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# Reinforcement Detailing to Improve Life Safety
# Changes in AS 3600-2018



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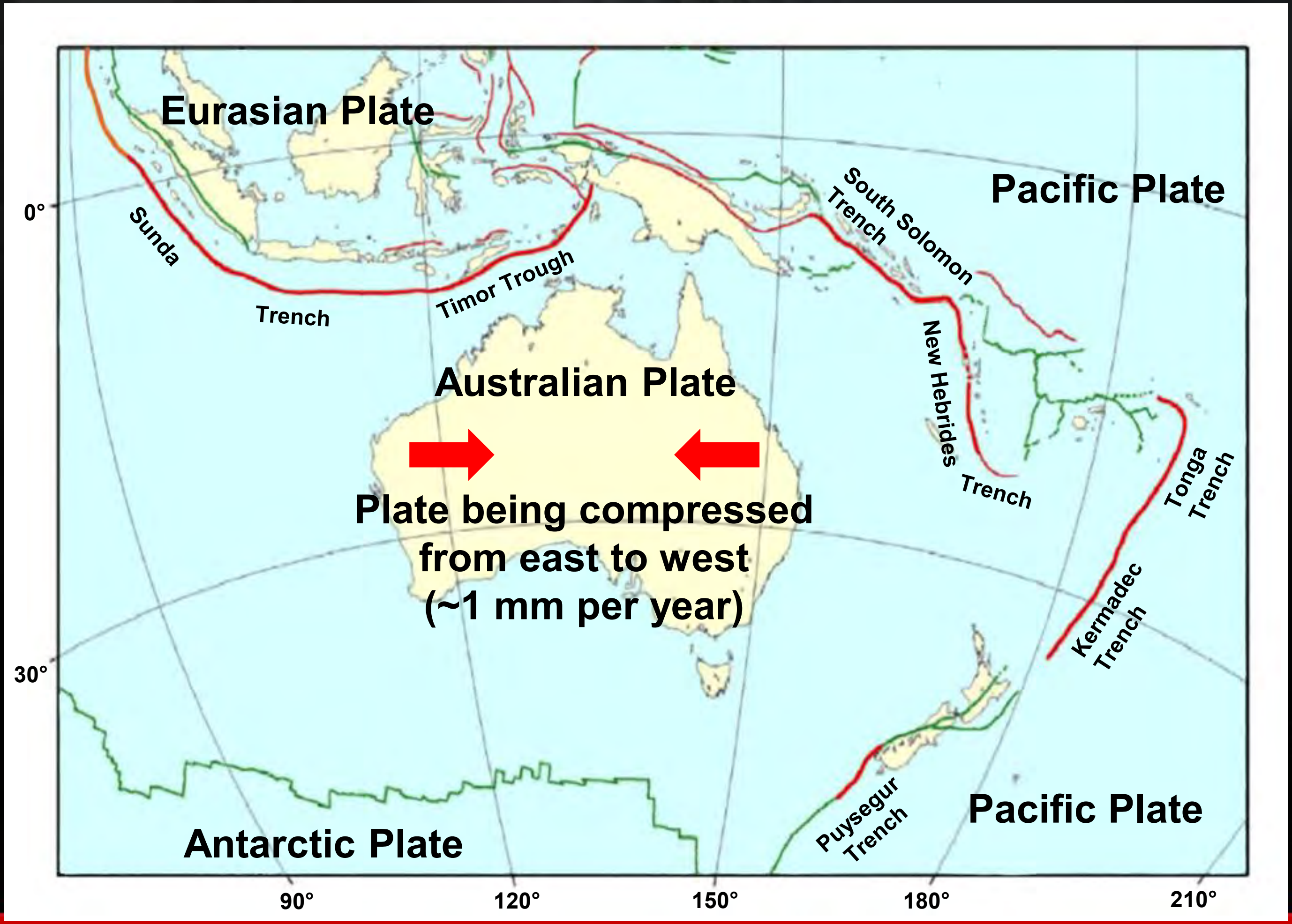
# Earthquakes in Australia

- Plate boundaries are remote from Australia but run through NZ
- Australian Plate being compressed in east-west direction
- Results in Intraplate earthquakes

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# Past Earthquakes

**Top 10 Worst Australian Onshore Earthquakes in Modern Times – Ranked by Cost, Magnitude and Damage**
**(source Australian Geographic July 10, 2012)**

| | | | |
|---|---|---|---|
| 1. | Newcastle NSW | 28 Dec 1989 | (Magnitude 5.6) Public Holiday |
| 2. | Beachport SA | 10 May 1897 | (Magnitude 6.5) |
| 3. | Meckering WA | 14 Oct 1968 | (Magnitude 6.9) Public Holiday |
| 4. | Ellalong NSW | 6 Aug 1994 | (Magnitude 5.4) |
| 5. | Adelaide SA | 1 Mar 1954 | (Magnitude 5.5) |
| 6. | Warooka SA | 19 Sept 1902 | (Magnitude 6.0) |
| 7. | Meeberrie WA | 29 Apr 1941 | (Magnitude 7.2) |
| 8. | Tennant Creek NT | 22 Jan 1988 | (Magnitude 6.3-6.7) |
| 9. | Kalgoorlie-Boulder WA | 20 Apr 2010 | (Magnitude 5.0) |
| 10. | Cadoux WA | 2 June 1979 | (Magnitude 6.1) |

Note: Christchurch earthquake was magnitude 6.2

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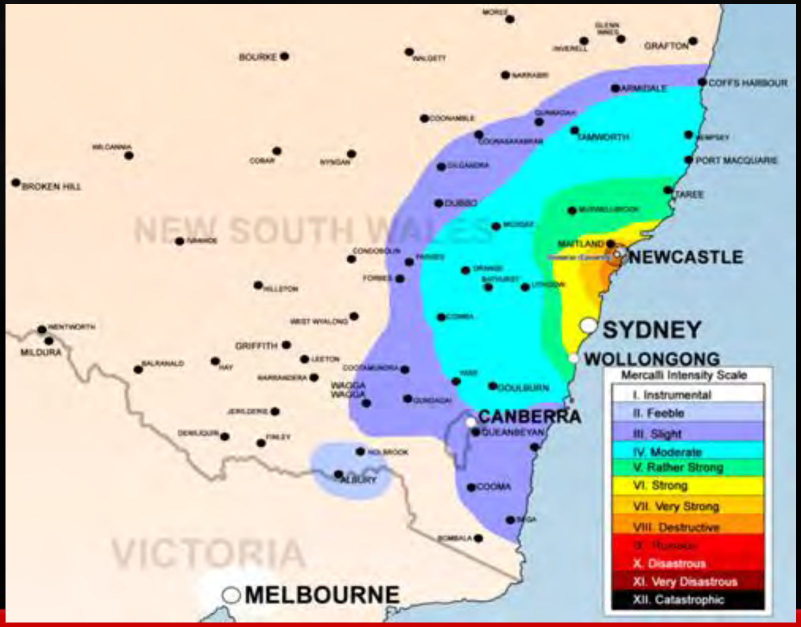
# Past Earthquakes

## 1989 Newcastle NSW

- Magnitude 5.6
- Duration – 35 to 40 seconds
- One of Australia's worst natural disasters
- Killed 13 people, hospitalised 160
- A small intraplate event with soft soils intensifying shaking
- Boxing Day Public Holiday so few people in CBD
- Several events had occurred previously
- Estimated $4 billion of damage to 35,000 homes, 147 schools & 3000 buildings
- Damage over 9,000 square kms with movement up to 800km away

The Newcastle Worker Club - Subsequently demolished & rebuilt. (Photo Courtesy Newcastle Library)



# Past Earthquakes

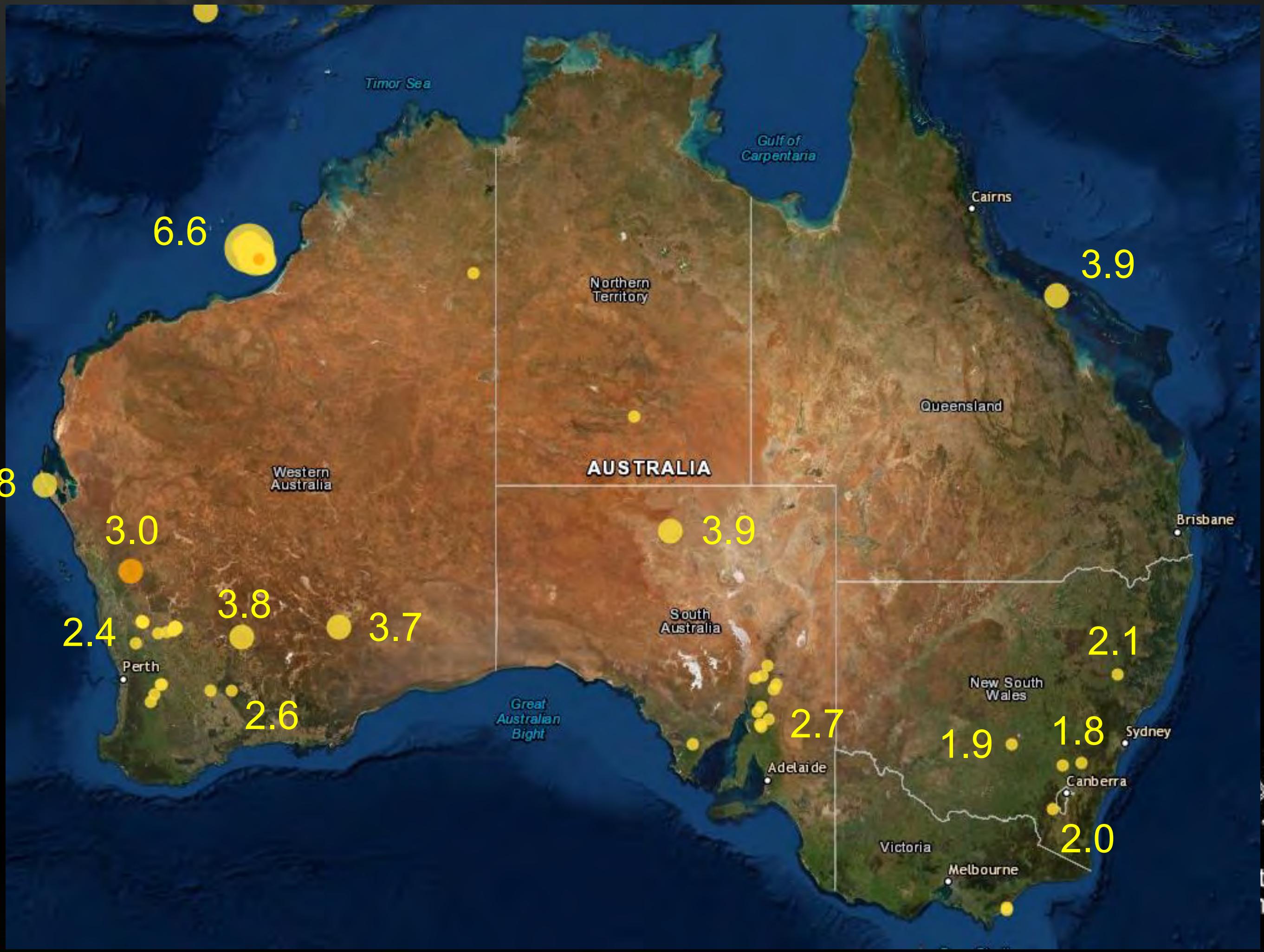
**1968 Meckering, WA (130 kms east of Perth)**

- Magnitude 6.9
- Duration - 40 seconds at 10.59 am
- Length of fault line scarp 37km, height of step 1.5 m
- 20 people injured 50 buildings damaged
- Epicentre 9km SW of town and felt over 700km radius (2nd strongest onshore in Australia)
- Most structures damaged or completely destroyed
- More deaths would have resulted if it hit in the night & again not on a public holiday!
- Cost $1.5 M equal to $57 M today
- The Great Eastern Highway, Transcontinental Railway, Eastern Goldfields water supply pipeline and the telephone lines were disrupted at the fault

# Most Recent Earthquakes

**Last 30 days (23/7/2019)**

- Magnitude: 1.5 to 6.6

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# Earthquake Frequency

**Geosciences Australia**

On average Australia will experience:

- 1 shallow earthquake of magnitude 6.0 or more once every 10 years (equivalent to the 2011 Christchurch earthquake – magnitude 6.2)
- 2 magnitude 5 earthquakes every year

# Is Earthquake Design required?

1. NCC requires design for both wind and earthquake
2. Class 10 Buildings – non-habitable (Importance Level 1) - NO
   Private garage, carport, shed, fence, retaining or free-standing wall, swimming pool, private bushfire shelter
3. Class 1 Buildings – domestic structures – NO if
   - Less than 8.5 in height, and
   - Hazard factor $k_p Z \leq 0.11$, and
   - Material type covered by Standards

For domestic structures outside these limits:

Design as Importance Level 2 (IL2) structures in accordance with Section 2 of AS 1170.4, or use Paragraph A2 in AS 1170.4

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# Minimum Reinforcement in AS 3600

## Section 8.3 General Details for Beams

### 8.3.1 Detailing of flexural reinforcement and tendons

8.3.1.1 Distribution of reinforcement and integrity reinforcement

8.3.1.2 Continuation of negative moment reinforcement

8.3.1.3 Anchorage of positive moment reinforcement

8.3.1.4 Shear strength requirements near terminated flex. reinforcement

8.3.1.5 Deemed to comply arrangement for flexural reinforcement

8.3.1.6 Restraint of compressive reinforcement

8.3.1.7 Bundled bars

8.3.1.8 Detailing of tendons

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# Minimum Reinforcement in AS 3600

## Section 8.3 General Details for Beams

### 8.3.2 Detailing of shear and torsional reinforcement

8.3.2.1 General

8.3.2.2 Spacing

8.3.2.3 Extent

8.3.2.4 Anchorage of shear reinforcement

8.3.2.5 End anchorage of mesh

### 8.3.3 Detailing of torsional reinforcement

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# Minimum Reinforcement in AS 3600

**Section 9.1.3 Detailing of tensile reinforcement in slabs**

**Section 9.2 Structural Integrity Reinforcement**

9.2.2 Minimum structural integrity reinforcement

9.2.3 Minimum reinforcement for distributed loads

9.2.3 Spacing of reinforcement and tendons

**Section 9.3.6 Detailing of shear reinforcement**

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# Minimum Reinforcement in AS 3600

## Section 10.7 Reinforcement requirements for columns

10.7.1 Limitations on longitudinal steel

10.7.3 Confinement to the core

10.7.4 Restraint of longitudinal reinforcement

10.7.5 Splicing of longitudinal reinforcement

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# Minimum Reinforcement in AS 3600

## Section 11.7 Reinforcement requirements for walls

11.7.1 Minimum reinforcement

11.7.2 Horizontal reinforcement

11.7.3 Spacing of reinforcement reinforcement

11.7.4 Restraint of vertical reinforcement

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# Why Minimum Reinf. Requirements?

**Requirements ensure DUCTILITY of Structural Elements**

**DUCTILITY allows structure to behave inelastically**

- Dead Load
- Live Load
- Wind Load

} Designed elastically

- Earthquake Load (1:500 to 1:2500 years)

Designed:

Elastically for nominal static load

Inelastically for remainder of load

Ductility - Clause 14.2.2 of AS 3600:2018

Ability of a structure to sustain its load-carrying capacity and dissipate energy when responding to cyclic displacements in the inelastic range during an earthquake.

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# Displacement of Structure

Christchurch Art Gallery Bookstore during 2011 earthquake


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# AS 1170.4 Earthquake Actions

**Structural Ductility Factor ($\mu$)**

- **determines nominal static earthquake load**

Clause 1.3.23 of AS 1170.4 (Also Clause 14.2.8 of AS 3600:2018)

Numerical assessment of the ability of a structure to sustain cyclic displacements in the inelastic range.

Depends on:

- Structural form
- Ductility of the materials
- Structural damping characteristics

*California State University car park collapse*
*Northridge 1994*

# Structural Ductility Factor $(\mu)$

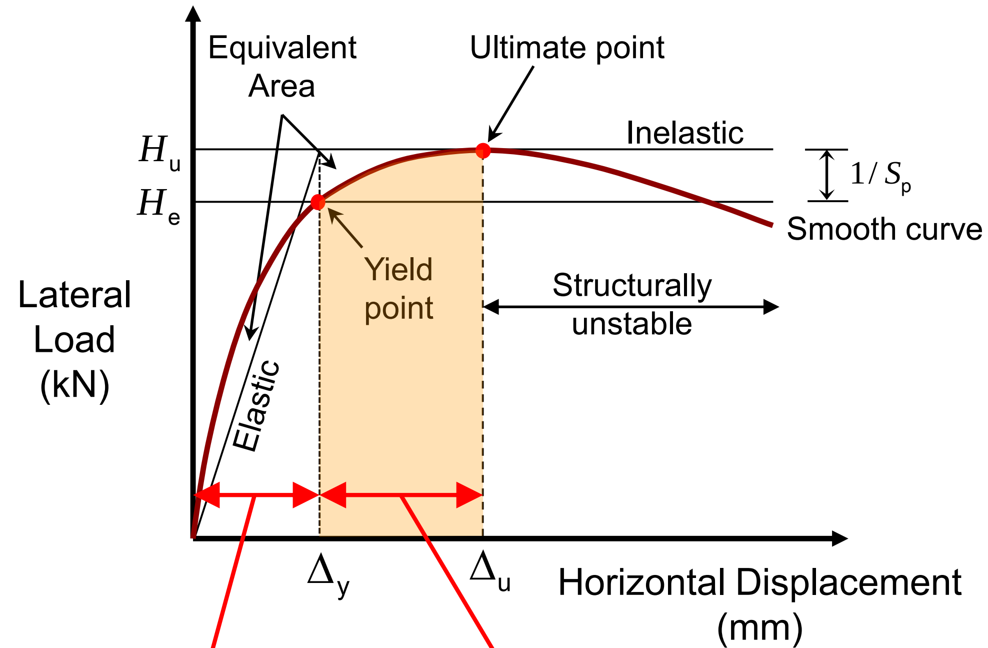
## Table 14.3 of AS 3600 (2018) – 4 ductility levels defined for walls

| Structural system description | $(\mu)$ | $S_p$ | $S_p / \mu$ | $\mu / S_p$ |
|---|---|---|---|---|
| Special moment-resisting frames (fully ductile) designed in accordance with NZS 1170.5 and NZS 3101 and the AS 1170.4 Hazard Map | 4 | 0.67 | 0.17 | 6 |
| Ductile structural walls designed in accordance with NZS 1170.5 and NZS 3101 and the AS 1170.4 Hazard Map | 4 | 0.67 | 0.17 | 6 |
| Ductile partially or fully coupled walls designed in accordance with NZS 1170.5 and NZS 3101 and the AS 1170.4 Hazard Map | 4 | 0.67 | 0.17 | 6 |
| Intermediate moment-resisting frames (moderately ductile) designed in accordance with Section 2.2 of this Standard and Clauses 14.4 and 14.5 of this section | 3 | 0.67 | 0.22 | 4.5 |
| Combined systems of intermediate moment-resisting frames and moderately ductile structural walls designed in accordance with Section 2.2 of this Standard and Clauses 14.4, 14.5 and 14.7 of this section | 3 | 0.67 | 0.22 | 4.5 |
| Moderately ductile structural walls designed in accordance with Section 2.2 of this Standard and Clause 14.4 and 14.7 of this section | 3 | 0.67 | 0.22 | 4.5 |
| Ordinary moment-resisting frames designed in accordance with Section 2.2 of this Standard and Clause 14.4 of this section | 2 | 0.77 | 0.38 | 2.6 |
| Ordinary moment-resisting frames in combination with limited ductile shear walls designed in accordance with Section 2.2 of this Standard and Clauses 14.4 and 14.6 of this section | 2 | 0.77 | 0.38 | 2.6 |
| Limited ductile structural walls designed in accordance with Section 2.2 of this Standard and Clauses 14.4 and 14.6 of this section | 2 | 0.77 | 0.38 | 2.6 |
| Non-ductile structural walls designed in accordance with Section 2.2 of this Standard and Clause 14.4 of this section | 1 | 0.77 | 0.77 | 1.3 |

# Importance of Ductility

**Allows displacement of structure with reduced risk of failure**

$$\mu = \frac{\Delta_u}{\Delta_y}$$




**AS 1170.4 Earthquake Actions**

| | | |
|---|---|---|
| Ordinary Moment-resisting frame, $\mu \leq 2$ | 38% of loading designed for elastically | 62% of loading taken inelastically |
| Intermediate Moment-resisting frame, $2 < \mu \leq 3$ | 22% of loading designed for elastically | 78% of loading taken inelastically |
| Special Moment-resisting frame, $\mu > 3$ | 17% of loading designed for elastically | 83% of loading taken inelastically |

# Ductility of Structural Elements

**3 options for ductility available in AS 3600:**

a) Design structure elastically (non ductile)

b) Design and detail in accordance with: Sections other than 14.5 and 14.7

- Structural Ductility Factor, $\mu \leq 2$ (limited ductile)
- Ordinary moment-resisting frame (OMRF)

c) Design and detail in accordance with Section 14.5 to 14.7

- Structural Ductility Factor, $2 < \mu \leq 3$ (moderately ductile)
- Intermediate moment-resisting frame (IMRF)

NOTE: For $\mu > 3$ (ductile) the structure should be designed and detailed in accordance with NZS 1170.5 and NZS 3101.

- Special moment-resisting frame

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# Reinforcement Design & Detailing

## Section 14 in AS 3600 (2018)

All RC structures and elements requiring seismic design to comply with General requirements (Clause 14.1 to 14.4)

- Vertical load bearing elements designed for horizontal drift
- Connections between prefabricated elements to allow for movement
- Structural Integrity reinforcement required
- Columns detailed to Clause 14.5 if $L_u \leq 5D$

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# Reinforcement Design & Detailing

Columns detailed to Clause 14.5 if $L_u \leq 5D$

Greater ductility required to allow drift over shorter length


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# Reinforcement Design & Detailing

## Section 14 in AS 3600 (2018)

Walls designed to Section 10 or 11

- Limited ductile also to Clause 14.6
- Moderately ductile also to Clause 14.7
- Simplified design method only for non-ductile walls

**11.2 DESIGN PROCEDURES (AS 3600 – 2009)**

- **11.2.1 General**

Braced walls where in-plane horizontal forces, acting in conjunction with the axial forces, are such that where a horizontal cross-section of the wall-

(a) Is subject to compression over the entire section, in-plane bending may be neglected and the wall designed for horizontal shear forces in accordance with Clause 11.6 and for the vertical compressive forces either-

(i) in accordance with the simplified method of Clause 11.5; or

(ii) as columns in accordance with Section 10 where vertical reinforcement is provided in each face, except that Clause 11.7.4 may override the requirements of Clause 10.7.4; or

# Detailing of Walls

## AS 3600 (2009) Simplified Method of Design

**Compression over entire section - Basic problem with assumptions**

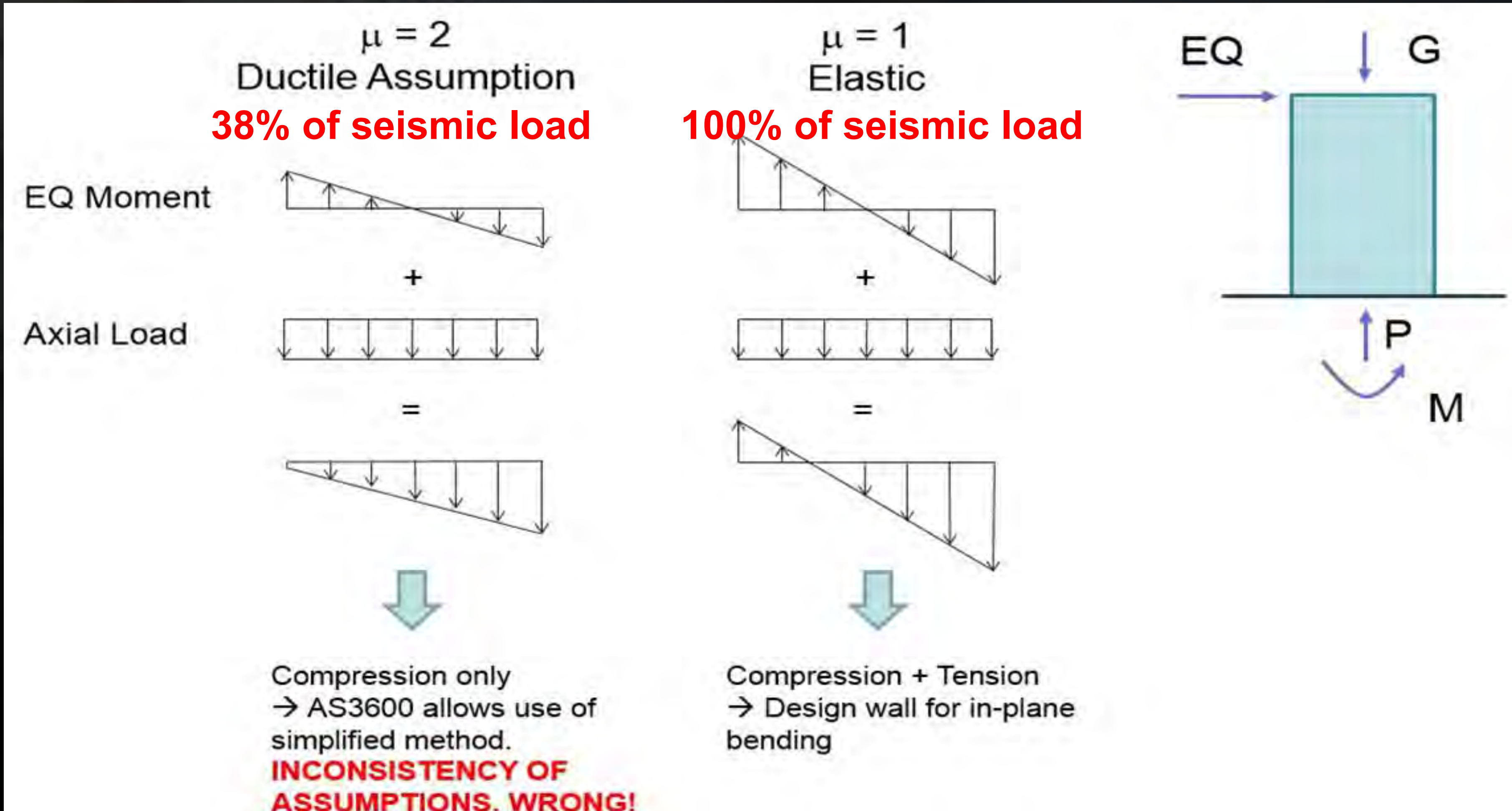
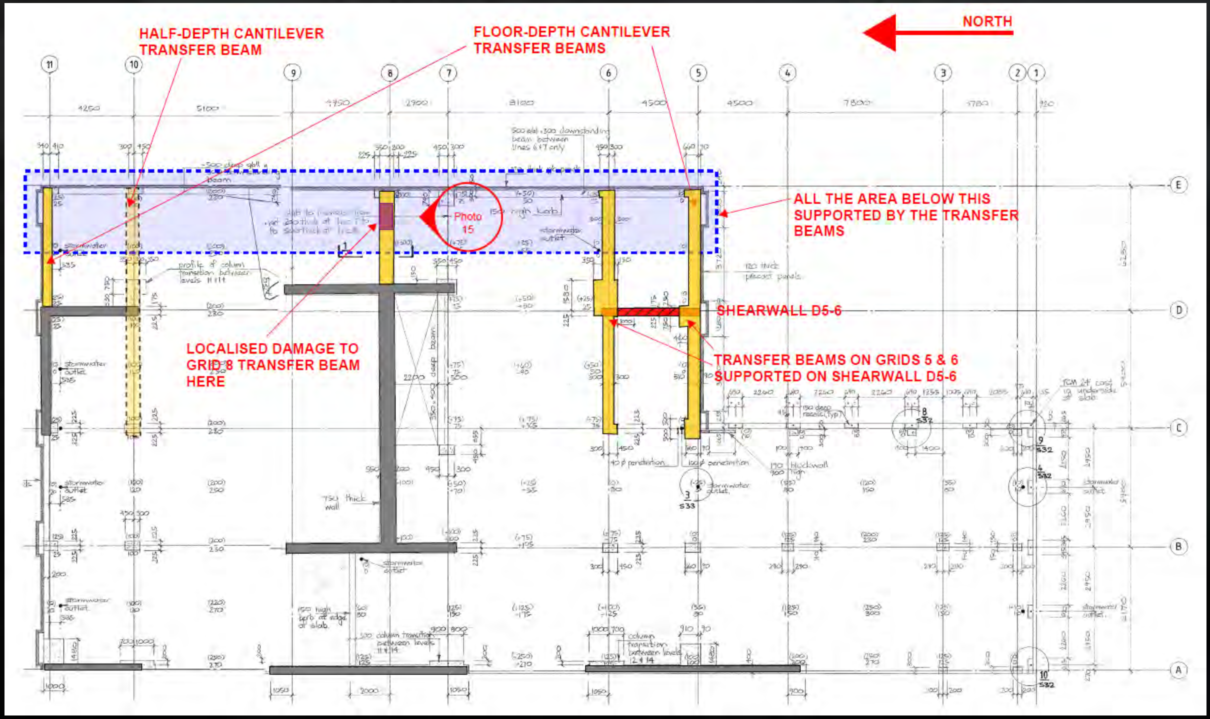



Image: WGA

# Detailing of Walls

**Heavily loaded walls and columns exhibit lower ductility**

Also, mean value of 28 day strength $< 1.4\, f'_c$ (Clause 14.6.4)





Failure of shear wall D5-6
Hotel Grand Chancellor, Christcurch, NZ

(Images courtesy Dunning Thornton Consultants Ltd)

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# Detailing of Walls

## Ensure boundary elements for limited and moderately ductile walls are adequately detailed

Failure of shear wall D5-6
Hotel Grand Chancellor, Christcurch, NZ

(Images courtesy Dunning Thornton Consultants Ltd)

Figure 28 in Guide to Seismic Design

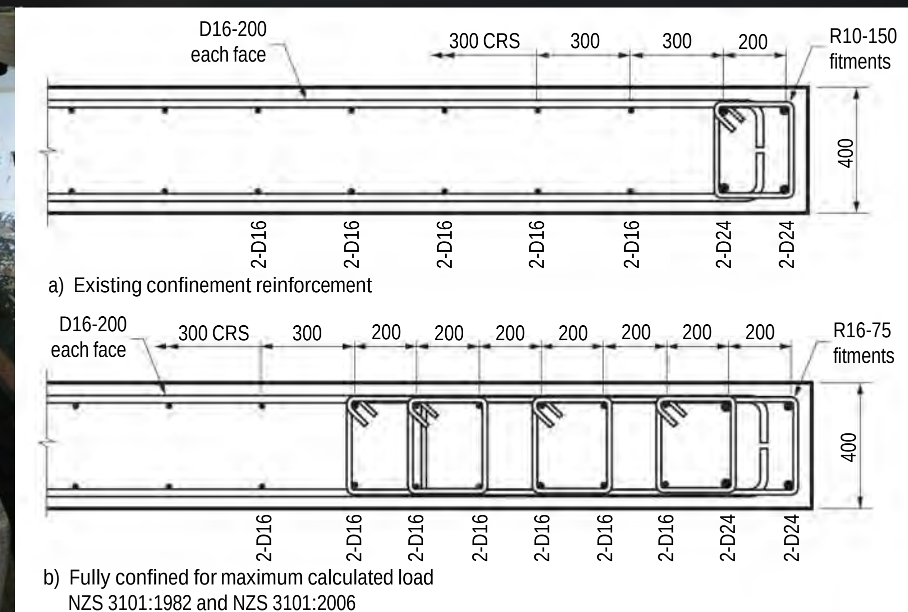


Figure 29 in Guide to Seismic Design

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# Detailing of Walls

**Boundary elements required for limited and moderately ductile walls if:**

- End of wall is discontinuous and around openings (with exceptions)
- Extreme fibre compressive stress $> 0.15 f_c'$
- Clause 14.6.2 for limited ductile structural walls - IMRFs

Reinforcement buckling at the end region

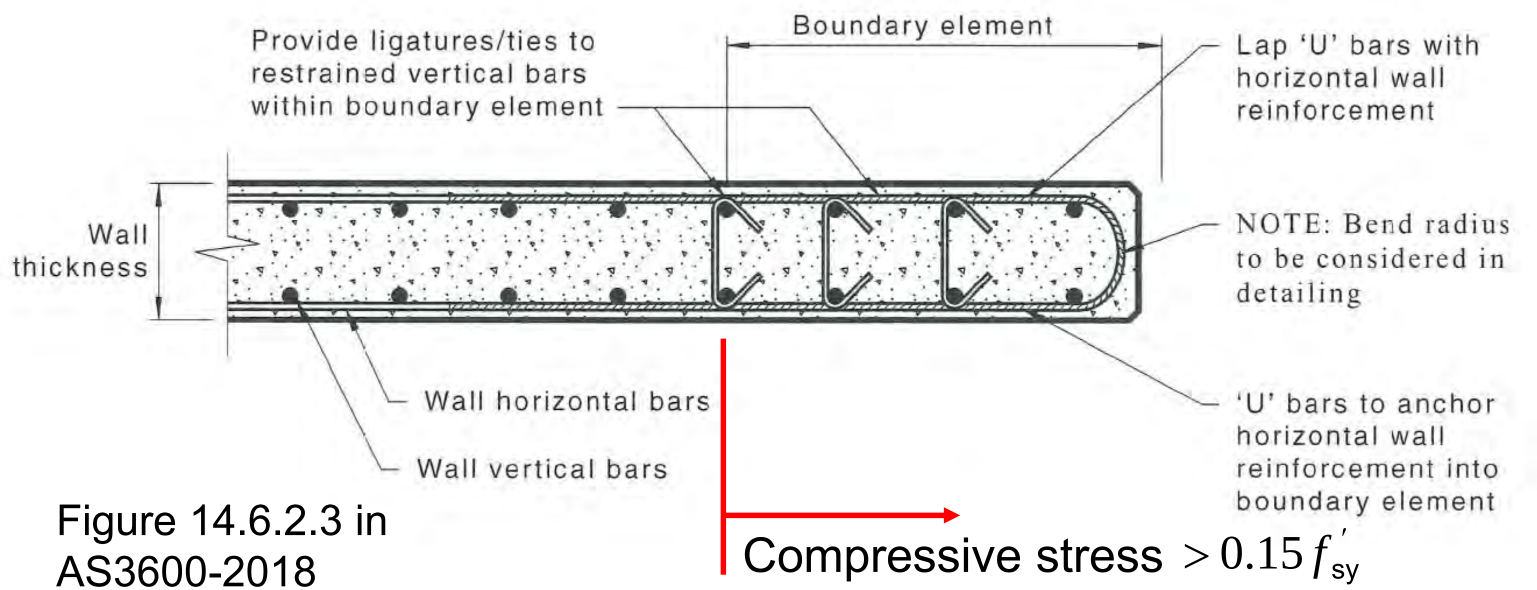


Figure 14.6.2.3 in AS3600-2018

If more than 4 stories - detail reinforcement to Clause 10.7.4

If extreme fibre compressive stress $> 0.2 f_c'$, detail to Clause 14.5.4

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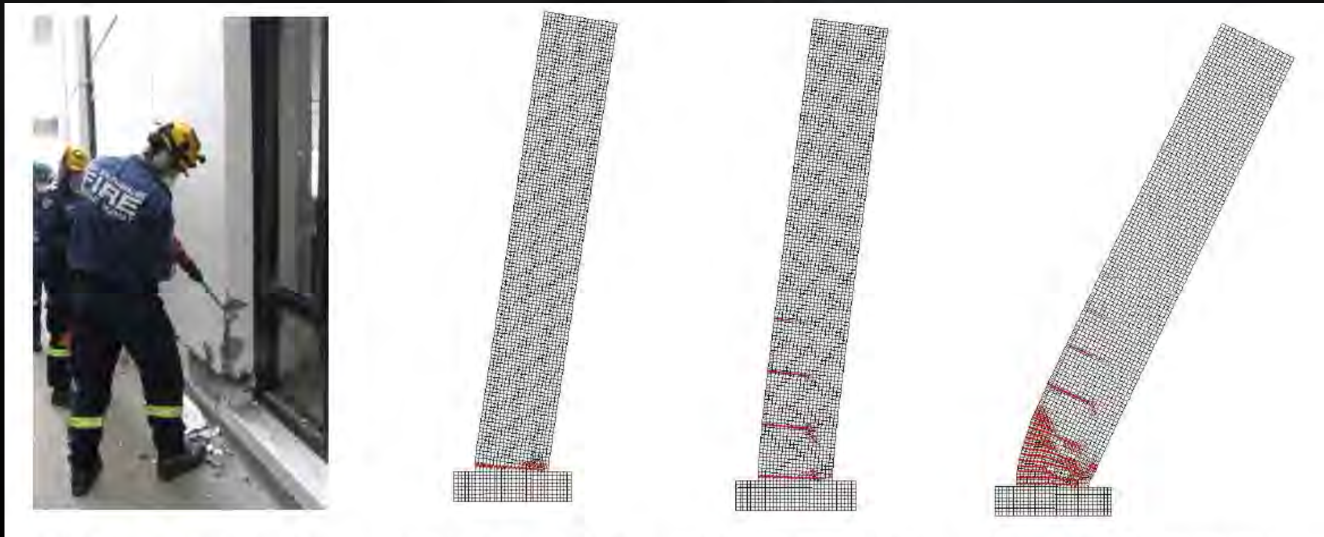
# Detailing of Walls

## Limited and Moderately Ductile Shear Walls - Clause 14.6.7 of AS 3600

Horizontal and vertical reinforcement ratio $\geq 0.0025$

- Lightly reinforced walls tend to develop single crack
- Reinforcement unable to handle strain and fractures



(a) Crack in grid-F wall (b) As-built grid-F (c) NZS 3101 (A2) (d) Additional reo at ends

Actual damage and crack patterns from wall models

*(Henry et al., University of Auckland, 2015)*

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# Detailing of Walls

**Fractured bars in wall**

Gallery Apartments,
Christchurch NZ

*"The building's overall damage state may be described as being at near collapse. A potentially catastrophic failure might have been observed for a slightly longer duration of severe ground shaking." (Morris et al., 2015)*


*(Sritharan et al., 2014)*

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# Detailing of Slabs

## One way slabs

OMRF – Clause 9.1.3.2 of AS 3600

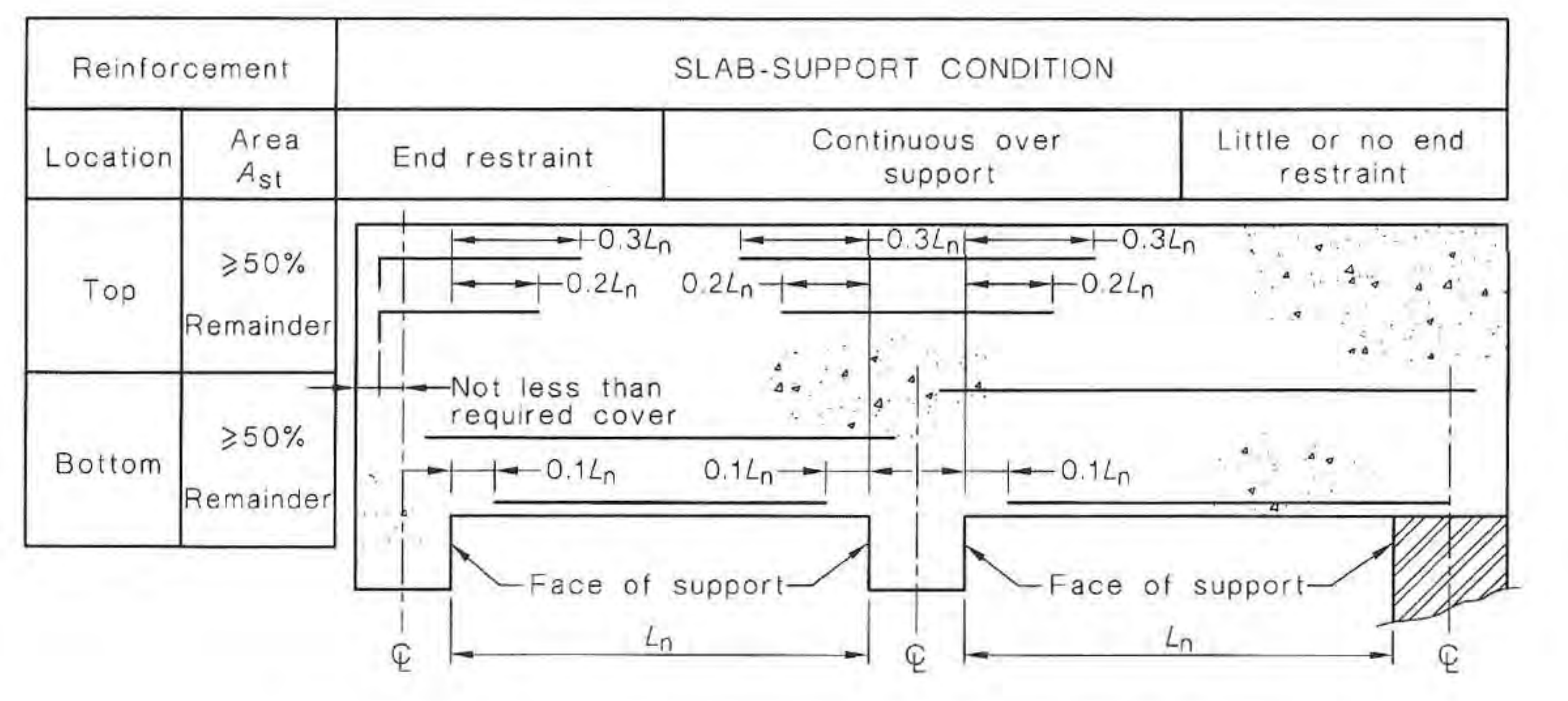


FIGURE 9.1.3.2 ARRANGEMENT OF REINFORCEMENT

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# Detailing of Slabs

**One way slabs**

IMRF – Clause 14.5.3.1 of AS 3600

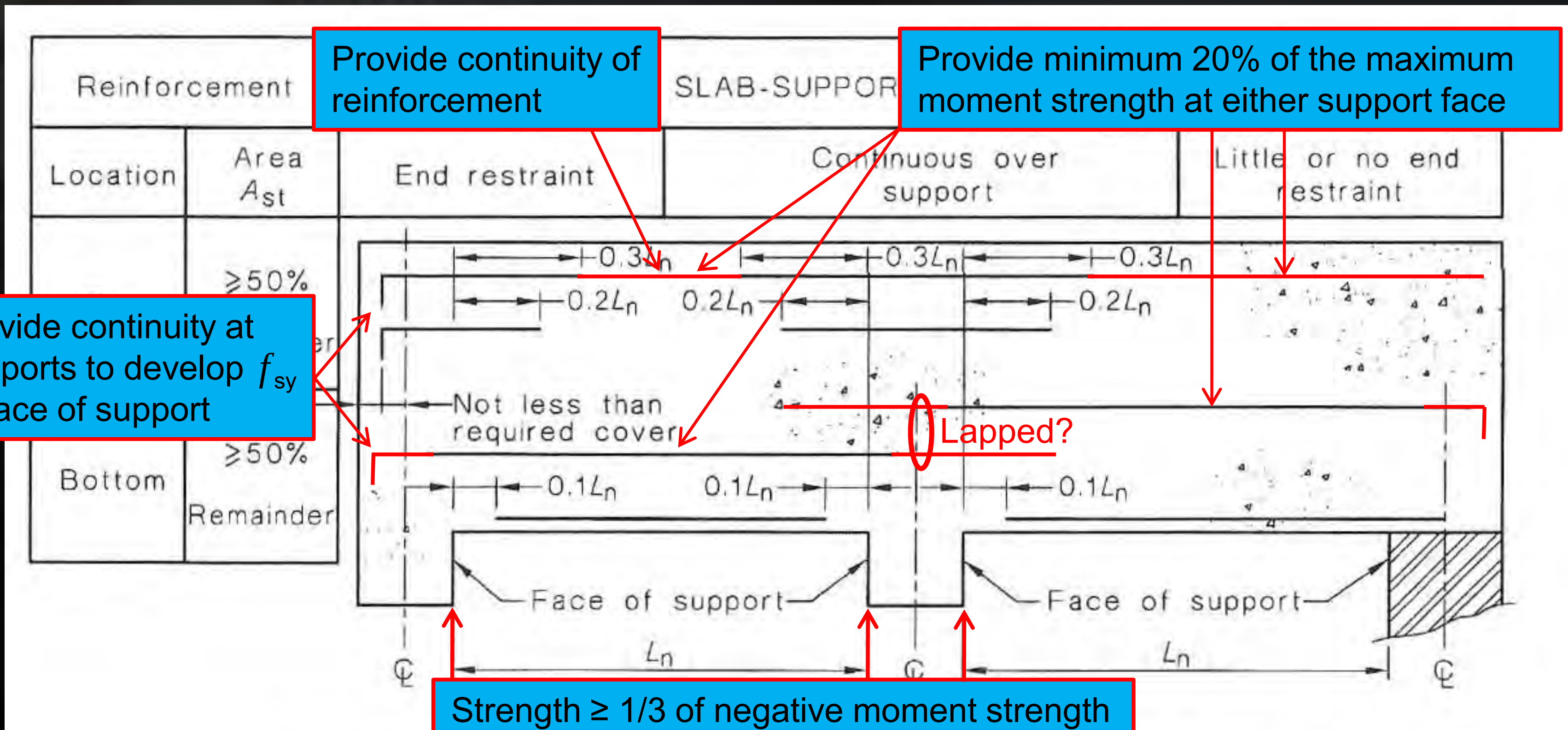


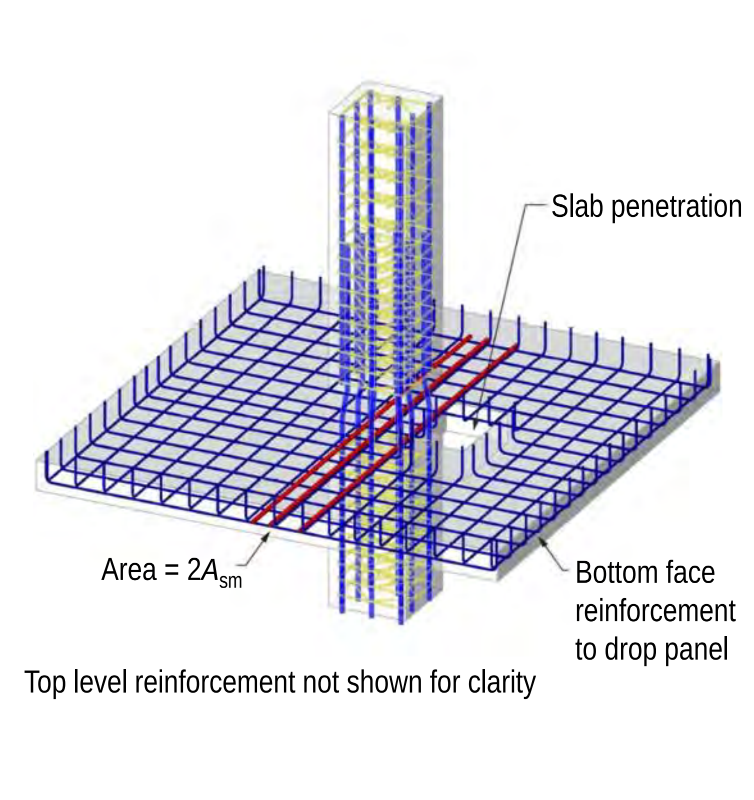

FIGURE 9.1.3.2 ARRANGEMENT OF REINFORCEMENT

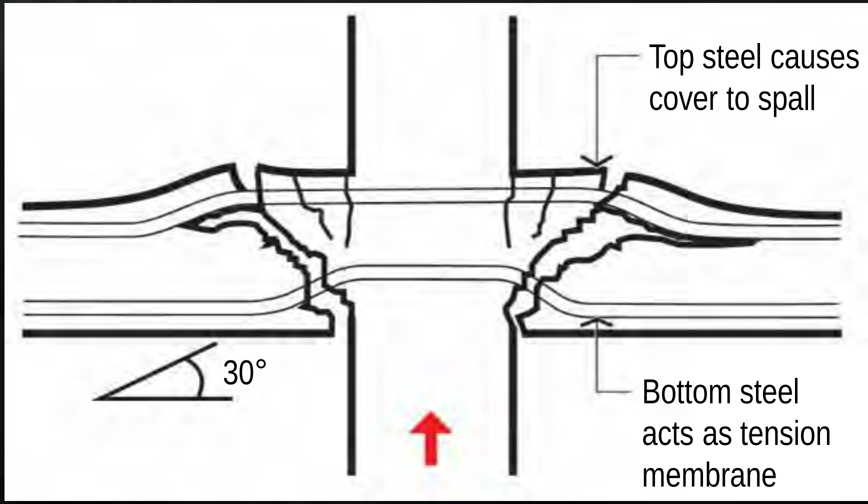
# Detailing of Slabs

**Structural Integrity Reinforcement (Clause 9.2)**

Increases resistance of structural system to progressive collapse

Simple Reinforcement Detailing ➡ Improves Life Safety




Figures 36 and 37 from SRIA's Seismic Guide

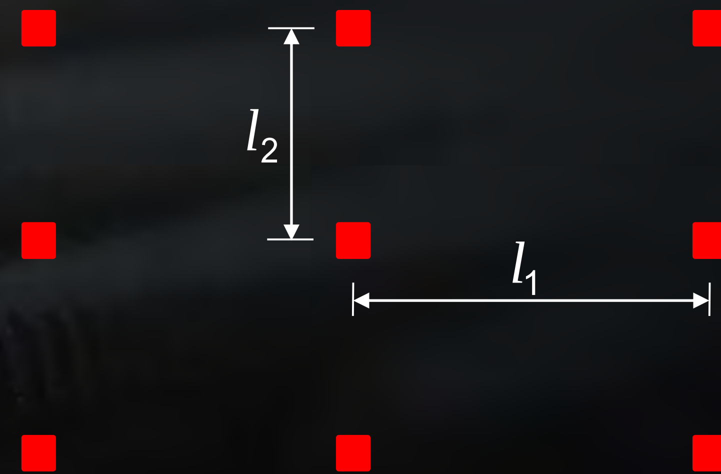
# Detailing of Slabs

## Structural Integrity Reinforcement (Clause 9.2)

AS 3600: 2018 (all connections)

Total bottom reinforcement

$$A_{s.min} = \frac{2N^*}{\phi f_{sy}} \quad \text{(Equation 9.2.2)}$$




ACI 352.1R-11 Equation 6.3.1

Area in each direction, $A_{sm} = \dfrac{0.5\ \omega_u\ l_1\ l_2}{\phi f_{sy}}$

where:

$\omega$ = factored uniformly distributed load

$\geq$ two times the slab dead load $(N/mm^2)$

$\phi = 0.9$

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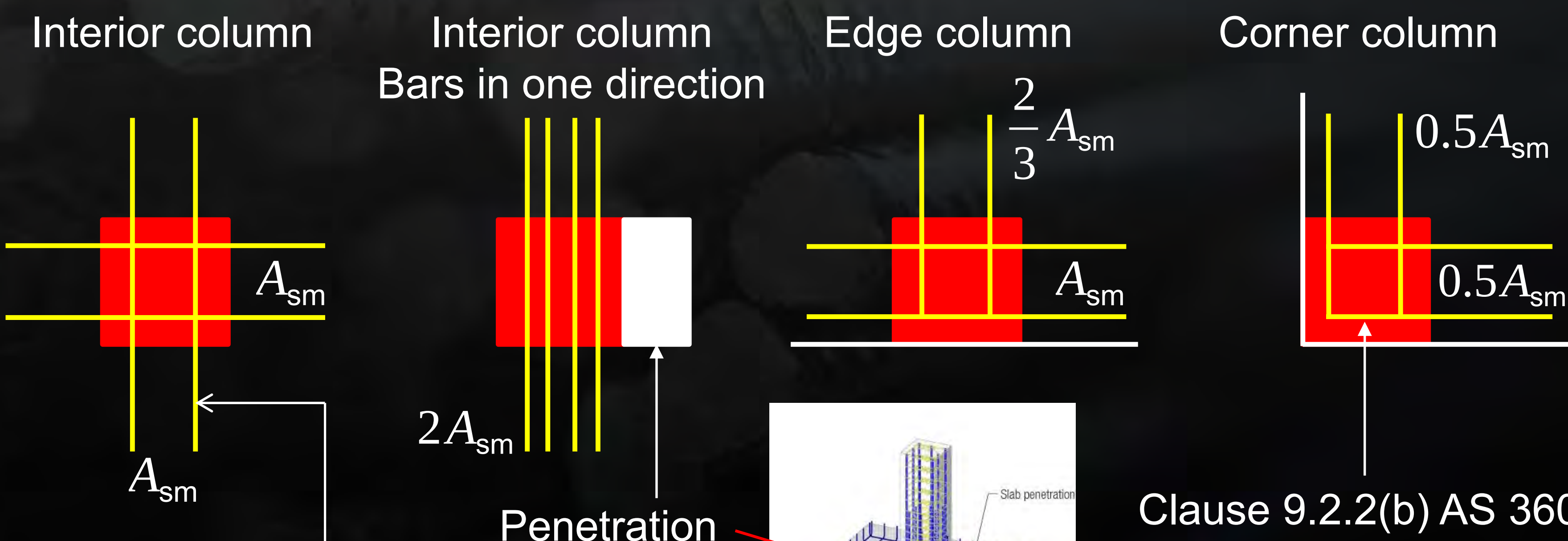
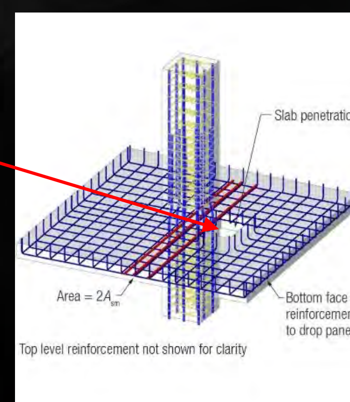
# Detailing of Slabs

## Structural Integrity Reinforcement

Area at various column locations (ACI 352.1R-11 and Section 5.11.3 of Seismic Guide)




Clause 9.2.2(b) AS 3600
Extend $2L_{sy.tb}$ from face of column

Clause 9.2.2(b) AS 3600
Hooked or cogged ends at discontinuous edges

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# Detailing of Slabs

**Structural Integrity Reinforcement** – Improves Life Safety

Remains of car park floor – Old Newcastle Workers Club NSW - Brittle failure & progressive collapse
(Photo courtesy Cultural Collections, The University of Newcastle, Australia)

Punching shear failure
Hotel Grand Chancellor
Christchurch, NZ

# Detailing of Slabs

**Structural Integrity Reinforcement** – Improves Life Safety

Clauses 2.1.3, 8.3.1.1, 9.2 and 14.4.7 for structural integrity reinforcement

Remains of post-tensioned car park floor – Christchurch

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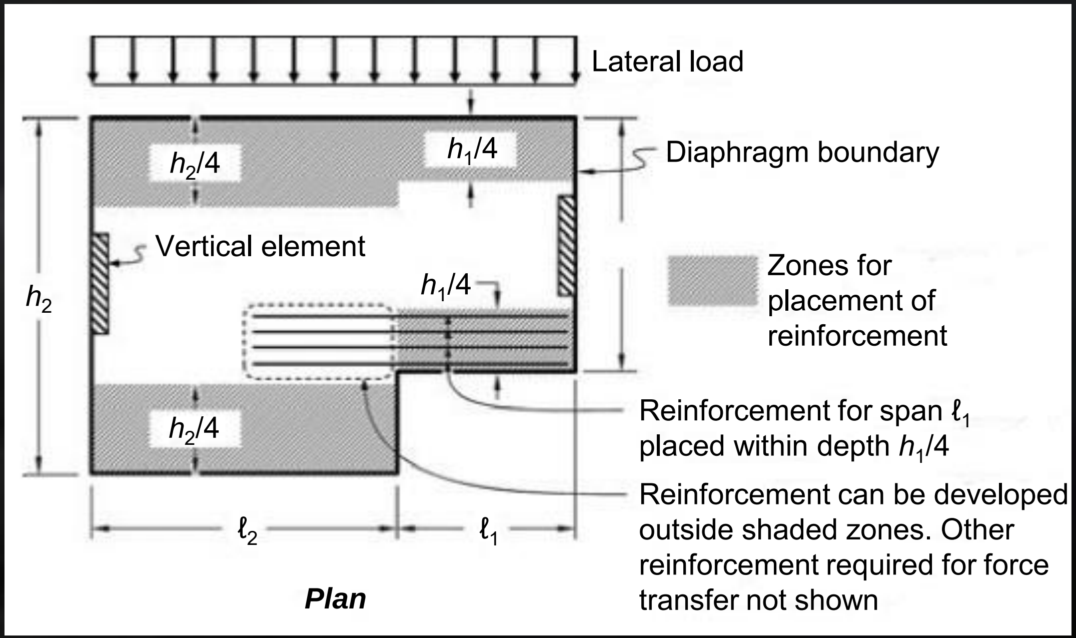
# Slabs as Diaphragms

## Clause 15.2 Design Actions

- 15.2.1 General design actions
- 15.2.2 Analysis procedure
- 15.2.2.2Stiffness of diaphragm




Location of reinforcement resisting tension due to moment and axial force

(Figure R12.5.2.3 from ACI 318M-14)

## Clause 15.3 Cast-in-place toppings

- Acting on its own - Minimum thickness of 75 mm and reinforced for loading
- Acting compositely with precast elements:
  - Minimum thickness 65 mm
  - Reinforce to act compositely with precast elements

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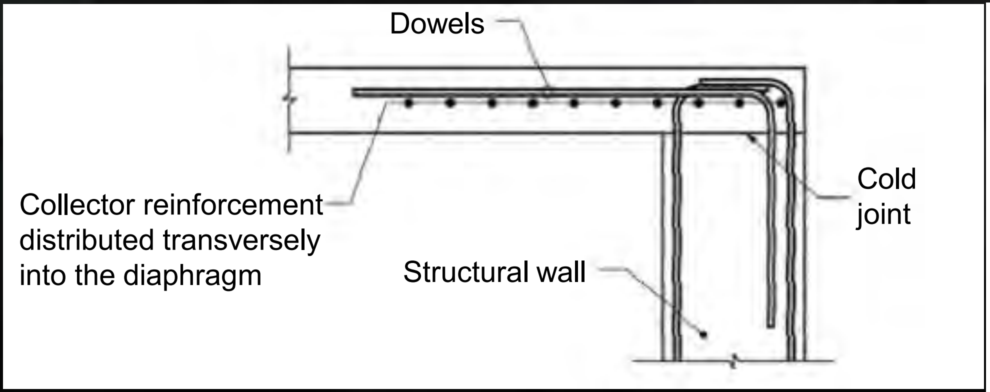
# Slabs as Diaphragms

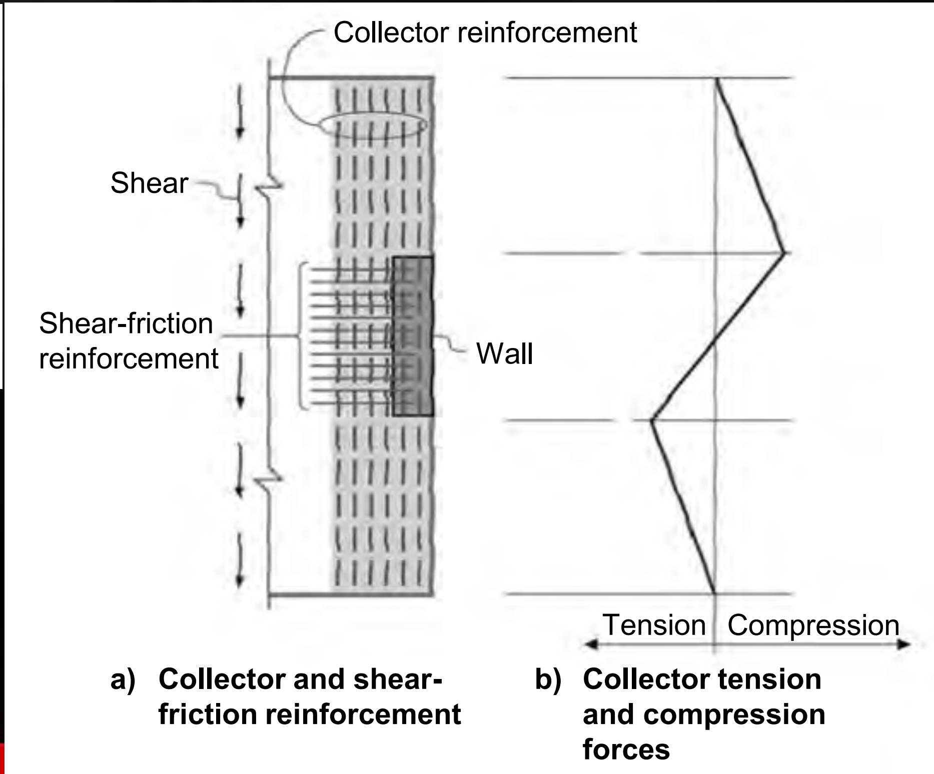
## Clause 15.4 Diaphragm reinforcement

- Minimum – in accordance with Clause 9.5.3
- Spacing – in accordance with Clause 9.5.1
- Development and laps – sufficient to transfer forces
- Collectors – reinforce to transfer loads into shear-resisting elements
- Construction joints – reinforcement must transfer forces across joint




Typical detail showing dowels provided for shear transfer to a structural wall through shear-friction

(Figure R12.5.3.7 of ACI 318M-14)

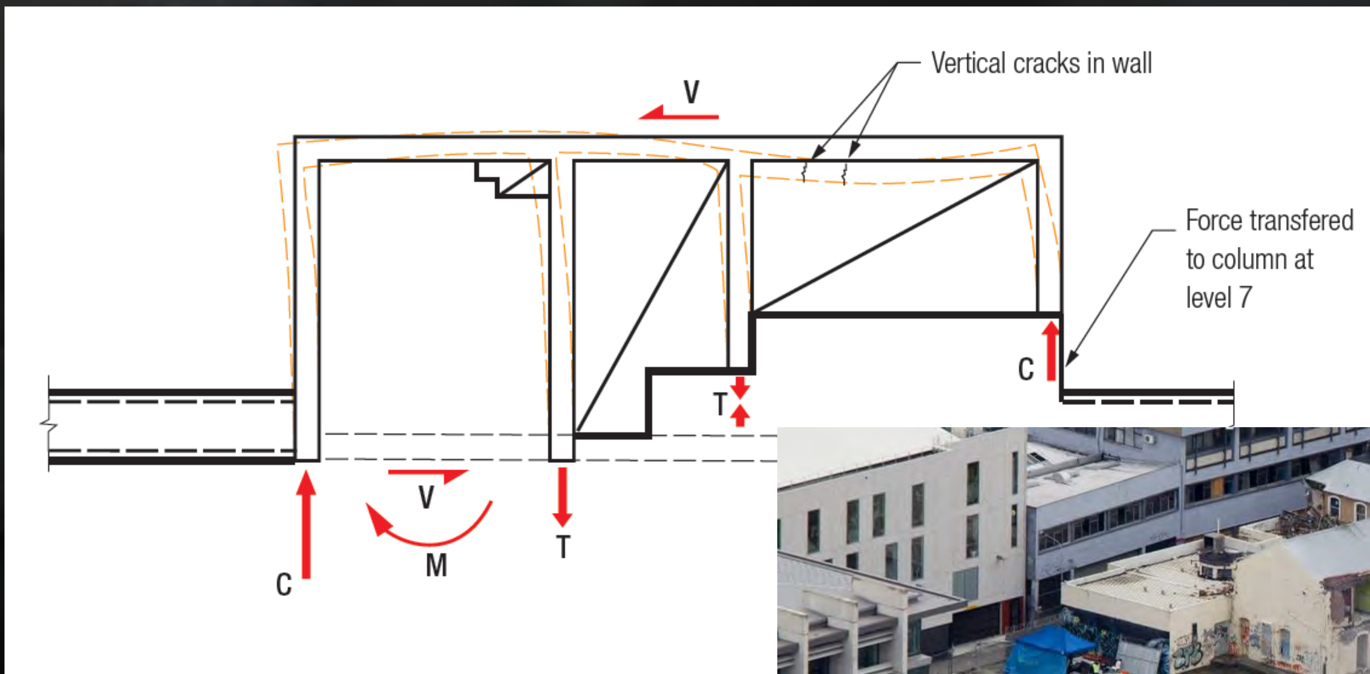



Collector and shear-friction reinforcement required to transfer collector force into wall

(Figure R12.5.4.1 of ACI 318M-14)

# Slabs as Diaphragms

**Must provide adequate life safety through good design and detailing**




Failure of shear wall/diaphragm connection

CTV Building, Christchurch NZ

# CTV Building

**Poor detailing of connections and columns**

Inadequate connections

- Tie everything together

Poorly detailed, heavily loaded columns failed

For reinforcement to be effective it is critical that it be properly anchored.

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# Detailing of Beams

**Prefabrication of reinforcement cages saves time**


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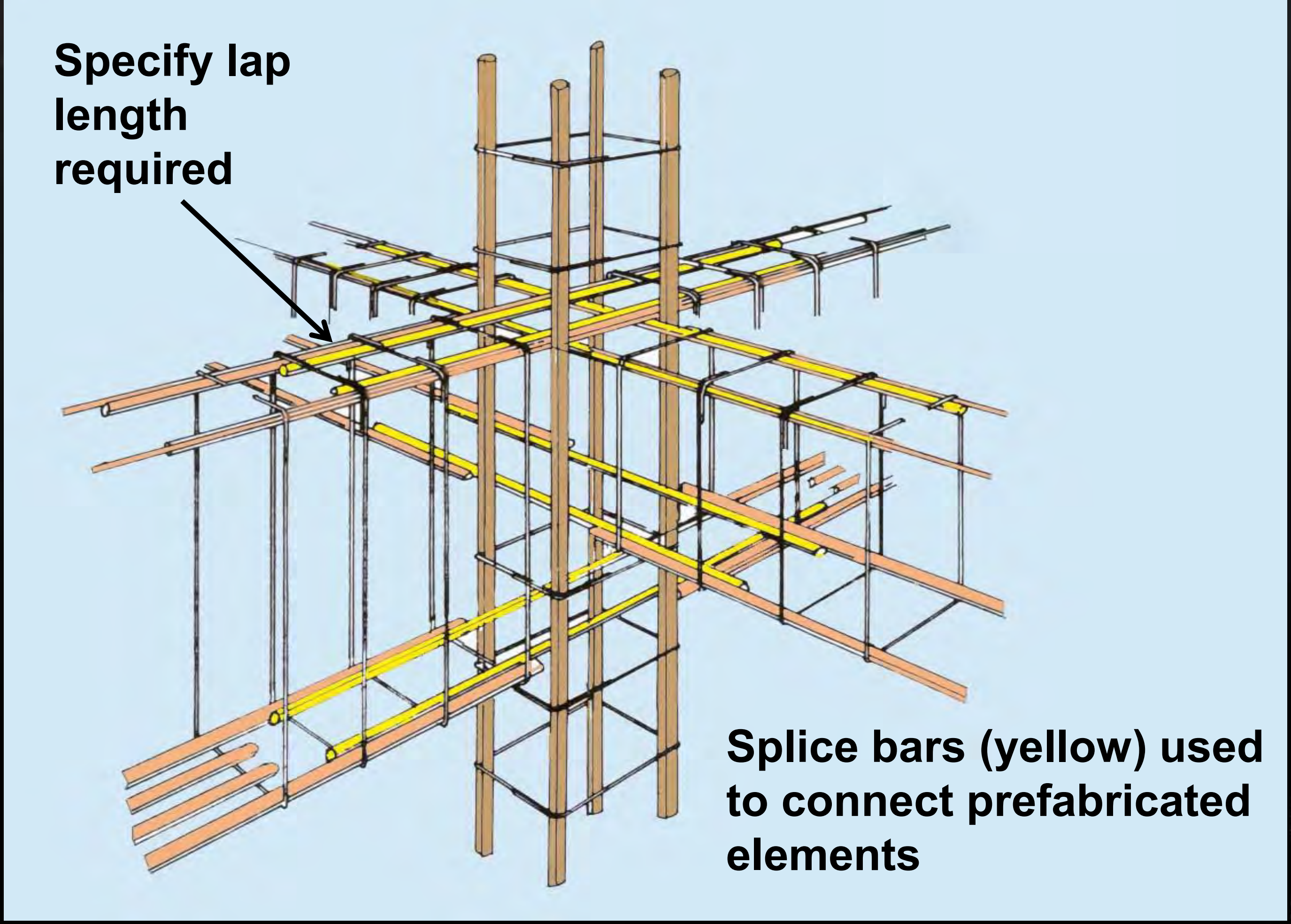
# Detailing of Beams

'Loose bar' detailing allows assembly of prefabricated cages

Satisfactory for ordinary moment-resisting frames (OMRF)

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# Detailing of Beams

## Splice and fitment requirements for IMRFs

**S1 Region**

Fitment spacing

Clause 14.5.2.2

Max. $\leq 0.25d_o$

$8d_b$

$24d_f$

300 mm

**S2 Region**

Fitment spacing

Max. $\leq 0.5D$

300 mm

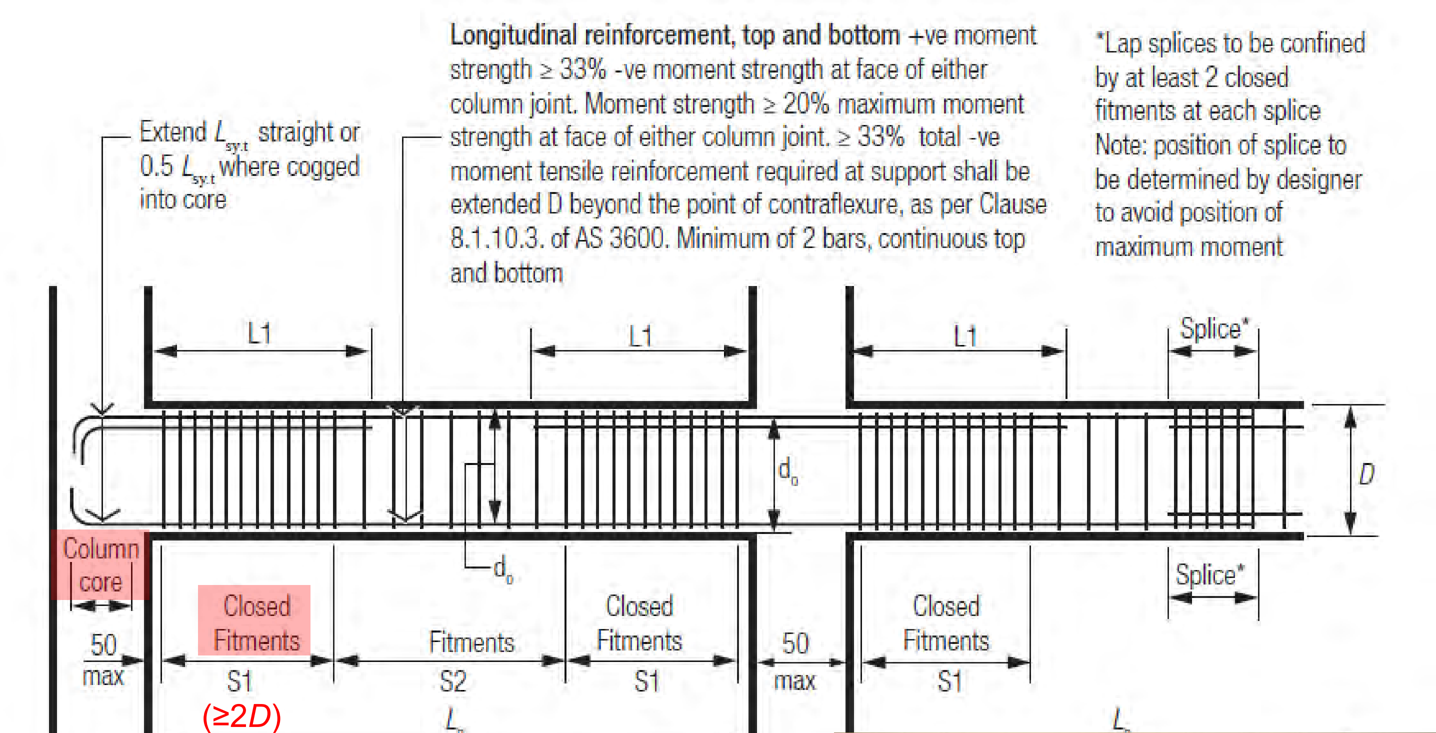



Figure 38 of SRIA Guide to Seismic Design and Detailing

# Detailing of Beams

**Anchor beam bars in confined column core**

**Why? ➡ At about 1.5% drift, the cover concrete will typically be lost**

Bottom bars not anchored in the confined region of the column

Failure of a transfer beam column joint at Copthorne Hotel, Christchurch 2011

Images courtesy of Peter McBean Walbridge and Gilbert

# Design Recommendations

## LOAD PATHS

- Use simple, well established, direct load paths that offer predictable behaviour.
- Avoid non-redundant load paths i.e. transfers.

  Consider designing them to remain elastic.


**Copthorne Hotel**

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Image courtesy of Peter McBean, Walbridge and Gilbert

# Direct Load Paths

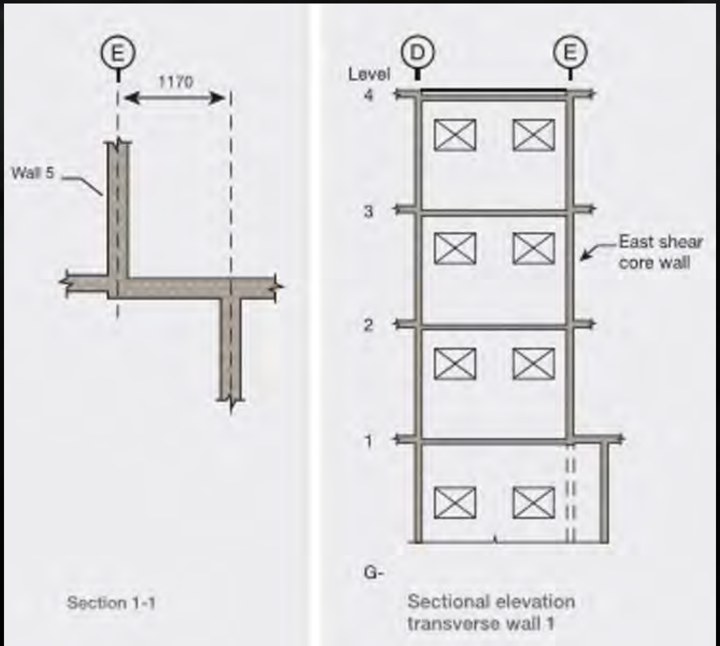
**Pyne Gould Building**

Poor detailing issues

Lightly reinforced core walls

Poorly restrained columns

Indirect load paths




Images courtesy of Peter McBean, Wallbridge and Gilbert

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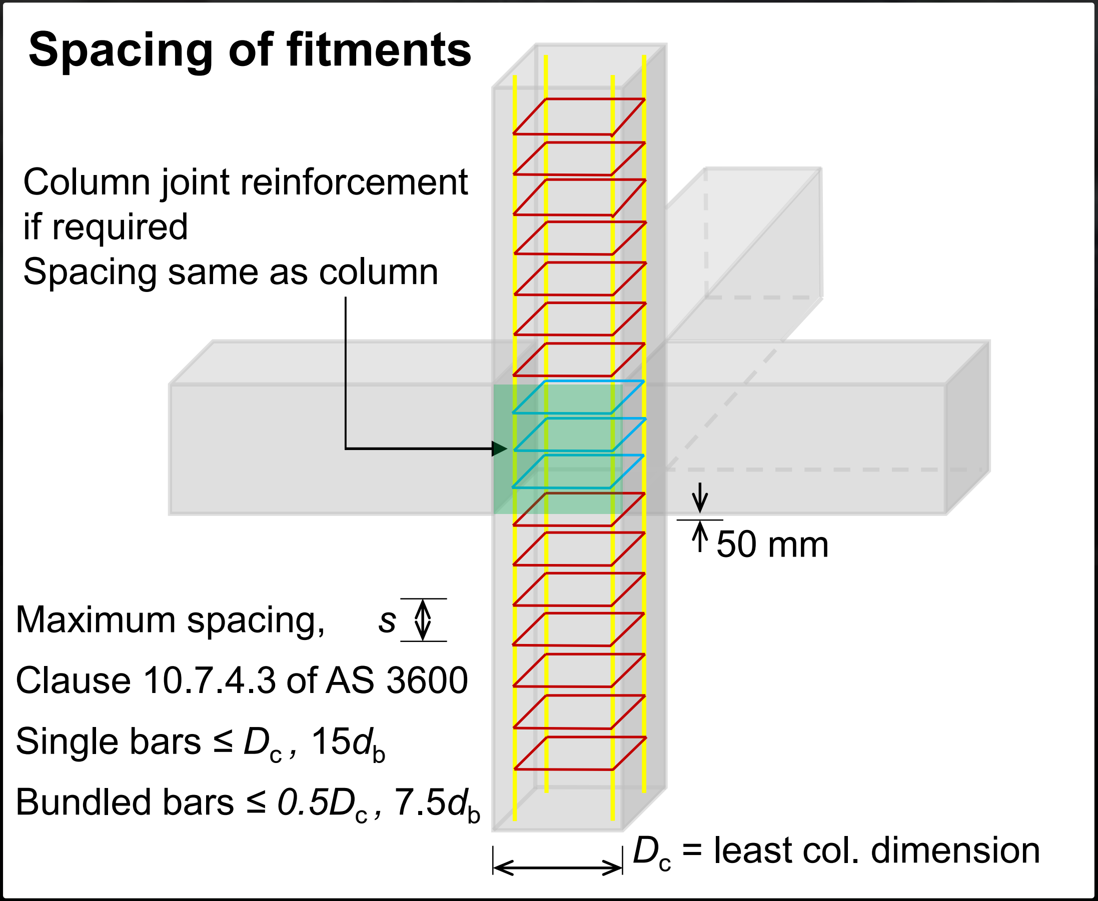
# Detailing of Columns

## Fitments for Ordinary moment-resisting frames

( $f'_c \leq 50$ MPa and all load levels)




### Size of fitments

Table 10.7.4.3 of AS 3600

| Longitudinal bar diameter mm | Minimum bar diameter of fitment and helix mm |
|---|---|
| Single bars up to 20 | 6 |
| Single bars 24 to 28 | 10 |
| Single bars 32 to 36 | 12 |
| Single bars ≥40 | 16 |
| Bundled bars | 12 |

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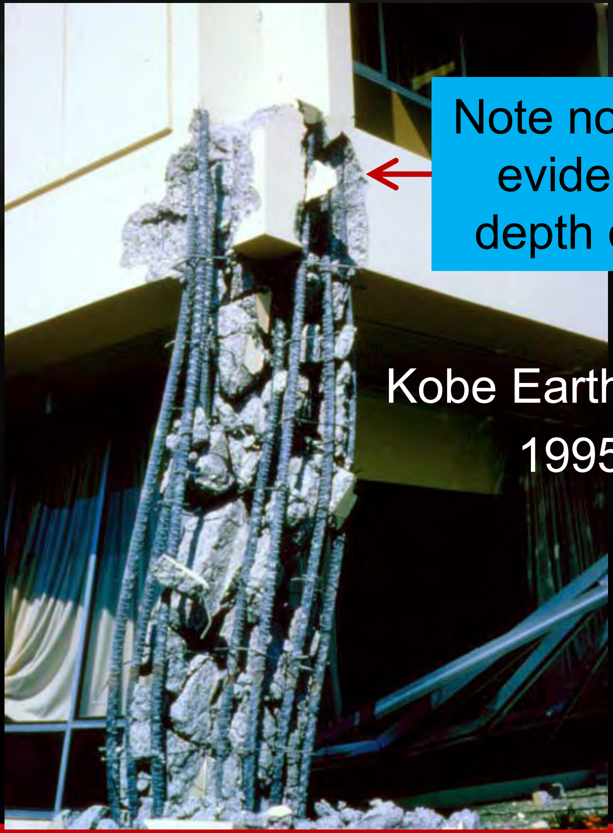
# Detailing of Columns

**Detailing of reinforcement critical**

- Fitments designed not to yield and fail, because
- Once fitments fail, column will general fail
- Fitments provide confinement and ductility to allow drift of column



Note no fitments evident over depth of beam

Kobe Earthquake 1995

Insufficient lateral restraint of column reinforcement

Hotel Grand Chancellor, Christchurch, NZ
(Photograph courtesy Peter McBean)

# Detailing of Columns

## Lateral restraint of longitudinal bars – OMRF's

- Single longitudinal bars
  Spacing > 150 mm – all bars
  < 150 mm – every alternate bar
- Bundled longitudinal bars – each bundle

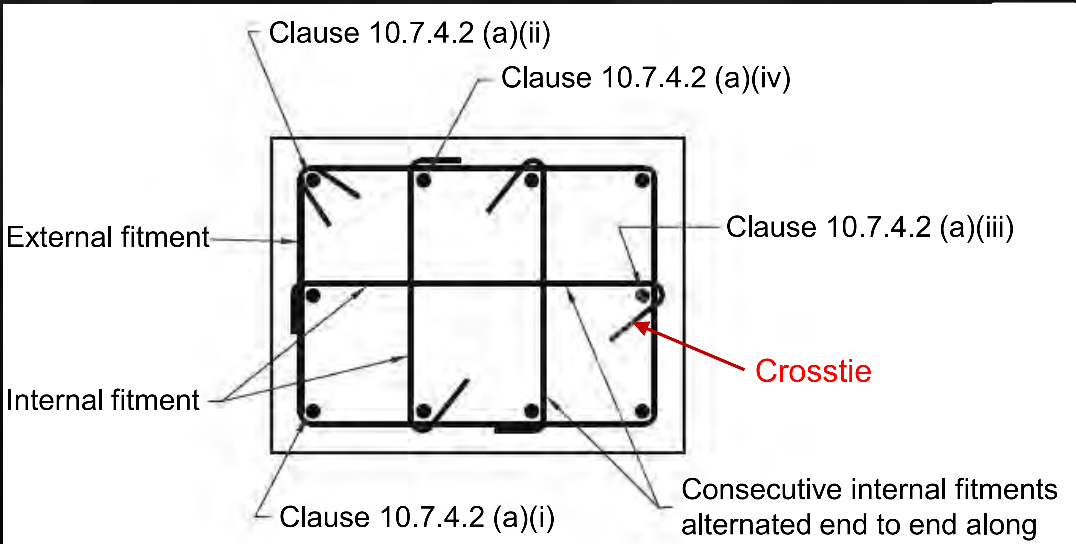



Figure 10.7.4.2 of AS 3600

Cogs must be alternated

Internal fitments with 90° cog not allowed for:

- IMRFs (Clause 14.5.4) or limited/moderately ductile walls (Clause 14.6.2.3)
- Where the design axial force is $> 0.3 \times 0.3 A_g f_c'$ (Clause 10.7.4.2)
- When $f_c' > 65$ MPa (Clause 10.7.4.2)

# Detailing of Columns

**IMRF - Minimum Reinforcement Details**

Note:

- Maximum fitment spacing (similar to beams)

  Clauses 10.7.3 and 10.7.4

  Clause 14.5.2.2 (b) (c) (d)

  $0.25d_o,\ 8d_b,\ 24d_f$ or 300

  Clause 14.5.4 (a) to (d)

  $0.5D_c,\ 8d_b,\ 24d_f$ or 300

- Closed fitments required over length D
- Crossties require seismic hook at both ends

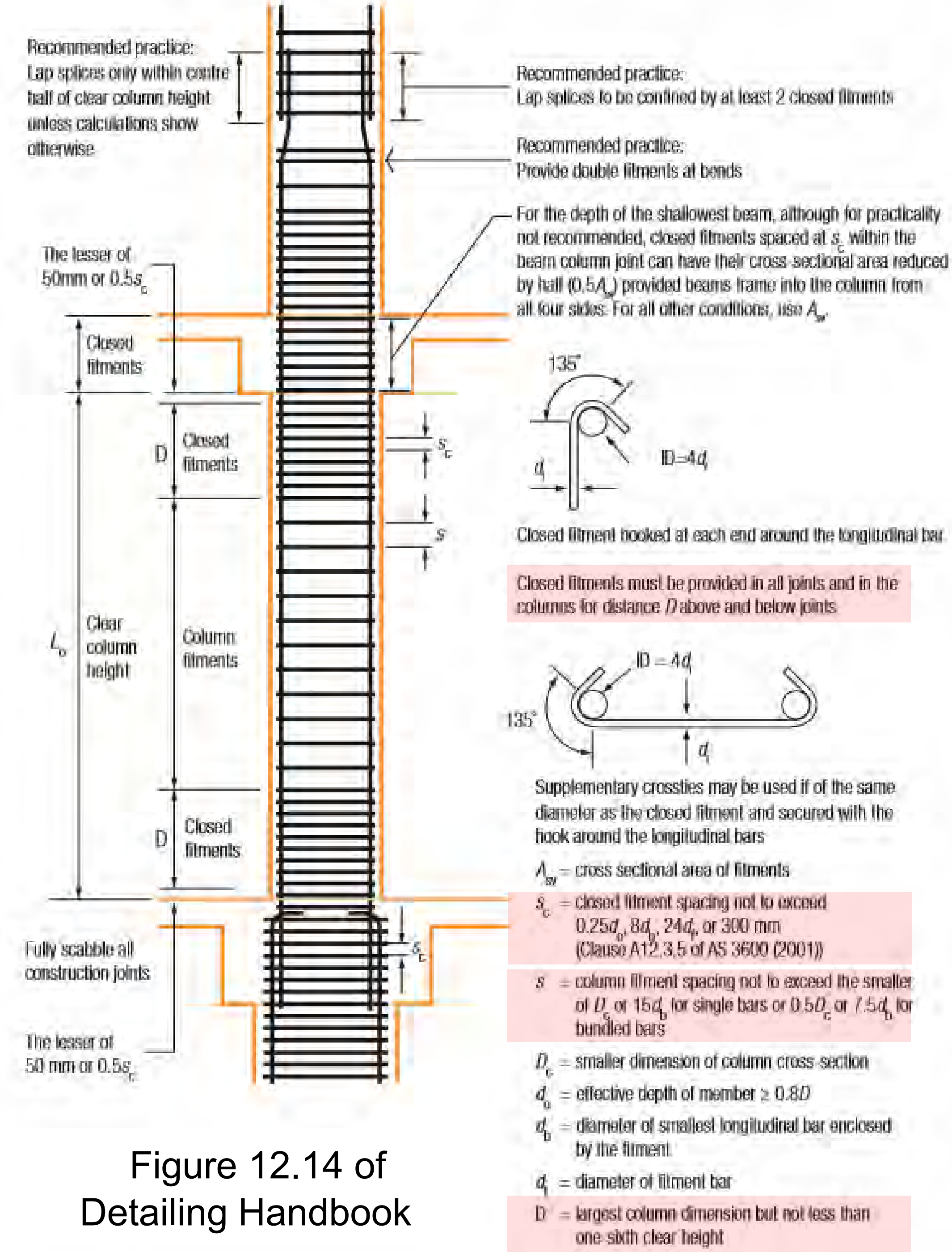



Figure 12.14 of Detailing Handbook

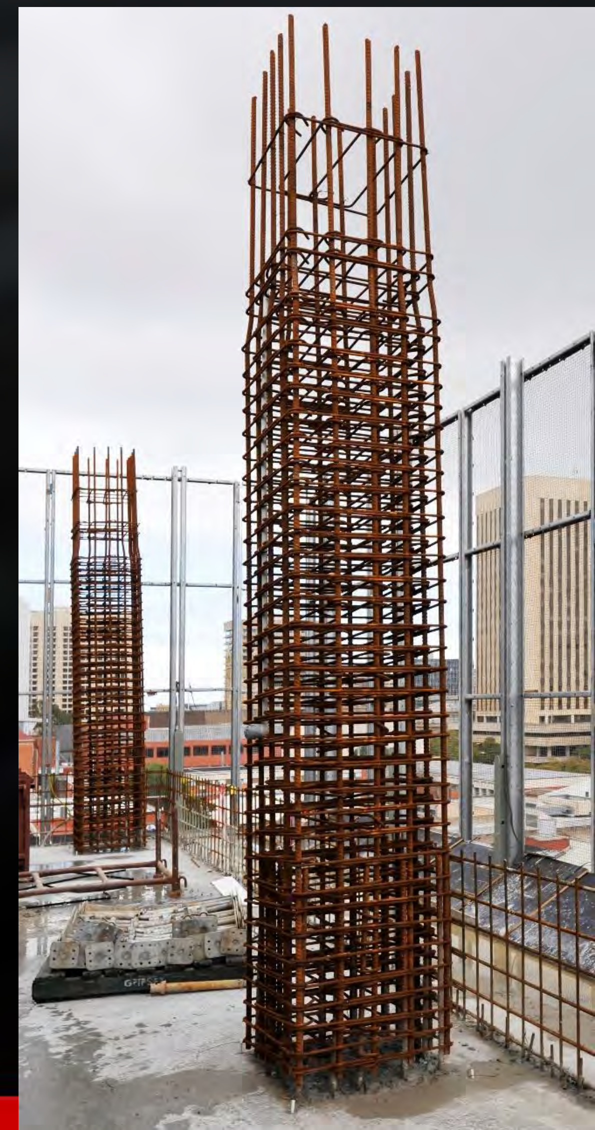
# Detailing of IMRF Columns

**Strong column / weak beam design**

- Clause 14.5.6 of AS 3600 (2018)
- Requires $\sum M_{nc} > (6/5)\sum M_{nb}$
- From ACI318M-14 for SMRFs
- Only if columns are part of a moment-resisting frame system

Failure of columns in San Fernando Earthquake, 1971
Olive View Hospital, California

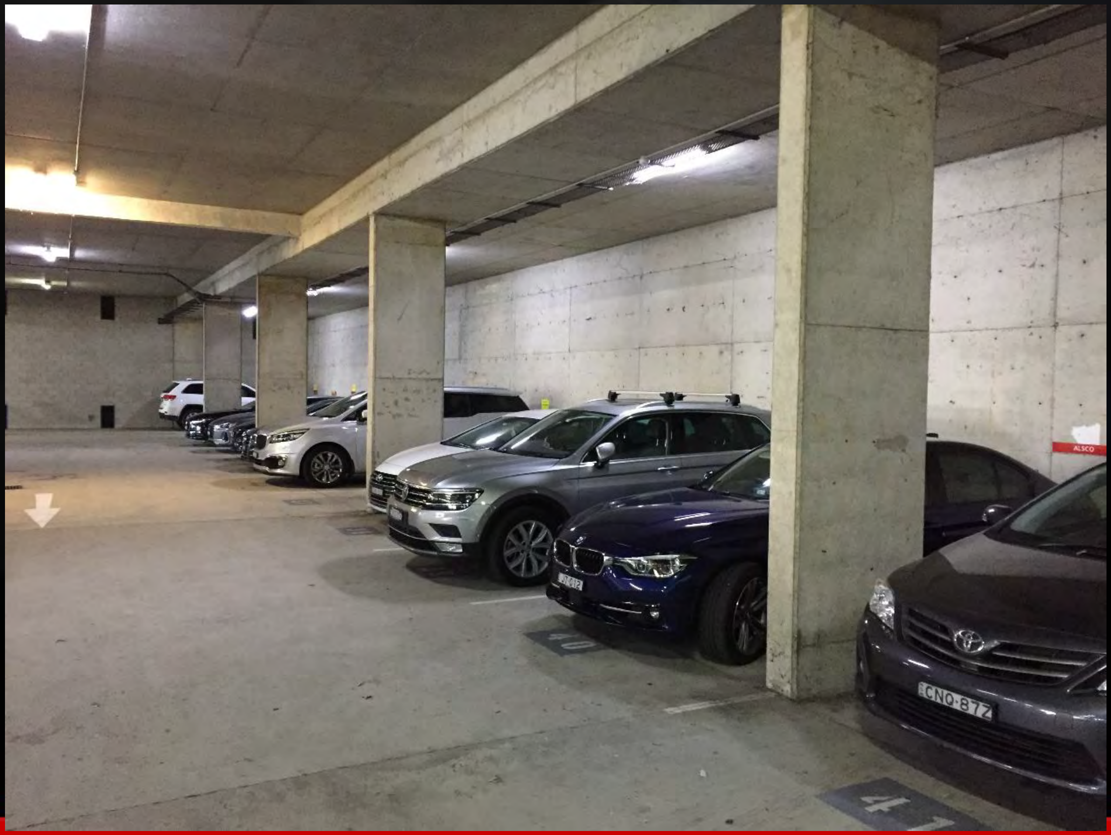
IMRF column, Adelaide



# Detailing of IMRF Columns

**Strong column / weak beam concept – Clause 14.5.6 of AS 3600 (2018)**

- If impossible to achieve in IMRF
- Provide alternate lateral support system
- Design columns for drift induced moments arising from frame action



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# Reinforcing Bar Classification

All reinforcing bar to comply with AS/NZS 4671

| AS/NZS 4671 Designation | Yield Stress, $R_e$ MPa | Ductility Class | Description | Typical Size mm |
|---|---|---|---|---|
| D500N | 500 | N | Hot-rolled Deformed bar | Coil 10, 12, 16<br>Straight 12 – 40<br>Special 50 |
| R250N | 250 | N | Hot-rolled Plain round | 6.5, 10, 12, 16, 20, 24 |
| D250N | 250 | N | Hot-rolled Deformed bar | 12 (pool steel) |
| D500L | 500 | L | Cold-rolled Deformed bar | 5 - 12 |
| R500L | 500 | L | Cold-drawn Round rod | 5 - 12 |

NOTE: AS/NZS 4671 Seismic (Earthquake) Ductility Class E steels are also available in Australia through advanced ordering (Grades 500E or 300E)

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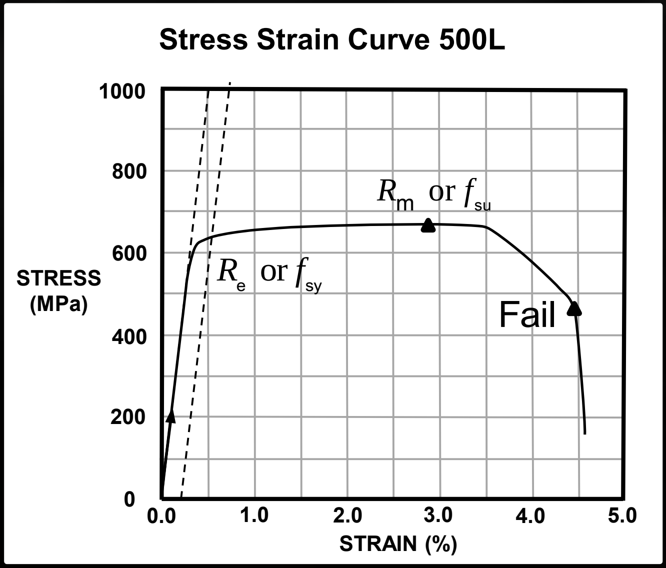
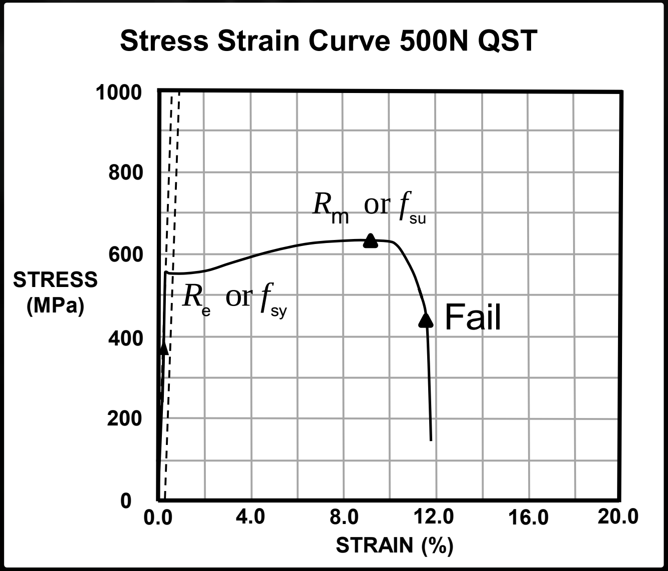
# Mechanical Properties (from AS/NZS 4671)

| Property | 500L | 500N | Probability of exceedance |
|---|---|---|---|
| Nominal Diameter (mm) | 5 to 12 | 10 to 40 | - |
| Characteristic Yield Stress (MPa), $R_{ek.L}$<br>$R_{ek.U}$ | 500<br>750 | 500<br>650 | 95%<br>5% |
| Ratio: $\frac{\text{Tensile Stress}}{\text{Yield Stress}} = \frac{R_m}{R_e}$ | ≥ 1.03 | ≥ 1.08 | 90% |
| Uniform Elongation, $A_{gt}$ (%) | ≥ 1.5 | ≥ 5 | 90% |

Ductility of reinforcement

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# Use of Class N and L reinforcement

**The ductility required $(\mu)$ determines the Class of reinforcement:**

## For OMRF ($\mu \leq 2$)

- Class L can be used as flexural reinforcement in the form of mesh $(\phi = 0.65)$
- Class L can be used as fitments in the form of rod, bar or mesh
- Class N can be used for both with no restrictions $(\phi = 0.85 \text{ max})$.

## For IMRF ($2 < \mu \leq 3$) and Limited/Moderate Ductile Walls

- Only Ductility Class N allowed as a ‘flexural’ reinforcement (Clause 14.5.1)
- Ductility Class L is permitted to be used for fitments and non-flexural reinforcement eg shrinkage and temperature
- Ductility Class L not permitted as structural reinforcement in walls (Clause 14.6.7 (C))

## For SMRF ($\mu > 3$)

- Not covered by AS 3600
- ‘Complete’ design & detailing is required to NZS 1170.5, NZS 3101 and AS 1170.4 Hazard Map, using Ductility Class E steels

# Thank you

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