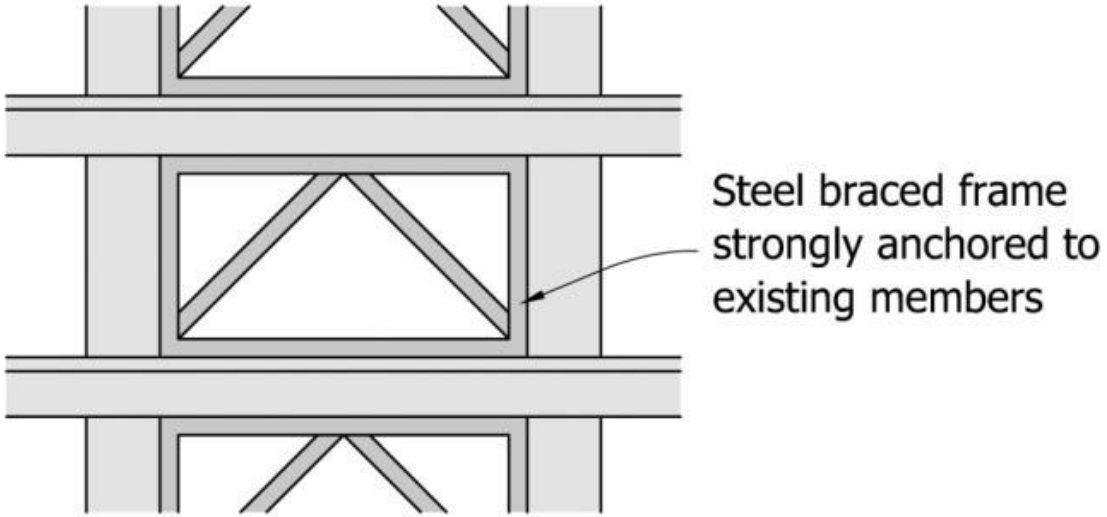

Rear wall rendered "non-structural" to reduce torsion with vertical saw cuts
Boundary
Unreinforced masonry wall
New moment frame
y
x
Plan

Retrofit Approaches

2. Provision of new structural systems



Frame elevation



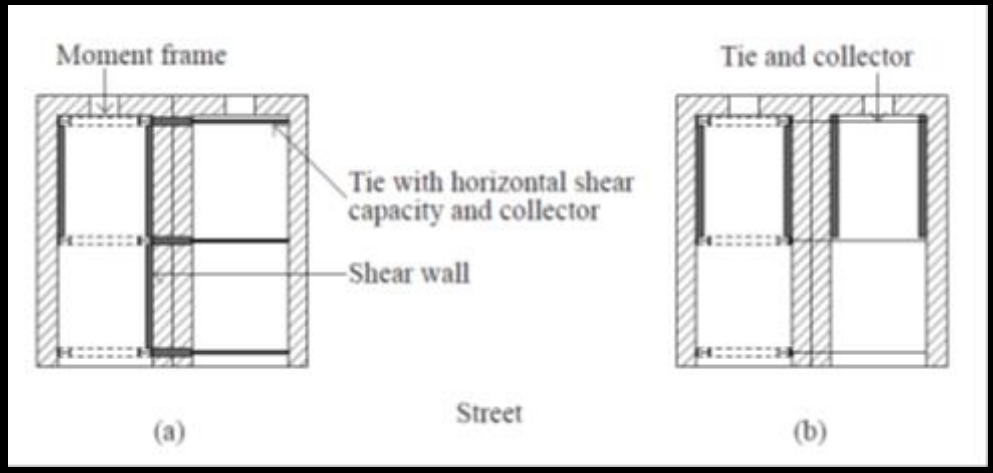
Frame elevation

Retrofit Approaches

3. Weight reduction

Retrofit Approaches

4. Consider pounding of adjacent buildings



Tie buildings together

Examples of retrofitting


Ipoh
DOWNER
Portacom


ABOVE

Resources

Key Resource

"Seismic assessment of existing buildings"

Published Nov. 2018

https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/seismic-assessment-existing-buildings/

PART C

Unreinforced Masonry Buildings C8

Unreinforced Masonry Buildings C8

- Typical Building Practices in NZ
- Observed Seismic Performance
- Factors Affecting Seismic Performance
- Assessment Approach

Unreinforced Masonry Buildings C8 (continued)

- On-site Investigation
- Material Properties and Weights
- Member/Element Capacities
- Global Capacity
- Earthquake force and Displacement Demands

Table C8.2: Historical techniques used for URM buildings and common features

Chimneys	Internal post-tensioning
	Internal steel tube reinforcement
	Concrete filling
	External strapping

Face-loaded walls	Vertical steel mullions (refer to Figure C8.23)	Stiffness vs out-of-plane rocking/displacement capability important Regularity/robustness of attachment to wall is important
	Vertical timber mullions	Stiffness vs out-of-plane rocking/displacement capability important Regularity/robustness of attachment to wall is important
	Horizontal transoms spanning between abutting frames or walls	Stiffness and attachment requirements need to consider wall above which gives clamping action to masonry at level of attachment
	Internal post-tensioning	Durability Anchorage level and fixity Level of pre-stress to allow rocking without brittle crushing
	External post-tensioning	As above
	Internal bonded reinforcement	Maximum quantity to ensure ductile failure Anchorage beyond cracking points, and consider short un-bonded lengths
	Composite fibre overlay	Preparation to give planar surface very involved

Connection of walls to diaphragms	Steel angle with grouted bars (refer to Figure C8.24(a))	Bar anchorage Diaphragm/bar eccentricity must be resolved
	Steel angle with bolts/external plate (refer to Figure C8.24(b))	Diaphragm/bar eccentricity must be resolved
	Timber joist/ribbon plate with grouted bars	Bar anchorage Diaphragm/bolt eccentricity causes bending of timber across grain - a potential point of weakness
	Timber joist/ribbon plate with bolts/external plate	Diaphragm/bolt eccentricity causes bending of timber across grain - a potential point of weakness
	Blocking between joists notched into masonry	Joist weak axis bending must be checked Tightness of fit of joists into pockets Degradation of joists

In-plane wall strengthening **New primary strengthening elements** (refer to Figure C8.26)	Sprayed concrete overlay	Restraint to existing floor/roof structure Out-of-plane capacity of wall Ductility capacity if used very dependent on aspect ratio Chords Foundation capacity needs to be checked (uplift/rocking)
	Internal vertical post-tensioning	Ensure pre-stress limited to ensure no brittle failure See out-of-plane issues also
	External vertical post-tensioning	Ensure pre-stress limited to ensure no brittle failure See out-of-plane issues also
	Internal horizontal reinforcement	Coring/drilling difficult Stressing horizontally requires good vertical (perpendicular) mortar placement and quality
	External horizontal post-tensioning	Stressing horizontally requires good vertical (perpendicular) mortar placement and quality
	Bed-joint reinforcement	Workmanship critical Low quantities of reinforcement only possible

A TUTORIAL: Improving the Seismic Performance of Stone Masonry Buildings

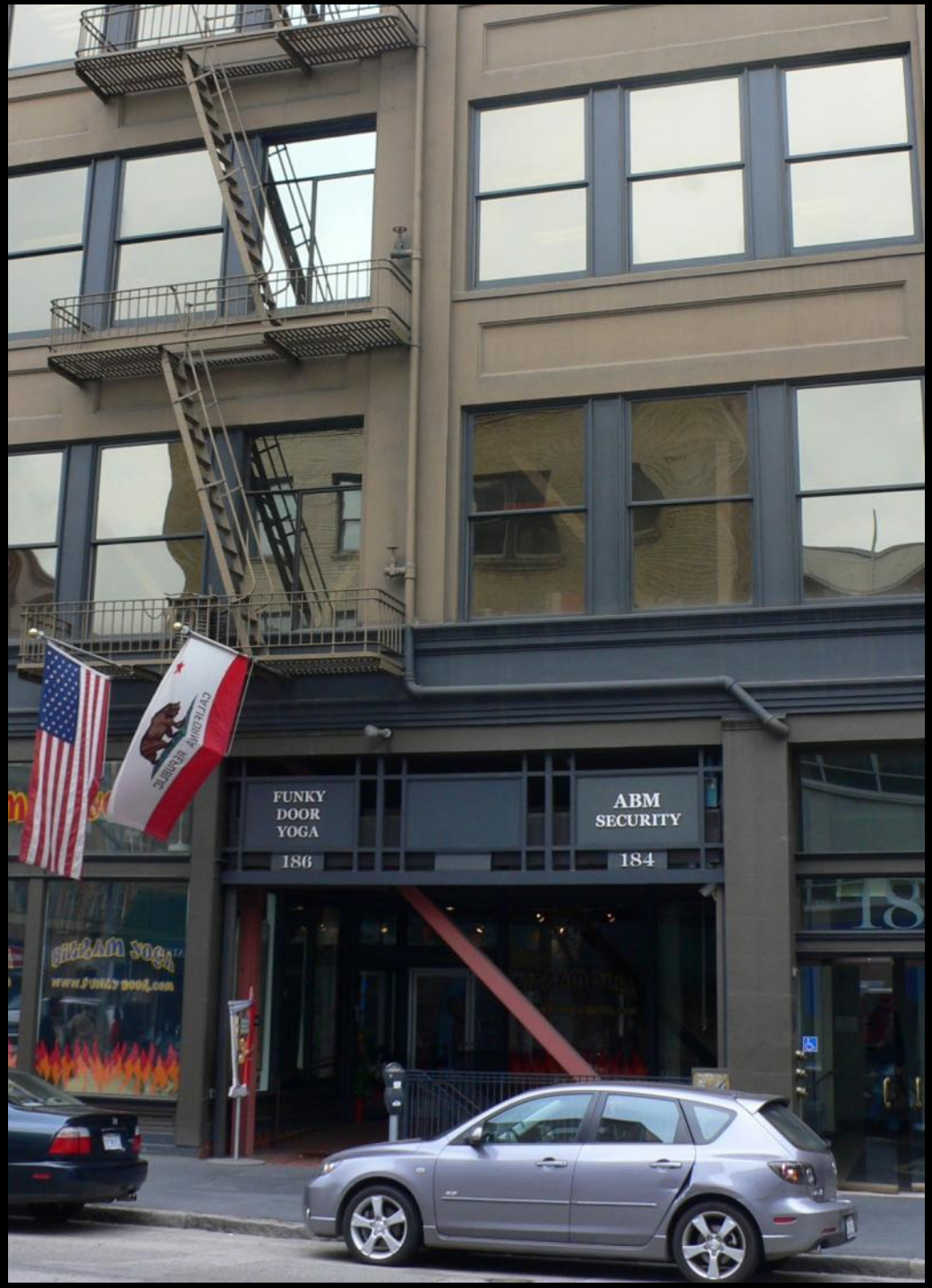
Jitendra Bothara • Svetlana Brzev

First Edition, July 2011

EERI

Final thought

Retrofitting should respect existing architecture


FUNKY
DOOR
YOGA
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ABM
SECURITY
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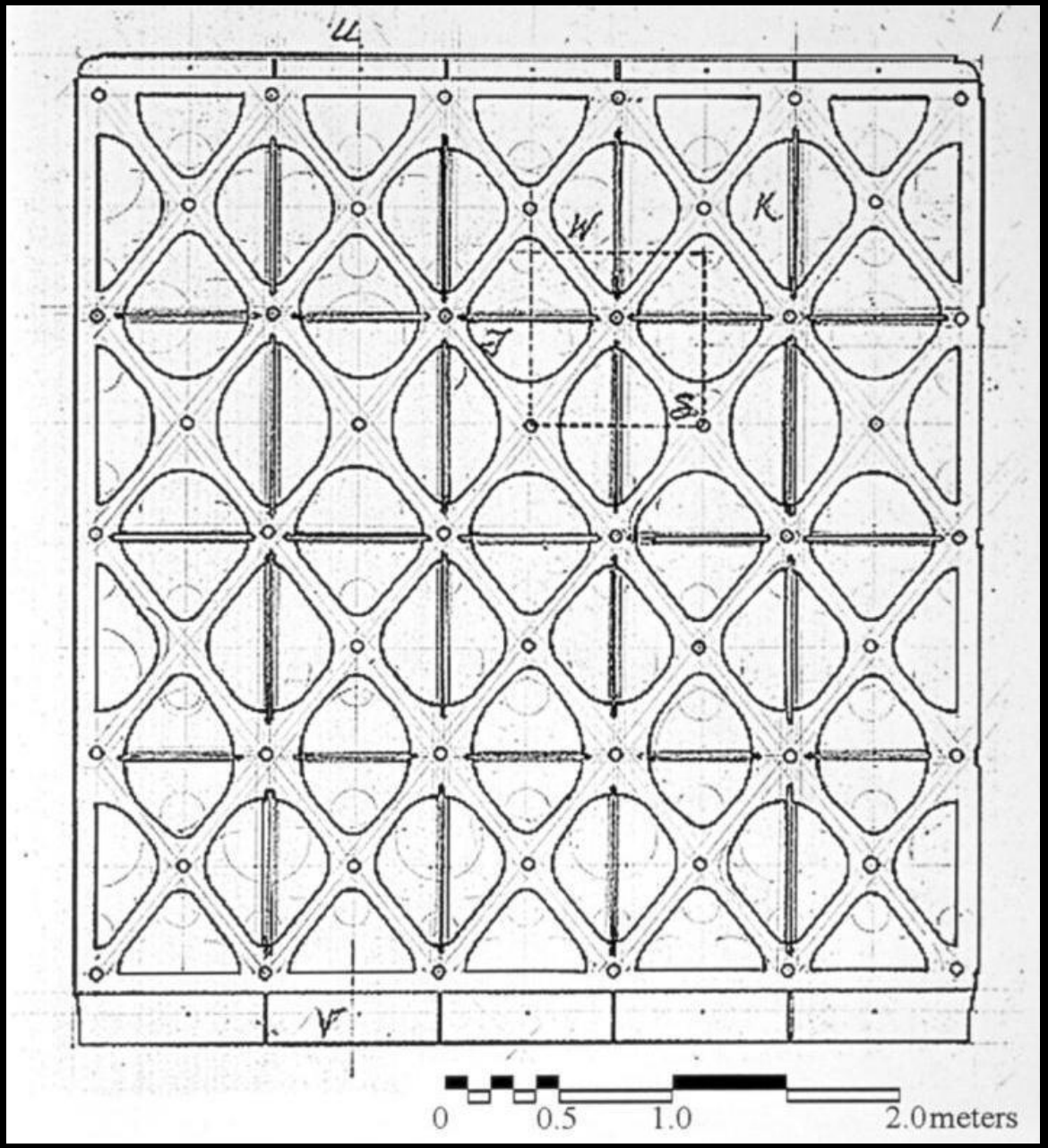
Refer to “Moments of Resistance” by Taylor, Preston and Charleson



Thank you

Questions?

Additional slides if needed for question time

Seismic Safety Policy regarding existing buildings in New Zealand and an approach to avoiding pounding

Andrew Charleson

Building Act 2004

The core framework for managing earthquake-prone buildings took effect from 1 July 2017 (through an Amendment Act)

The 2017 system affects owners of earthquake-prone buildings, territorial authorities (local councils), engineers, other building professionals and building users.

Definition of earthquake-prone

If a building, or part of it, will have its ultimate capacity exceeded, and would collapse in a moderate earthquake.

(Less than 33% of the strength of a new building (NBS))

- In determining the %NBS the engineer must:

- have a clear understanding of the structure and how it will respond in an earthquake, and
- be confident that there are no aspects of the structure that require more specific or detailed investigation and assessment; ie no potential Critical Structural Weaknesses that could lead to a %NBS that is less than 34%NBS.

Procedures

1. Territorial authorities (TAs) identify potentially earthquake-prone buildings (ISA)
2. Owners must obtain engineering assessments of the building carried out by qualified engineers (DSA)
3. TAs determine whether buildings are earthquake prone, assign ratings, issue notices and publish information about the buildings in a public register
4. Owners must display notices on their building and remediate their building.

Key Resource

"Seismic assessment of existing buildings"

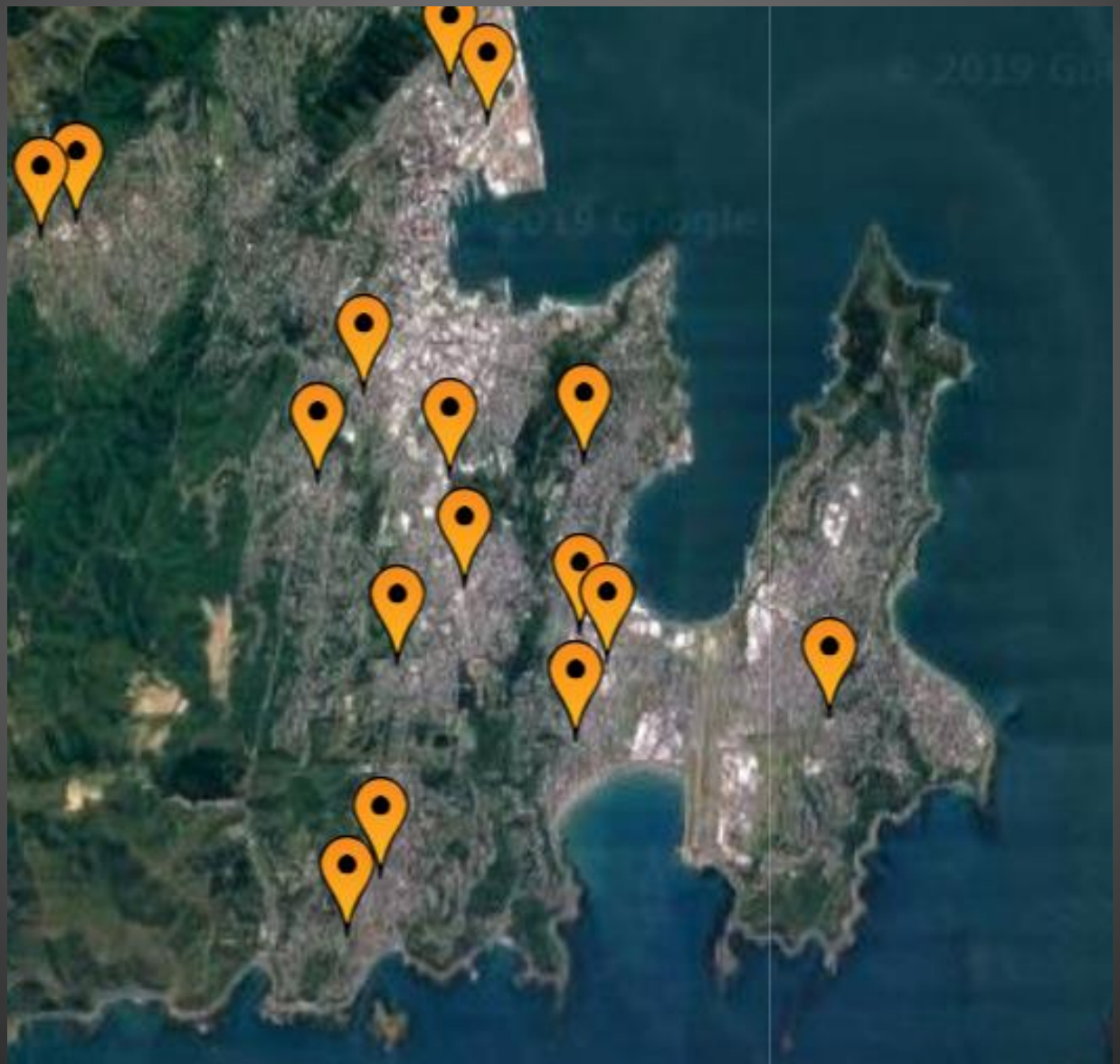
Published Nov. 2018

https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/seismic-assessment-existing-buildings/

Contents

- Assessment objectives, principles, procedures and analysis techniques
- Initial seismic assessment (ISA)
- Geotechnical considerations
- Concrete, steel and timber buildings
- Moment frames with infill panels
- Non-structural elements
- Report and assessment templates

Register of earthquake-prone buildings



EARTHQUAKE STRENGTHENING: THE COURTENAY PLACE QUARTER

WCC offices, 101 Wakefield St

Town Hall, 101 Wakefield St

National Bank, 60 Courtenay Pl

Central Fire Station, 2 Oriental Pde

Opera House 109-117 Manners St

Kitty O'Sheas, right, Kenny's Cafe, Mish Mosh, 28-30 Courtenay Pl

Malthouse, 48 Courtenay Pl

Victory Building, 66-72 Courtenay Pl

Earthquake-prone: The building has been through the assessment process and the WCC has issued a notice saying it requires earthquake strengthening, and putting a time limit on when work has to be completed.

Potentially earthquake-prone: Initial assessments have confirmed the building fits the criteria for an earthquake-prone building. The owner has been notified, and will provide a response before final assessment is made.

Heritage: The building has official heritage status with WCC. To be included a place must have significant aesthetic, historic, scientific or social value, or be significant to tangata whenua and other Maori.

EARTHQUAKE-PRONE BUILDING

Absolutely Positively Wellington City Council
Me Heke Ki Pōneke

Notice under section 133AL of the Building Act 2004

SR: 435602
Earthquake rating is 20% NBS

Wellington City Council has previously issued a written notice under section 124(2)(c)(i) of the Building Act 2004.

This notice is for –

The building situated at 146 Riddiford Street, Newtown, Wellington, LOT 1 DP 13219.

The building has been determined by Wellington City Council to be earthquake-prone.

The building is a priority building (as defined in section 133AE of the Building Act 2004).

The owner of the building is required to carry out building work to ensure that the building is no longer earthquake-prone (seismic work).

The owner is required to complete seismic work by 13/12/2026.

The owner of the building may apply to Wellington City Council, under section 133AN of the Building Act 2004, for an exemption from the requirement to carry out seismic work. The building must have certain characteristics to be granted an exemption (see also the Building (Specified Systems, Change the Use, and Earthquake-prone Buildings) Regulations 2005).

The owner of the building may provide further information at any time. In the event that Wellington City Council determines or is satisfied, in accordance with section 133AQ of the Building Act 2004, that the building is not earthquake-prone, the owner is not required to complete the seismic work.

Wellington City Council requires that the owner attaches a copy of this notice in a prominent place on or adjacent to the building. If this notice ceases to be attached in a prominent place on or adjacent to the building, or becomes illegible, the owner of the building to which the notice relates must notify Wellington City Council.

A person who fails to attach this notice or fails to notify Wellington City Council as required above commits an offence. Offenders are liable to a fine not exceeding $20,000.

A person who wilfully removes or defaces this notice or incites another person to do commits an offence. Offenders are liable on conviction to a fine not exceeding $5,000.

Hayley Moselen
Position: Technical Manager, Resilient Buildings
On behalf of: Wellington City Council
Date: 13/06/2019

Timeframes for action

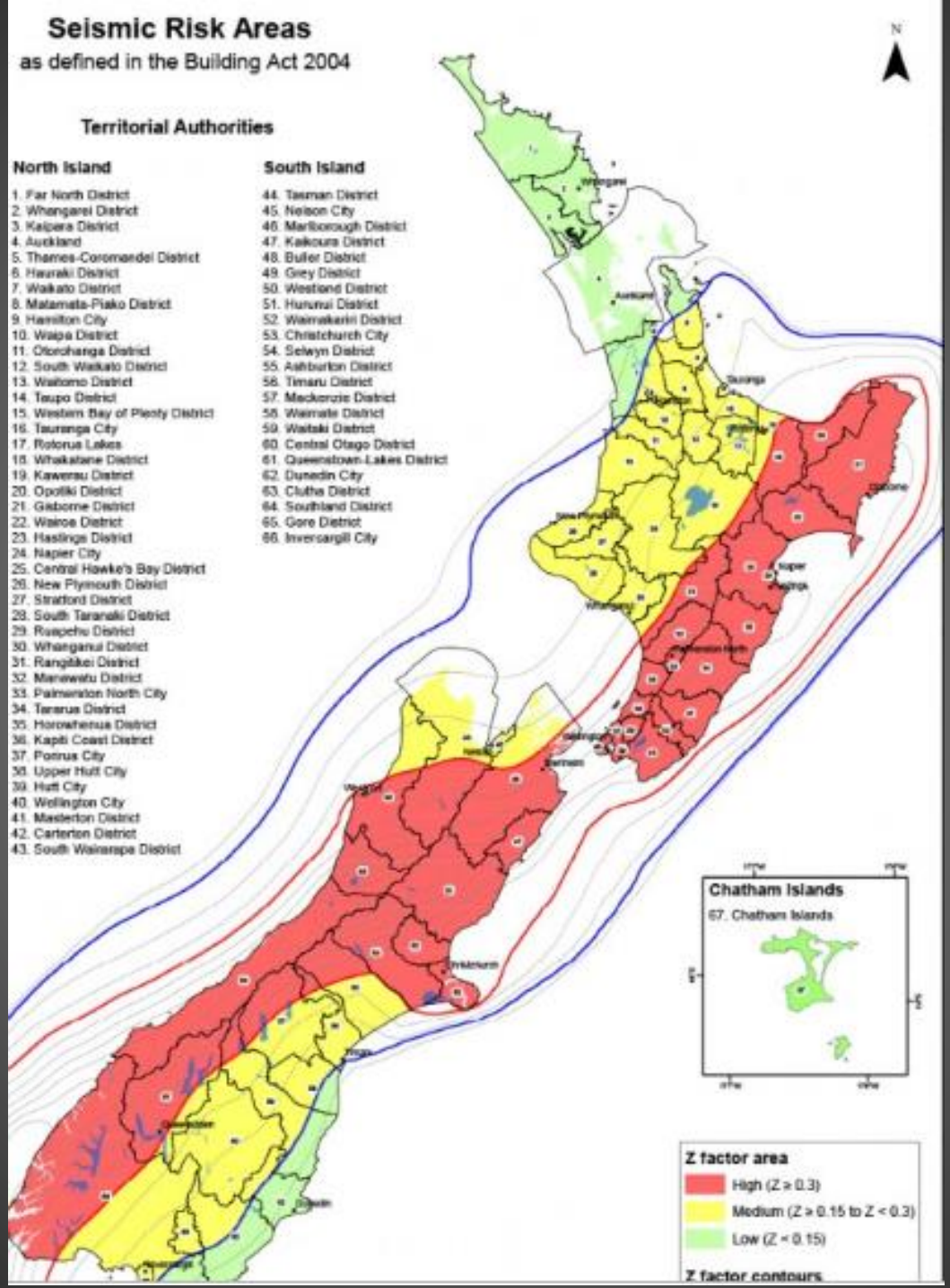
Seismic risk area: High

TAs must identify potentially earthquake-prone buildings by: Priority 1 Jan 2020, Other 1 July 2022

Owners of buildings must carry out seismic work within (time from issue of EPB notice): Priority 7.5 years, Other 15 years

Seismic Risk Areas

as defined in the Building Act 2004



Why retrofit?

Procedures

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