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

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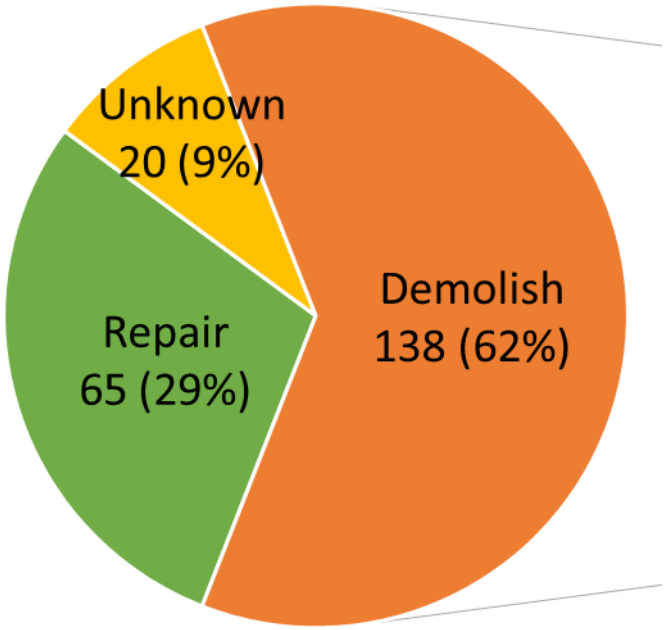
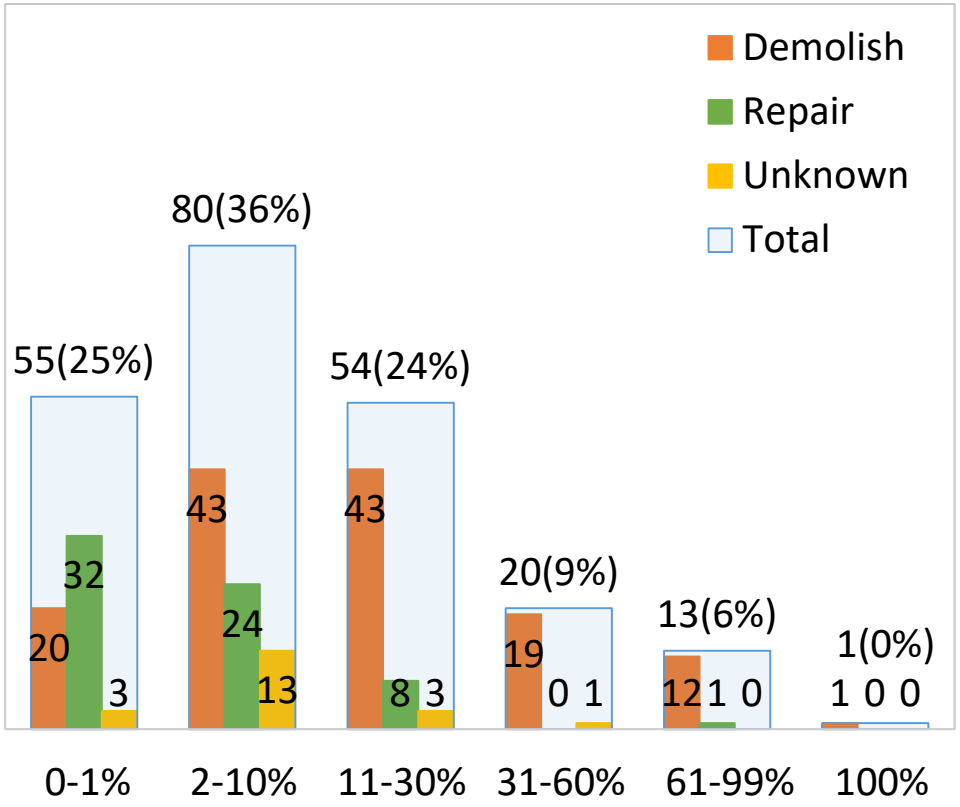
Christchurch Building Damage Statistics

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

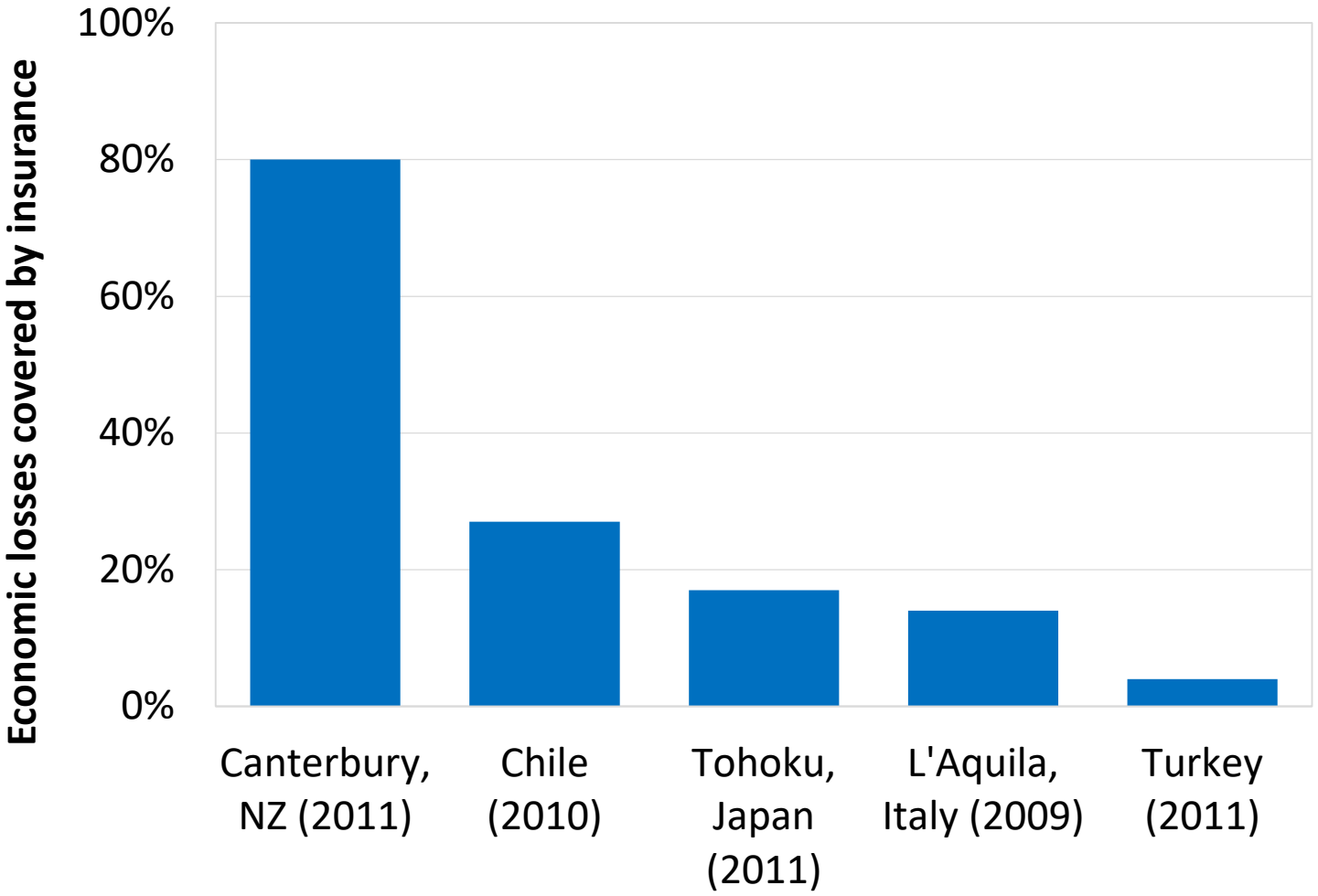


Damage Ratio ≈ repair cost / replacement cost (visual estimate)



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

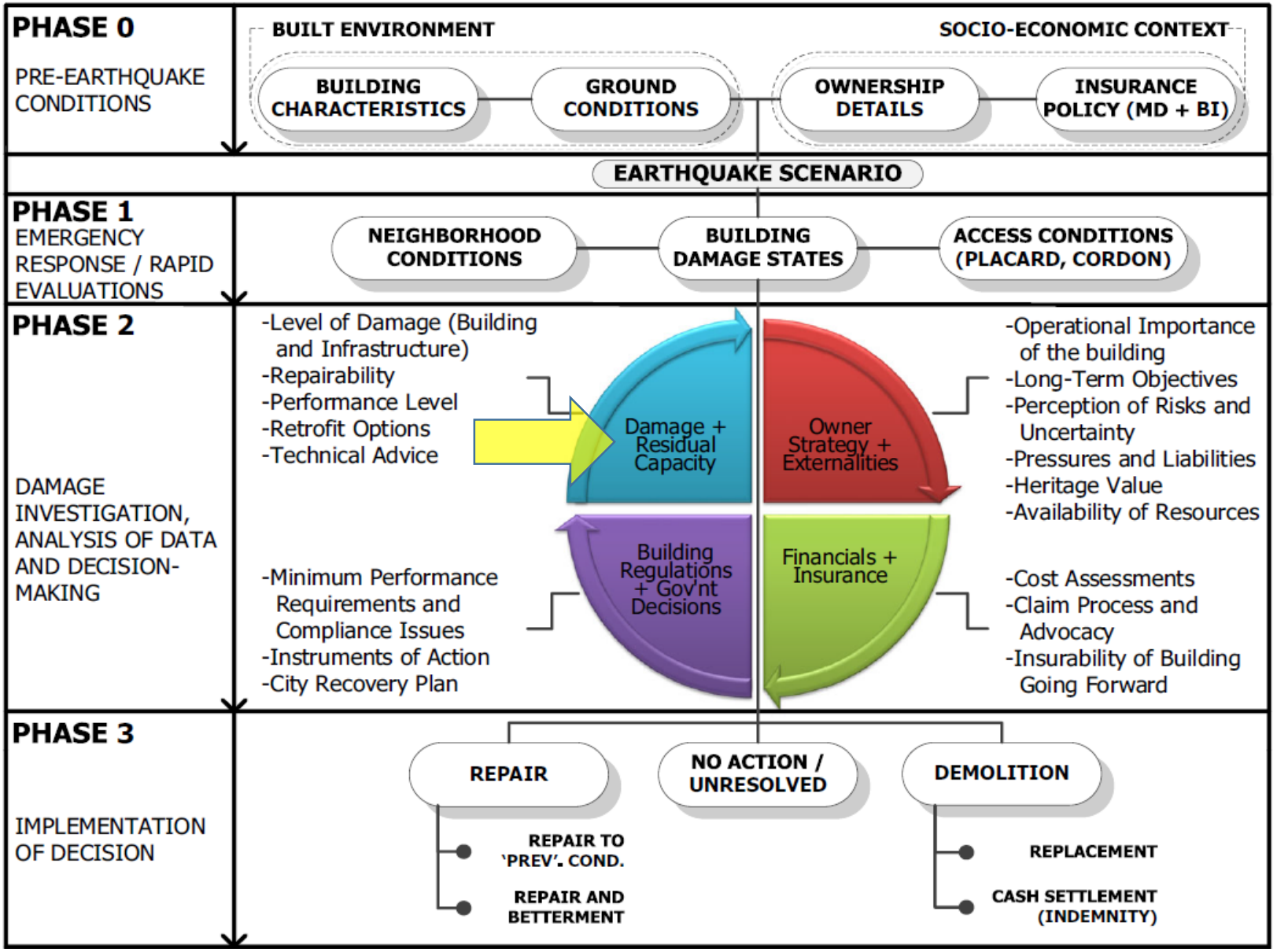
External factors: Insurance



SwissRe, 2013

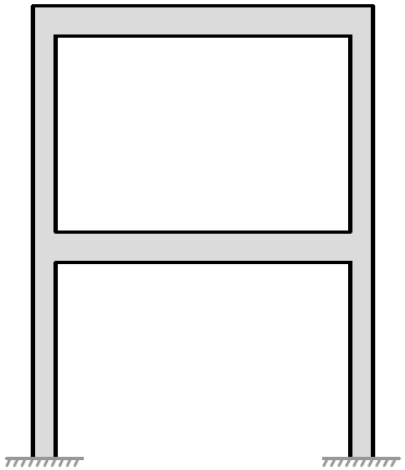
Demolition Decision Framework

- Marquis et al. 2015

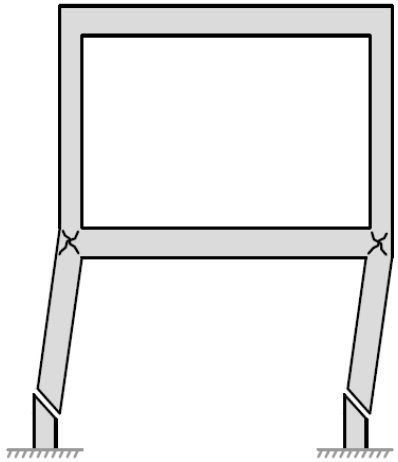


When is residual capacity important?

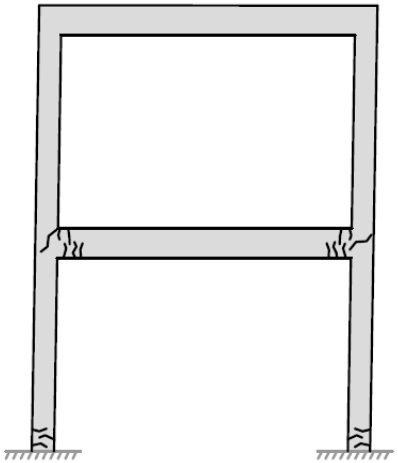
In post-earthquake situations, RC buildings can be broadly categorized into three categories:



1. Minimal damage: no further action required

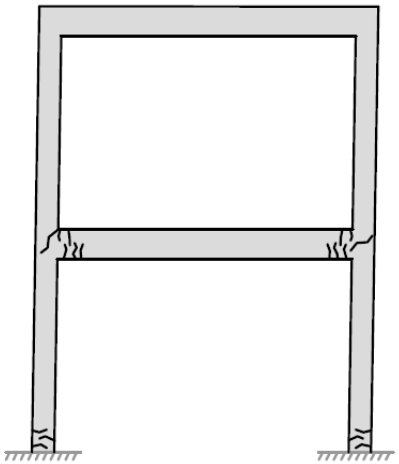


2. Heavy damage: demolition is necessary



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

When is residual capacity important?



Moderately damaged building

Non-structural damage

- Economically important
- Does not affect structural capacity

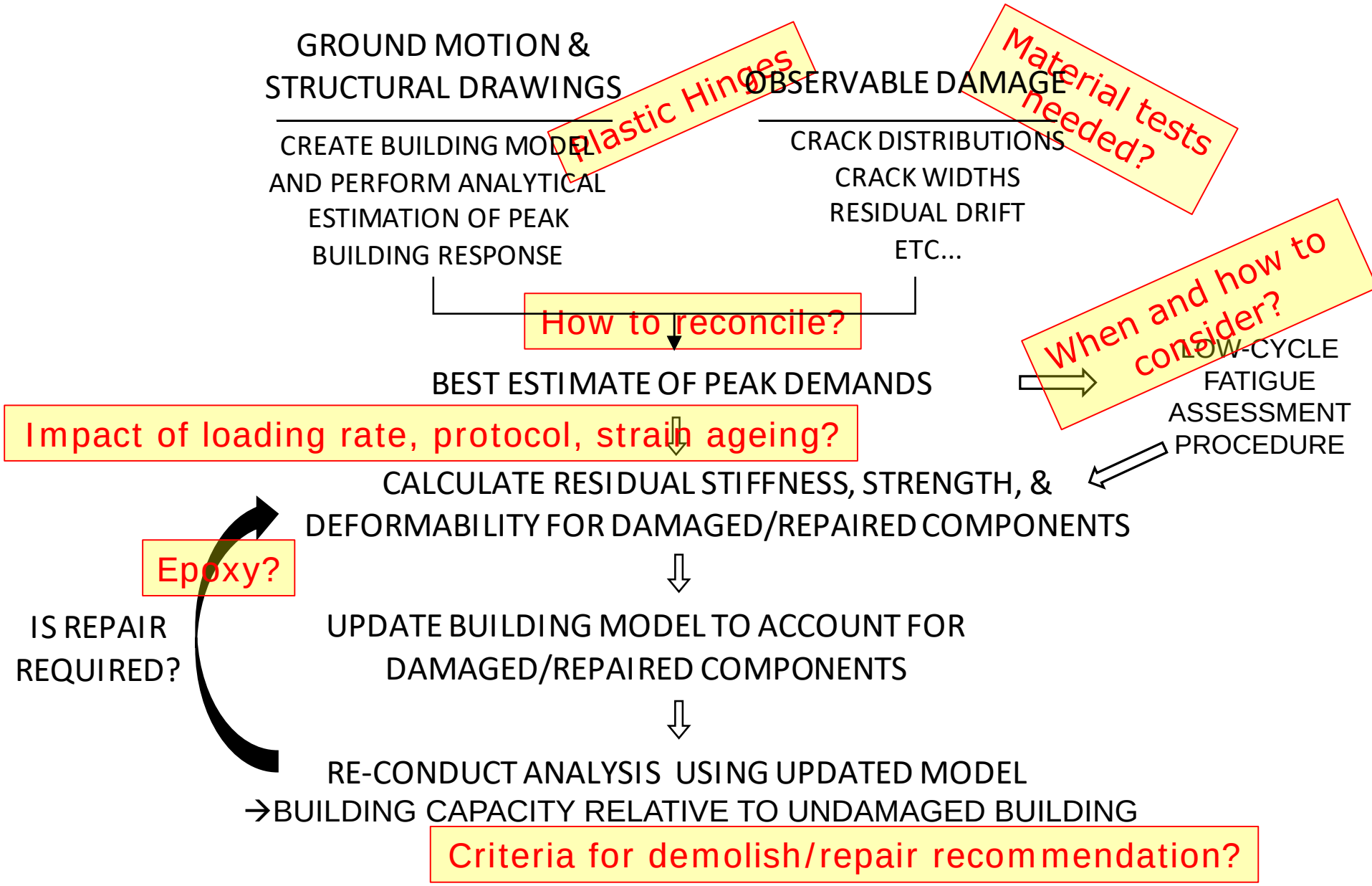
Non-ductile damage

- Likely requires full retrofit or replacement

Flexural damage (plastic hinging)

- **Outcome less clear**
- **Need guidance on residual capacity**

Draft Framework



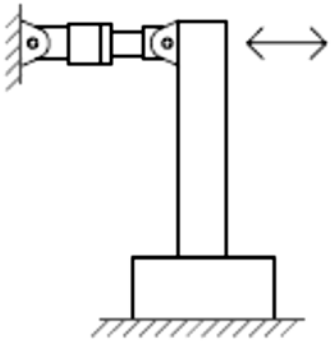
Draft Framework: Research needs

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.

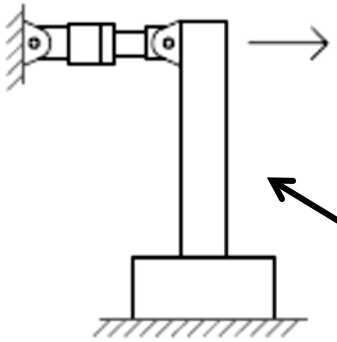
Ongoing Research: UA study

- *Experimental study*

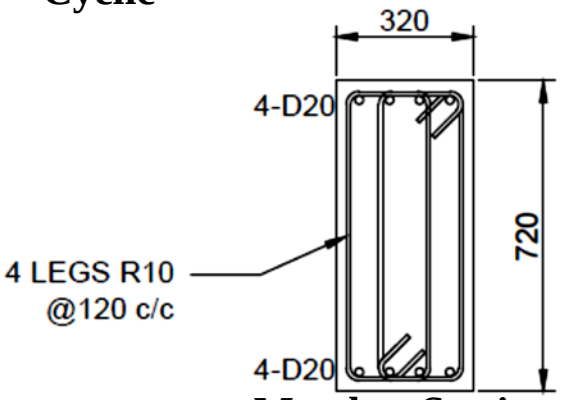
Baseline Static Tests to Failure



Cyclic

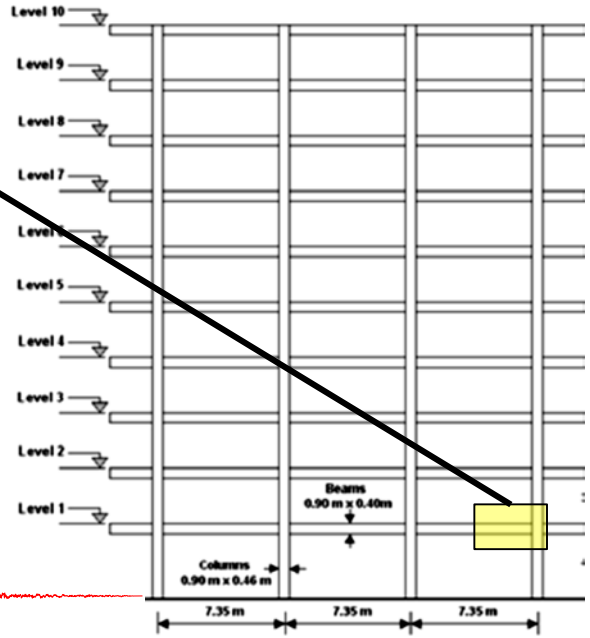


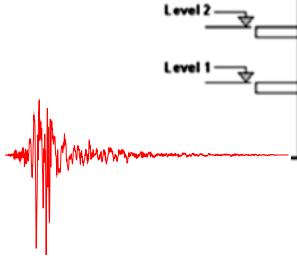
Monotonic

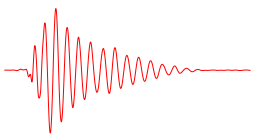


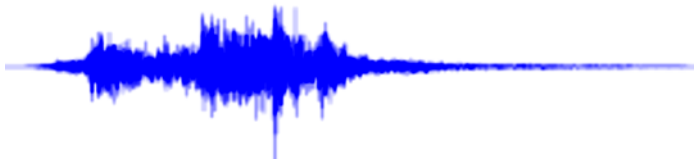
Member Section

4/5 scale from Red Book building



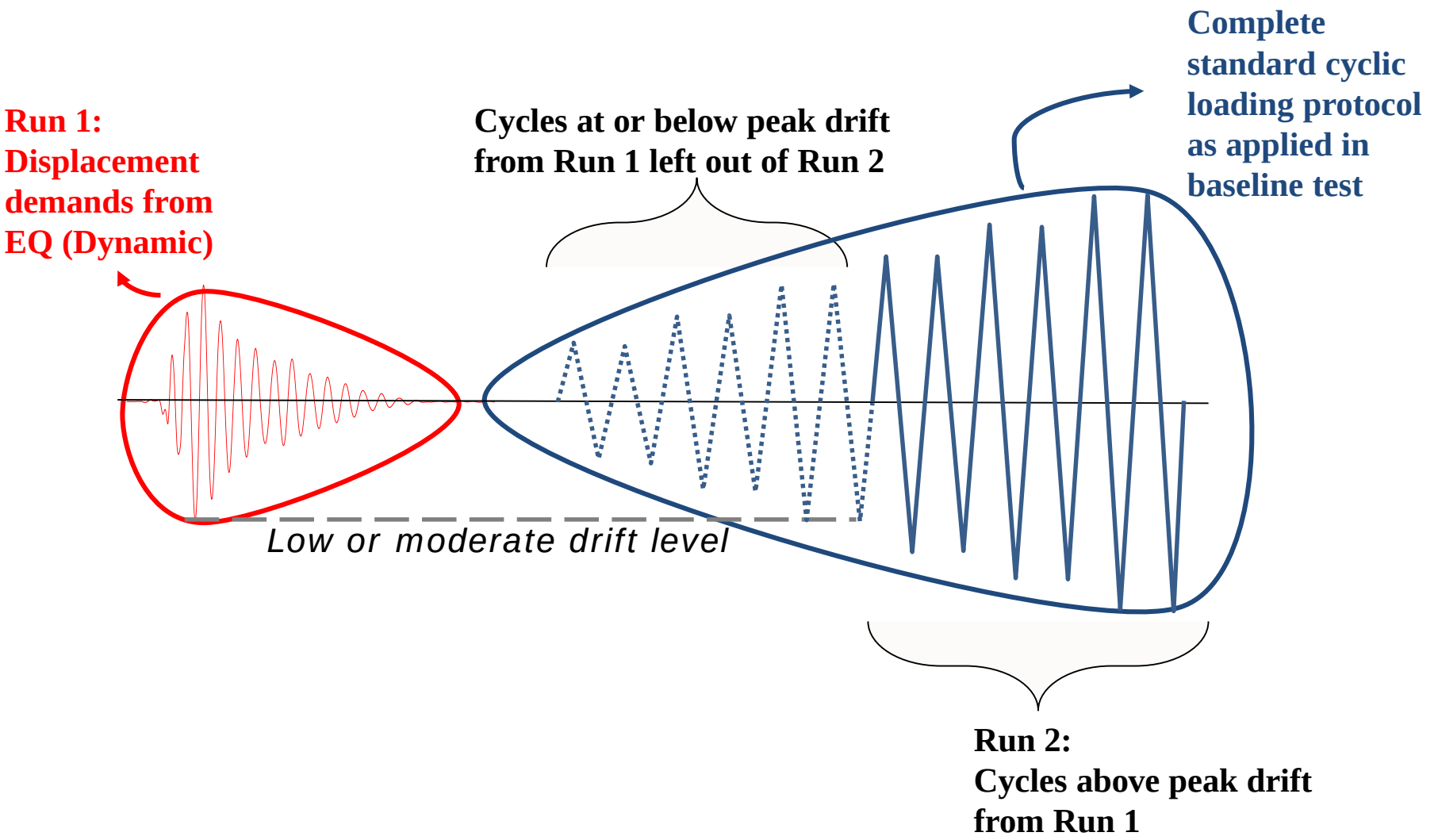






Ongoing Research: UA study

- *Loading Protocol*



Ongoing Research: UA study

- *Unrepaired vs. repaired*

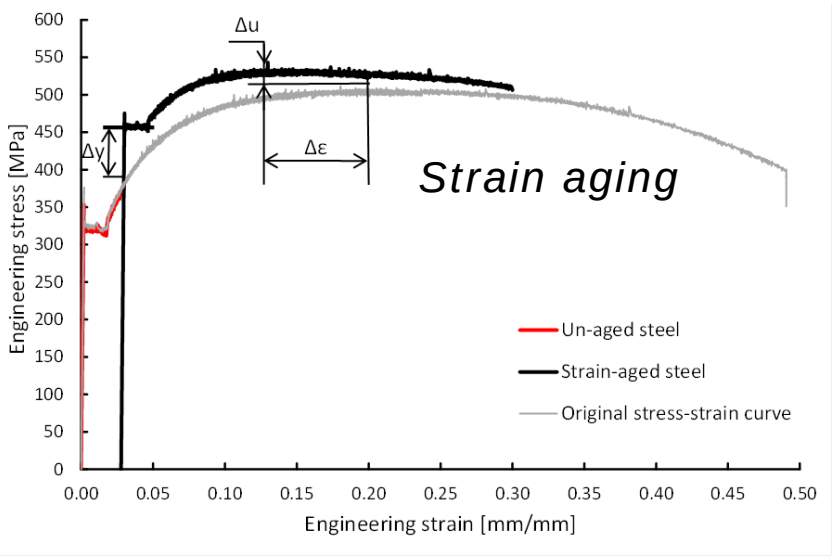
No Repair Specimen

No repair

Epoxy Specimen

Epoxy

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



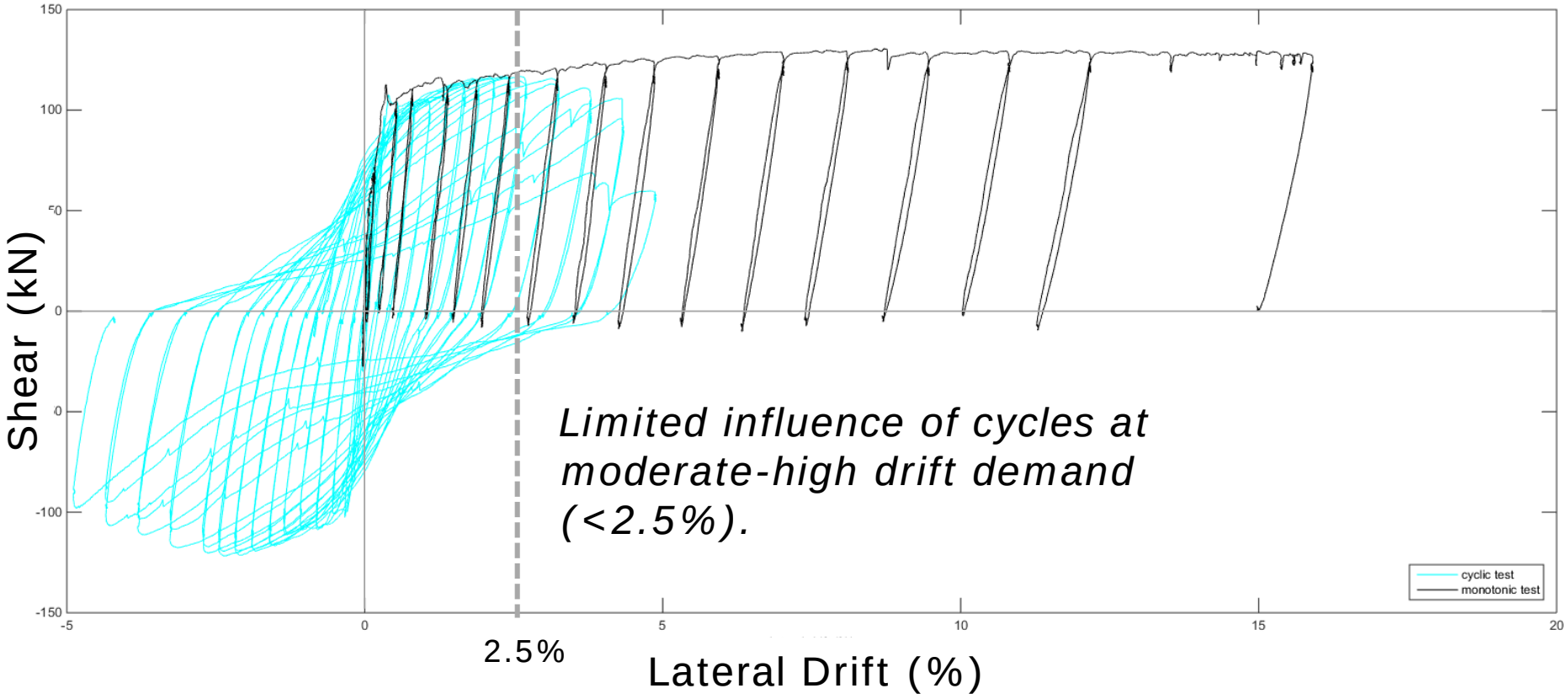
Loporcaro,et al, 2014

Run 1:
Dynamic EQ loading from analysis of Bldg

Run 2:
Static cyclic loading to failure

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:

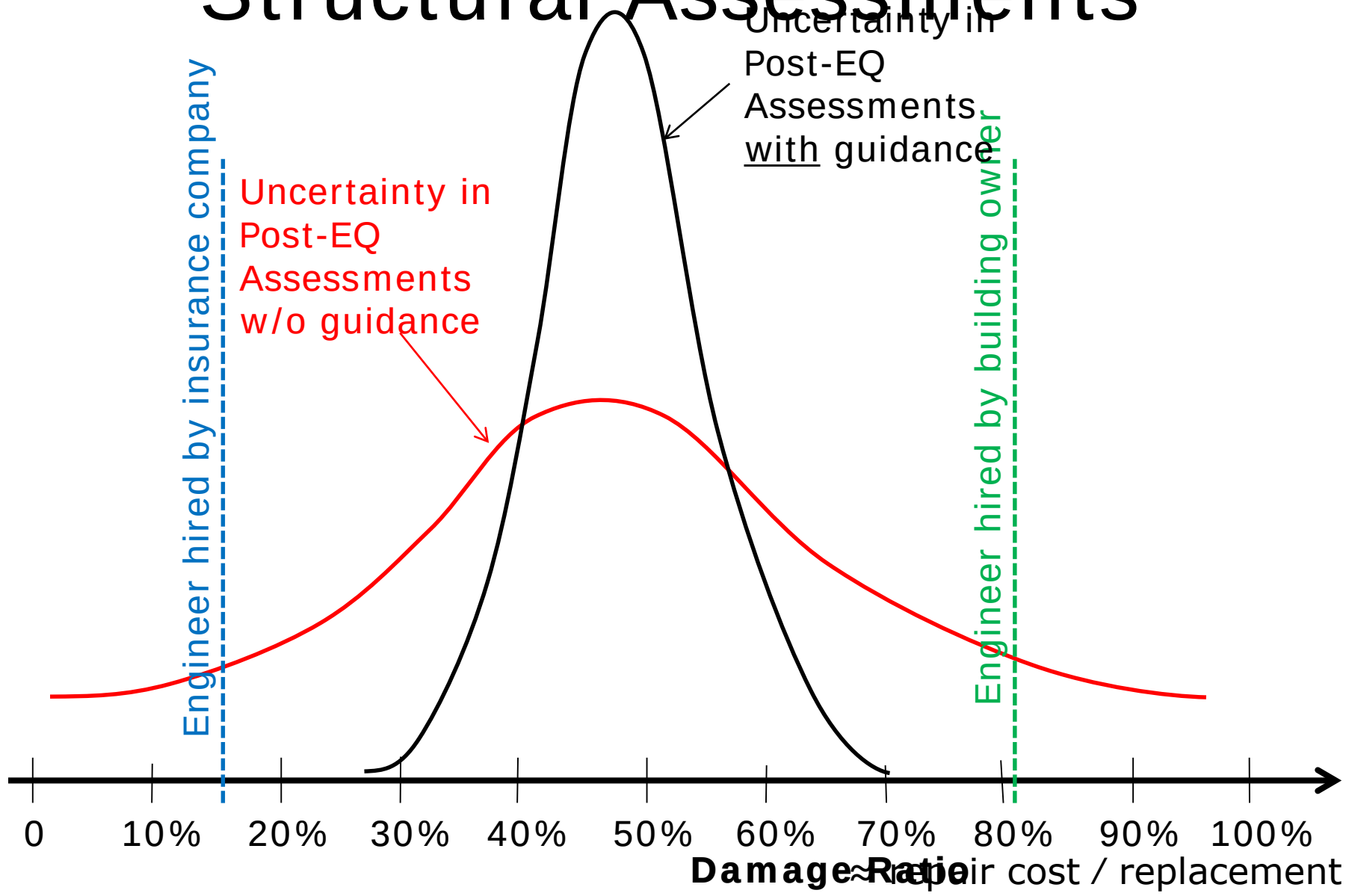
MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

NATURAL HAZARDS RESEARCH PLATFORM

QuakeCoRE
NZ Centre for Earthquake Resilience

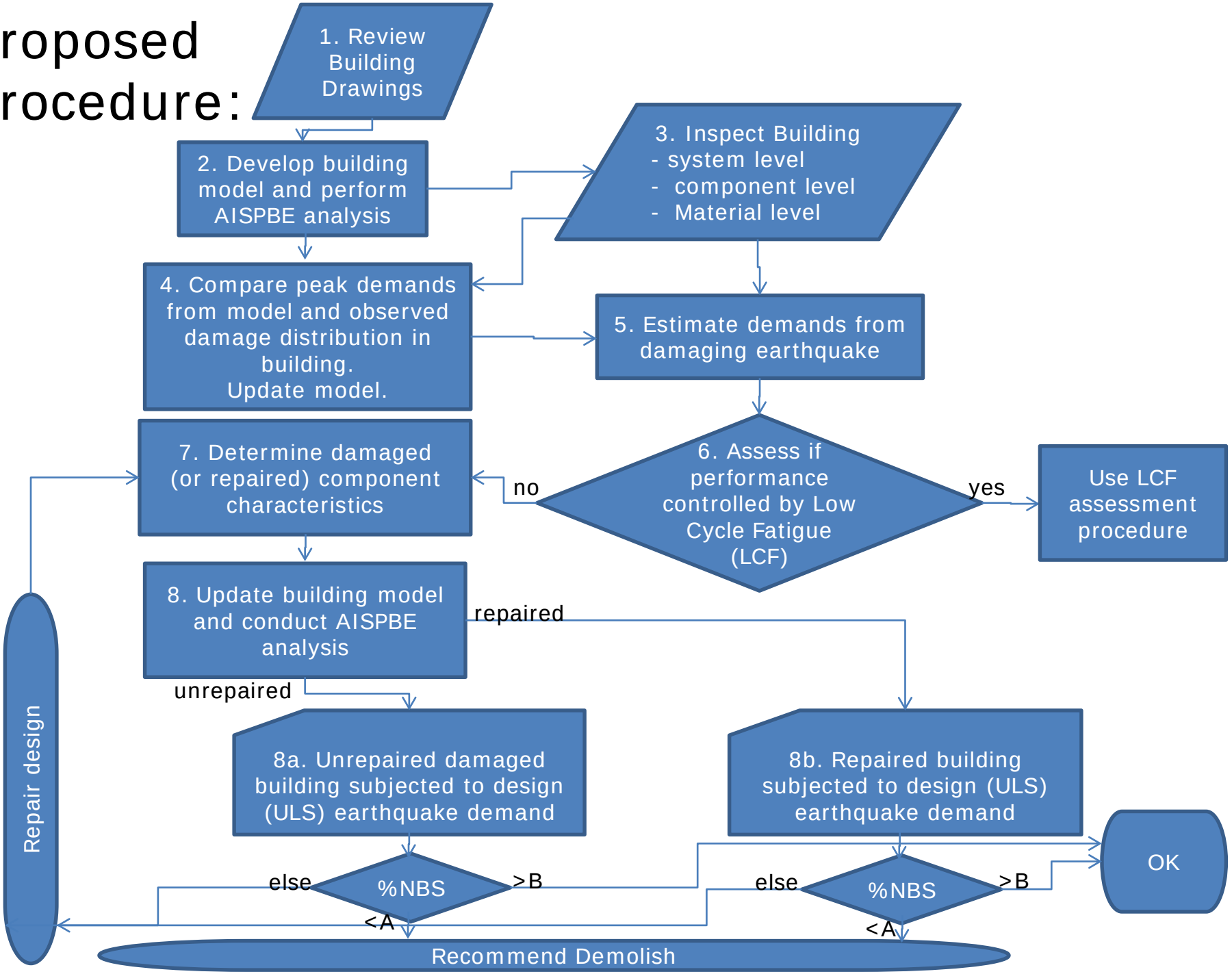
Thank you!

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