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# SENSE 600<sup>®</sup> Welding Guidelines





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**Document: T05a V4.0**

# 1. Introduction

This publication provides guidance on welding SENSE 600<sup>®</sup> (registered trademark of InfraBuild Trading) reinforcing bar to align with the requirements of AS/NZS 1554.3 – *Structural steel welding, Part 3: Welding of reinforcing steel*. AS/NZS 1554.3, provides prequalified welding procedures for Grade 500N bars that are manufactured to AS/NZS 4671 – *Steel for the reinforcement of concrete*, to simplify the process of qualifying welds. As these prequalified weld procedures do not extend to the higher grades of steel – 600N, the equivalent information specific for welding SENSE 600<sup>®</sup> is provided in this guide.

All Clauses in AS/NZS 1554.3 are applicable to qualifying welds with SENSE 600<sup>®</sup> as a parent material unless specific reference is made to the contrary in this guide. Extensive reference is made to AS/NZS 1554.3, particularly where elements of the welding procedures are applicable for SENSE 600<sup>®</sup> weld procedures, rather than reproducing it in this guide.

## 2. Definitions and Symbols

The definitions and symbols used in this guide are consistent with those in AS/NZS 1554.3. Reference shall be made to AS/NZS 1554.3 Clause 1.4.

### **2.1 Loadbearing Welded Joints**

Welded joints used for the transmission of specified loads between reinforcing steel bars or between reinforcing steel bars and other steel product. (AS/NZS 1554.3 Clause 1.4.15.1)

### **2.2 Non-loadbearing Welded Joints**

Welded joints for which the strength is not taken into account during the design of the reinforced concrete structure. (AS/NZS 1554.3 Clause 1.4.15.2)

### **2.3 Quality Management**

Fabricators shall ensure that all welding and related activities prescribed within Clause 1.7.2 of AS/NZS 1554.3 and are managed under a suitable quality management system, incorporating the key elements of AS/NZS ISO 3834.

# 3. General Principle of Equivalent Load Capacity

SENSE 600<sup>®</sup> reinforcing bars are manufactured by InfraBuild in diameters that are equivalent in load capacity (Strength Grade x Area) to Standard 500N reinforcing bars.

Table 1 shows the equivalent diameters for each of the two grades of bar – 500N (500 MPa) and SENSE 600<sup>®</sup> (600 MPa). Where bars have the same load capacity, the welding consumables, weld sizes, widths and lengths for lap splice and cross joint welds should also be the same. For example, in Table 1, an N16 (500 MPa) bar has the same load capacity as a S15 (15 mm SENSE 600<sup>®</sup>) bar, therefore the lap splice or cross joint weld for the two bars will have the same welding consumables, weld size, width and length parameters as they are required to support the equivalent loads.

The principle of the same weld obviously does not extend to butt welds as the area of the weld is reduced for bars with equivalent load capacities in higher steel grades. To cater for the higher grade capacities, alternative welding consumables may be required. For direct butt splice welds refer to AS/NZS 1554.3 Clause 1.4.14.2.

**Table 1: Equivalent diameters for 500N, SENSE 600<sup>®</sup>**

500N	Diameter	SENSE 600 <sup>®</sup>	Diameter	Load Capacity (Strength Grade x Area)
	(mm)		(mm)	(kN)
N10	10	NA	NA	39
N12	12	S11	11.0	57
N16	16	S15	14.6	101
N20	20	S18	18.3	157
N24	24	S22	21.9	226
N28	28	S26	25.6	308
N32	32	S29	29.2	402
N36	36	S33	32.9	509
N40	40	S37	36.5	628

## 4. Parent Material

This guide covers the welding of SENSE 600<sup>®</sup>, parent material – conforming to the requirements of AS/NZS 4671 – Steel for the reinforcement of concrete, herein referred to as AS/NZS 4671. While SENSE 600<sup>®</sup> conforms to AS/NZS 4671 Grade 600N its chemical composition is tightly controlled in a smaller range than AS/NZS 4671 permits.

Therefore, it follows that this guide only applies to SENSE 600<sup>®</sup> and not 600N bars more generally. The steel grades and InfraBuild chemistry limits are summarised in Table 2 below:

Table 2: Grade and chemical properties 500N, SENSE 600 <sup>®</sup>						
Reinforcing Steel	Grade (MPa)	Chemical Composition % Max				Weldability Group Number
		C	P	S	Carbon Equivalent Value (CEV)	
500N	500	0.22	0.050	0.050	0.44	4
SENSE 600 <sup>®</sup>	600	0.33	0.050	0.050	0.49	4

**NOTE:**

Values conform to AS/NZS 4671 Table 7.1 (A) and (B)

# 5. Welding Consumables

The recommended welding consumables for direct butt and end plate splice welds as per Table F1 and F3 of AS/NZS 1554.3 for SENSE 600® steels are shown in Table 3 below:

**Table 3: Welding consumables – direct butt welds for SENSE 600®**

Welding Process	Welding Consumable
GMAW – Gas Metal Arc Welding	AS/NZS 16834 B-G76
FCAW – Flux Cored Arc Welding	AS/NZS ISO 18276 B-T76 H5
MMAW – Manual Metal Arc Welding	AS/NZS 4857 B-E7618 H5

The recommended welding consumables for all welds, excluding direct butt welds and transverse end plate splice welds, for SENSE 600® steels are shown in Table 4 below:

**Table 4: Welding consumables – all other welds, excluding direct butt welds for SENSE 600®**

Welding Process	Welding Consumable
GMAW – Gas Metal Arc Welding	AS/NZS ISO 14341 B-G49A
FCAW – Flux Cored Arc Welding	AS/NZS ISO 17632 B-T49 H5
MMAW – Manual Metal Arc Welding	AS/NZS 4855 B-E4918 H5

**NOTE:**

Welding consumables for transverse end plate splice welds shall be matched to the lower yield strength of the plate. Refer to AS/NZS 1554.3 Clause 4.6.

# 6. Loadbearing joints

Loadbearing joints include direct and indirect butt splices, lap splices and transverse end plate splices.

## 6.1 Direct Butt Splices

Direct butt splices shall comply with

- a) All appropriate Sections of AS/NZS 1554.3 – including
  - i. Clauses 3.1.3 (a), 3.1.6, 3.2.1.1, 4.5.2, 4.9, 5.2 (b), 5.7.1,
  - ii. Appendix F and Table F1
- b) Pre heat and inter-run temperatures in Table 7.

## 6.2 Indirect Butt Splices

Indirect butt splices shall comply with

- a) All appropriate Sections of AS/NZS 1554.3 – including
  - i. Clause 3.2.1.2 (a), (b) and (c)
  - ii. Figure 3.1.3.
- b) The weld size (S), width (W) and length (L) in Table 5
- c) Pre heat and inter-run temperature in Table 7.

## 6.3 Lap Splices

Lap splices shall comply with

- a) All appropriate Sections of AS/NZS 1554.3 – including
  - i. Clause 3.2.2
  - ii. Figure 3.1.3.
- b) The weld size (S), width (W) and length (L) in Table 5
- c) Pre heat and inter-run temperatures in Table 7.

## 6.4 Transverse end plate splices

Transverse end plate splices shall comply with

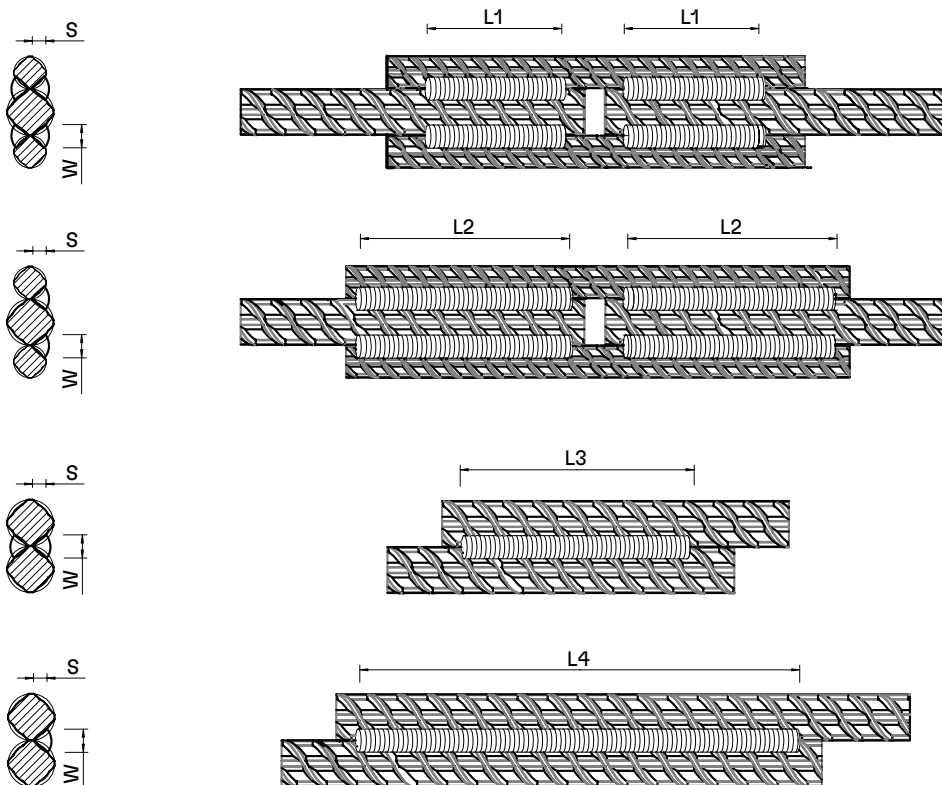
- a) All appropriate Sections of AS/NZS 1554.3 – including Clause 3.2.3
- b) Pre heat and inter-run temperatures in Table 7.

**Table 5: Minimum effective weld size (S), width (W) and length (L) for SENSE 600®**

Reinforcing Bar		Minimum Weld Size (mm)	Minimum Weld Width (mm)	Minimum Effective Length of Weld - L (mm)		
				Type of Splice		
500N	SENSE 600®	S	W	S1	S2 and S3	S4
N10	NA	2.5	4.5	30	50	100
N12	S11	3	6	36	60	120
N16	S15	4	8	48	80	160
N20	S18	5	9	60	100	200
N24	S22	6	11	72	120	240
N28	S26	7	13	84	140	280
N32	S29	8	15	96	160	320
N36	S33	9	17	108	180	360
N40	S37	10	18	120	200	400

**NOTE:**

Minimum values are based on the diameter of the smallest equivalent 500N bar.





# 7. Non-loadbearing welded joints

Non-loadbearing welded joints used for the preassembly of reinforcing elements, the temporary positioning of reinforcing steel or the location of steel during transport and placement shall comply with AS/NZS 1554.3 Clause 3.3.1. These welds include cross joints and lap joints.

## 7.1 Cross Joints

Cross joint welds have a width ( $W$ ), size ( $S$ ) and effective length ( $L$ ) not less than the values shown in Table 6.

## 7.2 Lap Joints

Lap joint welds that combine or locate reinforcing members or components not subject to design stresses that lie in the same plane shall have a width ( $W$ ), size ( $S$ ) and effective length ( $L$ ) complying with Table 6.

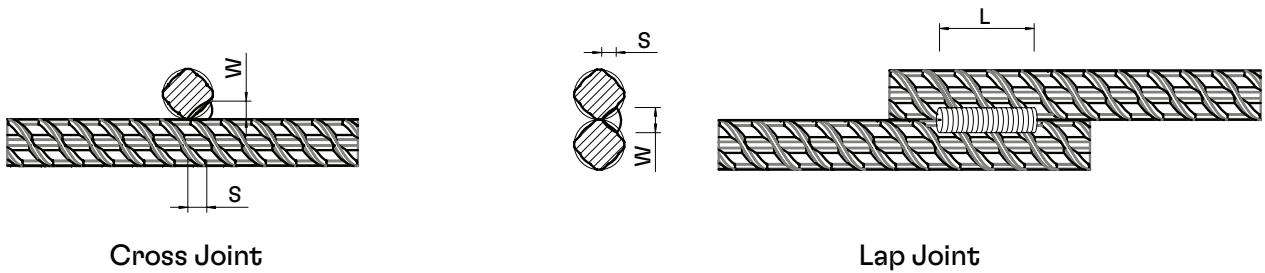
**Table 6: Non-loadbearing joints**

Smallest SENSE Bar in Joint	Equivalent 500 MPa Bar	Cross Joints			Lap Joints		
		S* (mm)	W* (mm)	L* (mm)	S* (mm)	W* (mm)	L* (mm)
<b>SENSE 600®</b>							
S11	N12	4.0	6	6	3	6	24
S15	N16	4.8	8	8	4	8	32
S18	N20	5.4	9	10	5	9	40
S22	N24	6.6	11	12	6	11	48
S26	N28	7.8	13	12	7	13	56
S29	N32	8.7	15	12	8	15	64
S33	N36	10.0	17	12	9	17	72
S37	N40	11.1	18	12	10	18	80

\* – Minimum based on the diameter of the smallest equivalent 500N bar.

**NOTE:**

The effective length (L) of lap joint welds may be made up of a number of weld runs. Each weld shall have a minimum effective length of not less than the size of the smaller bar.



# 8. Preheat and inter-run Control

**Table 7: Minimum preheat and inter-run temperatures**

Reinforcing steel	Weldability group number (see Note 4)	Bar diameter range (see Note 5) (mm)	Minimum preheat temperature (°C)								
			Butt welds				Other welds (see Note 6)				
			Arc energy (kJ/mm)								
			≥1.0<1.5	≥1.5<2.5	≥2.5<3.5	≥3.5	≥1.0<1.5	>1.5<2.5	≥2.5<3.5	≥3.5	
(a) Hydrogen-controlled electrodes EXX15, EXX16, EXX18 and EXX28, and semi-automatic and automatic welding processes (see Note 3)											
Sense®600	4	≤22	NR	NR	NR	NR	NR	NR	NR	NR	NR
		>22≤30	NR	NR	NR	NR	NR	NR	NR	NR	NR
		>30≤37	NR	NR	NR	NR	NR	NR	NR	NR	NR

**LEGEND:**

NR = preheat not required (refer AS/NZS 1554.3 Clause 5.3), except where welding under adverse weather conditions (see AS/NZS 1554.3).

**NOTES:**

- 1. A H5 hydrogen-controlled consumable shall be used. A H5 consumable is any consumable depositing weld metal containing not more than 5 mL of hydrogen per 100 g deposited weld metal when assessed to ISO 3690. Consumables not stored and conditioned in accordance with the manufacturer’s instructions (see AS/NZS 1554.3 Clause 2.3.2) are deemed non-hydrogen-controlled.**
- Table 7 applies to the welding of transverse end plate splice joints under the grouping ‘other welds’, provided that for the baseplate its weldability group is not greater than that of the bar grade to be welded, and its thickness does not exceed 12 mm. For all other cases, refer to Weld Australia Technical Note 1.
- Mill heat-treated bars may be subject to inter-run temperature limitations (see AS/NZS 1554.3 Clause 5.3).
- For an explanation and determination of weldability group number, refer to Weld Australia Technical Note 1.
- Bar diameter range refers to the diameter of the largest bar in the joint. Allowance has been made for the combined thickness cooling effects.
- Other welds include lap welds, indirect butt-splice welds, transverse end plate splice (see Note 1), cruciform and all tack welds other than tack welds to be incorporated into a direct butt-splice weld.

# 9. Qualification of welding procedures by testing

The welding procedure shall be qualified by making splices or cross joints using the applicable procedure and subjecting these welds to the tests specified in AS/NZS 1554.3 Clause 4.7, Tables 4.7.1(A) and 4.7.1(B). Provided the weld complies with the relevant test requirements of AS/NZS 1554.3 Clause 4.7, the weld procedure will be deemed to be qualified.

## 9.1 Visual Examination

Visual examinations: shall be carried out in accordance with AS/NZS ISO 17637:2019.

## 9.2 Macro Test

The macro test shall be carried out in accordance with AS/NZS 2205.5.1. The test specimen shall comply with the requirements of AS/NZS 1554.3 Table 6.2.

## 9.3 Tensile Test

Tensile Test: For loadbearing welded joints, the tensile test shall be carried out in accordance with AS 2205.2.1. and comply with Table 8.

The test specimen shall fracture outside the weld or its heat-affected zone (HAZ).

**Table 8: Minimum tensile strength for test welds**

Reinforcing Steel	Minimum Tensile Strength (MPa)
SENSE 600®	650

#### 9.4 Bend Test

The bend test shall be carried out in accordance with the AS/NZS 2205.3.1 using a former with a diameter of:

- (a)  $6d_b$  for bars  $\leq 12$  mm;
- (b)  $8d_b$  for bars  $> 12$  mm and  $\leq 20$  mm;
- (c)  $10d_b$  for bars  $> 20$  mm and  $\leq 32$  mm; and
- (d)  $12d_b$  for bars  $> 32$  mm.

The exposed section of the bar shall be ground or machined smooth to the diameter of the bar. The test piece shall be bent to an angle of at least  $90^\circ$ , without re-bending.

#### 9.5 Shear Tests

Shear tests shall be carried out in accordance with ISO 15630-2 – Steel for the reinforcement and prestressing of concrete – Test Methods Part 2: Welded fabric. The shear strength shall comply with the requirements of Table 9.

Table 9: Minimum shear strength for test welds	
	Minimum shear strength* (kN)
SENSE 600®	Min ( $0.24 \times A_s$ )

\*  $A_s$  is the lesser of the nominal cross sectional area in ( $\text{mm}^2$ ) of the smaller bar being tested or  $95\text{mm}^2$  for SENSE 600® bars. The minimum shear strength is 22.6kN.

#### 9.6 Hardness Test

Hardness tests: shall be carried out in accordance with AS/NZS 2205.6.1.

# 10. Bibliography

## Australian Standards

- AS 2205.2.1 – *Methods for destructive testing of welds in metal, Method 2.1: Transverse butt tensile test*
- AS 2205.6.1 – *Methods for destructive testing of welds in metal, Method 6.1: Weld joint hardness test*
- AS 3600 – *Concrete structures*

## Australian New Zealand Standards

- AS/NZS 1554.3 (Incorporating Amendment No.1) – *Structural steel welding, Part 3: Welding of reinforcing steel.*
- AS/NZS 2205.3.1 – *Destructive tests on welds in metallic materials, Method 3.1: Bend tests*
- AS/NZS 2205.5.1 – *Methods for destructive testing of welds in metal, Method 5.1: Macroscopic and microscopic examination of welds*
- AS/NZS ISO 3834.1 – *Quality requirements for fusion welding of metallic materials, Part 1: Criteria for the selection of the appropriate level of quality requirements*
- AS/NZS 4671 – *Steel for the reinforcement of concrete*
- AS/NZS 4855 – *Welding consumables – Covered electrodes for manual metal arc welding of non-alloy and fine grain steels – Classification*
- AS/NZS 4857 – *Welding consumables – Covered electrodes for manual metal arc welding of high-strength steels – Classification*
- AS/NZS ISO 14341 – *Welding consumables – Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels – Classification*
- AS/NZS 16834 – *Welding consumables – Wire electrodes, wires, rods and deposits for gas shielded arc welding of high strength steels – Classification*
- AS/NZS ISO 17632 – *Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels – Classification*
- AS/NZS ISO 17637 – *Non-destructive testing of welds – Visual testing of fusion-welded joints*
- AS/NZS ISO 18276 – *Welding consumables – Tubular cored electrodes for gas-shielded and non-gas-shielded metal arc welding of high strength steels – Classification*

## ISO Standards

- ISO 15630-2 – *Steel for the reinforcement and prestressing of concrete – Test Methods – Part 2: Welded fabric and lattice girders*

## Other

- Weld Australia Technical Note 1: *The Weldability of steels*

# 11. Acknowledgements



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# It just makes **SENSE**