Session 3:
Precast Concrete Stairs and Ramps

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Material provided by:
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Stairs & Ramps

- Critical structures for egress
- Same issues for steel and concrete stairs
- DBH / MBIE:
  Practice Advisory 13 - Egress Stairs
Stair Damage in Christchurch

• Many buildings suffered damage to various degrees:
  – Forsyth Barr
  – Grand Chancellor
  – Clarendon
  – Heritage Tower
• Connections between stairs and floors
• Underestimated interstorey drifts (<1992)
Stairs “built in” between floors
Stairs “built in” between floors
Ramps “built in” between floors
Stairs & Ramps built in at ends

- Act as giant struts or props between floors
- Change load paths in building
- Fail landings and mid-height landings
- Vertical acceleration
- Under axial compression
- Avoid in new designs (new clause in NZS 3101)
Stairs & Ramps sliding at one end
Stairs & Ramps sliding at one end

- 3 possible causes of failure:
  - The landing was too small for the interstorey drifts (as designed or tolerances used up)
  - The stairs were compressed and axially shortened (gap not large enough or filled in). On reversing drift, the stairs are pulled off the supports.
  - Vertical acceleration (not likely)
Compressed stairs

• Stair jams & is compressed & permanently shortened

• EQ reverses & pulls stair off the landing
Forsyth Barr
Grand chancellor

Steel corbels
Armoured ledge supports ??
Stairs and Ramps - occasionally

- Stairs and ramps with one end free:

  CLEARANCES – often not big enough

Lower end sliding in side pocket  Upper end sliding in seating member
Stairs and Ramps – more common

• Stairs and ramps with one end free:

Lower end sliding over lower floor
NZS 3101

• New clauses in NZS 3101:2006 A3
  – 2.2.3(d): Stairs must be serviceable in larger than ULS earthquake (MCE)
  – 18.7.6: Capable of sustaining:
    • 1.5x peak interstorey drifts
    • Allowance for potential elongation effects and construction tolerances
    • Friction forces due to sliding
NZS 3101

• New clauses in NZS 3101:2006 A3
  – c18.7.6: Fixed connection at top and sliding connection at base
Design Example
Stairs & Ramps sliding at one end

Support ledge width?
Design interstorey drift:

\[ \text{= 72 mm} \]

\[ \text{(\sim 2\% for 3.6m storey height)} \]

\[ \text{Sp = 0.7} \]

Peak interstorey drift @ MCE:

\[ \text{= 72 / 0.7 \times 1.5} \]

\[ \text{= 154 mm} \]
Elongation

Sliding at one end:
→ 2 hinges per storey

Elongation per hinge (new clause):
\[ e_i = 2 \cdot 0.036 \times (d - d') \leq 0.036 h_b \]
= 0.036 \times 800 \text{ mm} (h_b)
= 29 \text{ mm}

Elongation per storey per stair:
= 2 \times 29
= 58 \text{ mm}
Tolerances

Assume tolerances of 20 mm
Total Support Ledge Width

- Required width = 154 + 58 + 20 = 232 mm

Armoured ledge:
232 mm + bearing width

Unarmoured ledge:
232 mm + bearing width + allowance for spalling
Retrofit of Existing Stairs
Retrofit Concepts

• Replace the whole star and build supports that accommodate sliding
  – For damaged or lost stairs
• Widening existing clearances
• Extend the ledge support
• Put a supporting structure under the stair flight, typically at landings
Retrofit Concepts

• Cut away part of the beam/landing in front of the stair
Retrofit Concepts

- Support width too small
- Build additional support
Switchback stairs

- Mid height landing
- Full width, solid
Switchback stairs

Interstorey drift

Potential plastic hinges

Warping of landing
Switchback stairs

- Split landing with top half sliding on the support
- Lower half supported and braced by the lower floor
Switchback stairs

- Split landing with top half suspended from above
- Lower half supported and braced by the lower floor
Stair Improvements
Failure of stair flight to landing connection

- An issue in concrete stairs
Reinforcement details in Knee:  *Gravity only*
Reinforcement details in Knee:  **Gravity & Lateral Displacement** (Simmons 2000)
(a) split landing

Intermediate support options

Concrete walls, steel frames
(b) alternative landing sliding at top.

Intermediate support options
(c) Alternative split landing

Intermediate support options
Stairs bending in the horizontal plane

• Bending across the stair
  – Significant damage to connections
  – Needs to be considered by designers
Stairs built in to concrete Core

• Some damage during Canterbury EQs

• Still have deformation compatibility issues:
  – To a lesser extent
Summary

• Stairs and ramps span between floors and need to accommodate relative deformation
• Will act like struts/props if fixed at ends
• Sliding connection is required at one end
  – Support width for larger than ULS earthquake
  – Robust support and stair detailing
Questions?