Welding Procedure Specification for S355J0W Weathering Steel

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The welding procedure specification for S355J0W weathering steel includes the following: base metal properties, weldability analysis, pre-welding preparation, welding materials, welding parameters, key welding operations, post-welding treatment, welding quality inspection, and referenced standards.

Scope: This specification applies to manual metal arc welding (SMAW) and gas metal arc welding (GMAW/MAG) of EN 10025-5 S355J0W weathering structural steel, covering butt and fillet joints in plates with thicknesses ranging from 5 mm to 50 mm.

1 Base Metal Properties

1.1 Material Overview

Standards	Grade	Delivery Condition
EN10025-5	S355J0W	Hot Rolled, Normalized, Normalizing Rolling

1.2 Chemical Composition (Melting analysis, wt%)

Element	Content (max, %)
C	0.16
Si	0.50
Mn	0.50 - 1.50
P	0.035
S	0.035
N	0.012

Element	Content (max, %)
Cr	0.40 - 0.80
Cu	0.25 - 0.55

1.3 Mechanical Properties (0°C, Longitudinal)

Thickness (t) [mm]	Yield Strength (ReH) [min, MPa]	Tensile Strength (Rm) [MPa]	Elongation (A) [min, %]	Impact Energy (KV) [min]
t ≤ 16	355	470 - 630	22	27J
16 < t ≤ 40	345	470 - 630	22	27J
40 < t ≤ 63	335	470 - 630	21	27J
63 < t ≤ 80	325	470 - 630	20	27J
80 < t ≤ 100	315	470 - 630	20	27J
100 < t ≤ 150	295	450 - 600	18	27J

2 Weldability Analysis

2.1 S355J0W weathering steel possesses excellent weldability, with a carbon equivalent (CEV) ≤0.38 (IIW formula).

2.2 The special alloy system of weathering steel (Cu-Cr-Ni composite weathering system) imposes certain requirements on the welding process:

a) The addition of copper may lead to Cu segregation in the weld; controlling heat input helps prevent Cu segregation and porosity defects.

b) The weathering performance of the weld must be ensured through the selection of compatible

welding consumables.

c) The weathering oxide layer formed on the surface must be removed prior to welding to ensure weld quality.

3 Pre-welding Preparation

3.1 Surface Preparation

Prior to welding, thoroughly remove rust, oil, dirt, scale, paint and other contaminants from the groove and the 20–30 mm area on either side. Thoroughly remove oxides and oil from the area to be welded, and grind until a metallic sheen is exposed.

3.2 Groove Preparation

a) In principle, grooves shall be prepared by mechanical machining. If mechanical machining is not feasible, plasma cutting or flame cutting is permitted, provided that the groove surfaces are thoroughly ground until a bright metallic sheen is exposed to remove scale.

b) The groove surfaces must be free from defects such as notches, cracks or grooves.

c) For thick plate welding, a V-groove is recommended, with an angle of 60°±5°, a root face of 1–2 mm, and a gap of 2–3 mm.

3.3 Welding Environment

a) Ambient temperature ≥5°C.

b) Relative humidity ≤80%.

c) Where ambient temperature and humidity do not comply, appropriate protective measures shall be taken.

4 Welding Materials

4.1 Principles for the Selection of Welding Materials

The selection of welding materials shall adhere to the following principles:

a) Weather resistance compatibility: The chemical composition of the welding materials shall be compatible with that of the base metal to ensure that the weld itself possesses weather resistance. The use of weather-resistant filler metals is recommended to avoid a reduction in the weld’ s corrosion resistance caused by the use of incompatible welding materials.

b) Low-hydrogen principle: The use of low-hydrogen electrodes or welding wire is recommended.

c) Compliance with standards: Welding consumables shall comply with relevant standards such as EN ISO 14341 (Gas Shielded Arc Welding) and EN ISO 18275 (Electric Arc Welding).

4.2 Recommended Welding Consumables

Welding Process	Filler Metal / Model	Reference Standard
Shielded Metal Arc Welding (SMAW)	AWS E7018-W (low-hydrogen weathering steel electrode)	AWS A5.5
Gas Metal Arc Welding (GMAW/MAG)	EN ISO 14341-A G 42 5 M G3Si1 / AWS A5.18 ER70S-G / AWS A5.28 ER80S-G	EN ISO 14341 / AWS A5.18 / AWS A5.28

4.3 Management of Welding Consumables

a) Low-hydrogen electrodes shall be dried in accordance with requirements prior to use.

b) Dried electrodes shall be stored in insulated containers and taken out as and when required.

c) Welding wire shall be kept clean and dry, free from oil and rust.

d) Flux shall be dried in accordance with the instructions.

5 Welding Process Parameters

5.1 Preheating Temperature

The preheating temperature is determined by the plate thickness and is recommended as follows:

Plate Thickness t (mm)	Preheating Temperature
t ≤ 20	60℃ – 80℃
20 < t ≤ 40	80℃ – 120℃
t > 40	100℃ – 150℃

Note: When the ambient temperature is below 0°C or the restraint on the weld joint is significant, the preheating temperature should be appropriately increased.

5.2 Interpass Temperature

a) During multi-pass welding, the interpass temperature must be controlled, generally maintained between 100°C and 150°C.

b) The interpass temperature should not exceed 250°C to avoid excessive softening of the weld and the heat-affected zone.

c) The temperature measurement point should be located approximately 50 mm from the centreline of the weld.

5.3 Welding Heat Input

a) Recommended heat input range: 0.5 kJ/mm – 2.0 kJ/mm.

b) Excessive heat input may lead to copper segregation and reduced toughness in the HAZ, whilst insufficient heat input may compromise fusion quality.

5.4 Shielding Gas

Welding Process	Shielding Gas	Purity Requirement
MAG welding	80% Ar + 20% CO_2	Ar ≥99.99%, CO_2 ≥99.5%

5.5 Recommended Welding Parameters

Note: The following are reference values; actual parameter values should be determined in accordance with the welding consumables manual and the welding procedure qualification report (PQR).

5.5.1 Reference Parameters for SMAW Welding (Φ3.2/4.0 mm electrodes):

Electrode Diameter (mm)	Current I (A)	Voltage U (V)	Speed v (cm/min)	Interpass Temperature (℃)
Φ3.2	100 - 130	22 - 25	10 - 15	≤ 200
Φ 4.0	140 - 180	24 - 26	12 - 18	≤ 200

5.5.2 Reference Parameters for MAG Welding (Φ1.2 mm wire):

Weld Pass	Current I (A)	Voltage U (V)	Speed v (cm/min)	Gas Flow Rate (L/min)	Interpass Temperature (°C)
Root pass	180 - 220	22 - 24	25 - 35	20 - 25	≤ 200
Filling pass	240 - 280	25 - 27	30 - 40	18 - 22	≤ 200
Cover pass	220 - 260	24 - 26	28 - 38	18 - 22	≤ 200

5.6 Tack Welding

a) The length of the tack weld shall not be less than 50 mm.

b) Prior to tacking, the weld area and both sides thereof shall be preheated to a temperature appropriate for the plate thickness.

c) The welding consumables used for tacking shall be the same as those used for the main weld.

d) Tack welds shall be evenly distributed to prevent stress concentration.

6 Key Points for Welding Operations

6.1 General Requirements

a) Use a low-hydrogen welding process: Strictly control the sources of hydrogen to prevent hydrogen-induced cracking.

b) Multi-pass welding: Employ a multi-pass welding process; each weld pass should not be too thick to facilitate hydrogen escape and grain refinement.

c) Post-pass cleaning: After each pass, defects such as slag, porosity and spatter must be removed; the surface must be ground until a metallic sheen is visible before proceeding to the next pass.

d) Avoid excessive oscillation: The oscillation amplitude of the electrode (or wire) should not be excessive to prevent lack of fusion and slag inclusion.

6.2 Shielded Metal Arc Welding

a) Employ short-arc welding to maintain a stable arc.

b) Welding motion: straight, zigzag or crescent-shaped.

c) Avoid an excessively long arc during welding to prevent porosity.

6.3 Gas Shielded Arc Welding (MAG/MIG)

a) Ensure an adequate flow of shielding gas and that the nozzle is clean.

b) Avoid welding in windy conditions; take wind protection measures where necessary.

c) The distance between the contact tip and the workpiece should generally be maintained at 15–20 mm.

6.4 Welding Sequence

a) Groove cleaning and preheating

b) Tacking

c) Welding of the root pass

d) Layer-by-layer build-up welding (pay attention to interpass cleaning and temperature control)

e) Welding of the cover pass

f) Post-weld cleaning and inspection

7 Post-welding Treatment

7.1 Post-welding cleaning

a) Remove slag and spatter from the weld and both sides; grind and finish where necessary.

b) Weld appearance: free from cracks, porosity, inclusions and lack of fusion; weld height 0–3 mm.

7.2 Post-welding heat treatment

a) General structures: No heat treatment required.

b) Critical structures / thick plates (thickness ≥30 mm) / joints with high restraint / critical load-bearing structural components: Stress-relief annealing at 580–620 °C for 2 hours, followed by furnace cooling to 300 °C and air cooling.

c) The temperature and process for post-welding heat treatment shall be determined through welding procedure qualification.

7.3 Post-weld Slow Cooling

After welding is completed, measures shall be taken to maintain the temperature and allow for slow cooling to prevent rapid cooling of the weld, which may cause cold cracks and reduce residual stresses.

8 Welding Quality Inspection

8.1 Visual Inspection

a) The weld surface shall be free from defects such as cracks, porosity, undercut and lack of fusion.

b) The weld height shall comply with design requirements.

8.2 Non-Destructive Testing

Inspection Method	Application	Reference Standard
Ultrasonic Testing (UT)	Detection of internal defects	EN 10160 Class 2
Magnetic Particle Testing (MT)	Detection of surface and near-surface defects	EN ISO 17638
Penetrant Testing (PT)	Detection of surface-breaking defects	EN ISO 3452-1
Radiographic Testing (RT)	Detection of internal defects (when necessary)	EN ISO 17636

8.3 Mechanical Property Tests

Welding procedure qualification shall be carried out in accordance with EN ISO 15614-1 and shall include the following test items:

a) Tensile test

b) Bending test

c) Impact test (0 °C, ≥27 J)

d) Hardness test (where necessary)

9 Special Notes

a) The use of standard carbon steel welding consumables is strictly prohibited.

b) Control segregation of Cu, P and S.

c) Weathering steel is not recommended for galvanising or repainting; a stable rust layer forms naturally during use.

10 Referenced Standards

The main standards and specifications referenced in this procedure:

Standard	Title
EN 10025-5:2019	Hot rolled products of structural steels – Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
EN ISO 15614-1	Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys
EN ISO 5817	Welding – Fusion-welded joints in steel, nickel, titanium and their alloys (beam welding excluded) – Quality levels for imperfections
EN 1011-2	Welding – Recommendations for welding of metallic materials – Part 2: Arc welding of ferritic steels
EN ISO 14171	Welding consumables – Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels
EN ISO 14341	Welding consumables - Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and finegrain steels - Classification
EN 10160	Ultrasonic testing of steel flat products of thickness equal to or greater than 6

Standard	Title
	mm (reflection method)
EN ISO 6892-1	Metallic materials – Tensile testing – Part 1: Method of test at room temperature

Note: This procedure is intended solely as a general guidance document. Prior to actual construction, a welding procedure qualification shall be carried out in accordance with EN ISO 15614-1, and a formal welding procedure specification (WPS) shall be drawn up and approved by the relevant parties before implementation. The specific values of welding parameters (such as current, voltage, welding speed, preheating temperature, etc.) shall be determined through qualification tests and adjusted appropriately in accordance with the actual project conditions.

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