

An aerial photograph of a city, likely Auckland, New Zealand, showing a dense urban area with a river winding through it. The image is in grayscale and serves as the background for the presentation slides.

POST-EARTHQUAKE RESIDUAL CAPACITY OF REINFORCED CONCRETE BUILDINGS: *Draft Framework*

K. Elwood
QuakeCoRE Director
MBIE Chair in Earthquake Engineering
University of Auckland

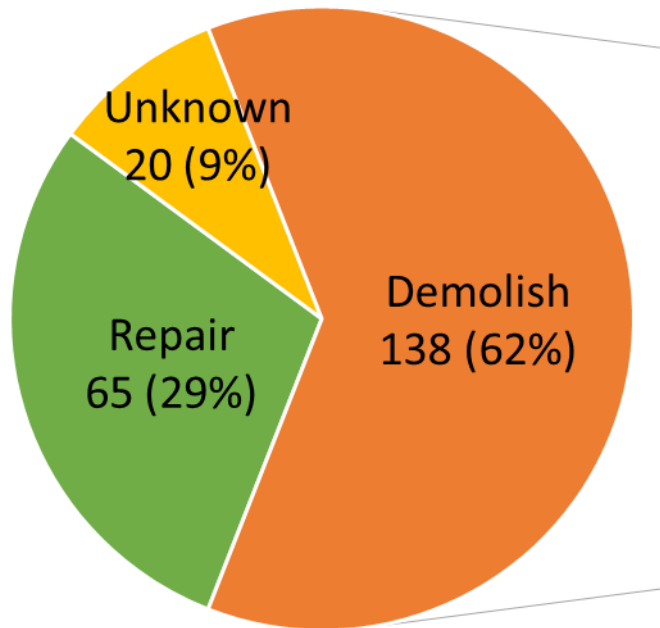
Representing:

MBIE (NZ) Working Group on Residual Capacity

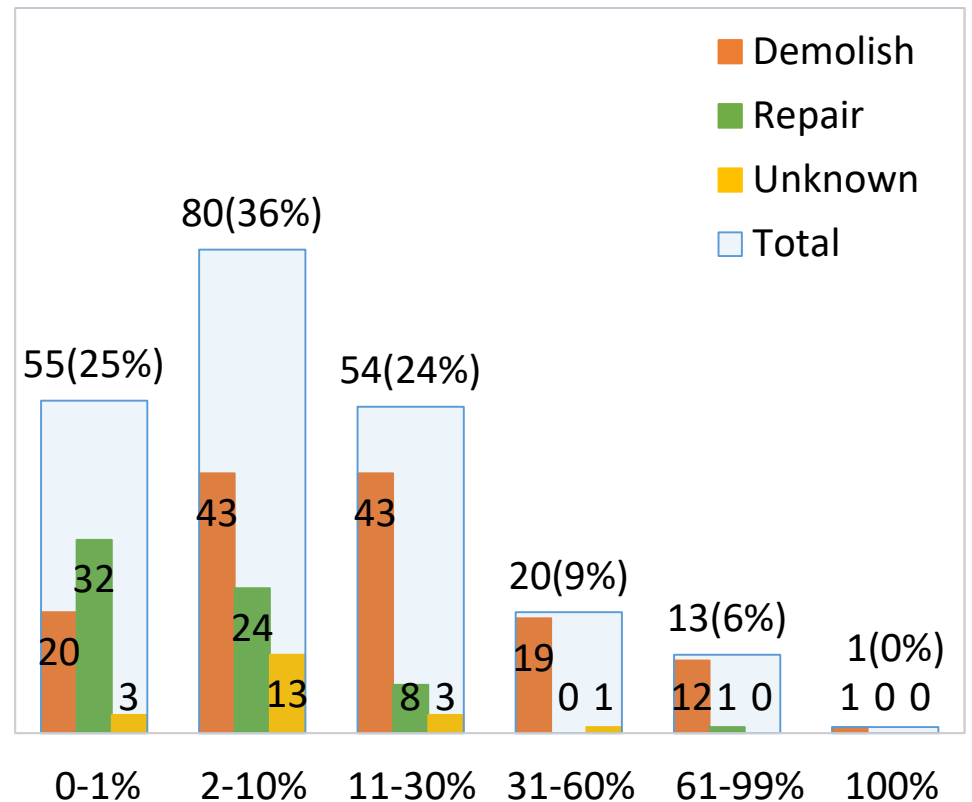
A. Cattanach, A. Cuevas Ramirez, M. Kral, K. Marder, S. Pampanin, P. Smith, M. Stannard

Christchurch Building Damage Statistics

223 RC Buildings over 2 stories
(Kim et al. 2015)

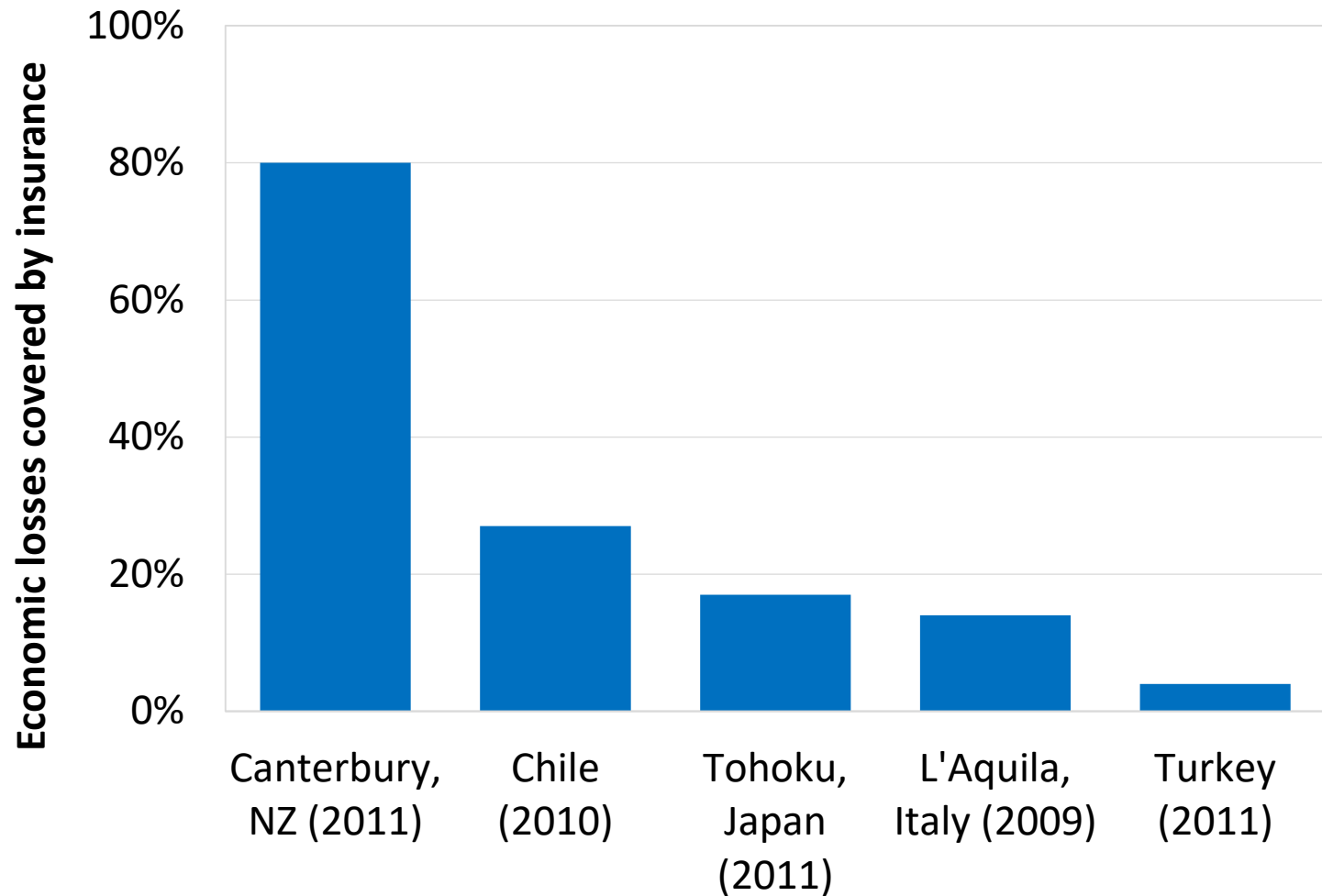


Damage Ratio \approx repair cost / replacement cost
(visual estimate)



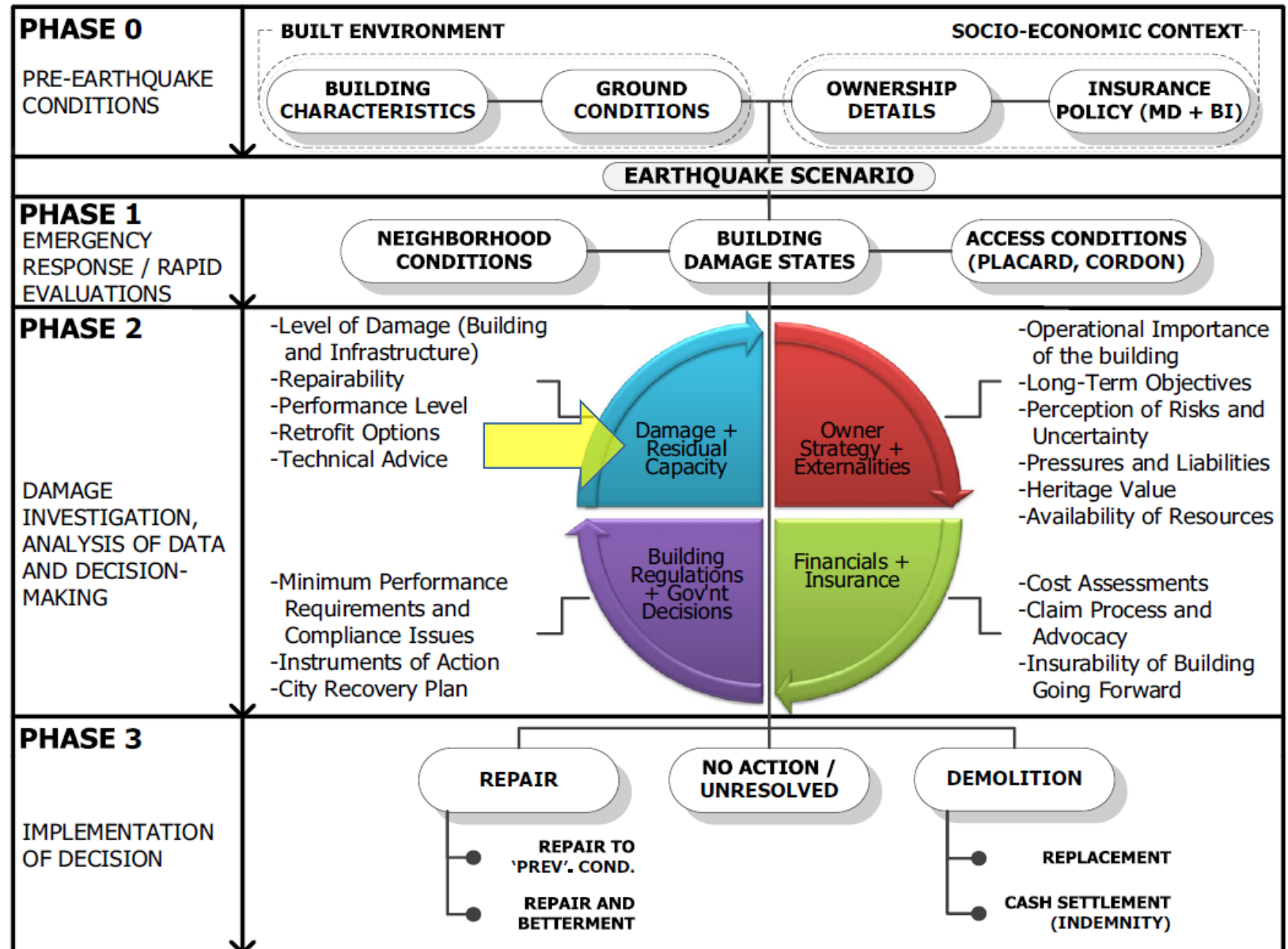
→ **Significant number of RC buildings with relatively low damage were demolished.**

External factors: Insurance



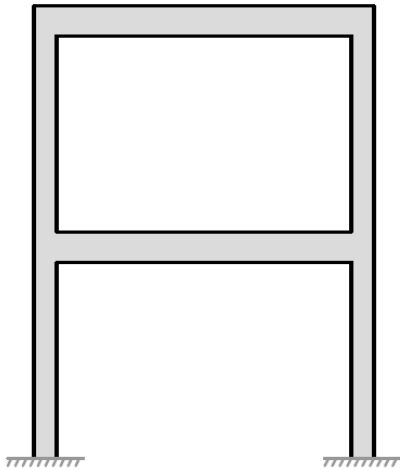
Demolition Decision Framework

- Marquis et al. 2015

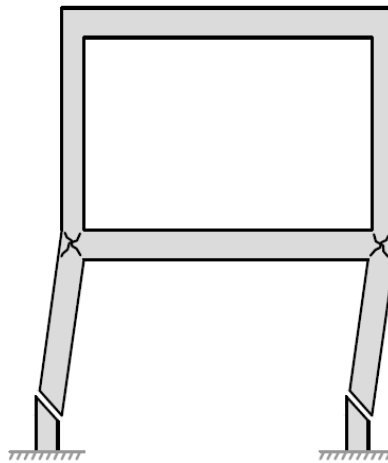


When is residual capacity important?

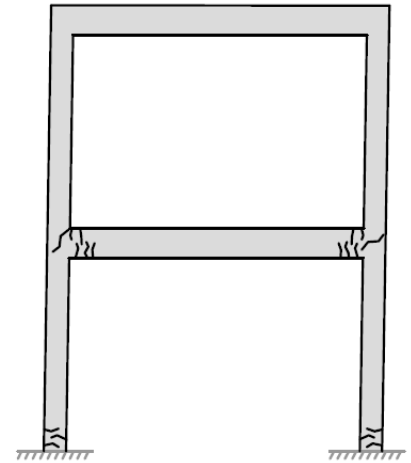
In post-earthquake situations, RC buildings can be broadly categorized into three categories:



1. Minimal damage: no further action required

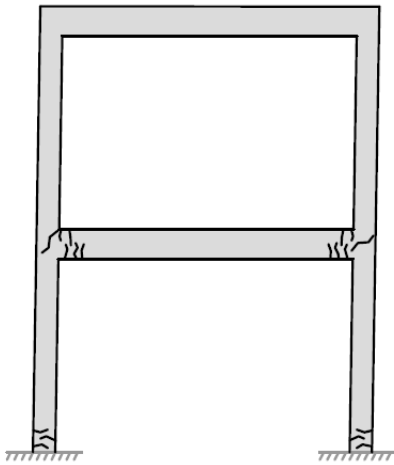


2. Heavy damage: demolition is necessary



3. Moderate damage: **residual capacity?**

When is residual capacity important?



Moderately
damaged
building

Non-structural damage

- Economically important
- Does not affect structural capacity

Non-ductile damage

- Likely requires full retrofit or replacement

Flexural damage (plastic hinging)

- Outcome less clear
- Need guidance on residual capacity

Draft Framework

GROUND MOTION &
STRUCTURAL DRAWINGS

CREATE BUILDING MODEL
AND PERFORM ANALYTICAL
ESTIMATION OF PEAK
BUILDING RESPONSE

OBSERVABLE DAMAGE

CRACK DISTRIBUTIONS
CRACK WIDTHS
RESIDUAL DRIFT
ETC...

How to reconcile?

BEST ESTIMATE OF PEAK DEMANDS

Impact of loading rate, protocol, strain ageing?

CALCULATE RESIDUAL STIFFNESS, STRENGTH, &
DEFORMABILITY FOR DAMAGED/REPAIRED COMPONENTS

Epoxy?

IS REPAIR
REQUIRED?

UPDATE BUILDING MODEL TO ACCOUNT FOR
DAMAGED/REPAIRED COMPONENTS

RE-CONDUCT ANALYSIS USING UPDATED MODEL
→ BUILDING CAPACITY RELATIVE TO UNDAMAGED BUILDING

Criteria for demolish/repair recommendation?

Material tests
needed?

When and how to
consider?

LOW-CYCLE
FATIGUE
ASSESSMENT
PROCEDURE

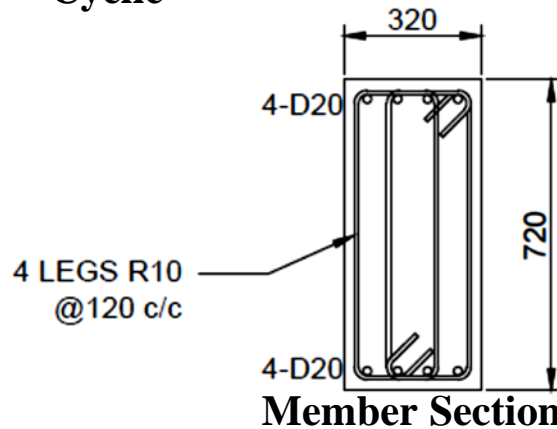
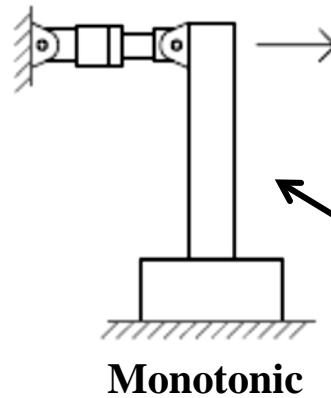
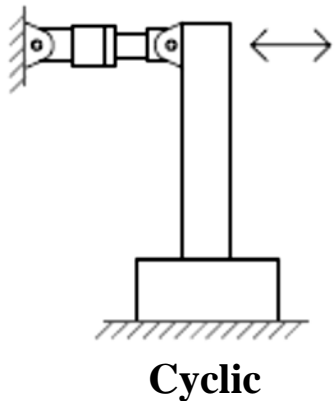
Draft Framework: Research needs

1. Define *plastic hinges* based on observed damage.
2. When is detailed assessment of *bar strain* necessary?
3. Observed damage → *peak demands*
4. When to consider *low-cycle fatigue* (LCF)?
→ LCF residual capacity?
5. Peak demand → *Stiffness and strength degradation*
 - Influence of strain rate, crack distribution, strain ageing, etc
6. *Epoxy repair* → Stiffness and strength degradation
7. *Criteria* for repair or demolition recommendation.

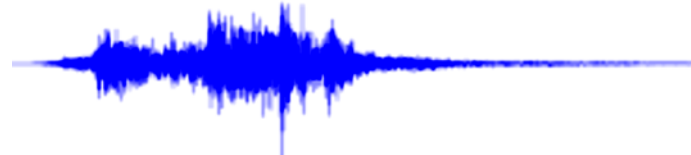
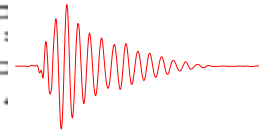
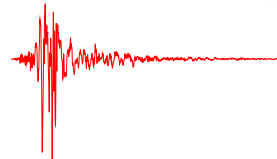
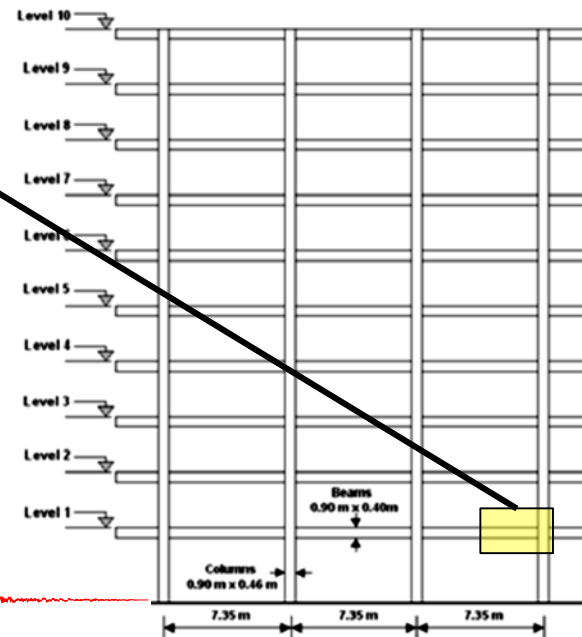
Ongoing Research: UA study

- *Experimental study*

Baseline Static Tests to Failure



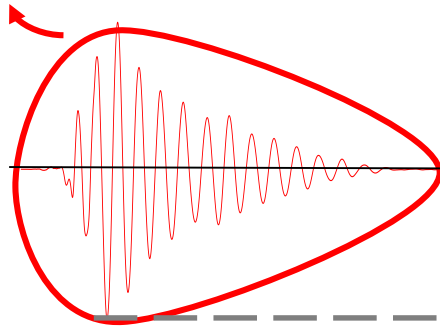
4/5 scale from Red Book building



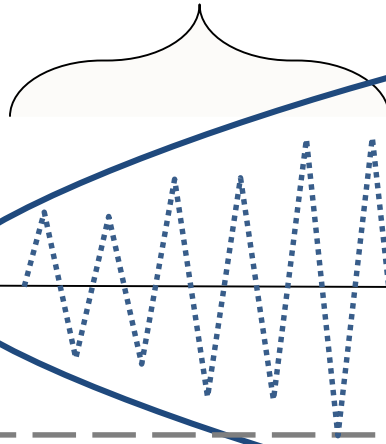
Ongoing Research: UA study

- *Loading Protocol*

Run 1:
Displacement
demands from
EQ (Dynamic)

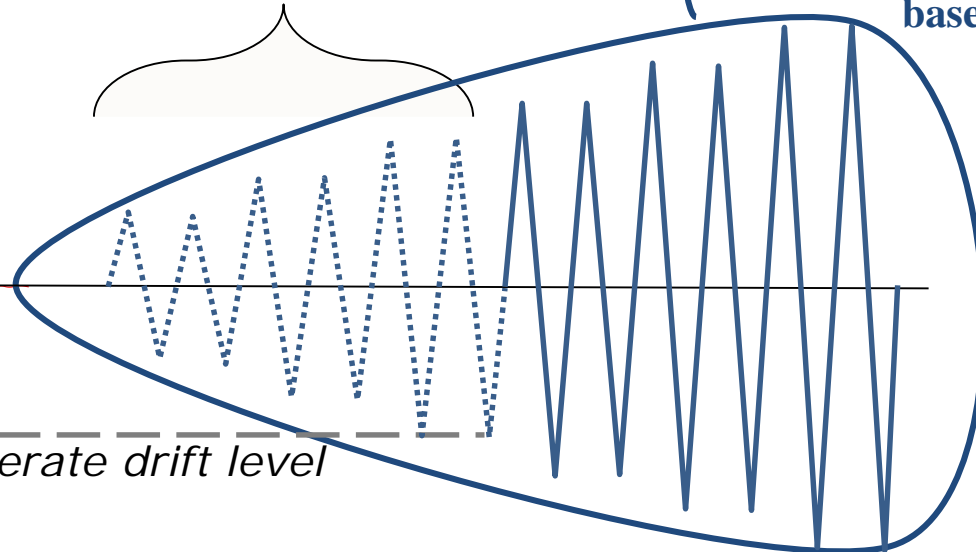


Cycles at or below peak drift
from Run 1 left out of Run 2



Low or moderate drift level

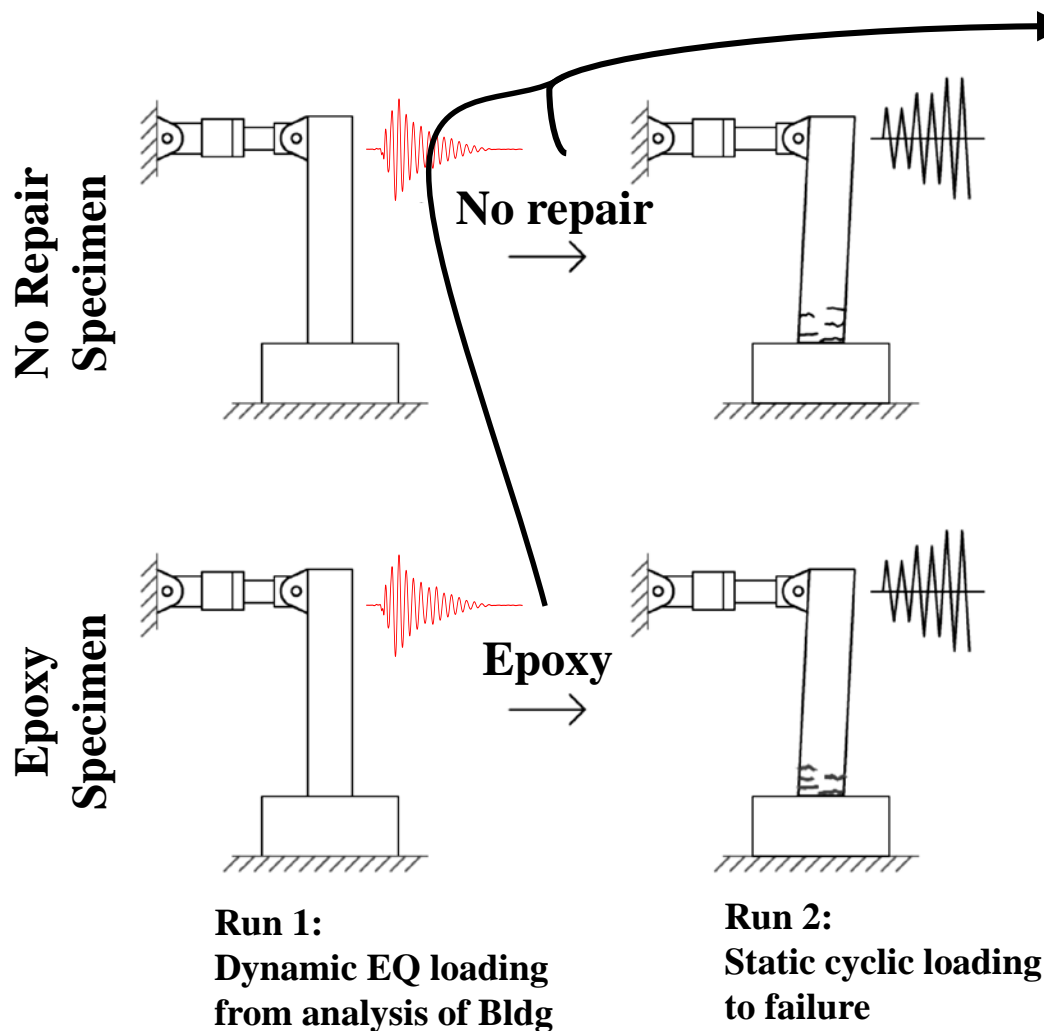
Complete
standard cyclic
loading protocol
as applied in
baseline test



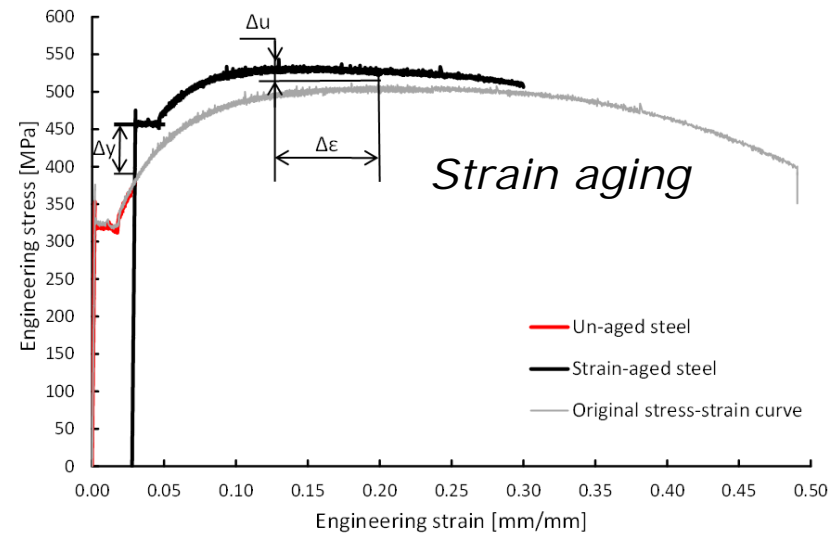
Run 2:
Cycles above peak drift
from Run 1

Ongoing Research: UA study

- *Unrepaired vs. repaired*



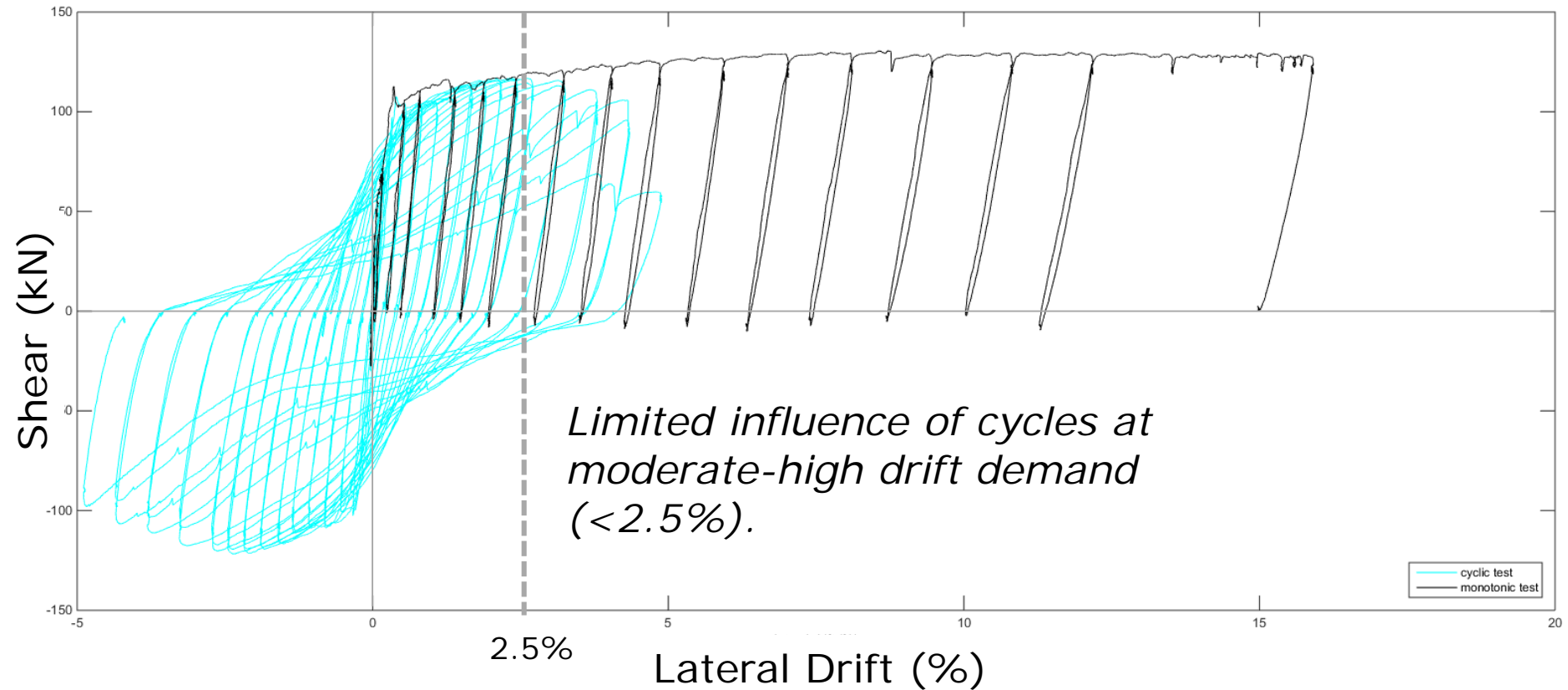
Two specimens will be left to "age" after Run 1:



Loporcaro, et al, 2014

Ongoing Research: UA study

- *Cyclic vs Monotonic*



Elephant in the room...

- Post-earthquake demolition decisions.
- Engineers need to lead this decision process, not follow.
- Need guidance on assessment of Residual Capacity.
 - *International Challenge*

Supported by:



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**NATURAL
HAZARDS**
RESEARCH PLATFORM

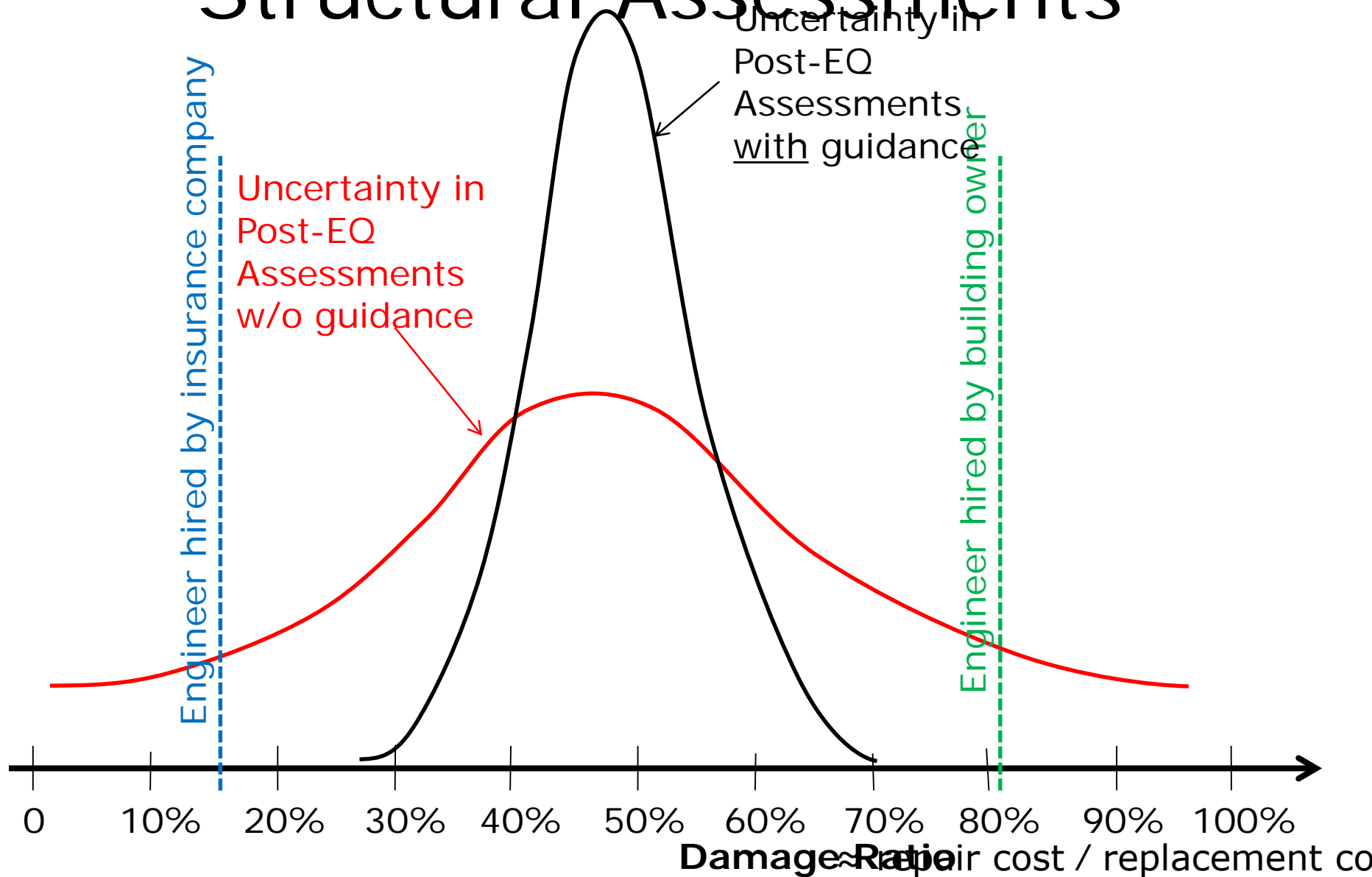


QuakeCoRE
NZ Centre for Earthquake Resilience



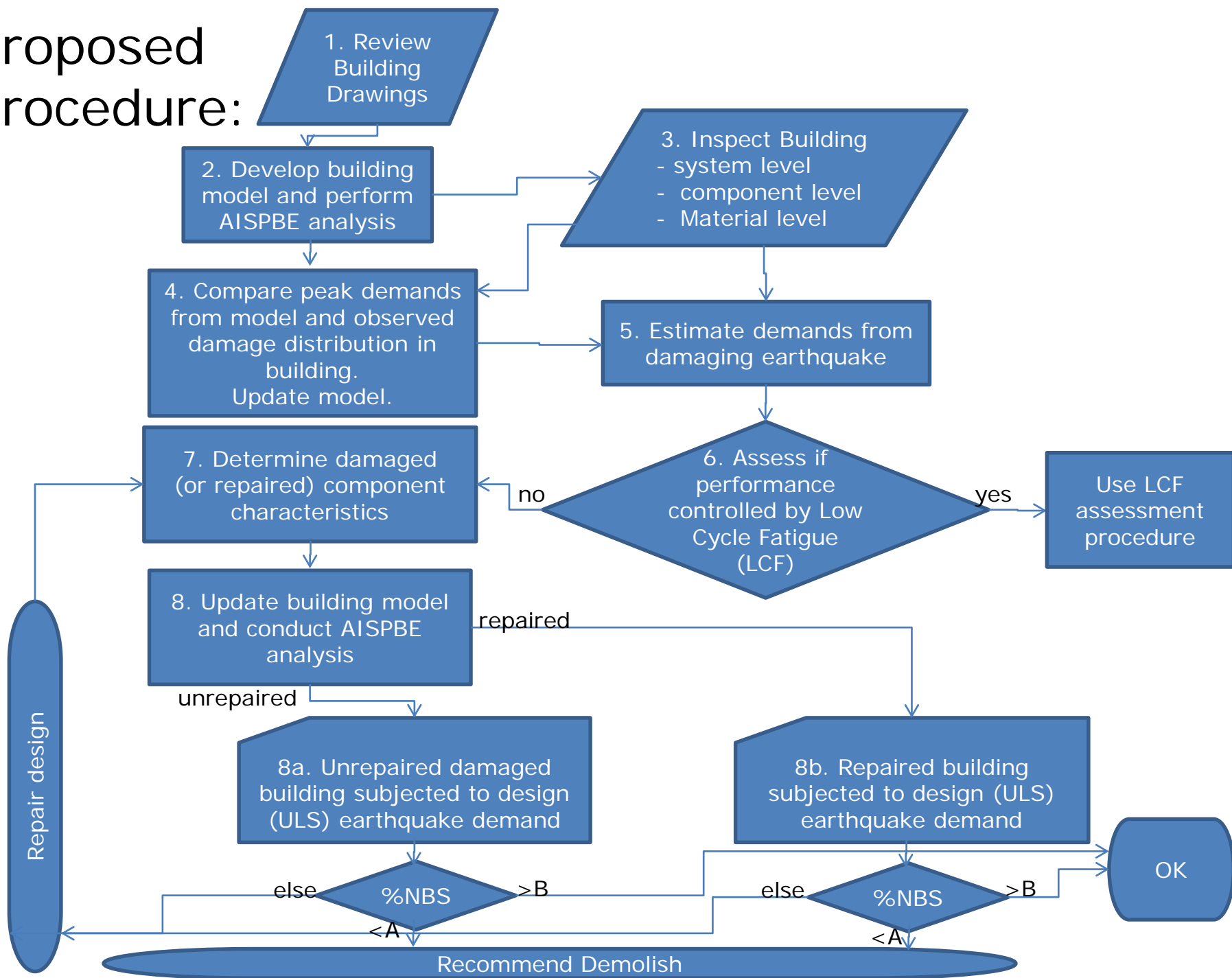
Thank you!

Impact of Uncertainty in Structural Assessments



Specimen name ¹	Initial damaging loading type	Failure loading type	Repaired after initial damage?
Cyc	-	Static cyclic	No
Mono	-	Static monotonic	No
Cyc-ER	-	Static cyclic	No
Mono-ER	-	Static monotonic	No
LD-1.5	Dynamic long duration ~1.5% drift	Static cyclic (cycles above 1.5% drift only)	No
LD-1.5-R	Dynamic long duration ~1.5% drift	Static cyclic (cycles above 1.5% drift only)	Yes
LD-2.5	Dynamic long duration ~2.5% drift	Static cyclic (cycles above 2.5% drift only)	No
LD-2.5-R	Dynamic long duration ~2.5% drift	Static cyclic (cycles above 2.5% drift only)	Yes
P-1.5	Dynamic pulse-type ~1.5% drift	Static cyclic (cycles above 1.5% drift only)	No
P-1.5-R	Dynamic pulse-type ~1.5% drift	Static cyclic (cycles above 1.5% drift only)	Yes
P-2.5	Dynamic pulse-type ~2.5% drift	Static cyclic (cycles above 2.5% drift only)	No
P-2.5-R	Dynamic pulse-type ~2.5% drift	Static cyclic (cycles above 2.5% drift only)	Yes
LD-2.5-SA*	Dynamic long duration ~2.5% drift	Static cyclic (cycles above 2.5% drift only)	No
LD-2.5-SAR*	Dynamic long duration ~2.5% drift	Static cyclic (cycles above 2.5% drift only)	Yes

Proposed Procedure:



Specimen	Run 1 ground motion type	Approx. Run 1 peak drift*	Epoxy injection after Run 1?	Ageing after Run 1?
Monotonic	-	-	-	-
Cyclic	-	-	-	-
NewCyclic1	-	-	-	-
NewCyclic2	-	-	-	-
1A	Long duration	2%	No	No
1B	Long duration	2%	Yes	No
2A	Long duration	3%	No	No
2B	Long duration	3%	Yes	No
3A	Short duration	2%	No	No
3B	Short duration	2%	Yes	No
4A	Short duration	3%	No	No
4B	Short duration	3%	Yes	No
5A	Short duration	3%	No	Yes
5B	Short duration	3%	Yes	Yes

* Actual Run 1 peak drift levels will be decided based on observations from the drift required to reach a given damage state in the cyclic and monotonic control specimens