REINFORCEMENT HANDBOOK

YOUR GUIDE TO STEEL REINFORCEMENT

ARC
THE AUSTRALIAN REINFORCING COMPANY

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Sunshine VIC 3020 Australia

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Preamble

This handbook is the latest of many publications, since the 1920s, from ARC.

It has the continuing objective of providing engineering details and properties of reinforcement available throughout Australia, together with an interpretation of the requirements of Australian Standards within the context of practical solutions.

The information is considered to be of value to all who work in the structural design and construction industry – in a design office, on a construction site or a student preparing to enter the industry.

There is considerable emphasis on the requirements of many Australian Standards. Standards are changing continuously to ensure that the latest practices are included. It is hoped that this publication will retain its relevance for several years, given that the major standards for reinforcing steel and reinforced concrete design have been recently released.

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1.0 Introduction

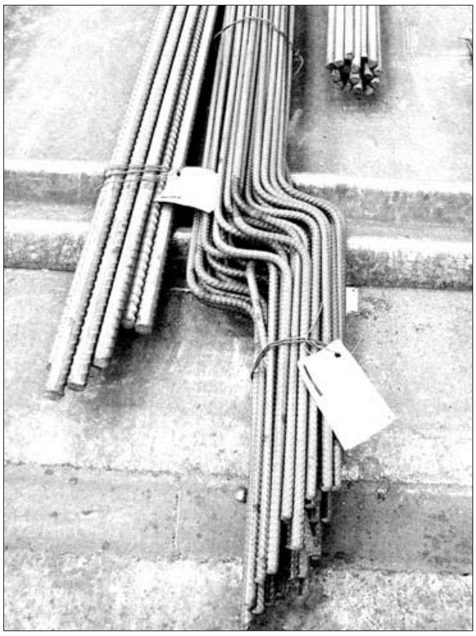


Figure 1: Reinforcement cut, bent and bundled for delivery to site

The Reinforcement Handbook provides information about the use of steel reinforcement when embedded in 'plain' concrete, in normal reinforced concrete or in prestressed concrete.

Other information includes guidance on some applicable Australian Standards, design and construction tolerances, fabrication of reinforcement and tabulated data on fabric and bars.

The major source of information is AS3600-2001, the Concrete Structures Standard.

To design and detail concrete structures correctly, the reader will need access to several other books and reference manuals. Some suggestions are given in the following pages.

Recycling and restoration of older buildings is becoming more and more economical so that modern design techniques, combined with knowledge of the condition of the building, enable the existing reinforced concrete to be used with only minor modifications. For this reason, historical data is given in Appendix C, Refurbishment of Buildings.

Figure 2: Reinforcement being tied on site

2.0 Australian Codes, Standards and References

Standards Australia is responsible for preparing and publishing those standards that relate to building materials and design. In the preparation of this handbook, it has been assumed that the user will have access to a copy of the relevant standards.

All building construction within each state and territory is controlled by its relevant building regulations. Cross-references to other Australian Standards incorporates them into the regulations.

The Building Code of Australia, first published in 1988, was originally intended to provide uniformity of design and construction throughout Australia. Because each state and territory can incorporate its own special rules, designs prepared outside your state may require checking because of differing interpretations.

Other national bodies such as the Steel Reinforcement Institute of Australia (SRIA), the Cement and Concrete Association (C&CA) and Austroads prepare information helpful to the design of reinforced and prestressed concrete.

Further information may be obtained from the appropriate organisation in each state.

Ref. No.	Title of Standard	Reference Date
AS3600	Concrete Structures Standard	(2001)
AS3600 Supp1	Supplement No. 1 Commentary on AS3600 (being revised)	(1994)
AS/NZS 4671	Steel Reinforcing for Concrete	(2001)
AS3679.1	Hot-Rolled Structural Steel Bars and Sections	(1996)
AS1391	Methods for Tensile Testing of Metals	(2007)
AS1554.3	Structural Steel Welding Code - Welding of Reinforcing	(2008)
AS4680	Hot-Dipped Galvanised (Zinc) Coatings on Fabricated Ferrious Articles	(2006)
AS/NZS 4534	Zinc and Zinc/Aluminium-Alloy Coatings on Steel Wire	(2006)
ASTM A775M	Epoxy Coated Steel Reinforcing Bars, ASTM, Philadelphia, USA	(2001)
ASTM A934M	Epoxy Coated Steel Prefabricated Reinforcing Bars, ASTM, Philadelphia, USA	(2001)
AS2783	Concrete Swimming Pools Code	(1992)
AS2870	Residential Slabs and Footings - Construction	(2003)
AS3850	Tilt-Up Concrete Construction	(2003)
AS/NZS 1100.501	Technical Drawing - Structural Engineering Drawing	(2002)
AS3610	Formwork for Concrete	(1995)
AS/NZS9001	Quality Management Systems	(2000)
AS5100	Bridge Design Specification	(2004)

Table 1: Australian Standards relevant to steel reinforcement (as at November 2008)

1. "Reinforcement Detailing Handbook", Concrete Institute of Australia, Sydney, 1988
2. "Concrete Design Handbook", Cement and Concrete Association of Australia, Sydney, 1989
3. "Design and Analysis of Concrete Structures", Fairhurst and Attard, McGraw-Hill, 1990
4. "Concrete Structures", Warner, Rangan, Hall and Faulkes, Longman, 1998
5. "After-Fabrication Hot Dip Galvanizing", Galavanizers Association of Australia, Melbourne, Australia, 1999
6. "Two Hundred Years of Concrete in Australia", Concrete Institute of Australia, Sydney, 1988
7. "Guidelines for Economical Assembly of Reinforcement", SRIA, Sydney, 1988 (TPN2)
8. "Effect of Rust and Scale on the Bond Characteristics of Deformed Reinforcing Bars", Kemp, Brenzy and Unterspan, ACI Jrnl Proc. Vol 65, No 9, Sept 1968, pp 743-756
9. "Effect of Rust on Bond of Welded Wire Fabric", Rejab and Kesler, Technical Bulletin No 265, American Road Builders Association, Washington DC, 1968
10. "The Effect of Initial Rusting on Bond Performance of Reinforcement", CIRIA report No 71, 1977
11. "Precast Concrete Handbook", NPCAA, 2002

Table 2: Technical references

3.0 Glossary of Terms

3.1 General Reinforcement

Figure 3: Coiled bar

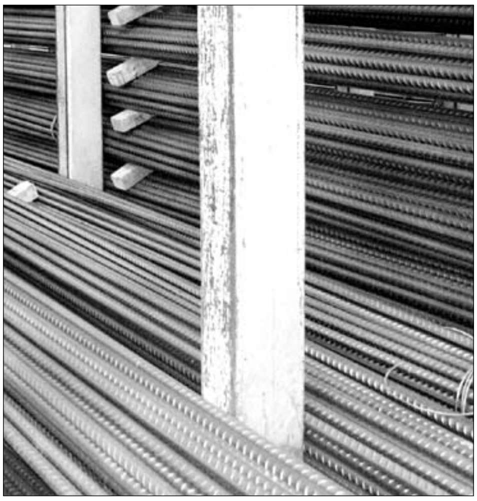


Figure 4: Straight rolled bar

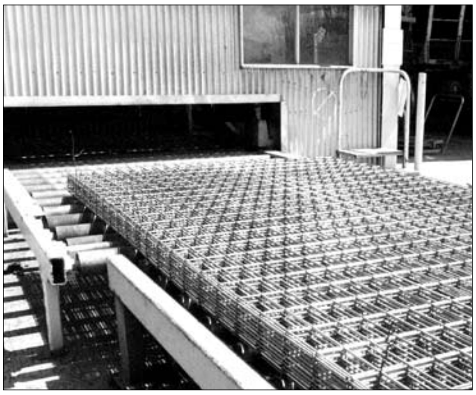


Figure 5: Mesh sheets

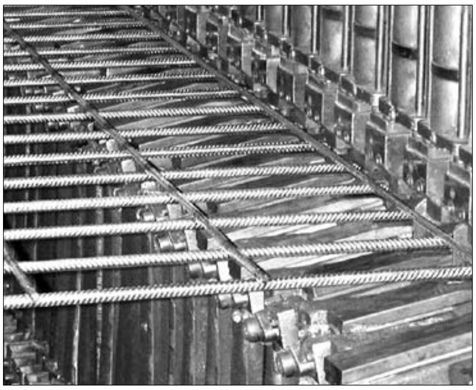


Figure 6: Mesh production

Reinforcement

Reinforcement is a general term used in AS3600-2001 (Concrete Structures Standard) and by designers, reinforcement processors and building contractors.

Reinforcement includes deformed bars, plain bars, wire, fabric and steel products, all of which increase the tensile and compressive stress carrying properties of concrete.

Steel reinforcement is also the essential contributor towards crack control of concrete structures.

Reinforcing Bar

A bar is a finished product rolled to close tolerances. Generally regarded as being supplied in straight lengths, it is also manufactured in coiled form.

Australian Standard AS/NZS 4671 is a performance standard for reinforcing bars. There is no distinction between:

- methods of manufacture such as coiled-bar or straight-rolled bar.
- methods of production such as quench and self temper steels and micro-alloy steels.
- hot rolled and cold worked reinforcement.

Mill-produced lengths of straight bars range from 6 to 18 metres. Availability of lengths varies across Australia. For local availability contact ARC.

Reinforcing Mesh

Mesh is manufactured in flat sheets with bars up to 12 mm diameter, or rolls for fabric with bars up to 5 mm diameter. The sheets are typically 6 metres by 2.4 metres. The fabric consists of reinforcing bar welded in either a square or rectangular grid.

Automatic welding machines ensure that the grid of bars has consistent spacing to provide a defined cross-sectional area for designers. The bars are welded electronically using fusion combined with pressure. This fuses the intersecting bars into a homogeneous section without loss of strength or cross sectional area.

Most reinforcing fabrics available in Australia are produced from deformed cold rolled bar of grade D500L reinforcement. One of the advantages of cold rolling is that the applied force required to drag the bar through the rolling cassettes provides an automatic check of the bar tensile strength in addition to the quality testing required by AS/NZS 4671.

3.2 Reinforcement Production Terms

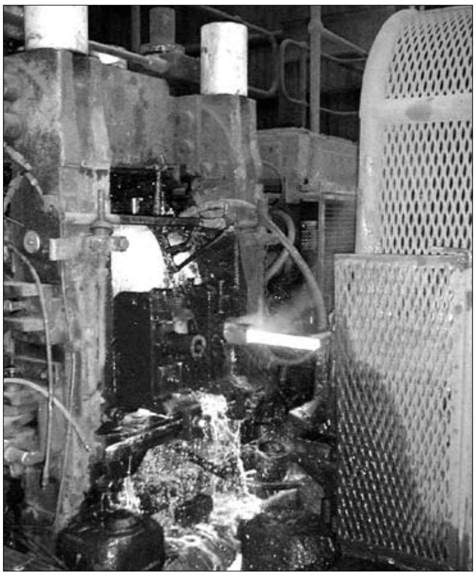


Figure 7: Hot rolled bar

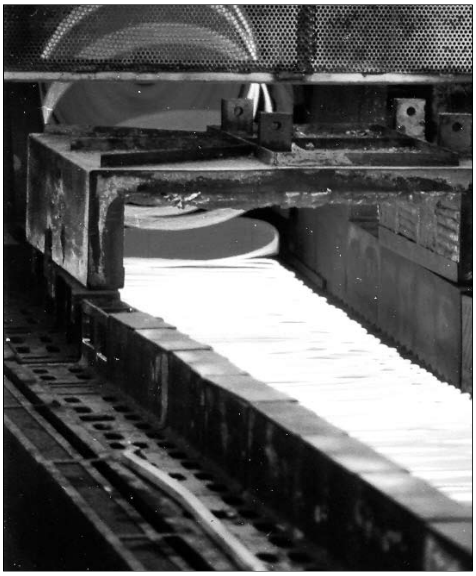


Figure 8: Hot rolled coil

Hot Rolled Steel

A product rolled to final shape and tolerances at a temperature of about 1150°C. The strength properties at room temperatures are obtained by chemistry or by rolling techniques. The finished surface may be plain or deformed.

Micro-Alloyed Deformed Bar and Coil

This is a low carbon, micro–alloyed high strength hot rolled reinforcing bar. Its strength comes from a small controlled addition of Vanadium, or similar alloying element, to the steel composition during smelting. ARC processes N12 and N16 coils and N40 and D450N50 mill bars as micro-alloyed bars. Micro-alloyed bars have constant metallurgical properties across their section which gives superior welding characteristics to quench and self tempered bars.

The N12 and N16 coils are a continuous length of finished low carbon steel, coiled hot as the final part of the rolling process from a billet. The current maximum size of deformed bar available in Australia in coil form is 16 mm, although 20 mm is available overseas. Coiled bar may be straightened and then cut to length, or straightened and bent to shape in one operation.

The surface finish and physical properties allow it to be used in its 'as rolled' condition. The coil mass is typically two tonnes. Coils of up to five tonnes are produced.

Quench and Self Tempered Deformed Bar (QST)

This is a low carbon, hot rolled steel which obtains its high strength from a mill heat treatment and tempering process. After the bar is rolled to size and shape, it passes through a water cooling line where the surface layers are quenched to form martensite while the core remains austenitic. The bar leaves the cooling line with a temperature gradient through its cross-section. The natural heat within the core flows from the centre to the surface resulting in self tempering of the martensite. The core is still austenitic. Finally, the austenitic core transforms to ferrite and pearlite during the slow cooling of the bar on the cooling bed. The product therefore exhibits a variation in mircostructure in its cross-section with a tough tempered martensite as the surface layer, and a ductile ferrite-pearlite core.

Hard Drawn and Cold Rolled Bar

A continuous length of finished material produced from coiled rod having a very low carbon content and a yield stress of approximately 300MPa.

The hot rolled rod is subjected to two or more cold rolling operations which produces a circular or triangular cross-section. An additional pass through a set of deforming rollers produces the required surface pattern.

Bar, whether hard drawn or cold rolled, is covered by AS/NZS 4671. Previous codes referred to hard drawn and cold rolled products as wire.

Production can be by rolling under intense pressure, or by drawing the rod through a 'die' having a diameter smaller than the rod, or both. Rolling followed by drawing provides a smooth surface.

During rolling or drawing, the diameter of the rod is reduced to approximately 88% of its original value. This gives a reduction in area of approximately 20-25% with a consequent increase in length. The mass of the original rod and the final wire coil is not changed.

The cold work process raises the yield stress of the finished bar to above 500MPa. Australian metric sizes for cold rolled bars are given in Table 28 in section 11.6.

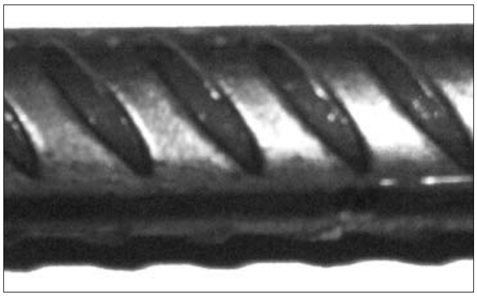


Figure 9: Cold rolled bar

As a generalisation, cold working rod by drawing or rolling has the following effects on steel:

- The yield stress is increased: eg, from 300 MPa to 500 MPa.
- The tensile strength is increased above the original hot rolled value: eg, from 500 MPa to 600 MPa.
- The Agt is reduced: eg, from 20% to 1.5%.
- The strain ageing properties become worse.
- The effect of rebending may be severe.
- Galvanising bent material can increase brittleness.

Bar produced by cold rolling has the following characteristics:

- Close control of quality since the operation is largely automatic.
- Deformations can be added during the rolling process.
- The cross-section is almost circular allowing good control and thus improved bending accuracy.
- The surface appearance is rougher than hard drawn material, but this is of little consequence for reinforcement after it is encased in concrete. Surface roughness improves anchorage in the concrete.
- Alternately rolling followed by drawing can provide a smooth surface finish.
- Cold rolled wire does not require a lubricant during manufacture, as does drawn wire. Although this lubricant may postpone for a few days the advent of rusting, the fine film of rust which appears on rolled wire soon after exposure to weather is more likely to improve the bond than to reduce it. See technical references 8, 9 and 10 in Table 2.

Indented Wire

Here the outer shape is formed firstly by drawing hot rolled rod through a die of circular cross-section, and then a pattern is indented into the surface. This product is common in Europe, but not in Australia or USA.

Cold Worked Bars (1957-1983)

Cold working is a process by which the final properties of a steel are provided by rolling, twisting, drawing or tensioning a hot rolled steel, or by a combination of two or more of these processes. Between 1957 and 1983, the only high strength steels in common use were cold worked.

Before twisting, the Grade 230 bars were either of square section (1957 to 1963) or deformed (1963 to 1983). After twisting, the yield stress (at 0.2% proof stress) was 410MPa for design calculations and they were designated as Grade 410C bars.

Cold worked bars are no longer produced by ARC and are not included in AS/NZS 4671.

3.3 Reinforcement Material Property Terms

Deformations

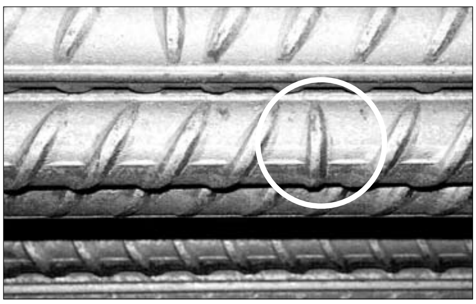


Figure 10: A vertical rib used as a mill mark

Deformations appear as a raised pattern on the surface of the bar. The overall cross-section should be as circular as possible to facilitate uniform straightening and bending. Deforming the surface is the final rolling operation.

The surface pattern consists of transverse deformations and longitudinal ribs. Only the deformation contributes to the anchorage of a bar. The deformation pattern allows considerable scope for steel makers to use additional ribs for product and mill identification.

When considering the cross-sectional area or the mass per metre of a bar or wire, the deformation is regarded as a redistribution of the material and not as an appendage.

Modulus of Elasticity

This is often called ‘Young’s Modulus’ and is denoted by the notation E_S. It is a measure of the constant relationship between stress and strain up to the elastic limit. For all reinforcement steels E_S has a value of 200,000 MPa.

The Modulus of Elasticity is the slope of the stress-strain graph prior to yielding of the steel.

Stress and Strain in reinforcing steel

Stress is a term that allows comparison between the strength of different sizes of the same material. Stress measures the force applied to a unit of area and is stated in megapascals (MPa).

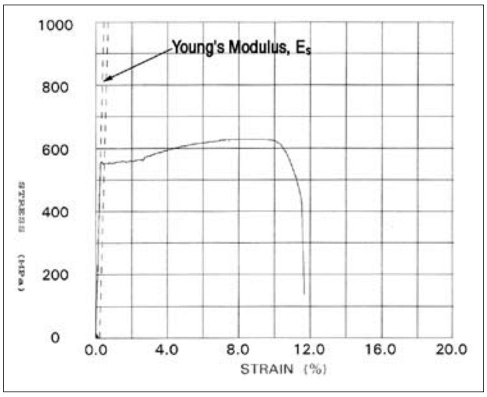


Figure 11: Stress-strain curve

Example 1

- If a force of 60 kilonewtons (kN) is applied to an N16 bar of area 200 mm^2, the stress in that bar is:
  = 60,000/200
  = 300 newtons per mm^2, 300 megapascals or 300 MPa
- If the same force is applied to an N32 bar of area 800 mm^2, the stress is
  = 60,000/800
  = 75 MPa, a lower value because of the larger area
- Conversely, for the same stress of 300 MPa, the N32 bar would be carrying a load
  = 300 x 800 newtons
  = 240 kN

Strain is a measure of the amount by which a tensile force will stretch the bar. Strain is expressed in the units of ‘mm/mm’, or ‘percentage strain’ based on the original gauge length.

Example 2

Using our N16 example from above, the relationship between stress and strain is:

- Strain
  = the stress divided by Young’s Modulus
  = 300/200,000
  = 0.0015 mm/mm
  = 0.15% of the gauge length

Using the N16 example again with a gauge length of 5 bar diameters, we have:

- Extension under load
  = 0.0015 x 5 x16 mm
  = 0.12 mm at a stress of 300 MPa

Example 3

For the same N32 bar at a stress of 75 MPa:

- Strain
  = 75/200,000
  = 0.0004 mm/mm

A lower stress in the bar means smaller strain and thus narrower crack widths in the reinforced concrete element, if they occur.

Yield Stress of Steel

This is the property which determines the maximum usable strength of a reinforced concrete member.

The yield stress of steel is determined by stretching a sample (approximately 600 mm long) in a tensile-testing machine.

When a steel is tensioned, the amount by which the length increases (called 'strain') is directly proportional to the load (or 'stress') applied to the bar in the elastic range. The 'yield point' of the steel is reached when strain is no longer directly proportional to the stress applied to the bar. Beyond the yield point the bar behaves plastically and is permanently deformed.

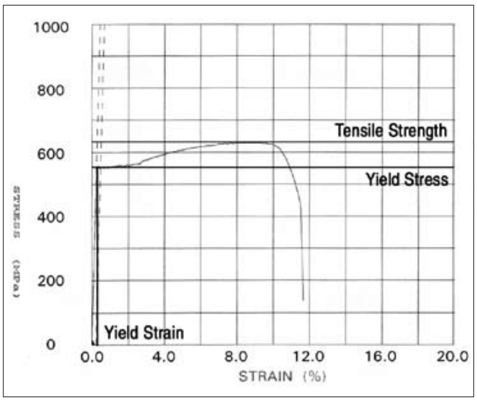


Figure 12: Yield stress

With hot rolled bars, the 'yield point' is quite visible on the stress–strain curve. Once the yield point is reached, the strain increases rapidly for a minor increase in the applied load. The stress level at yield is called the yield stress and the steel is said to have 'yielded'. After yield, the strength of the bar increases due to strain hardening until the tensile strength is reached. After maximum tensile strength has been reached, the capacity of the bar reduces and necking is visible. Eventually the bar breaks.

In fact, if the bar is unloaded part way through the test, below the yield point, the bar will return to its original length. This is why it is called elastic behaviour. The yield stress measured with a second test will be at least as high as it was during the first test.

The characteristic yield stress specified in Australian Standards determines the Grade of the steel. Grade D500N bars must have a characteristic yield stress not less than 500 MPa; Grade D250N and R250N bars must have a characteristic yield stress not less than 250 MPa.

To illustrate the connection between stress, strain and yield stress, there is also a 'yield strain' calculated as follows:

Yield Strain of Bars

= yield stress/modulus of elasticity
= 500/200,000
= 0.0025 mm/mm
= 0.250% of the gauge length

There are three properties that relate to each other in the elastic range:

Stress = Strain x Young's Modulus

1. Young's Modulus
   = 200,000 MPa for all steels

2. Yield stress for Grade D500N
   = 500 MPa, and the calculated yield strain is
   = 0.0025 mm/mm
   = 0.250% of the gauge length

3. Yield stress for Grade R250N and D250N
   = 250 MPa, and the calculated yield strain is
   = 0.00125 mm/mm
   = 0.125% of the gauge length

Yield Stress of Cold Rolled Bar

Cold rolled bar does not exhibit a true yield point; there is no point during a stress-strain test where true yielding is visible.

AS/NZS 4671 allows the 0.2% proof stress to be used as the yield stress when there is no observable yield point.

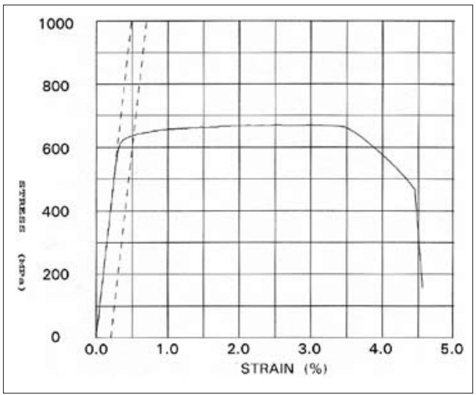


Figure 13: Cold rolled bar stress-strain curve

Tensile Strength of Steel

This is the maximum stress which the steel can carry. In the past, this strength was called the 'ultimate tensile strength'. It is not used directly in reinforced concrete design, however the ratio of tensile strength to yield stress is important to ensure a ductile failure mechanism.

Stress and Strain in Reinforced Concrete

Up to the point where the concrete starts to crack, the strains in the steel and concrete are equal but the stresses are not. The steel carries a much higher proportion of the applied load at a much higher stress – because it has a higher modulus of elasticity.

AS3600 is based on steel strengths of up to 500 MPa. This determines all the 'deemed to comply' rules such as cog lengths, transverse-wire overlaps for fabric, and the requirements for minimum areas of reinforcement.

Plastic and drying shrinkage are two other causes of stress in concrete.

For Australian concretes, the shrinkage strain ranges from 0.0005 mm/mm to 0.0012 mm/mm. This range is close to the yield strain of Grade 250 bars (0.00125 mm/mm). AS3600-2001 contains rules for control of cracks caused by shrinkage and flexure for bars and fabric up to Grade 500 (yield strain 0.0025 mm/mm).

Ductility

Ductility is the ability of a structure to undergo large deformations and deflections when overloaded. If a structure cannot withstand large deformations and deflections when overloaded, then it is subject to brittle failure.

AS/NZS 4671 has introduced three ductility grades for reinforcing steel and two ductility measures. AS3600-2001 has also retained the ductility control of a reduced strength reduction factor for bending members with a $k_u > 0.4$, that is for bending members with excessive tensile steel.

The three ductility grades are Low (L), Normal (N) and Earthquake/Seismic (E). The measures for ductility are Uniform Elongation and the Tensile Strength / Yield Stress Ratio. E Grade material is specifically for use in New Zealand and is not available in Australia.

The Uniform Elongation provides a measure of the ability of the reinforcement to deform, both elastically and plastically, before reaching its maximum strength.

The Tensile Strength / Yield Stress Ratio is a measure of the reinforcement's ability to work harden when undergoing plastic deformation. This means the strength of the steel increases when it is loaded beyond its yield strength.

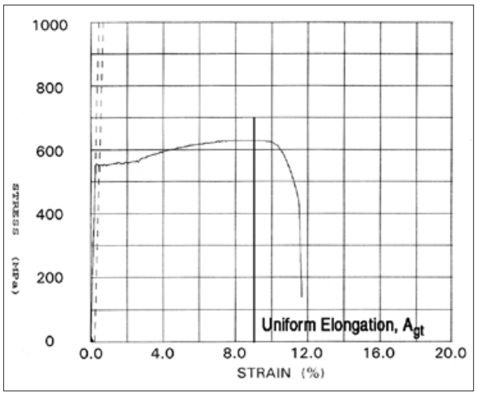


Figure 14: Uniform elongation

Uniform Elongation (Agt)

Uniform elongation is a strain measure. It is a measure of the maximum amount by which a steel sample will stretch before it reaches maximum stress. For strains up to 1% elongation, an extensometer is used. Elongations greater than 1% are measured from the crossheads of the tension testing machine. Uniform elongation can be measured manually by marking a bar at 1 mm intervals prior to tensioning. The bar is then loaded in tension until failure. An elongation measurement (L) is obtained by measuring the length of the bar at a distance of 50 mm from the break for a length between 100 marks (that is, 100 mm length prior to tensioning). The uniform elongation for manual testing is obtained from the formula:

$$A_{gt} = \left(\frac{L\text{-}100}{100} + \frac{\textit{Tensile Strength}}{200{,}000}\right) \times 100\%$$

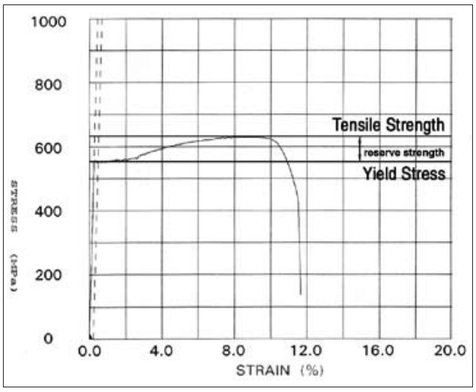


Figure 15: Reserve strength of steel

The first part of the equation measures the plastic deformation of the bar away from the zone affected by necking. The second term measures the elastic deformation. At failure the bar shortens as elastic strain is relaxed, hence the elastic deformation must be added back onto the permanent plastic deformation to obtain the total elongation at maximum stress.

Uniform elongation is a measure of the ductility of the steel.

A steel with high uniform elongation (greater than 5%) is considered ductile; low ductility (under 5%) is considered to be a sign of brittleness.

Uniform elongation is not required directly for design purposes, however, its value is important when specifying and checking the properties of a steel. Design methods requiring high rotation, such as moment redistribution and plastic hinge design, should not use low ductility steels.

AS/NZS 4671 gives minimum values for the Uniform Elongation (A_{gt}) for the different reinforcing steels.

	250N	500L	500N
A_{gt}	5%	1.5%	5%

Strain Ageing

When normal mill steels such as plate, wire, and plain or deformed bars are bent or otherwise reshaped, the steel becomes less ductile with time. There are many reasons, but the main cause seems to be change in crystal structure and the effects of the chemical composition.

Strain ageing causes problems when:

- the steel is bent around a small pin
- bent material is galvanised
- a weld is located close to (within 3 d_b) or at the bend.

Chemical Composition

The selection of the correct chemistry for any steel product is extremely important because it can have a marked effect on the use of the final product.

The most important elements in the composition of reinforcing steel are Iron (Fe) Carbon (C) and Manganese (Mn). AS/NZS 4671 allows both a cast analysis and a product analysis.

Carbon

Carbon turns iron into steel. The Carbon content of steel is limited because as the carbon content increases, the ductility of the steel decreases.

Other Elements

- Manganese increases the strength of steel up to a certain point
- Nitrogen, Phosphorous, Silicon and Sulphur can be deleterious
- Micro-alloying and grain-refining elements, such as Aluminium, Niobium, Titanium and Vanadium, can be used to increase the strength but they can affect other properties, sometimes not to the best advantage of the steel.
- Residual elements such as Copper, Nickel, Chromium and Molybdenum can occur in steel if they are present in any scrap used in steel making. Up to a certain limit they may be considered as incidental and not detrimental to the product.

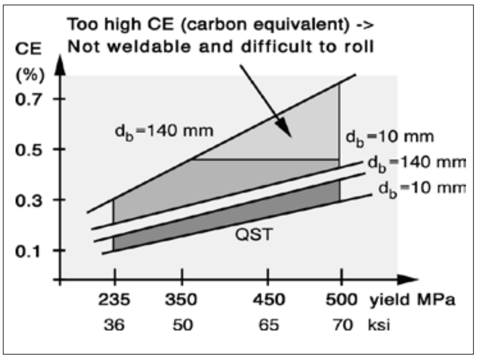


Figure 16: Carbon equivalence versus yield strength

Carbon Equivalence (CE)

This term is regarded as a measure of the weldability of a steel. It is derived from a formula that allows for the influence of Carbon, Manganese, Chromium, Molybdenum, Vanadium, Nickel and Copper. The Australian formula for CE is:

$$C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

When the CE exceeds 0.45, the steel cannot be welded (see Figure 16).

4.0 ARC Product Range

Material Grade	Size Range	Yield stress	Usage	Rolling Mill Type
Plain rod R250N	6.5, 10, 12.5 mm coil	250 MPa	Fitments	As-rolled, rod mill
Plain rod R250N	5.5 to 14 mm coil	250 MPa	Feed for wire	As-rolled, rodmill
Deformed bar D500L	4 to 11.9 mm coil	500 MPa	Fabric, fitments	Drawn or rolled from rod
Deformed mesh D500L	SL43 to RL1218 fabric	500 MPa	General use	Drawn or rolled from rod
Round mesh R500N	6 to 12 mm fabric	500 MPa	Suspended slabs	Drawn or rolled from rod
Plain bar R250N	R10 to R36 straight	250 MPa	Dowel bars	Merchant mill
Deformed bar D250N	S12 straight	250 MPa	Swimming pools	Merchant mill
Deformed bar D500N	N12 & N16 coil	500 MPa	General use	Rod mill
Deformed bar D500N	N12 to N36 straight	500 MPa	General use	Merchant mill
Deformed bar D500N	N40 straight	500 MPa	Special order	Merchant mill
Deformed bar D450N	D450N50 straight	450 MPa	Special order	Merchant mill

Table 3: Reinforcing steel product range

The Concrete Structures Standard, AS3600, and the Reinforcing Steel Standard, AS/NZS 4671, must be regarded as interrelated performance standards. However, although a particular reinforcing steel may comply with, or even exceed, some of the minimum requirements of its Standard, that steel must not be used above the maximum stress limits set down in AS3600.

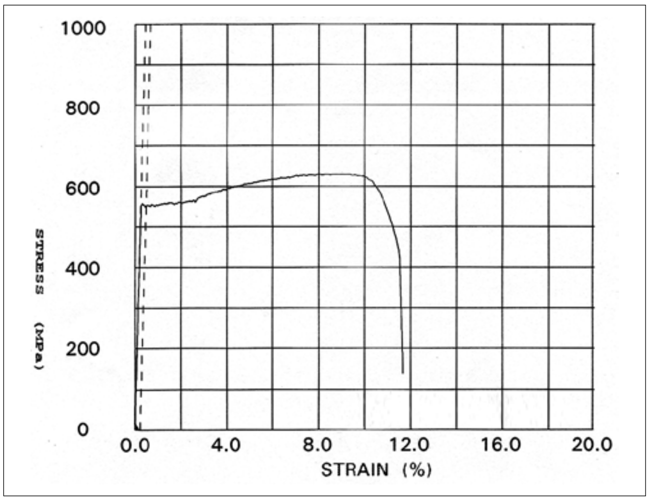


Figure 17: D500N straight stress-strain curve

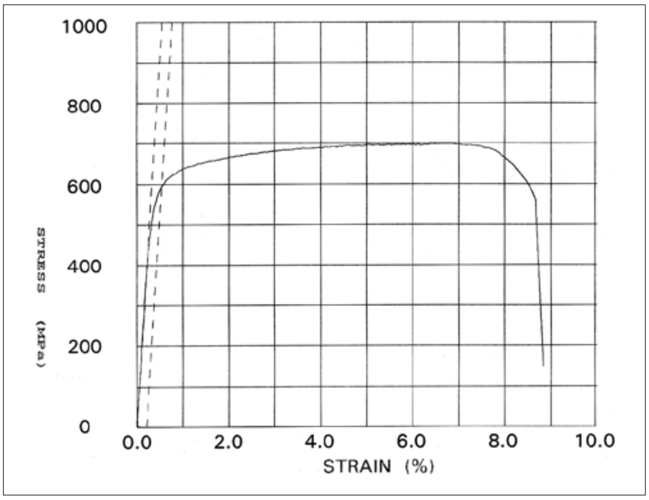


Figure 18: D500N coil stress-strain curve

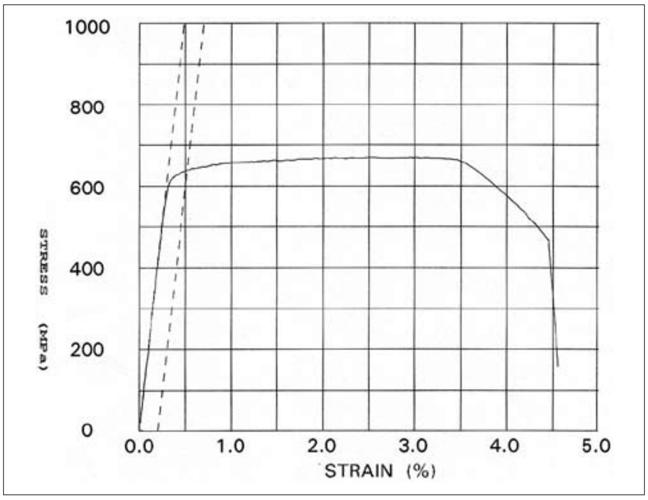


Figure 19: D500L stress-strain curve

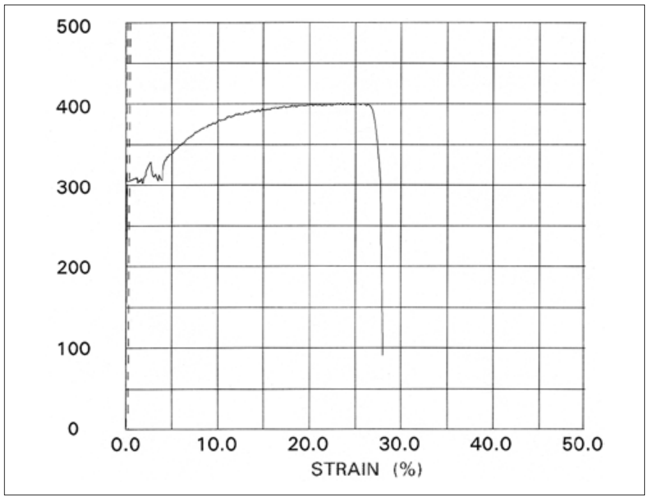


Figure 20: D250N stress-strain curve

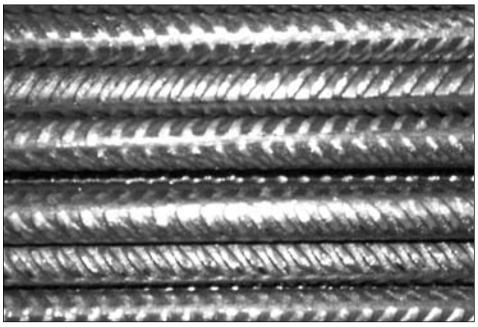


Figure 21: D500L deformations

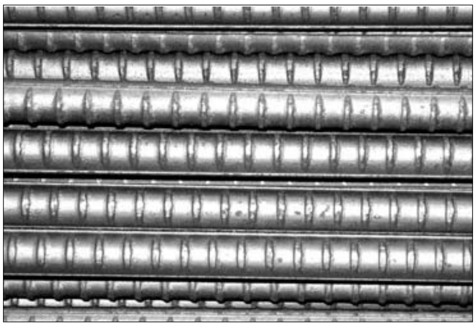


Figure 22: D250N deformations

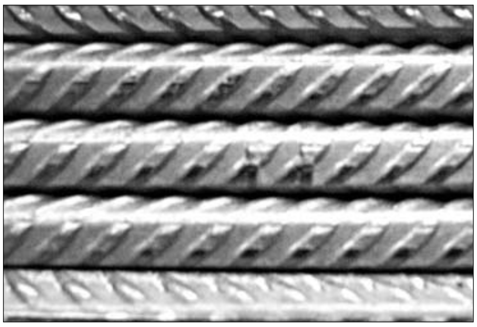


Figure 23: D500N coil bar deformations

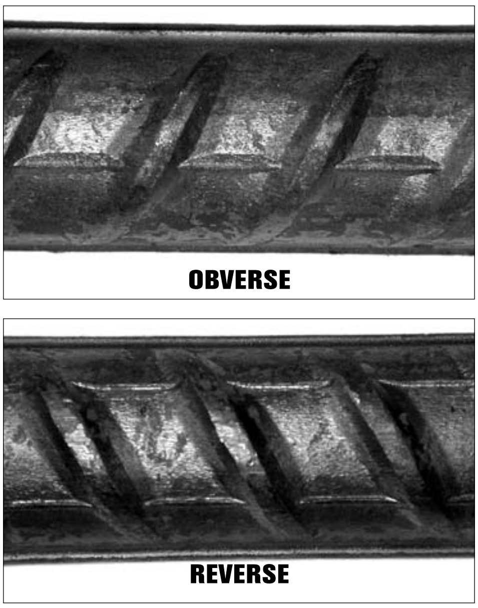


Figure 24: D500N straight bar deformations

Grade R250N Plain Rod in Coils

This is a continuous length of semi-finished, low carbon steel, coiled hot as the final part of the rolling process. Rod provides feed for material with finer tolerances (eg, mesh bars), or is manufactured directly into fitments.

Rod diameters are not the same as bar sizes: rod is available in 0.5 mm increments in the range 4 mm to 14 mm. Only selected sizes are used for reinforcement as fitments.

Grade D500L Deformed Bar and Coil

This is a low carbon, deformed 500 MPa steel. The steel is produced in coils by cold rolling, which is straightened to produce bars. D500L bar and coil are available in sizes from 4 mm to 11.9 mm.

Grade D500L Mesh

Most automatically welded reinforcing fabrics in Australia are made of deformed grade D500L bars. The bar diameters for the fabrics typically range from 4 mm to 11.9 mm. D500L fabric is produced in standard 2.4 by 6.0 metre sheets, however purpose built sheets are available.

Grade R500N Mesh

This is a low carbon, round 500 MPa steel of Ductility Class N. The bar diameters for the fabrics typically range from 6 mm to 12 mm. R500N mesh is produced as purpose built sheets to suit project requirements.

Grade R250N Plain and D250N Deformed Bars

Plain round bars and deformed bars, both of Grade 250, are also manufactured as low carbon, hot rolled steels in straight lengths.

D250N bar is available ex-stock in 12 mm only, being primarily supplied for construction of swimming pools. The D250N12 bar is designated as S12 reinforcement.

Grade D500N Deformed Bar

Grade D500N bar is produced as low carbon, hot rolled deformed bar in straight lengths and in coils. Straight lengths are available from 12 mm to 40 mm diameter. 12 mm and 16 mm diameter D500N bar typically are supplied from coils.

Grade D450N Deformed Bar

50 mm straight bar is manufactured as low carbon, hot rolled micro-alloyed steel with a 450 MPa characteristic yield stress.Grade R500N.

Grade R500N Plain Rod in Coils

Available only in 10 mm.

5.0 Reinforcing Bar Processing

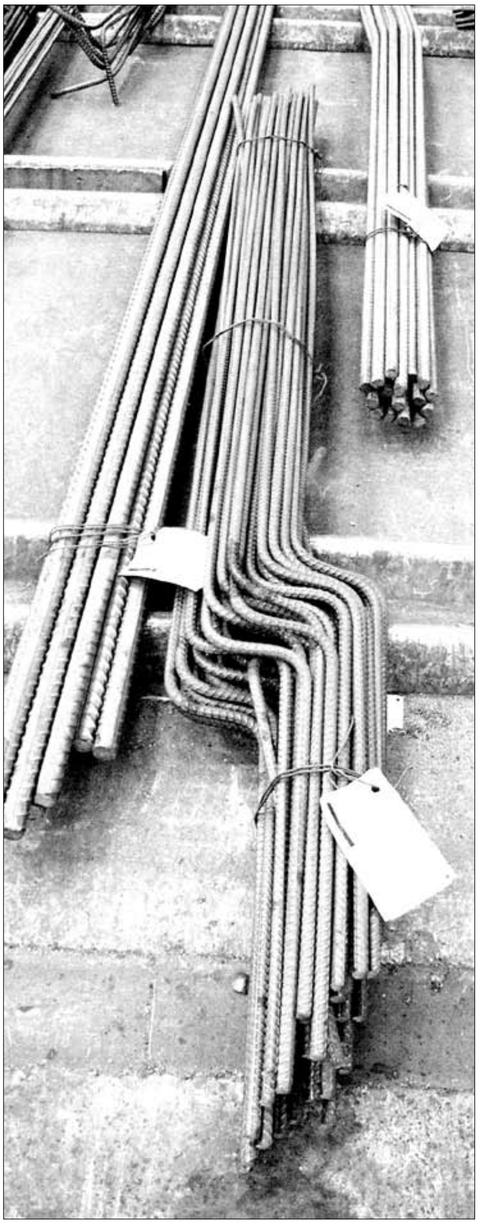


Figure 25: Reinforcement cut, bent, bundled and tagged

Figure 26: Trailer loaded with reinforcement ready to be delivered to site

Introduction

The Australian reinforcement industry involves a very short supply chain from steel maker to consumer.

There is one producer of reinforcing steel in Australia. Next in the chain are the reinforcement processors/suppliers, the largest of which is ARC.

There are 37 ARC branches in all states and territories ranging from large plants, which manufacture mesh and process steel bar for major projects, down to small centres situated in metropolitan and country areas to service local needs quickly. These ARC outlets sell to the public as well as to building contractors. There is also a well established reseller network which maintain stocks of fabric and other materials.

Reinforcement Processing

The term "processing", as used in the reinforcement industry, includes the complete range of operations that translate information on an engineering drawing into usable pieces of steel delivered to the building site. The summary that follows applies to the processing of reinforcing bar:

The bar and mesh schedule

A document giving details for manufacture, delivery and fixing prepared by a "Scheduler". The Scheduler reads the engineering and architectural drawings to determine the number, size, length and shape of reinforcement required. The schedule contains most of the instructions that enable the following processes to be carried out.

Cutting to length

Bar reinforcement is manufactured in stock lengths as straight bars, or in coils for sizes 16 mm and below. One or two stock lengths are held for each bar size. As the dimensions of concrete members rarely match these lengths, the bars must be cut to the required length.

Bending to shape

After cutting, reinforcement may need to be bent to shape. The required shape is determined by the shape of the concrete outline. The shape is defined by a dimensioned sketch on the schedule and tag.

Bundling and tagging

Following bending and/or cutting, bars of similar size and shape are grouped and tied together. A tag identifying the location of the steel in the structure is tied to each bundle. This location, or label, corresponds with the member-numbering system shown on the structural drawings. If the structural drawings show insufficient detail to identify the reinforcement location, a marking drawing may be required.

Delivery instructions

Transport from the ARC factory to the job may be by truck or rail, and in each case requires an identifying tag and associated delivery instructions such as address and customer.

Invoicing

After delivery, the normal commercial procedures of invoicing for each delivery take place. Depending on the contractual arrangements before the commencement of the job, supply may be on the basis of a schedule of rates per tonne, or as a lump sum cost for the total project. It is normal practice for an agreed rise-and-fall or escalation clause to be included.

5.1 Cutting Bars to Length

For bars, the following cutting methods are available:

Guillotine shear

This is a large machine suitable only for factory cutting. Up to 20 smaller diameter bars can be cut at once. Although rough, the ends are suitable for welding, where specified, but not for end-bearing splices.

Diamond-tipped or similar saw

Factory mounted, this can produce an accurate neat end for an end-bearing splice.

Friction saw

A portable saw of this type can be used on site.

Oxy-acetylene torch

For trimming or removing steel. The heat generated during cutting extends only a short way along the bar and, as such, does not affect either the strength or anchorage of a bar end. Take care to avoid spatter on to adjacent steel during cutting. Bars cut using heat are not suitable for end-butt welding.

Manufacturing Tolerances

To enable building materials to fit together, an allowance is required to permit minor variations from the exact value specified. This allowance is called a tolerance. Tolerances on reinforcement are given in AS/NZS 4671, Section 7, and AS3600, Section 19.

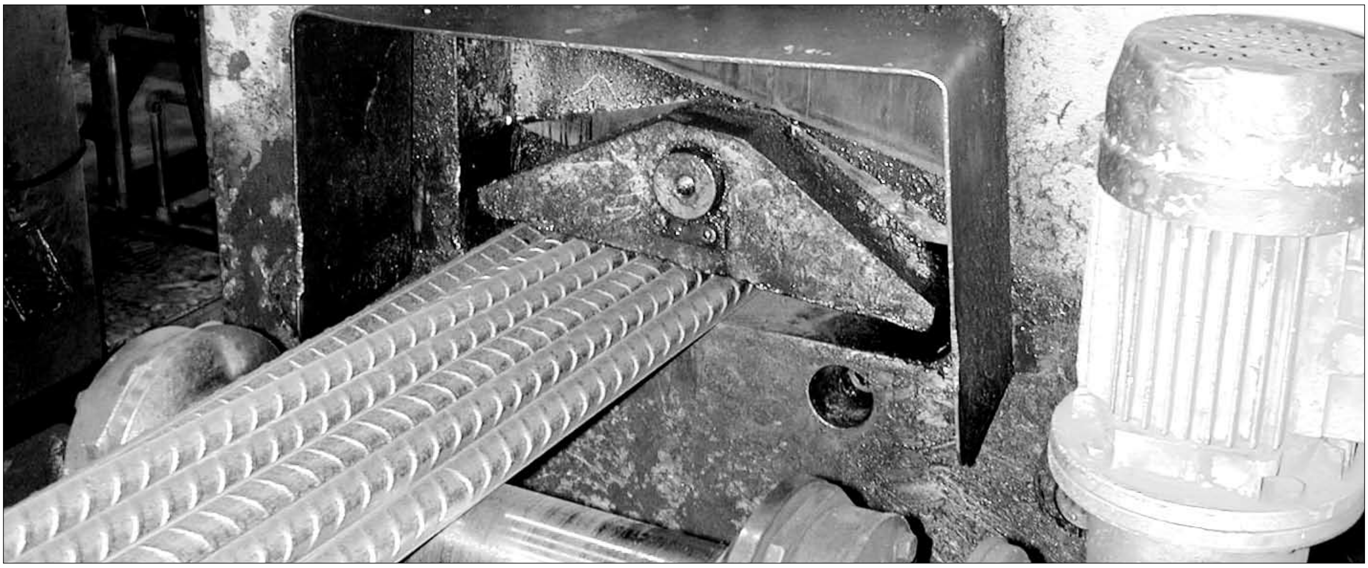


Figure 27: Guillotine shear cutting reinforcement

Economics of Cutting Steel to Length

The need to cut scheduled lengths of steel from stock lengths has already been mentioned in this handbook. Where possible, an order for one scheduled length will be cut from one particular stock length. However, the economics of steel cutting require that minimum scrap is generated. For maximum steel utilisation then, different scheduled lengths are grouped together to be cut from the most economic stock length.

Example A

	Required	*Cut from stock*	*Scrap*
i.	20 x 6000	20 x 6000	0 m
ii.	20 x 6000	10 x 12000	0 m
iii.	20 x 6100	20 x 9000	20 x 2900 mm
iv.	20 x 6100 +		
	20 x 2800	20 x 9000	20 x 100 mm

- In cases (i) and (ii), different stock lengths allow alternative solutions.
- In case (iii), a slight change in length causes an unacceptable scrap length.
- Intercutting between two orders, in case (iv), reduces scrap and utilises one stock length for two scheduled lengths.

Example B

	Required	*Cut from stock*	*Job*
i.	20 x 6100	20 x 9000	Slab S1
ii.	20 x 6100 +		Slab S1
	20 x 2800	20 x 9000	Wall W3
iii.	20 x 6100 +		to job #23
	20 x 2800	20 x 9000	to job #41

- In case (i), all bars from one bundle go to the same site for one particular slab marked S1.
- In case (ii), the two bundles go to the same site, but one bundle is used for slab and the remainder for wall which may not be poured for another week.
- In case (iii), because of the advantages of inter-cutting between different orders, totally different sites would be using steel from the one heat.

These examples illustrate how widely the material from one heat can be spread and why traceability after processing has been replaced by a quality assurance programme, with better results at a realistic cost.

5.2 Bending Reinforcement to Shape

Bar Shapes

There are several reasons for bending bars:

- Where anchorage cannot be provided to a straight length within the available concrete shape or size, it may be necessary to bend a 180° hook or 90° cog on the end. Hooks and cogs are never scheduled unless they are shown on the engineer's drawings.
- Where continuity of strength is required between two intersecting concrete members, the bar will be bent to allow this stress transfer. Such bends are never scheduled unless they are shown on the engineer's drawings.
- Where ties, stirrups, ligatures or spirals (called 'fitments' by the industry) enclose longitudinal bars in a beam or a column, the fitment will be scheduled to match the shape of the surrounding concrete. Mostly the shape is defined by the concrete surface and the specified cover. The actual shape is defined by the scheduler, provided the designer's intentions are given in the drawings. The designer must indicate if cogged or hooked ends are required.
- Where intersecting reinforcement is likely to clash, or where parallel bars require lapping, the scheduler will decide whether or not to provide small offsets.

Standardised Bar-Bending Shapes

The standard shapes used by ARC are based on a combination of Australian and American standards to utilise the best features of each system. ARC's shapes are not subject to copyright. Appendix B contains ARC's standard shape library.

AS3600-2001 Addresses Bending of Reinforcement

The pin diameters given in Clause 19.2.3 of AS3600-2001 have been selected for very good reasons.

Steel is an elastic material, which means that when it is stretched it will return to its original length after the load is released. This is true up to the 'yield point'. When stretched in tension beyond the yield point, the increase in length of the bar becomes permanent. The bar's tensile strength has not been reduced however. If this 'stretched' bar is stretched again it may, under some circumstances, recover its elastic properties and possibly also have a new yield point.

When straight steel is bent a very limited amount, it will spring back to straight. This is because it is still in the elastic range.

When a bar is bent to shape during processing, the steel again has been strained beyond its yield point; if it had not, it would have straightened out! Thus all steel bending changes the material from its original state and any investigation of its properties must allow for this.

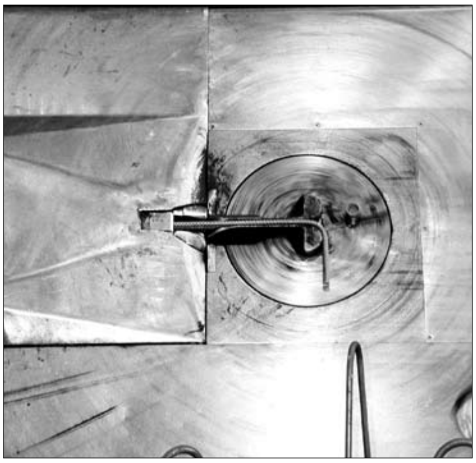


Figure 28: Automatic bending machine for coil reinforcement

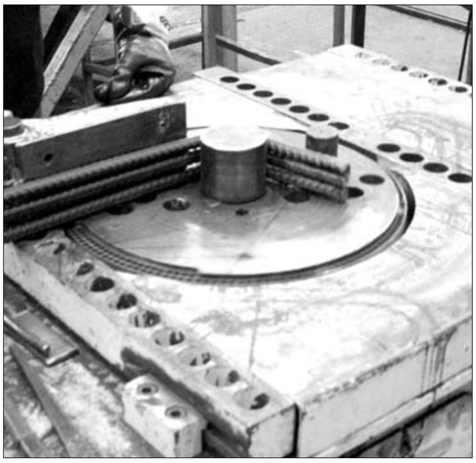


Figure 29: Manual bending machine for straight reinforcement

A similar situation exists with bars straightened from a coil. In this case the final properties may differ from those it would have had if it had been supplied straight, but they are the properties of the steel when used in concrete and they must comply with the relevant standards.

Excessive bending can be classified as having a pin diameter at or below the bend-test diameter. This can change the metallurgical structure of the steel and can also crush the deformations thus initiating a zone of weakness.

The diameter of a bend should not be so large that the hook cannot fit inside the concrete or that it will pull out rather than act as a hook. Nor should it be so small that the pressure between the bend and the concrete will crush the concrete. A compromise value of $5d_b$ for general bending has worldwide acceptance. One of the quality control requirements for a reinforcing steel is that it will pass a bend test. For bars, this test is described in AS/NZS 4671. Despite claims made about the degree of bending which can be sustained by some steels in a laboratory, treatment on a building site can be much more severe. For this reason AS3600 prohibits the use of small diameter pins at or below the bend test sizes. Cold weather bending and the occasional on-site 'adjustment' also require larger pin sizes.

Coated bars are bent about larger pins than uncoated bars. The minimum pin diameters specified for galvanised or epoxy-coated bars are based on three requirements:

(i) Firstly, particularly with epoxy-coated bars, damage to the coating is more likely with small pins because of the greater pressure between bar and pin.

(ii) Secondly, with galvanised bars, a small bending diameter is more likely to break the zinc surface coating.

(iii) Thirdly, the pickling process during hot dip galvanising can lead to hydrogen embrittlement of the reinforcement. The greater the cold working of the steel, the more susceptible it is to hydrogen embrittlement. The larger pin diameter for galvanised bars and for bars to be galvanised reduces the cold working of the reinforcement.

Where there is a problem of fitting a hooked bar into a thin concrete section, it must not be solved by using a smaller pin diameter. Instead, the bar must be rotated, possibly up to 90º, to ensure adequate cover.

Cutting and Bending Bars from a Coil

Bar 16 mm and smaller is available in coil form, each coil being about 2 tonnes (approximately 2200 metres of N12 bar). Bars are cut from a coil, either singly or in pairs, after passing through a straightener. Handling is the main limit on available length.

The straightener often leaves a series of marks on the bar surface, but this does not affect the anchorage properties.

An alternative machine permits a coiled steel to be straightened and then bent in a continuous operation, after which the bent piece is cut from the coil. The shape and dimensions can be programmed.

Bending Bars Cut from Stock Lengths

After cutting, a separate operation is used to produce the required shape. Again, depending on bar diameter, one to six bars can be bent at once.

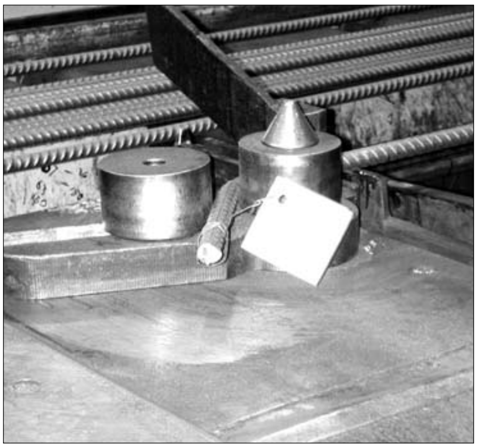


Figure 30: Reinforcing bar being bent about a forming pin

Cutting and Bending Mesh

Reinforcement mesh can be cut to size in the factory using a guillotine or cut on-site using bolt cutters. Site cutting is slow and very labour intensive.

The reinforcing fabric can be bent to suit the concrete profile. The mesh is bent to the required shape using equipment specifically designed to ensure that the bends on each wire are accurate and within construction tolerances.

Heating and Bending

Hot bending is not a normal factory operation. It is more likely to be done on-site, generally with poor supervision and inadequate quality control. Since the strength of the steel will be reduced, uncontrolled hot bending is a dangerous practice.

As a general rule, heating Grade D500N bars of any type must be avoided at all times. AS3600-2001 Clause 19.2.3.1 (b) gives a maximum temperature for reinforcement as 600° C. At 600° C the bar is only just starting to change colour. If any colour change is observed whilst heating, the reinforcement should be discarded. If the bar is heated over 450° C, the steel is softened due to changes in the crystalline structure of the metal. Once heated over 450° C the yield strength of the bar is reduced to 250 MPa. The only practical method of monitoring heat in the bar is the use of heat crayons.

Galvanised bars should not be hot bent.

Using Bars after Heating

Overheating beyond 600°C will alter the structure of the steel. 450°C has been found to be a realistic limit because above this temperature the yield stress, while under load, reduces to 250 MPa. See Clause 5.9 of AS3600 for material strengths during a fire.

On-Site Rebending

Rebending or straightening bars is a common practice on-site. Instructions on a suitable procedure should be given in the structural drawings, even if it is known that such bending will not be needed. A tolerance on straightness should also be provided; an axial deviation of the centre line of one bar diameter along with a directional change of 5° is considered acceptable.

Any on-site cold bending should only be done with a proper bar bending tool. Pulling the bar against the edge of the concrete, hitting the bar with a sledge hammer or using a length of pipe damages the surface of the reinforcement, reduces its ductility, can cause breakage of the steel and may cause premature failure of the concrete element.

When reinforcement is bent about a curve smaller than the recommended minimum pin diameter, or bent against an edge, the steel is excessively strained on the compression and tension faces. An attempt to straighten a bar bent too tightly may lead to bar failure.

On-Site Bending of Reinforcing Mesh

Site bending of mesh is usually done by poking a bar through the opening in the mesh, then rolling the bar over to bend the mesh about a cross wire. This is then repeated every two or three openings for the width of the mesh. This practice is not recommended as it bends the reinforcement about an effective pin size of one bar diameter, with the cross wire acting as the bending pin. This is well below the three diameter pin size required for Ductility Class L bars or the four diameter pin size required for Ductility Class N bars in AS3600-2001, Clause 19.2.3.2. On-site bending of reinforcement also tends to be very variable and inaccurate, usually outside construction tolerances.

Final Advice on Mistreatment of Steel

It cannot be stated enough that steel cannot be expected to perform its proper function if it has been mistreated by excessive tight bending or by overheating. Site bending, welding or heating of bars should only be permitted under very strict and competent supervision. A detailed job procedure and quality control system should be employed for site bending, welding or heating of bars.

5.3 Welding Reinforcement

Figure 31: Welded reinforcement

Welding of reinforcement must comply with AS1554.3, Structural Steel Welding, Part 3: Welding of Reinforcing Steel.

In general, preheat is not required for welding reinforcing steel. The heat input should be controlled to avoid changing the metallurgical properties of the steel and hydrogen controlled electrodes should be used.

Tack welds require a minimum 4 mm throat and a minimum length equal to the diameter of the smaller bar being welded. AS3600-2001 Clause 13.2.1 (f) prohibits welds within 3 d_b from any part of the reinforcement that has been bent and re-straightened. AS1554.3 Clause 1.7.3 (b) restricts straightening or bending of a bar within 75 mm of a weld location.

Special care is required when welding galvanised reinforcement. Welding galvanised reinforcement should be avoided.

5.4 Mechanical Splices

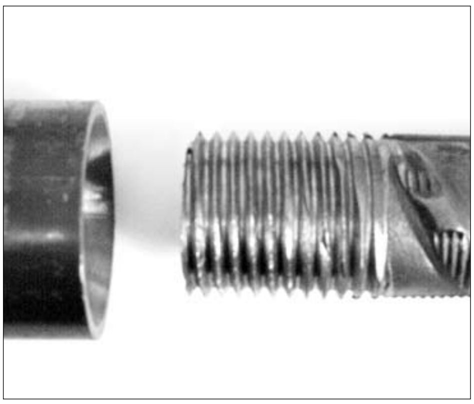


Figure 32: Bartec thread

Mechanical splices to reinforcing bars are usually achieved using any one of the wide-range of coupling systems available on the Australian market. The most common types of couplers are Ancon Bartec, Erico Lenton and Reidbar.

AS3600-2001 does not have any rules governing the adequacy of mechanical splices. Factors that should be considered when selecting a coupler are:

- Slip – Most international codes limit the slip in the coupler to 0.1 mm at 70% of the yield load. This is to restrict the width of cracking at the coupler location. Typically cracks in concrete are limited to 0.3 mm width. If the coupler slips 0.1 mm under load, then the crack at the surface of the concrete will be greater than 0.1 mm. Shrinkage, creep and flexural cracking will add to the crack width that has resulted from slip within the coupler.

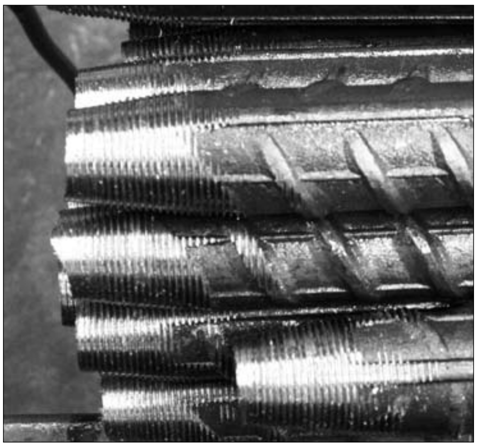


Figure 33: Lenton thread


Figure 34: Reidbar bar and coupler

- Uniform Elongation – To maintain the ductility of the structure, the coupling system must also be ductile. Although a uniform elongation greater than 5% would be desirable very few coupling systems can achieve this. The ISO standard is a minimum uniform elongation of 3.5% for mechanical splices. Care should be taken when locating couplers to ensure the ductility of the structure is not reduced below the design requirements.
- Minimum Yield Stress – The coupler system should be strong enough to develop the characteristic yield stress of the reinforcement, typically 500 MPa. Be aware that actual yield stresses for D500N reinforcement can range from 500 MPa to 650 MPa.
- Tensile Strength / Yield Stress Ratio – To maintain the ductility of the structure, the Tensile Strength / Yield Stress Ratio of the coupler system should not be less than 1.08, measured for actual stresses across the full range of yield stresses (500 MPa to 650 MPa for a D500N bar).
- Dynamic Capacity – In areas subjected to dynamic loads, a coupler system that has been tested for cyclic loading and fatigue should be used. The ISO and ICBO codes have good cyclic and fatigue testing programs.

When selecting the grade of reinforcement, whether it is L or N, assumptions are made about the design method and the structure's performance. It is important that the designer ensures the coupler system selected is able to perform in a manner that is consistent with the reinforcement design.

6.0 Rust and Protective Coatings

Rust and Reinforcement

Accepting or rejecting a bar or fabric with visible rust is a decision often facing site engineers and superintendents. The criteria for acceptance or rejection is usually not known by the decision maker. When does the reinforcement have excessive rust that is detrimental to its performance?

A moderate coating of rust is not detrimental to the reinforcement and can actually improve its bond strength. The improved bond due to moderate rusting is well documented and is included in the commentary to AS3600. Rust usually appears first at the bends of reinforcement, where the steel has undergone some cold working.

Rust is only excessive if the cross-sectional area of the steel is reduced below the minimum tolerance permitted for a bar or wire. To check the area, take a rusty piece of steel, wire brush it to remove the rust, measure its length and then weigh it. The area is calculated taking the density of steel as 7850 kg/m^3.

Rust due to exposure to salt water can be detrimental to the reinforcement. The chloride ions in the salt water cause pitting of the steel, and this reinforcement should not be used without rigorous testing of yield stress, uniform elongation, tensile strength and cross-sectional properties. Even reinforcement that has only had mild exposure to salt water should be washed prior to use to remove any salt from the steel surface.

Reinforcement that has been fixed for some time before concrete placement may, after rain, show lines of iron oxide (rust) on the forms. If the forms are not cleaned and the staining removed prior to pouring the concrete a rusty looking line will be visible on the concrete soffit. This is an aesthetic problem, not a structural or durability problem.

Mill Scale

Mill scale on hot rolled products, in the levels found on Australian produced reinforcement, is not detrimental to the reinforcement. Wire and fabric are free of mill scale.

Types of Coating

The two principal protective coatings are hot dipped galvanising and fusion-bonded epoxy coating. The former is generally available in most major centres, although there may be a physical limit to the size of the zinc bath in some localities. Fusion bonded epoxy coating in Australia is not easily obtainable.

The note to AS3600 Clause 4.3.1 General, says, "a protective surface coating (to the concrete) may be taken into account in the assessment of the exposure classification". AS3600 does not allow any reduction on cover when a protective coating is added to the reinforcement.

Hot Dip Galvanising of Reinforcement

Galvanising of reinforcement is to AS4680 and AS4534. AS3600-2001 requires galvanised bars to be bent about a 5 db pin if 16 mm diameter or less and an 8 db pin for larger bars. This is regardless of whether the bar is to be galvanised before or after bending.

The Galvanising Process

1. Preparation – Mill scale, rust, oil and dirt are removed from the reinforcement. It is then placed in a pickling bath of hydrochloric acid. After pickling the reinforcement is rinsed.

2. Fluxing – The pickled reinforcement is immersed in a solution of zinc ammonia chloride at about 65° C.

3. Galvanising – The reinforcement is immersed into a molten zinc bath at 445° C to 465° C. The molten zinc reacts with the steel to form layers of zinc – iron alloys.

The galvanised coating of zinc improves the reinforcement's corrosion resistance. The zinc forms a sacrificial coating about the reinforcement. Minor breaks in the coating, such as may be caused by bending of the reinforcement, are not detrimental to the corrosion protection offered by the galvanising.

Embrittlement of reinforcement is rare in steels below 1000 MPa, however it must be considered when galvanising reinforcement. The major factors affecting embrittlement of reinforcement are the length of time the steel is in the pickling bath, the heat of the galvanising process and the presence of cold working, particularly at bend locations. A detailed explanation of this is given in the May 1994 edition of Corrosion Management, "Designing for Galvanizing – Avoiding Embrittlement".

Galvanised reinforcement should not be in contact with stainless steel, aluminium or copper and their alloys as the zinc corrodes preferentially to these metals.

More detailed information regarding hot dip galvanising can be obtained from the Galvanizers Association of Australia. Their publication, "After-Fabrication Hot Dip Galvanizing", provides an excellent overview of this subject.

Galvanising of Reinforcement – AS/NZS4680:2006

AS/NZS4680, Hot-Dipped Galvanised Coatings on Fabricated Ferrous Articles, includes provisions for galvanising wire, bar and fabric in Section 5 General Articles. As a general requirement for reinforcement, the minimum average coating is 600 grams per square metre, or approximately 0.085 mm thick.

Limits for the molten metal and finished appearance are given, together with test requirements for coating mass and adherence.

It should be noted that a smooth finish on reinforcing products cannot be expected. The deformation on the surface of bars does not allow a particularly pleasing appearance but this does not detract from the overall performance. The steel should be reasonably free of dags of surplus zinc.

Appendix D of AS/NZS4680, Properties of the Steel to be Coated, which can affect or be affected by hot-dip galvanising, gives an excellent overview of steel embrittlement. Reinforcement that has been galvanised should not be bent on pin diameters smaller than those given in AS3600:2001, should not be heated or bent on site and should not be welded.

Appendix E of AS/NZS4680, Renovation of Damaged or Uncoated Areas, states that exposed steel situated within 1 mm of a substantial zinc layer, should receive sacrificial protection. This implies that cut ends of pre-galvanised bar or fabric should be repaired.

Galvanising of Welded Wire Fabric - AS/NZS4534:2006

AS/NZS4534, Zinc and Zinc/Aluminium-Alloy Coatings on Steel Wire addresses galvanising of welded wire fabric. As a general requirement for reinforcement fabric, the minimum average coating is 610 grams per square metre, or approximately 0.085 mm thick.

Appendix C of AS/NZS4534 gives an overview of hydrogen embrittlement. Appendix F is a comprehensive guide to coating thickness selection for corrosion protection.

Epoxy Coating

An excellent reference is 'The Epoxy Coated Rebar CD-Rom', produced by the Concrete Reinforcing Steel Institute, 9333 North Plum Tree Grove, Schaumber, IL, 60173, USA.

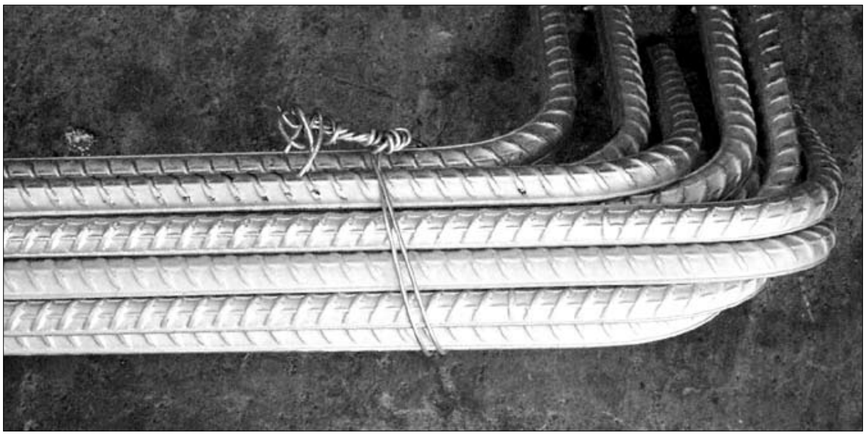


Figure 35: Galvanised reinforcement

Figure 36: Testing the chemical and physical properties of the steel in the molten state

Applicable Standards

AS/NZS ISO9001:2000 Quality Management Systems provides the basis for steel industry QA systems. Explanations of the application of these standards is beyond the scope of this handbook.

Quality Assurance for Steel and Wire

In supplying reinforcement, there are two separate levels of quality assurance.

Firstly, the quality of the raw material (steel bar and wire) is controlled during steel making and wire drawing. These materials are covered by test certificates or certificates of compliance with the appropriate standards. Each bundle or coil is tagged and identified by a serial number, from which the heat number, date of production and other details can be obtained. Delivery dockets show that the material is 'deemed to comply' with the relevant standard, indicating that the steel maker has a certified Quality Assurance programme in place.

On arrival at the reinforcing steel supplier's works the material is placed in racks from which it is withdrawn as needed.

Quench and self tempered bars and micro alloy bars are not segregated because they are both Grade D500N to AS/NZS 4671.

Secondly, accuracy of fabrication must be assured by the reinforcement supplier to comply with AS3600 as well as any relevant parts of AS/NZS 4671.

Methods of Demonstrating Compliance

AS/NZS 4671 has an Appendix A which sets out the various methods by which a manufacturer can show compliance with the Standard.

These methods are described in the Standard as:

(a) Assessment by means of statistical sampling.

(b) The use of a product certification scheme.

(c) Assurance using the acceptability of the supplier's quality system.

(d) Other such means proposed by the manufacturer or supplier and acceptable to the customer.

Traceability of Heat Numbers for Bars

Quality assurance procedures have removed the need for traceability to heat numbers.

Whilst large structural steel sections and plate can be readily identified back to their heat, bar and wire cannot. The latter have one big advantage - if there is any doubt about quality, a sample length can be taken and tested very easily.

Each heat of steel produces about 80 to 100 tonnes of steel, which is cast into billets of approximately 1.5 tonnes. The chemical composition of the heat is obtained by spectroscopic methods and is documented as a whole.

Each billet is rolled to one size producing 1.5 tonnes so that if 4 tonne bundles are ordered, more than one billet is required. More than one heat may be involved, but this is unusual. After rolling, the finished bar is tensile and bend tested, and the results documented.

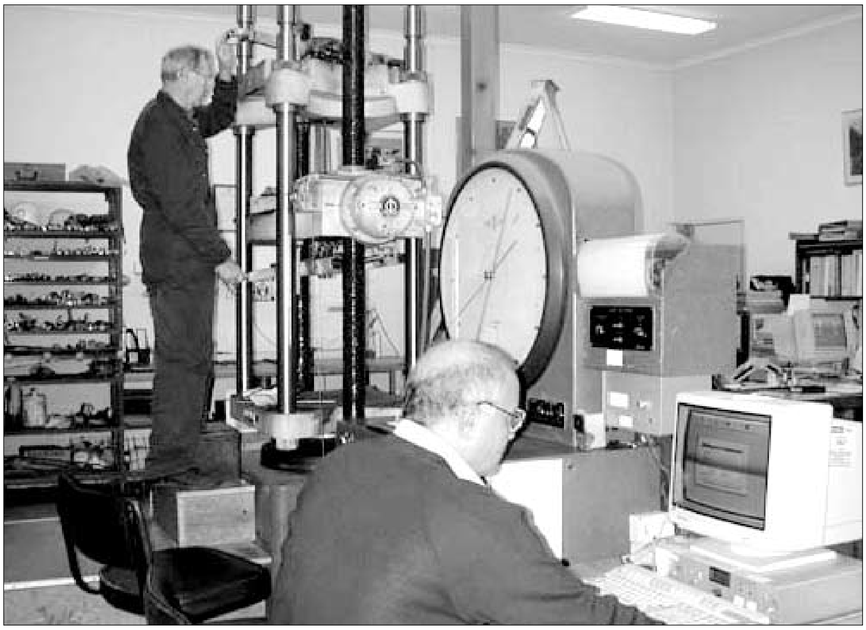


Figure 37: Testing reinforcing steel in ARC's NATA registered laboratory

Certificates of compliance with AS/NZS 4671 are received from the steel maker close to the time when each bundle of steel is delivered. These are cross-checked with the tag on the bundle which remains there until the bundle is opened and steel removed to the cutting bench.

After cutting, an individual bar is no longer traceable back to its originating heat or bundle. Nevertheless, a bar on site can be related back to a group of bundles of stock material released to production on a specified date, but a direct link to a specific bundle is not available.

Traceability of Wire and Mesh

In each step of the manufacturing process there are several test procedures which must be followed and each one applies to the product manufactured by that operation.

Wire is drawn from coiled rod which in turn has been rolled from the original billet. Rather than attempt full traceability for wire production, the wire making process is covered by a certificate stating that the converted material complies with AS/NZS 4671. This certificate is issued by the wire maker.

After welding the wire to make fabric, an additional assurance is given by the fabric manufacturer that the fabric complies with AS/NZS 4671.

It can be seen that traceability of wires in a sheet of fabric is not practical. A standard 2.4 metre wide sheet contains up to 25 individual longitudinal wires and 30 transverse wires, each coming from a separate coil weighing a tonne or more.

Traceability of Material

On-site traceability is the responsibility of the contractor. When performance assurance is given for the material, on-site traceability should not be required.

8.0 Tolerance on Bar Manufacture

Tolerances on Bar Manufacture (AS/NZS 4671)

(a) Chemical composition

A cast analysis and a product analysis is required. See AS/NZS 4671 Table 1.

Steel Grade	C %	CE %
Cast Analysis	Max.	Max.
D500N	0.22	0.44
R250N, D250N	0.22	0.43
D500L	0.22	0.39
Product Analysis		
D500N	0.24	0.46
R250N, D250N	0.24	0.45
D500L	0.24	0.41
Some average results are:		
QST bar	0.18	0.34
Micro alloy bar	0.13	0.37
Mesh, cold rolled bar	0.12	≤0.35

Table 4: Carbon content of reinforcing steel

An upper limit is given for the cast analysis. This is made while the steel is in a liquid form and therefore while the composition of the steel can be adjusted.

Due to changes during casting of billets and subsequent rolling into the finished product, slightly higher limits are allowed for the product analysis.

(b) Drawing/Rolling tolerances

Mass/unit length ± 4.5%

(c) On bar length (bars AS/NZS 4671)

L ≤ 7 m	+ 0, - 40 mm
L > 7 but < 12 m	+ 40, - 40 mm
L ≥ 12 m	+ 60, - 40 mm

(d) Straightness on length L, in units of L

Bar sizes ≤16 mm	L/50
Bar sizes ≥ 20 mm	L/100

(e) Deformations

There are no tolerances given for deformations. Values are maximum or minimum. See Clause 7.4 and Appendix C3 of AS/NZS 4671.

(f) Manufacturer and mill identification

The distance between the identifying marks (deformed bars), equals the circumference of the rolls which have the deformations cut into them. Identifiers are usually on one side only. They identify the steel maker and the rolling mill.

(g) Mesh tolerance between adjacent wires

Distance ±0.075 x pitch

(h) Mesh sheet size

Dimension	≤ 6000 mm	±40 mm
Dimension	L > 6000 mm	±0.007 L

9.0 Information from AS3600-2001

Extracts from AS3600-2001 must be read in conjunction with the latest approved edition of the complete Standard. They are reproduced here, in boxes, for the reader's guidance purposes only.

Although there are many clauses which refer to reinforcing steel, the following references are those most applicable to its supply and fabrication.

1.1.2	**Application.** Lists applicable reinforcing steels.
1.4	**Information on Drawings.** Lists the information expected to be given.
4.10	**Requirements for cover to reinforcing steel and tendons.** These values are for durability.
Section 5	**Design for fire resistance.** Additional cover may be required for this purpose.
6.2	**Properties of reinforcement.**
7.6.8.3	**Approval for Class L reinforcement.**
Section 13	**Stress development and splicing of reinforcement and tendons.** see sections 11 and 12.
19.2	**Material and construction requirements for reinforcing steel.**
19.5	**Tolerances for structures and members.**

9.1 Clause 1.1.2 Application

The Standard also applies to reinforcing steels complying with-

(a) AS1302, or having a yield strength (f_{sy}) of 500 MPa and Ductility Class N in accordance with AS/NZS4671. These reinforcing materials may be used, without restriction, in all applications referred to in this Standard; and

(b) AS1303 or AS1304, or having a yield strength (f_{sy}) of 500 MPa and Ductility Class L in accordance with AS/NZS 4671. These reinforcing materials shall not be used in any situation where the reinforcement, or member, is expected to undergo large deformation under strength limit state conditions.

NOTE: The use of Ductility Class L reinforcement is further limited by other clauses within this Standard.

AS1302, AS1303 and AS1304 have been withdrawn. Design methods such as Moment Redistribution and Plastic Hinge Design assume large deformations and as such should not be used with Ductility Class L reinforcement.

9.2 Clause 1.4 Information on Drawings

The information listed in these extracts is required by all sections of the construction chain from the designing and checking engineers, draftsmen, quantity surveyors and reinforcement schedulers, through to steel fixers and site supervisors. Without these details quality assurance will break down. Poorly detailed drawings result in increased construction costs and site delays as time is lost determining the requirements for the structure.

1.4.1 Design Data

The following design data shall be shown in the drawings:

(a) Reference number and date of issue of applicable design Standards
(b) Live loads used in design
(c) Exposure classification for durability
(d) Fire-resistance rating, if applicable
(e) Class and where appropriate, grade designation of concrete
(f) Grade, ductility class and type of reinforcement and grade and type tendons
(g) The appropriate earthquake design category, acceleration coefficient and site factor determined from AS1170.4

1.4.2 Design Details

The drawings or specification for concrete members and structures should include, as appropriate, the following:

(a) The shape and size of each member
(b) The finish and method of control for unformed surfaces
(c) Class of formwork in accordance with AS 3610 for the surface finish specified
(d) The size, quantity and location of all reinforcement, tendons and structural fixings, and the cover to each
(e) Any required properties of the concrete
(f) The curing procedure
(g) The force required in each tendon, the maximum jacking force to be applied and the order in which tendons are to be stressed
(h) The location and details of planned construction or movement joints, connections and splices, and the method to be used for their protection
(i) The minimum period of time before stripping of forms and removal of shores
(j) Any constraint on construction assumed in the design
(k) Any other requirements

Examples of preferred specifications in a drawing:

SL92	The style of standard D500L fabric covering the whole area of a slab. There is no need to specify either the number of sheets required to provide full coverage or the lap dimension.
8-N28	The number (8) of 28 mm deformed bars of Grade D500N in a layer or cross-section.
20-N16-200	The number (20) of 16 mm deformed bars of Grade D500N spaced at 200 mm centres across the width of a slab.
6-R10-150-T1	The number (6) of 10 mm plain round bars of grade R250N used for fitments of shape T1 and spaced at 150 mm centres.
ARCN102	R500N mesh with 10 mm nominal diameter wires at 200 mm centres each way covering the whole area of a slab. There is no need to specify either the number of sheets required to provide full coverage or the lap dimension.

9.3 Cover to Reinforcing Steel

According to AS3600, 'cover is the distance between the outside of the reinforcing steel or tendons and the nearest permanent surface of the member, excluding any surface finish. Unless otherwise noted, the tolerances on position of reinforcement and tendons given in Clause 19.5.3 apply'.

The two primary purposes of cover are durability and fire resistance. As a general rule, cover is selected from an appropriate table but there are several cases where additional cross checks are required.

A secondary reason for adequate cover is to ensure that the stresses in steel and concrete can be transferred, one to another, by bond. These actions are called stress development and anchorage. The cover required for these purposes is measured not to the nearest bar, but to the bar whose stress is being developed.

9.4 Section 4 Cover for Durability

In AS3600, durability of the structure is very much related to individual surfaces of a member and to the compressive strength of the concrete.

For one member to have the same durability resistance as another member, AS3600 requires the same cover to the nearest reinforcement or tendon, but the method of selecting the exposure classification and the appropriate concrete strength requires a number of factors to be considered.

The following information must be obtained before cover for corrosion protection is determined:

(a) the most severe Exposure Classification for durability (A1 to U);

(b) the characteristic compressive strength of the concrete f'_c for the most severe situation for use in strength, serviceability and durability design, allowing for abrasion and freeze/thaw conditions;

(c) the degree of compaction; and

(d) the type of formwork.

Cover for Concrete Placement

Clause 4.10.2 limits the minimum cover, in the absence of a detailed analysis, to either the reinforcement bar diameter or the maximum nominal aggregate size, whichever is the larger.

Combined Table from Clauses 4.3, 4.4, 4.5, 4.6, 4.10.3.2 and 4.10.3.3, for the selection of minimum cover for corrosion resistance of reinforcing and prestressing steel.

Surface and Exposure	Exposure Classification	Concrete Quality		Concrete Cover to Nearest Steel
		Strength	Curing	
A. External surfaces above ground				
- Within 1 km of coastline	B2	40 MPa	7 days	45 mm
- Within 1 to 50 km of coastline	B1	32 MPa	7 days	40 mm
- Further than 50 km from coastline and				
• Within 3 km of industry	B1	32MPa	7 days	40 mm
• In tropical zone	B1	32MPa	7 days	40 mm
• In temperate zone	A2	25 MPa	3 days	30 mm
• In arid zone	A1	20 MPa	3 days	20 mm
B. Internal surfaces (check for fire resistance)				
- In industrial buildings, the member being subjected to repeated wetting and drying	B1	32 MPa	7 days	40 mm
- Other	A1	20 MPa	3 days	20 mm
C Surfaces in contact with the ground				
- cast against an aggressive soil	U	Designer must assess all requirements		
- cast against a damp-proof membrane	A1	20 MPa	3 days	30 mm
- residential footings, no membrane	A1	20 MPa	3 days	40 mm
- other members	A2	25 MPa	3 days	50 mm
D. Surfaces in contact with water				
- in soft or running water	U	Designer must assess all requirements		
- in fresh water	B1	32 MPa	7 days	40 mm
- in sea water and				
• permanently submerged	B2	40 MPa	7 days	45mm
• in tidal or splash zone	C	50 MPa	7 days	50 mm
E. Other situations	U	Designer must assess all requirements		

Table 5: Cover for corrosion resistance

The above table does not consider abrasion, freezing and thawing, rigid formwork or spun or rolled members.

9.5 Section 5 Cover for Fire Resistance

During the course of a fire, temperatures in excess of about 200°C reduce the strength of both steel and concrete. Fortunately the insulation properties of concrete are greater than those of steel, and the concrete cover is the best and cheapest method of increasing the fire resistance of structures.

The cover for fire resistance depends on:

(a) the type of member;

(b) how that member carries the loads imposed on it;

(c) whether or not it is continuous (flexurally or structurally) with other members; and

(d) the fire resistance period it provides.

Concrete strength is not taken into account when selecting cover for fire resistance. Similarly, the effects of fire need only be considered for members which are required, by Building Regulations or through other Authorities, to attain a specified fire resistance level. In certain structures which have a high exposure classification, due to proximity with hazardous materials for example, resistance to fire may take precedence over all other factors.

9.6 Clause 6.2 Properties of Reinforcement

6.2.1 Strength and Ductility

The yield strength of reinforcement (f_{sy}) shall be taken as not greater than the value specified in Table 6.2.1 for the appropriate type of reinforcement (see also Clause 19.2.1.1).

The ductility of the reinforcement shall be characterized by its uniform strain (E_{su}) and tensile-to-yield stress ratio and designated as low (L) or normal (N) as given in Table 6.2.1. Values of these parameters for each ductility class shall comply with AS/NZS 4671.

Reinforcement		Yield Stress (f_{sy}) Mpa	Ductility Class
Type	Designation Grade		
Bar deformed toAS/NZS 4671	D500L (fitments only) D500N	500 500	L N
Welded wire mesh, plain, deformed and indented to AS/NZS 4671	D500L D500N	500 500	L N

NOTE: Reference should be made to AS/NZS 4671 for explanation to designations applying to 500 MPa steels. Plain round bars are manufactured in accordance with AS3679, however they are deemed to comply with AS/NZS 4671 and should be specified by this Standard.

6.2.2 Modulus of elasticity

The modulus of elasticity of reinforcement (E_S) for all stress values not greater than the yield strength (f_{sy}) may be either:

(a) taken as equal to 200 x 10^3 MPa; or

(b) determined by test.

6.2.3 Stress-strain curves

A stress-strain curve for reinforcement may be either:

(a) assumed to be of a form defined by recognised simplified equations; or

(b) determined from suitable test data.

6.2.4 Coefficient of thermal expansion

The coefficient of thermal expansion of reinforcement may be either:

(a) taken as equal to 12 x 10^{-6}/°C; or

(b) determined from suitable test data.

9.7 Clause 7.6.8.3 Class L Reinforcement

7.6.8.3 Approval for Class L Reinforcement

Where Ductility Class L reinforcement is used, moment redistribution shall not be permitted unless an analysis, as specified in Clause 7.6.8.1, is undertaken.

Particular attention should be given to the final paragraph of Clause 7.6.8.1. Special consideration shall be given to the detrimental effects that significant relative foundation movements can have on the strength of continuous beams and slabs incorporating Ductility Class L reinforcing steel (low ductility) as the main reinforcement. The designer should also consider other potentially detrimental effects such as differential shortening in columns of high rise buildings and differential deflections of adjacent beams.

9.8 Clause 19.2 Material and Construction Requirements for Reinforcing Steel

19.2.1 Materials

19.2.1.1 Reinforcement

Reinforcement shall be deformed bars Class N bars, or Class L or Class N welded wire mesh (plain or deformed), with a yield stress of up to 500 MPa, except that fitments may be manufactured from Class L wire or bar, or plain Class N bar.

All reinforcement shall comply with AS1302, AS1303, AS1304 or AS/NZS 4671 as appropriate.

Dowel bars for pavements are not specifically mentioned in AS3600-2001. They are generally cut from Grade R250N plain round bars.

Designs using fibre reinforcement, either steel or plastic, is not covered by AS3600-2001.

Class L reinforcement should not be used as the main reinforcement. If a designer wishes to use L grade main reinforcement, they must ensure the design does not require the reinforcement or the member to undergo large deformation or large rotation, a relatively non-ductile failure can be tolerated and there are no foreseeable causes of overload to the reinforcement or member, then Ductility Class L reinforcement will perform satisfactorily. Ductility of the bar is an issue after the bar has yielded and permanent plastic deformation of the bar has occurred.

19.2.1.2 Protective Coatings

A protective coating may be applied to reinforcement provided that such coating does not reduce the properties of the reinforcement below those assumed in the design.

19.2.2 Fabrication

(a) Reinforcement shall be fabricated to the shape and dimensions shown in the drawings and within the following tolerances-

(i) On any overall dimension for bars and mesh except where used as a fitment.

(A) For lengths up to 600 mm .... –25, +0 mm.

(B) For lengths over 600 mm .... –40, +0 mm.

(ii) On any overall dimension of bars or mesh used as a fitment.

(A) For deformed bars and mesh .... –15, +0 mm.

(B) For plain round bars and wire .... – 10, +0 mm.

(iii) On the overall offset dimension of a cranked column bar .... −0, +10 mm.

(iv) For the sawn or machined end of a straight bar intended for use as an end-bearing splice, the angular deviation from square, measured in relation to the end 300 mm, shall be within .... 2°.

(b) Bending of reinforcement shall comply with Clause 19.2.3.

(c) Welding if required shall comply with AS 1554.3. Tack welding not complying with that Standard shall not be used.

19.2.3 Bending

19.2.3.1 General

Reinforcement may be bent either:

(a) Cold, by the application of a force around a pin of diameter complying with Clause 19.2.3.2, so as to avoid impact loading of the bar and mechanical damage to the surface of the bar; or

(b) Hot, provided that:

(i) The steel must be heated uniformly through and beyond the portion of be bent;

(ii) The temperature of the steel must not be allowed to exceed 600° C,

(iii) The bar must not be cooled by quenching, and

(iv) If during heating the temperature of the bar exceeds 450° C, the design yield strength of the steel after bending shall be taken as 250 MPa.

The temperature can be controlled by thermal crayons, etc. Quenching would totally alter the crystal structure.

Reinforcement which 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.

This distance is intended to keep cold working from the original bending zone separated from additional bending.

Reinforcement partially embedded in concrete may be field bent (ie, in situ) provided that the bending complies with items (a) or (b) above, and the bond of the embedded portion is not impaired thereby.

The greatest need encountered with this bending is to control the bend curvature without notching the bar, and to prevent spalling of the concrete, particularly in thin members. It is very rare for a site bent bar to be bent correctly, with bars often being pulled out against the edge of the concrete or bent with a pipe. These methods of bending severely notch the bar and can cause bar breakage.

19.2.3.2 Internal diameter of bends or hooks

The nominal internal diameter of a reinforcement bend or hook shall be taken as the external diameter of the pin around which the reinforcement is bent. The diameter of the pin shall be not less than the value determined from the following as appropriate:

(A) For fitments of –

(i) Wire .... $3d_b$;

(ii) Grade 250 bars .... $3d_b$; and

(iii) Grade 400 and 500 bars .... $4d_b$.

Clause 8.2.12.4 requires a 4 d_b pin be used for all beam ligatures

(b) For reinforcement, other than specified in Items (c) and (d) below, of any grade........ $5d_b$.
(c) For reinforcement, in which the bend is intended to be subsequently straightened or rebent, of
  (i) 16 mm diameter or less........ $4d_b$;
  (ii) 20 mm diameter or 24 mm........ $5d_b$; and
  (iii) 28 mm diameter or greater .... $6d_b$.

Any such straightening or rebending shall be clearly specified or shown in the drawings.

(d) For reinforcement that is epoxy-coated or galvanized, either before or after bending, of
  (i) 16 mm diameter or less .... $5d_b$;
  (ii) 20 mm diameter or greater........ $8d_b$.

19.2.4 Surface Condition

At the time concrete is placed, the surface condition of reinforcement shall be such as not to impair its bond to the concrete or it's performance in the member. The presence of millscale or surface rust shall not be cause for rejection of reinforcement under this clause.

Rust and millscale, of themselves, do not adversely affect bond. Dirt and oil are much worse.

9.9 Clause 19.5.3 Tolerance on Position of Reinforcement

AS3600 Clause 19.5.3, provides the basis for reinforcement placing tolerances.

The position of reinforcement and tendons may differ from that specified as follows where a '+' value indicates that the cover may be greater than specified and a '-' indicates the cover may be less.

(a) Where the position (mm) is controlled by the minimum design cover, eg, all round ties and stirrups, the cover at ends and from surfaces in walls and slabs.

  (i) Beam, slab, column, wall........ -5, + 10 mm
  (ii) Slab on ground .... -10, + 20 mm
  (iii) Footing cast in ground........ -20, + 40 mm

(b) Where the position is not controlled by the minimum design cover, for example on-

  (i) The position of the ends of a main bar........ 50 mm
  (ii) The spacing of parallel bars in a slab or wall, or spacing of fitments 10% of specified spacing or 15 mm, whichever is greater

10.0 Reinforcing Bar

10.1 Bar General Information

Hot Rolled, High Strength Deformed Bars of Grade D500N

Both quench and self tempered and micro-alloy reinforcing bars are classified as Grade D500N and no distinction is made between them for supply purposes. Each steel-maker identifies their rolling mill with its individual surface mark.

Bar Size *mm*	Nominal Area *mm²*	Calculated Area *mm²*	Calculated Mass *kg/m*
N12	110	113.1	0.8878
N16	200	201.1	1.5783
N20	310	314.2	2.4662
N24	450	452.4	3.5513
N28	620	615.8	4.8337
N32	800	804.2	6.3133
N36	1020	1017.9	7.9903
N40	1260	1256.6	9.8646
D450N50	1960	1963.5	15.4131

Table 6: Basic information about grade D500N deformed bars - AS/NZS 4671

Notes:

1. The calculated area of a deformed bar is calculated from the bar size, in mm, as if it was a circle.
2. The nominal area of a deformed bar is the calculated area, rounded to two significant places, and should be used in all design calculations and for routine testing for quality control.
3. The calculated mass is the calculated area multiplied by 0.0078 kg/mm2/m (7850kg/m^3) taken to four decimal places to assure accuracy for quantities measured by length but sold by the tonne. The actual area of a test bar (measured mass of a sample 0.00785) should be used only for fundamental research.
4. The nominal mass includes the rolling margin, based on the calculated mass, and is used for calculating the mass of material sold in all commercial transactions.

Cold Rolled, High Strength Deformed Bars of Grade D500L

Cold rolled bars are typically Ductility Class L. D500L bars are used as fitments and in residential slabs on ground. AS2870 currently permits D500L main bars, however, this is currently under review.

Bar Size *mm*	Diameter *mm*	Area *mm²*	Mass *kg/m*
L4	4.00	12.6	0.0986
L5	4.75	17.7	0.1391
L6	6.00	28.3	0.2220
L7	6.75	35.8	0.2809
L8	7.60	45.4	0.3561
L9	8.55	57.4	0.4507
L10	9.50	70.9	0.5564
L11	10.65	89.1	0.6993
L12	11.90	111.2	0.8731

Table 7: Basic information about grade D500L deformed bars - AS/NZS 4671

Bar Size mm	Nominal Area mm^2	Calculated Area mm^2	Calculated Mass kg/m
R6.5	30	33.2	0.2605
R10	80	78.5	0.6165

Table 8: Basic information about plain round grade R250N bars for use as fitments only - AS/NZS 4671

Notes:

1. Availability of these sizes can depend on local practice throughout Australia. They are produced from coiled rod of grade 250 MPa, or from coiled wire of grade 500 MPa. Specify your required strength.
2. All values given in the above table are for 6.5 mm and 10 mm coiled rods.
3. Plain round bars for dowel bars are available in larger sizes to AS3679, Grade 250. These sizes are: R12, R16, R20, R24, R27, R33 and R36, but the full range may not be available from stock at all times.

Bar Size No.	N12 mm²	N16 mm²	N20 mm²	N24 mm²	N28 mm²	N32 mm²	N36 mm²	N40 Mm²	N50 mm²
1	110	200	310	450	620	800	1020	1260	1960
2	220	400	620	900	1240	1600	2040	2520	3920
3	330	600	930	1350	1860	2400	3060	3780	5880
4	440	800	1240	1800	2480	3200	4080	5040	7840
5	550	1000	1550	2250	3100	4000	5100	6300	9800
6	660	1200	1860	2700	3720	4800	6120	7560	11760
7	770	1400	2170	3150	4340	5600	7140	8820	13720
8	880	1600	2480	3600	4960	6400	8160	10080	15680
9	990	1800	2790	4050	5580	7200	9180	11340	17640
10	1100	2000	3100	4500	6200	8000	10200	12600	19600
11	1210	2200	3410	4950	6820	8800	11220	13860	21560
12	1320	2400	3720	5400	7440	9600	12240	15120	23520
13	1430	2600	4030	5850	8060	10400	13260	16380	25480
14	1540	2800	4340	6300	8680	11200	14280	17640	27440
15	1650	3000	4650	6750	9300	12000	15300	18900	29400
16	1760	3200	4960	7200	9920	12800	16320	20160	31360
17	1870	3400	5270	7650	10540	13600	17340	21420	33320
18	1980	3600	5580	8100	11160	14400	18360	22680	35280
19	2090	3800	5890	8550	11780	1520	19380	23940	37240
20	2200	4000	6200	9000	12400	16000	20400	25200	39200
21	2310	4200	6510	9450	13020	116800	21420	26460	41160
22	2420	4400	6820	9900	13640	17600	22440	27720	43120
23	2530	4600	7130	10350	14260	18400	23460	28980	45080
24	2640	4800	7440	10800	14880	19200	24480	30240	47040
25	2750	5000	7750	11250	15500	20000	25500	31500	49000
26	2860	5200	8060	11700	16120	20800	26520	32760	50960
27	2970	5400	8370	12150	16740	21600	27540	34020	52920
28	3080	5600	8680	12600	17360	22400	28560	35280	54880
29	3190	5800	8990	13050	17980	23200	29580	36540	56840
30	3300	6000	9300	13500	18600	24000	30600	37800	58800

Table 9: Design cross-sectional area of deformed bars

Notes:

1. This table would generally be used for the design of beams, columns and narrow footings, etc.
2. Before selecting the number of bars in one layer of a beam or column, check that they can fit across the member width. The table below allows a quick assessment of spacing per bar.
3. Sizes N12 and N16 are available in as-rolled straight lengths, or as straightened lengths from coil. They may be either quench and self tempered steel or micro alloy steel.
4. Sizes N40 and D450N50 are micro alloy bars and are available to special order only.

Bar Size	N12	N16	N20	N24	N28	N32	N36	N40	N50
Space/bar	40	50	60	70	90	100	110	160	200

Table 10: Estimation of member minimum width to allow placement of concrete, mm/bar

To estimate the minimum width, allow the space for each bar.

Example: A beam with 4-N32 main bars, 30 mm cover to L10 fitments
Use a beam width of 4 x 100 = 400 mm

Bar Size Spacing	N12 mm²	N16 mm²	N20 mm²	N24 mm²	N28 mm²	N32 mm²	N36 mm²	N40 mm²	N50 mm²
50	2200								
75	1467	2667							
100	1100	2000	3100	4500					
125	880	1600	2480	3600	4960				
150	733	1333	2067	3000	4133	5333	6800		
167	659	1198	1856	2695	3713	4790	6108	7545	
175	629	1143	1771	2571	3543	4571	5829	7200	
200	550	1000	1550	2250	3100	4000	5100	6300	9800
225	489	889	1378	2000	2756	3556	4533	5600	8711
250	440	800	1240	1800	2480	3200	4080	5040	7840
275	400	727	1127	1636	2255	2909	3709	4582	7127
300	367	667	1033	1500	2067	2667	3400	4200	6533
325	338	615	954	1385	1908	2462	3138	3877	6031
333	330	601	931	1351	1862	2402	3063	3784	5886
350	314	571	886	1286	1771	2286	2914	3600	5600
375	293	533	827	1200	1653	2133	2720	3360	5227
400	275	500	775	1125	1550	2000	2550	3150	4900
450	244	444	689	1000	1378	1778	2267	2800	4356
500	220	400	620	900	1240	1600	2040	2520	3920
550	200	364	564	818	1127	1455	1855	2291	3564
600	183	333	517	750	1033	1333	1700	2100	3267
650	169	308	477	692	954	1231	1569	1938	3015
700	157	286	443	643	886	1143	1457	1800	2800
750	147	267	413	600	827	1067	1360	1680	2613
800	138	250	388	563	775	1000	1275	1575	2450
850	129	235	365	529	729	941	1200	1482	2306
900	122	222	344	500	689	889	1133	1400	2178
950	116	211	326	474	653	842	1074	1326	2063
1000	110	200	310	450	620	800	1020	1260	1960

Table 11: Design cross-sectional area of deformed bars per metre width

Notes:

1. This table would generally be used for the design of slabs, walls and wide footings, etc.
2. Values for a centre-to-centre spacing of less than $4d_b$ is not provided because concrete is difficult to place and splitting can occur along this plane. Note also that to apply AS3600 Clause 13.1.2.2, development lengths to develop yield stress, the clear distance between bars must be not less than twice the cover to the bar being designed.
3. Sizes N12 and N16 are available in as-rolled straight lengths, or as straightened lengths from coil. They may be either quench and self tempered steel or micro alloy steel.
4. Sizes N40 and D450N50 are micro alloy bars and are available to special order only.

10.2 Bar Tension Lap and Anchorage

The most important factor for successful detailing of concrete structures is ensuring that all stresses can be transferred from concrete to steel.

The information in this ARC - Reinforcement Handbook must be read in conjunction with, and with a full understanding of, the principles of reinforced concrete design and detailing given in AS3600.

In general, the parameters used to calculate the anchorage and lap lengths are given with the tables. Where there are differences between our ARC - Reinforcement Handbook and values obtained from other sources, the user should check the parameters and recalculate as seen fit.

Lengths are based only on full yield stress of the steel. It is most unwise to specify lap or anchorage lengths for a lower steel stress. For laps, this practice is not permitted in AS3600-2001.

Anchorage and Development Length of Deformed Bars in Tension, $L_{sy.t}$

The anchorage and lap length formula in AS3600, Clause 13.1.2, for a straight piece of deformed bar in tension is –

$$L_{sy.t} = \frac{\text{Depth factor } k_1 \text{ x spacing factor } k_2 \text{ x bar yield stress } f_{sy} \text{ x bar area } A_b}{[(\text{smaller of twice actual cover or clear spacing 2a}) + \text{bar size } d_b] \text{ x } \sqrt{(\text{concrete strength } f'_c)}}$$

This expression shows that:

- When the yield stress of the bar increases, the anchorage length increases;
- When the clear spacing between adjacent parallel bars increases, the anchorage length decreases;
- When the actual cover to the bar increases, the anchorage length decreases;
- When a higher grade of concrete is used, the anchorage length will decrease; and
- When the size (and therefore cross-sectional area) increases, the anchorage length will also increase.

Calculations will show a dramatic reduction in the anchorage length when cover or spacing is increased.

To assist with anchorage you can use a standard hook to provide end anchorage of a bar where there is insufficient embedment for a straight length to develop its design stress. A hook or cog reduces the development length by 50%.

AS3600-2001 Clause 8. 2. 12.4 gives the requirements for fitment hooks.

Whether or not a bar should be anchored by a hook is a design matter. It is not a scheduling decision, however the hook orientation must be such that it will stay within the concrete with adequate cover and also satisfy bending-pin requirements.

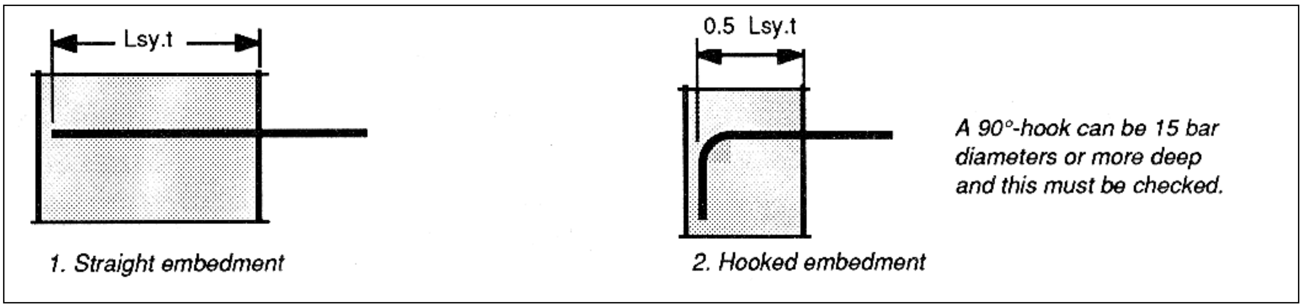


Figure 38: Bar embedment

Although hooked deformed bars can reduce the development length, the hook can cause congestion of steel in critical areas and are a primary source of rusting if they intrude into the cover concrete. Straight bars are much easier to fix and protect. If there is so little room available for stress development that hooks are required, it is probably a better solution to use more bars of a smaller size with a consequential smaller development length.

A fully stressed hook or cog will create a lateral splitting force on the surrounding concrete, caused by the bearing stress between steel and concrete at the bend. Hooked bars should never be used in thin sections, say less than 12 bar diameters in the plane of the hook, or as top bars in slabs.

A 90° bend which is longer than 10db overall, gives the same anchorage as a 90° cog.

Slab and wall bars with less than 300 mm of concrete cast below the bar Clear spacing is not less than 150 mm

"a" = the smaller of the actual cover and one-half of the clear distance between parallel bars

Concrete strength f'_cMPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
20	20		410	680	990	«	«	«	«
	25		340	580	850	1160	«	«	«
	30		300	510	740	1020	1340	«	«
	35		300	450	660	910	1210	1500	«
	40		300	400	590	830	1100	1360	1680
	50		300	400	500	690	930	1160	1430
	60		300	400	500	600	800	1010	1250
	70		300	400	500	600	710	890	1110
	80		300	400	500	600	700	800	990
Concrete strength f'_cMPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
25	20		360	610	880	«	«	«	«
	25		310	520	760	1040	«	«	«
	30		300	450	660	920	1200	«	«
	35		300	400	590	820	1080	1340	«
	40		300	400	530	740	980	1220	1500
	50		300	400	500	620	830	1040	1280
	60		300	400	500	600	720	900	1120
	70		300	400	500	600	700	800	990
	80		300	400	500	600	700	800	900
Concrete strength f'_cMPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
32	20		320	540	780	«	«	«	«
	25		300	460	670	920	«	«	«
	30		300	400	590	810	1060	«	«
	35		300	400	520	720	960	1180	«
	40		300	400	500	660	870	1080	1330
	50		300	400	500	600	730	920	1130
	60		300	400	500	600	700	800	990
	70		300	400	500	600	700	800	900
	80		300	400	500	600	700	800	900
Concrete strength f'_cMPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
40	20		300	480	700	«	«	«	«
	25		300	410	600	820	«	«	«
	30		300	400	530	720	950	«	«
	35		300	400	500	650	860	1060	«
	40		300	400	500	600	780	960	1190
	50		300	400	500	600	700	820	1010
	60		300	400	500	600	700	800	900
	70		300	400	500	600	700	800	900
	80		300	400	500	600	700	800	900
Concrete strength f'_cMPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
50	20		300	430	630	«	«	«	«
	25		300	400	540	740	«	«	«
	30		300	400	500	650	850	«	«
	35		300	400	500	600	770	950	«
	40		300	400	500	600	700	860	1060
	50		300	400	500	600	700	800	910
	60		300	400	500	600	700	800	900
	70		300	400	500	600	700	800	900
	80		300	400	500	600	700	800	900
Concrete strength f'_cMpa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
65	20		300	400	550	«	«	«	«
	25		300	400	500	650	«	«	«
	30		300	400	500	600	750	«	«
	35		300	400	500	600	700	830	«
	40		300	400	500	600	700	800	930
	50		300	400	500	600	700	800	900
	60		300	400	500	600	700	800	900
	70		300	400	500	600	700	800	900
	80		300	400	500	600	700	800	900
Minimum			300	400	500	600	700	800	900

Table 12: Slab and wall tension lap

Slab and wall bars with more than 300 mm of concrete cast below the bar Clear spacing is not less than 150 mm

“a” = the smaller of the actual cover and one-half of the clear distance between parallel bars

Concrete strength $f'_c MPa$	“a” mm	Bar size	N12	N16	N20	N24	N28	N32	N36
20	20		510	850	1230	«	«	«	«
	25		430	720	1060	1450	«	«	«
	30		375	630	930	1280	1680	«	«
	35		375	560	820	1140	1510	1870	«
	40		375	500	740	1030	1370	1700	2090
	50		375	500	625	870	1160	1440	1790
	60		375	500	625	750	1000	1260	1560
	70		375	500	625	750	880	1110	1380
	80		375	500	625	750	875	1000	1240
Concrete strength $f'_c MPa$	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
25	20		450	760	1100	«	«	«	«
	25		380	650	950	1300	«	«	«
	30		375	560	830	1140	1500	«	«
	35		375	500	740	1020	1350	1670	«
	40		375	500	660	920	1220	1520	1870
	50		375	500	625	780	1030	1290	1600
	60		375	500	625	750	900	1120	1390
	70		375	500	625	750	875	1000	1240
	80		375	500	625	750	875	1000	1125
Concrete strength $f'_c MPa$	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
32	20		400	680	980	«	«	«	«
	25		375	570	840	1150	«	«	«
	30		375	500	730	1010	1330	«	«
	35		375	500	650	900	1190	1480	«
	40		375	500	625	820	1080	1350	1660
	50		375	500	625	750	910	1140	1410
	60		375	500	625	750	875	1000	1230
	70		375	500	625	750	875	1000	1125
	80		375	500	625	750	875	1000	1125
Concrete strength $f'_c MPa$	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
40	20		375	600	870	«	«	«	«
	25		375	510	750	1030	«	«	«
	30		375	500	660	900	1190	«	«
	35		375	500	625	810	1070	1320	«
	40		375	500	625	750	970	1200	1480
	50		375	500	625	750	875	1020	1260
	60		375	500	625	750	875	1000	1125
	70		375	500	625	750	875	1000	1125
	80		375	500	625	750	875	1000	1125
Concrete strength $f'_c MPa$	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
50	20		375	540	780	«	«	«	«
	25		375	500	670	920	«	«	«
	30		375	500	625	810	1060	«	«
	35		375	500	625	750	960	1180	«
	40		375	500	625	750	875	1080	1330
	50		375	500	625	750	875	1000	1130
	60		375	500	625	750	875	1000	1125
	70		375	500	625	750	875	1000	1125
	80		375	500	625	750	875	1000	1125
Concrete strength $f'_c Mpa$	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
65	20		375	500	690	«	«	«	«
	25		375	500	625	810	«	«	«
	30		375	500	625	750	930	«	«
	35		375	500	625	750	875	1040	«
	40		375	500	625	750	875	1000	1160
	50		375	500	625	750	875	1000	1125
	60		375	500	625	750	875	1000	1125
	70		375	500	625	750	875	1000	1125
	80		375	500	625	750	875	1000	1125
Minimum			375	500	625	750	875	1000	1125

Table 13: Slab and wall tension lap

Beam and column longitudinal bars with fitments. Less than 300 mm of concrete cast below the bar

"a" = the smaller of the actual cover and one-half of the clear distance between parallel bars

Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
20	20		530	880	1280	«	«	«	«
	25		440	750	1090	1500	«	«	«
	30		380	650	960	1320	1740	«	«
	35		330	580	850	1180	1560	1930	«
	40		300	520	770	1070	1420	1760	2170
	50		300	430	640	900	1200	1500	1850
	60		300	400	550	770	1040	1300	1610
	70		300	400	500	680	910	1150	1430
	80		300	400	500	610	820	1030	1290
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
25	20		470	790	1140	«	«	«	«
	25		400	670	980	1340	«	«	«
	30		340	580	860	1180	1550	«	«
	35		300	520	760	1060	1400	1730	«
	40		300	460	690	960	1270	1580	1940
	50		300	400	570	800	1070	1340	1650
	60		300	400	500	690	930	1160	1440
	70		300	400	500	610	820	1030	1280
	80		300	400	500	600	730	920	1150
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
32	20		420	700	1010	«	«	«	«
	25		350	590	870	1190	«	«	«
	30		300	520	760	1050	1380	«	«
	35		300	460	670	940	1240	1530	«
	40		300	410	610	850	1120	1390	1710
	50		300	400	510	710	950	1180	1460
	60		300	400	500	610	820	1030	1280
	70		300	400	500	600	720	910	1130
	80		300	400	500	600	700	820	1020
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
40	20		370	630	900	«	«	«	«
	25		310	530	780	1060	«	«	«
	30		300	460	680	940	1230	«	«
	35		300	410	600	840	1110	1370	«
	40		300	400	540	760	1000	1250	1530
	50		300	400	500	640	850	1060	1310
	60		300	400	500	600	730	920	1140
	70		300	400	500	600	700	810	1010
	80		300	400	500	600	700	800	910
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
50	20		330	560	810	«	«	«	«
	25		300	480	690	950	«	«	«
	30		300	410	610	840	1100	«	«
	35		300	400	540	750	990	1230	«
	40		300	400	500	680	900	1120	1370
	50		300	400	500	600	760	950	1170
	60		300	400	500	600	700	820	1020
	70		300	400	500	600	700	800	910
	80		300	400	500	600	700	800	900
Concrete strength f'_c Mpa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
65	20		300	490	710	«	«	«	«
	25		300	420	610	830	«	«	«
	30		300	400	530	740	970	«	«
	35		300	400	500	660	870	1080	«
	40		300	400	500	600	790	980	1200
	50		300	400	500	600	700	830	1030
	60		300	400	500	600	700	800	900
	70		300	400	500	600	700	800	900
	80		300	400	500	600	700	800	900
Minimum			300	400	500	600	700	800	900

Table 14: Beam and column bars with fitments

Beam and column longitudinal bars with fitments. More than 300 mm of concrete cast below the bar.

"a" = the smaller of the actual cover and one-half of the clear distance between parallel bars

Concrete strength f'_c MPa	"a" mm	Bar size	N12	N16	N20	N24	N28	N32	N36
20	20		660	1100	1590	«	«	«	«
	25		550	940	1370	1870	«	«	«
	30		470	810	1200	1650	2170	«	«
	35		420	720	1060	1480	1950	2420	«
	40		375	650	960	1340	1770	2200	2710
	50		375	540	800	1120	1490	1870	2310
	60		375	500	690	970	1290	1620	2020
	70		375	500	625	850	1140	1440	1790
	80		375	500	625	760	1020	1290	1610
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
25	20		590	990	1430	«	«	«	«
	25		490	840	1220	1680	«	«	«
	30		430	730	1070	1480	1940	«	«
	35		375	640	950	1320	1740	2160	«
	40		375	580	860	1190	1580	1970	2420
	50		375	500	720	1000	1340	1670	2070
	60		375	500	625	860	1160	1450	1800
	70		375	500	625	760	1020	1280	1600
	80		375	500	625	750	910	1150	1440
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
32	20		520	870	1260	«	«	«	«
	25		440	740	1080	1480	«	«	«
	30		375	640	950	1310	1720	«	«
	35		375	570	840	1170	1540	1910	«
	40		375	510	760	1060	1400	1740	2140
	50		375	500	630	890	1180	1480	1830
	60		375	500	625	760	1020	1280	1590
	70		375	500	625	750	900	1140	1410
	80		375	500	625	750	875	1020	1270
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
40	20		460	780	1130	«	«	«	«
	25		390	660	970	1330	«	«	«
	30		375	580	850	1170	1540	«	«
	35		375	510	750	1050	1380	1710	«
	40		375	500	680	950	1250	1560	1920
	50		375	500	625	790	1060	1320	1640
	60		375	500	625	750	920	1150	1430
	70		375	500	625	750	875	1020	1260
	80		375	500	625	750	875	1000	1140
Concrete strength f'_c MPa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
50	20		420	700	1010	«	«	«	«
	25		375	590	870	1190	«	«	«
	30		375	520	760	1050	1380	«	«
	35		375	500	670	940	1240	1530	«
	40		375	500	625	850	1120	1390	1710
	50		375	500	625	750	950	1180	1460
	60		375	500	625	750	875	1030	1280
	70		375	500	625	750	875	1000	1130
	80		375	500	625	750	875	1000	1125
Concrete strength f'_c Mpa	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
65	20		375	610	890	«	«	«	«
	25		375	520	760	1040	«	«	«
	30		375	500	670	920	1210	«	«
	35		375	500	625	820	1080	1340	«
	40		375	500	625	750	980	1220	1500
	50		375	500	625	750	875	1040	1280
	60		375	500	625	750	875	1000	1125
	70		375	500	625	750	875	1000	1125
	80		375	500	625	750	875	1000	1125
Minimum			375	500	625	750	875	1000	1125

Table 15: Beam and column bars with fitments

All other longitudinal bars. Less than 300 mm of concrete cast below the bar

“a” = the smaller of the actual cover and one-half of the clear distance between parallel bars

Concrete strength f'_c MPa	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
20	20		570	960	1390	«	«	«	«
	25		480	820	1190	1640	«	«	«
	30		410	710	1040	1440	1900	«	«
	35		360	630	930	1290	1700	2110	«
	40		330	560	840	1170	1550	1920	2360
	50		300	470	700	980	1300	1630	2020
	60		300	400	600	840	1130	1420	1760
	70		300	400	520	740	1000	1250	1560
	80		300	400	500	660	890	1120	1400
Concrete strength f'_c MPa	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
25	20		510	860	1240	«	«	«	«
	25		430	730	1070	1460	«	«	«
	30		370	640	930	1290	1700	«	«
	35		330	560	830	1150	1520	1890	«
	40		300	500	750	1040	1380	1720	2120
	50		300	420	620	880	1170	1460	1800
	60		300	400	540	750	1010	1270	1570
	70		300	400	500	660	890	1120	1400
	80		300	400	500	600	800	1000	1250
Concrete strength f'_c MPa	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
32	20		450	760	1100	«	«	«	«
	25		380	650	940	1290	«	«	«
	30		330	560	830	1140	1500	«	«
	35		300	500	740	1020	1350	1670	«
	40		300	450	660	920	1220	1520	1870
	50		300	400	550	770	1030	1290	1600
	60		300	400	500	670	890	1120	1390
	70		300	400	500	600	790	990	1230
	80		300	400	500	600	700	890	1110
Concrete strength f'_c MPa	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
40	20		410	680	990	«	«	«	«
	25		340	580	850	1160	«	«	«
	30		300	500	740	1020	1340	«	«
	35		300	450	660	910	1210	1490	«
	40		300	400	590	830	1090	1360	1670
	50		300	400	500	690	920	1150	1430
	60		300	400	500	600	800	1000	1250
	70		300	400	500	600	710	890	1100
	80		300	400	500	600	700	800	990
Concrete strength f'_c MPa	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
50	20		360	610	880	«	«	«	«
	25		310	520	760	1040	«	«	«
	30		300	450	660	910	1200	«	«
	35		300	400	590	820	1080	1340	«
	40		300	400	530	740	980	1220	1500
	50		300	400	500	620	830	1030	1280
	60		300	400	500	600	720	900	1110
	70		300	400	500	600	700	800	990
	80		300	400	500	600	700	800	900
Concrete strength f'_c Mpa	**“a” mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
65	20		320	540	770	«	«	«	«
	25		300	460	660	910	«	«	«
	30		300	400	580	800	1050	«	«
	35		300	400	520	720	950	1170	«
	40		300	400	500	650	860	1070	1310
	50		300	400	500	600	730	910	1120
	60		300	400	500	600	700	800	980
	70		300	400	500	600	700	800	900
	80		300	400	500	600	700	800	900
Minimum			300	400	500	600	700	800	900

Table 16: All other longitudinal bars

All other longitudinal bars. More than 300 mm of concrete cast below the bar

"a" = the smaller of the actual cover and one-half of the clear distance between parallel bars

Concrete strength *f'cMPa*	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
20	20		710	1200	1740	«	«	«	«
	25		600	1020	1490	2040	«	«	«
	30		520	890	1300	1800	2370	«	«
	35		450	790	1160	1610	2130	2640	«
	40		410	700	1040	1460	1930	2400	2950
	50		375	580	870	1220	1630	2040	2520
	60		375	500	750	1050	1410	1770	2200
	70		375	500	650	930	1240	1570	1950
	80		375	500	625	830	1110	1400	1750
Concrete strength *f'cMPa*	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
25	20		640	1080	1550	«	«	«	«
	25		540	910	1330	1830	«	«	«
	30		460	790	1170	1610	2120	«	«
	35		410	700	1040	1440	1900	2360	«
	40		375	630	930	1300	1730	2150	2640
	50		375	520	780	1090	1460	1820	2250
	60		375	500	670	940	1260	1580	1970
	70		375	500	625	830	1110	1400	1740
	80		375	500	625	750	990	1250	1570
Concrete strength *f'cMPa*	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
32	20		570	950	1380	«	«	«	«
	25		480	810	1180	1620	«	«	«
	30		410	700	1030	1430	1870	«	«
	35		375	620	920	1270	1680	2080	«
	40		375	560	830	1150	1530	1900	2340
	50		375	500	690	970	1290	1610	1990
	60		375	500	625	830	1120	1400	1740
	70		375	500	625	750	980	1240	1540
	80		375	500	625	750	875	1110	1380
Concrete strength *f'cMPa*	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
40	20		510	850	1230	«	«	«	«
	25		430	720	1060	1450	«	«	«
	30		375	630	920	1280	1680	«	«
	35		375	560	820	1140	1510	1870	«
	40		375	500	740	1030	1370	1700	2090
	50		375	500	625	870	1150	1440	1780
	60		375	500	625	750	1000	1250	1560
	70		375	500	625	750	880	1110	1380
	80		375	500	625	750	875	1000	1240
Concrete strength *f'cMPa*	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
50	20		450	760	1100	«	«	«	«
	25		380	650	940	1290	«	«	«
	30		375	560	830	1140	1500	«	«
	35		375	500	740	1020	1350	1670	«
	40		375	500	660	920	1220	1520	1870
	50		375	500	625	770	1030	1290	1600
	60		375	500	625	750	890	1120	1390
	70		375	500	625	750	875	1000	1230
	80		375	500	625	750	875	1000	1125
Concrete strength *f'cMpa*	**"a" mm**	**Bar size**	**N12**	**N16**	**N20**	**N24**	**N28**	**N32**	**N36**
65	20		400	670	970	«	«	«	«
	25		375	570	830	1140	«	«	«
	30		375	500	730	1000	1320	«	«
	35		375	500	650	900	1180	1460	«
	40		375	500	625	810	1070	1330	1640
	50		375	500	625	750	910	1130	1400
	60		375	500	625	750	875	1000	1220
	70		375	500	625	750	875	1000	1125
	80		375	500	625	750	875	1000	1125
Minimum			375	500	625	750	875	1000	1125

Table 17: All other longitudinal bars

10.3 Bar Compression Lap Length and Anchorage

The lengths below rationalise the values given in AS3600. If both tension and compression can act at different times on the same cross-section, anchorage must be designed for the worst case situation.

If the factors given in Clause 13.1.4 for bundled bars are applied directly to the compression development length given in Clause 13.1.3, they become $24d_b$ and $26.6d_b$ respectively. Bundled bars in compression are not commonly used other than in the columns of very high buildings so that, for practical use, all development lengths have been rounded up to $30d_b$.

For practical use also, the lap splice for a single bar in compression is rounded up to $41d_b$ (Clause 13.2.4) and to $54d_b$ for a bundled bar (Clause 13.2.5).

Lap splices are always based on full yield strength f_{sy}. To permit other values would create uncertainty in the mind of fixers and inspectors, and would certainly require more work from detailers. AS3600-2001 Clause 13.2.4 does not allow reductions in compression lap lengths.

	Application	Lengths for grade D500N single and bundled bars						
		N12	N16	N20	N24	N28	N32	N36
$L_{sy.c}$ 20 d_b	Compression development length (Clause 13.1.3) Do not use these for column lap splices	240	320	400	480	560	640	720
$L_{sy.t}$ 25 d_b	Tensile stress development length (Clause 13.1.2.1 bottom bars) minimum values	300	400	500	600	700	800	900
$L_{sy.t}$ 25 $k_1 d_b$, $k_1 = 1.25$	Tensile stress development length (Clause 13.1.2.1 top bars) minimum values	375	500	625	750	875	1000	1125
$L_{sy.c}$ 41 d_b	compression lap splice of a single column bar (Clause 13.2.4)	500	660	820	990	1150	1320	1480
$L_{sy.c}$ 30 d_b	3 and 4- bar bundle compression development length (Clause 13.1.3 modified by 13.1.4)	360	480	600	720	840	960	1080
$L_{sy.c}$ 54 d_b	3 and 4- bar bundle compression lap splice (Clause 13.2.4 modified by 13.2.5) Also 8.1.8.8, 10.7.2, 10.7.4	650	870	1080	1300	1520	1730	1950

Table 18: Development and lengths for deformed bars

Compression Development Length for Single Bars, $L_{sy.c}$ *(Clause 13.1.3)*

The formula for L sy.c given in Clause 13.1.3 is not dependent upon concrete strengths, steel strengths, or on the width or depth of the member. It is equal to $20d_b$.

Although it is not stated in Clause 13.1.3, the minimum cover and spacing rules still apply. Compression causes splitting of the cover in a different way to tensile forces. A realistic spacing is required to ensure concrete can be consolidated properly. Encircling ties may also be advisable in zones of heavy reinforcement.

Compression bars must not be hooked.

Compression Lap Splices for Single Bars (Clause 13.2.4)

For 500 MPa bars in a compression zone of the concrete, the lap length is $41d_b$. This is twice the compressive stress development length. This value also applies to lap splice lengths for column bars.

Compression bars must not be hooked. This is not restricted to columns and walls. It applies to all members.

Where the concrete at the bottom of a beam over a column carries an excessively large compression load, extra bars lapped for compressive stress transfer will be required there.

Development Length of Bundled Bars in Compression (Clauses 8.1.8.8, 10.7.2, 13.1.3, 13.1.4)

When two bars are tied together over their full length, to form a two-bar bundle, an increase in development length is not required.

Three or four bars can be tied tightly together to form a bundle. Each bar of the "unit" therefore presents a smaller surface in contact with the surrounding concrete. This requires an increased development length for bundled bars (Clauses 13.1.3, 13.1.4).

In beams, the bar cut-off point of each bar in a bundle must be staggered by $40d_b$ (Clause 8.1.8.8).

Compression Lap Splices for Bundled Bars (Clauses 13.2.1, 13.2.5)

Lap splicing of bundled bars is messy, complicated, uses excessive steel, and causes overcrowding of the column area. These lap splices must be avoided.

Wherever possible bundled bars should be spliced by end bearing (no laps) or by mechanical splice because these give a simpler solution.

The values in the table also apply to an extra splice bar added to a bundle which did not have a sawn-end preparation for an end-bearing splice. The splice bar must be at least twice the lap length given above, and located centrally about the section where the splice is.

10.4 Additional Information on Lap Splices

Deemed to Comply Values for Lap Splices of Main Bars in Tension

The table below provides tabulated values of development length and lap splices in flexural members, provided the following rules are observed:

- The characteristic compressive strength of the concrete, f'c and the corresponding value of the cover, c, are not less than given in the table below.
- For slabs and walls, the clear distance between adjacent parallel bars being designed, over the length in which they are considered to be developing stress or over the lap length, must not be less than 150 mm. This does not restrict the spacing to 150 mm over the remainder of the length.
- For beams and columns, at least the minimum quantity of fitments (stirrups, ties etc) must surround the main bars being designed, and the clear distance between adjacent parallel bars must be at least twice the cover given in the table.

Combination of minimum values			Tensile development length and lap splice length, $L_{sy.t}$						
			Slab or wall		Beam or column bar in tension				
Concrete strength f'_c MPa	Min cover	*Bar size*	*N12*	*N16*	*N20*	*N24*	*N28*	*N32*	*N36*
20 MPa	20 mm		450	700	1300				
20 MPa	50 mm		300	400	650	900	1200	1500	1900
25 MPa	30 mm		300	450	900	1200	1550		
25 MPa	60 mm		300	400	500	700	950	1200	1450
32 MPa	25 mm		300	500	900	1200			
32 MPa	40 mm		300	400	650	850	1150	1400	1750
32 MPa	65 mm		300	400	500	600	800	1000	1200
40 MPa	30 mm		300	400	700	950	1250		
40 MPa	45 mm		300	400	500	700	950	1150	1450
65 MPa	45 mm		300	400	500	600	750	900	1150

Table 19: Minimum tensile development lengths

The minimum cover is from the surface of the concrete to the bar being detailed.

Intermediate values of $L_{sy}.t$ must not be interpolated. Alternative combinations must be calculated from AS3600-2001.

For bars with more than 300 mm of concrete cast below them, the above values must be increased by 25%.

Which Should be Used – A Tension Splice or a Compression Splice?

The simple answer is that if a bar can be in tension under one loading condition, and change to compression under another (or vice versa), then the splice must carry the “worst case” load. As examples, the above situation can occur when the wind blows alternately from opposite directions, or when trucks move across a bridge. It is suggested that detailers incorporate only the values 20, 25, 30, 41 and $54d_b$ given in Table 18.

Lap Splices v Overlapped Bars and Cogs v 90° Bends

There are obviously many situations where there is no need to transfer load, however bars need to be overlapped and tied together. In these cases the overlap may only need to be 100-150 mm for a small bar and up to 300 mm for a large bar. The overlap should be specified in the drawings, otherwise a full splice may be provided, or even worse, a short overlap provided where a full lap is essential. These overlaps can be tabulated in many cases to avoid repetitive notes.

At the end of some bars, a 90° bend can be mistaken for a 90° hook. Without knowing the purpose of the bend, a clear distinction often cannot be made.

Where the bar dimension appears to fit into the concrete, allowing for covers, a 90° bend would be assumed. Where it won't fit, then the detail should be revised to avoid the bar-end from sticking out of the concrete.

See Tables 21 and 22.

10.5 Bar Hooks and Cogs

Hooks are defined in AS3600 Clauses 8.2.12.4, 13.1.2.5 and 19.2.3.2. The length of steel needed to physically make each hook is given in Tables 20, 21 and 22. The length of steel in a bar with a hook is the overall length of the straight portion plus hook or cog length.

AS3600-2001 requires a longer hook to provide end anchorage of a beam ligature than the standard hook defined in Clause 13.1.2.5. This is due to the change in Clause 8.2.12.4.

AS3600-1994 Clause 8.2.12.4 End anchorage of bars

Bars used as shear reinforcement shall be anchored to develop the yield strength of the bar at mid-depth of the member.

A fitment hook shall be deemed to develop $0.5f_{sy.f}$ in accordance with Clause 13.1.2.5.

A fitment hook which encloses a longitudinal bar shall be deemed to develop $0.67f_{sy.f}$

Notwithstanding the above, fitment cogs shall not be used when the anchorage of the fitment is solely in the concrete cover of the beam. Fitment hooks shall be used in this case.

AS3600-2001 Clause 8.2.12.4 Anchorage of shear reinforcement

The anchorage of shear reinforcement transverse to the longitudinal flexural reinforcement may be achieved by hooks, cogs, welding of the traverse bars or welded splices.

NOTE: The type of anchorage used should not induce splitting or spalling of the concrete cover.

Shear reinforcement shall be deemed to be adequately anchored provided the following requirements are met:

a) Bends in bars used as fitments shall enclose a longitudinal bar with a diameter larger than the diameter of the fitment bar. The enclosed bar shall be in contact with the fitment bend.

b) A fitment hook should be located preferably in the compression zone of the structural member, where anchorage conditions are most favourable. Such an anchorage is considered satisfactory, if the hook consists of a 135° or 180° bend with a nominal internal diameter of $4d_b$ plus a straight extension of $10d_b$ or 100 mm, whichever is the greater.

c) Where a fitment hook is located in the tension zone, the anchorage described in Item (b) is deemed to be satisfactory provided the stirrup spacing calculated using Clause 8.2.10 is multiplied by 0.8 and the maximum spacing specified in Clause 8.2.12.2 is also multiplied by 0.8.

d) Notwithstanding the above, fitment cogs shall not be used when the anchorage of the fitment is solely in the cover concrete of the beam.

The straight extension of a fitment hook has been increased six bar diameters, from $4d_b$ to $10d_b$. Fitment hooks in AS3600-2001 are not standard hooks, as they were for previous codes. These changes are due to the change in the requirement for development of the yield strength in the bar at mid height of the beam to development of yield strength in the bar at all points along the height of the beam stirrup. This is a departure from the traditional design theory that derived from Truss Analogy. The full height development and extra hook length for beam fitments is a requirement for earthquake detailing.

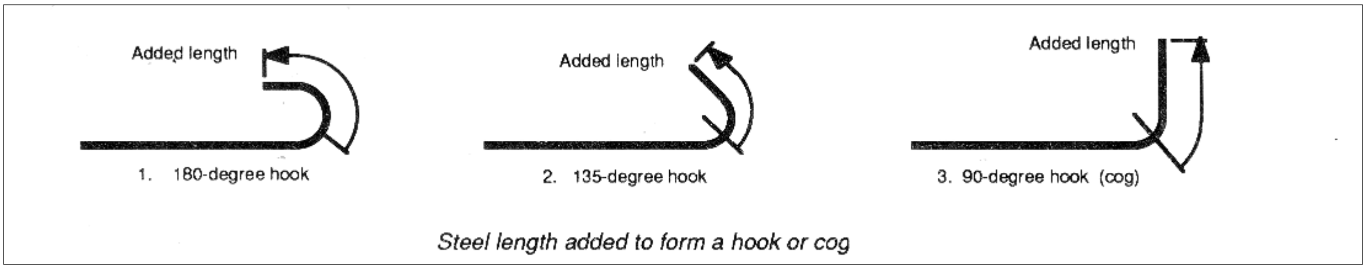


Figure 39: Steel length to form a hook or cog

Added length for a hook or a cog

Diameter of pin	R6	R10	N12	N16	N20	N24	N28	N32	N36
$4d_b$ Grade 250N beam fitments	145	170	205	275	Not to be used				
$4d_b$ Grade D500N beam fitments	-	-	205	275	340	410	480	550	615
$5d_b$ All main bars	120	250	205	245	300	360	420	480	540
$6d_b$	130	265	235	280	330	390	485	545	570
$8d_b$	140	300	265	340	395	485	595	620	730

Table 20: Length of steel required to bend a hook and cog

Notes:

1. See section 10.8 for background information from AS3600, including rebent and coated bars.
2. A pin size equal to or less than the quality-control bend test must never be used.

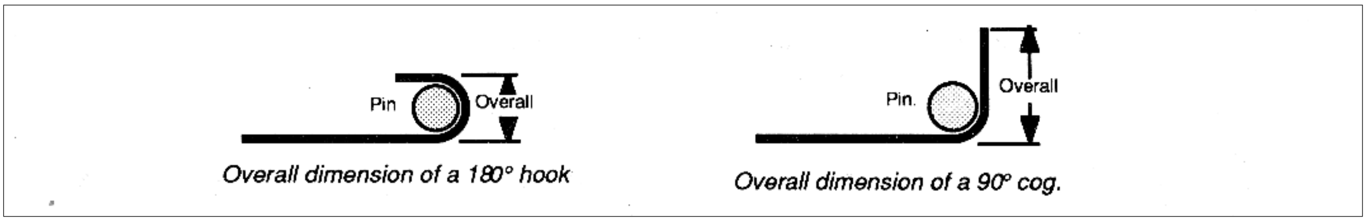


Figure 40: Overall dimension of a hook or cog

Overall Dimension, mm

Diameter of pin	R6	R10	N12	N16	N20	N24	N28	N32	N36
$4d_b$ Grade 250N beam fitments	40	60	85	110	Not to be used				
$4d_b$ Grade D500N beam fitments	-	60	85	110	120	150	175	195	200
$5d_b$ main bars, AS 3600	-	70	85	110	140	170	200	225	250
$6d_b$	-	80	105	130	160	190	235	265	290
$8d_b$	-	100	125	175	200	250	305	315	375

Table 21: Approximate overall dimension of a 180° hook

Overall Dimension, mm

Diameter of pin	R6	R10	N12	N16	N20	N24	N28	N32	N36
$4d_b$ Grade 250 beam fitments					Not to beused				
$4d_b$ Grade D500N beam fitments					Not to be used				
$5d_b$ main bars, AS 3600	-	220	170	200	245	295	340	390	440
$6d_b$	-	235	200	230	270	320	395	445	465
$8d_b$	-	260	220	280	320	400	485	570	595

Table 22: Approximate overall dimension of a 90° cog

In the above tables, no allowance has been made for spring-back after bending. All dimensions are therefore nominal. The real overall diameter of a deformed bar is approximately 112% of the nominal diameter. A 90° bend longer than $10d_b$ overall gives the same anchorage as a 90° cog.

11.0 Reinforcing Mesh

11.1 Mesh General Information

Cold Rolled, High Strength Fabric of Grade R500N

ARC produces a 500 MPa Ductility Grade N mesh to suit your project requirements. The DuctileMesh 500™ fabric sheets are a welded square or rectangular grid of R500N bars.

Contact your local ARC branch to discuss your project requirements for Ductility Grade N mesh.

Cold Rolled, High Strength Deformed Fabric of Grade D500L

ARC fabric is available in 2.4 x 6.0 metre sheets and in 2.4 metre wide rolls. It is also available in purpose made sheets to suit your project requirements. The mesh sheets are a welded square or rectangular grid of D500L bars.

Welded fabric permits maximum construction speed and economies. The cost and time required to lay mesh sheets is much less than that required to place, space and tie together loose bars. Typically fabric also provides greater crack control than loose bars as the bars that make up the sheet are of smaller diameter and at closer spacings.

ARC fabric is commonly available in sheet sizes ranging from SL42 to RL1218 and in trench mesh strips from L8TM3 to L12TM5.

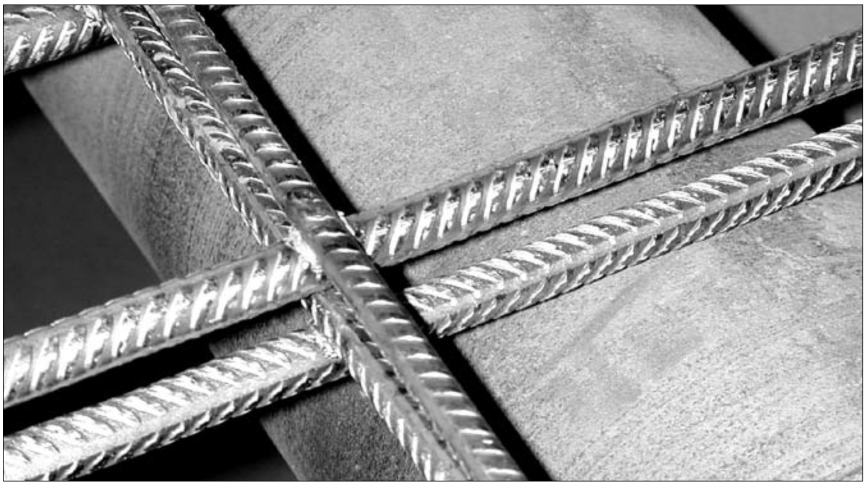


Figure 41: Welded mesh intersection

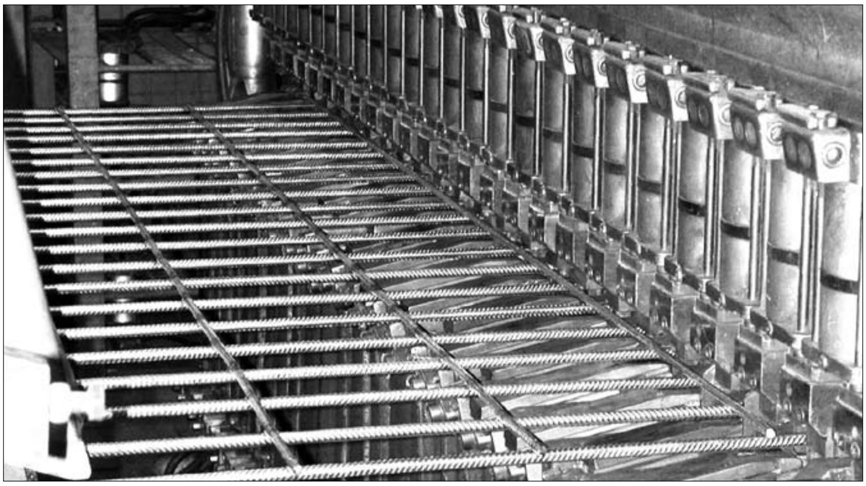


Figure 42: Mesh production by automatic welding machines

11.2 Cross-Sectional Area of ARC Mesh

ARC Mesh Designation	Longitudinal Wires mm²	Cross Wires mm²
RL 1218	1112	227
RL 1118	891	227
RL 1018	709	227
RL 918	574	227
RL 818	454	227
RL 718	358	227
Square meshes with edge side lapping wires		
SL 102	354	354
SL 92	287	287
SL 82	227	227
SL 72	179	179
SL 62	141	141
SL 52	89	89
SL 63	94	94
SL 53	59	59
Square meshes without edge side lapping wires		
SL 81	454	454
SL 41	126	126
SL 42	63	63

Trench meshes

Types	Approximate design area for strips with - 3 wires mm²	4 wires mm²	5 wires mm²
L 12TM	333	444	555
L 11TM	267	356	445
L 8TM	136	182	227

Table 23: Design area of ARC mesh

Notes:

1. Trench mesh is normally specified by the number of wires used in either the top and/or bottom of the footing so that the design cross-sectional areas given above are not often referred to. Common trench mesh strip widths are 200 mm (3 wires), 300 mm (4 wires), and 400 mm (5 wires). See AS2870.1
2. The steel grade for standard fabric and trench mesh is D500L.
3. Fabric configurations are not limited to the standard fabrics shown above. Fabric main wire spacings are the most critical factor for special meshes, and detailers should check with ARC before finalising a design using any fabric not included in the list of standard fabrics.
4. Fabrics SL 63 and SL 53 have an internal mesh size of 300 mm x 300 mm. The sheet size is 6 m long by 2.3 m wide. The 100 mm closer wire spacings on the side reduce the minimum side lap to 100 mm, rather than 300 mm. They are not available in every state.
5. Although the fabrics listed above are generally available ex-stock, we recommend that designers and users check with their local ARC office if they have any questions about properties or availability.

11.3 Physical Dimensions of ARC Mesh

Mesh Specification

ARC	Longitudinal Wires		Cross Wires		Approximate Mass	
	No. x size	@ pitch	No. x size	@ pitch	/ area	/ sheet
Mesh Designation	*mm*	*mm*	*mm*	*mm*	*kg / m²*	*kg*
Rectangular meshes						
RL 1218	25 x 11.90	@100	30 x 7.60	@200	10.9	157
RL 1118	25 x 10.65	@100	30 x 7.60	@200	9.1	131
RL 1018	25 x 9.50	@100	30 x 7.60	@200	7.6	109
RL 918	25 x 8.55	@100	30 x 7.60	@200	6.5	93
RL 818	25 x 7.60	@100	30 x 7.60	@200	5.6	79
RL 718	25 x 6.75	@100	30 x 7.60	@200	4.7	68
Square meshes with edge side lapping wires						
SL 102	10 x 9.5 +4 x 6.75	@200 @100	30 x 9.50	@200	5.6	80
SL 92	10 x 8.55 +4 x 6.0	@200 @100	30 x 8.55	@200	4.5	65
SL 82	10 x 7.6 +4 x 6.0	@200 @100	30 x 7.60	@200	3.6	52
SL 72	10 x 6.75 +4 x 4.75	@200 @100	30 x 6.75	@200	2.8	40
SL 62	10 x 6.0 +4 x 4.75	@200 @100	30 x 6.00	@200	2.3	33
SL 52	10 x 4.75 +4 x 4.0	@200 @100	30 x 4.75	@200	1.5	21
SL 63	6 x 6.0 +4 x 4.75	@300 @100	20 x 6.00	@300	1.6	22
SL 53	6 x 4.75 +4 x 4.0	@300 @100	20 x 4.75	@300	1.0	14
Square meshes without edge side lapping wires						
SL 81	25 x 7.60	@100	60 x 7.60	@100	7.3	105
SL 41	25 x 4.0	@100	60 x 4.0	@100	2.0	29
SL 42	13 x 4.0	@200	30 x 4.0	@200	1.0	15
Trench meshes						
L 12TM	11.90	@100	4.75	@300	See Note 2	
L 11TM	10.65	@100	4.75	@300	See Note 2	
L 8TM	7.60	@100	4.0	@300	See Note 2	

Table 24: ARC mesh details

Notes:

1. The mass of fabric per square metre is based on a piece cut from the interior of a full sheet which is one metre square with equal overhangs on opposite sides.
2. Common trench mesh strip widths are 200 mm (3 wires), 300 mm (4 wires) and 400 mm (5 wires). See AS2870.1, Residential Slabs and Footings Part 1- Construction, for applications.
3. Fabrics SL 63 and SL 53 have an internal mesh size of 300 mm x 300 mm. The sheet size is 6 m long by 2.3 m wide. The 100 mm closer wire spacings on the side reduce the minimum side lap to 100 mm, rather than 300 mm. They are not available in every state.
4. Although the fabrics listed above are generally available ex-stock, we recommend that designers and users check with their local ARC office if they have any questions about properties or availability.

11.4 Wire and Fabric Development Length

Development Length $L_{sy.t}$ For Plain Wire

AS3600 Clause 13.1.2.1 (c) allows a development length of 50 d for hard drawn wire. The D500L grade bars are cold rolled wires.

Value of $L_{sy.t}$ for wires of grade 500 MPa									
Wire size	4.0 mm	4.75 mm	6.0 mm	6.75 mm	7.60 mm	8.55 mm	9.50 mm	10.65 mm	11.90 mm
50 d_{wire}	200	240	300	340	380	430	475	535	595

Table 25: Development length and laps for deformed wire fabric (AS/NZS 4671 and AS3600)

It is often not appreciated that the requirements of these Standards are closely inter related.

AS/NZS 4671, Clause 7.2.5 gives the minimum welded connection shear force for mesh as 0.5 $R_{ek.L}$ A_s, that is, half the yield force of the largest bar at the weld.

To develop the design stress of the wire ($R_{ek.L}$ A_s) at least two welded intersections must be embedded (2 x 0.5 ($R_{ek.L}$ A_s). To transfer this stress from one sheet to another, a minimum overlap of two welded intersections must be specified. These are the reasons for the requirements of Clause 13.2.3 of AS3600.

Thus embedment of two cross wires by 25 mm or more, from where full strength is required can be assumed to develop the full design strength of the mesh wire.

Each wire of welded wire fabric develops its stress by normal adhesive bond with concrete together with bearing, against the concrete, of cross wires welded transversly to it. Adhesive bond to the wire is usually neglected for cross-wire spacings up to 200 mm. No advantage is given to deformed wires. Most overseas Standards specify the minimum overlaps of 200 mm or more because the weld-shear strength is limited to $0.3f_{sy.wire}$. Thus at least three, and often four, wires must be overlapped leading to serious bunching.

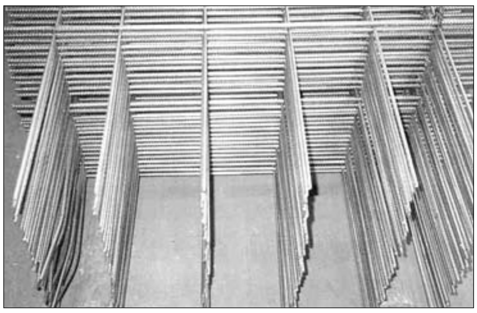


Figure 43: Mesh with an overhang

Development Length for Mesh with an Overhang

In certain circumstances, such as at a support, the bond of the overhanging wires can be utilised for stress development. Clause 13.1.2.1 (c) allows $L_{sy.t}$ for wire to be 50 d_{wire}. AS/NZS 4671 requires a weld strength of 0.5 $R_{ek.L}$ A_s.

The following table shows the development strength of one cross wire plus an overhang of 25 d_{wire}.

Wire size.	4.0 mm	4.75 Mm	6.0 mm	6.75 mm	7.6 mm	8.55 mm	9.50 mm	10.65 mm	11.90 mm
25 d_{wire} + 25	125	145	175	195	215	240	265	295	325

Table 26: Embedment length of one weld plus an overhang of 25 d_{wire} + one weld + 25 mm

Note: Values are provided as a basis for an engineering judgement.

11.5 Mesh Detailing

Specify the Sheet Direction

The most important requirement for structural safety of a slab is that the correct reinforcement is placed in the direction of the span which controls the strength characteristics.

In slabs supported on beams or walls, the controlling span is the SHORTER span – this is true whether the slab is supported on three sides or on all four sides.

In slabs supported by columns, such as flat-slab floors and flat-plate floors, it is the LONGER of the two spans which control the strength. Because the reinforcement for these is complicated, well prepared detail drawings must be provided.

However for minor structures, the reinforcement details are often not well documented and steel fixers must be given additional instructions on the sheet direction.

All drawings should indicate the direction in which to place the longitudinal wires of fabric, and also illustrate how fabric sheets are to be lapped.

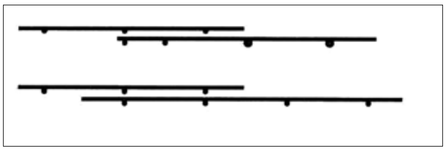
Rectangular fabrics such a RL718 and RL818 require particular care when detailing them.

Where suspended slabs have a span less than 6 metres, it is unusual that fabric would need to be lapped at the end of a sheet.

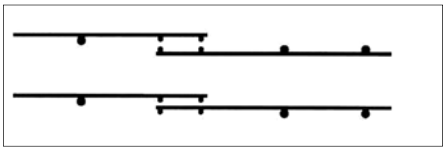
If end laps are required, the actual length of the overhang should be allowed for and specified, and a clear statement made on the drawings whether or not the overhang is included in the lap unless the following rules are observed:

1. Full width sheets are overlapped by the distance between the two outermost edge wires.
2. When cut sheets are lapped, the outermost two wires are also overlapped, and the length of the overhang is neglected.

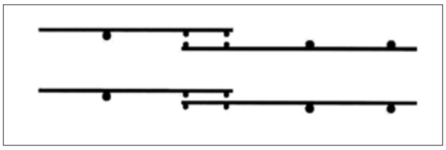
Example of laps are given in Figure 44.



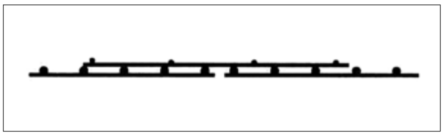
Overlap at end of sheet with overhang, all fabric styles



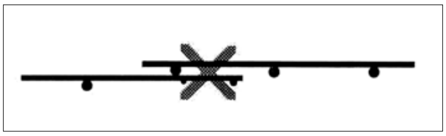
Overlap at side of sheet, rectangular meshes, RL1218 to RL718, and square mesh SL81



Overlap at side of sheet, square meshes edge side-lapping wires SL102 to SL52, SL63 and SL53



Additional lap-splice strip. The cross-wires are being spliced in this example, so the cross-sectional area (bar or wire sizes and spacing) must match.



This example shows an INCORRECT method of lapping. Only one mesh is overlapped here instead of two as required. The outermost wires of the lower sheet are spaced at 100 mm. The upper sheet has wires spaced at 200 mm.

Figure 44: Mesh laps

Specify the Fabric Position

The next factor to be considered is to locate the fabric in the right position. Fabric in the bottom of a slab must be supported on bar chairs from the formwork.

Continuous bar chairs, such as the ARC “Goanna” chair, are the most suitable here because they can be set out on the forms before the fabric is placed and the weight of the fabric is evenly spread over many legs. Thus, there is no need to place chairs under the steel that fixers are standing on.

Top reinforcement must be supported on high bar chairs, on high “Goannas” or on “Deckchairs”.

Mesh Laps

These laps are based on AS3600 and on AS2870.1. The wires should be tied together to prevent slippage. For tying, the orientation of the sheets is not critical. That is, the lapped wires may be in the same layer or separated by the wires at right angles.

Additional strips or finger mesh must be used when it is critical that the effective depth be maintained.

11.6 Special Fabric Design Information

Wire size	4.00	4.75	6.00	6.75	7.60	8.55	9.50	10.65	11.90
Spacing	mm²/m	mm²/m	mm²/m	mm²/m	mm²/m	mm²/m	mm²/m	mm²/m	mm²/m
50	252	354	566	716	908	1148	1418		
75	168	236	377	477	605	765	945	1188	1483
100	**126**	**177**	**283**	**358**	**454**	**574**	**709**	**891**	**1112**
125	101	142	226	286	363	459	567	713	890
150	84	118	189	239	303	383	473	594	741
175	72	101	162	205	259	328	405	509	635
200	**63**	**89**	**142**	**179**	**227**	**287**	**355**	**446**	**556**
250	50	71	113	143	182	230	284	356	445
300	**42**	**59**	**94**	**119**	**151**	**191**	**236**	**297**	**371**
350	36	51	81	102	130	164	203	255	318
400	**32**	**44**	**71**	**90**	**114**	**144**	**177**	**223**	**278**
450	28	39	63	80	101	128	158	198	247
500	**25**	**35**	**57**	**72**	**91**	**115**	**142**	**178**	**222**
1000	**13**	**18**	**28**	**36**	**45**	**57**	**71**	**89**	**111**

Table 27: Design cross-sectional area for reinforcing wire

Diameter mm	4.00	4.75	6.00	6.75	7.60	8.55	9.50	10.65	11.90
Area mm²/m	12.6	17.7	28.3	35.8	45.4	57.4	70.9	89.1	111.2
Mass kg/m	0.0989	0.1389	0.2222	0.2810	0.3564	0.4506	0.5566	0.6994	0.8729

Table 28: Nominal dimensions of reinforcing wire

Nominal diameter of wire	**mm**	4.00	4.75	6.00	6.75	7.60	8.55	9.50	10.65	11.90
Nominal area of one wire	mm²/m	13	18	28	36	45	57	71	89	111
	Area provided by the number of wires as shown on left									
Number of wires		mm²	mm²	mm²	mm²	mm²	mm²	mm²	mm²	mm²
2 wires		25	35	57	72	91	115	142	178	222
3 wires		38	53	85	107	136	172	213	267	334
4 wires		50	71	113	143	182	230	284	356	445
5 wires		63	89	142	179	227	287	355	556	556
6 wires		76	106	170	215	272	344	425	535	667
7 wires		88	124	198	251	318	402	496	324	778
8 wires		101	142	226	286	363	459	567	713	890

Table 29: Cross-sectional areas of engineer designed fabric

Notes:

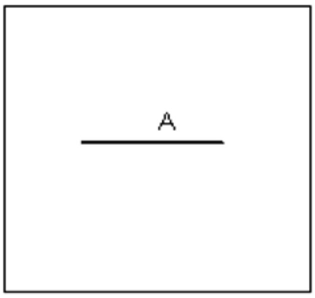
1. The longitudinal wire spacing should be restricted to between 100 mm and 200 mm, although a 300 mm spacing is acceptable provided the quantity of fabric can be manufactured economically for the project.
2. The longitudinal wire spacings given in Table 27 should be regarded as a practical manufacturing limitation to conserve costs. The size of the cross wire should be not less than approximately one-half the diameter of the longitudinal wire, and spaced at 200 mm or 300 mm centres. Cross wire size and spacing is determined by the design requirements.
3. Strip fabrics resemble trench mesh in that the sheets are narrow (usually restricted to eight wires as a maximum) but of a length calculated to fit the job dimensions. The controlling factor of the size of the sheet is its mass. Where possible each sheet should be capable of being carried and placed by one or two men.
4. In all cases, please consult with your local ARC engineer before commencing a project using these fabrics. A simple variation of a standard fabric may prove the most economical.

Figure 45: Project mesh simplifies mesh laps

Area Comparison Table
D500L Mesh and D500N Bar

D500L Mesh	D500N 12	D500N 16
RL 1218 (1112)	N12-100 (1100)	N16-200 (1000)
RL 1118 (891)	N12-125 (880)	N16-225 (889)
RL 1018 (709)	N12-150 (733)	N16-250 (800)
RL 918 (574)	N12-175 (629)	N16-300 (667)
RL 818 / SL81 (454)	N12-200 (550)	N16-350 (571)
RL 718 (358)	N12-225 (489)	N16-400 (500)
SL 102 (354)	N12-250 (440)	N16-500 (400)
SL 92 (287)	N12-300 (367)	N16-1000 (200)
SL 82 (227)	N12-400 (275)	
SL 72 (179)	N12-500 (220)	
SL 62 (141)	N12-1000 (110)	
SL 41 (126)		
SL 63 (94)		

AS3600-2001 has restrictions on the use of D500L Reinforcing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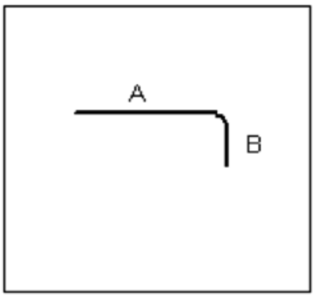
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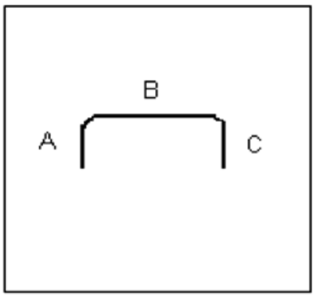
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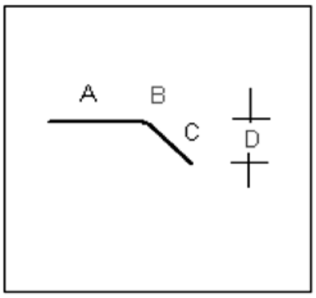
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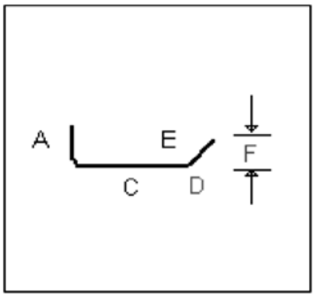
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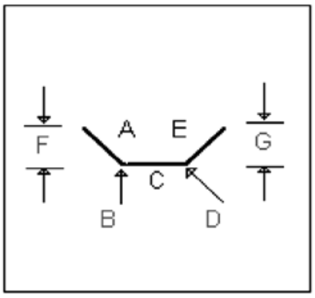
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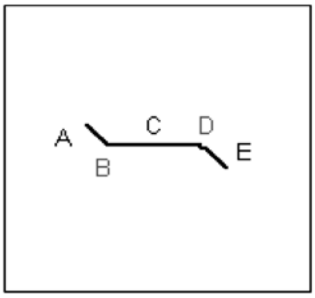
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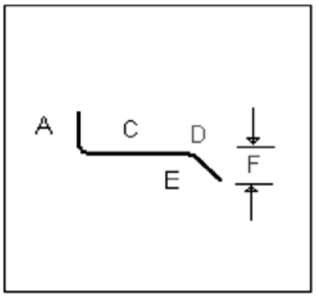
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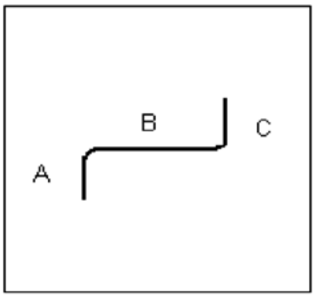
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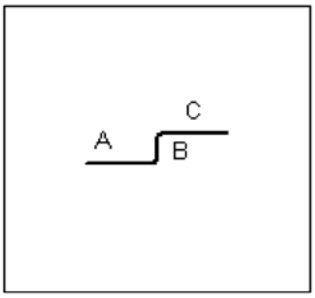
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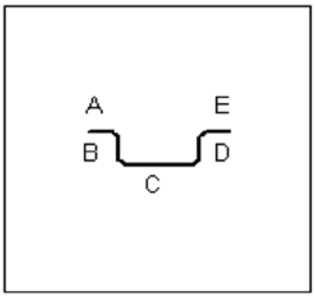
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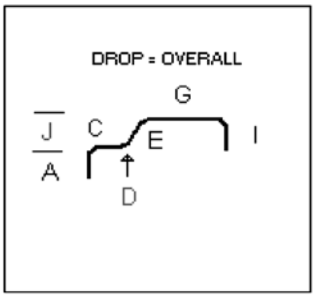
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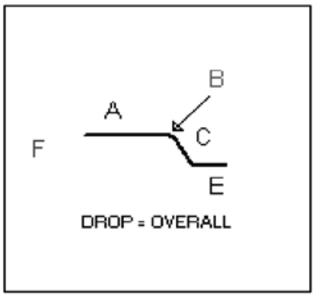
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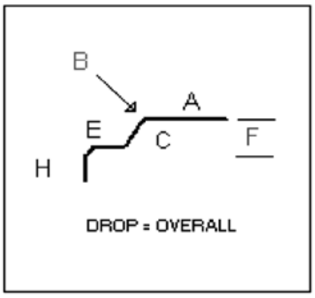
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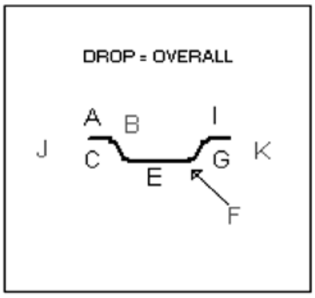
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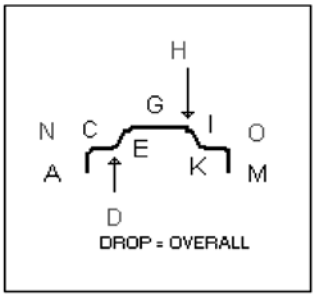
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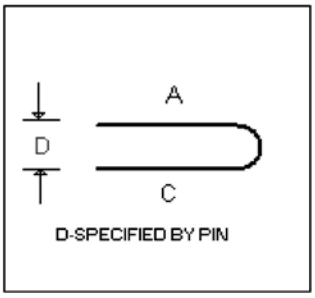
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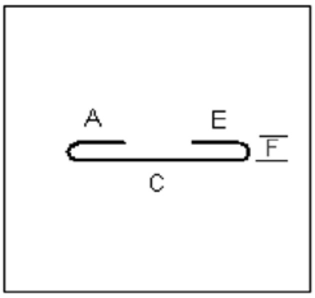
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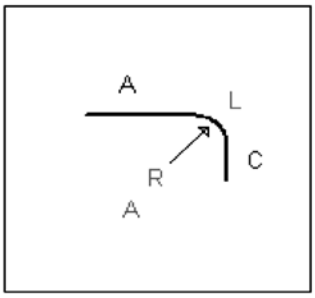
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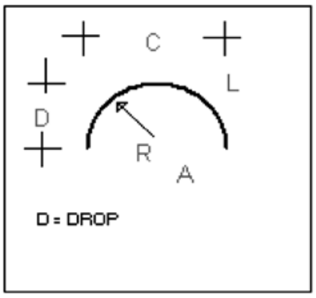
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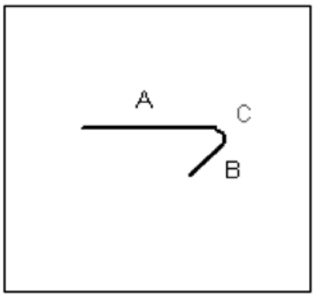
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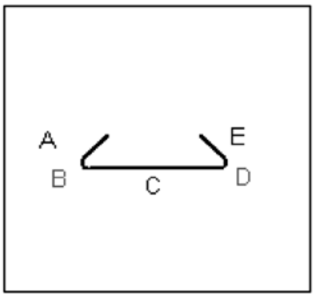
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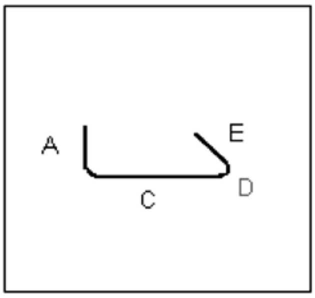
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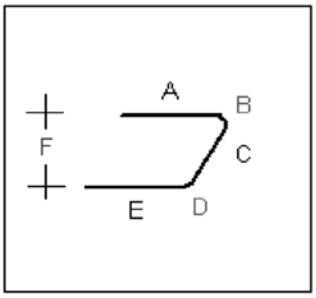
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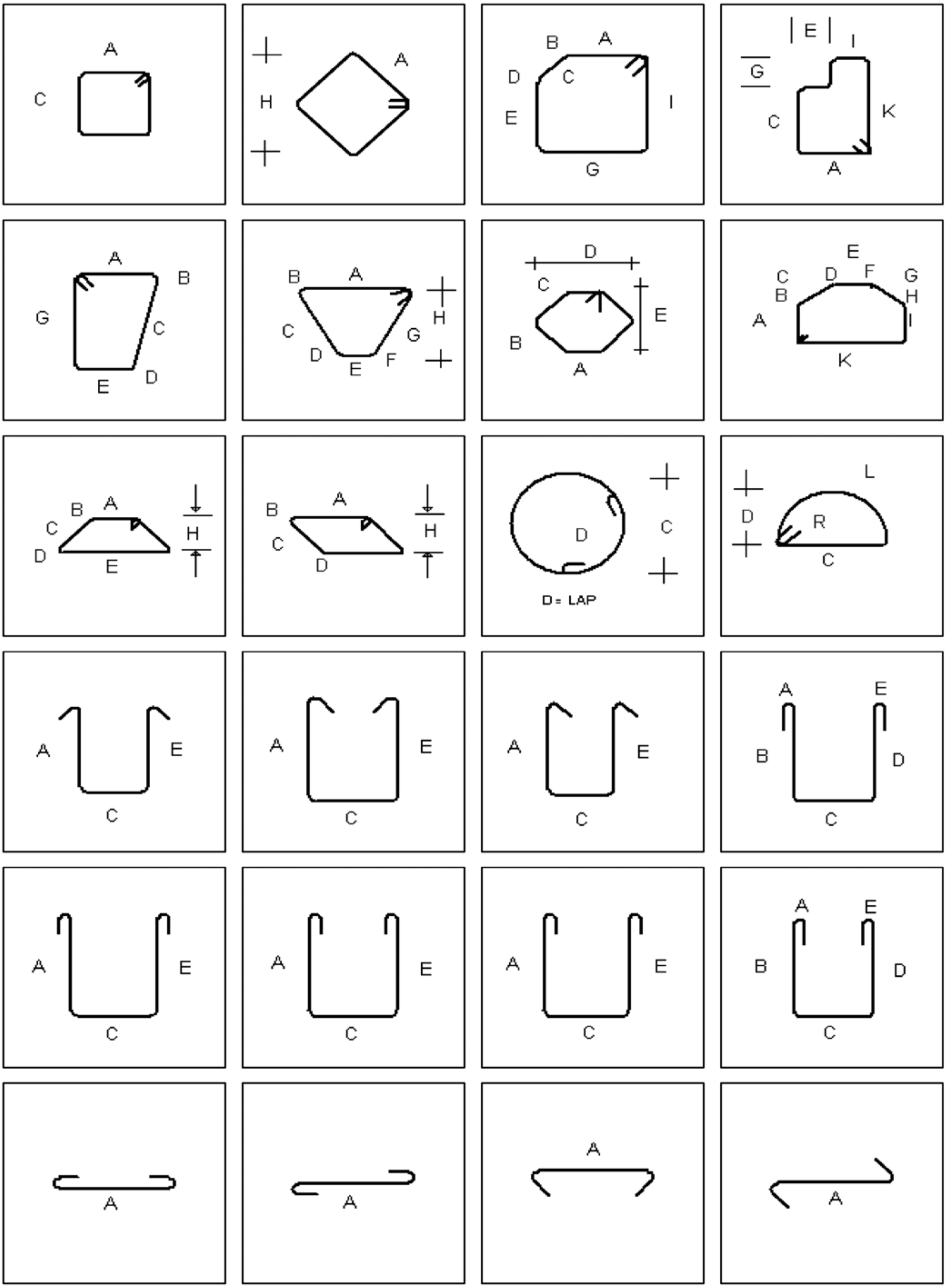
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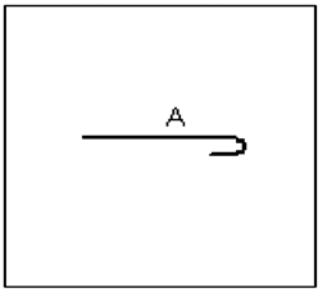
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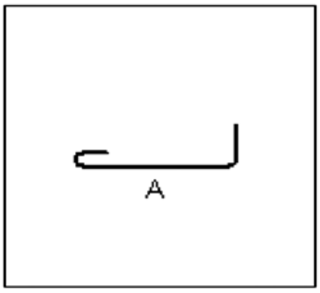
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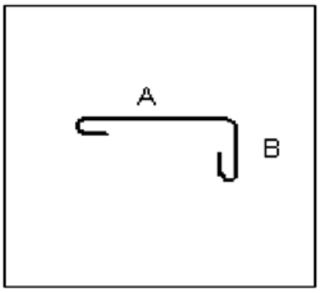
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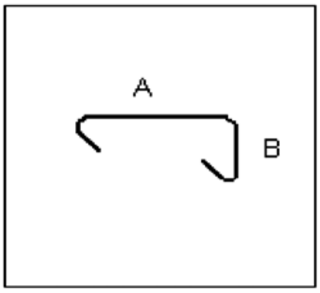
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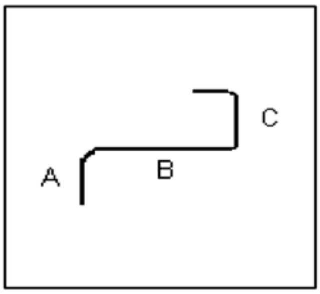
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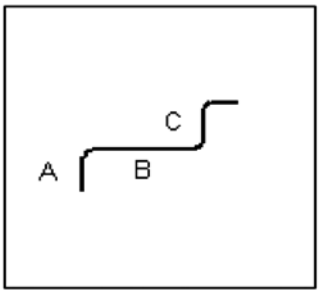
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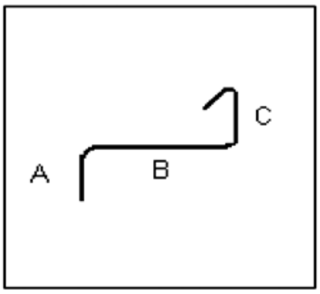
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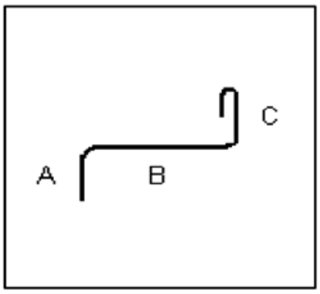
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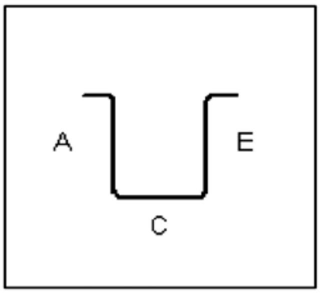
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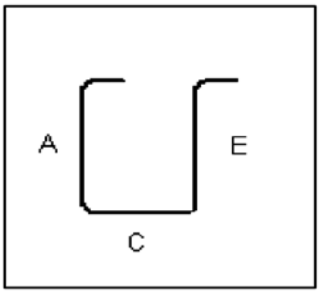
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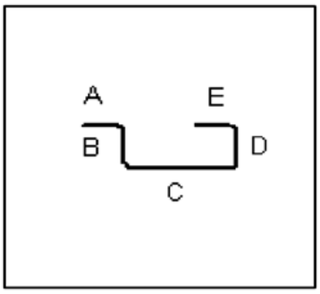
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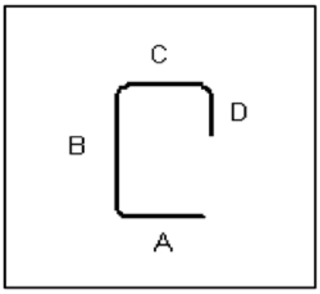
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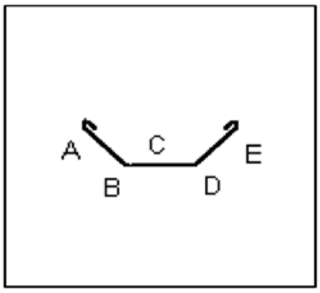
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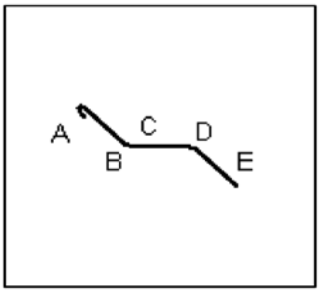
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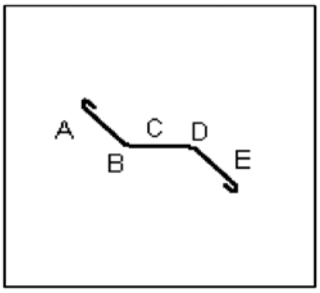
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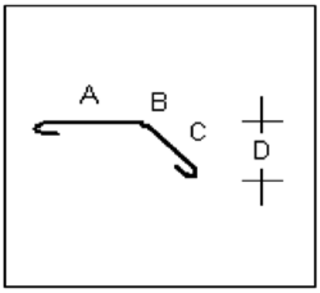
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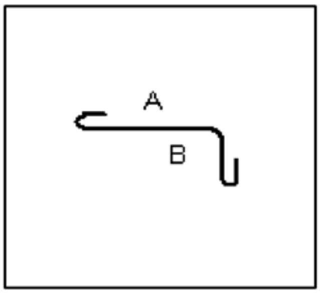
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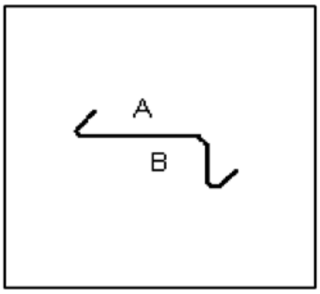
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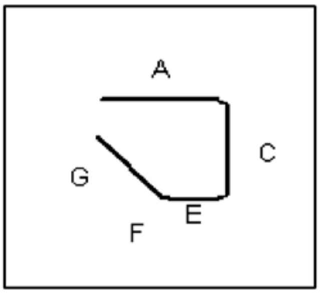
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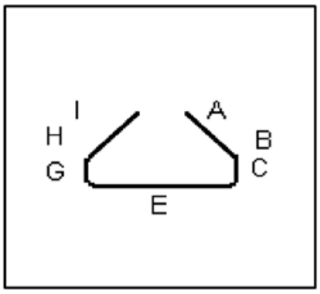
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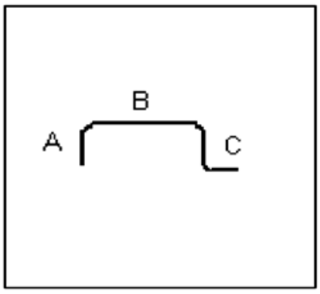
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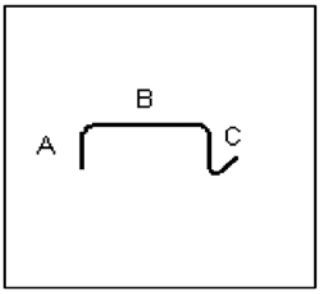
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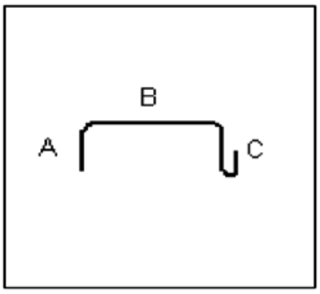
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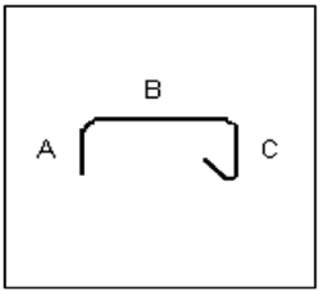
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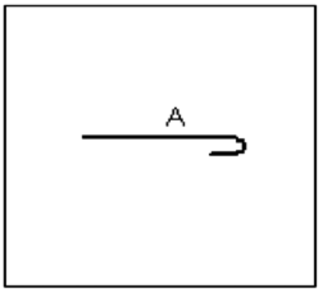
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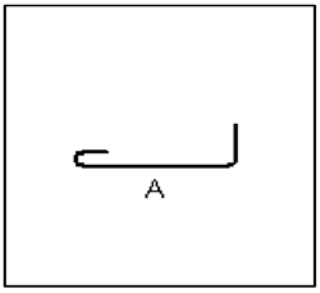
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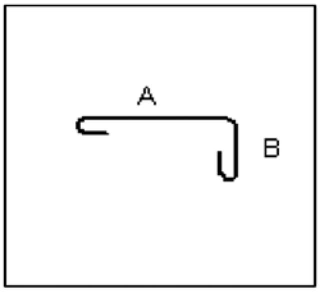
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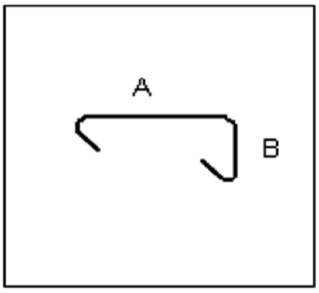
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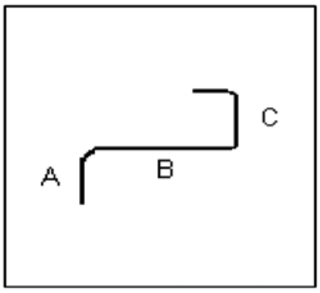
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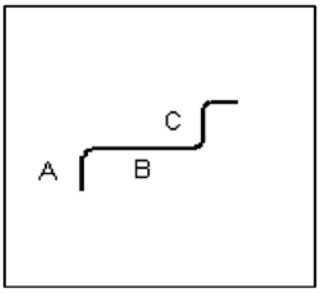
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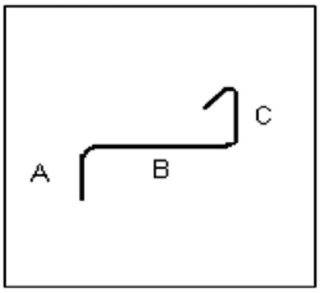
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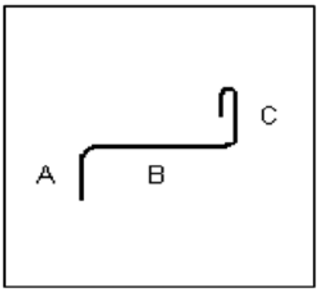
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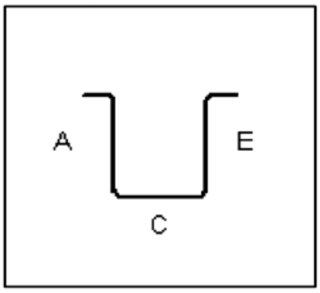
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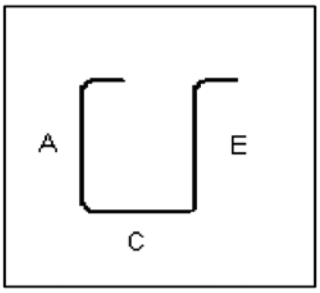
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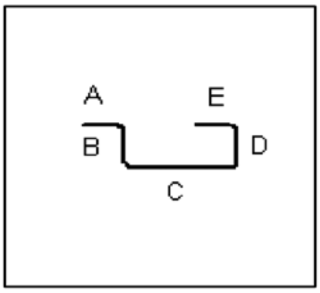
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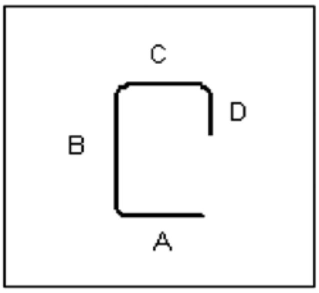
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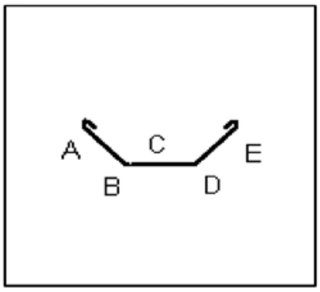
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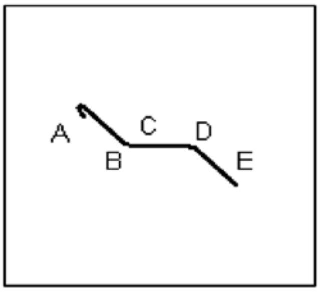
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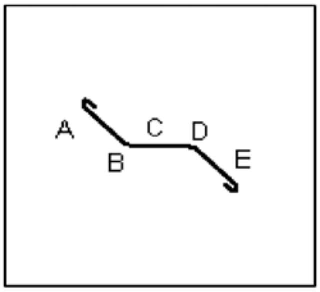
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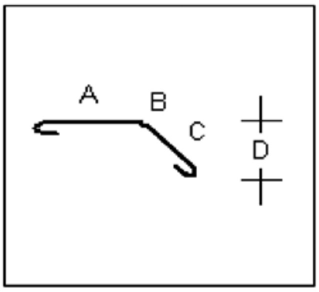
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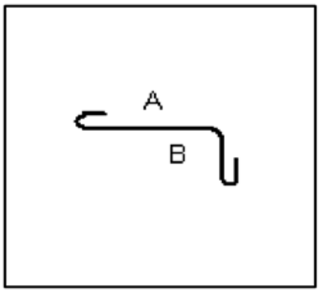
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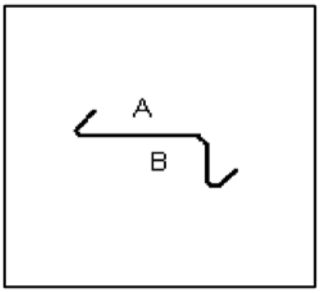
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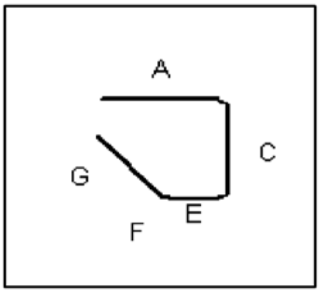
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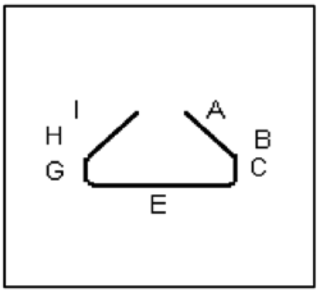
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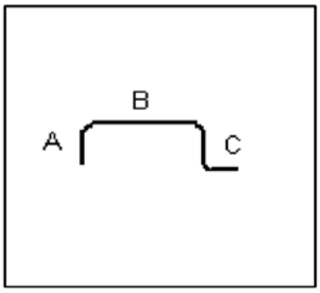
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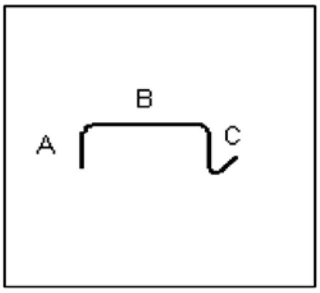
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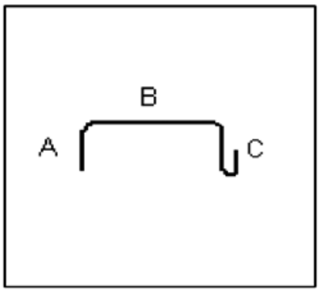
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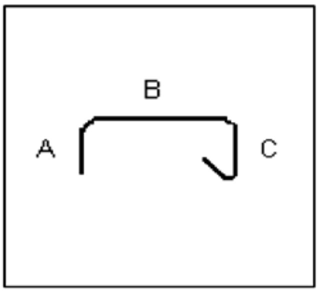
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The following tables summarise the design cross-sectional areas of fabric in imperial sizes manufactured by, or available from, the company since the early 1920s up to the introduction of metric measurement in 1973.

The sources of the information are books published by the British Reinforced Engineering CO. Limited of Stafford, England (BRC) up to 1950, and ARC Engineering CO. Pty. Ltd. (ARC) thereafter to 1973. Fabrics manufactured by other Australian companies cannot be identified with certainty and are therefore not included.

Whilst the information given here is believed to be accurate, it is one thing to identify the notation given on a drawing but it is an entirely different matter to be sure that the specified material was actually used.

The design drawings are the only guide to the quality of steel and concrete intended to be used. It is always possible to test steel for yield stress, tensile strength, elongation, cross-sectional area (allowing for corrosion), etc. by removing a sample from the structure. If the original diameter is difficult to determine because of corrosion, it may be better not to proceed further.

Table 30 summarises the design yield stress of reinforcing steels. This should be adequate for most purposes using present day analyses by limit state methods. Any attempt to compare the original working stress designs with AS3600 would require more information, probably not available, for little benefit in accuracy. In any case, to determine the current structural adequacy requires application of current loading conditions.

The effective strength of steel does not decrease with time, however the contribution of the surrounding concrete can be quite different from the original design specifications.

Surface Appearance of Steel	Year of Construction		Probable Yield stress, f_{sy}	
			MPa	Pounds per square inch
Fabric [1]	Before	1914 to 1995	450	65 000
Deformed Fabric		1995 to now	500	-
Plain round, or any unidentifiable	Before	1914 to 1990		
deformed bars or other steels			230	33 600
Twisted square bars [2]		1957 to 1963	410	60 000
Intermediate Grade deformed [3]		1960 to 1968	275	40 000
Hard Grade deformed, Grade 50 [4]		1960 to 1968	345	50 000
Twisted deformed and CW.60 [2]		1962 to 1983	410	60 000
Hot rolled deformed, Grade 410Y		1983 to 1988	410	-
Hot rolled deformed, Grade 400Y [5]		1988 to 2000	400	-
Hot rolled deformed, Grade 500N		2000 to now	500	-

Table 30: Design yield stress of reinforcing steel

Notes:

1. Prior to 1960, the specified minimum yield stress of fabric was given as 70 000 pounds per square inch. For refurbishment purposes, the tabulated value of 450 MPa is recommended.
2. Twisted bars can be identified by surface appearance. Remove untwisted ends (about 150 – 200 mm) before splicing by end-butt welding or mechanical methods.
3. Intermediate Grade was rare and probably used only for projects designed in USA or designed to ASTM standards for construction in Australia. Weldability is very doubtful and should not be considered.
4. Hard Grade was common in NSW, but unusual elsewhere. It is not weldable.
5. From 1988, AS3600 specified only a design yield stress of 400 MPa for deformed bars. This strength was not manufactured until 1991 when AS1302 was amended.

As can be seen from Table 31, the cross wires for early rectangular mesh fabrics were very thin and the spacing was much greater than AS/NZS 4671 types. Their purpose was simply to hold the sheets together. Unless transverse cracking is excessive, this will probably be of little consequence, but the fact should be noted.

Of greater concern may be the quality of the concrete. Again, if there is little evidence of excessive deflection, spalling or rust, then the integrity of the structure is probably not in doubt for the loads it has carried in the past.

It is not well known that, until publication of AS3600, the fire resistance requirements of prior Standards was determined from information available before 1949. This was before the introduction of cold worked bars in Australia yet the rules were assumed to be satisfactory without amendment. It is suggested that the provisions of AS3600-2001 be considered rather than using standards in vogue at the time of construction.

Wire spacing inches					**2 in.**	**3 in.**	**4 in.**	**6 in.**	**8 in.**	**12 in.**
Wire spacing, millimetres					**50.8**	**76.2**	**101.6**	**152.4**	**203.2**	**304.8**
Size	**Wire diameter**		**Cross sectional area**		**Steel crossing areas for wire spacing:-**					
ISWG	**(inches)**	**(mm)**	**Sq in.**	**Sq mm**	**mm²/m**	**mm²/m**	**mm²/m**	**Mm²/m**	**mm²/m**	**mm²/m**
7/0	0.500	12.70	0.1963	126.7	2494	1662	1247	831	623	416
6/0	0.464	11.79	0.1691	109.1	2147	1432	1074	716	537	358
5/0	0.432	10.97	0.1466	94.6	1861	1241	931	620	465	310
4/0	0.400	10.16	0.1257	81.1	1596	1064	798	532	399	266
3/0	0.372	9.45	0.1087	70.1	1380	920	690	460	345	230
2/0	0.348	8.84	0.0951	61.4	1208	805	604	403	302	201
1/0	0.324	8.23	0.0824	53.2	1047	698	524	349	262	175
1	0.300	7.62	0.0707	45.6	898	598	449	299	224	150
2	0.276	7.01	0.0598	38.6	760	507	380	253	190	127
3	0.252	6.40	0.0499	32.2	633	422	317	211	158	106
4	0.232	5.89	0.0423	27.3	537	358	268	179	134	89
5	0.212	5.38	0.0353	22.8	448	299	224	149	112	75
6	0.192	4.88	0.0290	18.7	368	245	184	123	92	61
7	0.176	4.47	0.0243	15.7	309	206	154	103	77	51
8	0.160	4.06	0.0201	13.0	255	170	128	85	64	43
9	0.144	3.66	0.0163	10.5	207	138	103	69	52	34
10	0.128	3.25	0.0129	8.3	163	109	82	54	41	27
12	0.104	2.64	0.0085	5.5	108	72	54	36	27	18
14	0.080	2.03	0.0050	32.	64	43	32	21	16	11

Table 31: Imperial standard wire gauges expressed as metric cross-sectional areas

Identification of 400Y and D500N Bar

410 mPa and 400 mPa deformed bars from 1983 to 2000 were identified by two longitudinal ribs and transverse deformations. For D500N Bar, two longitudinal half ribs were added to one side and one half rib to the other to provide a visual identification of the steel grade.

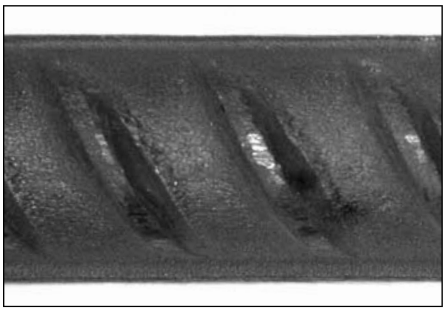


Figure 46: 400Y bar obverse and reverse

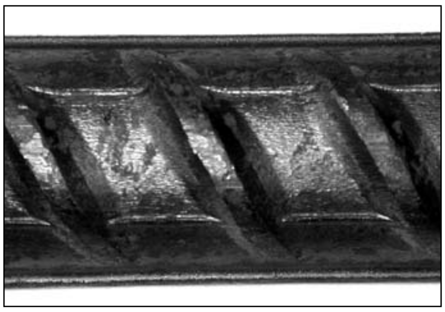


Figure 47: D500N bar reverse

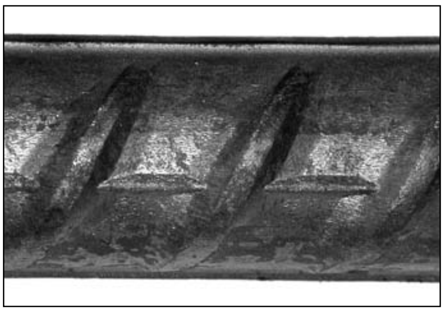


Figure 48: D500N bar obverse

Appendix C

BRC (1925)	BRC (1939)	BS1221A (c. 1949)	BRC (c. 1949)	ARC (1949-63)	AS A 84 (1966-73)	AS A 84 (1966-73)	Main Wires Size ISWG	Main Wires Spacing Inches	Fabric Area Main Wires mm^2/m
-	-	-	-	-	-	300	5/0	@3 in.	1241
1	1	101	1	1	301	301	4/0	@ 3 in.	1064
2	2	102	2	2	302	302	3/0	@ 3 in.	920
3	3	103	3	3	303	303	2/0	@ 3 in.	805
4	4	104	4	4	304	304	1/0	@ 3 in.	698
5	5	105	5	5	305	305	1	@ 3 in.	598
6	6	106	6	6	306	306	2	@ 3 in.	507
7	7	107	7	7	307	307	3	@ 3 in.	422
8	8	108	8	8	308	-	4	@ 3 in.	358
9	9	109	9	9	309	-	5	@ 3 in.	299
10	10	110	10	10	310	-	6	@ 3 in.	245
-	-	-	-	-	-	308	1/0	@ 6 in.	349
-	-	-	-	-	-	309	1	@ 6 in.	299
-	-	-	-	-	-	310	2	@ 6 in.	253
11	11	111	11	-	-	-	7	@ 3 in.	206
12	12	112	12	12	312	312	8	@ 3 in.	170
14	14	113	14	14	314	314	10	@ 3 in.	109

Table 32: Rectangular – Mesh Fabrics. Only main wire details can be identified with any degree of certainty

BRC (1925)	BRC (1939)	BS1221A (c. 1949)	BRC (c. 1949)	ARC (1949-63)	AS A 84 (1966-73)	AS A 84 (1966-73)	Main Wires Size ISWG	Main Wires Spacing Inches	Fabric Area Main Wires mm^2/m
-	-	-	-	-	-	640	4/0	@ 6 in.	532
-	-	-	-	-	-	630	3/0	@ 6 in.	460
-	-	-	-	-	-	620	2/0	@ 6 in.	403
-	-	-	-	-	-	600	1/0	@ 6 in.	349
-	611	121	61	611	601	601	1	@ 6 in.	299
-	622	122	62	622	602	602	2	@ 6 in.	253
-	-	123	63	633	603	603	3	@ 6 in.	211
-	-	124	64	644	604	604	4	@ 6 in.	179
655	655	125	65	655	605	605	5	@ 6 in.	149
-	-	126	66	666	606	606	6	@ 6 in.	123
-	688	-	-	688	608	608	8	@ 6 in.	85
610	610	130	610	610	610	610	10	@ 6 in.	54

Table 33: Square – Mesh Fabrics. Main wire and cross wire sizes, spacing and areas are the same

BRC (1925-49) ISWG at		ARC & BRC (1949-58) ISWG at		AS A84 (1958-63) ISWG at		AS A84 (1963-73) ISWG at		Fabric Area Cross Wires
Ref No.	Inches	Ref No.	Inches	Ref No.	Inches	Ref No.	Inches	mm^2/m
-		-		-		300	1 g @ 8 “	224
1	4 g @ 16”	1	2 g @ 9”	301	2 g @ 8”	301	1 g @ 8”	224
2	4 g @ 16”	2	2 g @ 9”	302	2 g @ 8”	302	1 g @ 8 “	224
3	6 g @ 16”	3	2 g @ 9”	303	3 g @ 8”	303	1 g @ 8 “	224
4	6 g @ 16”	4	2 g @ 9”	304	3 g @ 8”	304	1 g @ 8 “	224
5	6 g @ 16”	5	2 g @ 9”	305	3 g @ 8”	305	1 g @ 10 “	180
6	6 g @ 16”	6	2 g @ 12”	306	2 g @ 12”	306	1 g @ 10 “	180
7	6 g @ 16”	7	3 g @ 12”	307	3 g @ 12”	307	1 g @ 10 “	180
8	8 g @ 12”	8	4 g @ 12”	308	4 g @ 12”	308*	1 g @ 12 “	150
9	8 g @ 12”	9	5 g @ 12”	309	5 g @ 12”	309*	1 g @ 12 “	150
10	8 g @ 12”	10	6 g @ 12”	310	6 g @ 12”	310*	1 g @ 12 “	150

Table 34: Cross wire size and spacings only

Deformed bar size and (area) Area in Sq mm

From 2001	1973 to 2000	Pre-1973
This area applies to a hot rolled deformed bar of grade D500N	The area applies to a hot rolled deformed bar of Grade 400Y, to a plain bar of Grade 250R, and to a cold worked Grade 410C bar, from 1973 to 1983	The area applies to a pre-metric bar with a yield strength of 60ksi (ARC CW.60 and cold twisted deformed bar) or 33.6ksi (structural grade plain and deformed bar) but not to Square Twist. Sizes are in 1/8" :- e.g. #11 = 1-3/8" Ø
D450N50 (1960)	Y50 (1960)	
N40 (1260)	Y40 (1260)	
N36 (1020)	Y36 (1020)	
		#11 (961)
N32 (800)	Y32 (800)	
		#10 (794)
		#9 (639)
N28 (620)	Y28 (620)	
		#8 (510)
N24 (450)	Y24 (450)	
		#7 (387)
N20 (310)	Y20 (310)	
		#6 (284)
N16 (200)	Y16 (200)	#5 (200)
		#4 (129)
N12 (110)	Y12 (110)	
	R10 (80)	
		#3 (71)
		#2 (32)
	R6 (30)	

Wire size and (area) Area in Sq mm

AS/NZS 4671	1995 to 2001 AS130	1973 to 1995 AS1303
These bars are cold rolled deformed bars of Ductility Grade D500L	These bars are cold rolled deformed 500MPa bars	These bars are cold rolled deformed 450 MPa bars
		12.5 (122.7)
11.90 (111.2)	11.90 (111.2)	
		11.2 (98.5)
10.65 (89.1)	10.65 (89.1)	
		10.0 (78.5)
9.50 (70.9)	9.50 (70.9)	
		9.0 (63.6)
8.55 (57.4)	8.55 (57.4)	
		8.0 (50.3)
7.60 (45.4)	7.60 (45.4)	
		7.1 (39.6)
6.75 (35.8)	6.75 (35.8)	
		6.3 (31.2)
6.0 (28.3)	6.0 (28.3)	
		5.0 (19.6)
4.75 (17.7)	4.75 (17.7)	
4.0 (12.6)	4.0 (12.6)	4.0 (12.6)
		3.15 (7.8)

Cross reference table for metric and imperial reinforcing bars

Square meshes Area in Sq mm

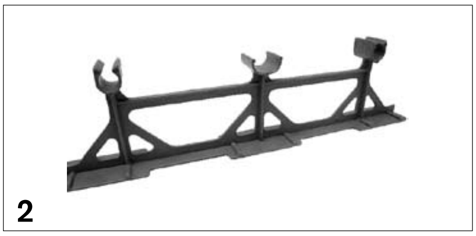
From 2001	1995 to 2000	1973 to 1995	pre - 1973
AS/NZS 4671 200x200	AS1304 200X200	AS1304 200X200	150X150
Deformed 500 MPa Ductility Grade D500L mesh	Deformed 500 MPa mesh	Round 450 MPa mesh	Round 450 MPa mesh
SL81 (454)	RF81 (454)	F81 (503)	F640 (532)
SL102 (354)	RF102 (354)	F102 (393)	F630 (460)
SL92 (287)	RF92 (287)	F92 (318)	F620 (403)
SL82 (227)	RF82 (227)	F82 (251)	F600 (349)
SL72 (179)	RF72 (179)	F72 (198)	F601 (299)
SL62 (141)	RF62 (141)	F62 (156)	F602 (253)
SL41 (126)	RF41 (126)	ARC63 (104)	F603 (211)
SL63 (94)	RF63 (94)	ARC53 (63)	F604 (179)
SL52 (89)	RF52 (89)		F605 (149)
SL42 (63)	RF42 (63)		F606 (123)
SL53 (59)	RF53 (59)		F608 (85)
			F610 (54)

Rectangular meshes Main wire area in Sq mm

From 2001	1995 to 2000	1973 to 1995	pre - 1973
AS/NZS 4671 100x200	AS1304 100X200	AS1304 100X200	150X300
Deformed 500 MPa Ductility Grade D500L mesh 227 sq mm cross wire area	Deformed 500 MPa mesh 227 sq mm cross wire area	Round 450 MPa mesh 251 sq mm cross wire area	Round 450 MPa mesh Cross wire area is variable. Generally cross wire area is below 227 sq mm area
RL1218 (1112)	RF1218 (1112)	F1218 (1227)	F300 (1241)
RL1118 (891)	RF1118 (891)	F1118 (985)	F301 (1064)
RL1018 (709)	RF1018 (709)	F1018 (785)	F302 (920)
RL918 (574)	RF918 (574)	F918 (636)	F303 (805)
RL818 (454)	RF818 (454)	F818 (503)	F304 (698)
RL718 (358)	RF718 (358)	F718 (396)	F305 (599)
			F306 (507)
			F307 (422)
			F308 (349)
			F309 (299)
			F310 (253)

Cross reference table for metric and imperial reinforcing fabric


1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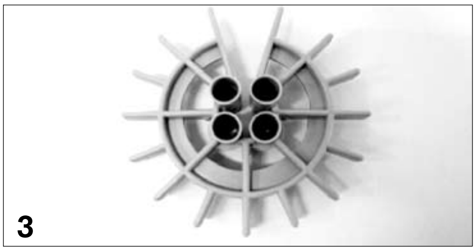
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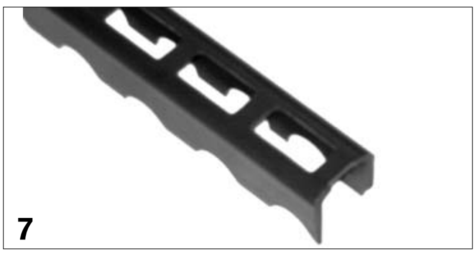
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Chairs and spacers are used to position steel reinforcement so that the durability, strength and serviceability of the structure is in accordance with the design specification.

AS3600-2001 considers bar chairs and spacers as embedded items. They are covered by Clause 14.2. AS3600-2001 does not give any design guidelines for the type, spacing or arrangement of reinforcement supports.

Durability is the most common form of failure for bar chairs. This is particularly prevalent on the exposed underside of balconies. Wire bar chairs can cause rust spotting of the concrete surface if care is not taken during construction. The choice of bar chair also impacts on the durability of the concrete structure as it affects the cover to the reinforcement.

For strength requirements, the bar chairs and spacers must hold the reinforcement in position until the concrete has achieved initial set. The loads that the chairs can incur include people walking over the reinforcement, stacked materials, mounded wet concrete and vibration during the concrete placement. The bar chairs must also hold these loads when subjected to heat. The forms can get as hot as 80°C in northern Australia.

As bar chairs and spacers are placed against the form, they are usually visible upon close inspection of the concrete surface. Some bar chairs are more visible than others as they have a larger base area. Plastic bar chairs come in several colours, depending on the manufacturer and the available plastic. Typical colours are black or grey, however white, purple, green and many other colours are made.

Types of Bar Chairs

1. Slab on Ground Plastic Bar Chairs - Dual size plastic reinforcing spacers with a flat base to minimise penetration through the moisture barrier. These bar chairs are purpose built for supporting reinforcement in slabs that are cast against the ground or for slabs cast on plastic sheeting. They are available for 25, 40, 50, 65, 75, 85, 90 and 100 mm. 105, 110, 125, 130, 140 and 150 mm cover chairs are available on special order.
2. Trench Mesh Supports - Plastic bar chairs for supporting trench mesh in strip footings. These chairs provide 50 mm of cover. The trench mesh supports clip onto the trench mesh before lowering into the trench.
3. Fast Wheels - Plastic spacers for precast concrete and column applications. These spacers are ideal for column cages where the cage is assembled then lowered into position. Fastwheels are available in 15, 20, 25, 30, 40, 50 and 75 mm covers.
4. Clipfast Plastic Bar Chairs - Plastic bar chairs that clip onto the reinforcement. They are available for bar and mesh reinforcement. Plastic bases are available for slab on ground applications. As these chairs clip onto the reinforcement, they can be used in vertical and top cover applications. They suit 15, 20, 25, 30, 35, 40, 45, 50, 60, 65 and 75 mm covers.
5. Plastic Tipped Wire Bar Chairs - These bar chairs are for suspended slab and beam reinforcement being cast on timber or metal forms. The chair is made of wire and each leg is plastic tipped. These are the most common bar chair used for suspended slabs. They suit a large range of covers and slab thicknesses. Plastic tipped wire bar chairs are available in 20, 25, 30, 35, 40, 45, 50, 60, 65, 70, 75, 80, 85, 90, 100, 110, 120, 125, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 280, 300, 320, 340 and 360 mm covers from the underside of the bar to the bottom form. Metal bases are available for the plastic tipped wire bar chairs when used for slab on ground applications.

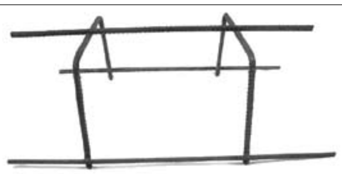
8a

8b

9

10

11



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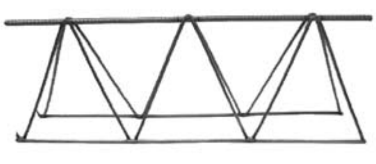

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6. Goanna Continuous Wire Bar Chairs - A continuous, 2 m long wire bar chair for use in suspended slabs. Each leg has a plastic tip for corrosion protection. They are available for 20, 25, 30, 40, 50, 65 and 75 mm covers.

7. Plastic Continuous Bar Chairs - A continuous, 2 m long plastic bar chair for use in suspended slabs. They are available in 20, 30, 40 and 50 mm covers.

8. Plastic Deck Spacers - Plastic deck spacers are for suspended slabs and beams cast on timber or metal forms. They are available for 20, 25, 30, 35, 40, 45, 50, 65, 75, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190 and 200 mm covers from the underside of the bar to the bottom form. Spacers 50 mm and less are as shown in 8a. Spacers 65 mm and taller are as shown in 8b.

9. Plastic Deck Chairs - Plastic deck chairs are ideal for suspended slabs. The design of the chair accommodates both the bottom reinforcement and the top reinforcement from the one chair. The base provides covers of 25, 30 and 40 mm cover to the bottom reinforcement. The top clip is available to suit covers from 90 to 220 mm in 10 mm increments from the underside of the bar to the bottom form.

10. Concrete Spacers - Concrete spacers are available for 25, 30, 35, 40, 45, 50, 55, 60, 65, 75 and 100 mm cover.

11. Heavy Duty Clip-On Chairs - These chairs are made of plastic and are suitable for most formed applications. The chair can clip to N12 and N16 reinforcement. They are available for 30, 35, 40, 45 and 50 mm cover when clipped to a N16 bar. The covers when clipped to N12 bars are 34, 39, 44, 49 and 54 mm.

12. Folded Mesh Spacers - Folded mesh in 2.4 metre lengths provides a fast and accurate method for spacing layers of reinforcement. Folded mesh spacers are suitable for separations between layers from 70 mm to 400 mm. Mesh is folded to order, hence the height is made to suit the project.

13. Truss Spacers - Truss spacers are used in suspended slabs and are made in lengths from 3 to 6 m. They are available in 80, 110, 150 and 190 mm heights.

Notes

Notes

FOR FURTHER INFORMATION CONTACT:

Your local ARC Service Centre on **131 557**

Main offices at :

Pinkenba QLD
Sunshine VIC
Darwin NT
Dry Creek SA
St Marys NSW
Forrestfield WA
Launceston TAS

arcreo.com.au