Steel Reinforcement Institute of Australia

Residential Slabs and Footings Reinforcement and Slab Design

Scott Munter, Executive Director

SRIA Disclaimer

The information presented by the Steel Reinforcement Institute of Australia in this presentation has been prepared for general information only and does not in any way constitute recommendations or professional advice. While every effort has been made and all reasonable care taken to ensure the accuracy of the information contained in this presentation, this information should not be used or relied upon for any specific application without investigation and verification as to its accuracy, suitability and applicability by a competent professional person in this regard. The Steel Reinforcement Institute of Australia, its officers and employees and the authors and reviewers of this presentation do not give any warranties or make any representations in relation to the information provided herein and to the extent permitted by law (a) will not be held liable or responsible in any way: and (b) expressly disclaim any liability or responsibility for any loss or damage costs or expenses incurred in connection with this presentation by any person, whether that person is the reader or downloader of this presentation or not. Without limitation, this includes loss, damage, costs and expenses incurred as a result of the negligence of the authors or reviewers.

The information in this presentation should not be relied upon as a substitute for independent due diligence, professional or legal advice and in this regard the services of a competent professional person or persons should be sought.

SRIA

Steel Reinforcement Institute of Australia

Overview

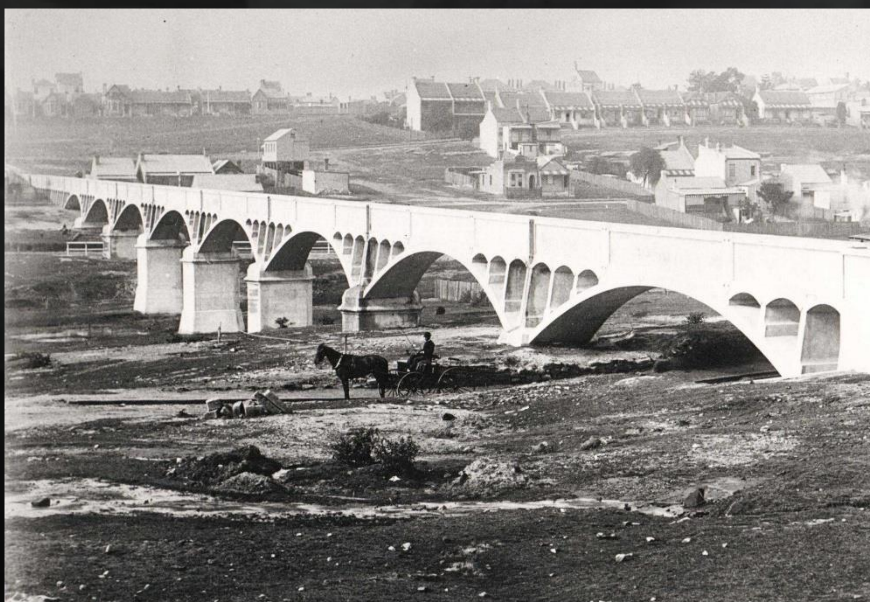
- Australian Reinforcement History
- Manufacturing to AS/NZS 4671-2001 & Design Standards
- Quality Certification - Reinforcement Steels
- AS 2870 Reinforcement Design & Detailing
- Recent SRIA Conference Papers & Industry Research
- SRIA Technical Information & Resources

Steel Reinforcement Institute of Australia

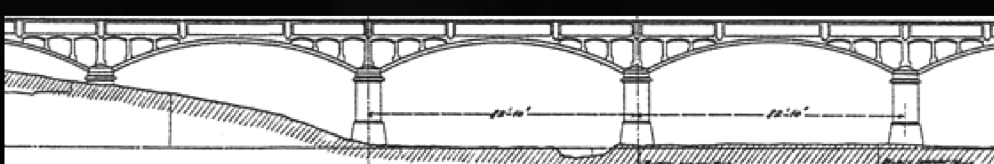
Reinforced Concrete invented by Joseph Monier, France, 1868

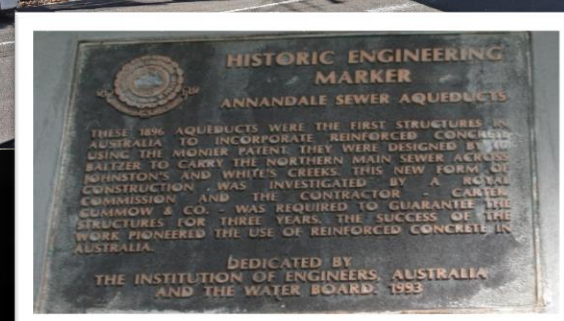
Johnstons Creek Sewer Aqueduct

Annandale, Sydney (1896)



Today





SRIA
Steel Reinforcement
Institute of Australia

History of Bar Reinforcement in Australia

Bar Type	Introduction (year)	Yield Stress (MPa)
Plain round	1895	230
Deformed	1920’s	230
Square twisted	1957	410
Intermediate grade deformed	1960	275
Hard grade deformed	1960	345
Twisted deformed (CW.60)	1962	410
Hot-rolled deformed (410Y)	1983	410
Hot-rolled deformed (400Y)	1988	400
Hot-rolled deformed (500N)	2000	500

Steel Reinforcement Institute of Australia

Examples: Past Bar Types

Plain round circa 1895
230MPa

Square twisted 1957
410MPa

Twisted deformed
CW.60 1962 - 410MPa

Microalloy (MA)
500N – 500MPa

Hot-rolled deformed (QST)
D500N - 500MPa

Basic requirements for rib design, spacing, height & coverage essentially unaltered since 1958

Steel Reinforcement
Institute of Australia

Warnings: Past Bar Types

- **Square twisted bars (1957-1963) & Twisted deformed CW.60 (1962-1983):**
  - Identified by surface appearance
  - Can be spliced by end-butt welding or mechanical methods with removal of untwisted ends (150-200 mm)
- **Intermediate grade deformed (1960-1968):**
  - Was rare in Aust construction & likely only used for USA designed projects or to ASTM standard
  - Weldability very doubtful – should not be considered
- **Hard Grade Deformed (1960-1968):**
  - Was common in NSW & unusual elsewhere
  - NOT weldable
- **RECOMMENDATION: Any welding of existing reinforcement should always be carried out by proper personnel skilled in this area and in accordance with relevant codes. If weldability is in doubt or is a special issue, then metallurgical testing may be required.**

SRIA
Steel Reinforcement Institute of Australia

History of Mesh Reinforcement

Mesh Type	Introduction (year)	Yield Stress (MPa)
Plain mesh	1914	450
Deformed mesh	1995	500

Material properties of hard drawn wire & reinf mesh made from this wire have remained basically unaltered from 1958 until 1990's.

SRIA
Steel Reinforcement Institute of Australia

Reinforcing Bar Classification

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

SRIA
Steel Reinforcement Institute of Australia

D500N Bar (Straight eg TEMPCORE)

Bar Size mm	**Nominal Area** mm^2
N10	80
N12	110
N16	200
N20	310
N24	450
N28	620
N32	800
N36	1020
N40	1260

Steel Reinforcement Institute of Australia

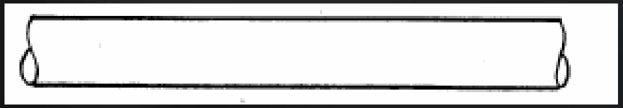
D500N Bar (Off Coil - Microalloy)

Bar Size mm	Nominal Area mm^2
N10	80
N12	110
N16	200
N20	310
N24	450
N28	620
N32	800
N36	1020
N40	1260

SRIA
Steel Reinforcement Institute of Australia

R250N Bar (Off Coil)

Bar Size mm	Nominal Area mm^2
R6.5	30
R10	80
R12	110
R16	200
R20	310
R24	450

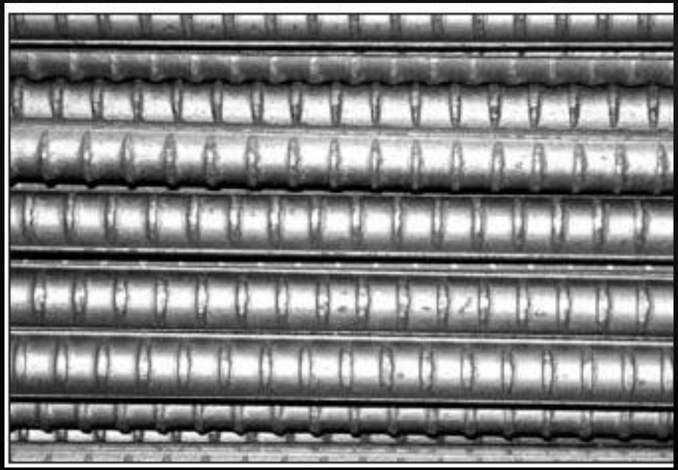


SRIA
Steel Reinforcement
Institute of Australia

D250N Bar (Straight)

‘bamboo ribs’

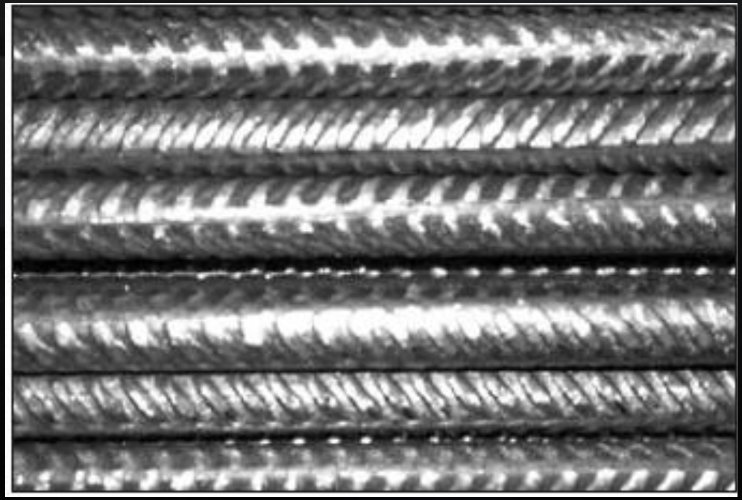
Bar Size mm	Nominal Area mm^2
S12	110



Steel Reinforcement Institute of Australia

D500L Cold-Rolled Deformed Bar (Ribbed - Off Coil)

Bar Size mm	**Diameter** mm	**Area** mm^2
L4	4.00	12.6
L5	4.75	17.7
L6	6.00	28.3
L7	9.75	35.8
L8	7.60	45.4
L9	8.55	57.4
L10	9.50	70.9
L11	10.65	89.1
L12	11.90	111.2

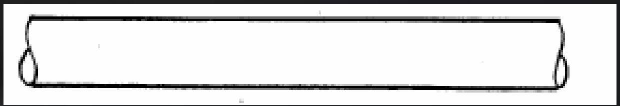


Note: AS/NZS4671 500L steels d<5mm Does not have ductility criteria (only strength criteria) unless used as edge wires.

SRIA
Steel Reinforcement Institute of Australia

R500L Cold-Drawn Plain Rod (Plain - Off Coil)

Wire Size mm	**Diameter** mm	**Area** mm^2
L4	4.00	12.6
L5	4.75	17.7
L6	6.00	28.3
L7	9.75	35.8
L8	7.60	45.4
L9	8.55	57.4
L10	9.50	70.9
L11	10.65	89.1
L12	11.90	111.2



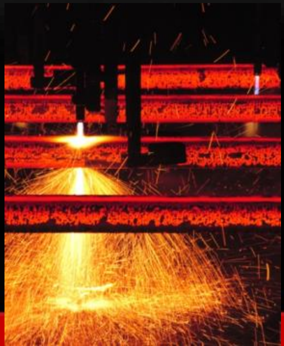
NOTE:
Wire in accord with AS/NZS 4671 is now called bar, supplied in coils then straightened.
Some detailers are still specifying fitments as W or RW (wire or ribbed wire)
This is INCORRECT and they should be specified as L Bar.

RW10@200
Should be.... L10@200

Steel Reinforcement Institute of Australia

Manufacturing to AS/NZS 4671 & AS 3600

Electric Arc Furnace (EAF)



SRIA

Steel Reinforcement Institute of Australia

Chemical Composition

Table 1 of AS/NZS 4671-2001

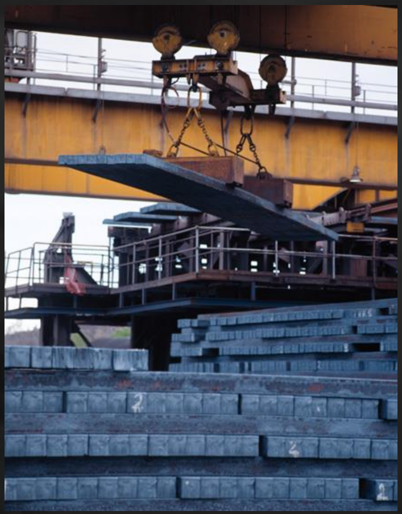
Type of analysis	Chemical Composition (%) Max				
	All Steel Grades			Carbon Equivalent Value for Class	
	C	P	S	500L	500N
Cast analysis	0.22	0.050	0.050	0.39	0.44
Product analysis	0.24	0.055	0.055	0.41	0.46

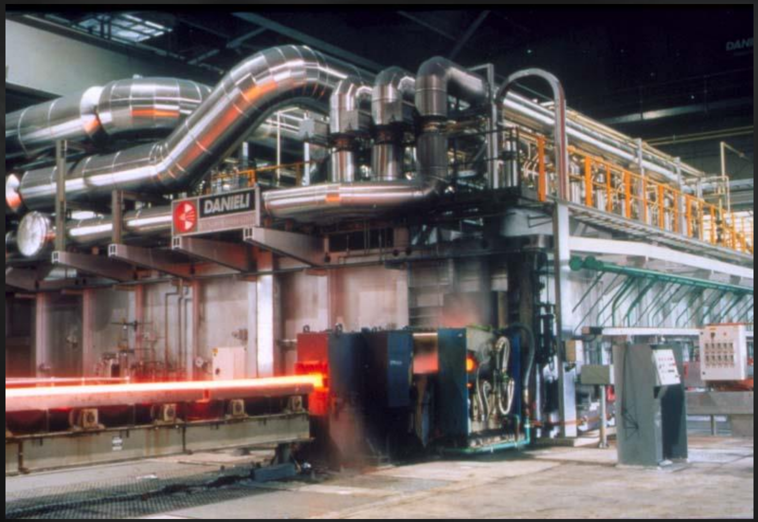
Carbon Equivalent:

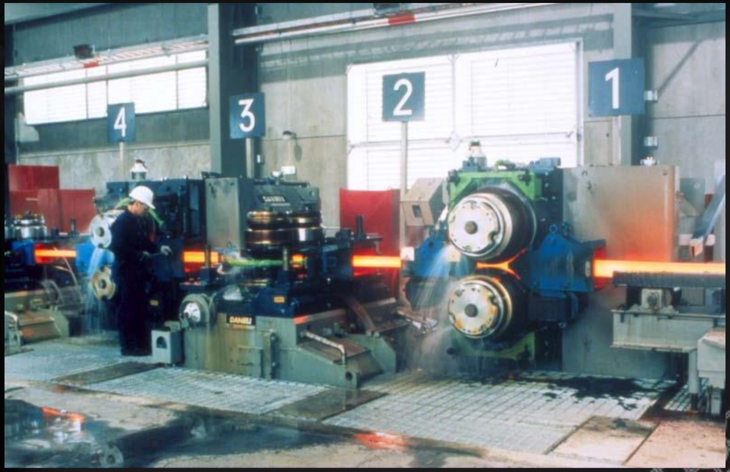
$$C_{eq} = \mathrm{C} + \frac{\mathrm{Mn}}{6} + \frac{\mathrm{Cr}+\mathrm{Mo}+\mathrm{V}}{5} + \frac{\mathrm{Ni}+\mathrm{Cu}}{15}$$

SRIA
Steel Reinforcement Institute of Australia

Hot Rolling Mill







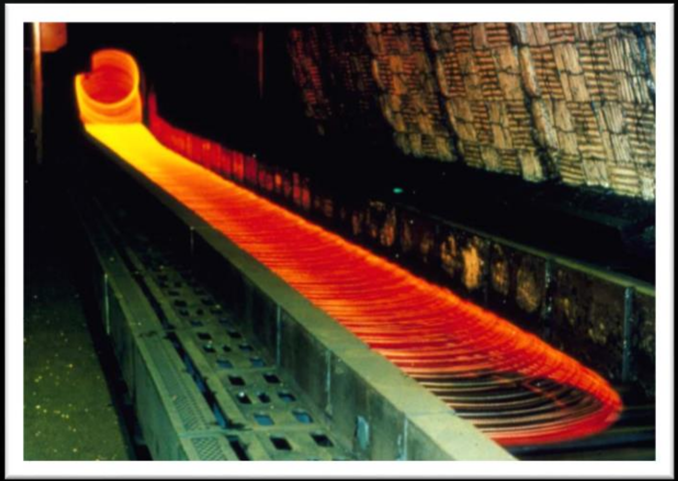
RIA

Steel Reinforcement Institute of Australia

Hot Rolled Product

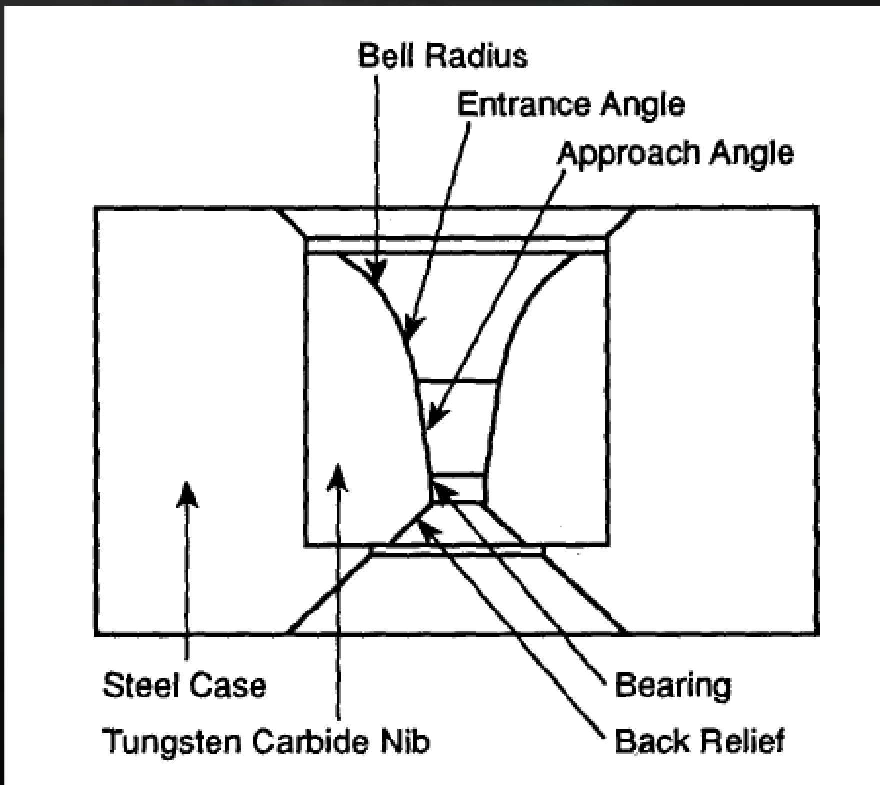
Straight QST D500N, D250N & coiled MA D500N

R250N coiled bar

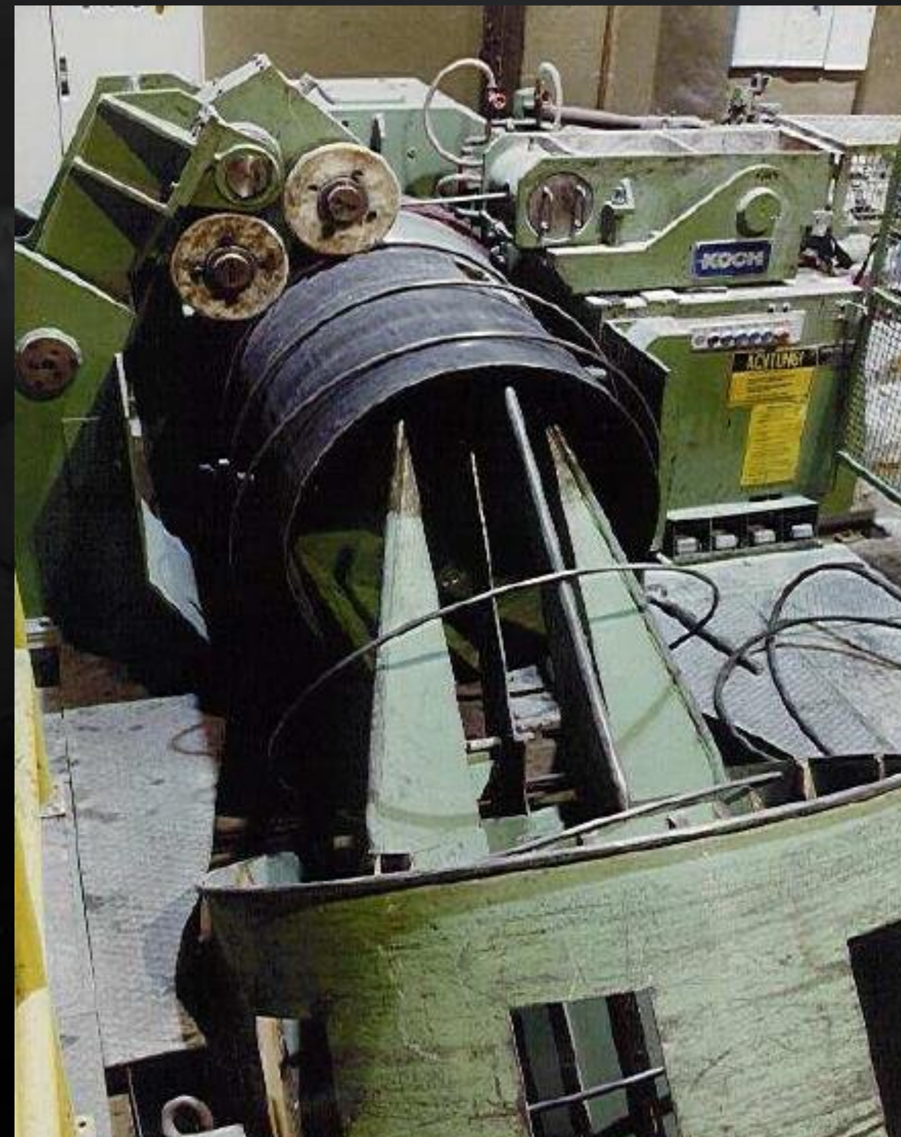


Cold-rolled deformed bar (wire): D500L

Cold-drawn plain bar (wire): R500L



– Section through wire drawing die.

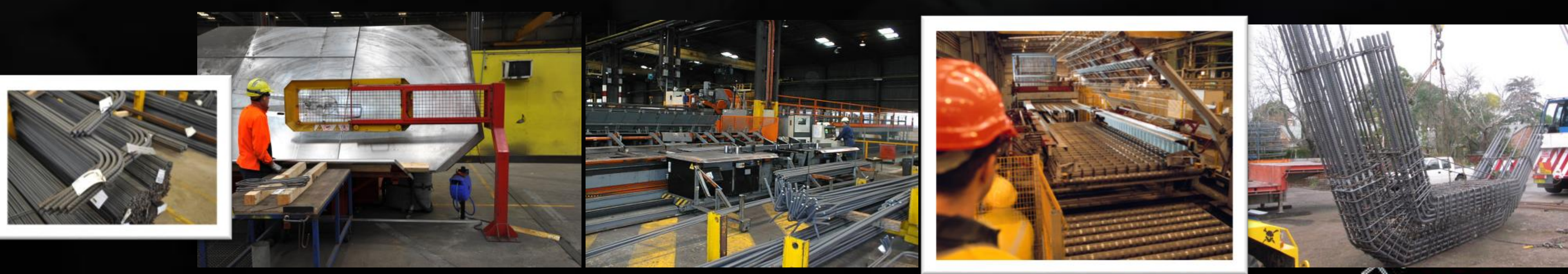


Quality Assurance & Traceability

One such scheme is ACRS….

ACRS certifies compliant suppliers worldwide…

- ISO-65 compliant
- Independent (via board of directors)
- 3rd-Party (no affiliation)
- User/specifier driven – not supplier driven
- Non-profit (minimum cost)
- Focused only on AS/NZS steel materials Standards & associated specs.



Third Part/Independent Certification ACRS or Equivalent

What does ACRS certify?

- Reinforcing bar and mesh to AS/NZS 4671 & relevant design Codes (AS3600, AS5100.5 & AS2870)
- Prestressing strand to AS4672
- 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

SRIA
Steel Reinforcement Institute of Australia

Third Part/Independent Certification ACRS or Equivalent

ACRS certificates

VALID TO 31 DEC 2015

This document is uncontrolled when printed
View original at www.steelcertification.com

ACRS
www.steelcertification.com

Australasian Certification Authority for Reinforcing and Structural Steels Ltd

Certificate of Product Performance

Certificate Number: 81 102

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

Reinforcing Mesh Manufacture to AS/NZS 4671

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 2015

First certified: November 2008

1 of 2

JAS-ANZ
www.jas-anz.org/register

VALID TO 31 DEC 2015

This document is uncontrolled when printed
View original at www.steelcertification.com

ACRS
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: 81 102

AUSREO

AUSREO
WETHERILL PARK, NSW, AUSTRALIA

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

2 of 2

JAS-ANZ
www.jas-anz.org/register

SRIA
Steel Reinforcement Institute of Australia

Third Part/Independent Certification ACRS or Equivalent

Need for an ACRS certificate?

Steel Reinforcement Institute of Australia

AS 2870 Section 1: Scope and General

1.2 APPLICATION

To comply with this Standard —

(a) all sites shall be classified in accordance with Section 2; &

(b) footing system design shall be performed by either—

(i) prescribing a standard design in accordance with Section 3; or

(ii) applying the engineering principles described in Section 4; &

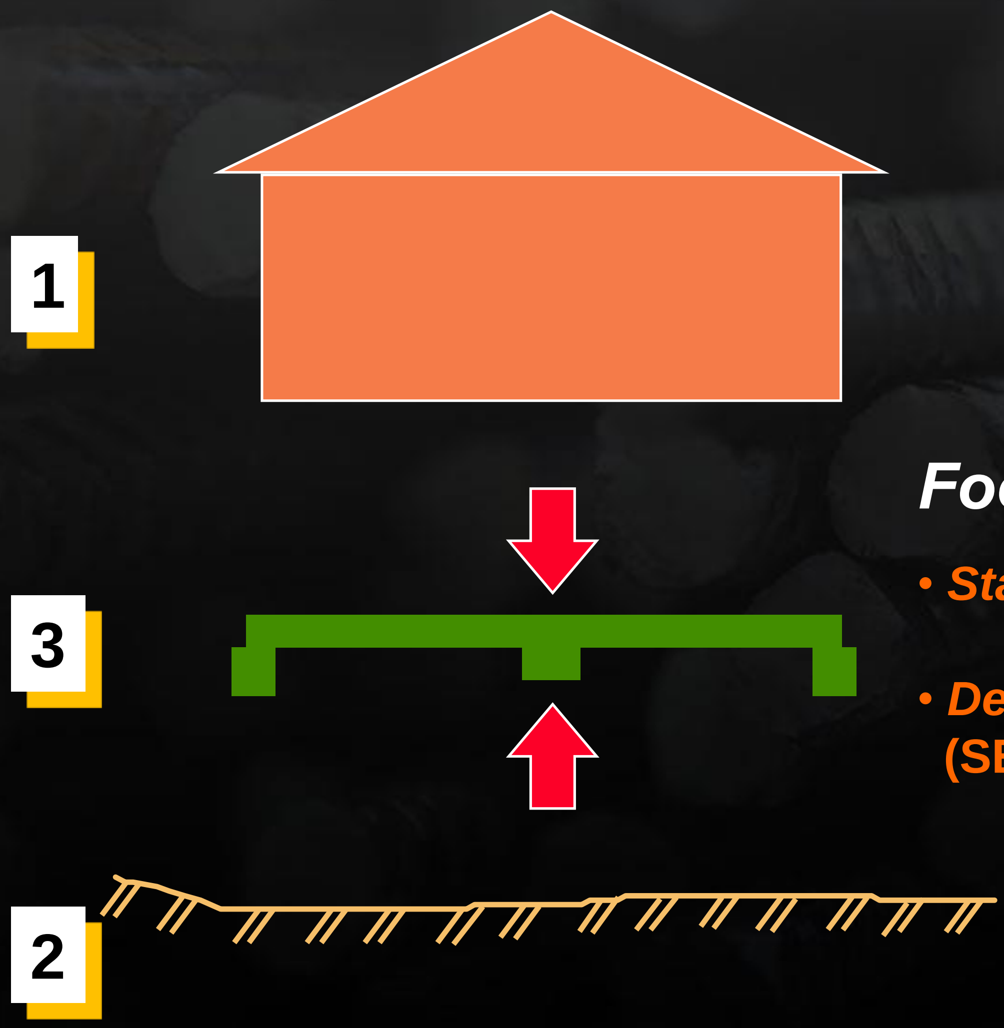
(c) all design and construction shall comply with Sections 5 and 6.

Residential concrete footing system design, detailing and construction should also comply with AS 3600,

except that if in conflict, AS 2870 takes precedence.

Steel Reinforcement Institute of Australia

AS 2870: Design Process



Residential Building

Footing System ("barrier"):

- *Standard Designs* (SECTION 3)

or

- *Design by Engineering Principles* (SECTION 4)

Foundation:

- Site classification (Section 2)

Steel Reinforcement Institute of Australia

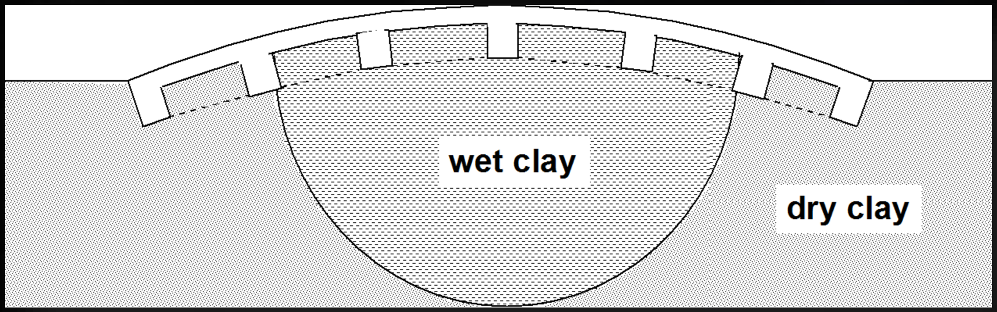
AS 2870 Section 3: Standard Designs

- DTS Designs - calibrated empirically by observing the real performance and reserve strength of completed buildings.
- Less emphasis on design loads & greater emphasis on foundation movement
- Clause 1.4.2 - design actions are:
  - 1.0 × Foundation movement + 1.0 × Permanent action (DL) + 0.5 × Imposed action (LL)
- Why this design philosophy:
  - Foundation movement is a primary design consideration for footing systems which act as a "*barrier*" to protect the structure they support.
  - Less emphasis given to dead and live loads reduces overall cost of housing nationally.
  - Failure due to overloading poses only a minimal or nonexistent risk to life.
- The minimum requirements will not necessarily result in a defect-free building, as stated in Clause 1.3.1.

Steel Reinforcement Institute of Australia

AS 2870 Section 3: Standard Designs

- Section 3 Deem-to-comply 'recipe' footing system designs cover most sites (except class E & P)
- Maximum differential footing deflection (i.e. serviceability) is specified for the design of footing & rafts in Table 4.1
- Limits damage depending on sensitivity and type of supported elements e.g. masonry.
- Slabs & footings modelled as beams or rafts supported on a foundation are indeterminate systems.
- Software is an efficient modelling tool and has been used to check Section 3 design models to Section 4 engineering principles.
- One such program is '*CORD*' – Code Orientated Raft Design, a commercial footing design program.



Steel Reinforcement Institute of Australia

AS 2870 Section 3: Standard Designs

Standard reinforcement designs satisfy the following criteria (of Section 4):

BENDING STRENGTH (cross-section design):

- **$M^* \leq \phi M_u$**
  - M_u = nominal moment capacity calculated in accordance with AS 3600, e.g. f_{sy}=500 MPa
  - ϕ = capacity reduction factor (**NOTE:** ϕ=0.8 for both Class L & N steels in AS 2870)

SHEAR STRENGTH (region design, e.g. punching shear):

- **$V^* \leq \phi V_u$**
  - V_u = nominal shear capacity (with or without shear reo) calculated in accordance with AS 3600
  - ϕ = capacity reduction factor (ϕ=0.7 for both Class L & N steels)

DUCTILITY (overall member design):

- **$M_u \geq 1.2 M_{cr}$** (minimum bending strength for multiple crack development)
  - flexural cracking moment, M_{cr} (for f'_c= 20 MPa : sagging f_t = 2.7 MPa; hogging f_t = 1.8 MPa)

NOTE: All standard footing designs developed with:

- ϕ = 0.8 (flexure) or 0.7 (shear) for Ductility Class L & N steels.

SRIA
Steel Reinforcement Institute of Australia

AS 2870 Section 3: Standard Designs

Greatest ductility demand is in Clad or Articulated Masonry Veneer

TABLE 4.1

MAXIMUM DESIGN DIFFERENTIAL FOOTING DEFLECTION (Δ) FOR DESIGN OF FOOTINGS AND RAFTS

Type of construction	Maximum differential deflection, as a function of span, mm	Maximum differential deflection, mm
Clad frame	L/300	40
Articulated masonry veneer	L/400	30
Masonry veneer	L/600	20
Articulated full masonry	L/800	15
Full masonry	L/2000	10

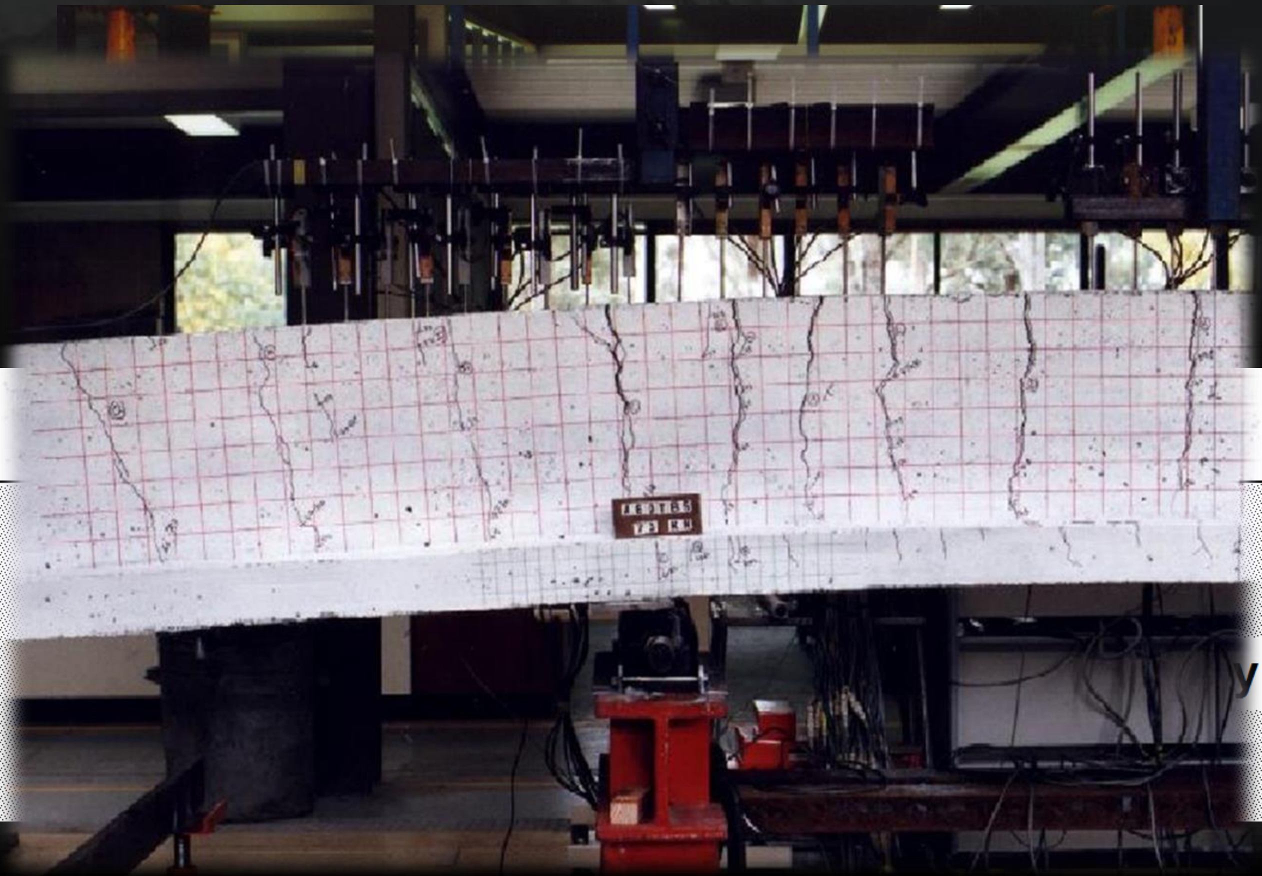
NOTE: Deeper (stiffer) members are required as the design differential deflection reduces.

Their ductility is less, but so is the ductility demand.

Steel Reinforcement Institute of Australia

AS 2870 Section 3: Standard Designs

These deformations can be accommodated by the ductility of the reinforced-concrete sections incorporating either Class L or N reinforcing steel provided they are designed for multiple cracking.



Steel Reinforcement Institute of Australia

AS 2870 Section 4: Design by Engineering Principles

Reinforcement Requirements for Higher Concrete Grade:

- Standard footing designs are all based on f'_c=20MPa and **do not** apply for concrete grades of 32 MPa or greater.
- Higher grade concretes may be required e.g. saline conditions.
- Tensile strength and modulus of elasticity will both increase in proportion to the square root of compressive strength grade, f'_c.

Concrete grade	Modulus of elasticity E MPa	Tensile strength Hogging deformation MPa	Tensile strength Sagging deformation MPa
N20	15000	1.8	2.7
N25	16800	2.0	3.0
N32	19000	2.3	3.4
N40	21200	2.5	3.8

- **If concrete sections remain unchanged, then designers must calculate the steel reinforcement required to satisfy ductility, i.e. $M_u \geq 1.2 M_{cr}$.**

Steel Reinforcement Institute of Australia

AS 2870 Section 4: Design by Engineering Principles

Ductility Requirements & Durability:

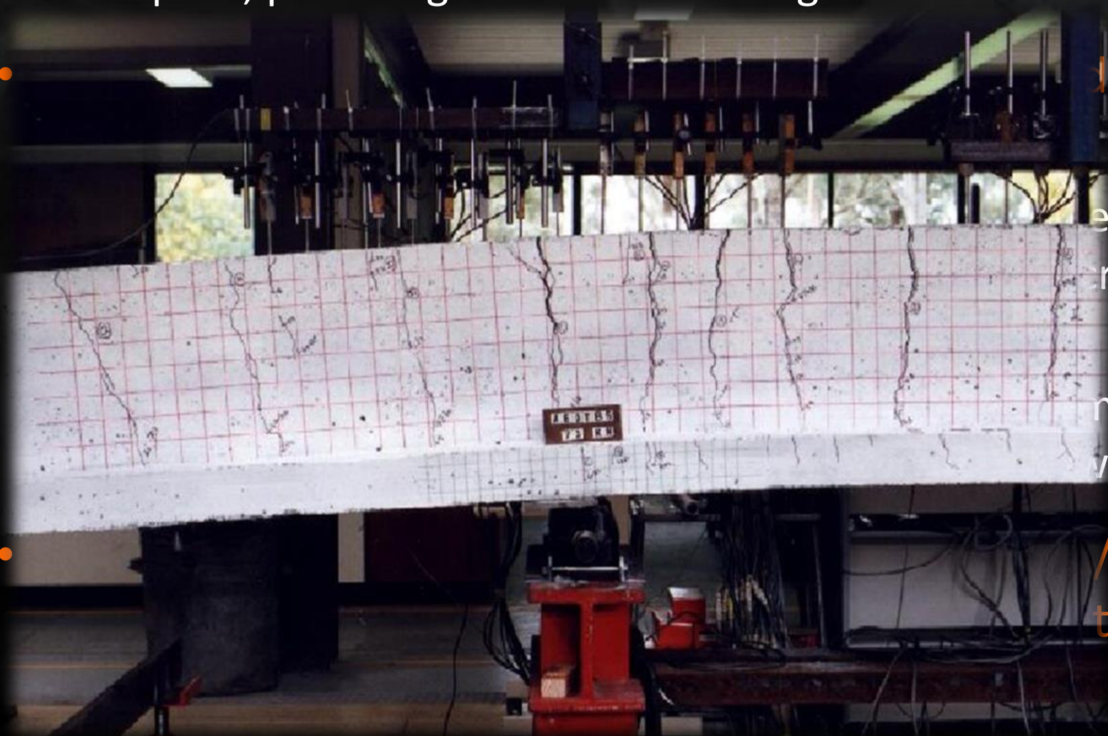
- Satisfying the ductility requirement $M_u \geq 1.2M_{cr}$ allows multiple cracks to form over any zone under a high degree of bending.
  - Concrete block elements form between adjacent cracks spaced approximately *D* apart , providing a mechanism for greater overall member deformation
- Multiple cracking in peak moment regions avoids concentrating the crack width at the first-cracked section.
  - With 3-4 cracks forming in each peak region, more rotation is achieved as demanded by the soil movement, etc., and finer cracks normally maintain durability
  - e.g. 1 crack 0.6 mm wide can be visually a problem, damage finishes or be a corrosion issue, while 3 fine cracks each 0.2 mm wide is good design.
- Class L and N reinforcing steels complying to AS/NZS 4671 have sufficient ductility to ensure adequate deformation capacity.

SRIA
Steel Reinforcement Institute of Australia

AS 2870 Section 4: Design by Engineering Principles

Ductility Requirements & Durability:

- Satisfying the ductility requirement $M_u \geq 1.2 M_{cr}$ allows multiple cracks to form over any zone under a high degree of bending.
  - Concrete block elements form between adjacent cracks spaced approximately *D* apart , providing a mechanism for greater overall member deformation



- ls concentrating the crack

  e rotation is achieved as
  racks normally maintain

  n, damage finishes or be a
  vide is good design.

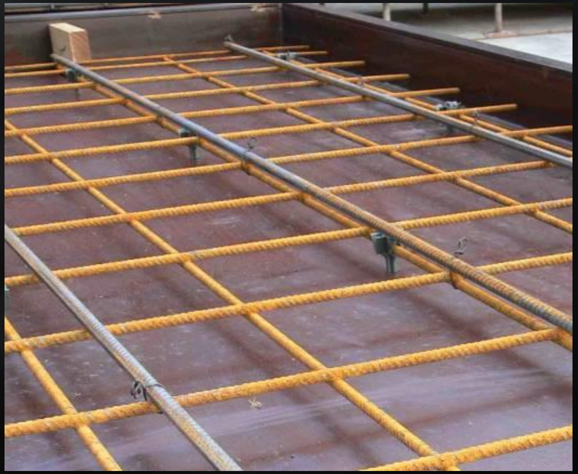
- /NZS 4671 have
  tion capacity.

SRIA
Steel Reinforcement
Institute of Australia

Mixing Ductility Class L & N Steels

If mixing Ductility Class L & N steels together in a single layer, for AS 2870 footing designs they are treated as fully equivalent:

- $\phi = 0.8$ to calculate ϕM_u
  - Moment redistribution is not normally assumed when calculating M^*, which reduces ductility demand on the reinforcing steel
  - No imminent warning requirements
  - Sections normally under-reinforced
  - When calculating nominal moment capacity, M_u, assume all steel is at yield stress, f_{sy} = 500 MPa
- $\phi = 0.7$ to calculate ϕV_u
  - When calculating nominal shear capacity excluding contribution of shear reinforcement, V_{uc}, for example, all fully-anchored Class L & N main bars are fully effective, i.e. use full cross-sectional area.



Class N bars and Class L mesh effectively in a SINGLE LAYER

SRIA
Steel Reinforcement Institute of Australia

SRIA Recent Conference Papers

Available on SRIA website www.sria.com.au

CECAR5/ASEC 2010

- A Review of recent Australian Bond Test Results and the New Stress Development Design Rules of AS 3600-2009
- New Design Tables for Development and Lap Splice Lengths in accordance with AS 3600-2009
- Review of Australian Support-Settlement Tests on Continuous, One-Way Reinforced-Concrete Slabs incorporating Low-Ductility Reinforcement

CIA - Concrete 2011

- New design rules and tables for development and lap splice lengths in accordance with AS 3600-2009

ASEC 2012

- SRIA's Class L Mesh Elevated Slab Tests: Part 1 – Details and Results
- SRIA's Class L Mesh Elevated Slab Tests: Part 2 – Strength Design to AS 3600-2009 and Comparison with Test Results

Steel Reinforcement Institute of Australia

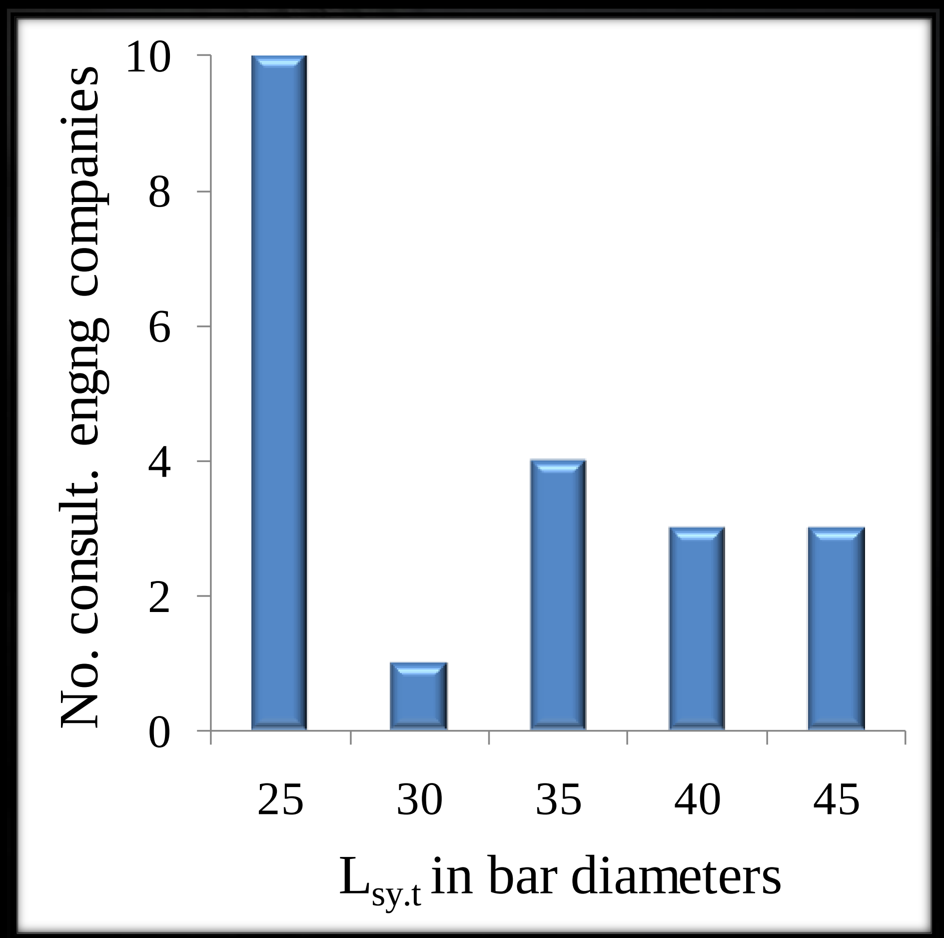
Past AS 3600-2001 Clause 13.1:

Reinforcement stress development vs present

SRIA Industry Survey of current Engineering Drawings

$L_{sy.t}$ for D500N12 bars

in slabs or beams



AS 3600-2001

Tensile Development or Lap Length:

$$L_{sy.t} = \frac{k_1 k_2 f_{sy} A_b}{(2a + d_b)\sqrt{f'_c}} \geq 25 k_1 d_b$$

NOTE: AS 3600-2009

Basic Tensile Lap Length:

$$L_{sy.tb.lap} = k_7 \frac{50k_1\left[(1.0 - 0.15(c_d - d_b)/d_b\right] f_{sy} d_b}{(132 - d_b)\sqrt{f'_c}} \geq 29 k_1 d_b$$

SRIA
Steel Reinforcement Institute of Australia

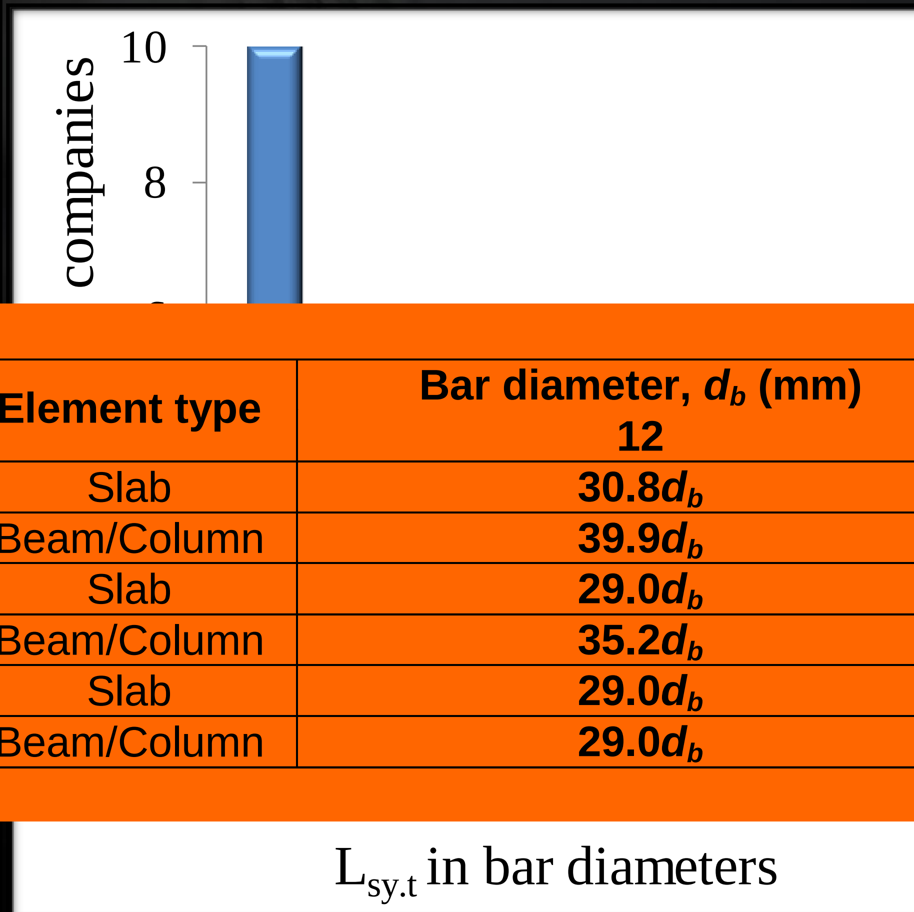
Past AS 3600-2001 Clause 13.1:

Reinforcement stress development vs present

SRIA Industry Survey of current Engineering Drawings

$L_{sy.t}$ for D500N12 bars

in slabs or beams



Exposure classification (EC) & strength grade f'_c	**Element type**	**Bar diameter, d_b (mm) 12**
A1 & f'_c = 25 MPa	Slab	**30.8d_b**
	Beam/Column	**39.9d_b**
A1 & $f'_c \geq$ 32 MPa	Slab	**29.0d_b**
	Beam/Column	**35.2d_b**
B1 & $f'_c \geq$ 32 MPa	Slab	**29.0d_b**
	Beam/Column	**29.0d_b**

Steel Reinforcement Institute of Australia

SRIA Professional Resources

www.sria.com.au

PUBLICATIONS:

- ***Guide to Seismic Design and Detailing of Reinforced Concrete Buildings In Australia***

SRIA Technical Notes:

- **TN1:** Surface condition of steel reinforcement
- **TN2:** Substitution of N12 rebar in AS 2870 Residential Slabs & Footings
- **TN3:** Restrictions on the use of wire bar chairs
- **TN4:** Fabrication & site handling of reinforcing bars
- **TN5:** Guidelines for the economical assembly of reinforcement
- **TN6:** Design to AS 3600:2001 of suspended concrete floors reinforced with class L mesh
- **TN7:** *Coming soon...* New Design Tables for Tensile Development and Lap Splice Lengths to AS 3600:2009

www.sria.com.au

Crack width gauge

SRIA
Steel Reinforcement Institute of Australia

SRIA Processor Members

ARC THE AUSTRALIAN REINFORCING COMPANY

AUSREO

onesteel reinforcing

BIANCO REINFORCING

SRIA Steel Reinforcement Institute of Australia

NEUMANN STEEL

activesteel

WIRE INDUSTRIES

A K Z Reinforcing

BESTBAR REINFORCING THE FUTURE

VICMESH

SRIA Steel Reinforcement Institute of Australia

SRIA Associate Members

Action Products

Ancon
Building Products

aSa

Connolly
Concrete Jointing Systems

ERICO

SRIA
Steel Reinforcement Institute of Australia

RBSC Pty Ltd
"Supporting the building industry everywhere"

FRANK

Spacers Australia
"Supporting Australia"

MB direct
supporting the construction industry

ramsetreid
Innovative construction solutions

SRIA
Steel Reinforcement Institute of Australia

Thank You

SRIA

Steel Reinforcement
Institute of Australia