Steel Reinforcement Institute of Australia

CONCRETE 2019
Concrete in Practice – Progress through Knowledge
8–11 September 2019
Sydney Australia

Guide to Historical Reinforcement In Australia

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BE (Civil), MIE Aust.

The Importance of Historical Reinforcement Information

- History shows the average life of a reinforced concrete structure or building will typically exceed the design life by a considerable period
- Australia's first reinforced concrete (RC) structure still in service today – 124 years later

Johnstons Creek Sewer Aqueduct
Annandale, Sydney (1896)

2018

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The Importance of Historical Reinforcement Information

- The need to maintain heritage buildings and re-purpose existing building stock (and infrastructure) will increase in future generations
- Replacing existing RC building stock prematurely is not sustainable
- We are now in a period of generational change over and digital transition and at great risk of losing the past <u>printed form</u> of key technical design knowledge

State Library of Victoria (ca. 1913) Largest dome in the world when completed

Slender existing building stock, George St Sydney

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Development of Reinforcement

Australia has seen times of significant change in material properties over the years

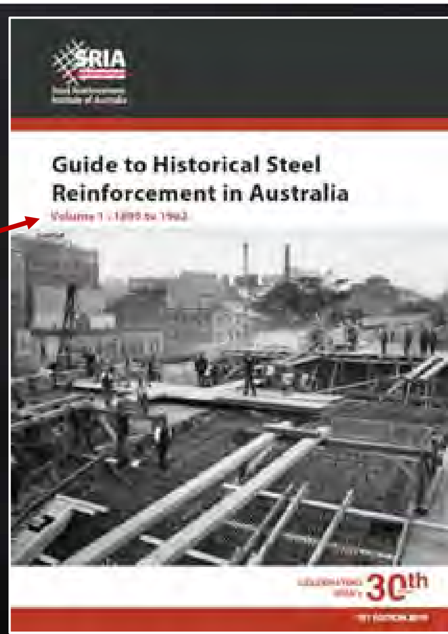
Bar Type	Introduction (year)	Yield Stress (MPa)
Plain round	1895	200
Square twisted	1957	410
Intermediate grade deformed	1960	275
Hard grade deformed	1960	345
Twisted deformed (CW.60)	1963	410
Hot-rolled deformed (410Y)	1983	410
Hot-rolled deformed (400Y)	1988	400
Hot-rolled deformed (500N)	2000	500
Mesh Type		
Plain mesh	1914	450
Deformed mesh	1995	500

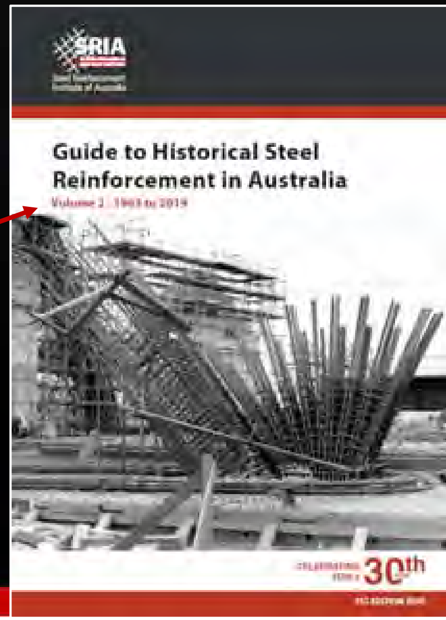
Most common question at SRIA concerns past properties and interpretation of imperial sized reinforcing bars & fabric.

New Guide follows Key Developments

Preserving the past engineering printed knowledge for future designers

- **1855 to 1895** - Patented systems
  The Early years - development of reinforced concrete
- **1895 to 1920** – Limited texts
  Reinforced concrete adopted in Australia
  B.H.P. produces merchant bar, 1915
- **1920 to 1957** – Proprietary 'printed' information begins
  A.R.C. manufactures fabric (mesh) in Australia
- **1957 to 1963** (Research begins)
  Square twisted bar introduced
- **1963 to 1983** (Electronics discovered)
  CW.60 bar introduced, 1970s metrification
- **1983 to 2001** – Digital transition
  QST steel and micro alloy manufactured
- **2001 to 2018** – Computer revolution
  D500N bar introduced





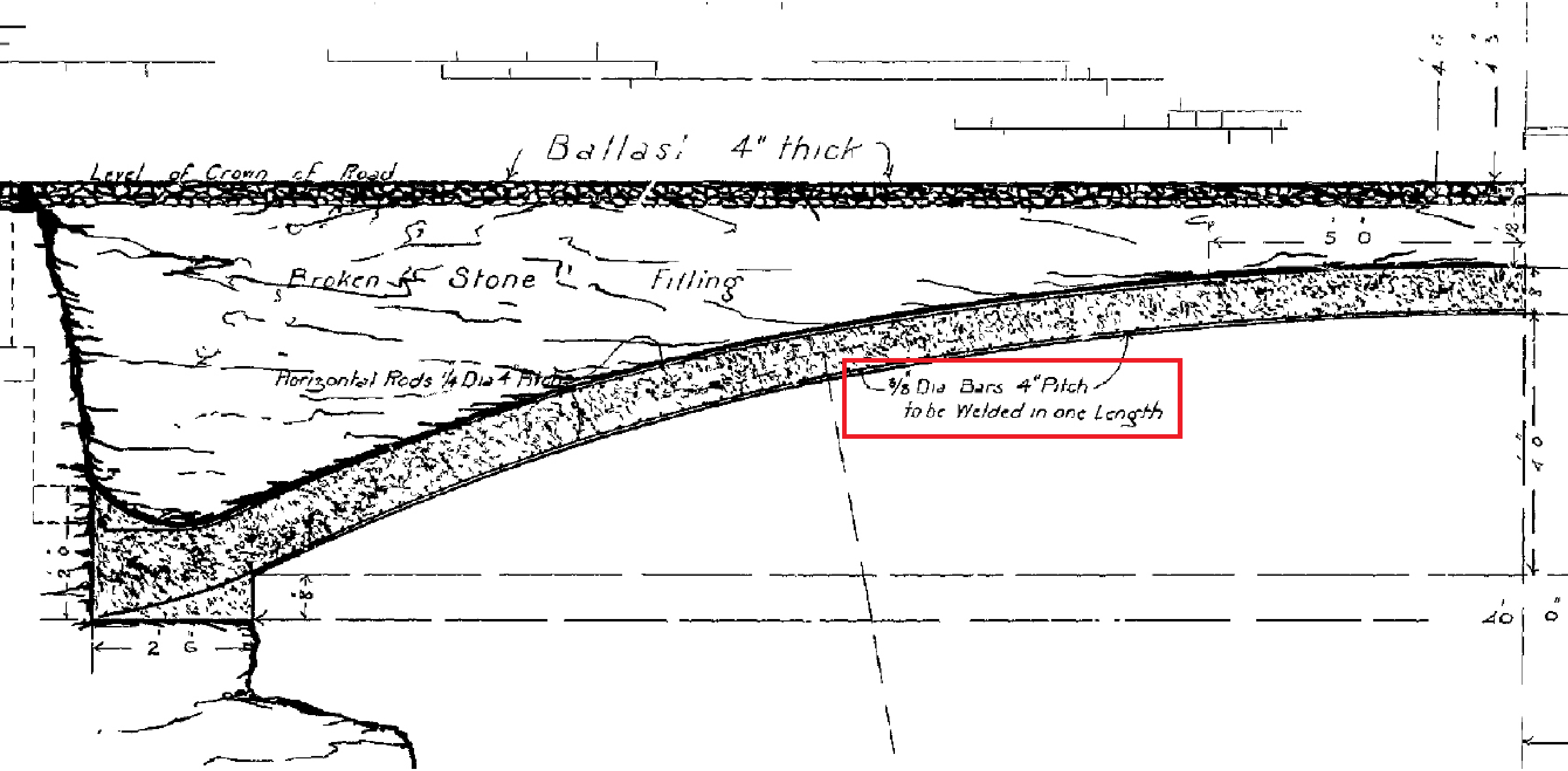
The Early Years

In 1867, Joseph Monier took out patents in many European and overseas countries

- Monier knew little about reinforced concrete
- Gustav Wayss acquires patents in Germany and Austria
- He further develops the Monier System
- Pioneers scientific calculations in reinforced concrete
- Frank Gummow takes out patent in Australia on behalf of Wayss
- Carter, Gummow & Co. builds first reinforced concrete structure
- Gummow's design Engineer is William Baltzer

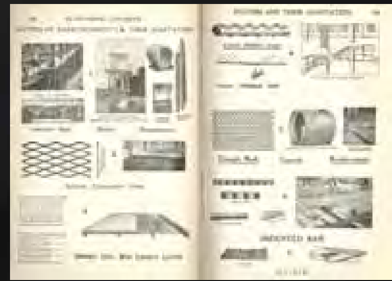
Johnstons Creek Aqueduct,
Sydney, 1895

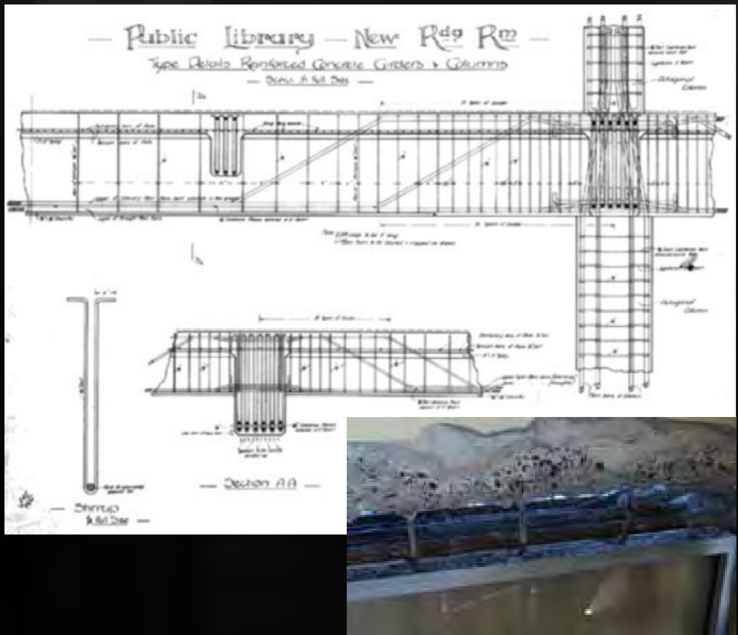
Reinforcement 1895 to 1920



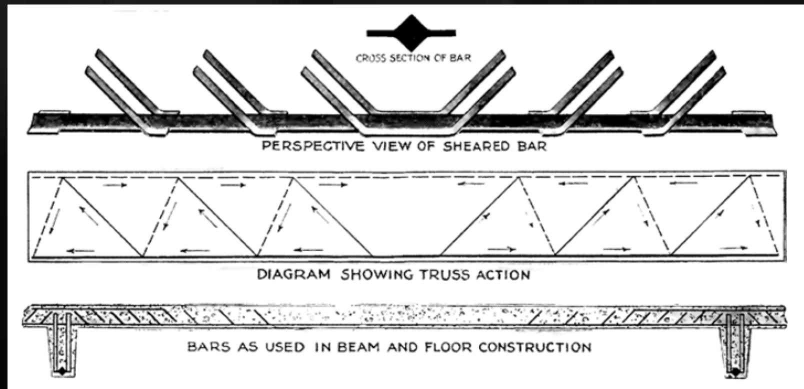
Reinforcement 1895 to 1920

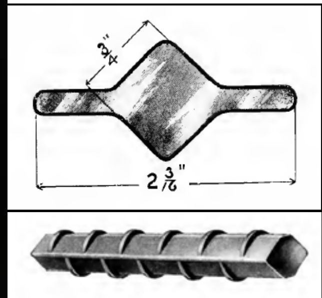
- Much of the reinforcement in the early years, and in particular from 1911, was imported into Australia from the British Reinforced Concrete Engineering Company Limited (B.R.C.)
- Early reinforcement systems (generally Grade 200) were all patented by the inventors
- Common systems used in Australia included the Monier, Kahn and Hennebique Systems





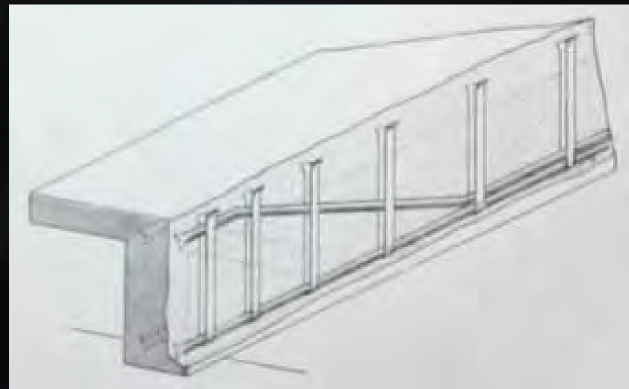
Monier System - Round Bars bent up ends for anchorage





Kahn Ribbed Bar (circa 1907)

Kahn System
- Bar sheared and bent up flanges for anchorage & early rib bars



Hennebique System
- Fishtail ends for anchorage

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Reinforcement 1895 to 1920

Overseas Systems adopted in Australia included:

- Monier System – predominant Australian system
- Kahn System - USA
- Hennebique System
- Coignet System
- Ransome System - USA
- Thacher Bars
- Johnson (or corrugated) Bars

  Indented Steel Bar Reinforcement Co. of London
- Habrich System (or Thomas and Steinhoff System)
- Hollow Tile or Innis-Bell system
- Expanded Steel System. Triangle Mesh Concrete Reinforcement

Early systems (generally 30,000 psi/207 MPa yield stress) patented by the inventors

Challenge was how to anchor bars in concrete to more fully utilise the tensile capacity of the bars

Reinforcement 1895 to 1920

Most design was undertaken by agents for the systems in Australia.
They had access to the proprietary testing information to ensure quality/system performance.

Failure of two Kahn reinforced beams
Load: Pig iron 101100 lbs.
Weight of floor slab 9300 lbs.
Total weight on beams 110400 lbs.
Beam failed in center pulling four bars of steel in two.

35 Tons Load testing of completed reinforced concrete floor of the Sniders and Abrahams warehouse, Melbourne, 1909
Deflection 3/16 in.

82 Tons Plate Test for Melbourne Harbour Trust

13.5 Tons (23.5kPa) Test loading of the Innes-Bell flooring system on the Smith and Waddington's Limited Factory, Camperdown, NSW, circa 1927.
Deflection of 1/16 in. (1.6 mm)

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Reinforcement 1895 to 1920

Arches were gradually replaced by beam and pier construction

Hindmarsh Railway Bridge, Victor Harbor, South Australia, 1907

McIsaac's Bridge, Mitchell Shire, Victoria, 1907

Geelong Sewage Aqueduct, 1914

Test of Darraweit Guim Bridge, Macedon Ranges, Victoria, 1914

All Images Uni of Melbourne Archives

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Reinforcement 1895 to 1920

The first Building Floors were unreinforced arches

Essentially for fire proofing

Image Miles Lewis

Traegerwellblech or bearing corrugated iron plate system (photograph Miles Lewis)

Verandah of the Sydney Hospital, Macquarie Street, circa 1881

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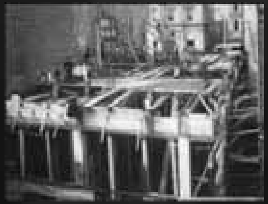
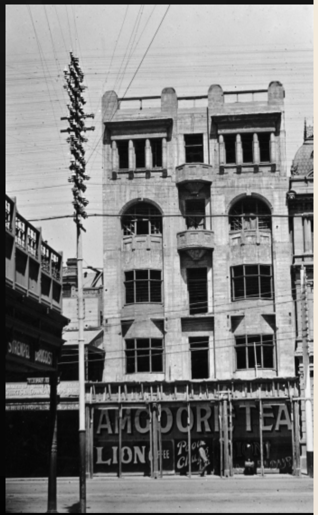
Reinforcement 1895 to 1920

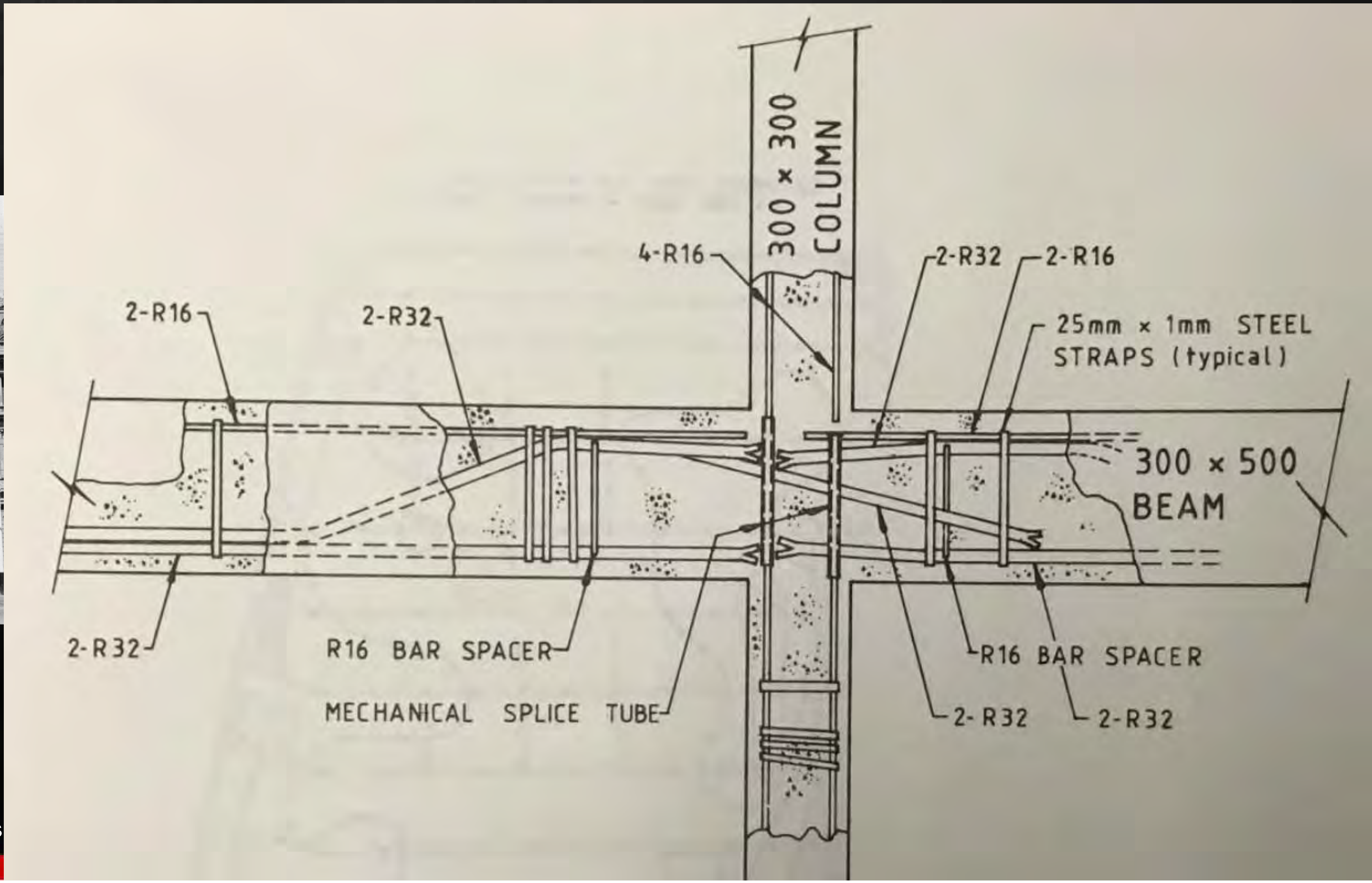
Use in Buildings in Australia – commenced from 1905 in Melbourne



Kither's Building, Adelaide, 1908



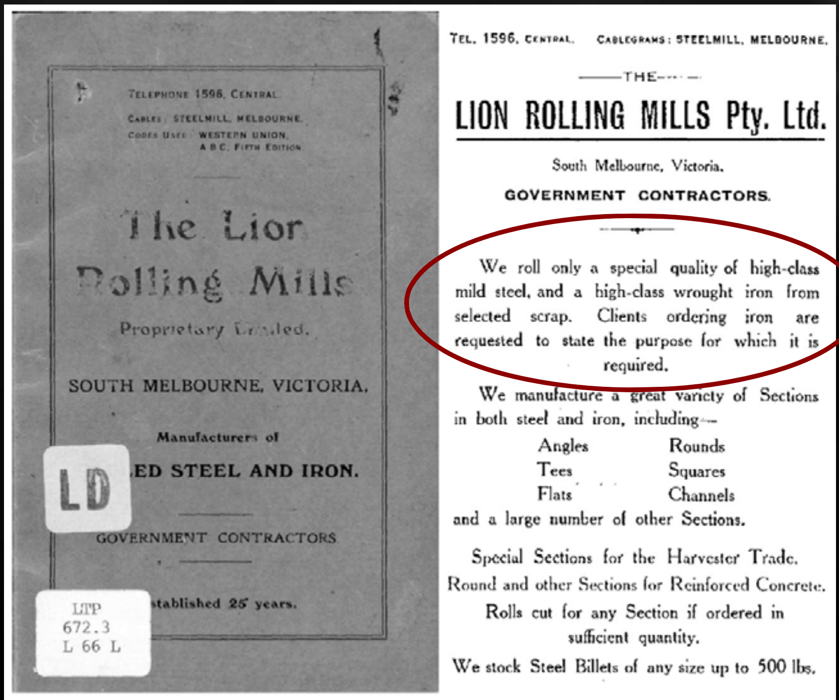
All Images Uni of Melbourne Archives



Development of Reinforced Concrete

Steel Reinforcement Materials

- From first use in 1895 most steel reinforcement would be mild steel.
- Some wrought iron may have been used as reinforcement up until approximately 1910.
- The Lion Rolling Mills – earliest Australian Rolling Mill 1900s (possibly commencing late 1800s).


TELEPHONE 1596, CENTRAL.
CABLES: STEELMILL, MELBOURNE.
CODES USED: WESTERN UNION. A B C, FIFTH EDITION.

The Lion Rolling Mills
Proprietary Limited.
SOUTH MELBOURNE, VICTORIA.
Manufacturers of
...ED STEEL AND IRON.
GOVERNMENT CONTRACTORS.
...tablished 25 years.

TEL. 1596, CENTRAL. CABLEGRAMS: STEELMILL, MELBOURNE.

—THE—

LION ROLLING MILLS Pty. Ltd.

South Melbourne, Victoria.

GOVERNMENT CONTRACTORS.

We roll only a special quality of high-class mild steel, and a high-class wrought iron from selected scrap. Clients ordering iron are requested to state the purpose for which it is required.

We manufacture a great variety of Sections in both steel and iron, including—

Angles	Rounds
Tees	Squares
Flats	Channels

and a large number of other Sections.

Special Sections for the Harvester Trade.
Round and other Sections for Reinforced Concrete.
Rolls cut for any Section if ordered in sufficient quantity.
We stock Steel Billets of any size up to 500 lbs.

The Lion Rolling Mills Catalogue, South Melbourne, circa 1904

Settlement — Convict Period — Gold Boom — Consolidation

	1820s	1830s	1840s	1850s	1860s	1870s	1880s	1890s	1900s	1910s	1920s
Cast iron											
Wrought iron	Rolled angles	Rolled tees		Rolled I beams				Eiffel Tower			
Mild Steel					First made		Forth Bridge				
Corrugated iron		Patent-ed	Galvan-ised								

Plain round circa, 1908 (Grade 200)

Development of Reinforced Concrete

Concrete Materials

- Generally hand mixed up until about 1910
- Typically 1:2:4 mix of cement, sand and aggregate (14 MPa)
- First readymixed concrete plant was in 1939, Sydney

Concrete mixer, c.1910

Construction of Wannon Bridge, Ararat, Victoria, 1917

Hand-mixing concrete in Clarence Street, Sydney, 1924

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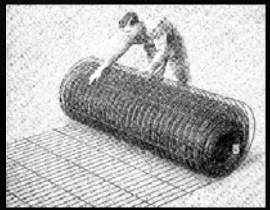
Reinforcement 1920 to 1957

- An Australian company known as the Australian Reinforced Concrete Engineering Company Proprietary Limited (A.R.C.) was established in 1919. In the early months of 1920, fabric (today know as mesh) was being manufactured at their plant in Sunshine, Melbourne.
- A.R.C. opened a manufacturing factory in NSW in 1928 when the first Port Kembla blast furnace was commissioned by Australian Iron and Steel Limited.
- Early prosperity was driven by supplying rolled mesh product for roads, railways, harbour works, water supplies and sewerage.
- Along with private sector demand, production reached a peak of 7,034 tons in 1929.

1920's Melbourne Tram track



ARC, 1920 & Light rolled out fabric

1920's North Sydney roadway

A.R.C. fabric Cabarita Road, Concord, Sydney, 1923

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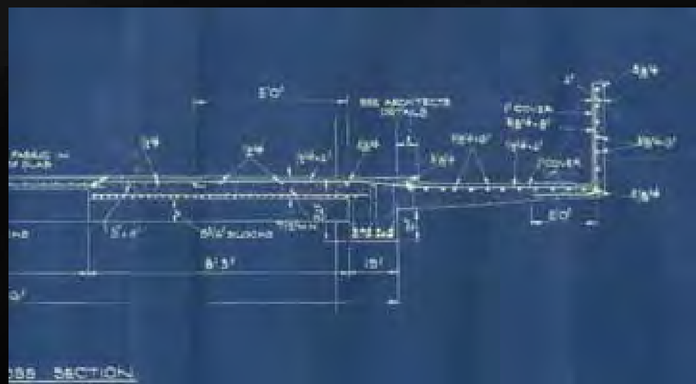
Reinforcement 1920 to 1957

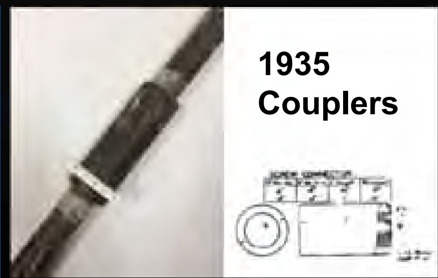
- The importation of bar product was extremely large in 1949 & 1950, principally from the UK in the form of hot-rolled round or square merchant bars.
- Imports meet demand after the Second World War
- In Australia…..
- The tensile breaking strength for plain bar was 28 to 33 Tons/sq inch (433 MPa to 509 MPa)
- Minimum yield strengths of 55,000 psi (380 MPa) for cold drawn wire and fabric products and from 1958 had a working stress of 30,000 psi and yield strength of 70,000 psi (450 MPa) .

Square bars and key stones
Nambucca Heads, NSW 1950s

Plain round fabric, 1929
(Grade 380)



Plain round bar blueprint



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Reinforcement 1920 to 1957

Example of round reinforcement (Monier System)
Construction of Sydney City subway system, 1920s

Railway bridge over Eddy Avenue on 24 March, 1925 (Australian Railway Historical Society image 517458)

Concrete placement' 2 April, 1925 (Australian Railway Historical Society image 517470)
Note: John Job Crew Bradfield CMG on left side of image inspecting the works.

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Reinforcement 1957 to 1963

A.R.C. introduce square twisted bars in 1957

- Cold-worked square-twisted bars had a yield strength of 60,000 psi (414 MPa) – usually taken as Grade 410.
- 1958 saw the introduction of the following Grades of plain and deformed bars:
  - Mild (30,000 psi/Grade 207)
  - Structural (33,500 psi/Grade 231)
  - Intermediate (40,000 psi/Grade 276); and
  - Hard (50,000 psi/Grade 345) - may be difficult to distinguish, so testing is recommended

Square twisted, 1957
(Grade 410)

Twin twisted bars

Hard Grade bars, 1970

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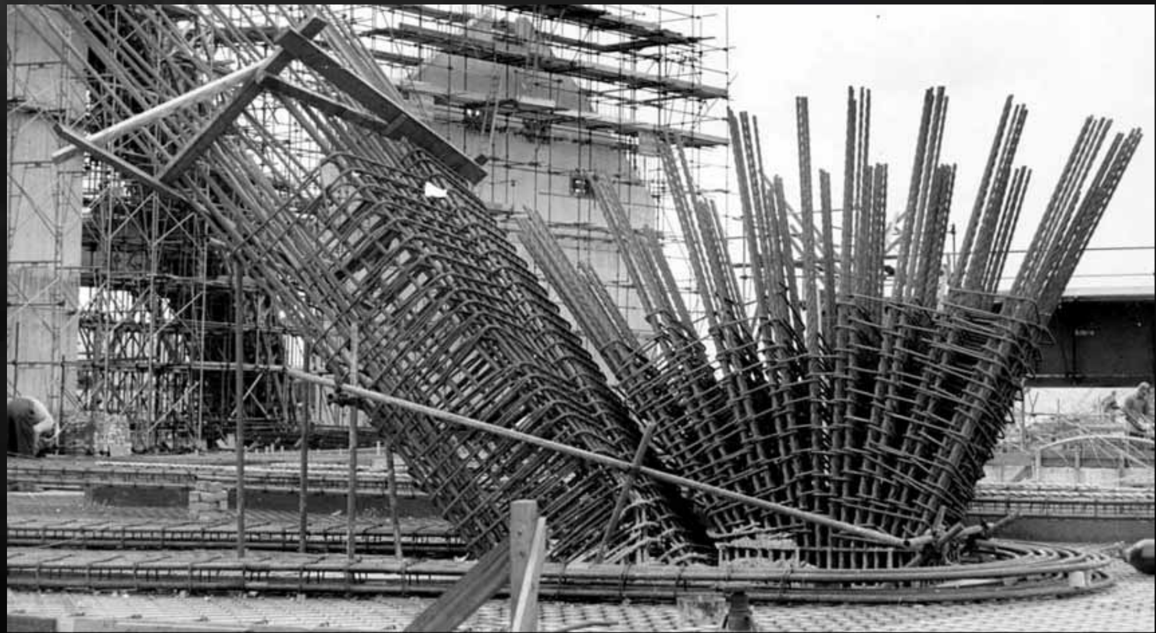
Reinforcement 1957 to 1963

Example of Square Twisted bar – Sydney Opera House, 1960s

Main Hall, January 1961
(image: NAA Series A1200, L37184)



September 21, 1963
(image: Daily Telegraph)

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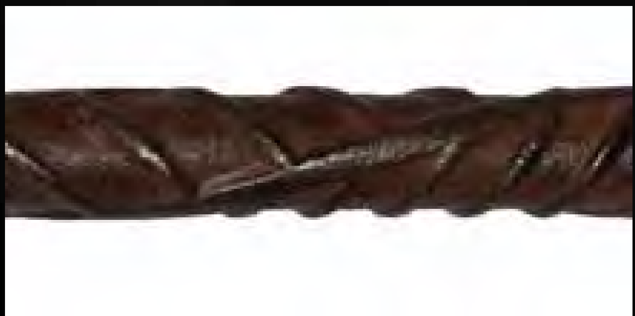
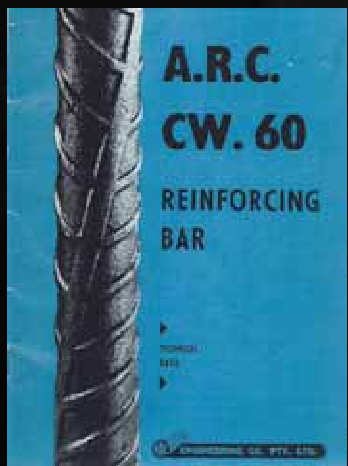
Reinforcement 1963 to 1983

- In 1963, BHP introduced a hot rolled structural Grade 230 MPa deformed bar (known as DB Bars), yield strength of 33,500 psi (228 MPa) to A.S. A92 (& A97 for deformations)
- A.S. A83 Cold working of this deformed bar by twisting (pitch of 12 bar diameters) resulted in a yield strength of approximately 62,000 psi (427 MPa)
- Referred to as CW.60 bars (cold worked bars having design yield strength of 60,000 psi (414 MPa) and post metrification (from 1973) as 410C or sometimes designated CW.410
- Welded fabric continued to be manufactured from cold drawn high yield strength round wire with a working stress of 30,000 psi and yield strength of 70,000 psi (450 MPa)


Twisted deformed CW.60, 1963 (Grade 410)



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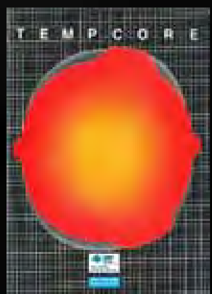
Reinforcement 1983 to Present

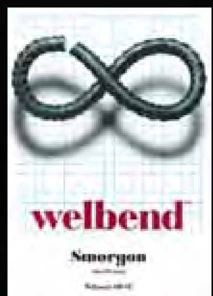
- The next major advancement occurred in 1983, with the introduction of quenched and self-tempered deformed bars (QST).
- BHP's QST product was known as 'Tempcore'.

- Smorgon steel entered the market in 1983 with an equivalent microalloy product, 'Wellbend™'.

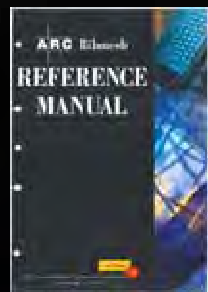
- The yield strength was 410 MPa – known as Grade 410Y bar.
- When AS 3600 was first published in 1988, the strength was downgraded to 400 MPa.
- In 1995 the yield strength of mesh product was increased from 450 MPa to 500 MPa with the introduction of a cold rolling process to produce ribbed bars from plain round wire . Later, ductility parameters were added in AS/NZS 4671-2001.
- In 2001 the yield strength of bars was also increased to 500 MPa.

Hot-rolled deformed (D500N) 2017





Cold-rolled deformed (D500L), 1995



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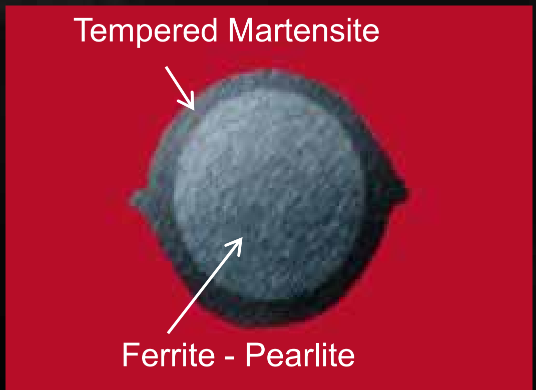
Reinforcement 1983 to Present

- Development of highly ductile microalloy reinforcement coincided with the 1983 ‘Tempcore’ introduction, when the carbon equivalence limits were lowered significantly for weldability
- Microalloy high strength is achieved from small quantities of Vanadium (V) and Niobium (Nb) grain refining elements



Quenched and self-tempered bar from 1983

Micro-alloy D500N bar, from 1983

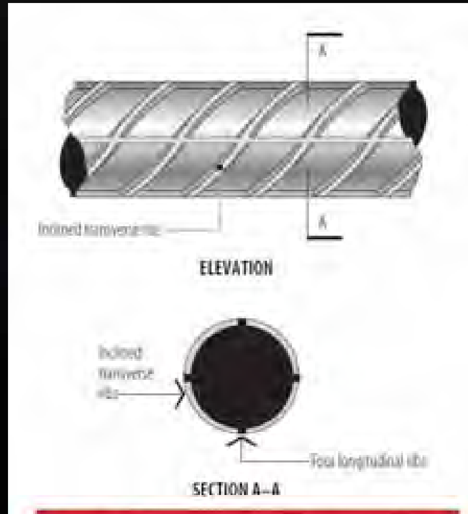
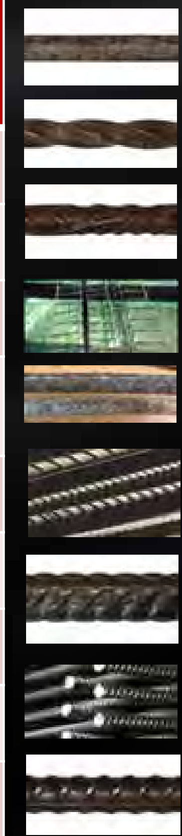


FIGURE 2 *General Identification of Micro-Alloy (Off-Coil) 500N Bars*

Summary: Improvements in reinforcement bar properties

Bar Type	Introduction (year)	Yield Stress (MPa)	Probable Yield Stress (psi)
Plain round	1895	200	30,000
Deformed	1920's	200	30,000
Square twisted	1957 to 1963	410	60,000
Intermediate grade deformed	1960 to 1968	275	40,000
Hard grade deformed	1960 to 1968	345	50,000
Twisted deformed (CW.60)	1962 to 1983	410	60,000
Hot-rolled deformed (410Y)	1983	410	-
Hot-rolled deformed (400Y)	1988	400	-
Hot-rolled deformed (500N)	2000	500	-



1908 Plain Round

1957 Square Twisted

1963 CW.60, later 410C or CW.410

1958-1995 'Fabric'
(from 'W' wire)

1970 Hard Grade

1983 QST/Microalloy
Tempcore/Welbend™

1983 (MA) D500N Coils

1995 'Mesh'
(from 'D500L' Bar)

D500N QST Bar

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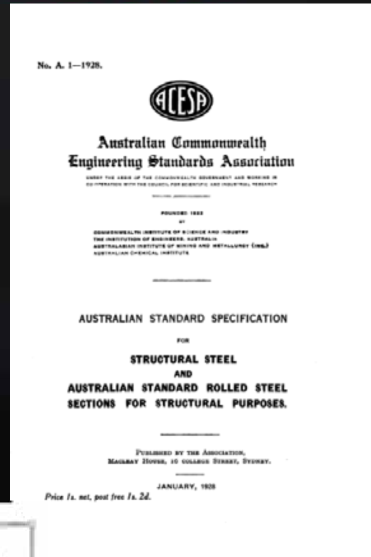
Use of Reinforcement Underpinned by Standards

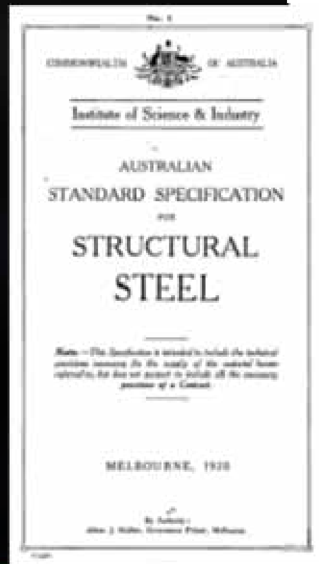
- **Primary Design Standards**
- 1934 CA 2 Code for Concrete in Buildings (revised in 1937, 1943, 1953, 1958, 1963 and 1973)
  - Allowed design based on permissible stresses
- 1963 revision allowed for ultimate strength design in Appendix A
- 1974 AS 1480 (amended 1975, 1976, 1978 and revised as 2^{nd} Edtn 1982)
- 1988 AS 3600 (revised in 1996, 2000, 2009 and 2018)
- **Secondary Material Standards**
- 1920 Australian Standard Specification for Structural Steel
- AS No. A.1 released 1928 (revised 1931 and 1940)
- 1958 A.S. No. A.81, A.82, A.83, A.84 and A.92 (with A.92 revised in 1965)
- 1965 A.S. No. A.97
- 1973 AS 1302, AS 1303 & AS 1304
- 2001 AS/NZS 4671 Steel reinforcing materials (2^{nd} edtn 2019)


No. A. 1—1928.

ACESA

Australian Commonwealth
Engineering Standards Association

AUSTRALIAN STANDARD SPECIFICATION
FOR
STRUCTURAL STEEL
AND
AUSTRALIAN STANDARD ROLLED STEEL
SECTIONS FOR STRUCTURAL PURPOSES.


COMMONWEALTH OF AUSTRALIA

Institute of Science & Industry

AUSTRALIAN
STANDARD SPECIFICATION
FOR
STRUCTURAL
STEEL

MELBOURNE, 1920

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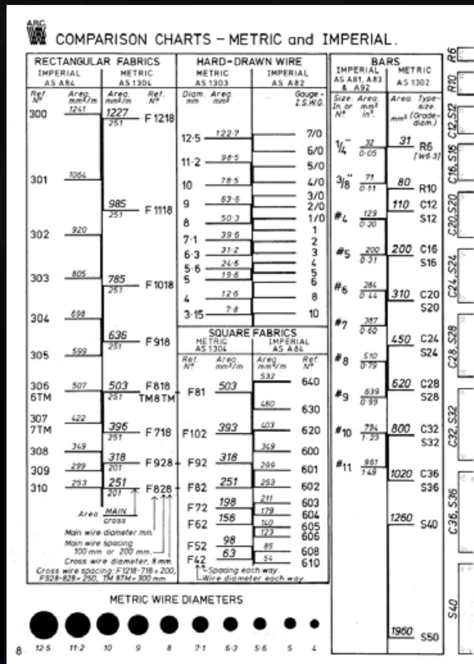
New Guide to Historical Reinforcement

- **Provides all mechanical and dimensional properties in Australia since 1895**
- Guide addresses the most common question at SRIA being properties and interpretation of imperial sized reinforcing bars & fabric
- A major change in the industry occurred in 1970 with the beginning of metrication
- NOTE: * The Bar Designation Number refers to the bar diameter in multiples of eights of an inch ie No. 8 bar = 8 x 1/8 in. = 1 inch diameter.

Deformed Bar Designation Number*	Unit weight		Effective Dimensions			
			Diameter (d)		Cross sectional area	
	(lb/ft)	(kg/m)	(in)	(mm)	(in²)	(mm²)
3	0.376	0.599	0.375	9.53	0.11	71
4	0.668	0.994	0.500	12.70	0.20	129
5	1.043	1.552	0.625	15.88	0.31	200
6	1.502	2.235	0.750	19.05	0.44	284
7	2.044	3.041	0.875	22.23	0.60	387
8	2.670	3.973	1.000	25.40	0.79	510
9	3.380	5.029	1.125	28.58	0.99	645
10	4.172	6.108	1.250	31.75	1.23	794
11	5.049	7.513	1.375	34.93	1.49	961

Dimensional and properties of imperial deformed round steel bars (after Table II of A.S. No. A.92-1958 (1) and Table 1 of A.S. A.92-1965 (2))



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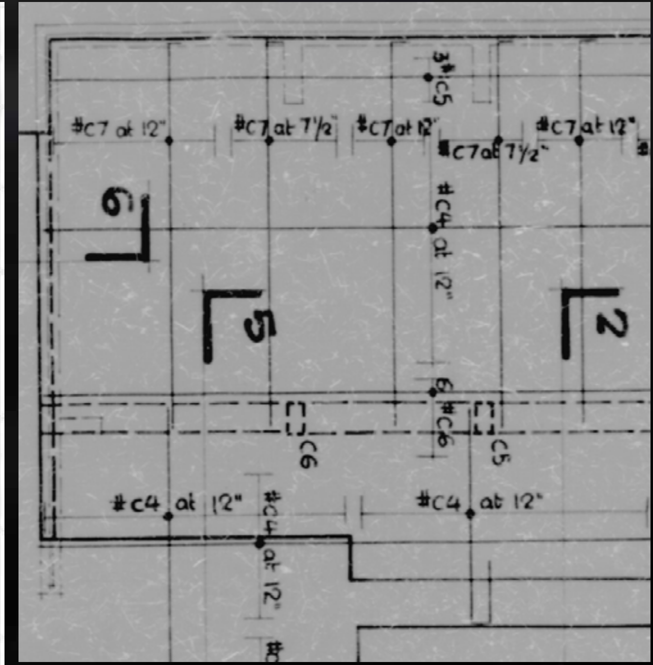
New Guide to Historical Reinforcement

- The Guide provides designations of all reinforcement types with period drawing examples

Symbol	Description
#	Deformed bar (ie ribbed).
#H	Hard grade deformed bar. The hash (#) was often not used, and H simply used.
#S	Structural grade deformed bar. The hash (#) was often not used, and S simply used.
#C #CT #CW	Cold-twisted or cold worked, round deformed bars. The hash (#) symbol was typically not used.
Ø R	Structural grade, plain round reinforcing bar. For example, reinforcement could be shown as 5/8Ø or 5Ø or sometimes as R5 depending on the designer and drafter.
ST $	Square twisted bar.
F	Hard-drawn wire reinforcing fabric (currently known as mesh).
W	Hard-drawn wire (today designated by L).
L	Ductility Class L bar.
N	Ductility Class N bar.
E	Ductility Class E bar.



Example: A designation **6 - #C4 at 12" (or 6 - #4 CW @ 12")** would mean six, number 4 size (or ½ inch) deformed CW.60 bars laid at 12 inch centres.

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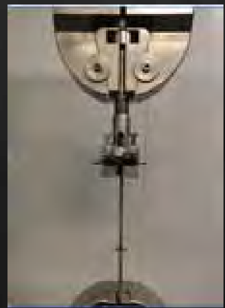
Assessment of Historical Structures

- **The Guide provides basic principles for assessment of historical reinforcement:**
  - Determine year of construction.
  - Identify bar type for the period from visual inspection, existing drawing dates, symbols and designations.
  - Test mechanical and chemical properties if in any doubt exists.
  - A summary of suggested reinforcement yield strengths applicable during the various periods are provided.



Before 1895	International developments before first use of reinforced concrete in Australia.
1895 to 1920	**Bars:** If the proprietary system cannot be established, use 200 MPa unless samples tested. **Fabric:** Assume 380 MPa.
1920 to 1957	**Bars:** Locally manufactured Hot-rolled plain steel bars or for proprietary systems that cannot be identified, assume 200 MPa unless samples tested. **Fabric:** Assume 380 MPa.
1957 to 1963	**Bars:** Square Twisted, 410 MPa; Hot-rolled plain or deformed, use 200 MPa unless samples tested. **Fabric:** Pre 1958, assume 380 MPa and Post 1958, assume 450 MPa.
1963 to 1983	**Bars:** Square Twisted or CW.60, 410 MPa; Hot-rolled plain or deformed, Pre 1965, use 200 MPa and Post 1965, use 230 MPa unless samples tested. **Fabric:** Assume 450 MPa.
1983 to 2001	**Bars:** Hot-rolled plain round or deformed bars Pre 1988, use 230 MPa and Post 1988, use 250 MPa. If deformed high-strength bars are identifiable by the rib pattern, use 410 MPa (1983 to 1988) then 400 MPa (1988 to 2001). **Fabric:** Pre 1995, assume 450 MPa and Post 1995, assume 500 MPa.
2001 to 2019	**Bars:** Hot-rolled plain round or deformed bars, use 250 MPa. If deformed high-strength bars are identifiable by the rib pattern, use either 400 MPa or 500 MPa. Note: At the beginning of the period as AS 3600 included both Grade 400 and 500 bars, it is essential to determine which Grade of bar was used from the design drawings. **Mesh:** Assume 500 MPa.

Unidentifiable reinforcement: If the building or structure was constructed during a period when several different types of bar reinforcement were available in the market or the material is unknown, testing of several different samples of the reinforcement is recommended. Alternatively, assume a yield strength of 200 MPa prior to 1965; 230 MPa from 1965 to 1988; and 250 MPa after 1988.

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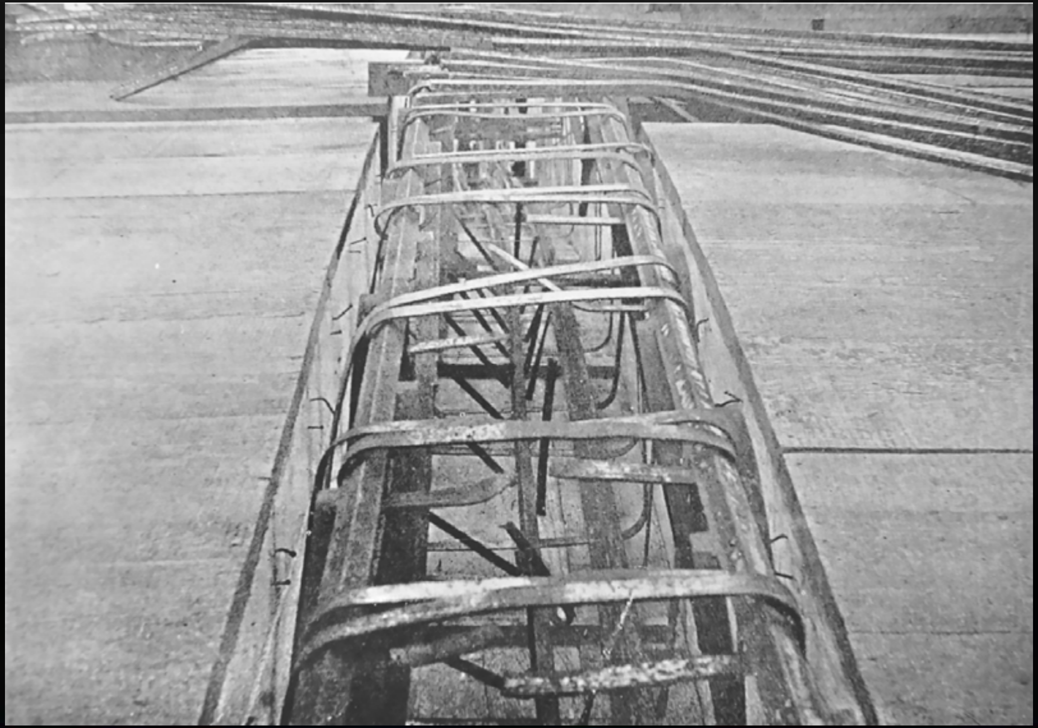
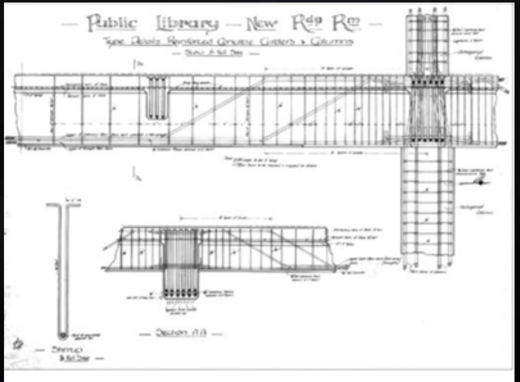
Capacity of Historical Projects

- Use caution when using modern design techniques on historical projects
- Capacity may be governed by anchorage detailing
- Use design methods appropriate to the system and period
- A Designer Checklist and sample of imperial vs metric calculations are also provided.

La Trobe Journal, No 72, Spring 2003 Image:
1910 Assembly of trussed bars Radial beam of the reading room floor Victoria State Library – Kahn & Truscon system





New Reading Room, type details of reinforced concrete girders & columns, showing the proposed Monier system reinforcement, which was to be set aside for the Truscon/Kahn system.
Bates, Smart & McCutcheon Collection, University of Melbourne Archives

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Conclusions

The new *Guide to Historic Steel Reinforcement in Australia* will:

- Emphasise the importance of maintaining our past technical history.
- Demonstrate the printed technical information is becoming more difficult to source.
- Show the importance of bringing this knowledge into a single document and capturing it for the benefit of assessing and preserving historical buildings and structures.
- Provide all historic steel reinforcement properties in one Guide for the assessment.
- Provide a roadmap of reinforced concrete materials and design over the past 124 years in Australia.

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