WELDING CONSUMABLES AND DESIGN OF WELDS IN AS 4100—1998 WITH AMENDMENT 1, 2012

INTRODUCTION

In respect of materials, AS 4100 Section 2 specifies the materials which form part of the provisions of AS 4100. All materials nominated are covered by Standards, either Australian (AS prefix) or joint Australia/New Zealand (AS/NZS prefix). The 2012 Amendment of AS 4100 contains a number of changes that affect welding due to the inclusion of quenched and tempered steels and the updated requirements to match the changed requirements of the Standards for welding consumables.

All welding electrodes and deposited weld are required to comply with AS/NZS 1554.1 in Clause 2.3.3 of AS 4100, except for welding quenched and tempered steel which requires that welding comply with AS/NZS 1554.4. Clauses 2.3.3 and 11.1.5 of AS 4100 requires that welds in certain welded detail categories shall have a weld quality conforming to AS/NZS 1554.5.

Welded studs are required to be welded in accordance with AS/NZS 1554.2. Such welding does not form part of the discussion in this Technical Note.

Likewise, Section 9 of AS 4100 dealing with design of connection elements such as bolts, welds and connection components is based on design expressions and capacity factors that are directly related to the welding consumables/deposited weld metals specified in AS/NZS 1554.1, 1554.4 and 1554.5. The relevant capacity factors for welds were also derived using a statistical analysis of test results obtained from complying welding consumables, used with steels that comply with Australian Standards.

Clause 14.3.4 Welding of AS 4100 refers to AS/NZS 1554.1, 1554.4 or 1554.5 (the AS/NZS 1554 suite of Standards) for all welding requirements and these Standards have their own set of provisions that must be met in order for the welding to be compliant. A general discussion of the requirements of AS/NZS 1554.1 is contained in the ASI publication 'Design Guide 2: Welding in steel connections'. Requirements in the other two Standards are similar.

The AS/NZS 1554 suite of Standards requires that the welding consumables and procedure be qualified before welding commences and that the fabricator establish a welding procedure and list the applicable parameters on a welding procedure qualification record which must be available for inspection. Prequalified welding procedures are permitted subject to nominated provisions being complied with.

The AS/NZS 1554 suite also contains specific provisions related to the welding process including:

—Edge preparation and assembly;

—Preheat;

—Tack welds;

—Distortion and residual stress;

—Cleaning and dressing welds.

Welds are either weld category SP or GP in AS/NZS 1554.1 and AS/NZS 1554.4 and each category has different inspection requirements and permissible imperfection levels. AS/NZS 1554.5 has different inspection and permissible imperfection levels for welds subject to fatigue loading. Inspections may involve one or more of the following: visual examination, magnetic particle examination, liquid penetrant examination, radiographic examination or ultrasonic examination—as specified by the structural design engineer in the design documentation. Any site welding should comply with Clause 14.3.4 of AS 4100.

DESIGN OF WELDS IN AS 4100 (1990 and 1998 editions)

The design capacity of a full penetration butt weld is specified in Clause 9.7.2.7 of AS 4100 to be taken as equal to the nominal capacity of the weaker part of the parts joined, multiplied by the appropriate capacity factor for butt welds given in Table 3.4 of AS 4100, provided that the welding procedure was qualified in accordance with AS/NZS 1554.1 or AS/NZS 1554.5 as applicable. The butt weld must be made using a welding consumable which will produce butt tensile test specimens in accordance with AS 2205.2.1 for which the minimum strength is not less than that given in Table 2.1 of AS 4100 for the parent material. Hence, for butt welds, the structural engineer specifying the weld does not need to be concerned with what is specified in the welding consumable Standards.

However, the design capacity of fillet welds in Clause 9.7.3.10 of AS 4100 is based on the nominal tensile strength of the weld metal, which is derived from the strength of the welding consumables specified in the relevant Australian Standards. Clause 9.7.2.7 specifies that the design capacity of incomplete-penetration butt welds shall be that for a fillet weld of the same design throat thickness so it also is related to the tensile strength of the welding consumable.

Table 9.7.3.10(1) of the 1990 and 1998 editions of AS 4100 specified the nominal tensile strength of the weld metal as either 410 or 480 MPa as shown in the extract below.

TABLE 9.7.3.10(1)

NOMINAL TENSILE STRENGTH OF WELD METAL (f_{uw})

Manual metal arc electrode (AS/NZS 1553.1)	Submerged arc (AS 1858.1) Flux cored arc (AS 2203) Gas metal arc (AS/NZS 2717.1)	Nominal tensile strength of weld metal, f_{uw} MPa
E41XX	W40X (see Note)	410
E48XX	W50X	480

NOTE: Not included in AS/NZS 2717.1.

As can be seen, reference is made in this Table to a number of Australian Standards for welding consumables, which reflected those in use at the time these editions of AS 4100 were published. Using these nominal tensile strengths of weld metal, tables of design capacity for fillet welds and partial penetration butt welds of various throat thicknesses for SP and GP weld categories were published by the Australian Steel Institute in a number of its publications including ‘Design capacity tables for structural steel: Volumes 1 and 2’ and ‘Connections Handbook 1 : Background and theory’.

RECENT CHANGES TO AUSTRALIAN STANDARDS FOR WELDING CONSUMABLES

New editions of the AS/NZS 1554 suite of welding Standards have recently been published and these refer to newly published editions of the Australian Standards for welding consumables.

Appendix F of AS/NZS 1554 Parts 1, 4 and 5 entitled ‘Weld procedure requirements associated with changes to the welding consumable classification system’ explains the changes made in the classification system for welding consumables. These changes in the welding consumable classification system impact on structural engineers designing fillet welds and partial penetration butt welds.

The following is an extract from Appendix F of AS/NZS 1554.1 which explains these changes:

> 'Australia and New Zealand have adopted the harmonised ISO welding consumable classification system for the manual metal arc (MMAW) and flux-cored arc welding (FCAW) of carbon and other steels. For these steels, the new ISO based consumable classification system brings together two seemingly incompatible systems in common usage:
>
> (a) System A used in Europe where consumables are classified predominantly by yield strength and the temperature at which 47J minimum impact energy is guaranteed.
>
> (b) System B used extensively around the Pacific Rim and North America where consumables are classified by tensile strength and the temperature at which 27J minimum impact energy if guaranteed.
>
> Australia and New Zealand have generally followed the AWS based System B practice using a tensile strength based classification system ... With the adoption of the harmonised ISO system, it is expected that usage of the AWS based "B" classification system will continue to dominate, however, there will be situations where the European based "A" classifications system will be preferred.'

It should be noted that virtually all welding consumables used in steel fabrication in Australia are now imported rather than being manufactured in Australia as previously. They will be identified using either system in their accompanying documentation.

For the structural engineer designing welds to AS 4100 Section 9, the changes made to the welding consumables Standards has some implications as set out below.

2012 AMENDMENT TO AS 4100

An Amendment to AS 4100—1998 was prepared primarily in order to bring AS 4100 into alignment with changes to the large number of referenced Standards cited in Appendix A of AS 4100.

The 2012 Amendment aligns Clause 9.7.3.10 and Table 9.7.3.10(1) with the new welding consumable designations as shown in the extract from Table 9.7.3.10(1) below.

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TABLE 9.7.3.10(1) PART 1

NOMINAL TENSILE STRENGTH OF WELD METAL (f_{uw})

Structural steel welding to AS/NZS 1554.1 and AS/NZS 1554.5—Steel Types 1–8C					
Manual metal arc (AS/NZS 4855)	**Submerged arc (AS 1858.1)**	**Flux cored arc (AS/NZS ISO 17632)**	**Gas metal arc (AS/NZS 2717.1) (ISO 14341)**	**Gas tungsten arc (ISO 636)**	**Nominal tensile strength of weld metal, f_{uw} (MPa)**
A-E35, A-38 B-E43XX	W40X	A-T35, A-T38 B-T43	A-G35, A-G38 B-G43	A-W35, A-W38 B-W43	430
A-E42, A-E46 B-E49XX	W50X	A-T42, A-T46 B-T49	A-G42, A-G46 B-G49, W50	A-W42, A-W46 B-W49	490
A-E50 B-E55XX	W55X	A-T50 B-T55, B-T57	A-G50 B-G55, B-G57 W55X, W62X	A-W50 B-W55, B-W57	550

NOTES:

1 The minimum tensile strength of the European type A classification series consumables is slightly higher than that shown in this table.

2 The B-E57XX, B-E59XX, B-E78XX and equivalent strength consumables for other welding processes, may be difficult to source commercially.

3 The letter '*X*' represents any flux type (manual metal arc welding process) or impact energy value (submerged arc and gas metal arc welding processes).

The main features of the above Table 9.7.3.10(1) from a structural engineers point of view are as follows:

(1) There are now three possible nominal tensile strengths of weld metal listed rather than two previously;

(2) The previous values of 410 and 480 MPa for the nominal tensile strength have been increased to 430 (extra 4.9%) and 490 MPa (extra 2%) respectively;

(3) There are multiple designations of suitable electrodes for most processes using both the A and B systems.

As a consequence of this change, the design strengths of fillet welds and incomplete-penetration butt welds for various throat thicknesses will be as set out below for weld categories SP and GP.

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TABLE 1

STRENGTH LIMIT STATE
DESIGN CAPACITIES OF EQUAL LEG FILLET WELDS PER UNIT LENGTH
Category SP, $\phi = 0.8$, $k_r = 1.0$

Weld size (mm)		Design capacity per unit length of weld, ϕv_w (kN/mm)		
Leg: t_w	Throat: t_t	f_{uw} = 430 MPa	f_{uw} = 490 MPa	f_{uw} = 550 MPa
3	2.12	0.438	0.499	0.560
4	2.83	0.584	0.665	0.747
5	3.54	0.730	0.831	0.933
6	4.24	0.876	0.998	1.12
8	5.66	1.17	1.33	1.49
10	7.07	1.46	1.66	1.87
12	8.49	1.75	2.00	2.24
	$t_t = t_w/\sqrt{2}$			

where: f_{uw} = nominal tensile strength of the weld metal (Table 9.7.3.10(1))

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TABLE 2

STRENGTH LIMIT STATE
DESIGN CAPACITIES OF EQUAL LEG FILLET WELDS PER UNIT LENGTH
Category GP, $\phi = 0.6$, $k_r = 1.0$

Weld size (mm)		Design capacity per unit length of weld, ϕv_w (kN/mm)		
Leg: t_w	Throat: t_t	f_{uw} = 430 MPa	f_{uw} = 490 MPa	f_{uw} = 550 MPa
3	2.12	0.329	0.374	0.420
4	2.83	0.438	0.499	0.560
5	3.54	0.547	0.624	0.700
6	4.24	0.657	0.746	0.840
8	5.66	0.876	0.998	1.12
10	7.07	1.09	1.25	1.40
12	8.49	1.31	1.50	1.68
	$t_t = t_w/\sqrt{2}$			

where: f_{uw} = nominal tensile strength of the weld metal (Table 9.7.3.10(1))

Structural engineers will have to clearly identify on the structural drawings and in the specification both the weld size, the weld category and the nominal tensile strength of the weld metal as shown in Table 9.7.3.10(1) of the 2012 Amendment. Since there are a number of different electrode designations involved for each process and a number of potential welding processes and since the selection of the welding process to be used should be left to the fabricator, specifying the tensile strength of the weld metal is what is now recommended to be done. The previous method of specifying an electrode designation won't work with the new multiple electrode designations.

QUENCHED AND TEMPERED STEEL AND 2012 AMENDMENT TO AS 4100

The 2012 Amendment 1 to AS 4100 now permits quenched and tempered steel complying with AS 3597 'Structural and pressure vessel steel—Quenched and tempered plate' to be designed using AS 4100 for grades with a yield stress not exceeding 690 MPa. Welding of these steels is required to be in accordance with AS/NZS 1554.4.

Table 9.7.3.10(1) of AS 4100 has been expanded to include welding consumables suitable for such grades of quenched and tempered plate as shown in the attached extract from Table 9.7.3.10(1) which lists seven possible nominal tensile strengths of weld metal.

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TABLE 9.7.3.10(1) PART 2
NOMINAL TENSILE STRENGTH OF WELD METAL
QUENCHED AND TEMPERED STEELS

Structural steel welding to AS/NZS 1554.4—Steel Types 8Q–10Q					
Manual metal arc (AS/NZS 4855, AS/NZS 4857)	**Submerged arc (AS 1858.1, AS 1858.2)**	**Flux cored arc (AS/NZS ISO 17632, AS/NZS ISO 18276)**	**Gas metal arc (AS/NZS 2717.1) (ISO 14341, ISO 16834)**	**Gas tungsten arc (ISO 636, ISO 16834)**	**Nominal tensile strength of weld metal, f_{uw} (MPa)**
A-E35, A-38 B-E43XX	W40X	A-T35, A-T38 B-T43	A-G35, A-G38 B-G43	A-W35, A-W38 B-W43	430
A-E42, A-E46 B-E49XX	W50X	A-T42, A-T46 B-T49	A-G42, A-G46 B-G49 W50	A-W42, A-W46 B-W49	490
A-E50 B-E55XX B-E57XX B-E59XX	W55X	A-T50 B-T55, B-T57 B-T59	A-G50 B-G55, B-G57 B-G59 W55X	A-W50 B-W55 B-W57, B-W59	550
A-E55 B-E62XX	W62X	A-T55 B-T62	A-G55 B-G62 W62X	A-W55 B-W62	620
A-E62 B-E69XX	W69X	A-T62 B-T69	A-G62 B-G69 W69X	A-W62 B-W69	690
A-E69 B-E76XX B-E78XX	W76X	A-T69 B-T76,B-T78	A-G69 B-G76,B-G78 W76X	A-W69 B-W76, B-W78	760
A-E79 B-E83XX	W83X	A-T79 B-T83	A-G79 B-G83 W83X	A-W79 B-W83	830

REFERENCES

Standards Australia, AS 4100 ‘Steel structures’ (1998 edition and 2012 amendment).

Standards Australia/Standards New Zealand, AS/NZS 1554.1:2011 ‘Structural steel welding, Part 1: Welding of steel structures’.

Standards Australia/Standards New Zealand, AS/NZS 1554.2:2003 ‘Structural steel welding, Part 2: Stud Welding (steel to steel)’.

Standards Australia/Standards New Zealand, AS/NZS 1554.4:2010 ‘Structural steel welding, Part 4: Welding of high strength quenched and tempered steels’.

Standards Australia/Standards New Zealand, AS/NZS 1554.5:2011 ‘Structural steel welding, Part 5: Welding of steel structures subject to high levels of fatigue loading’.

Australian Steel Institute, ‘Design Guide 2—Welding in Structural Steel Connections’, 2007, Author Hogan, T.J., Contributing Author and Editor, Munter, S.A.