Steel Reinforcement Institute of Australia

ENGINEERS AUSTRALIA

Reinforcement Quality Issues

Scott Munter

Executive Director, SRIA

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Manufacturing of Billets - EAF

Reinforcement made
from recycled metal

Scrap melted in EAF

Billet casting
150 x 150 mm in size

Chemical properties tested
prior to billet casting

Manufacturing of Billets - EAF

Billets cut to length

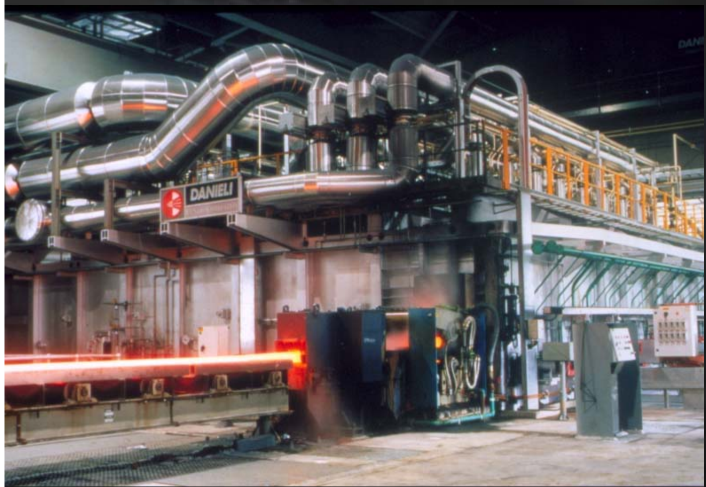
Billets moved to cooling beds

Billets allowed to cool slowly
Steel strength 250 to 300 MPa

Stacked in yard

Hot Rolling Bar Mill

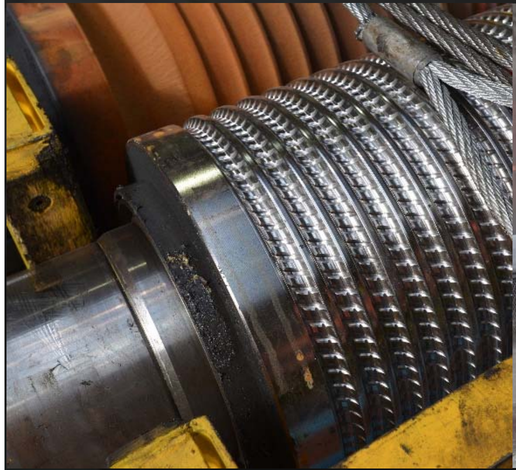
Turning billets into reinforcement



Billets reheated in oven and then rolled to required size

Hot Rolling Bar Mill

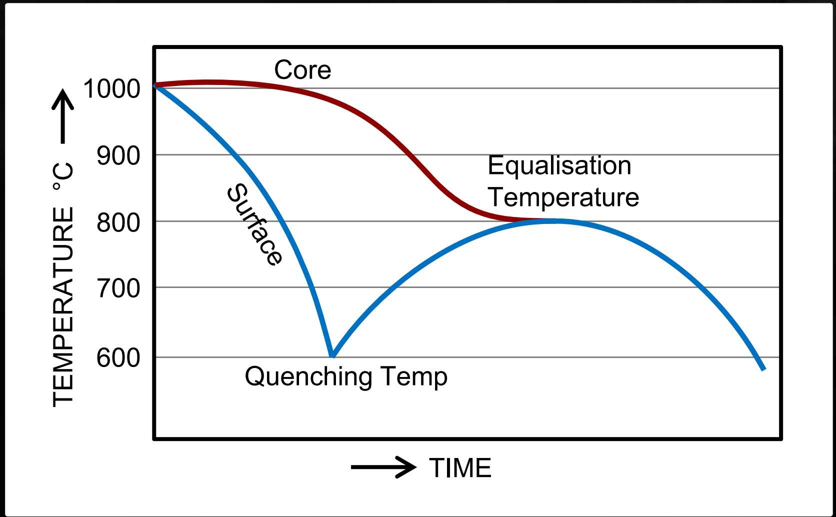
Straight Quenched and Self Tempered (QST) D500N (12 to 40 mm)



Rolling ribbed profile

Quenching process

Self-tempering in cooling beds



Schematic diagram on a
Time – Temperature Curve

Microstructure of QST
Reinforcing Bars

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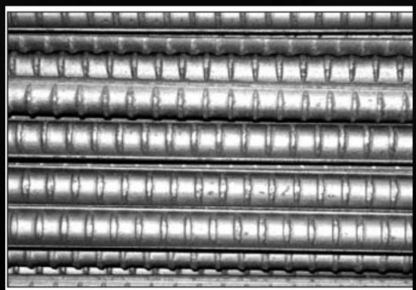
Hot Rolling Bar Mill

Coiled Microalloy D500N (12 and 16 mm) and D250N



D250N

Mill mark

Microalloy (MA) D500N coils -12 and 16 mm

(alloy is vanadium and bars have constant metallurgical properties across their section)

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Hot Rolling Rod Mill

Smooth Rod (R250N) and coiled deformed bar (D250N)

'Wild' coils of smooth rod 5.5 to 16 mm

Deformed bar coils
10, 12 & 16 mm

Typical labels

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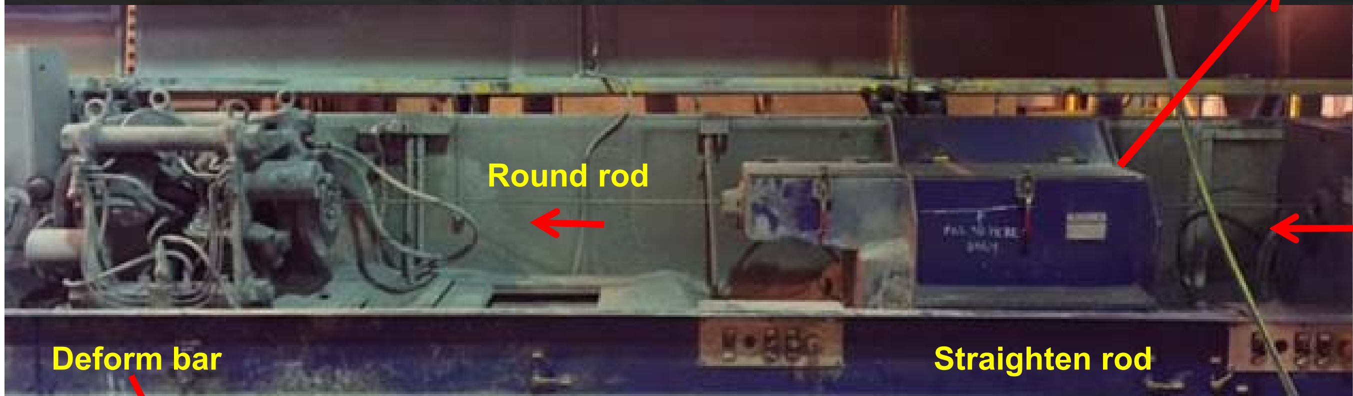
Cold rolled deformed bar

Produce ribbed bar from plain round rod

Increases yield stress to 500MPa



Used for mesh and fitments

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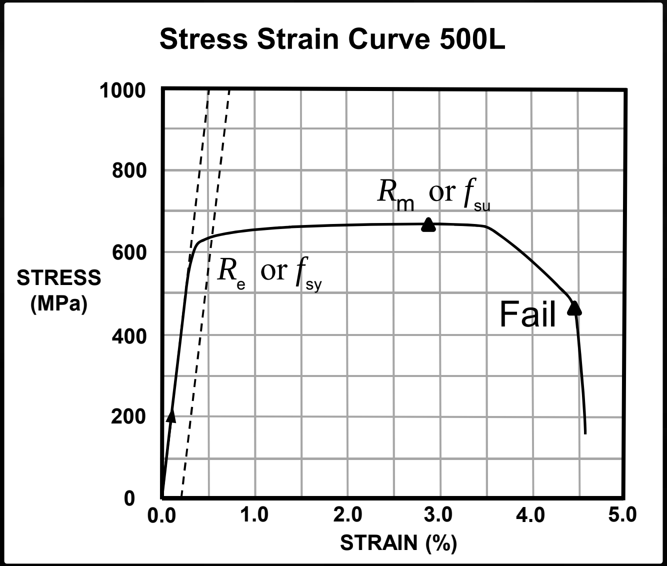
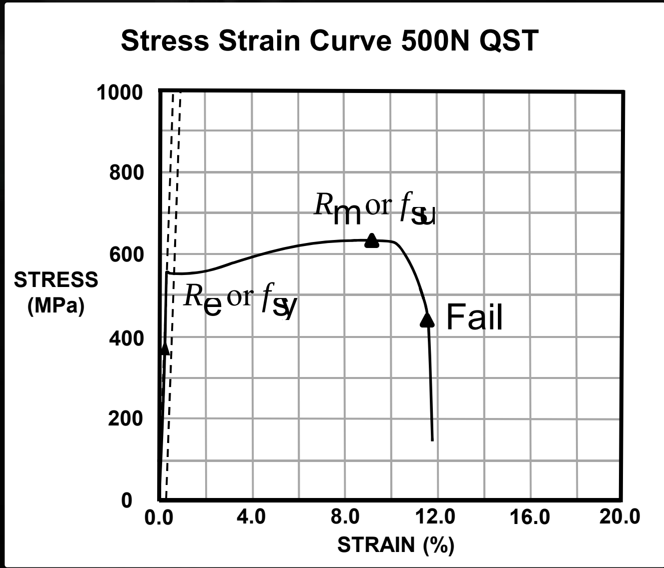
Mechanical Properties (from AS/NZS 4671)

Property	500L	500N	Probability of exceedance
Nominal Diameter (mm)	5 to 12	10 to 40	-
Characteristic Yield Stress (MPa), $R_{ek.L}$ $R_{ek.U}$	500 750	500 650	95% 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%





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Chemical Composition

Type of analysis	Chemical Composition (%) Max				
	All Steel Grades			Carbon Equivalent Value for Class	
	C	P	S	500L	500N
Cast analysis	0.22	0.050	0.050	0.39	0.44
Product analysis	0.24	0.055	0.055	0.41	0.46

Carbon Equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

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Correct Chemistry allows Welding to AS/NZS 1554.3

Third Party/Independent Certification ACRS or Equivalent

What does ACRS certify?

- Reinforcing bar and mesh to AS/NZS 4671 & relevant design Codes (AS 3600, AS 5100.5 & AS 2870)
- Prestressing strand to AS 4672
- Structural steel to AS/NZS Standards

Details of current ACRS Certificate Holders can be found at www.steelcertification.com

If in doubt, contact ACRS on (02) 9965 7216 or
Email: info@steelcertification.com

Joint Accreditation System of Australia and New Zealand

JAS-ANZ

ACRS

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Third Party/Independent Certification ACRS or Equivalent

ACRS certificates cover company and products

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VALID TO 31 DEC 2017

ACRS

www.steelcertification.com

Australasian Certification Authority for Reinforcing and Structural Steels Ltd

Certificate of Product Performance

Certificate Number: *811021*

AUSREO

AUSREO

WETHERILL PARK, NSW, AUSTRALIA

has satisfied the Authority that it complies with the rules of the ACRS Scheme. Where appropriate, and as listed below, it has further satisfied the Authority that it manufactures and/or supplies products that conform consistently with the standards listed below and is entitled to use the ACRS mark in relation to the products listed on this certificate.

Scope of Certification

Processing and distribution of carbon steel bars and welded mesh in accordance with AS/NZS 4671, plus the requirements of the "material and construction requirements for reinforcing steel" clauses of AS 3600 Concrete structures and AS 5100.5 Bridge design – Concrete, or the "Reinforcement" clauses of NZS 3109 Concrete Construction

Full details of the products for which certification has been achieved should be viewed at: *www.steelcertification.com*

By authority of ACRS Board: Philip Sanders, Executive Director

Valid until: 31 December 2017

First certified: November 2008

JAS-ANZ

www.jas-anz.org/register

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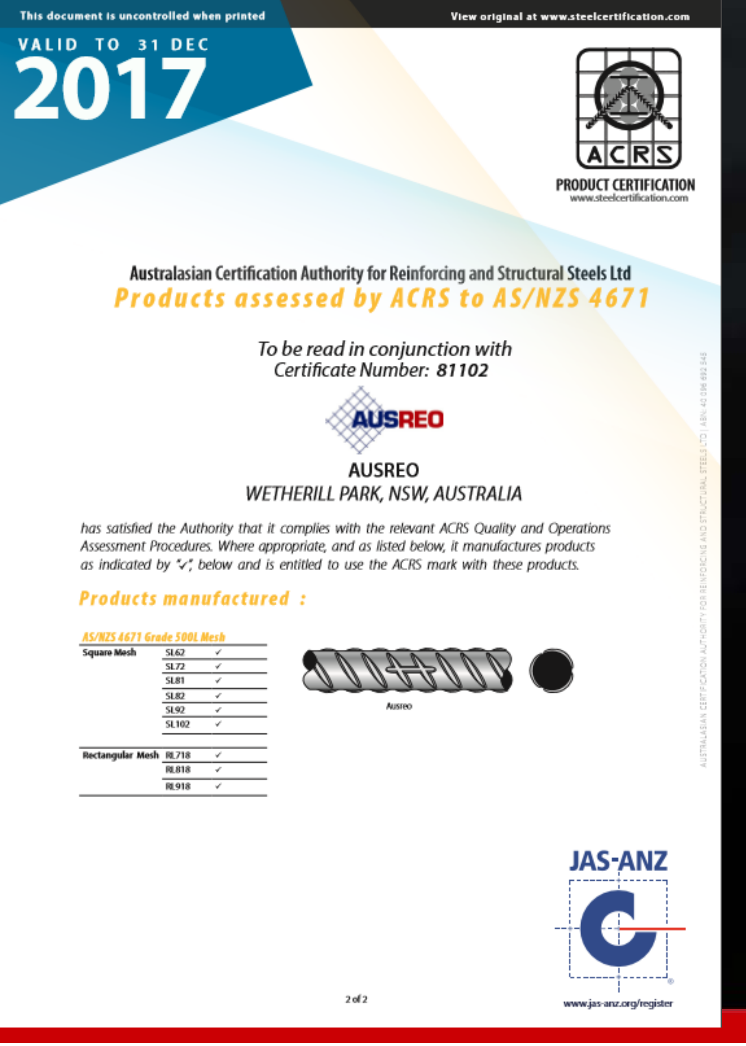

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VALID TO 31 DEC 2017

ACRS

PRODUCT CERTIFICATION

www.steelcertification.com

Australasian Certification Authority for Reinforcing and Structural Steels Ltd

Products assessed by ACRS to AS/NZS 4671

To be read in conjunction with Certificate Number: 81102

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has satisfied the Authority that it complies with the relevant ACRS Quality and Operations Assessment Procedures. Where appropriate, and as listed below, it manufactures products as indicated by '✓', below and is entitled to use the ACRS mark with these products.

Products manufactured :

AS/NZS 4671 Grade 500L Mesh		
Square Mesh	SL62	✓
	SL72	✓
	SL81	✓
	SL82	✓
	SL92	✓
	SL102	✓
Rectangular Mesh	RL718	✓
	RL818	✓
	RL918	✓

Ausreo

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www.jas-anz.org/register

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Third Party/Independent Certification ACRS or Equivalent

Concerns about non-conforming building materials in both Australia and New Zealand

- The AiG report (2013), "*The quest for a level playing field - The non-conforming building products dilemma*" and the
- Government SOG Report (2016), "*Strategies to address risk related to non-conforming building products*"
- Highlights the need for Australian Standards to be updated to address any gaps in the requirements for demonstrating product conformity

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Third Party/Independent Certification ACRS or Equivalent

Need for an ACRS or equivalent certificate?

Every project should have one

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Mesh Processing

Mesh welding process – quality of welding critical

Typical mesh-making machine

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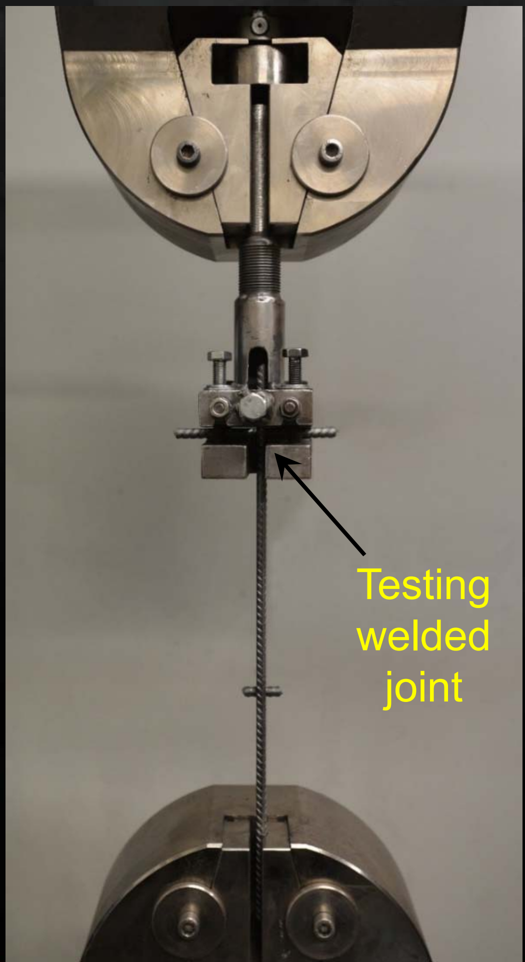
Mesh Processing

Mesh weld testing & lapping

- Each welded joint develops 50% of the bar's yield stress
- Overlap a minimum of 2 crosswires



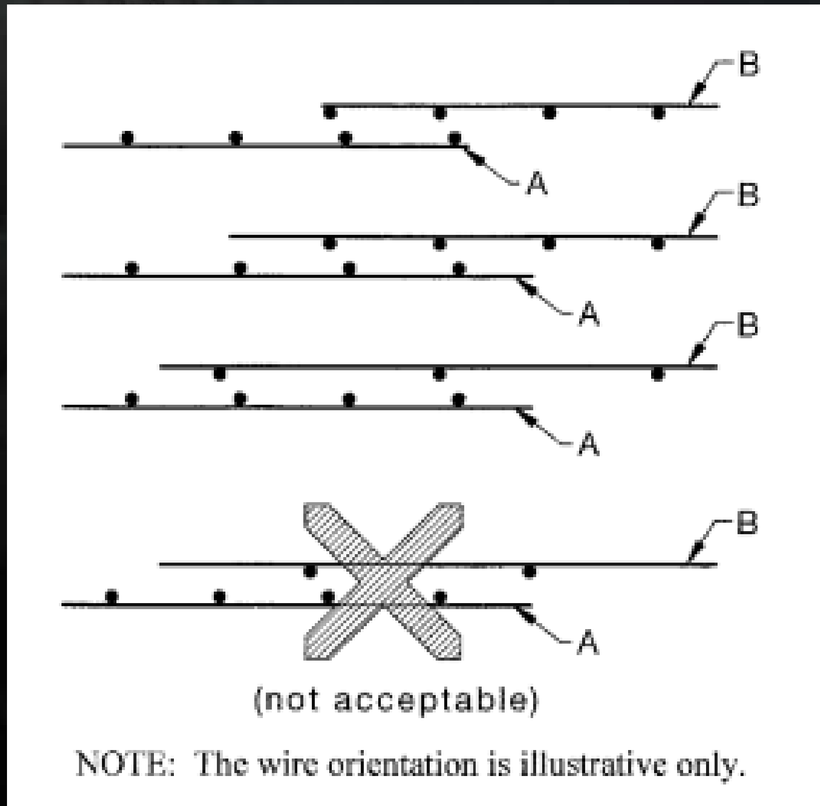


Figure 5.1 from AS 2870

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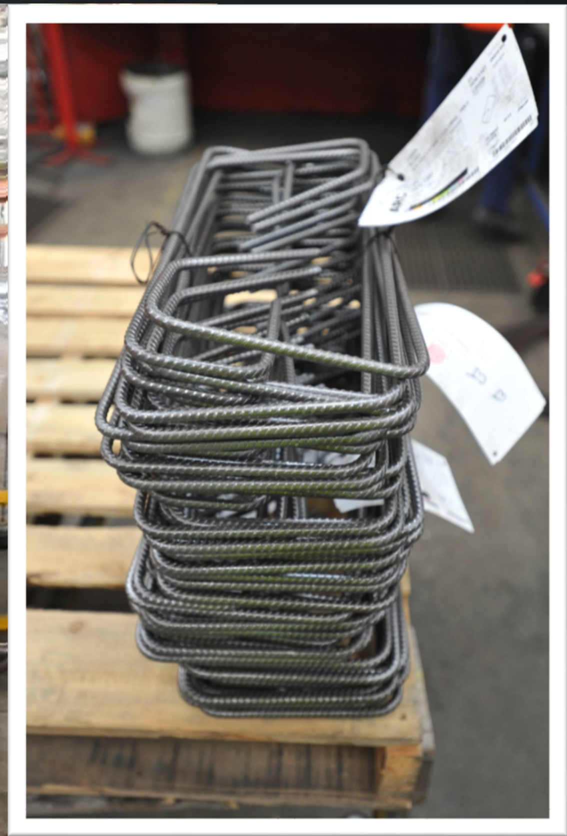
Cutting & Bending – Off Coil

Bar continually drawn from coil and bent around pin of specific diameter



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Cutting & Bending – Straight Bar

Larger bars also bent around pin of specific diameter

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Bending Reinforcement

Clause 17.2.3.2 of AS 3600 – required pin diameters

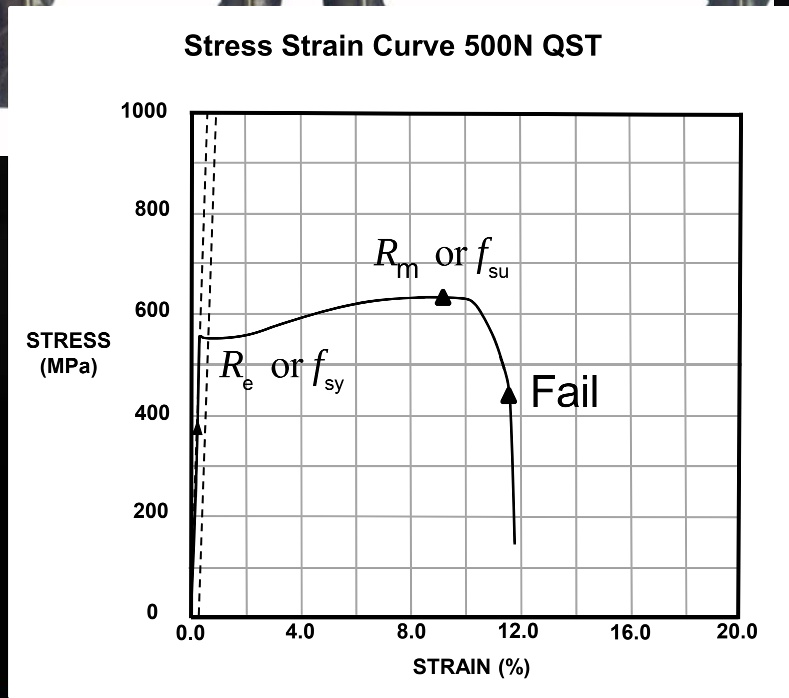
Avoids excessive steel strain and crushing of concrete

Fitments

500L & R250N	$3d_b$
D500N	$4d_b$

General

D500N	$5d_b$
Galvanised ≤16mm	$5d_b$
Galvanised ≥ 20mm	$8d_b$



Bending Reinforcement

Incorrect Site Practices

Not bending around correct pin diameter

'Necking' and fracture of steel at small radius

Over-heating (max.600°C allowed – Clause 17.2.3.1)
If temp. exceeds 450°C, yield strength taken as 250 MPa in design

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Bending Reinforcement
Correct Site Practices

Manual and electric bending equipment - preferred

Bends up to 180
Maximum D16 bar
63 mm bending roller

Bends of 90, 135 and 180
Maximum D20 bar
Roller diameter to suit

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Bending Reinforcement

Recent bending problem – soil anchors

AS 3600 requires 8 bar diameters for N32 galvanised bars – ie 256 mm dia. pin

Accept or reject?

Engineer prepared to certify? YES

Authority prepared to accept? NO

Pre-galvanised N32 bars bent around 47 mm diameter pin then cracking touched up with a zinc rich paint

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Re-bending Reinforcement (SRIA TN4)

Recent bending problem – column starter bars

Starter bars can be straightened in compliance with the provisions of Clause 17.2.3.1 of AS 3600.

- Use approved rebending tool
- Pipe of diameter 2d_b was able to be used - removed from current AS 3600 public comment draft
- Use single, smooth action
- Bend against flat surface or pin
- Never over-bend (typically 90°)
- Avoid impact from hammers etc

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Re-bending Reinforcement

AS 3600 Provisions – Clause 17.2.3.1

- Reinforcement must be bent around a pin of diameter complying with Clause 17.2.3.2
- Avoid impact loading and damage to surface of bar
- Reinforcement that has been bent and subsequently straightened or bent in the reverse direction shall not be bent again within 20 bar diameters of the previous bend
- Reinforcement partially embedded in concrete may be field-bent provided the bending complies with the above and the bond of the embedded portion is not impaired

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Re-bending Reinforcement

AS 4671:2001 Extract

Class L are bent around smaller pin diameter

Not rebent as far only 20 degrees as minimal adjustments in site application

TABLE 4

MANDREL DIAMETER AND ANGLE FOR BEND AND REBEND TEST

Nominal diameter (mm)	Mandrel diameter for ductility class			Bend angle	Bend angle after 90° initial bend
	L	N	E		
$d \leq 16$	$3d$			90°	20°
		$4d$	$4d$		90°
$d \geq 20$		$4d$	$4d$	180°	NA

SRIA Seismic Guide Extract

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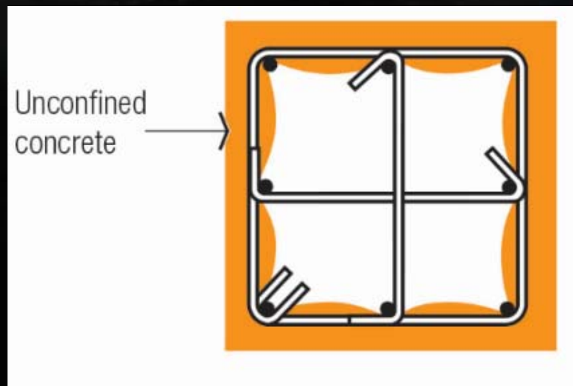

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Surface Condition of Reinforcement

Unacceptable?

Unacceptable

Severely corroded and pitted steel should not be used unless the material has been checked for strength and cross-sectional area limitations (SRIA TN1).

If in doubt, clean 1 m length and compare to weight in Table 5A of AS/NZS 4671

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Fabrication Tolerances

Clause 17.2.2 of AS 3600

Fitments (stirrups & ties):

Plain round bars and wire	-10mm	+0mm
Deformed bars & mesh	-15mm	+0mm

General (bar and mesh)

Length ≤ 600mm	-25mm	+0mm
Length > 600mm	-40mm	+0mm


Fixing Tolerance
Clause 17.5.3 of AS 3600
WHERE CONTROLLED BY COVER
Beams, slabs, columns, walls -5mm +10mm
Slabs-on-ground -10mm +20mm
Footings -10mm +40mm
(less cover – more cover)
OTHER
End of reinforcement -50mm +50mm
Spacing of reinforcement greater of 15mm, or
10% of specified spacing
Note: Designer is responsible to ensure steel can be placed to
within tolerances

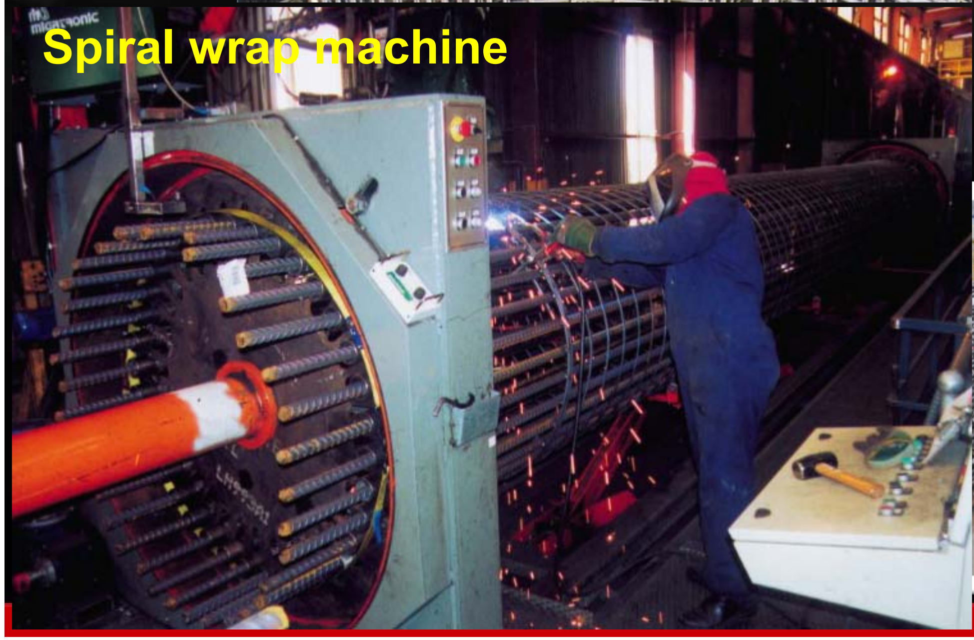
Welding of Prefabricated Reinforcement

Reduces congestion on site and speeds up construction

Airport rail link

Chatswood Station columns

Spiral wrap machine



Welding of Prefabricated Reinforcement

Often used for precast elements

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Welding of Prefabricated Reinforcement

Often used for difficult sites

Sea Cliff Bridge
(South coast NSW)

Welding of Prefabricated Reinforcement

Non-loadbearing locational welds are permitted on any bend

Must be done by person qualified to *AS/NZS 1554.3 Welding of reinforcing steel*, welding procedures

Acceptable / Unacceptable images courtesy of Welding Technology Institute of Australia (WTIA)

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Welding of Prefabricated Reinforcement

Types of AS/NZS 1554.3 welds used in the preassembly of reinforcing elements are:

- **Non-loadbearing welded joints** – in accordance with Section 3.3
  - These welds hold the cage during fabrication, transport & concreting
  - The welded joint strength does not contribute to the structure
- **Tack Welds** – in accordance with Clause 5.6
  - Used to hold parts of a weldment in alignment until final welds made
  - If left in place and included in prefabrication they have to meet Table 6.2. A new Note 7 is under consideration by WD-003 Committee which is likely to be "*Non-loadbearing welds shall not reduce the full loadbearing capacity of the structural elements (see Note 6)*".
  - Note 6 requirements ensure there is no loss of cross-sectional area or imperfections. If Tack welds are too small they will change the bar metallurgy underneath causing insufficient strength when lifted.
  - If removed properly – minimal (if any) impact.

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Welding of Prefabricated Reinforcement

Load bearing welds used for lifting points

- Must be designed by a suitably qualified person
- Must be approved by Design Engineer/Authority prior to lifting

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Welding of Prefabricated Reinforcement

EXAMPLE: TMR Qld Release 2011 "Engineering Certified Lifting Points for Transport and Main Roads Projects" for cages >500kgs

- Failures of reinforcing cages do occur from lifting incorrectly or poor non-loadbearing welding practices. Potential serious safety issue.
- TMR guidelines exist for welding cages not fabricated insitu
- Reinforcement design plans/shop drawings are certified by an RPEQ engineer:
  - highlighting location and design requirements for lifting points and welding requirements for the steel located around the lifting points.
  - Linked cage lifting points capacity is based on total mass.
  - Fabricated in accordance with the specification MRTS 71
  - Design to ensure the reinforcing cage remains rigid during the lifting and handling
- Each cage marked with a label identifying the cage type, mass, the design to which the cage was made and how the lifting points are identified.

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Welding of Prefabricated Reinforcement

Welding Technology Institute of Australia (WTIA) – Reinforcing steel welding coordinator course

- WTIA developed a one week welding supervisors course specifically tailored to the reinforcment industry.
- It is not an *AS 2214 Certification of welding supervisors* ticket, but is 1/3rd of the way there and used *ISO 14731 Welding Coordination* to identify key tasks and responsibilities which the course addresses.
- Improving weld quality compliance

TRAINING & CERTIFICATION

REINFORCED STEEL WELDING COORDINATOR COURSE

Industry has identified incidents of failures of manufactured reinforced steel structures due to poor weld quality. It has been determined that there is a requirement to have properly trained personnel to supervise and inspect the welding of reinforced steel structures used for construction.

This course has been developed to give the required knowledge to suitable personnel that will enable them to perform the required supervision. This is without having to complete the full Welding Supervisors training requirements as per AS 2214 Section 2 but will be certified to supervise specifically welding of Reinforced Steel only in accordance with AS/NZS 1554.3.

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AS 3600 Concrete structures Update

Draft for Public Comment: Commenced 21 Aug 17 & Closes 23 Oct 17

AS 3600 Update

Section 1 Scope and General

Clause 1.1.2 Application

- Higher reinforcing steel grades >500MPa to 800MPa meeting the requirements of Table 3.2.1 added

Table 3.2.1 Yield Strength & Ductility Class of Reinforcement

- NOTE added:
- For higher reinforcing steel grades permitted in Clause 1.1.2(d) the following characteristic properties shall be met:
  - i) The following limits for the chemical composition determined by cast analysis shall not be exceeded:

    Carbon – 0.33%, Phosphorus – 0.050%, Sulphur - 0.050%

    The Carbon equivalent value shall not exceed 0.49 by cast analysis
  - ii) the maximum yield strength does not exceed the nominal yield strength by more than 150 MPa
  - iii) for steels

    >500 MPa - 700 MPa

    uniform elongation $\varepsilon_{su} \geq 0.05$ and the tensile-to-yield stress ratio $R_m/R_e \geq 1.08$;

    >700 MPa - 800 MPa

    uniform elongation $\varepsilon_{su} \geq 0.04$ and the tensile-to-yield stress ratio $R_m/R_e \geq 1.04$

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AS 3600 Update

Section 2 Design Procedures, Actions and Loads

Clause 2.1.2 Design for Earthquake Actions

Where structures are required by AS 1170.4 to be designed for earthquake actions, they shall comply with that Standard, this Standard and the provisions of new Section 14 of this Standard

- AS 3600 Appendix C now becomes Section 14

Clause 2.1.3 Design for Robustness and Structural Integrity

When detailing of reinforcement and connections, members shall be effectively tied together to improve integrity of the overall structure.

- Requirements for structural integrity added
- Covers both cast-in-place and prefabricated concrete structures

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AS 3600 Update

Capacity Reduction Factors

TABLE 2.2.2

CAPACITY REDUCTION FACTORS (ϕ)

Type of action effect	Capacity reduction factor (ϕ)
(a) Axial force without bending:	
(i) Tension	
(A) members with Class N reinforcement and/or tendons	0.8
(B) members with Class L reinforcement	0.64
(ii) Compression	0.6
(b) Bending without axial tension or compression—	
(i) for members with Class N reinforcement and/or tendons	$0.6 \leq (1.19 - 13k_{uo}/12) \leq 0.8$
(ii) for members with Class L reinforcement	$0.6 \leq (1.19 - 13k_{uo}/12) \leq 0.64$
(c) Bending with axial tension—	
(i) for members with Class N reinforcement and/or tendons	$\phi + [(0.8 - \phi)(N_u/N_{uot})]$ and ϕ is obtained from Item (b)(i)
(ii) for members with Class L reinforcement	$\phi + [(0.64 - \phi)(N_u/N_{uot})]$ and ϕ is obtained from Item (b)(ii)
(d) Bending with axial compression, where—	
(i) $N_u \geq N_{ub}$	0.6
(ii) $N_u < N_{ub}$	$0.6 + [(\phi - 0.6)(1 - N_u/N_{ub})]$ and ϕ is obtained from Item (b)
(e) Shear	0.7
(f) Torsion	0.7
(g) Bearing	0.6
(h) Bending, shear and compression in plain concrete	0.6
(i) Bending, shear and tension in fixings	0.6
(j) Singly reinforced walls part of a primary lateral load resisting system	0.7
(k) Collector in Tension	0.6

NOTE: In members where Class L reinforcement together with Class N reinforcement and/or tendons are used as longitudinal tensile reinforcement in the design for strength in bending, with or without axial force, the maximum value of ϕ for calculating the member design strength should be taken as 0.64.

AS 3600 Update

Section 6 Methods of Structural Analysis

Clause 6.2.4 Stiffness

- Represent the conditions at the limit state being analysed
- Consistent with all loading conditions
- Generate critical worst-case actions under all failure modes to be considered
- Any assumptions regarding the relative stiffness of members shall be applied consistently throughout the analysis

Clause 6.2.4.1 Stiffness of lateral force resisting elements

- Requirements for the determination of the moment of inertia for flexural members, columns and walls
- Uncracked and cracked sections covered
- Cracked sections expressed as a proportion of *I*g (Table 6.2.4)

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AS 3600 Update

Section 8 Design of Beams for Strength and Serviceability

Clause 8.1.10 Maximum diameter of longitudinal beam bars in internal beam/column joint zones

- Requirements added where:
  - Earthquake actions need to be considered
  - No earthquake actions, or plastic regions cannot develop, adjacent to the face of the column

Clause 8.1.11.2 Distribution of reinforcement and integrity reinforcement

- Minimum requirements added for insitu construction

AS 3600 Update

Section 9 Design of Slabs for Strength and Serviceability

Clause 9.3.1.2 Deemed-to-comply arrangement for one-way slabs

- Extent of the bottom reinforcement extending into support defined
- Previously not defined

Clause 9.4 Structural Integrity Reinforcement - added

- Minimum bottom reinforcement requirements at walls and columns added to increase the resistance of the structural system to progressive collapse
- Not required if there are beams containing shear reinforcement and with at least two bottom bars continuous through the joint in all spans framing into the column

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AS 3600 Update

Section 10 Design of Columns for Strength and Serviceability

Clause 10.2.4 Design for shear

- Minimum requirements for shear reinforcement added

Clause 10.7.4.2 Lateral Restraint

- Arrangement of internal fitments clarified
- Limitations placed on the use of internal fitments having a cog at one end:
  - The design axial force $\leq \phi 0.3 A_g f'_c$
  - The characteristic concrete strength, $f'_c \leq 65$ MPa
- ISSUE: Cogs not anchored when (not if) spalling of cover concrete occurs

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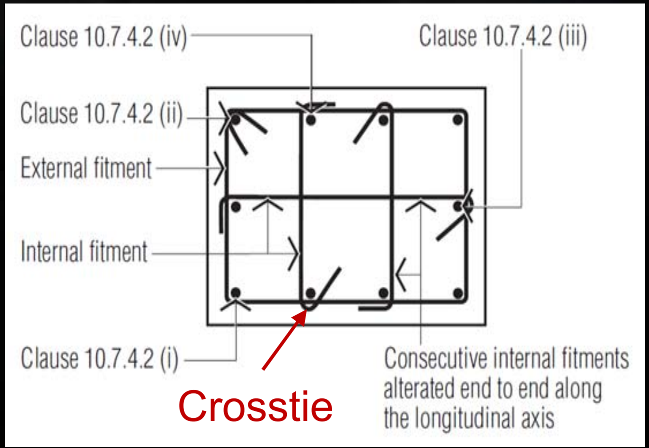
AS 3600 Update

Lateral restraint of longitudinal bars – IMRF's

Appendix C (IMRF) refers to 'closed ties'

However, no definition of closed tie within AS 3600:2009

- Closed tie definition now added
- Closed tie referred to in AS 3600-2001, where all ties are closed ties
- Crossties introduced in 2009 edition of Standard
- ISSUE: Was not clear whether these are 'closed ties' for use with IMRF's
- Internal fitments for IMRFs should have a 135° fitment hook at both ends



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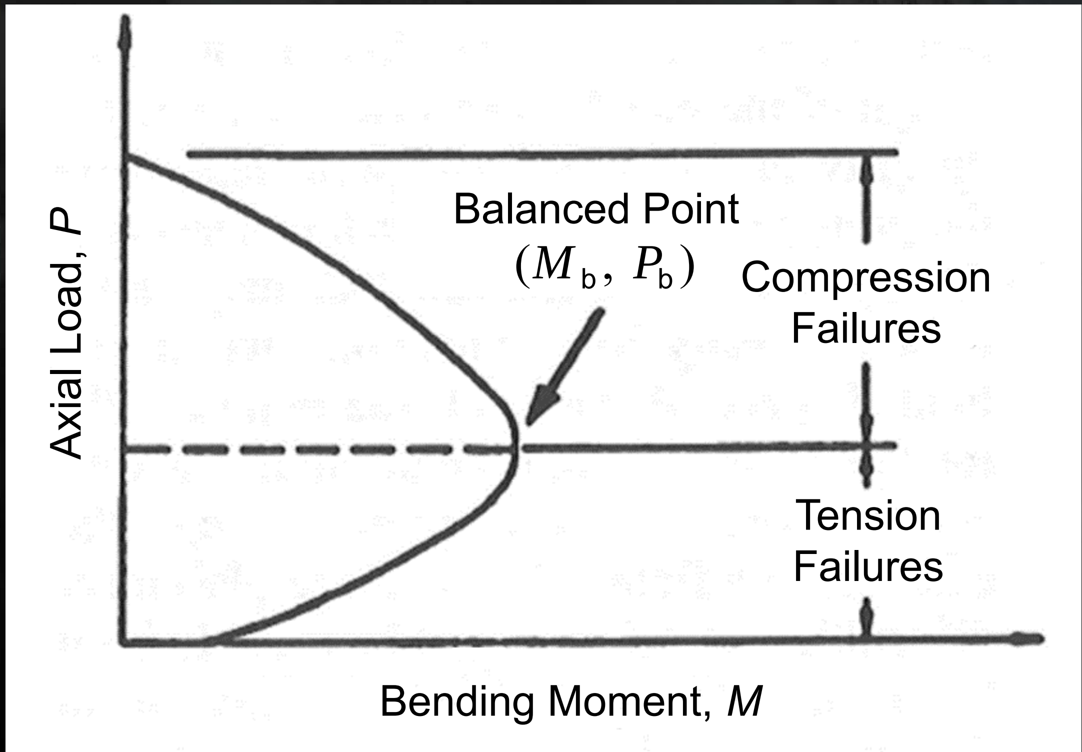
AS 3600 Update

Column Design

Don't push your column design too hard unless you have accounted for the drift induced ductility demands and have detailed accordingly.



IDEALLY: Design below balance point to ensure ductile tension failure,

or

Determine drift demand and include moment in design.

(ETABS won't do this)

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AS 3600 Update

Section 10 Design of Columns for Strength and Serviceability

Figure 10.7.4.3 Bar diameters for fitments and helices

- Minimum fitment diameter for 28 mm diameter bars now clarified
- Requires 12 mm fitment or helix (ACI 318M-14)
- Previously either 10 or 12 mm dia could be used

Clause 10.7.4.5 Column joint reinforcement

- Requirements clarified – where required and spacing

AS 3600 Update

Section 11 Design of Walls

Clause 11.2 Design Procedures

- Restrictions placed on the use of the simplified method
- For earthquake actions, when determining whether a wall cross section is under compression:
  - Use structural ductility factor, $\mu = 1.00$
  - Use structural performance factor, $S_p = 0.77$

Clause 11.5 Simplified design method for walls

- Clause 11.5.1 added placing limitations on the use of the method:
  - **Height ≤ 12 m**
  - When subject to earthquake action, **excludes site classes D_e and E_e**
  - **Effective height to thickness ratio** of:
    - 20 for singly reinforced walls
    - 30 for doubly reinforced walls
- **Otherwise**, required to design wall as a column

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AS 3600 Update

Section 11 Design of Walls

Clause 11.7.3 Spacing of Reinforcement

- Reinforcement provided in two grids if:
  - **Wall thicker than 200 mm**
  - **If tension exceeds the tensile capacity of the concrete under design ultimate loads.**
    - For earthquake actions, assessment based on:
      - structural ductility factor, $\mu = 1.00$
      - structural performance factor, $S_p = 0.77$
  - **Height > 12 m**

Clause 11.7.4 Restraint of vertical reinforcement

- For walls with a concrete strength > 50 MPa

  Restraint to be in accordance with Clause 14.5.4 ie closed ties.

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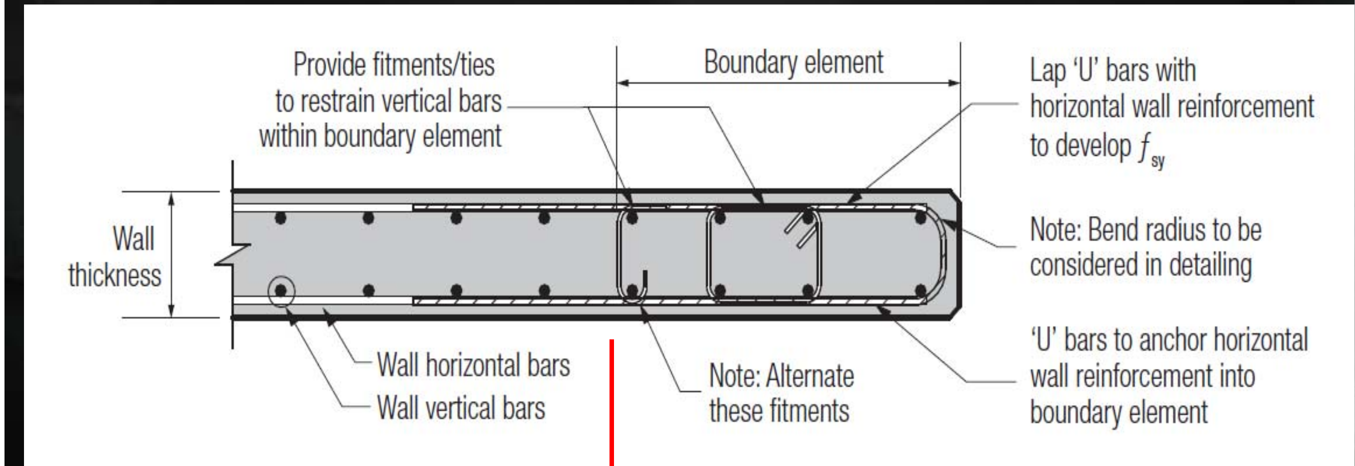
AS 3600 Update

Shear Wall boundary element required for IMRF if:

- Vertical reinforcement is not laterally restrained in accordance with Clause 10.7.4, and
- Extreme fibre compressive stress $> 0.15 f_c'$



Compressive stress $> 0.15 f_c'$

If extreme fibre compressive stress $> 0.2 f_c'$, detail wall as a column

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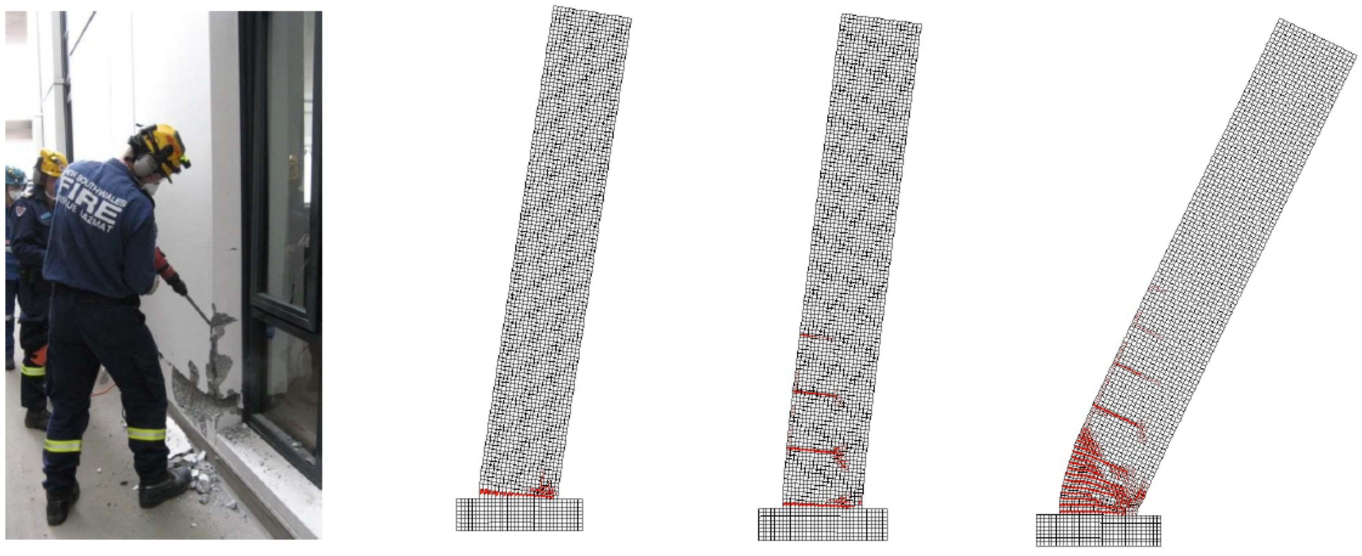
AS 3600 Update

Ductile Shear Walls

Clause C5 of AS 3600 - Horizontal and vertical reinforcement ratio ≥ 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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AS 3600 Update

Ductile Shear Walls

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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AS 3600 Update

Section 14 Requirements for Structures Subject to Earthquake Actions

Essentially existing Appendix C (with additions and corrections)

- Structures with IL 4 designed for μ > 2 with appropriate detailing
- Classification of structural walls expanded
  - Non ductile (S_p/μ = 0.77)
  - Limited ductile (S_p/μ = 0.38 no change)
  - Moderately ductile (S_p/μ = 0.22 - previously ductile shear walls)
  - Ductile (μ = 4 and S_p/μ = 0.17, so beyond scope of Standard)

    Design required to NZS 1170.5 and NZS 3101 + Ductility Class E

Table 14.3 New classifications added and S_p/μ factors amended

Note difference between designing for seismic and wind loads.

Clause 14.4.2 Inter-storey drift (added)

- General requirements – horizontal drift, relative movement, ductility & rotational capacity

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AS 3600 Update

Section 14 Requirements for Structures Subject to Earthquake Actions

Clause 14.4.3 Ordinary moment-resisting frames

- Requirements for OMRF (beams and columns) now in Section 14

Clause 14.4.4.3 Structural walls

- Limits simplified design method to non-ductile walls
- Limit on axial load $N^* / A_g \leq 0.2 f'_c$

Clause 14.4.5 Diaphragms

- Determination of inertia forces

Clause 14.4.6 Ductility of flexural members with 1.25 < $\mu \leq 3$

- Requirements for plastic hinge zones

Clause 14.5.4 Columns

- Maximum fitment spacing for IMRFs above and below slabs corrected
- Where $P_u > \phi 0.3 A_g f'_c$ or $f'_c \geq 65$ MPa

  each longitudinal bar shall be restrained by a 'closed fitment'

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AS 3600 Update

Section 14 Requirements for Structures Subject to Earthquake Actions

Clause 14.5.6 Robustness and Structural Integrity (added)

- Stairs and ramps
- Moment resisting frames (strong column/weak beam)
  - Only for IMRFs
  - Only where columns form part of the lateral seismic force-resisting system

Olive View Hospital
San Fernando Earthquake, 1971

Collapsed stairs to the Hotel Grand Chancellor

(Photograph courtesy of Dunning Thornton Consultants Ltd, NZ)

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AS 3600 Update

Section 14 Requirements for Structures Subject to Earthquake Actions

Strong column/weak beam requirement

- Column strength ≥ 1.2 times beam strength
- To promote preferred side sway mechanism

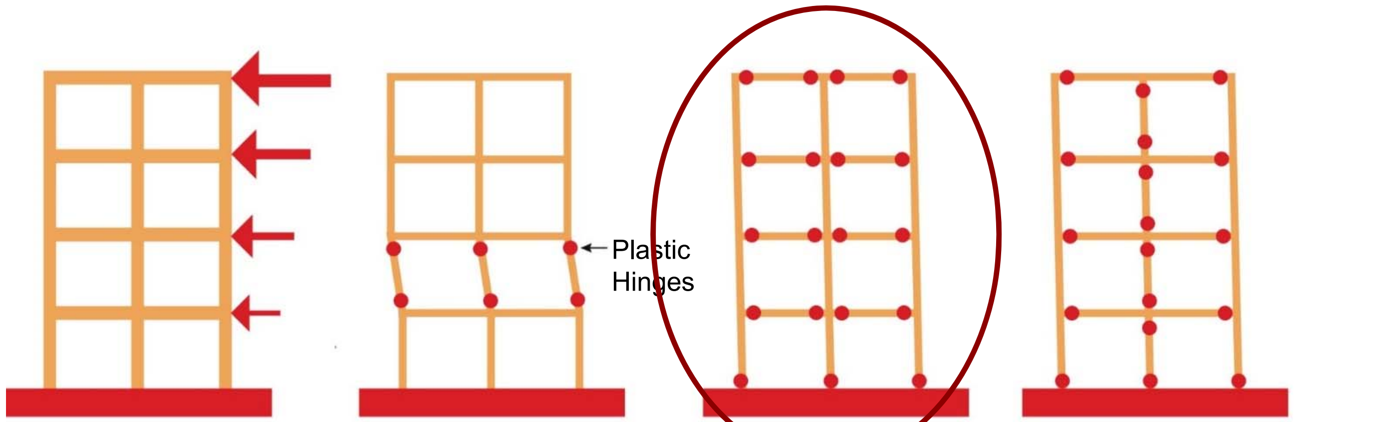

Figure 19 — Column, beam and mixed sidesway mechanisms

(after Goldsworthy)

AS 3600 Update

Section 15 Diaphragms

Clause 15.2 Design Actions

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

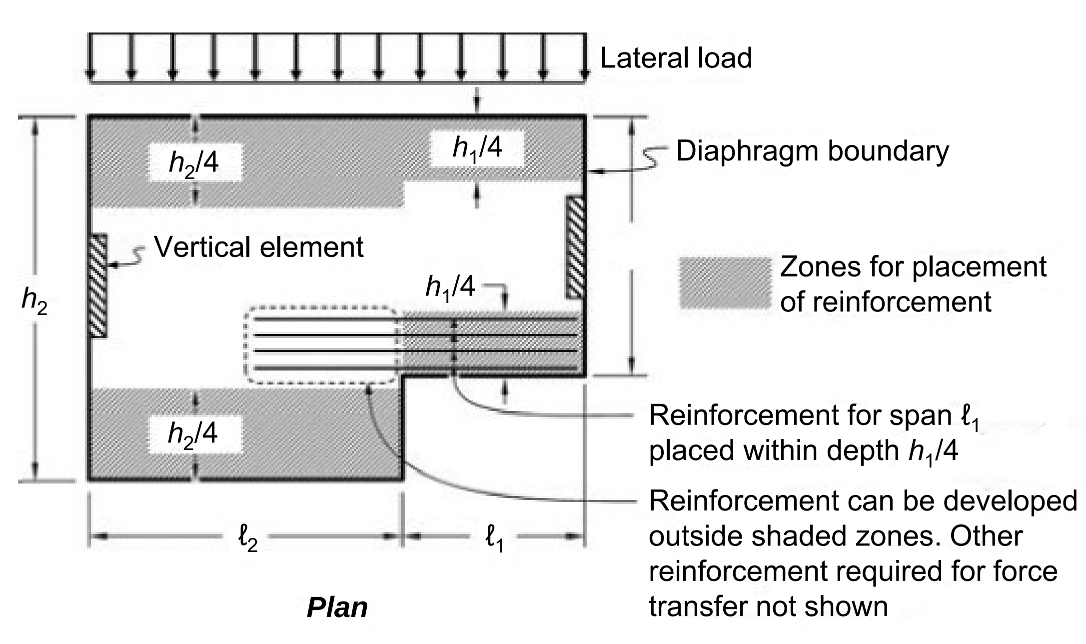

Figure R12.5.2.3 from ACI 318M-14

Clause 15.3 Cast-in-place toppings

- By itself - Minimum thickness of 75 mm and reinforced for loading
- Compositely with precast elements:
  - Minimum thickness 65 mm
  - Reinforce to act compositely with precast elements

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AS 3600 Update

Section 15 Diaphragms

Clause 15.4 Diaphragm reinforcement

- Minimum – in accordance with Clause 9.4.3
- Spacing – in accordance with Clause 9.4.1
- Development and laps – sufficient to transfer forces
- Collectors – reinforce to transfer loads into shear-resisting elements
- Construction joints – reinforcement must transfer forces across joint

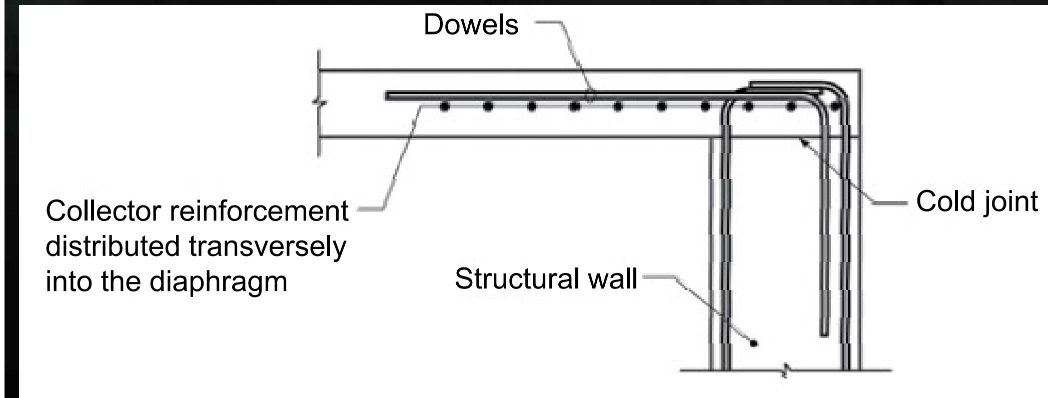

Figure R12.5.3.7 of ACI 318M-14

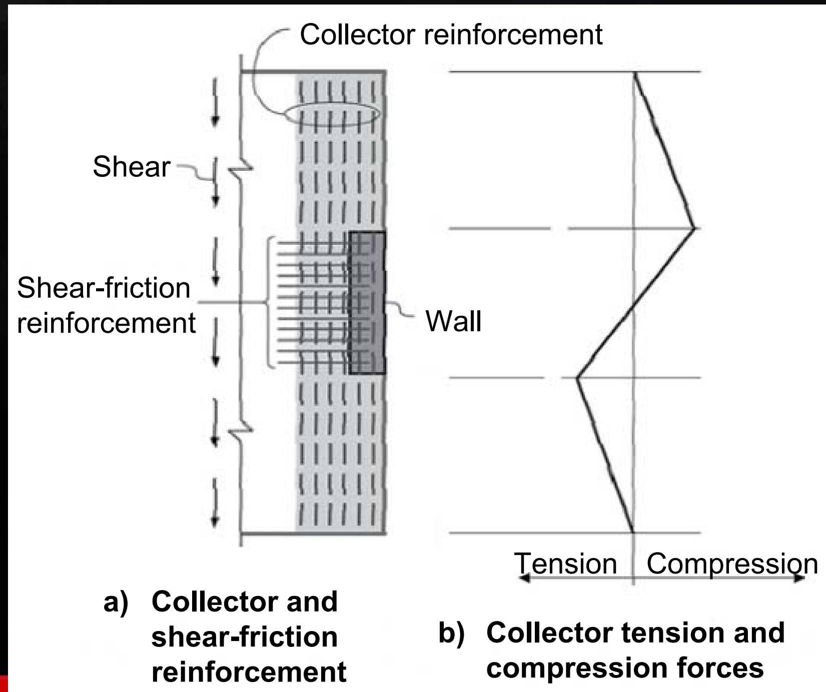

Figure R12.5.4.1 of ACI 318M-14

AS 3600 Update

Section 17 Material and Construction Requirements and Prefabricated Concrete

Clause 17.7 Prefabricated Concrete Structures

- Minimum provisions for structural integrity
  - Minimum connection capacities
  - Requirements for vertical tension ties
  - Connections that rely on friction from gravity loads not allowed
- Minimum requirements for bearing wall structures ≥ two storeys
- Requirements for:
  - Longitudinal and transverse ties
  - Vertical tension ties
- Requirements for grouted ducts
- Requirements for seating of floor elements
  - Minimum 1.5 times the Ultimate Limit State drifts

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AS 3600 Update

Grouted Ducts

Crowne Plaza Hotel, Christchurch

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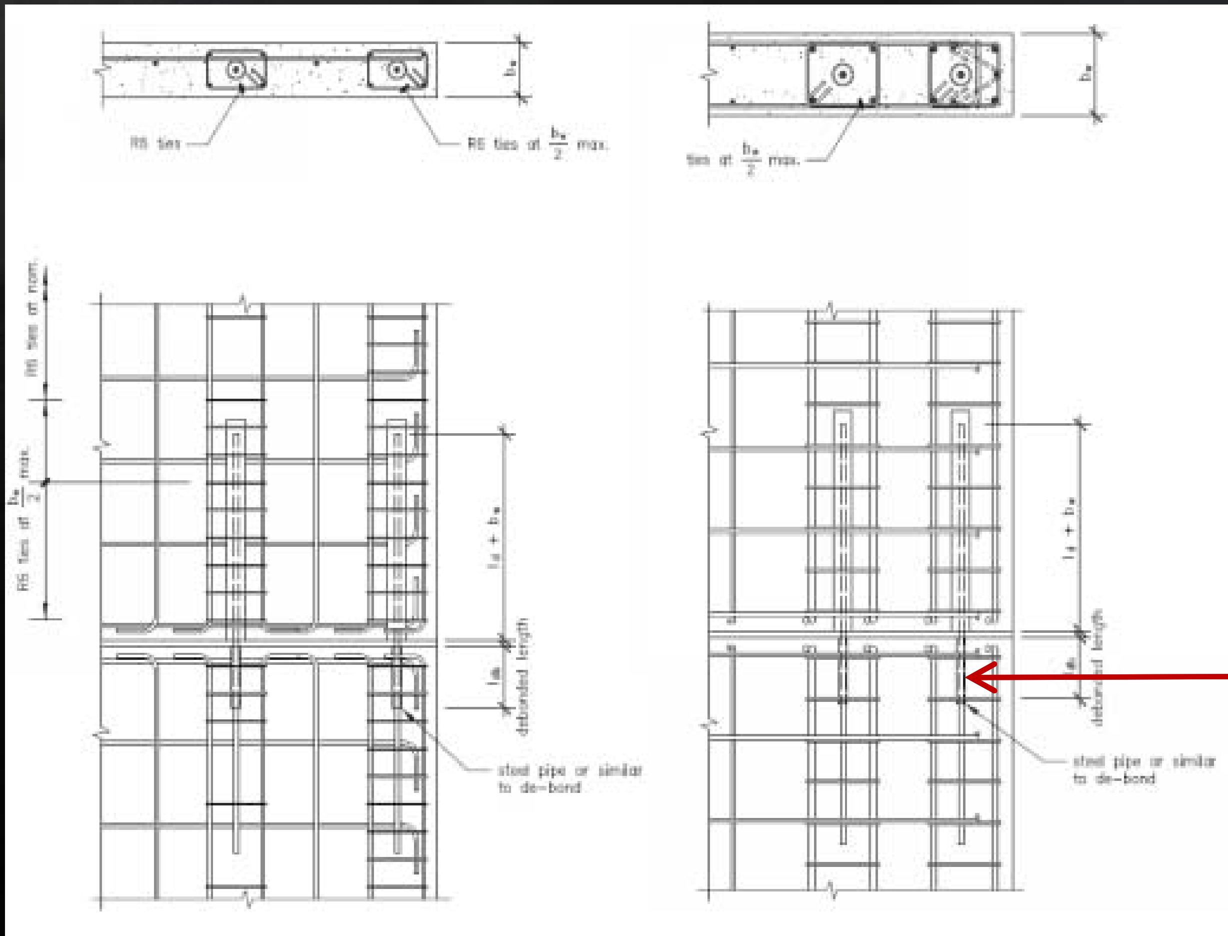
AS 3600 Update

SESOC 2012 Recommendations



Steel pipe or similar to de-bond grouted dowel bar

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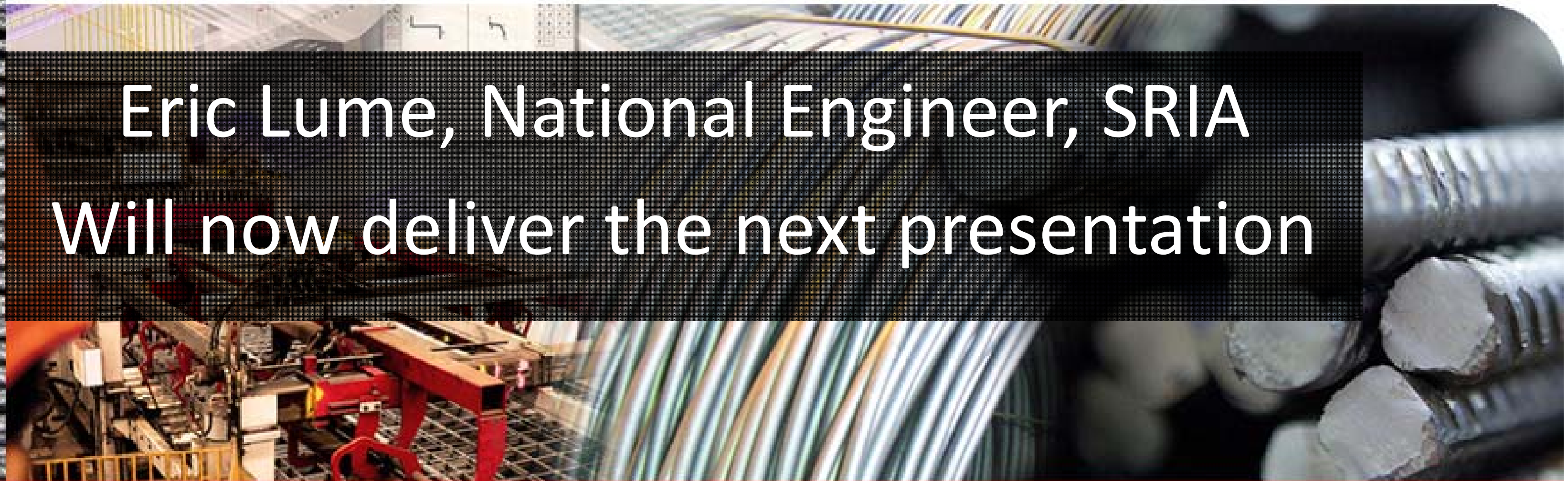
ENGINEERS AUSTRALIA

Thank you



Eric Lume, National Engineer, SRIA

Will now deliver the next presentation

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Tensile Development and Lap Splice Lengths

Eric Lume

National Engineer, SRIA

AS 3600 Section 13

Tensile development length – basic

$$L_{sy.tb} = \Psi_{bc}\Psi_{cd}\Psi_{sf}\frac{0.5k_1k_3 f_{sy}d_b}{k_2\sqrt{f_c'}} \geq 29k_1d_b$$

where :

k_1 = factor to allow for bond conditions

= 1.3 if ≥ 300 mm of concrete is cast below a non - vertical bar

= 1.0 otherwise

k_2 = factor to allow for bar diameter $= \frac{132 - d_b}{100}$

k_3 = factor to allow for cover and bar spacing

$= 1.0 - \frac{0.15(c_d - d_b)}{d_b}$ such that $0.7 \leq k_3 \leq 1.0$

$c_d =$ minimum c or $\frac{a}{2}$

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AS 3600 Section 13

Maximum value of $f'_c \leq 65$ MPa

- Clause 25.4.1.4 of ACI 318M-14: $\sqrt{f'_c} \leq 8.3$ MPa $\left(f'_c \approx 65 \text{ MPa} \right)$
- Development and lap splice tests indicate that force developed in a bar increases at a lesser rate than $\sqrt{f'_c}$ with increasing compressive strength
- Using $\sqrt{f'_c}$ sufficiently accurate for $\sqrt{f'_c}$ values up to 8.3 MPa
- AS 3600 Commentary Clause 13.1.2.2

  $L_{\text{sy.tb}}$ unreliable for $f'_c > 65$ MPa due to lack of data

$L_{\text{sy.tb}}$ multiplied by :

Ψ_{bc} = 1.5 for epoxy-coated bars; and

Ψ_{cd} = 1.3 when lightweight concrete is used; and

Ψ_{sf} = 1.3 for all structural elements built with slip forms

Note that in the current TN7 the symbol ξ (xi) is used

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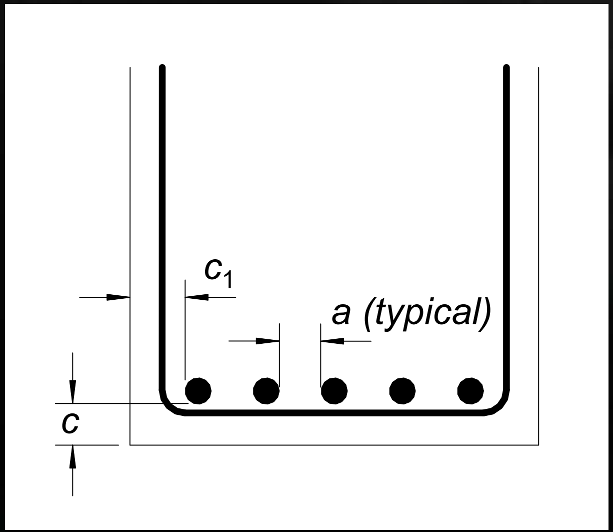
AS 3600 Section 13

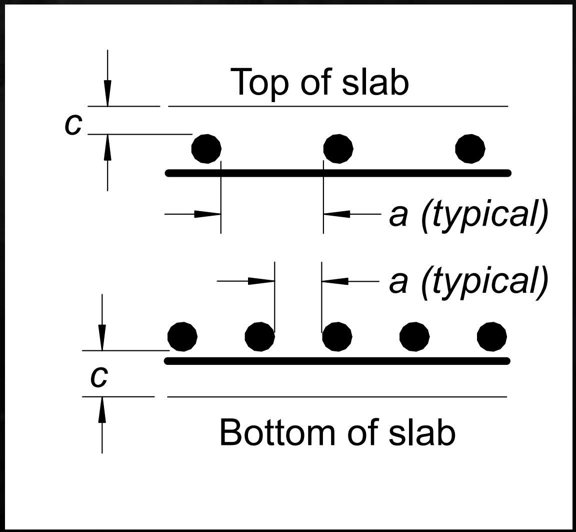
Value of c_d

A dimension equal to the lesser of:

- The least clear concrete cover to the bars in narrow elements or members: *c* or c_1
- The least bottom cover for wide elements, *c*
- Half the clear distance between parallel bars developing stress, *a*/2



Narrow elements/members



Wide elements/members

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AS 3600 Section 13

Tensile development length – refined

$$L_{sy.t} = k_4 k_5 L_{sy.tb}$$

where :

k_4 = factor for effect of transverse reinforcement

$= 1.0 - K\lambda$ with $(0.7 \leq \lambda \leq 1.0)$

$= 1.0$ with no transverse reinforcement

$$\lambda = \frac{\left(\sum A_{tr} - \sum A_{tr.min}\right)}{A_s} \text{ where } A_{tr.min} = \frac{A_s}{4} \text{ when } K > 0$$

k_5 = factor for effect of transverse pressure

$= 1.0 - 0.04\rho_p$ with $(0.7 \leq k_5 \leq 1.0)$

ρ_p = 0 to maximum 7.5 MPa

$$k_3 k_4 k_5 \geq 0.7$$

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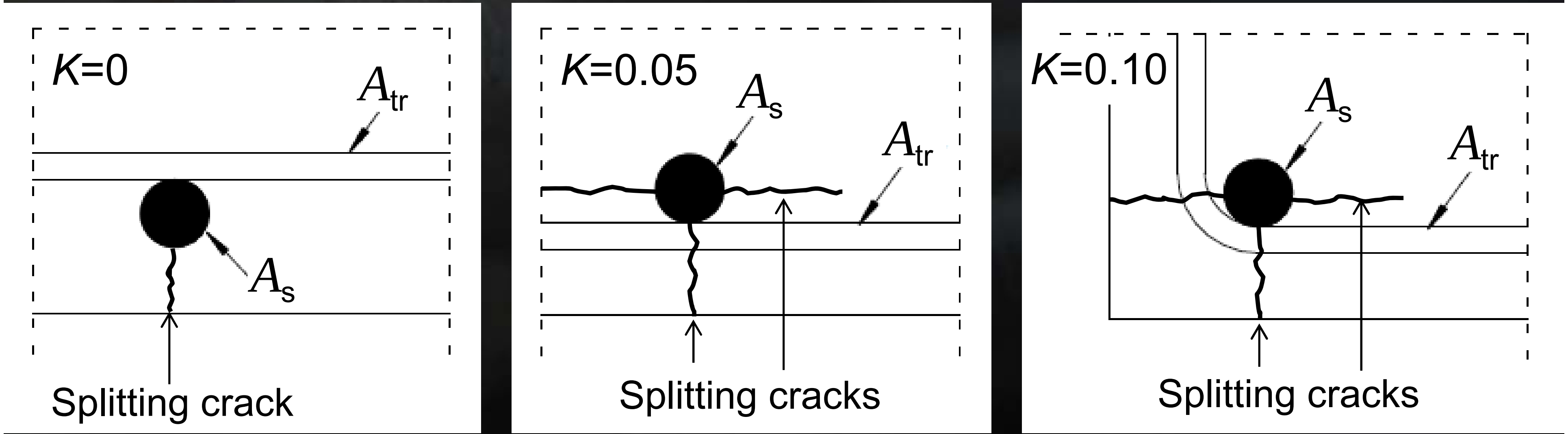
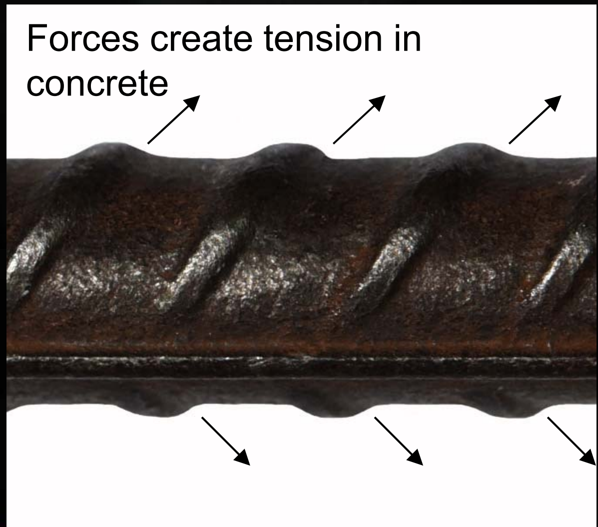
AS 3600 Section 13

***K* factor – allows for effectiveness of transverse reinforcement to control splitting cracks (value depends on bar location)**



AS 3600 currently requires use of different *K* values depending on bar location



(after Figure 13.1.2.3(B) of AS 3600)

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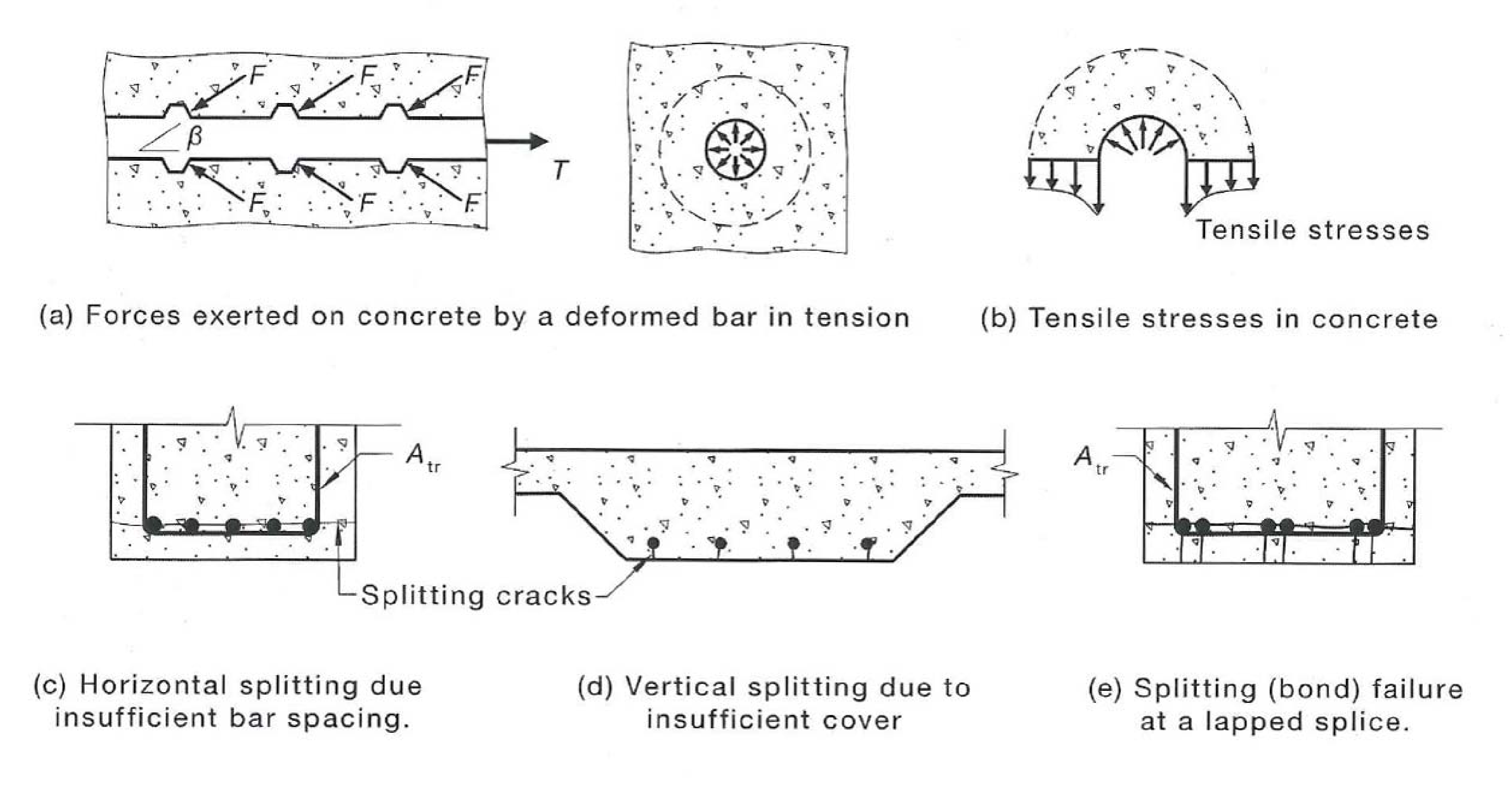
AS 3600 Section 13

Splitting failures around developing bars

(Figure C13.1.1 from AS 3600 Commentary)



AS 3600 Section 13

Tensile development length – refined

Can be less than $29k_1d_b$ if either k_4 or k_5 is less than 1, as minimum $29k_1d_b$ length not placed on Equation 13.1.2.3

$$L_{sy.t} = k_4k_5L_{sy.tb} \qquad \text{(Equation 13.1.2.3)}$$

Note that $L_{sy.tb}$ still has a minimum value of $29k_1d_b$

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Tensile Development and Lap Splice Lengths

Note: Basic Tables contained in Detailing Handbook

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TN 7 - Background Information

Multiplication factors for $L_{sy.tb}$

- Ψ_{cd} and Ψ_{bc} taken from ACI 318-05 (concrete density, bar coating)
- Ψ_{sf} taken from Eurocode 2 Part 1.1 (slip form construction)
- Eurocode 2 includes Ψ_{sf} in k_1 factor

Therefore:

$$L_{sy.tb} = \Psi_{bc}\Psi_{cd}\frac{0.5k_1k_3 f_{sy}d_b}{k_2\sqrt{f_c'}} \geq 29k_1d_b$$

Note: Factors Ψ_{bc} and Ψ_{cd} do not apply to minimum value of $29k_1d_b$

- Minimum $29k_1d_b$ relates to upper limit of bond strength due to bar pull-out rather than concrete splitting failure

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TN 7 - Background Information

Factor Ψ_{bc} for bar coating

- AS 3600 only mentions factor of 1.5 for epoxy coating
- ACI 318M-14 has a range of options:

Value of bar coating factor, ψ_{bc} (from Table 25.4.2.4 of ACI 318M-14)

Value of factor k_4	Condition
1.5	Epoxy-coated or zinc and epoxy dual-coated reinforcement with clear cover less than $3.0d_b$ or clear spacing less than $6.0d_b$
1.2	Epoxy-coated or zinc and epoxy dual-coated reinforcement for all other conditions
1.0	Uncoated or zinc-coated (galvanised) reinforcement

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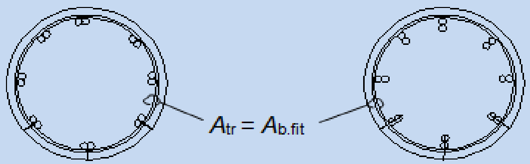
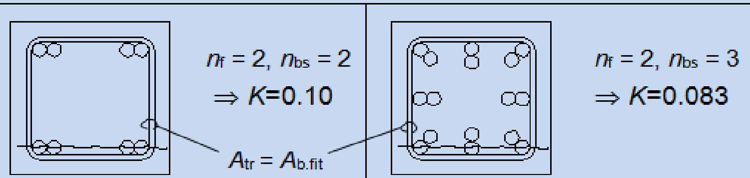
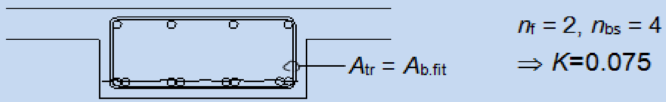
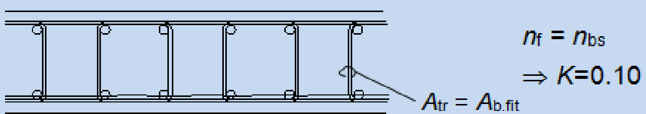
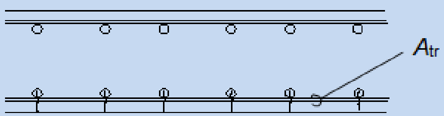
TN 7 - Background Information

k_4 factor $\quad k_4 = 1.0 - K\lambda \;\text{ with }\; (0.7 \le \lambda \le 1.0)$

Use of average K value $\quad K = 0.05 \times \left(1 + \dfrac{n_f}{n_{bs}}\right) \le 0.10$

Figure A.3 from SRIA TN 7

Member type	Examples of potential splitting cracks at a tensile face	n_f	n_{bs}	K (see Note 1)
Circular column		1	1	0.10
Rectangular column		≥1	≥1	$0.05 \le K \le 0.10$
Beam		≥1	≥1	$0.05 \le K \le 0.10$
Slab or wall with fitments		≥1	≥1	$0.05 \le K \le 0.10$
Slab or wall without fitments		0	1 per main bar spacing	0.05 (see Note 2)

TN 7 - Background Information

Bar areas used in determining refined factor k_4

$$k_4 = 1.0 - K\lambda \quad \text{with} \quad (0.7 \le \lambda \le 1.0)$$

$$\lambda = \frac{\left(\sum A_{\text{tr}} - \sum A_{\text{tr.min}}\right)}{A_{\text{s}}} \quad \text{where} \quad A_{\text{tr.min}} = \frac{A_{\text{s}}}{4} \quad \text{when } K > 0$$

Bar diameter mm	Cross-sectional area mm^2
L10	71
N10	78
N12	113
N16	201
N20	314
N24	452
N28	616
N32	804
N36	1020
N40	1260

TN 7 - Background Information

k_5 factor

$$k_5 = \text{factor for effect of transverse pressure}$$

$$= 1.0 - 0.04\rho_p \quad \text{with} \quad (0.7 \le k_5 \le 1.0)$$

$$\rho_p = 0 \text{ to maximum } 7.5 \text{ MPa}$$

- Compressive stress perpendicular to the longitudinal axis of the bar improves bond strength
- Strong influence if confinement sufficient to restrain splitting failure mode
- Once this point is reached, the rate of increase reduces

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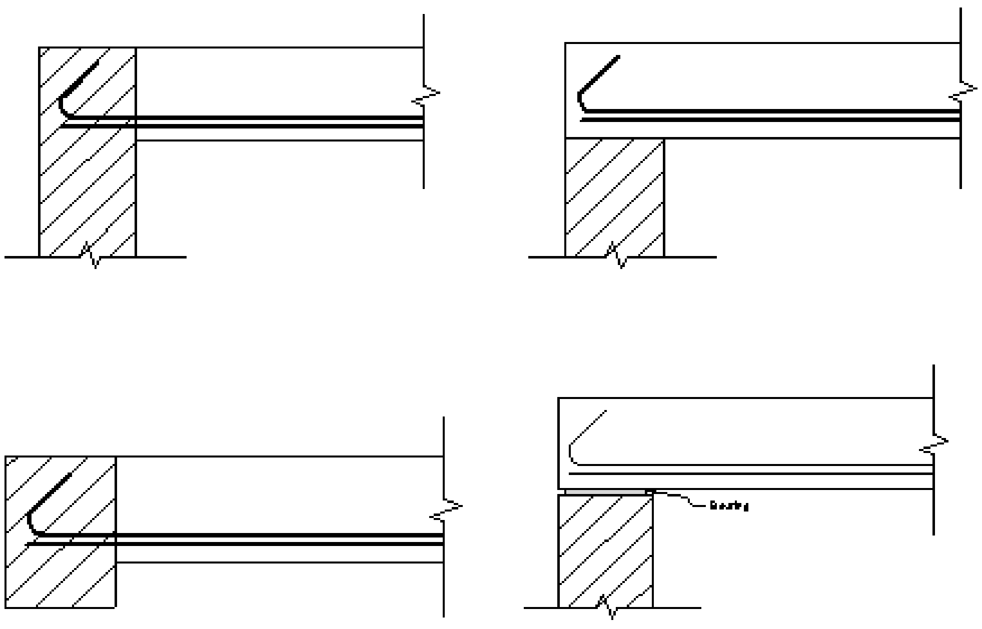
TN 7 - Background Information

k_5 factor

- Influence restricted to support region where the clamping pressure along the face where the stress is applied acts to confine the bars
- Ignore influence for indirect end support conditions
- Ignore influence for cogged and hooked portions of bars that are parallel to direction of compressive stress



Indirect end support   Direct end support

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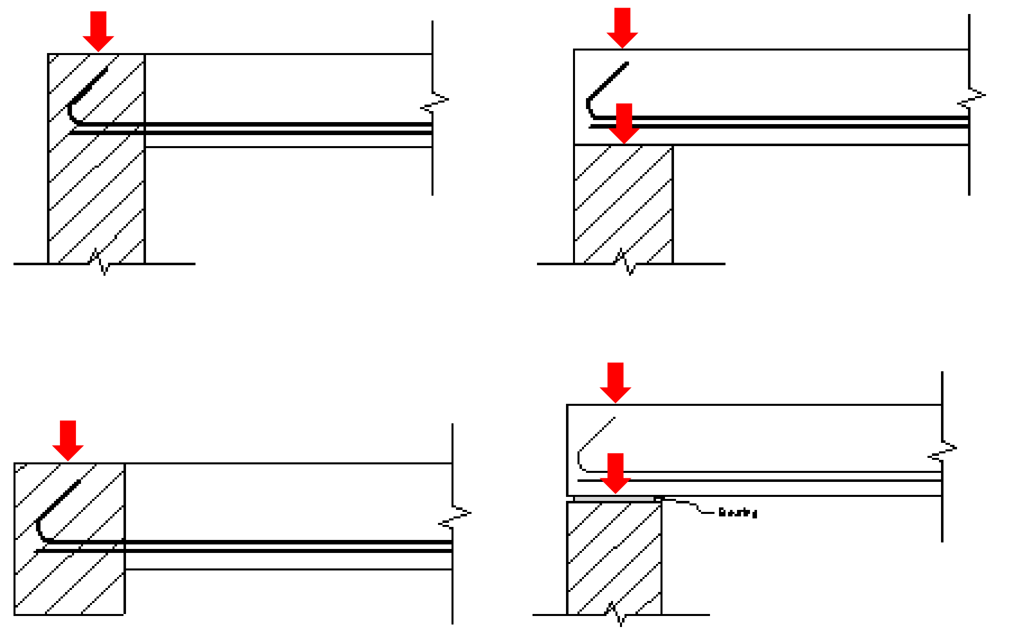
TN 7 - Background Information

k_5 factor

- When considering loads from upper storeys:
  - For indirect end support, ignore stress from floor in question
  - For direct end support, consider compressive stress from entire reaction acting at the soffit of the floor member



Indirect end support

Direct end support

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TN 7 - Background Information

Developing less than the yield strength – Equation 13.1.2.4

$$L_{st} = L_{sy.t} \frac{\sigma_{st}}{f_{sy}}$$

For k_4 and $k_5 = 1.0$

$$L_{st} = \max.\left(\frac{0.5 k_1 k_3 f_{sy} d_b}{k_2 \sqrt{f'_c}} \text{ and } 29 k_1 d_b \right) \frac{\sigma_{st}}{f_{sy}}$$

L_{st} shall not be less than:

- 12 d_b ; or
- For slabs, as permitted by Clause 9.1.3.1(a)(ii)

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TN 7 – Tensile Lap Splices

Tensile lap length (basic or refined) – Clause 13.2.2 of AS 3600

$$L_{\text{sy.t.lap}} = k_7 L_{\text{sy.t}} \geq 29 k_1 d_{\text{b}} \quad (\text{Note: } L_{\text{sy.t}} = L_{\text{sy.tb}} \text{ or } L_{\text{sy.t}})$$

For narrow elements:

$$L_{\text{sy.t.lap}} = \min.\left[k_7 L_{\text{sy.t}},\ k_7 L_{\text{sy.t}} + 1.5 s_{\text{b}},\ 29 k_1 d_{\text{b}}\right]$$

When calculating $L_{\text{sy.t}}$, minimum $29 k_1 d_{\text{b}}$ does not apply to $L_{\text{sy.tb}}$

$$L_{\text{sy.tb}} = \Psi_{\text{bc}} \Psi_{\text{cd}} \frac{0.5 k_1 k_3 f_{\text{sy}} d_{\text{b}}}{k_2 \sqrt{f'_{\text{c}}}} \geq 29 k_1 d_{\text{b}}$$

- k_7 – factor for staggered laps and bar stress levels

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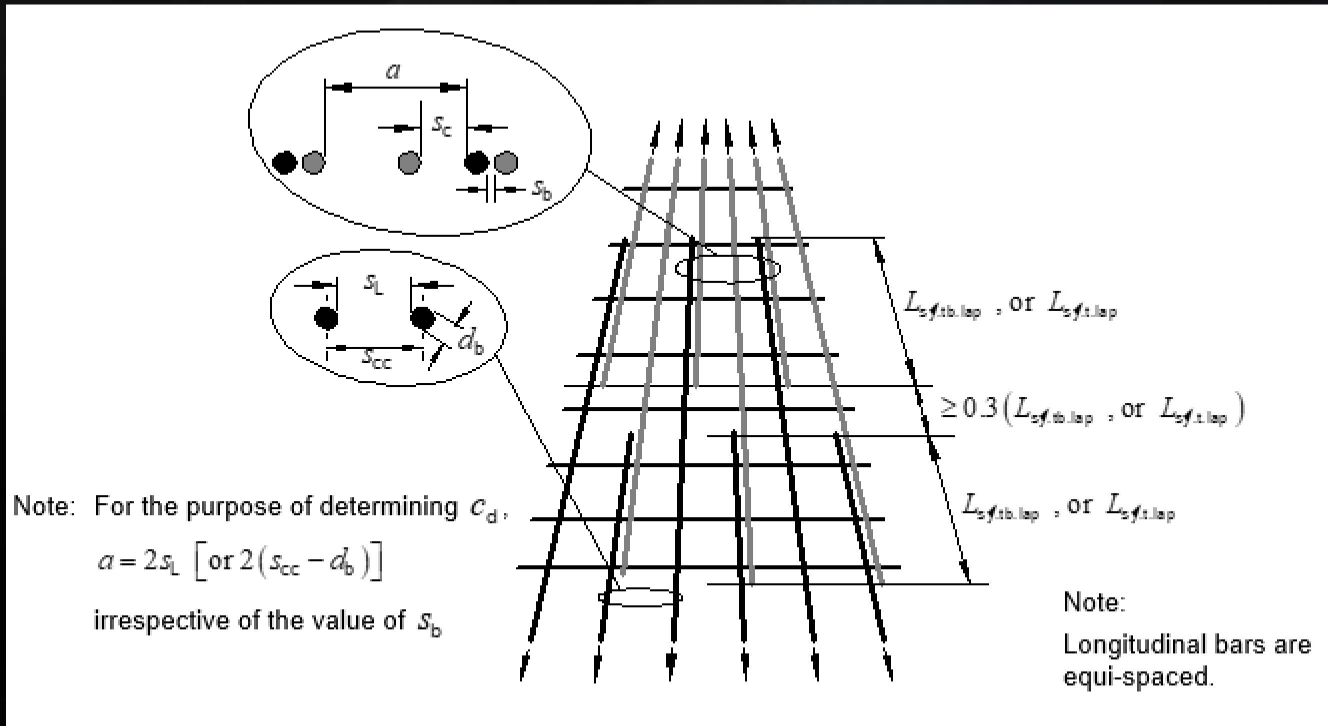
TN 7 – Tensile Lap Splices

Tensile lap length (basic or refined)

- k_7 = 1.0 if the cross-sectional area of the bars outside the laps equals at least twice the area required for strength, and no more than half the bars are lapped at any section
- k_7 = 1.25 otherwise



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TN 7 – Tensile Lap Splices

Tensile lap length (basic or refined)

- Bars of different sizes – lapped splice length equals:
  - Tensile lapped splice length of smaller bar
  - Development length of larger bar
- Minimum clear distance between bars:
  - 1.5 x nominal maximum aggregate size
  - 1.5 x bar diameter
- Clear distance between lapped bars, s_b:
  - If $s_b \le 3d_b$, or for narrow elements, treated as contact splice
  - For non-contact lapped splices, no upper limit specified in AS 3600
  - ACI 318M-14 Clause 25.5.1.3 specifies upper limit:

$$s_b = \text{ lesser of } \left[150 - d_b, \; \frac{L_{sy.tb.lap} \text{ or } L_{sy.t.lap}}{5} - d_b \right]$$

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TN 7 – Design Tables

3 Groups of Design Tables provided:

- General, Cover-controlled and Spacing-controlled
- Cover-Controlled and Spacing-controlled are subsets of the General Design Tables
- Recommend using General Design Tables
- Underlying assumptions need to be met to use either Cover-controlled or Spacing-controlled Design Tables
- All Tables based on plain uncoated bars and normal density concrete
  - Need to apply Ψ_{bc} and Ψ_{cd} factors

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TN 7 – Design Tables

All Design Tables provide:

- Basic development and lapped splice lengths
- Minimum possible refined development and lapped splice lengths

  Actual value depends on each individual circumstance
- c_d values up to 100 mm

  Based on Clause 8.6.1(b) of AS 3600 – distance to the centre of the nearest longitudinal bar not to exceed 100 mm
- Bar sizes up to 40 mm

  Based on Clause 13.2.1(e) of AS 3600 – lapped splices shall not be used for bars in tension with diameter > 40 mm
- For minimum cover based on bar size (*c* not less than *d*)
- Values rounded to the nearest 10 mm
- Maximum $f'_c \leq 65 \text{ MPa}$

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TN 7 – Design Tables

TN 7 - Benefit of refined calculation (Table B.2)

$$(k_4 k_5)_{\text{min}} = 1.0 \ \text{ if } \ k_3 = 0.7 \ (\text{as } 0.7 \le k_3 k_4 k_5 \le 1.0)$$

Table B.2 – *Unique, minimum values of refined factors product, k_4k_5, which apply to the solutions in every General Table with one-to-one correspondence*

	N10	N12	N16	N20	N24	N28	N32	N36	N40
C_d	MINIMUM REFINED FACTORS PRODUCT $(k_4k_5)_{min}$								
20	0.82	0.78	0.73	0.70	0.70	0.70	0.70	0.70	0.70
25	0.90	0.84	0.76	0.73	0.70	0.70	0.70	0.70	0.70
30	1.00	0.90	0.81	0.76	0.73	0.71	0.70	0.70	0.70
35	1.00	0.98	0.85	0.79	0.75	0.73	0.71	0.70	0.70
40	1.00	1.00	0.90	0.82	0.78	0.75	0.73	0.71	0.70
45	1.00	1.00	0.96	0.86	0.81	0.77	0.75	0.73	0.71
50	1.00	1.00	1.00	0.90	0.84	0.79	0.76	0.74	0.73
55	1.00	1.00	1.00	0.95	0.87	0.82	0.78	0.76	0.74
60	1.00	1.00	1.00	1.00	0.90	0.84	0.81	0.78	0.76
65	1.00	1.00	1.00	1.00	0.94	0.87	0.83	0.80	0.77
70	1.00	1.00	1.00	1.00	0.98	0.90	0.85	0.82	0.79
75	1.00	1.00	1.00	1.00	1.00	0.94	0.88	0.84	0.81
80	1.00	1.00	1.00	1.00	1.00	0.97	0.90	0.86	0.82
85	1.00	1.00	1.00	1.00	1.00	1.00	0.93	0.88	0.84
90	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.90	0.86
95	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.93	0.88
100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.95	0.90

TN 7 – Design Tables

Technical Note 7 – Example of General Design Tables

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TECHNICAL NOTE 7

STRESS DEVELOPMENT AND LAP SPLICING OF STRAIGHT D500N TENSILE REINFORCING BARS TO AS 3600-2009

TECHNICAL NOTE 7

December 2016

TABLE G/20/1.0/1.00 – Tensile Development and Lap Lengths | f'_c=20 MPa, k_1=1.0, k_7=1.00 {Eq. 1c: ξ_{cd}=1.0, ξ_{bc}=1.0}

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC DEVELOPMENT LENGTH (mm) $L_{sy.tb}$								
20	390	500	740	1000	-	-	-	-	-
25	360	470	710	960	1230	-	-	-	-
30	320	430	670	920	1200	1490	-	-	-
35	"	400	630	890	1160	1450	1760	-	-
40	"	390	600	850	1120	1410	1720	2060	2430
45	"	"	560	810	1080	1370	1680	2020	2380
50	"	"	540	770	1040	1330	1640	1970	2340
55	"	"	"	740	1000	1290	1600	1930	2290
60	"	"	"	700	960	1250	1550	1890	2250
65	"	"	"	"	920	1210	1510	1840	2200
70	"	"	"	"	890	1170	1470	1800	2160
75	"	"	"	"	870	1130	1430	1760	2110
80	"	"	"	"	"	1090	1390	1710	2070
85	"	"	"	"	"	1050	1340	1670	2020
90	"	"	"	"	"	"	1300	1620	1970
95	"	"	"	'	"	"	1260	1580	1930
100	"	"	"	"	"	"	1250	1540	1880

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUN REFINED DEVELOPMENT LENGTH (mm) $L_{sy.t.min}$								
20	320	390	540	700	-	-	-	-	-
25	320	390	540	700	870	-	-	-	-
30	320	390	540	700	870	1050	-	-	-
35	"	390	540	700	870	1050	1250	-	-
40	"	390	540	700	870	1050	1250	1470	1700
45	"	"	540	700	870	1050	1250	1470	1700
50	"	"	540	700	870	1050	1250	1470	1700
55	"	"	"	700	870	1050	1250	1470	1700
60	"	"	"	700	870	1050	1250	1470	1700
65	"	"	"	"	870	1050	1250	1470	1700
70	"	"	"	"	870	1050	1250	1470	1700
75	"	"	"	"	870	1050	1250	1470	1700
80	"	"	"	"	"	1050	1250	1470	1700
85	"	"	"	"	"	1050	1250	1470	1700
90	"	"	"	"	"	"	1250	1470	1700
95	"	"	"	'	"	"	1250	1470	1700
100	"	"	"	"	"	"	1250	1470	1700

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	BASIC LAP LENGTH (mm) $L_{sy.tb.lap}$								
20	390	500	740	1000	-	-	-	-	-
25	360	470	710	960	1230	-	-	-	-
30	320	430	670	920	1200	1490	-	-	-
35	"	400	630	890	1160	1450	1760	-	-
40	"	390	600	850	1120	1410	1720	2060	2430
45	"	"	560	810	1080	1370	1680	2020	2380
50	"	"	540	770	1040	1330	1640	1970	2340
55	"	"	"	740	1000	1290	1600	1930	2290
60	"	"	"	700	960	1250	1550	1890	2250
65	"	"	"	"	920	1210	1510	1840	2200
70	"	"	"	"	890	1170	1470	1800	2160
75	"	"	"	"	870	1130	1430	1760	2110
80	"	"	"	"	"	1090	1390	1710	2070
85	"	"	"	"	"	1050	1340	1670	2020
90	"	"	"	"	"	"	1300	1620	1970
95	"	"	"	'	"	"	1260	1580	1930
100	"	"	"	"	"	"	1250	1540	1880

c_d	N10	N12	N16	N20	N24	N28	N32	N36	N40
	MINIMUN REFINED LAP LENGTH (mm) $L_{sy.t.lap.min}$								
20	320	390	540	700	-	-	-	-	-
25	320	390	540	700	870	-	-	-	-
30	320	390	540	700	870	1050	-	-	-
35	"	390	540	700	870	1050	1250	-	-
40	"	390	540	700	870	1050	1250	1470	1700
45	"	"	540	700	870	1050	1250	1470	1700
50	"	"	540	700	870	1050	1250	1470	1700
55	"	"	"	700	870	1050	1250	1470	1700
60	"	"	"	700	870	1050	1250	1470	1700
65	"	"	"	"	870	1050	1250	1470	1700
70	"	"	"	"	870	1050	1250	1470	1700
75	"	"	"	"	870	1050	1250	1470	1700
80	"	"	"	"	"	1050	1250	1470	1700
85	"	"	"	"	"	1050	1250	1470	1700
90	"	"	"	"	"	"	1250	1470	1700
95	"	"	"	'	"	"	1250	1470	1700
100	"	"	"	"	"	"	1250	1470	1700

Note: The tabulated theoretical values of minimum refined development length, $L_{sy.t.min.}$, and minimum refined lap length, $L_{sy.t.lap.min.}$, are minimum possible solutions, based on the values of $(k_4k_5)_{min}$ in Table B.2. They are useful for indicating the lowest possible values achievable using refined design, but may not be appropriate for a particular design situation. Therefore, if they are less than basic development length, $L_{sy.tb}$, or basic lap length, $L_{sy.tb.lap}$, respectively, then refined design may be beneficial, but a designer must calculate the actual values of $L_{sy.t}$ ($\geq L_{sy.t.min.}$) and/or $L_{sy.t.lap}$ ($\geq L_{sy.t.lap.min.}$).

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TN 7 – Design Tables

Use of General Design Tables

- Determine the following:
  - Concrete strength grade
  - Bar diameter
  - Value of k_1
  - Value of k_7
  - Value of c_d

Modify value for:

- Bundled bars - increases
- Less than yield strength being developed - reduces
- Bar coating and/or lightweight concrete - increases

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TN 7 – Example 1

Lapping of top reinforcement

The situation

- N24 top reinforcement
- Spacing of bars= 120 mm
- Maximum lap length = 1200
- Slab thickness = 400 mm
- Concrete grade = 32 MPa
- Transverse bars laid on top of lapped bars
- Minimum top cover = 40 mm
- Laps of main bars are all non-contact

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TN 7 – Example 1

Solution

Determine if the basic lap length $L_{sy.tb.lap}$ is less than the 1200 mm available, and if not, whether a refined lap length $L_{sy.t.lap}$, will reduce the required lap length sufficiently.

1. Concrete strength grade – 32 MPa
2. Bar diameter – N24
3. Value of k_1 – 1.3 (> 300 mm below bar)
4. Value of k_7 – 1.25 (as all main bars are lapped at the same location)
5. Value of c_d – 40 mm

No adjustment for bundled bars, bar coating or lightweight concrete necessary

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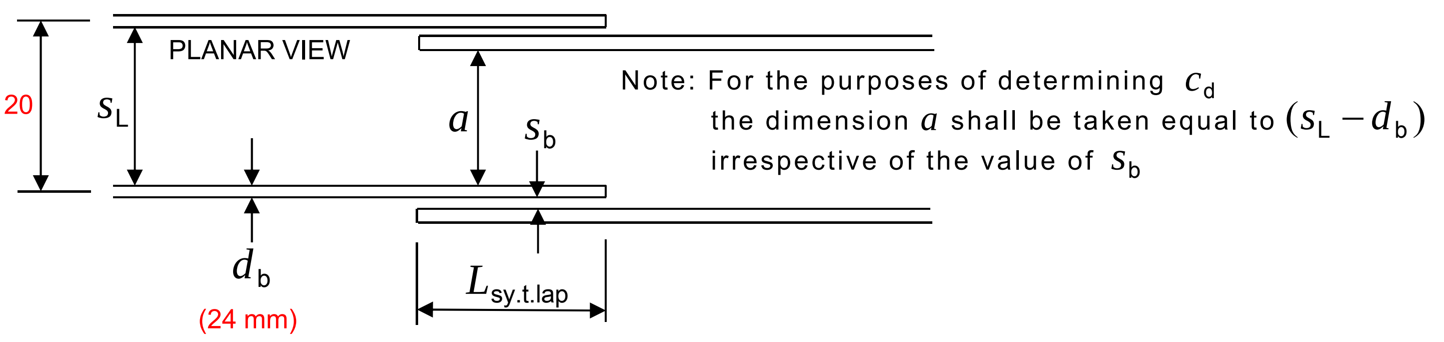
TN 7 – Example 1

5. Value of c_d – 40 mm (minimum *c* or *a*/2)

   c taken as 50 mm (40 mm cover + min. N12 transverse bars)

   a = 120 – 2 x 24 = 72 mm (refer Figure 13.2.2 of AS 3600)

   c_d = min. 72/2 or 50 mm ➡ 36 mm (round up to 40 mm)



(i) 100% of bars spliced (no staggered splice)

Figure 13.2.2(i) of AS 3600

TN 7 – Example 1

Determine basic lap length from General Design Table G21

Basic Tensile Lap Length, $L_{sy.tb.lap}$ **[Minimum refined tensile lap length,** $L_{sy.tb.lap.min.}$ **in red]**

c_d	Bar size, d_b (mm)								
	N10	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**	**N40**
20	500 (410)	650 (500)	950 (690)	1280 (900)	-	-	-	-	-
25	460 (410)	600 (500)	910 (690)	1230 (900)	1590 (1120)	-	-	-	-
30	410	560 (500)	860 (690)	1190 (900)	1540 (1120)	1910 (1350)	-	-	-
35	“	510 (500)	810 (690)	1140 (900)	1490 (1120)	1860 (1350)	2270 (1610)	-	-
40		500	770 (690)	1090 (900)	1440 (1120)	1810 (1350)	2210 (1610)	2650 (1890)	3120 (2190)
45		“	720 (690)	1040 (900)	1390 (1120)	1760 (1350)	2160 (1610)	2590 (1890)	3060 (2190)
50			690	990 (900)	1340 (1120)	1710 (1350)	2100 (1610)	2540 (1890)	3010 (2190)
55			“	950 (900)	1290 (1120)	1650 (1350)	2050 (1610)	2480 (1890)	2950 (2190)
60				900	1240 (1120)	1600 (1350)	2000 (1610)	2420 (1890)	2890 (2190)
65				“	1190 (1120)	1550 (1350)	1940 (1610)	2370 (1890)	2830 (2190)
70					1140 (1120)	1500 (1350)	1890 (1610)	2310 (1890)	2770 (2190)
75					1120	1450 (1350)	1830 (1610)	2260 (1890)	2710 (2190)
80					“	1390 (1350)	1780 (1610)	2200 (1890)	2650 (2190)
85						1350	1730 (1610)	2140 (1890)	2600 (2190)
90						“	1670 (1610)	2090 (1890)	2540 (2190)
95							1620 (1610)	2030 (1890)	2480 (2190)
100							1610	1970 (1890)	2420 (2190)

TN 7 – Example 1

Determine refined lap length

- As 1440 mm exceeds the 1200 mm available (basic no good)
- Minimum refined lap length of 1120 mm less than 1200 mm available

Calculate k_3 value based on actual c_d = 36 mm

$$k_3 = \left[1.0 - \frac{0.15(c_d - d_b)}{d_b}\right] = \left[1.0 - \frac{0.15(36 - 24)}{24}\right] = 0.925$$

As $k_3 k_4 k_5$ = 0.7, the value of k_4 equals (with k_5 = 1.0):

$$k_4 = \frac{0.7}{k_3 k_5} = \frac{0.7}{0.925 \times 1.0} = 0.757$$

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TN 7 – Example 1

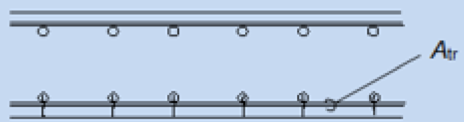
Determine transverse steel required to give k_4 factor of 0.757

$$k_4 = 1.0 - K\lambda \quad \text{such that} \quad 0.7 \le k_4 \le 1.0 \quad \text{(by definition)}$$

$$\text{As } \; k_4 = 0.757 \text{ which is} > 0.7\text{, condition is satisfied}$$

$$(K\lambda)_{\text{max.}} = 1.0 - k_4 = 1.0 - 0.757 = 0.243$$

From Figure A.3, K = 0.05

Slab or wall without fitments		0	1 per main bar spacing	0.05 (see Note 2)

$$\lambda = \frac{0.243}{K} = \frac{0.243}{0.05} = 4.86$$

$$\lambda = \frac{\sum A_{\text{tr}} - \sum A_{\text{tr.min}}}{A_{\text{s}}} = \frac{\sum A_{\text{tr}} - 0.25 A_{\text{s}}}{A_{\text{s}}} \ge 0 \quad \text{(by definition)}$$

$$\text{Note:} \quad \sum A_{\text{tr.min}} = 0.25 A_{\text{s}} \;\text{ as } K > 0 \quad (K = 0.5)$$

$$\text{If } \; K = 0 \text{ (ie no transverse steel)}, \; \sum A_{\text{tr.min}} = 0$$

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TN 7 – Example 1

New SRIA Technical Note TN7

$$\lambda = \frac{\sum A_{tr} - 0.25 A_s}{A_s} \xrightarrow[\text{re-arranging}]{\text{by}} \sum A_{tr} = \lambda A_s - 0.25 A_s$$

$$\text{As } A_s = 452 \text{ mm}^2$$

$$\sum A_{tr} = 4.86 \times 452 - 0.25 \times 452$$

$$\sum A_{tr} = 2{,}310 \text{ mm}^2$$

Try N20 at 200 top – number of bars over 1200 mm lap = 7

Area = 7 x 452 = 2,200 mm^2

Close to 2,310 mm^2, so check lap length

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TN 7 – Example 1

Check refined lap length required

$$L_{\text{sy.t.lap}} = k_7 \left[k_4 k_5 \frac{0.5 k_1 k_3 f_{\text{sy}} d_{\text{b}}}{k_2 \sqrt{f'_{\text{c}}}} \right] \geq 29 k_1 d_{\text{b}}$$

$$\lambda = \frac{\sum A_{\text{tr}} - 0.25 A_{\text{s}}}{A_{\text{s}}} = \frac{2200 - 0.25 \times 452}{452} = 4.62 \geq 0$$

$$k_4 = 1.0 - K\lambda = 1.0 - 0.05 \times 4.62 = 0.77$$

$$k_2 = \frac{132 - d_{\text{b}}}{100} = \frac{132 - 24}{100} = 1.08$$

$$k_3 = \left[1.0 - \frac{0.15(c_{\text{d}} - d_{\text{b}})}{d_{\text{b}}} \right] = \left[1.0 - \frac{0.15(36 - 24)}{24} \right] = 0.925$$

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TN 7 – Example 1

Check refined lap length required

$$L_{\text{sy.t.lap}} = k_7 \left[k_4 k_5 \frac{0.5 k_1 k_3 f_{\text{sy}} d_{\text{b}}}{k_2 \sqrt{f'_{\text{c}}}} \right] \geq 29 k_1 d_{\text{b}}$$

$$L_{\text{sy.t.lap}} = 1.25 \left[0.77 \times 1.0 \frac{0.5 \times 1.3 \times 0.925 \times 500 \times 24}{1.08 \times \sqrt{32}} \right]$$

$$L_{\text{sy.t.lap}} = 1137 \text{ mm} \quad (\text{which is greater than } 29 k_1 d_{\text{b}} = 905 \text{ mm})$$

Conclusion:

As 1137 mm is less than the 1200 mm available, lap length is satisfactory with N20 at 200 transverse bars provided.

Note that the lap length required (1137 mm) is only slightly longer than the minimum possible value of 1120 mm given in the General Design Table G21.

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AS 3700 Masonry structures Update

AS 3700 Update

Capacity Reduction Factor (Table 4.1)

Factor for grouted unreinforced masonry increased

Type of masonry or accessory and action effect	Capacity reduction factor (Ø)
(a) Unreinforced masonry:	
(i) Compression	
(A) Solid or cored	0.75
(B) Hollow ~~(including grouted)~~	0.50
(C) Grouted	0.60
(ii) Flexure	0.60
(iii) Shear	0.60
(iv) Other actions	0.60
(b) Reinforced and prestressed masonry:	
(i) Compression	0.75
(ii) All other actions	0.75
(c) Wall ties, connectors and accessories:	
(i) Wall ties in tension or compression	0.95
(ii) Connectors across a joint in masonry	0.75
(iii) Accessories and other actions	0.75

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AS 3700 Update

Unreinforced Masonry

Design of grouted members in compression (no testing)

2011

$$F_o \le \phi \left[f'_m A_b + k_c \sqrt{\left(\frac{f'_{cg}}{1.3}\right)} A_g \right]$$

$$k_c = 1.2 \text{ generally}$$

$$= 1.4 \text{ for hollow concrete masonry} > 2000 \text{ kg/m}^3$$

2017

$$F_o \le \phi \left[f'_m A_b + k_c \left(\frac{f'_{cg}}{1.3}\right)^{(0.55+0.055 f'_{cg})} A_g \right]$$

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AS 3700 Update

Reinforced Masonry

Design of members in compression

2011

$$F_{\mathrm{d}} \leq \phi k_{\mathrm{s}} \left[f'_{\mathrm{m}} A_{\mathrm{b}} + k_{\mathrm{c}} \sqrt{\left(\frac{f'_{\mathrm{cg}}}{1.3} \right)} A_{\mathrm{g}} + f_{\mathrm{sy}} A_{\mathrm{s}} \right]$$

$$k_{\mathrm{s}} = 1.18 - 0.03 S_{\mathrm{r}} \quad \text{but not greater than } 1.0$$

2017

$$F_{\mathrm{d}} \leq \phi k_{\mathrm{es}} \left[f'_{\mathrm{m}} A_{\mathrm{b}} + k_{\mathrm{c}} \left(\left(\frac{f'_{\mathrm{cg}}}{1.3} \right)^{\left(0.55 + 0.055 f'_{\mathrm{cg}}\right)} \right) A_{\mathrm{g}} + \alpha_{\mathrm{r}} f_{\mathrm{sy}} A_{\mathrm{s}} \right]$$

$$k_{\mathrm{es}} = \left(1.0 - 0.025 S_{\mathrm{r}}\right) \left(1.0 - 2.0 \frac{e}{t} \right)$$

- Requirement to design for interaction of compression and bending has been removed (Clause 8.11.1)
- α_{r} - reinforcing contribution factor

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AS 3700 Update

Reinforced Masonry

Design of members in compression

2011 Design strength of grout, $f'_{cg} =$ the lesser of: f'_{c} or $1.3 \times f'_{uc}$

2017 Design strength of grout, $f'_{cg} =$ not less than 12 MPa

$= f'_{c}$ of grout

$\geq f'_{m}$

Reinforcing contribution factor, $\alpha_{r} =$ 1.0 for piers

$=$ 0.4 for walls

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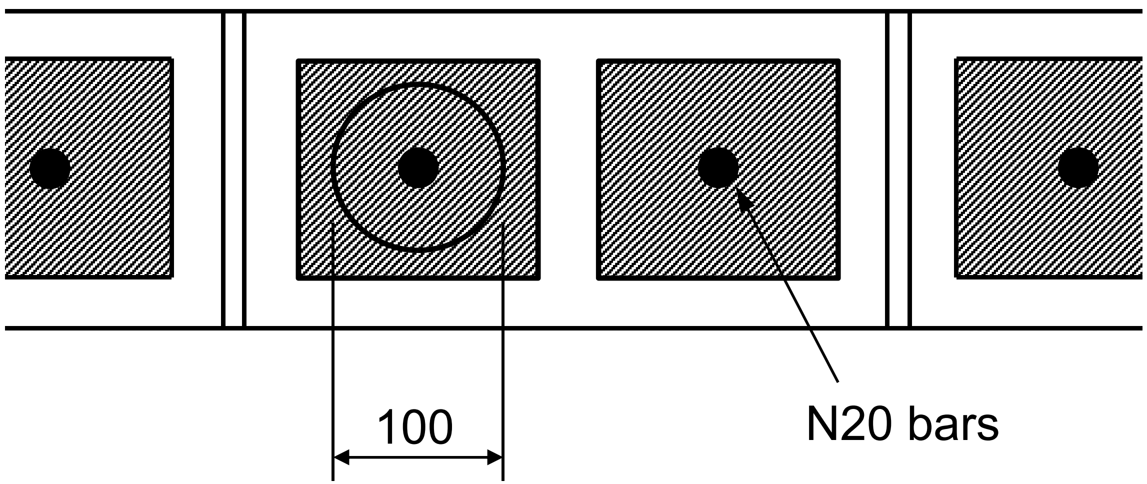
AS 3700 Update

Contribution of Reinforcement in Walls

Clause 8.5 (e)
Reinforcement in walls shall be surrounded by an annulus of grout of thickness not less than twice the diameter of the reinforcing bar



Annulus of grout, $5d_b$ = 100 mm for N20 bar

AS 3700 Update

Clause 8.4.6 Wide-spaced reinforcement

Clarification that walls can be fully or partially grouted

Stack Bonded Masonry

Clause 4.11.2 – Clarification provided regarding bonding

Where the following cannot be provided:

- At least 90 mm of engagement, or
- One quarter of a unit overlap

the masonry shall be considered to be stack bonded

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Stack Bonded Masonry (Clause 4.12 added)

Hollow unit masonry

- Reinforce or prestress to resist actions

Solid and cored unit masonry

- Reinforce with bed joint reinforcement
- Reinforcement continuous between lateral supports
- Max. vertical spacing = 6 x thickness of leaf
- Area ≥ 0.00035 x gross vertical cross-sectional area of the wall
- At specific locations – refer Figure 4.1
- Designed as:
  - unreinforced for compression
  - reinforced for one-way horizontal bending

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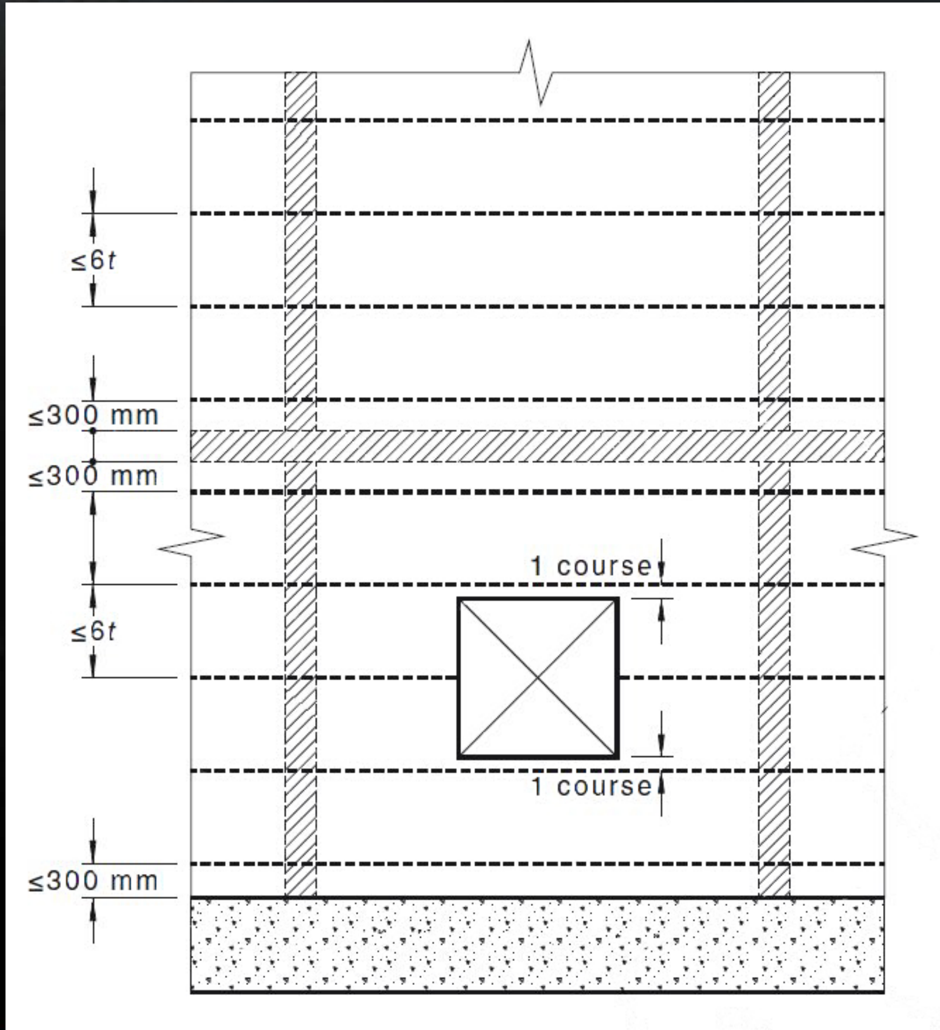
Stack Bonded Masonry (New Figure 4.1)

Figure 4.1 Reinforcement Placement for Stack Bonded Masonry



AS 3700 Update

Durability requirements expanded

Appendix I added (informative)

- Corrosivity Categories and Relationship to Durability Class (ISO 9223)
- Requirements for Durability Class of Components R1 to R5 in Table 5.1 explained

Stainless Steel Reinforcement

- Requirements included in Table 3.7
- Clause 5.9.5
  - Durability Class R1 to R3 – galvanised
  - Durability Class R4 – stainless steel reinforcement

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AS 3700 Update

Table 3.7 Strength and Ductility of Reinforcement

Reinforcement		Design yield strength ( ) MPa	Durability class
Type	**Designation grade**		
Bar plain to AS/NZS 4671	R250N	250	N
Bar deformed to AS/NZS 4671	D500L (fitments only)	500	L
	D500N	500	N
Welded mesh, plain, deformed and indented to AS/NZS 4671	D500L	500	L
	D500N	500	N
Stainless steel plain bar to EN 10088-5 (see Notes 2 and 3)	250	250	N
Stainless steel ribbed bar to BS 6744 (see Notes 2 and 3)	500	650	N

Note 2 Physical and mechanical properties in accordance with BS 6744 and EN 10088-5 and chemical composition conforming with 1.4311, 1.4162, 1.4362, 1.4462, 1.4404 or 1.4429 to EN 10088-1

Note 3 Stainless steel bars to BS 6744 and EN 10088-5 are deemed to comply with Ductility Class N in accordance with AS/NZS 4671

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AS 3727 Residential pavement Update

AS 3727 Update

Major Changes:

- 1993 Guide is now a mandatory Standard
- Concrete Pavements

Table 5.2 Concrete Base Parameters (changes highlighted)

Traffic	Minimum base thickness mm	Minimum concrete grade	Alternative 1 unreinforced		Alternative 2 reinforced		Alternative 3 reinforced	
			Maximum control joint spacing m	Minimum reinforcing mesh	Maximum control joint spacing m	Minimum reinforcing mesh	Maximum control joint spacing m	Minimum reinforcing mesh
Pedestrian only	75	N20	~~2.0~~ 1.5	-	N/A	N/A	N/A	N/A
Pedestrians and light vehicles	100	~~N20~~ N25	~~2.0~~ 1.5	-	~~3~~ 2	~~F52~~ SL 62	~~6~~ 4.5	~~F62~~ SL 72
Pedestrians and commercial vehicles	150	~~N25~~ N32	2	-	4	~~F72~~ SL 82	~~6~~ 4.5	SL 82

AS 3727 Update

Reinforcement

Required where:

- The panel is of irregular shape
- The length is greater than 1.5 x width (even if regular shape)
- Joint spacing greater than Alternative 1
- Re-entrant corners – 2 N12 x 1000 mm long min.

Cover using bar chairs in accordance with AS/NZS 2425

Lapping of mesh - minimum two transverse bars

Reinforcement NOT continuous through control joints

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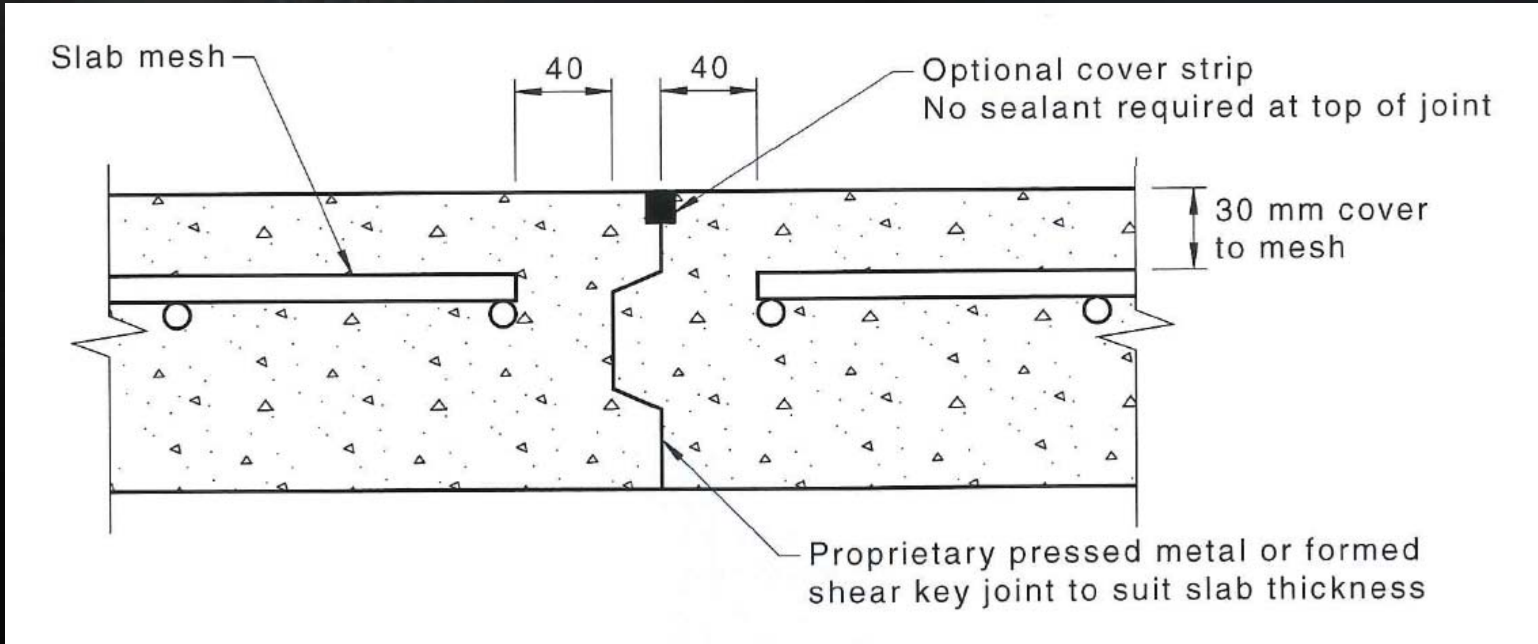
Typical Control Joints

Figure 5.4.2 (a) Formed joint (with shear key)

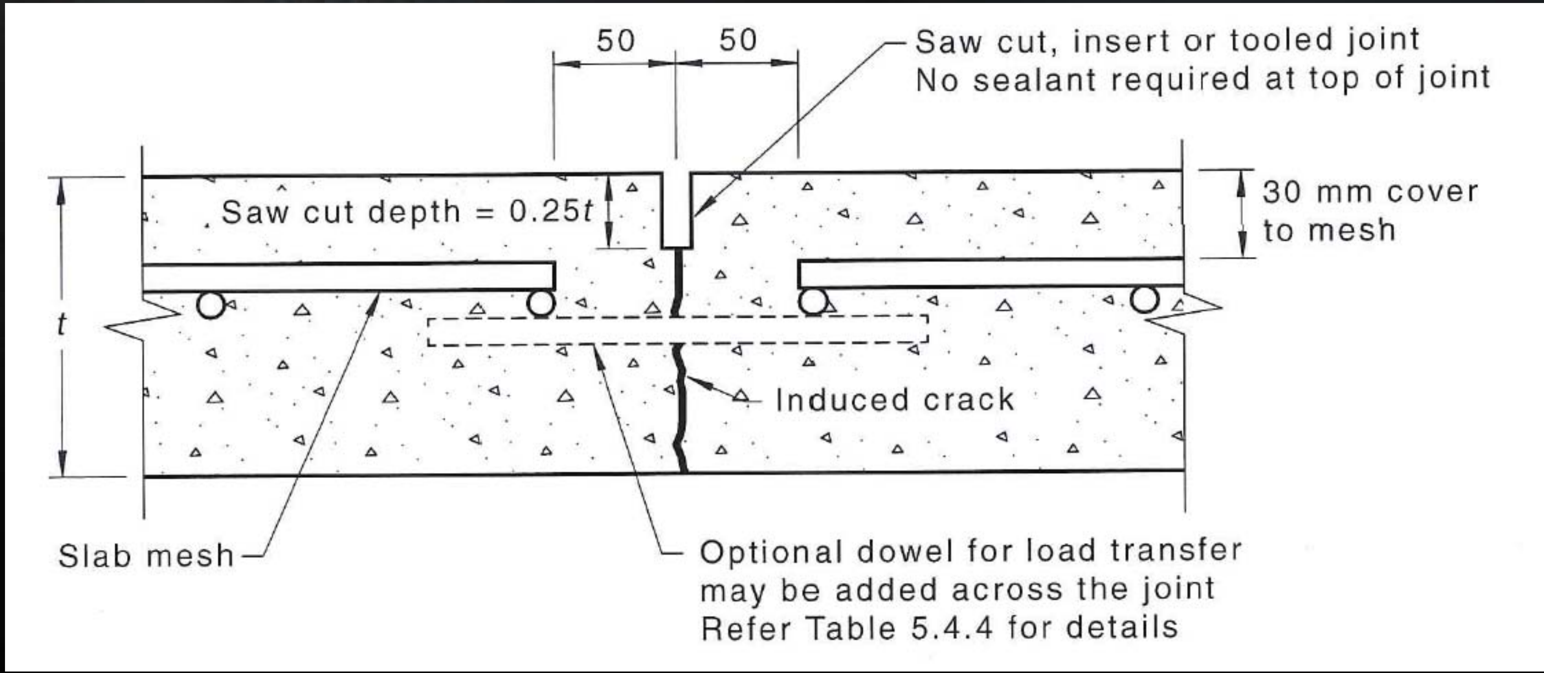


Use of formwork between concrete placements

AS 3727 Update

Typical Control Joints

Figure 5.4.2 (b) Weakened plane joint



Create plane of weakness

- Scoring surface (tooled joint)
- Insert proprietary crack-inducing device
- Sawing the concrete

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AS 3727 Update

Dowel Details

Pavement thickness mm	Dowel Type	Dowel dimensions mm	Minimum dowel length mm	Maximum dowel spacing mm
75	N/A	N/A	-	-
100	Round	12 diameter	300	400
	Square	12 x 12	300	400
	Plate	MR	MR	450
125	Round	16 diameter	350	300
	Square	16 x 16	350	300
	Plate	MR	MR	450
150	Round	20 diameter	400	300
	Square	20 x 20	400	350
	Plate	MR	MR	450

MR – Refer Manufacturer's Recommendations
Due to variety of plate dowel types, geometries and installation methods

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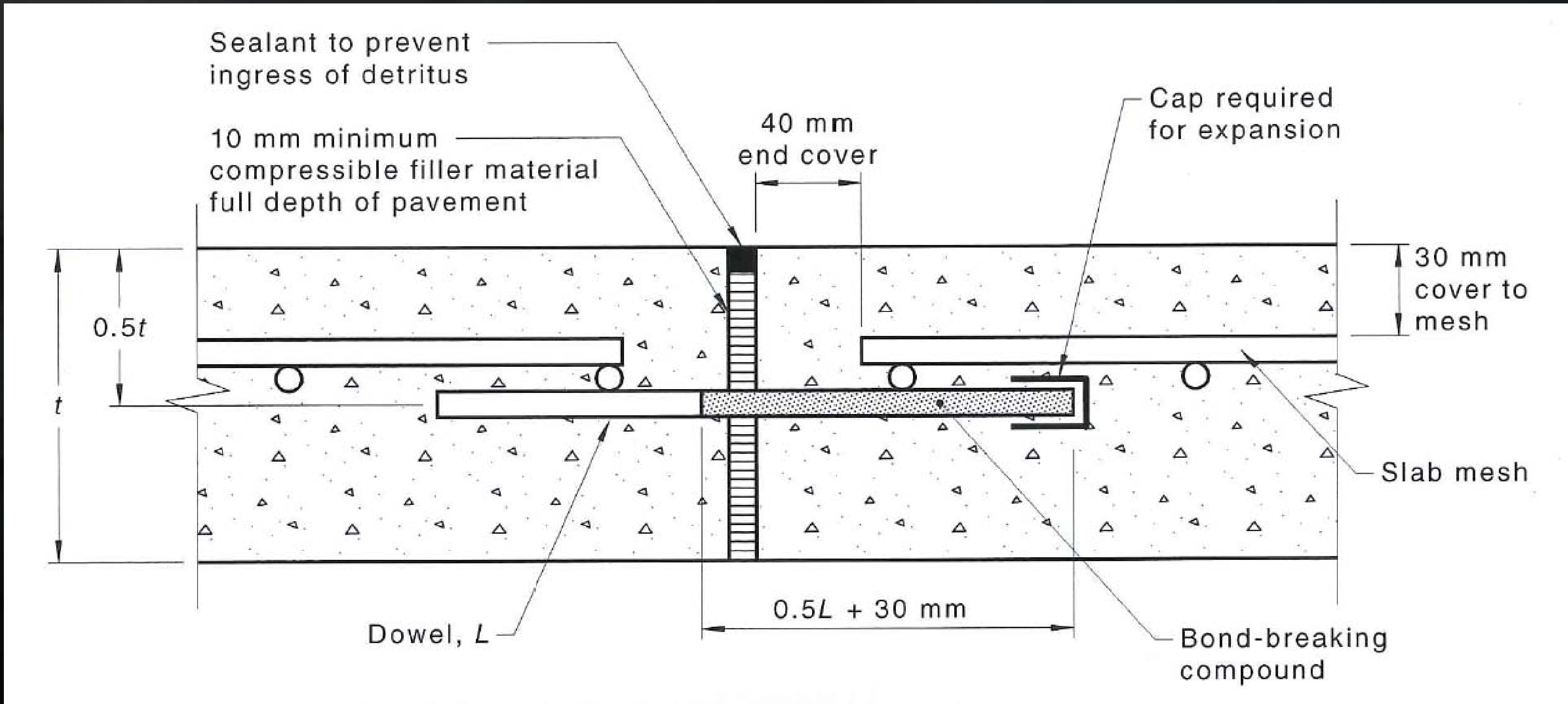
AS 3727 Update

Typical Dowelled Expansion Joint (Figure 5.4.4)



Spacing

Plain pavements < 100 mm thick – max. 6 m centres

Reinforced pavements ≥ 100 mm thick – max, 12 m centres

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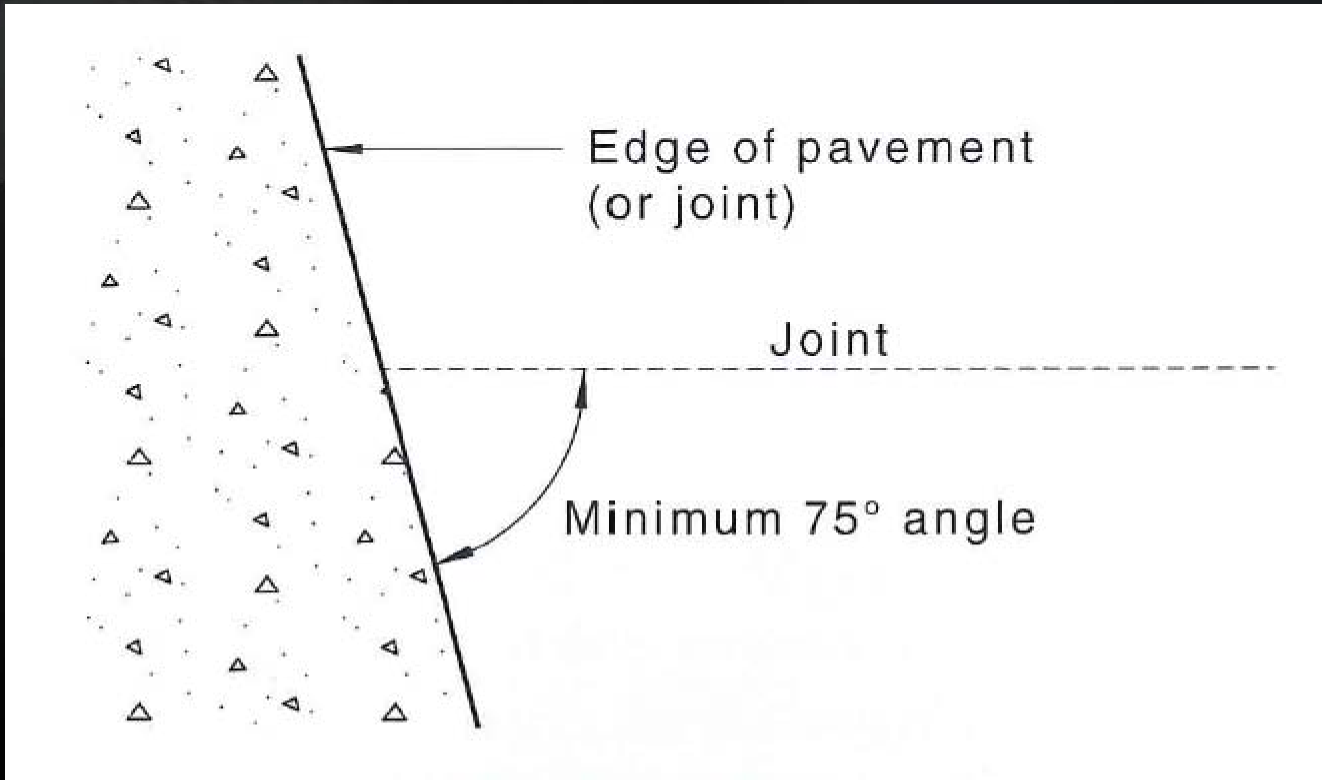
Joint Angles (Figure 5.4.6 added): Where possible ≥ 75°



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Joint Requirements

- Continuous from edge to edge
- Sealing
  - Surfaces clean and dry
  - Concrete fully cured and reached design strength
  - Surface temperature ≥ 5°
  - Correct depth of sealant (0.5W ≤ depth ≤ W)
  - Sealant only adheres to sides of joint
- Saw cutting
  - Correct timing
  - Clean all debris
  - No ravelling greater than 20 mm
- Dowels
  - Ensure adequate alignment and allowance for movement

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Appendix B included on Quality Issues

- Random crack width
  - Different to planned cracking
  - Factors causing random cracking
- Reinforcement
  - Brittle surface coverings eg tiles, decorative finishes
- Joint spacing
  - Decreased to reduce the risk of random cracking
- Joint detailing
  - Important issues concerning joint types
- Concrete
  - Importance of uncontrolled addition of water, compaction and curing

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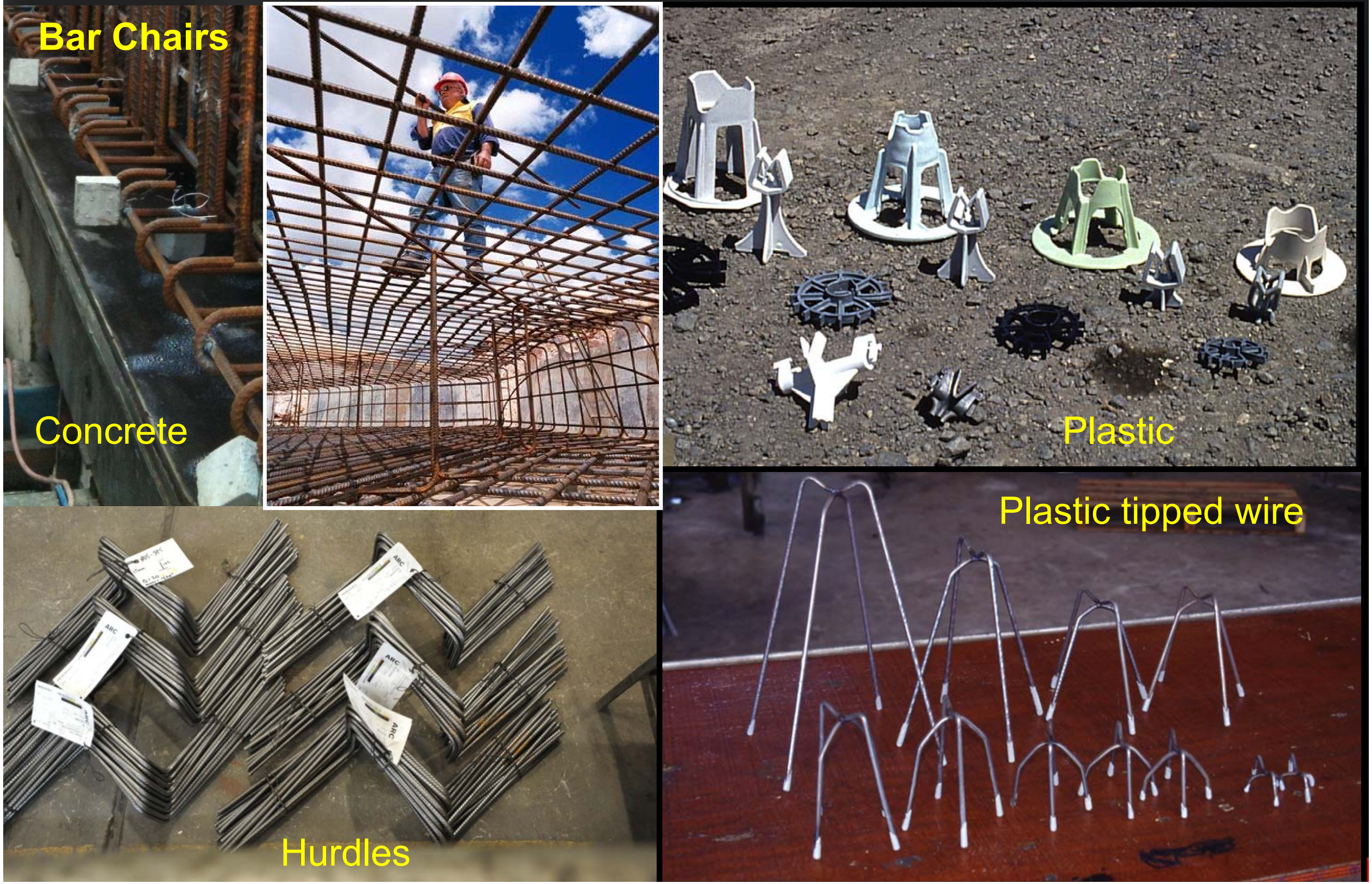
AS/NZS 2425 Bar chairs in reinforced concrete

Product requirements and test methods

Keeping Reinforcement in Place



AS/NZS 2425 Bar chairs in reinforced concrete – Product requirements

Load capacity

Test	Strength Grade			
Minimum test load capacity	60	120	200	> 300

Chloride permeability of concrete bar chairs

Maximum charge passed (coulombs)	Chloride permeability class
> 4,000	High
2,000 - 4,000	Moderate
1,000 – 2,000	Low
< 1,000	Very low

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Bar chairs

Specify

- Type of bar chair
  - Depends on application
- Load capacity
  - 60, 120, 200 or > 300 kg
- Spacing
  - To adequately support load
- Chloride permeability (if concrete)
  - Ensures suitability of concrete spacer for exposure

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Thank you

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