Residual Capacity Working Group

QuakeCoRE
NZ Centre for Earthquake Resilience

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Key aspects regarding residual capacity

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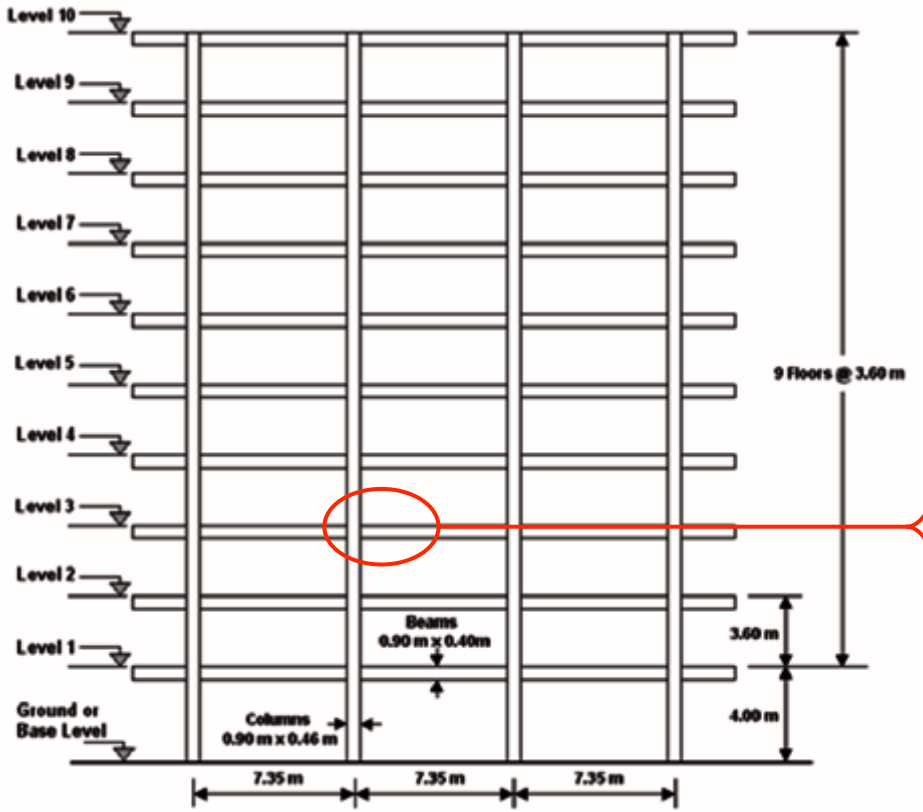
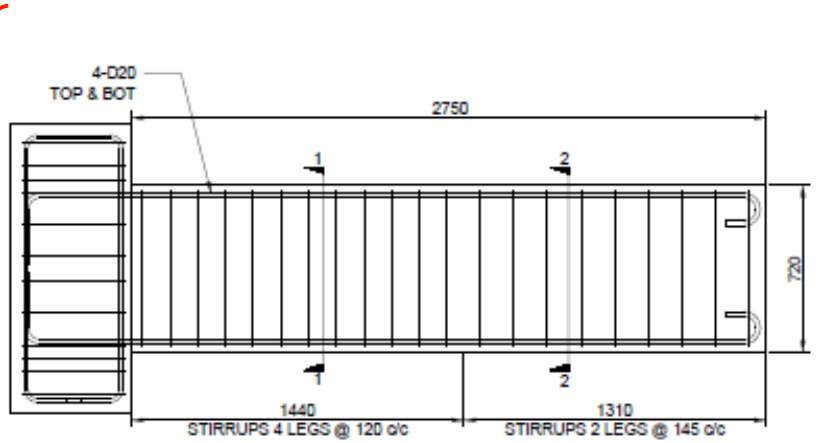
1. Plastic hinge capacity (Ken)
2. Support of precast units due to drift demand and frame elongation (Alistair)
3. Deformation induced damage to hollow core and ribs (Des)
4. Lateral support for columns over multiple floors and intact diaphragms
   - For buildings with lack of tension capacity across diaphragm over 2 stories.
   - Check for ties between columns into topping – not typ present in pre 1995
5. Frame capacity due to beam elongation – concern is shear demand on corner columns
   - Frames before 2006 need to be checked for high shear for columns

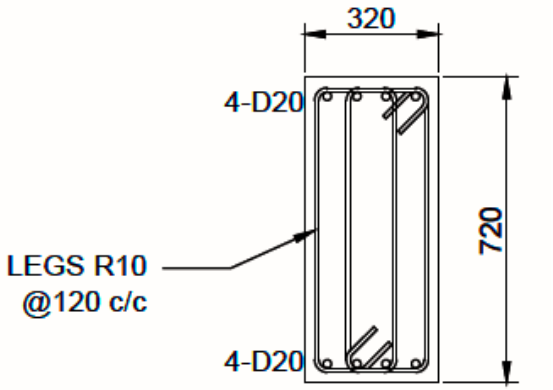
- Focus on high priority urgent guidance.
- Define damage state beyond which residual capacity must be considered.
  - How to assess the actual reduced capacity is next step.

Beam Test



"Red Book" frame building
CCANZ, 2008





SECTION 1-1

Beam Tests

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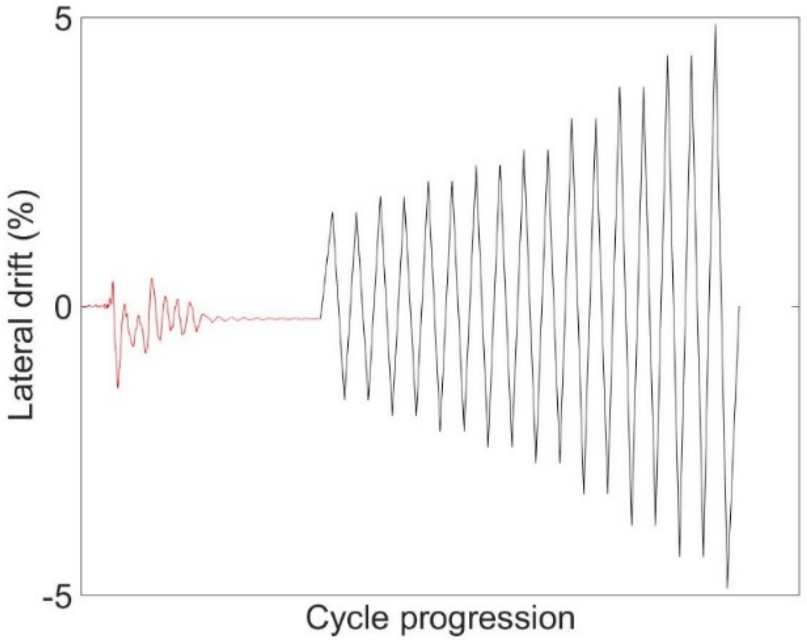
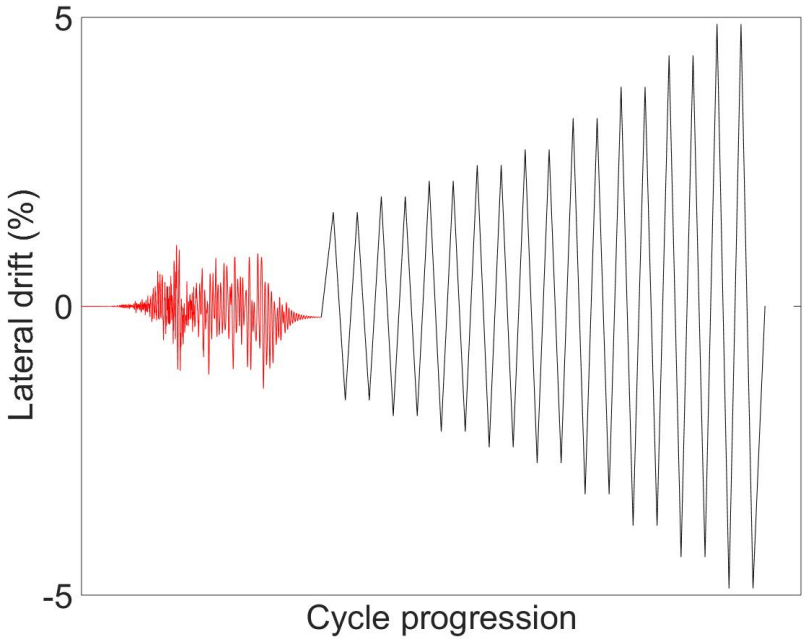
Pulse-type



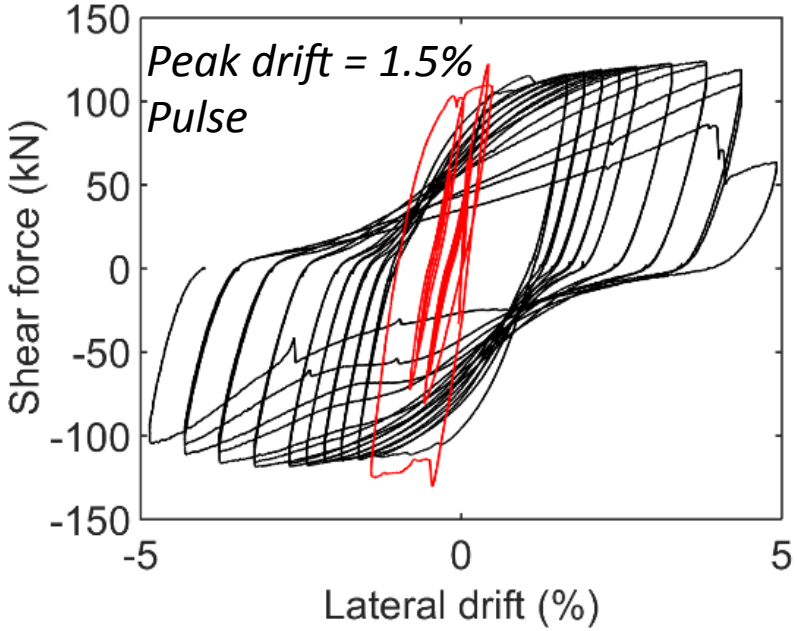
Long duration

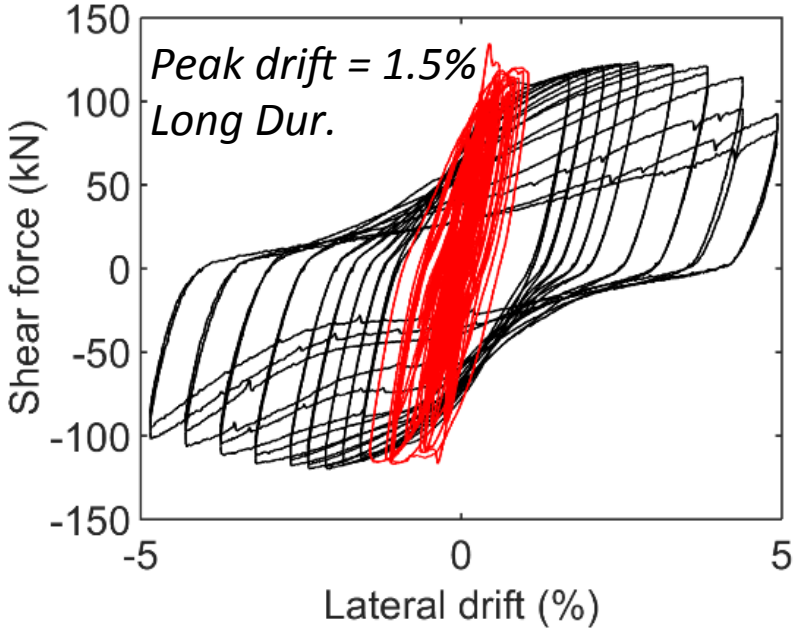


Pulse

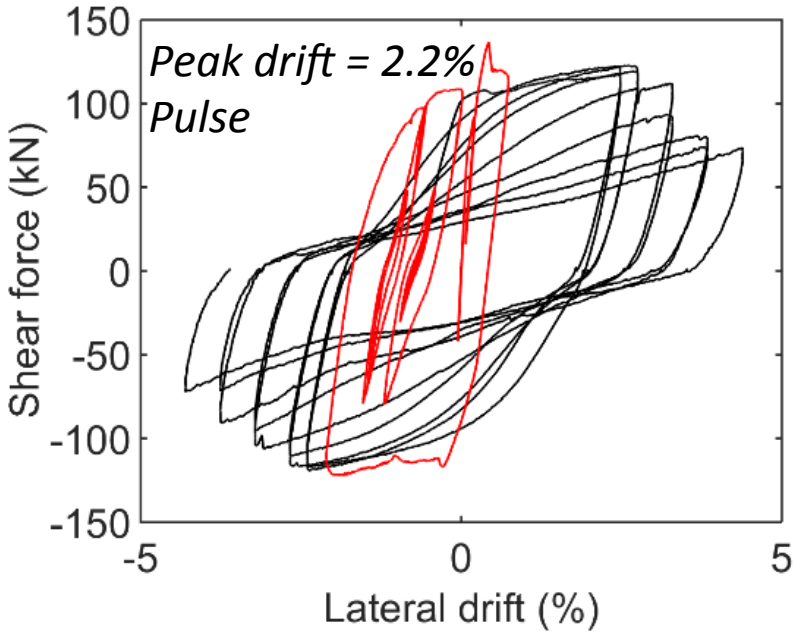
Long Duration

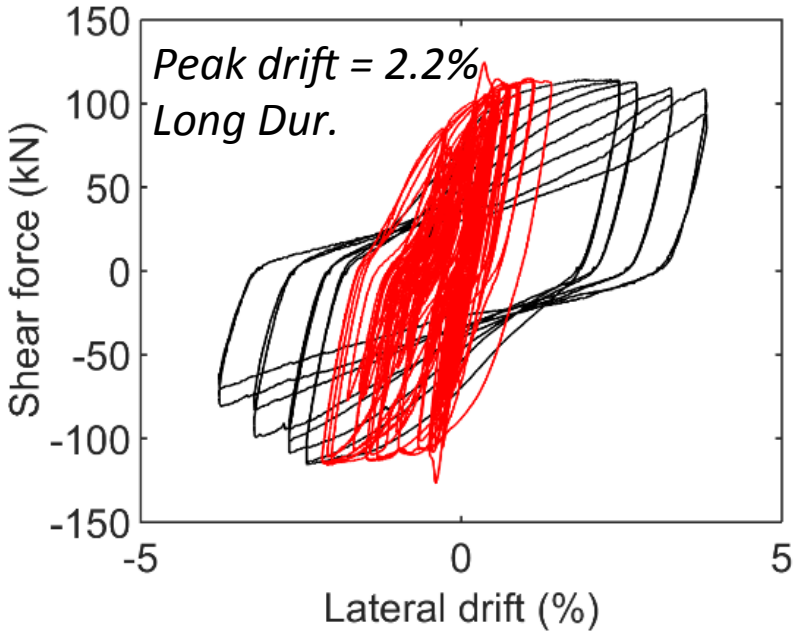
Peak drift = 1.5%





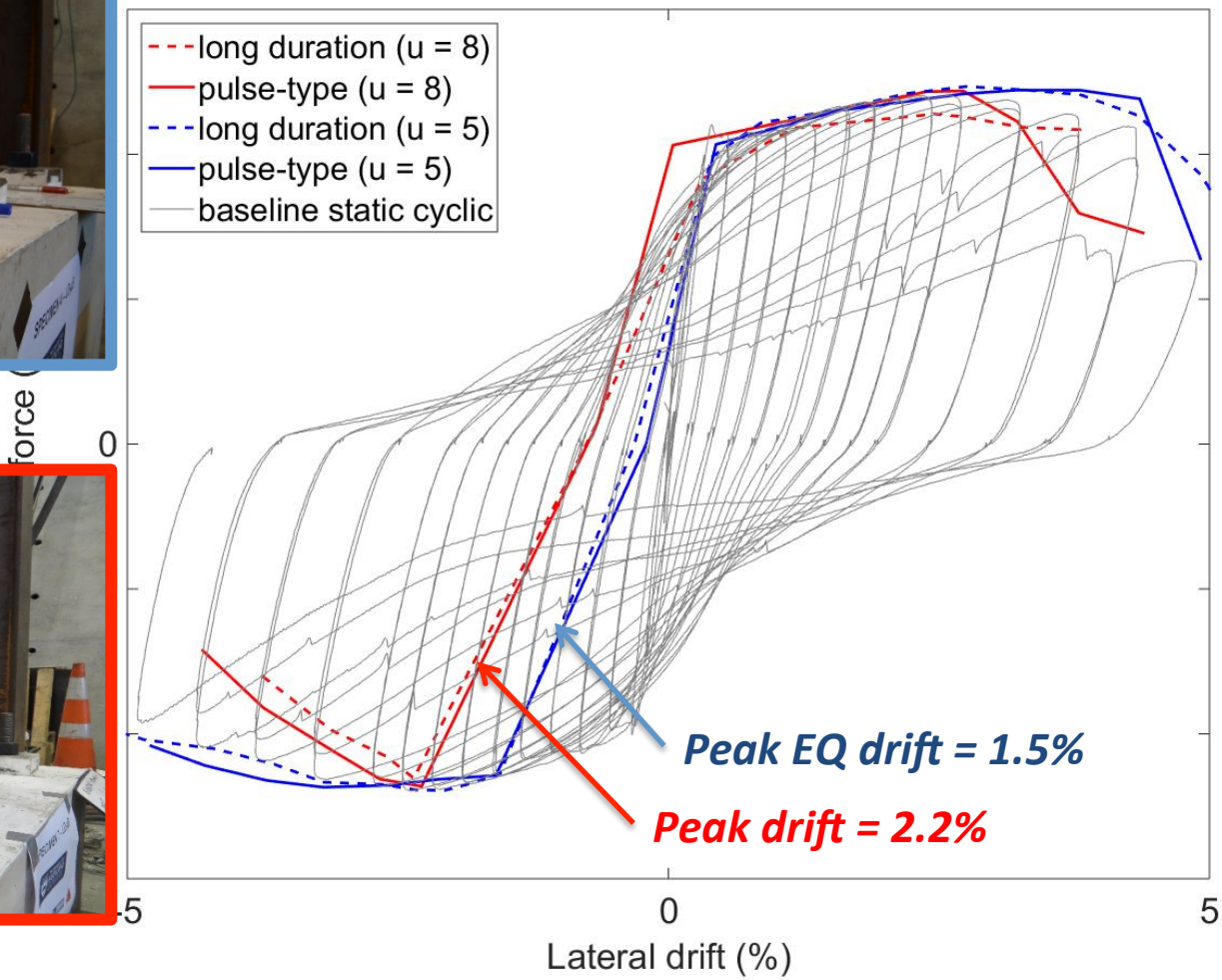
Peak drift = 2.2%





Effect of loading characteristics

Static loading backbone curves



Suggested criteria

If ANY of the following apply, ***plastic hinge***
residual capacity may have been reduced by earthquake:
(all indications of peak drift during EQ.)

1. Total crack width in plastic hinge > 0.005d
2. Sliding has occurred on a crack
3. Wide (>0.5mm) diagonal cracks
4. Concrete degradation, indicated by significant spalling (concrete cover can be removed by hand)

If none apply:
Do not expect degradation in strength, deformation capacity, or energy dissipation; but expect degradation in stiffness leading to larger displacement demands in next event.

Beam elongation

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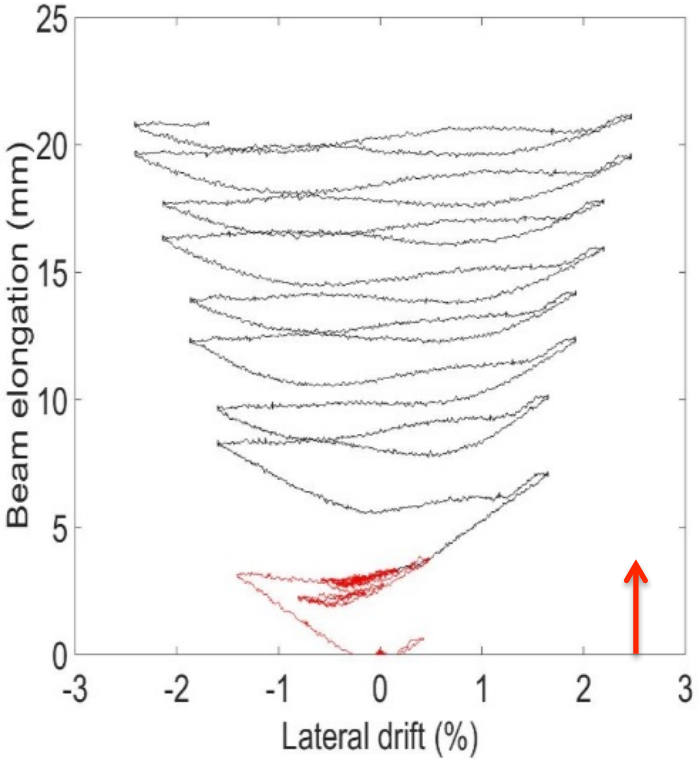
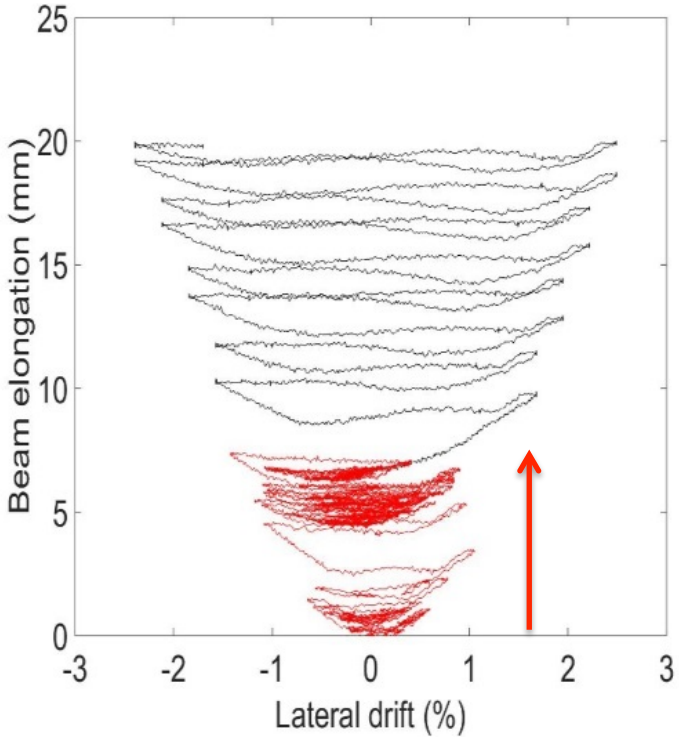
Pulse-type



Long duration



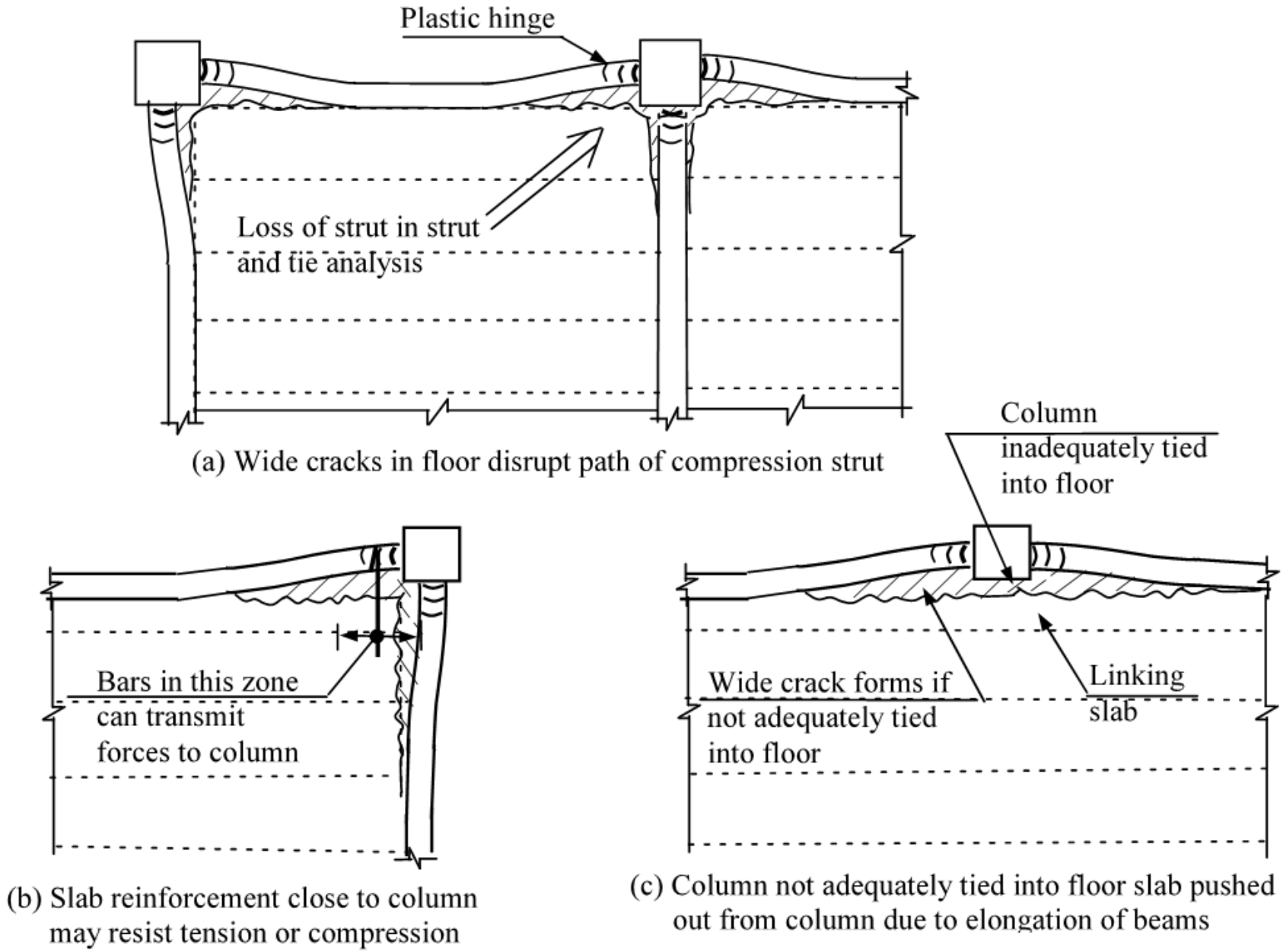


Figure 5-15: Influence of potential cracks on diaphragm action of floor

Signs of seating problems associated with frame elongation or drift:

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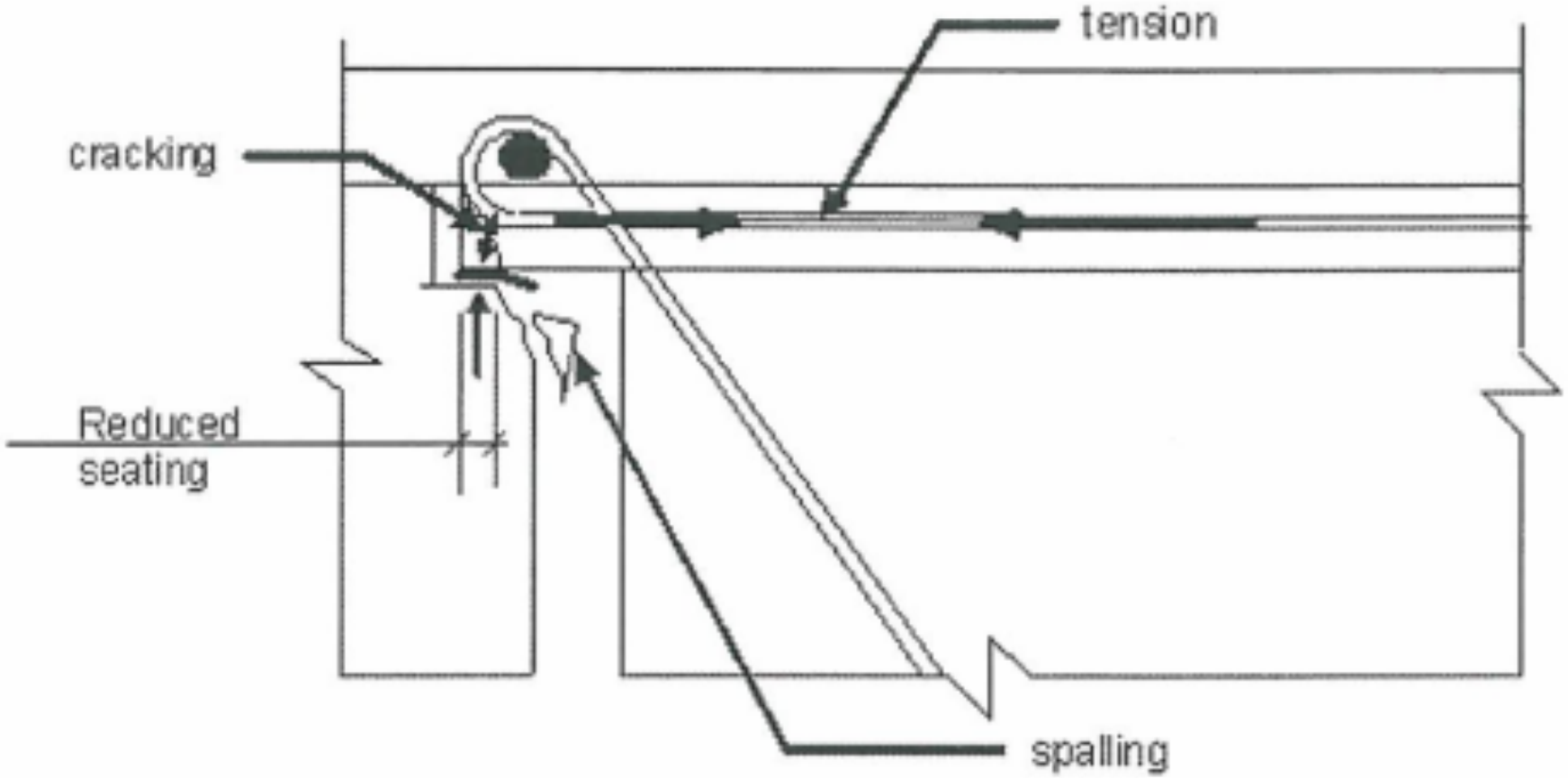
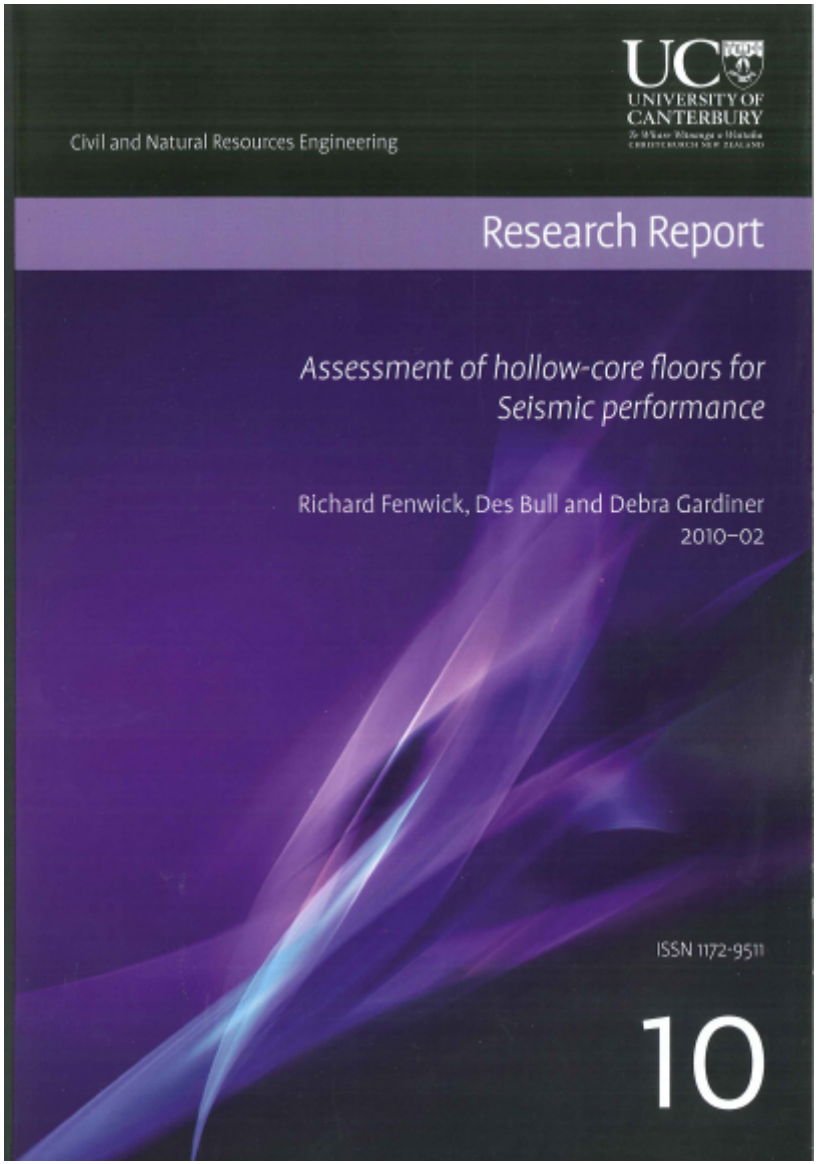
- Look at both bottom and top
- From top:
  - A crack from corner back to next column.
- From bottom:
  - Spalling of the seating (correlated to crack from top)
  - Any remedial seating? Sufficient?

- *Wise to check seating even for undamaged buildings!*



1. Edge spalling will reduce the available bearing
2. If the end of the rib cracks and spalls, the bearing may be lost altogether



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- Google "fenwick bull gardiner 2010-02"

Residual capacity based on seating

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Seating for units' parallel to frame element with elongation **(summary of Fenwick et al section 6.4)**:

- Evaluate the minimum seating required by the floor type, to account for as below:
  - Robustness of the end of the precast unit
  - Robustness of the ledge
  - Any remedial seatings that have been added
- Calculate minimum reduced seating
- Calculated the maximum dilation per hinge
  - 4% beam depth at peak drift demand for unrestrained hinge (corner) , 2% for restrained

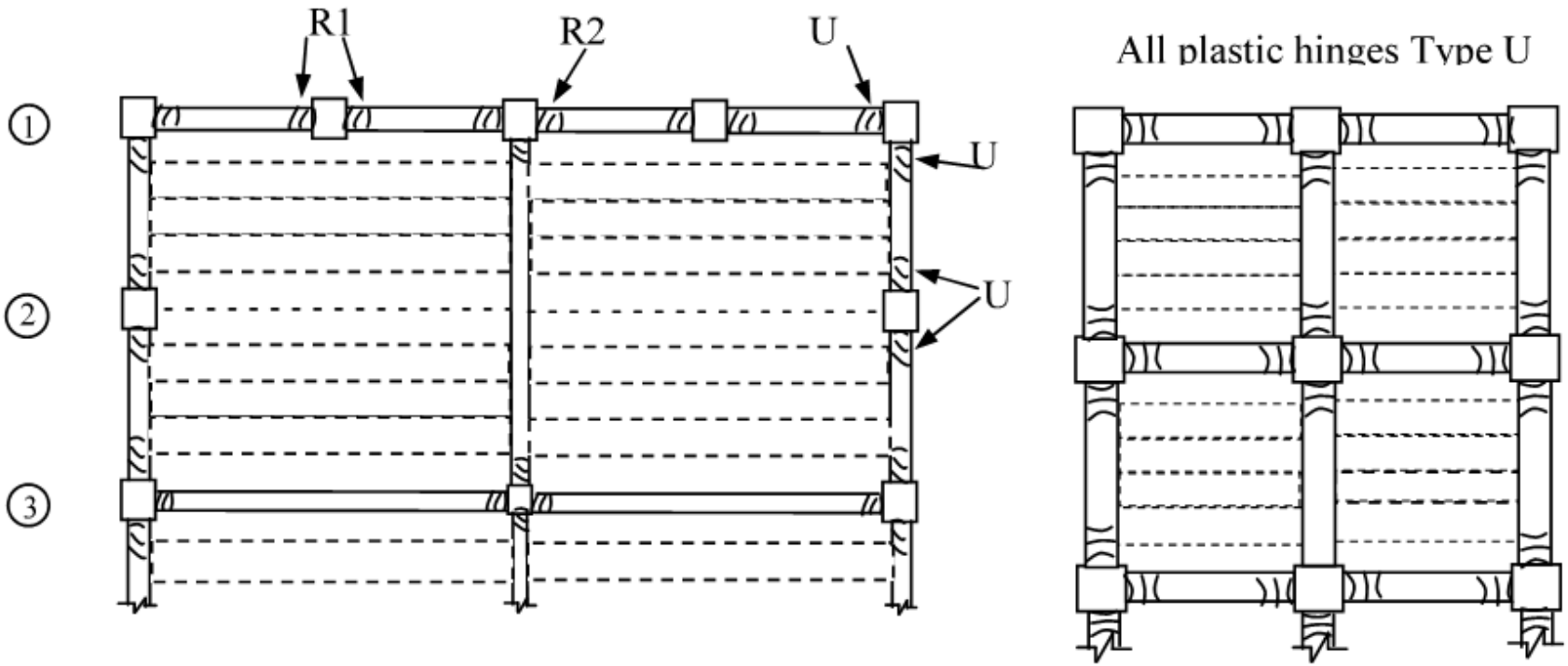

Figure 3-6: Part plan on floors showing plastic hinge elongation types, U, R1 and R2

Residual capacity based on seating (cont.)

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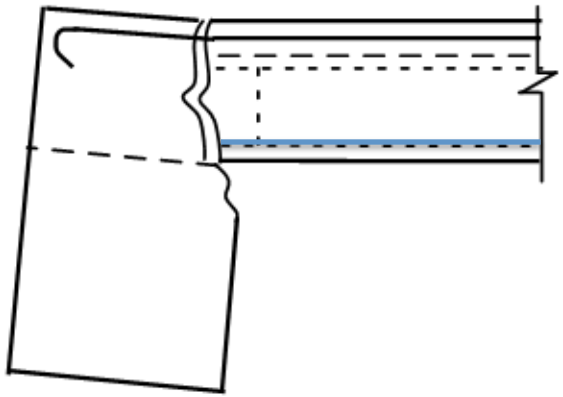
- Add up the maximum dilation tributary to a floor unit.
  - 50% to each end for cases with starter bars
  - 100% to one end if no starter bars
- Reduce available displacement capacity to the building by the ratio of dilation divided by the minimum reduced seating
- Recalculate %NBS based on available displ capacity and the yield drift, ensuring displacements of 2.5% are still not exceeded.
  - Note: dy~0.6% for WGT

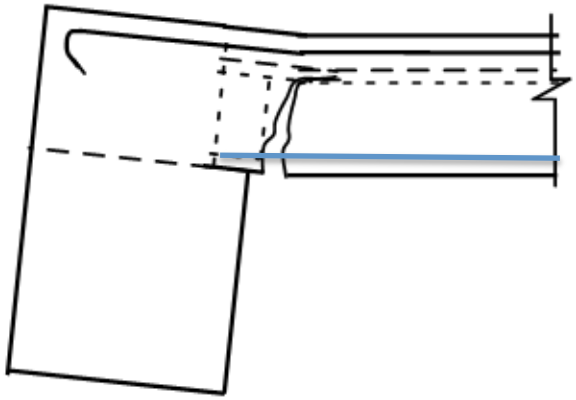
→ *Note issues may arise with drifts below yield*

Deformation induced damage to hollow core

- Refer to UC Report Fenwick et al.
- Look at drawings before leaving office!
  - Identifying vulnerable regions in building
- Identifying critical damage in building:
  - Transverse splitting – any crack is problem!
    - Next slides
    - No capacity left!
  - Longitudinal splitting
- 0.25% drift → splitting webs of hollow cores

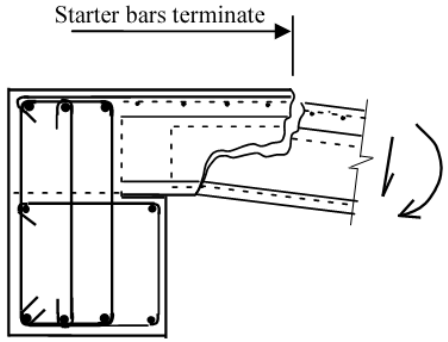


(a) Loss of support with critical section at back face of precast unit



(b) Positive moment flexural failure with critical section near front face of support (see Section A4)

Figure A-4: Loss of support and positive moment flexural failure



(a) Negative moment flexural failure

Lift the carpet 1 m out
Starts in the corner.
Look for drop.

Figure 5-10: Negative moment

Hollow core

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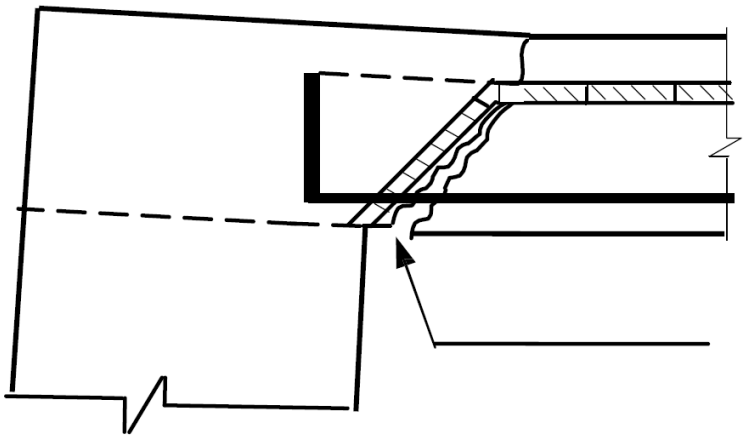
Topping delaminates

Figure 5-9: Positive moment failure of hollow-core unit (Photo from reference 7)

Ribs



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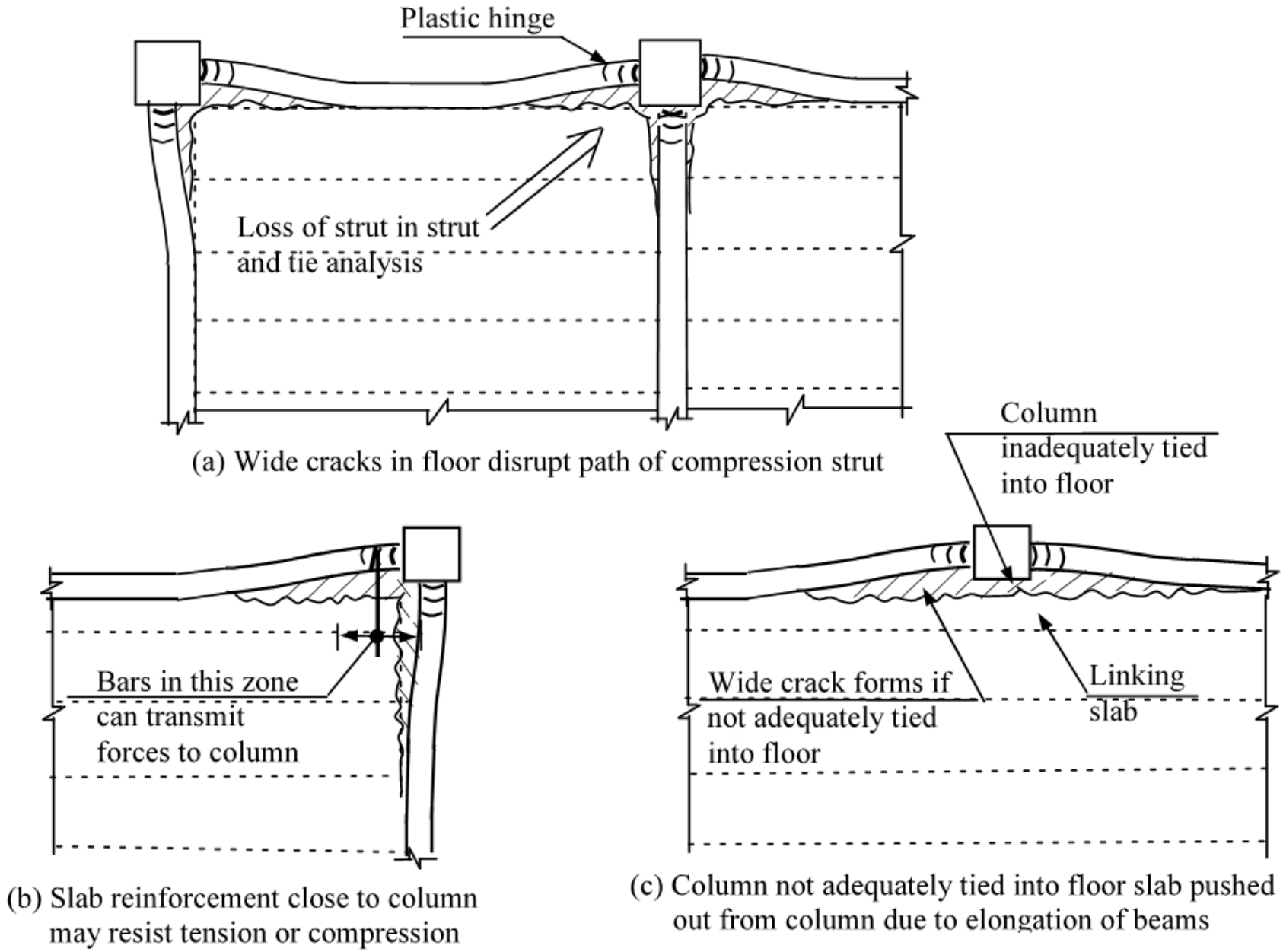

Figure 5-15: Influence of potential cracks on diaphragm action of floor

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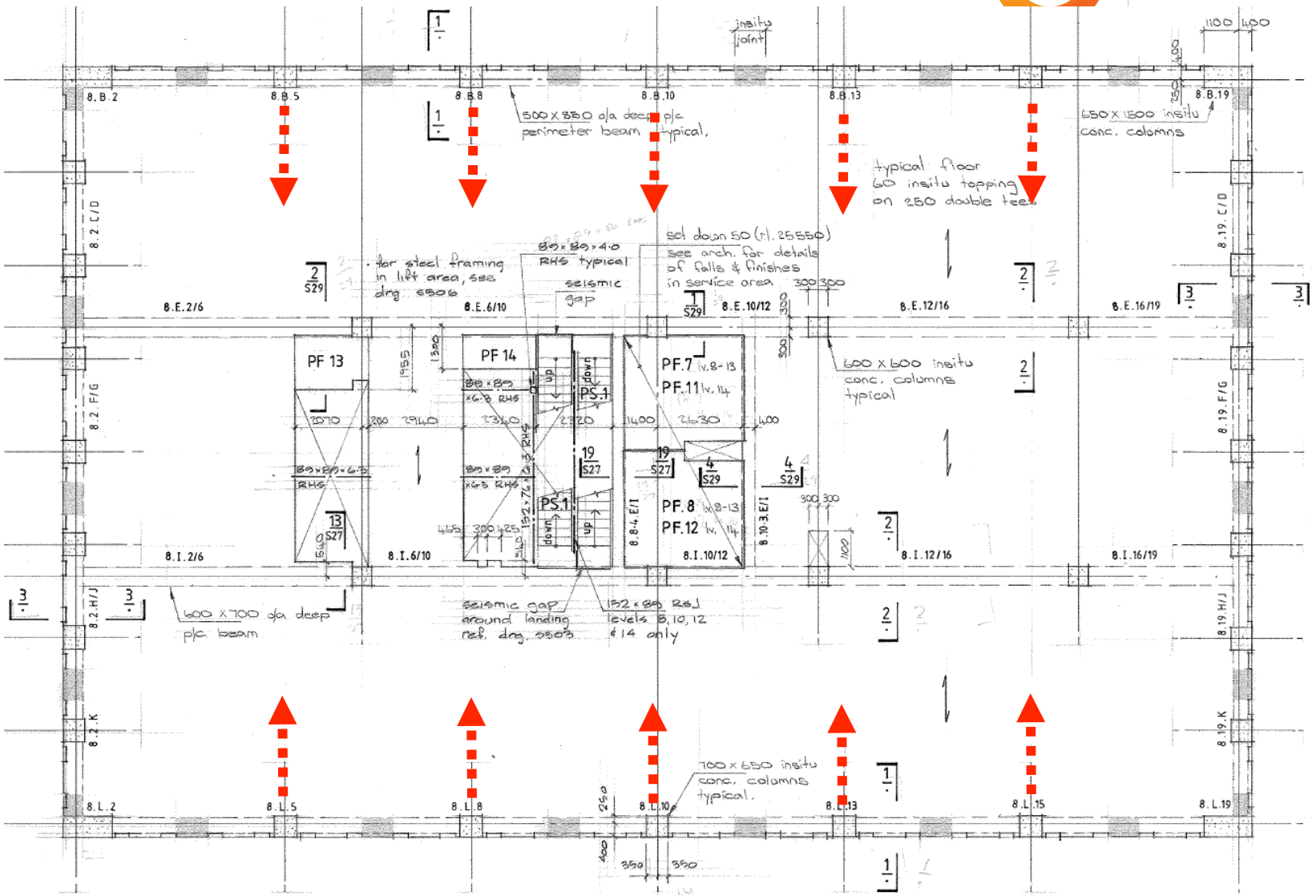
Buckling of columns?

Levels 5 -11

Clarendon, 1987



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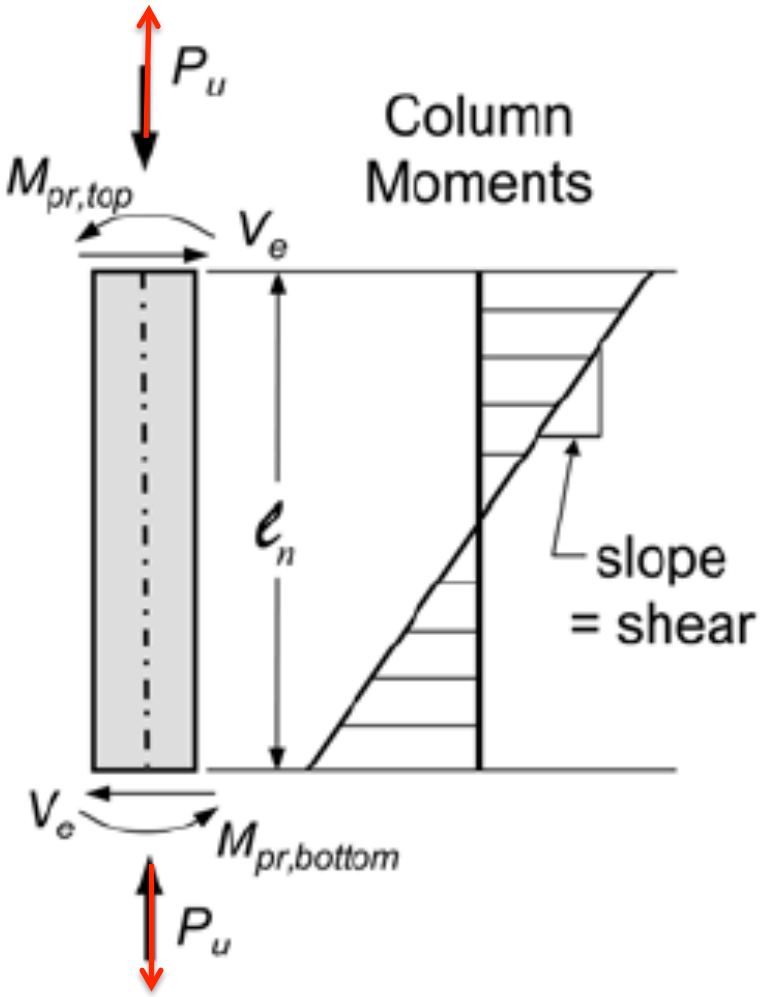
Column shear



(b) Column hinging

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Comments?

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Failure Modes

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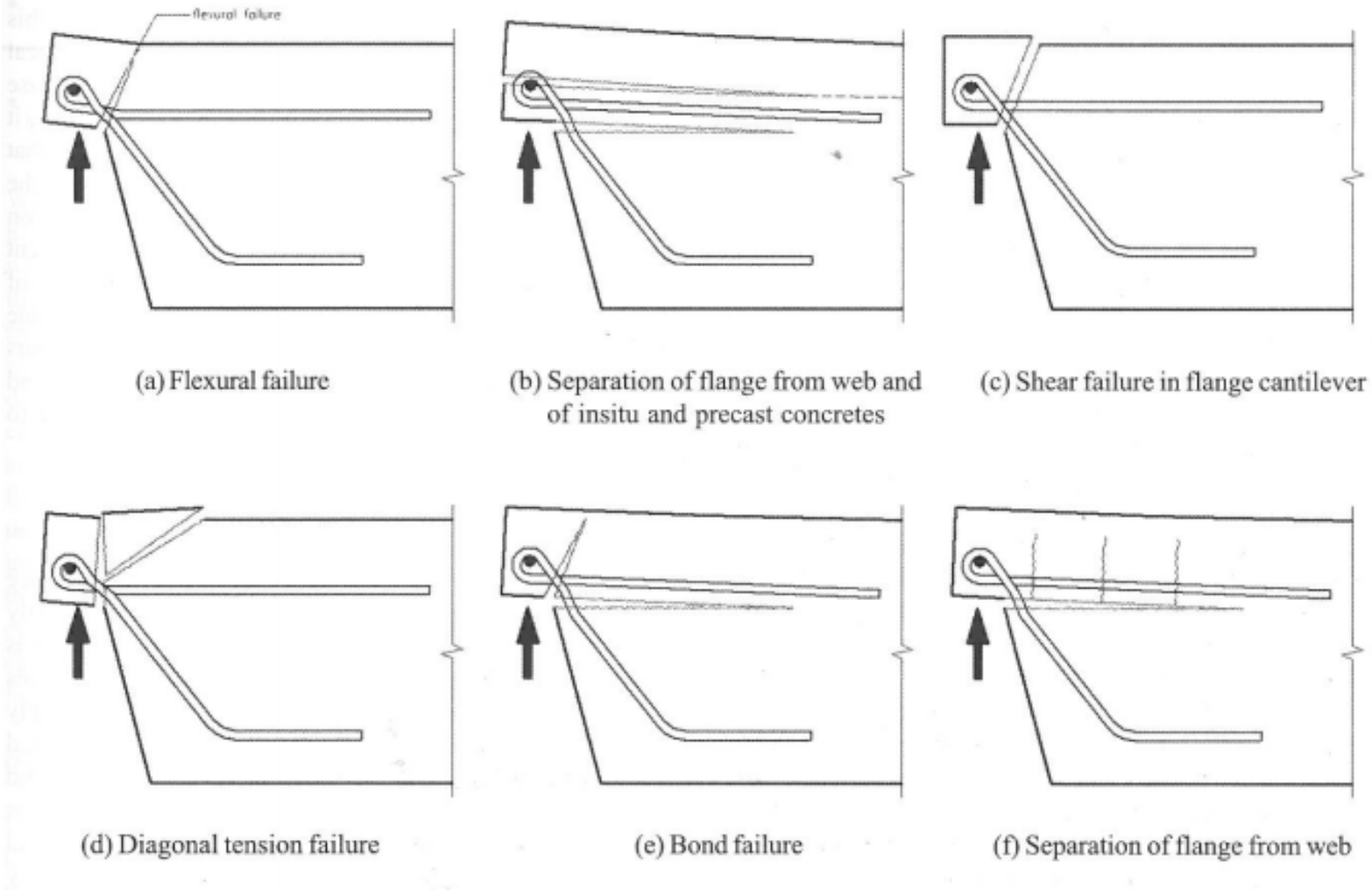

(a) Flexural failure

(b) Separation of flange from web and of insitu and precast concretes

(c) Shear failure in flange cantilever

(d) Diagonal tension failure

(e) Bond failure

(f) Separation of flange from web