



Guidance on the welding of weathering steels

1.0 Introduction

BlueScope REDCOR® weathering steel grades WR350 (Types A and B) and HW350 have similar welding characteristics to conventional hot rolled AS/NZS 3678 350. For general structural welding this means that no special welding consumable requirements apply unless a matching surface patina or similar corrosion resistance is required on the finished weld. This Technical Note describes the general precautions and consumable requirements for the welding of REDCOR™ weathering steel grades.

2.0 Precautions

2.1 Consumable selection

In all cases the use of hydrogen controlled welding consumables is preferred for the welding of high tensile steels including AS/NZS 1594 HW350, AS/NZS 3678 WR350 (Types A and B), AS/NZS 3678 WR350L0 (Types A and B) and AS/NZS 3678 WR350L20 (Types A and B). Whilst other consumables may be used, the suitability of all electrodes should be established via appropriate weld procedure qualification tests as specified in AS/NZS 1554.1 [1].

For general structural steel welding where a matching patina is not required, any of the welding consumables selected in accordance with Table 4.6.1(A) of AS/NZS 1554.1 [1] may be used. Where the weld metal applied to the weathering steel is required to have a similar corrosion resistance or to develop a patina similar to that of the steel being welded, consumables should be selected in accordance with Section 3 of this Technical Note.

2.2 Preheat

The welding of REDCOR™ weathering steels up to 50mm in thickness (as with the welding of similar section AS/NZS 3678 350), may require the application and maintenance of preheat to the weld joint to avoid excessive weld heat affected zone hardening and subsequent delayed cracking. Combined with the use of hydrogen controlled welding consumables, the risk of delayed cracking (also known as cold cracking or hydrogen assisted cold cracking) is reduced. Reference should be made to AS/NZS 1554.1 [1] or WTIA Technical Note 1 [2] to calculate minimum preheat temperature requirements.

For the welding of 50mm and thicker WR350(B), fabricators should be aware that the typical carbon equivalent (CE) of the supplied steel will place WR350(B) into Weldability Group 6 rather than the lower CE

associated with thinner section WR350 shown within Table 5.3.4(A) of AS/NZS 1554.1 [1], and WTIA Technical Note 1 [2]. Fabricators may calculate the minimum preheat requirements based on Weldability Group 6, or they may verify the plate analysis shown on the supplied heat certificate and adjust preheat requirements in accordance with the method given in Clause 5.3.4(a)(ii) of AS/NZS 1554.1 should the reported CE exceed 0.48.

2.3 Hot cracking susceptibility

As REDCOR™ weathering steel up to 12mm thick may typically contain levels of phosphorous and copper significantly higher than that found in general structural steels, in certain joint configurations and higher heat inputs (>2.5kJ/mm) the weld may be at increased risk of hot cracking. Conversely, because of the increase in strength gained from using these alloying elements, BlueScope have reduced the carbon content of these steels to offset and reduce the risk of hot cracking, and provide a guaranteed carbon equivalent limit to maintain the good weldability characteristics of these BlueScope steels. At normal heat inputs used in manual and semi automatic welding the risk of hot cracking is considered low, however at higher heat inputs, particularly >2.5kJ/mm, it is recommended that suitable hot cracking tests be conducted as part of the weld procedure qualification test requirements to verify freedom from hot cracking. Suitable tests include the Transvarestraint test [3] or the AS 2205.9.1 [4] method.

2.4 Weld procedure qualification tests

The information provided in this Technical Note does not override the user's obligations to demonstrate their ability to produce sound welds via documented weld procedure and welder qualification tests as required by application Standards including AS/NZS 1554.1 and AWS D1.1 [1, 5]. Where consumables are not deemed prequalified within these Standards, additional qualification tests may be required to establish suitability for use within the chosen application.

3.0 Welding consumable selection

3.1 General

Where the weld metal to be applied to the weather-resistant steel is required to have similar atmospheric corrosion resistance and similar patina colouring to that of the parent steel, nickel bearing low alloy steel electrodes may be required, particularly for multirun welds. With relatively small single pass welds, dilution effects between the weld metal and parent

material will ensure that sufficient alloying elements are present in the weld for adequate resistance to corrosion for high phosphorus weathering steels only. If the reinforcement can be left in place, some added protection against metal loss is gained.

The specific recommendations applicable to various weld joint configurations and welding techniques are:

- a. For single-run fillet welds and butt welds made with a single run or a single run each side and where the welds are made with no weave, welding consumables should be selected in accordance with Table 4.6.1(A) of AS/NZS 1554.1 for high phosphorous weathering steel only.
- b. For single-run fillet welds and butt welds made with a single run or a single-run each side and where weaving is used during the run, welding consumables should be selected in accordance with Table 4.6.1(C) of AS/NZS 1554.1 or Table 1.
- c. For capping runs on multi-run fillet or butt welds, welding consumables should be selected in accordance with Table 4.6.1(C) of AS/NZS 1554.1 or Table 2.
- d. For runs other than capping runs on multi-run fillet or butt welds, welding consumables should be selected in accordance with Table 4.6.1(A) of AS/NZS 1554.1.

Again, the use of hydrogen controlled welding consumables is preferred.

3.2 Consumables for Manual Metal Arc, Flux Cored Arc and Submerged Arc Welding

Suitable nickel bearing manual metal arc (MMAW), flux cored arc (FCAW), gas metal arc (GMAW) and submerged arc (SAW) welding consumables known to have similar weathering resistance to AS/NZS 1594 HW350, AS/NZS 3678 WR350 (Types A and B), AS/NZS 3678 WR350L0 (Types A and B) and AS/NZS 3678 WR350L20 (Types A and B) steels are listed in Table 1.

These consumables are deemed prequalified in the Standard AS/NZS 1554.1 thus minimal testing is required prior to use other than that necessary to establish and qualify the proposed weld procedure in accordance with AS/NZS 1554.1.

3.3 Consumables permitted within AWS D1.1 [5]

Whilst the choice of consumables deemed prequalified within AS/NZS 1554.1 is limited to certain MMAW, FCAW. GMAW and SAW consumables, the American Welding Society's Standard AWS D1.1 [5] provides a broader range of consumable options for the four common welding processes where a matching patina is required on multipass welds in particular. These are shown in Table 2 and consumables meeting these requirements may be used to weld BlueScope's WR350 (Types A and B) and HW350 grades. Qualification tests may be required [1].

4.0 References

1. AS/NZS 1554.1:2014 Structural steel welding Part 1: Welding of steel structures, Joint publication of Standards Australia and Standards New Zealand.
2. WTIA Technical Note 1 The Weldability of Steels, Welding Technology Institute of Australia, TN1 96, 1996.
3. ISO/TR 17641-3:2005 Destructive tests on welds in metallic materials — Hot cracking tests for weldments — Arc welding processes — Part 3: Externally loaded tests.
4. AS 2205.9.1 Methods for destructive testing of welds in metal—Method 9.1: Hot cracking test, Standards Australia, 2003.
5. AWS D1.1/D1.1M:2015 Structural Welding Code—Steel, American Welding Society, 2015.

Table 1: Prequalified welding consumables with similar weathering resistance to WR350 (Types A and B) and HW350 [1].

Steel grade	Consumables (see Notes)			
	Manual metal-arc (AS/NZS 4855)	Flux-cored arc (AS/NZS ISO 17632)	Gas-metal arc (AS/NZS 14341)	Submerged arc (AS/NZS ISO 14171)
AS/NZS 1594 HW350	A E42 2 2Ni A E46 2 2Ni	A T42 2 1.5Ni A T46 2 1.5Ni	A G42 2 3Ni1 A G46 2 3Ni1	A-S2Ni1 A-S2Ni1.5
AS/NZS 3678 WR350 (Types A and B)	A E42 2 3Ni A E46 3 3Ni	A T42 2 2Ni A T46 2 2Ni	A G42 2 2Ni2 A G46 2 2Ni2	A-S2Ni2 A-S2Ni3
AS/NZS 3678 WR350L0 (Types A and B)	B E49XX N5 B E55XX N5	A T42 2 3Ni A T46 2 3Ni	B G492U SN2 B G552U SN2	A-S3Ni1.5 B-SUN2
AS/NZS 3678 WR350L20 (Types A and B)	B E49XX N7 B E55XX N7	B T492U N2 B T552U N2 B T492U N3 B T552U N3 B T492U N5 B T552U N5 B T492U N7 B T552U N7	B G492U SN3 B G552U SN3 B G492U SN5 B G552U SN5 B G492U SN7 B G552U SN7 B G492U SN71 B G552U SN71	B-SUN21 B-SUN3 B-SUN31 B-SUN5 B-SUN7

Notes:

- Any listed consumable may be used with any listed steel grade.
- Consumables with a higher impact grading than that shown are also acceptable.
- The letter 'X' represents the flux covering.
- For submerged arc consumables only the wire composition is shown in the Table. Classifications shall also comply with the relevant strength and impact designations shown in Table 4.6.1(A).
- Guidance on the selection of welding consumables for weathering steel not listed in this Table should be sought from the steel manufacturer.
- Note the "Type A and B" grade designations are modifications of the standard AS/NZS 3678-WR350 grade names.

Table 2: AWS D1.1 Filler Metal Requirements for Exposed Bare Applications of Weathering Steels (Table 3.4 from [5])

Process	AWS Filler Metal Specification	Approved Electrodes ¹
SMAW (MMAW)	A5.5	All electrodes that deposit weld metal meeting a B2L, C1, C1L, C2, C2L, C3 or WX analysis per A5.5.
SAW	A5.23	All electrode-flux combinations that deposit weld metal with a Ni1, Ni2, Ni3, Ni4 or WX analysis per A5.23.
FCAW	A5.29 and A5.36	All electrodes that deposit weld metal with a B2L, K2, Ni1, Ni2, Ni3, Ni4, or WX analysis per A5.29 or A5.36.
GMAW	A5.28 and A5.36	All electrodes that meet filler metal composition requirements of B2L, G1, Ni1, Ni2, Ni3, analysis per A5.28 or A5.36.

General Notes

- Filler metals shall meet requirements of Table 3.2 of AWS D1.1 in addition to the compositional requirements listed above. The use of the same type of filler metal having next higher tensile strength as listed in AWS filler metal specification may be used.
 - Metal cored electrodes are designated as follows:
 - SAW: Insert letter "C" between the letters "E" and "X," e.g., E7AXECXXX-Ni1.
 - GMAW: Replace the letter "S" with the letter "C," and omit the letter "R," e.g., E80C-Ni1. AWS A5.36 composite electrode designation is either T15 or T16 e.g. E8XT15 XXX Ni1 or E8XT16 XXX Ni1.
- Deposited weld metal shall have a chemical composition the same as that for any one of the weld metals in this table.

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