BUILDING PERFORMANCE

Practice Advisory 11: Grade 500E reinforcing steel - good practice

This Practice Advisory supplements Practice Advisory 1, and replaces Practice Advisory 7 and the quick guide for designers, building consent authorities, and contractors. It reports on research into bend diameters for Grade 500E MA and QT reinforcing steel.

This information was confirmed as current in December 2016.

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Of interest to Building consent authorities, Builders, Designers, Engineers

This Practice Advisory is issued as guidance information in accordance with section 175 of the Building Act 2004 and, if used, does not relieve any person of the obligation to consider any matter to which the information relates according to the circumstances of the particular case. This document is not a compliance document in terms of the Act and not a substitute for professional advice.

Main points

- Effect of low temperatures: A caution is included that the in-service temperature of Grade 500E reinforcement, whether MA or QT, should not be lower than minus 10°C for 25mm and 32mm diameter bars, and minus 20°C for 20mm and smaller bars to bend below minimum diameters.
- Bend diameters: The minimum bend diameters in NZS 3101:2006 are adequate for Grade 500E MA and QT for in-service temperatures noted above.
- Bar ductility: Grade 500E MA and QT bars tested show similar resilience when bent and straightened.
- Cold re-bending / straightening of Grade 500E MA and QT are not permitted by NZS 3109.
- Welding of Grade 500E QT is not permitted by NZS 3109.
- Tack welding: AS/NZS 1554.3 Clause 3.3.1 does not permit tack welding to any reinforcing steel used for structural / seismic purposes, be it Grade 500E or Grade 300E.
- Site welding of Grade 500E MA should be avoided.
- Shop welding (but not tack welding) of Grade 500E MA is considered acceptable provided that evidence is presented that the procedures used do not affect compliance of the reinforcement with AS/NZS 4671. Means of demonstrating compliance are provided in AS/NZS 1554.3 “Structural Steel welding – Welding of Reinforcing Steel”.
- Bendometer: A picture has been included to show how the bendometer will promote correct bending of reinforcement.
- Good practice guide for designers, building consent authorities and contractors: The presentation has been simplified and the scope extended.

Background

Starting in 2003, when concerns were raised about the performance of Grade 500E reinforcing steel, the Building Industry Authority and the then Department of Building and Housing led investigations into and informed industry about the characteristics of the material and good practice in its use. Publications issued were:

- Grade 500E reinforcing steel guidance
- Practice Advisory No. 7 - Use with care (July 2005); and a chart Reinforcing Steel in New Zealand – A quick guide for designers, building consent authorities, and contractors (June 2005, revised March 2006, no longer available while an update is in preparation)

- Practice Advisory No. 1 - Bend the bar but not the rules (https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/practice-advisory-1/) (July 2005, revised December 2005)
- Report on Grade 500E Reinforcement (July 2005) (http://www.mbie.govt.nz/publications-research/research)

Further to this material being issued there were significant changes in the supply market of Grade 500E reinforcement, making the information on the chart associated with Practice Advisory No. 7 out of date. As a result, a market update was published. Research, commissioned by us, into the effect of bend diameter and temperature on the ductility of Grade 500E reinforcement was also completed.This confirmed the adequacy of bend diameters specified in NZS 3101, at least for temperatures down to minus 10°C and applies to both micro-alloy (MA) and quenched and tempered (QT) types.

A detailed paper describing the research was published on our website and was published in the Journal of the Structural Engineering Society of New Zealand, Volume 21, No.2, September 2008.

Market Update discontinued

The previously published Market Update has been discontinued. Designers and builders must satisfy themselves that the particular reinforcing steels on each project meet the requirements of AS/NZS 4671:2001. Random testing of samples delivered to site is recommended either directly or through one of the quality assurance companies or through product certification.

The Market Update has been discontinued because it is not the core business activity of MBIE and there is an increasing number of importers requesting to be included in the Market Update. There are now a number of third party quality assurance agencies operating for reinforcing steel which suppliers may use to meet their quality assurance requirements.

Section A: Summary of properties and characteristics

Values given are 'characteristic' properties from AS/NZS 4671. Results of testing must meet the requirements of Appendix B of AS/NZS 4671 (This Appendix sets out test protocols and acceptance criteria. For example Clause B4.1.2 allows a single test result to fall outside the stated characteristic limits).

*	Grade 500E MA	Grade 500E QT	Grade 300E
Steel grade	**NZS 3101:2006 requires reinforcing steel to comply with AS/NZS 4671:2001. 'E' stands for 'Earthquake'. These grades of steel are specially developed to have the ductility needed to perform in seismic conditions.**		
Manufacturing process	**Micro-alloy (MA) process: trace elements such as vanadium and titanium used to provide strength and ductility.**	**Quenched and tempered (QT) process: in-line quenching and self-tempering to provide strength and ductility.**	**Plain carbon, low tensile steel with maximum ductility to allow easy forming and robust handling.**
Key characteristics	**Properties uniform over the bar cross-section.**	**Outer portion of bar cross-section is harder and stronger than the ductile inner portion.**	**Properties uniform over the bar cross-section. Less strength but greater ductility and weldability than Grade 500E.**
Chemical, Mechanical and Dimensional Requirements (from AS/NZS 4671:2001)			
Carbon equivalent (%) (maximum) (Refer Table 1 in AS/NZS 4671)	**0.49 (Cast analysis), 0.51 (Product analysis)**		**0.43 (Cast), 0.45 (Product)**
Yield stress (Rek.L and Rek.U)	**500 MPa to 600 MPa**		**300 MPa to 380 MPa**
Ratio of tensile strength to yield stress	**1.15 to 1.40**		**1.15 to 1.50**
Uniform elongation (measured at maximum force or after fracture)	**10% minimum**		**15% minimum**

Manufacturer's bend tests	Up to and including 16mm diameter: A) Bend through 90° around 4d mandrel. B) Age and cool. C) Bend back to straight. D) No visible evidence of cracks. **20mm diameter or larger:** A) Bend through 180° around 4d mandrel. B) No visible evidence of cracks	
Dimensional properties	**Refer to AS/NZ 4671 Sections 7.3, 7.4 and 7.5**	
Overstrength factors (NZS 3101)		
Beams	**1.40**	**1.25**
Columns	**1.35**	**1.25**

Section B: Minimum bend diameters

(From NZS 3101:2006 Tables 8.1 and 8.2 and Clause 8.4.2)

A. Main bars

f_y (MPa)	Bar d_b (mm)	Plain	Deformed	Galvanised
300 or 500	6 to 20	$5d_b$	$5d_b$	
	24 to 40	$6d_b$	$6d_b$	
	6 to 16			$5d_b$
	20 to 40			$8d_b$

B. Stirrups and ties

f_y (MPa)	Bar d_b (mm)	Plain	Deformed	Galvanised
300 or 500	6 to 20	$2d_b$	$4d_b$	
	24 to 40	$3d_b$	$6d_b$	
	6 to 16			$5d_b$
	20 to 40			$8d_b$

Notes

Deformations can cause stress concentrations during bending, hence the requirement for larger bend diameters for deformed bars.

For galvanised bars, larger diameters are needed to reduce strain ageing effects and avoid hydrogen embrittlement. This applies whether bars are bent before or after galvanising.

Bendometer for checking bending of reinforcement

The notch in each disc measures the diameter of the bar. The diameter of the disc is the required diameter of bend for a deformed main bar.

Section C: Fabrication processes – Advice

	Grade 500E MA	Grade 500E QT	Grade 300E

Initial bending (to NZS 3101)	**Comply with NZS 3109 (Use proper tools. Prevent notching. Conform to minimum bend diameters.) Bend at temperatures above 5°C. (See Note 1)**	**Comply with NZS 3109 (Use proper tools. Prevent notching. Conform to minimum bend diameters.) Bend at temperatures above 5°C. (See Note 1)**	**Comply with NZS 3109 (Use proper tools. Prevent notching. Conform to minimum bend diameters.) Bend at temperatures above 5°C. (See Note 1)**
Re-bending or straightening (Cold)	**Not permitted* (See Note 2)**	**Not permitted* (See Note 2)**	**Avoid* (See Note 2)**
Butt welding	**Avoid* (See Note 3)**	**Not permitted* (See Note 3)**	**Avoid* (See Note 3)**
Lap welding	**Avoid* (See Note 3)**	**Not permitted* (See Note 3)**	**Avoid* (See Note 3)**
Tack welding (on bars critical to structural performance)	**Not permitted* (See Note 4)**	**Not permitted* (See Note 4)**	**Not permitted* (See Note 4)**
Galvanising	**Check with supplier (See Note 5)**	**Check with supplier (See Note 5)**	**Check with supplier (See Note 5)**
Threading	**Proceed with care (See Note 6)**	**Avoid* (See Note 6)**	**Proceed with care (See Note 6)**

Notes

Research conducted for the former Department (refer to **MBIE corporate)** showed ductile behaviour of Grade 500E bars that had been bent at above 10°C. Bending at temperatures likely to be experienced on New Zealand sites is not expected to have a significant influence on mechanical properties.

Strength and ductility cannot be relied upon after cold re-bending or straightening of either 500E MA or 500E QT. Special procedures are available to hot re-bend 500E MA (refer NZS 3109) but require careful control and supervision beyond that normally available on construction sites. Grade 300E is more tolerant of bending because of its higher uniform elongation capability and lower work hardening rate. NZS 3109 permits the cold re-bending of Grade 300E, but we are not aware of any tests showing that the strength and ductility after bending comply with the requirements of AS/NZS 4671.

All welding must comply with AS/NZS 1554.3. Note particularly the requirements of Appendix E of AS/NZS 1554.3. Compliance with AS/NZS 1554.3 is difficult to achieve on construction sites, and site welding should be avoided. If site welding becomes necessary, special efforts need to be made to achieve compliance. Welding of Grade 500E MA and Grade 300E may be permitted provided the processes used show consistently that, after welding, the reinforcing steel, including the weld material, complies with NZS 4671. Welding of Grade 500E QT is not permitted by NZS 3109 because of its nonuniform cross-section - the effect on strength and ductility is hard to predict.

AS/NZS 1554.3 Clause 3.3.1 requires that welding 'shall not substantially reduce the cross-section of the reinforcing steel nor adversely affect its strength'. The same applies to ductility. Tack welds are almost certain to adversely affect critical steel reinforcement properties and should be regarded as not permitted on Grade 500E or Grade 300E reinforcement which is intended to resist structural or seismic actions. Tack welding requires special care and, if unavoidable, should be confined to bars that are not critical to structural performance.

Verify with manufacturers of the Grade 500E (MA or QT) or Grade 300E steel that properties are unaffected by the particular galvanising process to be used. For example, for 500E QT the self-tempering temperature during manufacture must exceed the galvanising temperature.

Threading of any bar reduces the nett area available and may introduce stress concentrations. Because the outer section of QT steel bars is different from the core material, the effect of threading on the overall properties of the bar is difficult to determine with confidence.

* Compliance with New Zealand Standards: 'Not permitted' means that the practice is not permitted by the relevant NZ Standard. 'Avoid' means that the practice is permitted by the relevant NZ Standard in certain circumstances, but should be avoided in normal construction practice.

Section D: Good practice guide

Question	Recommended action by:		
	Designers	**Building Consent Authorities**	**Builders and fabricators**
Correct Grade of Steel?	**Select Grade 500E or Grade 300E according to particular project circumstances (Grade 300E reinforcement has greater ductility and toughness, and a lower overstrength limit than Grade 500E (MA or QT).** Find out the name of the manufacturer, manufacturing process and means of identification.	**Check that the steel grades have been correctly used and clearly specified. Check that fabrication and construction processes are consistent with the permitted use of the product.**	**Check markings on delivery. Clearly tag different grades of reinforcing. Avoid mix-ups. Check with designer if in doubt.** Report any problems or unfamiliar bar markings to the designer and us.

MA or QT?	**Use Section C of this Practice Advisory to decide on suitability of MA and/or QT for your project. Define any restrictions on use.**	**Look for clear statements that MA, QT or both are acceptable, and for any special restrictions on use.**	**Check specification. Confirm acceptability of MA and/or QT before ordering. Do not substitute MA for QT or QT for MA without approval from the designer. Follow any special restrictions on use.**
Adequate strength and ductility?	**Specify reinforcing steel to comply with AS/NZS 4671 Grade 500E or Grade 300E. Specify acceptable methods of manufacture (MA or QT). Require and obtain evidence that the reinforcing steel supplied meets the requirements of AS/NZS 4671.** Commission independent tests on bars and/or examine supplier's records as necessary to be satisfied of compliance.	**Check that steel grades are adequately specified and suitable for the intended use.** Check whether the specification calls for production of certificates or commissioning of tests. Check whether the specification requires compliance with the NZ standard for production, AS/NZS 4671.	**Verify that you have the specified product and are satisfied that it complies with AS/NZS 4671 Grade 500E or Grade 300E.** Confirm that the bar markings are correct. Consult the designer if in any doubt. Confirm that the mill certificate provided is the correct one for the batch of reinforcing provided to the project and indicates compliance. If in any doubt, do not accept delivery and refer to the designer.
Effect of low temperature?	**Seek advice if the in-service temperature of Grade 500E reinforcement will be lower than minus 10°C.**	**Refer to the designer if the in-service temperature of Grade 500E reinforcement will be lower than minus 10°C.**	**Be aware that Grade 500E reinforcement becomes more brittle as the temperature reduces. Refer to the designer if the in-service temperature of Grade 500E reinforcement will be lower than minus 10°C.**
	Note The strains induced during the bending process reduce available ductility. This underlines the importance of bending to correct diameters and the dangers of re-bending. The bending operation should be performed at reasonable ambient temperatures, say 20°C. Within a range of -10°C and + 100°C the temperature of the bending operation is not expected to have a significant influence on mechanical properties.		
Correct bend diameters?	**When showing details of reinforcement (for example, in cross-sections), draw all reinforcing bars and bends to scale with the correct bend diameters. Reproduce or refer to the bar bending table in NZS 3101 or NZS 3109. Promote use of Bendometers.**	**Check that specified requirements for bending of reinforcing bars will result in the correct bend diameters. Promote use of Bendometers.**	**Confirm correct bending of bars before accepting delivery on site. Look out for incorrect bending in starter bars in precast concrete elements delivered to site. Bend to correct diameters. Use the Bendometer. Reject bars bent to too tight a diameter.**
Re-bending?	**Design to avoid re-bending. If re-bending is unavoidable, use Grade 300E steel in preference to Grade 500E.** Do not allow cold re-bending of any Grade 500E reinforcement. Include statements in drawings and specifications indicating that re-bent Grade 500E reinforcing steel will be rejected. Look for damaged / re-bent bars during site inspections. Require remedial action as appropriate.	**Refer back to designer if it is evident that Grade 500E reinforcement will need to be re-bent. Encourage designers to avoid re-bending, and to use Grade 300E if unavoidable.** Do not allow cold re-bending of any Grade 500E reinforcement. Check the drawings and specification for statements indicating that re-bent Grade 500E reinforcing steel will be rejected. Look for damaged / re-bent bars during site inspections. Notify builder. Require designer to review the need for remedial action.	Refer back to designer if it is evident that Grade 500E reinforcement will need to be re-bent. Do not re-bend Grade 500E steel. Do not allow cold re-bending of any Grade 500E reinforcement. Discourage re-bending of any reinforcement at every opportunity. Follow the drawings and specifications. Look for damaged / re-bent bars during site inspections. Refer instances to designer and take remedial action as instructed.
Welding?	**Design to avoid welding of reinforcing bars.** If welding becomes necessary, specify welding procedures clearly. The requirements of AS/NZS 1554.3 must be met, especially those of Appendix E. Do not specify welding of QT reinforcing bar. Design and specify to avoid tack welds to any reinforcement that has an important structural role. Watch for instances on site which could reduce the strength of the affected bars to unsafe levels.	**Check for any requirement to weld reinforcing bars and confirm adequate processes are specified.** Watch for instances oftack welding on site which could reduce the strength of the affected bars to unsafe levels. Refer instances to the designer.	**Do not weld reinforcing bars without specific approval from the designer.** Follow specified procedures. Comply in full with requirements of Appendix E of AS/NZS 1554.3 Do not weld Grade 500E QT reinforcing bars. Follow the specification. Do not tack weld to any reinforcement that is important structurally. Refer to the designer if in doubt. Tack welding may reduce the strength of the affected bars to unsafe levels. If tack welding is done inadvertently, notify the designer and be prepared to replace the affected bars.
Problems?	**Report any problems or breakages to the supplier, manufacturer and MBIE.**	**Report any problems or breakages to the designer, the supplier, the manufacturer and MBIE.**	**Report any problems or breakages to the designer, the supplier, the manufacturer and MBIE.**

Welded wire fabric? (mesh)	**Do not use welded wire mesh unless:** 1. It is not expected to yield at the Ultimate Limit State of the building, or 2. Yielding or rupture will not affect structural integrity. Use Grade 300E or 500E reinforcing instead.	**Check that welded wire mesh is not used except in situations where:** 1. It is not expected to yield at the Ultimate Limit State of the building, or 2. Yielding or rupture will not affect structural integrity. Refer to designer if in doubt.	**Be aware that welded wire mesh should not be used unless:** 1. It is not expected to yield at the Ultimate Limit State of the building, or 2. Yielding or rupture will not affect structural integrity. If you have concerns request the designer to confirm that use of welded wire mesh is acceptable.

Further information

Department of Building and Housing, 2008. Grade 500E Reinforcing Steel – Tests on Micro-alloy and Quenched and Tempered samples available in New Zealand

Report on Grade 500E Reinforcement, July 2005 [PDF 4.5 MB] (https://www.mbie.govt.nz/dmsdocument/71-grade-500e-steel-pdf)

Beca Consultants, 2004. The Use of Grade 500E Reinforcing Steel in NZ; A Review of Current Standards. Report prepared for Building Industry Authority, July.

References – Standards:

- AS/NZS 1554. Part 3: 2014: Structural steel welding – Welding of reinforcing steel
- NZS 3101:2006: Concrete Structures Standard
- NZS 3109: 1997 Concrete Construction
- AS/NZS 4671: 2001: Steel reinforcing materials

All guidance related to B1 Structure (https://www.building.govt.nz/building-code-compliance/b-stability/b1-structure/)