Special Welding Applications

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Today’s AISC Live Webinar

Welding - Special Applications

written and presented by

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Manager, Engineering Services,
The Lincoln Electric Company,
Cleveland, OH.
Chapter 12
Special Welding Applications

- Extending Anchor Rod
- Welding Anchor Rod to Base Plates
- Welding on Coated Steels
- Welding Heavy Sections
- Welding Under High Restraint

- Welding HSS
- Welding AESS
- Welding on Existing Structures
- Field Welding
- Heat Shrinking
Special Welding Applications

- Extending Anchor Rod
- Welding Anchor Rod to Base Plates
- Welding on Coated Steels
- Welding Heavy Sections
- Welding Under High Restraint

Investigate Mechanical Options
Investigate “Weldability”
Use Appropriate Detail
Special Welding Applications

<table>
<thead>
<tr>
<th>AWS Standard Terms &amp; Definitions (A3.0-94)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Weldability</strong>:</td>
</tr>
<tr>
<td>“The capacity of a material to be</td>
</tr>
<tr>
<td>welded under the imposed fabrication</td>
</tr>
<tr>
<td>conditions into a specific, suitably</td>
</tr>
<tr>
<td>designed structure, and to perform</td>
</tr>
<tr>
<td>satisfactorily in the intended service.”</td>
</tr>
</tbody>
</table>

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<th>ASTM A6/A6M, Section X3</th>
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<td><strong>Weldability</strong>:</td>
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<tr>
<td>“A term that usually refers to the</td>
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<tr>
<td>relative ease with which a metal can</td>
</tr>
<tr>
<td>be welded using conventional</td>
</tr>
<tr>
<td>practice.”</td>
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</tbody>
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</thead>
<tbody>
<tr>
<td>• Based on composition</td>
</tr>
<tr>
<td>• Driven by carbon content</td>
</tr>
<tr>
<td>• Compounded by alloy content</td>
</tr>
<tr>
<td>• Related to “hardenability”</td>
</tr>
<tr>
<td>• “Hot cracking” concerns as well (S, Ph, others)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Weldability Concerns With Anchor Rod Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>• High Carbon</td>
</tr>
<tr>
<td>• High Alloy</td>
</tr>
<tr>
<td>• Undefined Carbon, Alloy</td>
</tr>
<tr>
<td>• Heat Treatment (Q&amp;T)</td>
</tr>
</tbody>
</table>
ASTM F1554

• Three Grades: 36, 55, 105

ASTM F1554

Grade 36
– Chemistry like that of ASTM A36
– Footnote: for rod diameters of up to ¾ in., the manganese content is “optional with the manufacturer, but shall be compatible with weldable steel.”
– Grade 55 substituted for Grade 36 (“only Grade 55 is made today”)

Grade 55, 105:
– Controls only on S and P
– Grade 55 can be ordered to Supplement S1 with limits on C, Mn, Si, P, S
– Also, two CE equations (“carbon” steel, “alloy” steel)

– “Weldability only assured if Grade 55 is ordered in accordance with Supplement S1”
– Grade 55 supplied for Grade 36
ASTM F1554
Grade 36:
– Chemistry indicates it should be readily weldable, but…..
– Confusion exists (mechanical properties or mechanicals plus composition)
– “Weldability only assured if Grade 55 is ordered in accordance with Supplement S1”
– Grade 55 supplied for Grade 36
Therefore, investigate on a case-by-case basis

ASTM F1554
Grade 55:
– Essentially no limits on chemistry indicate it may not be readily weldable
– “Weldability only assured if ordered in accordance with Supplement S1”

Therefore, investigate on a case-by-case basis

ASTM F1554

Grade 55:
– Essentially no limits on chemistry indicate it may not be readily weldable
– “Weldability only assured if ordered in accordance with Supplement S1”

Therefore, investigate on a case-by-case basis
ASTM F1554

**Grade 55:**
- Essentially no limits on chemistry indicate it may not be readily weldable
- “Weldability only assured if ordered in accordance with Supplement S1”

*Therefore, investigate on a case-by-case basis*

---

ASTM F1554

**Grade 55 with Supplement S1:**

*Good weldability should be assured.*

---

ASTM F1554

**Grade 105:**
- Essentially no chemistry control
- High strength
Special Welding Applications

ASTM F1554

Grade 105:
– Essentially no chemistry control
– High strength

Weldability likely to be poor.

• Extending Anchor Rod
• Investigate Mechanical Options
• Investigate “Weldability”
• Use Appropriate Detail
Note: chisel-point, not pencil-point
Special Welding Applications
Special Welding Applications

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Special Welding Applications

- Extending Anchor Rod
- **Welding Anchor Rod to Base Plates**
- Welding on Coated Steels
- Welding Heavy Sections
- Welding Under High Restraint
Special Welding Applications

- Welding Anchor Rod to Base Plates
- Investigate Mechanical Options
- Investigate “Weldability”
- Use Appropriate Detail
Special Welding Applications

- Welding Anchor Rod to Base Plates
- Investigate Mechanical Options
- Investigate “Weldability”
- Use Appropriate Detail

Fit of rod to base plate likely poor
• Extending Anchor Rod
• Welding Anchor Rod to Base Plates
• **Welding on Coated Steels**
• Welding Heavy Sections
• Welding Under High Restraint

**Welding on Coated Steels**
- Galvanized
- Painted

**M3. SHOP PAINTING**

5. Surfaces Adjacent to Field Welds

Unless otherwise specified in the design documents, surfaces within 2 in. (50 mm) of any field weld location shall be free of materials that would prevent proper welding or produce objectionable fumes during welding.
Special Welding Applications

Specification for Structural Steel Buildings
13th Edition

M4. ERECTION
5. Field Welding

Shop paint on surfaces adjacent to joints to be field welded shall be wire brushed if necessary to assure weld quality.

AWS D1.1
Structural Welding Code—Steel

5.15 Preparation of Base Metal
Surfaces to be welded, and surfaces adjacent to a weld, shall also be free from loose or thick scale, slag, rust, moisture, grease, and other foreign material that would prevent proper welding or produce objectionable fumes.

Common Elements

- Concern about fumes
- Concerns about inhibiting “proper welding”
- “Materials” broadly defined
- Outcome-based requirements
Welding Safety

• See ANSI Z49.1 Safety in Welding, Cutting and Allied Processes
• Available by free download from AWS
  www.aws.org/technical/facts
• “Fact Sheets” from AWS, also available as free download
METAL FUME FEVER

OVERVIEW

Metal Fume Fever is the name for an illness that is caused primarily by exposure to zinc oxide fume (ZnO) in the workplace. The main cause of this exposure is usually breathing the fumes from welding, cutting, or brazing on galvanized metal. Metal Fume Fever is an acute allergic condition experienced by many welders during their occupational lifetimes. Studies indicate that the most common cause of metal fume fever is overexposure to zinc fumes from welding, burning, or brazing galvanized steel. Since galvanized steel is more and more common in industry, the chances of welders having to work on it are occurring more frequently all the time. Other elements, such as copper and magnesium, may cause similar effects.

If you encounter these symptoms, contact a physician and have a medical examination/evaluation. There is no information in the literature regarding the effects of long-term exposure to zinc oxide fumes.

PERMISSIBLE EXPOSURE LIMIT (PEL)

The current OSHA standard for zinc oxide fume is 5 milligrams of zinc oxide fume per cubic meter of air (mg/m³) averaged over an eight-hour work shift. NIOSH recommends that the permissible exposure limit be changed to 5 mg/m³ averaged over a work shift of up to 10 hours per day. 40 hours per week, with a Short-Term Exposure Limit (STEL) of 10 mg/m³ averaged over a 15-minute period. Consult the NIOSH standard, Criteria Document for Zinc Oxide.

HOW TO AVOID THE HAZARD

- Keep your head out of the fumes.
- Do not breathe fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area.
- If adequacy of the ventilation or exhaust is uncertain, have your exposure measured and compared to the Threshold Limit Values (TLV) in the Material Safety Data Sheet (MSDS) for the galvanized material.

American Institute of Steel Construction
Special Welding Applications

Quality Concerns

– Fusion
– Porosity
– Cracking

Fusion problems occur when weld does not fuse to steel.

Porosity in weld made on galvanized steel
Centerline crack in weld made on galvanized steel

AWS D19.0-72 Welding Zinc-Coated Steel

Factors affecting cracking tendencies on galvanized steel
- The silicon content of the weld metal
- The degree of penetration of the weld beyond the root
- The thickness of the base metal (which affects restraint)
- The coating weight of the zinc (a function of the coating thickness)
- The microstructure of the zinc coating, which is related to the base metal composition and the silicon content in particular

For critical applications
- Qualify WPS by test
- Limitations of Table 4.5 may not be adequate
- Closely replicate field conditions
- Test thickest coating condition

Special Welding Applications
- Extending Anchor Rod
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- Welding Under High Restraint
Special Welding Applications
Special Welding Applications

Heavier Sections
- Larger Welds
- More Shrinkage
- Increased Stress

Heavier Sections
- More Restraint
- More Triaxiality
- Less Ductility

Heavier Sections
- Less Rolling
- Slower Cooling
- Lower Toughness
Special Welding Applications

Greater Cracking Tendencies

Heavier Sections
Special Welding Applications

Fracture Toughness
Stress
Crack Size

Fracture Toughness
Stress
Crack Size

W14x730

22”
3”
18”

5”
Special Welding Applications
Special Welding Applications

101

102

103

104

Compression  Tension
ASTM A6, Supplementary Requirement S30
Charpy V-Notch Impact Tests for Structural Shapes—Alternate Core Location

20 ft-lbs (27J) @ +70 °F (+21 °C)

ASTM A6, Supplementary Requirement S5
Charpy V-Notch Impact Test

20 ft-lbs (27J) @ +70 °F (+21 °C)

J3.6 Filler Metal Requirements

20 ft-lbs (27J) @ +40 °F (+4 °C)
Special Welding Applications

Fracture Toughness

Stress

Crack Size

109

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111

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Longitudinal shrinkage of web weld

Longitudinal shrinkage of flange welds

Transverse shrinkage of welds

STRENGTH OF METALS UNDER COMBINED STRESSES

“This is an important concept and needs to be emphasized: no shear stress, no plastic deformation or flow.”

Maxwell Gensamer
1941
Special Welding Applications

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American Institute of Steel Construction 30
Special Welding Applications
Critical Shear Strength

1.2, 1.3

TENSILE

σ1

σ2

σ3

σ_yield

σ_tensile

Ductility

1.2, 1.3

TENSILE

σ1

σ2

σ3

σ_yield

σ_tensile

Fracture

1.2, 1.3

TENSILE

σ1

σ2

σ3

σ_yield

σ_tensile
Special Welding Applications

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SHEAR

\[ \sigma_1 \]

TENSILE

\[ \sigma_{\text{yield}} \quad \sigma_{\text{tensile}} \]

134

SHEAR

\[ \sigma_1 \]

TENSILE

\[ \sigma_{\text{yield}} \quad \sigma_{\text{tensile}} \]

135

SHEAR

\[ \sigma_1 \]

\[ \sigma_2 \]

\[ \sigma_3 \]

TENSILE

\[ \sigma_{\text{yield}} \quad \sigma_{\text{tensile}} \]

136

SHEAR

\[ \tau_{1-2} \]

\[ \tau_{1-3}, \tau_{2-3} \]

TENSILE

\[ \sigma_1 \]

\[ \sigma_{\text{yield}} \quad \sigma_{\text{tensile}} \]
Special Welding Applications

SHEAR

\[ \sigma_1, \sigma_2, \sigma_3 \]

\[ \tau_{1-2}, \tau_{1-3}, \tau_{2-3} \]

\[ \sigma_{\text{yield}}, \sigma_{\text{tensile}} \]

TENSILE
Special Welding Applications

SHEAR

\[ \tau_{1-2}, \tau_{1-3}, \tau_{2-3} \]

\[ \sigma_1, \sigma_2, \sigma_3 \]

\[ \sigma_{\text{yield}}, \sigma_{\text{tensile}} \]

Narrow Weld Access Hole

Residual Tension

Residual Compression

Crack

Wide Weld Access Hole

Residual Tension

Residual Compression
Special Welding Applications

Reduce Weld Metal Volume to Reduce Shrinkage Stresses

Fracture Toughness

Stress

Crack Size
Special Welding Applications

Control Placement of Final Weld Passes

Fracture Toughness

Stress

Crack Size

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Special Welding Applications

Fracture Toughness
Stress
Crack Size
Special Welding Applications

Preheat to 150° F before thermal cutting
Grind after thermal cutting
Inspect with PT or MT

Alternate Method of Making Weld Access Holes
Drilled Hole

Extend Cut for Access Hole From Drilled Hole

Cut Bevel
Special Welding Applications

No Need to Grind Curved Portion of Access Hole

Catenary Truss

164 ft.

Tension

- W14x500
- W14x245
- W14x370, 397
Special Welding Applications
Special Welding Applications

- Extending Anchor Rod
- Welding Anchor Rod to Base Plates
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- Welding Heavy Sections
- Welding Under High Restraint

Welding Under High Restraint

Increase Fracture Resistance
Reduce Shrinkage Stresses
Reduce Restraint

- Increase Fracture Resistance
  - Avoid cracks and notches
    - Smooth transitions
    - Ground flame cut and rough surfaces
    - Ream punched holes
  - Use materials with defined notch toughness
  - Increase preheat levels
### Welding Under High Restraint

#### Reduce Shrinkage Stresses
- Specify the smallest weld size possible
- For a given weld size, select details that will require the least amount of weld metal
- Control fitup
- Don’t overweld
- Limit weld reinforcement
- For a given weld size, make the weld in the fewest number of weld passes
- For double-sided joints requiring backgouging, limit the backgouging to only that which is required

#### Reduce Shrinkage Stresses (continued)
- Use filler metal with the lowest strength level possible
- In general, but not always, use higher levels of preheat, and heat a greater volume of weld metal
- Limit weld penetration
- Complete highly restrained weldments without interruption
- When around-the-clock welding is impossible, maintain around-the-clock interpass temperature control
- Plan the welding to ensure the assembly will need to be welded only once

### Welding Under High Restraint

- **Reduce Restraint**
  - When possible, fabricate small subassemblies, and then join subassemblies into the final assembly
  - Weld components expected to have the greatest shrinkage first, then weld the members with less anticipated shrinkage
  - Weld the most rigid components first, saving the more flexible components for welding later
  - When possible, sequence the welding of various joints so that the shrinkage movement of the parts is all toward a relatively fixed central location

#### Reduce Restraint (continued)
- For individual joints, balance shrinkage on opposite sides of the member, when possible
- Slight gaps of 1/32–1/16 in. help accommodate shrinkage. Soft steel spacer wires in between members can help in this regard
- Increasing the preheat, and increasing the volume of material preheated, can sometimes assist, particularly when transverse cracking is being experienced and the joint can be expanded thermally before welding
- Preset members before welding and allow them to move during welding
Special Welding Applications

- Welding HSS
- Welding AESS
- Welding on Existing Structures
- Field Welding
- Heat Shrinking

Special Welding Applications

- Welding HSS
  - Connections and HSS member size

Special Welding Applications

- Welding HSS
  - Connections and HSS member size
  - Overall configuration

Matched Connection
Special Welding Applications

Stepped Connection

Overlapped
Special Welding Applications

Overlapped

Gapped

Provide Access for Welding and Inspection

\[ \Psi = 30^\circ \text{ minimum} \]

Special Welding Applications

- Welding HSS
- Connections and HSS member size
- Overall configuration
- Cutting and preparing HSS
Special Welding Applications

Box HSS

Box HSS

Box HSS

Gapped
Special Welding Applications

Box HSS

Overlapped

Round HSS
Special Welding Applications

Round HSS

Box HSS

Box HSS

Box HSS
Special Welding Applications

Round HSS

Cannot insert this member

Round HSS

Round HSS

Round HSS
Special Welding Applications

- Welding HSS
- **Welding AESS**
- Welding on Existing Structures
- Field Welding
- Heat Shrinking
Special Welding Applications
Special Welding Applications

Welding AESS
- Use of Mock-ups
- Visual Inspection from the observer’s distance and perspective
- Note requirements on drawings
- Technical issues

Required for strength

May be required for AESS
May be required for AESS

Cost
Distortion

Code required practice

May be AESS specified practice

Workmanship Concerns
Inspection Concerns

Code required practice
May be AESS specified practice

How can flange CJP groove weld be made?

Will splice crack when insert is welded?

Acceptable D1.1 distortion
May be AESS Specified Tolerance

Free Download from AISC

Special Welding Applications

• Welding HSS
• Welding AESS
• Welding on Existing Structures
  • Field Welding
  • Heat Shrinking

Welding on Existing Structures
  • Historic Steels
  • Welding Under Load
  • Fire
  • Cold Worked/Strain Aging

Chapter 4 Metallurgical Issues

• Historic (Obsolete) Steels
  – ASTM A9
  – ASTM A7
  – ASTM A373
  – ASTM A242

Welding on Existing Structures
  • Check weldability of steel (especially if riveted)
Special Welding Applications

Welding on Existing Structures

- Historic Steels
- **Welding Under Load**
- Fire
- Cold Worked/Strain Aging
Special Welding Applications
Special Welding Applications

From ASM "High-Temperature Property Data: Ferrous Alloys"

ASTM A36

Yield  
Tensile

Temperature (°F)

Strength (ksi)

0 10 20 30 40 50

0 200 400 600 800 1000 1200 1400

ASTM A441

Yield  
Tensile

Temperature (°F)

Strength (ratio)

0 0.2 0.4 0.6 0.8 1.0

0 200 400 600 800 1000 1200 1400 1600 1800

From ASM "High-Temperature Property Data: Ferrous Alloys"
Welding on members under load

- The amount of material at temperatures >650 °F is negligible (Blodgett)
- Only a very small percentage of the cross section experiences reduced properties (Tide)
- The impact of the weld orientation (longitudinal versus transverse) is typically inconsequential (Ricker)
- Each situation should be checked

---

Welding on Existing Structures

- Historic Steels
- Welding Under Load
- Fire
- Cold Worked/Strain Aging
Welding on Existing Structures

General precaution: Fire!
- From combustibles
- From unintended work circuits

Effects of cold working

<table>
<thead>
<tr>
<th>Yield</th>
<th>Tensile</th>
<th>Elongation</th>
<th>Notch Toughness</th>
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Effects of cold working

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</table>
Strain Aging

- Occurs when steel is heated to 400-700°F
- Yield, tensile increase
- Ductility, notch toughness decrease
- Aggravated by presence of “free” nitrogen

Effects of strain aging

- Stress relief helps, but…
  - Typically impractical
  - Depending on alloy, may experience cracking (Cr, Mo, V, B)

Welding on plastically deformed members

- Reduced notch toughness make sure material is crack and notch free
- Reduced ductility minimize practices that increase ductility demand
Special Welding Applications

- Welding HSS
- Welding AESS
- Welding on Existing Structures
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- Heat Shrinking

Shop versus Field Welding

- Primarily an issue of cost
- Some environmental factors
- Position of welding
- Easier to control project in shop
Special Welding Applications

**MYTHS**

- Can’t get quality weld out-of-position
- Can’t get quality in the field
- No codes apply
- Welders aren’t “certified”
- WPSs aren’t used
- No audit program for field contractors
- No contractor supplied inspectors

**Special Welding Applications**

- Welding HSS
- Welding AESS
- Welding on Existing Structures
- Field Welding
- Heat Shrinking
Special Welding Applications

Heated region
Heat Shrinking

- 1200 °F temperature limit for hot rolled steels
- 1100 °F temperature limit for quenched and tempered steels
- Pre-stress of up to 50% of room temperature yield (Avent)

Heat Shrinking

- For new steel being curved
  - No change in modulus of elasticity (E)
  - Slight increase in yield and tensile strength
  - 10-25% increase in ductility
- For bent steel being straightened
  - Yield strength increases 10%
  - Tensile strength increases 4-6%
Special Welding Applications
Special Welding Applications
Special Welding Applications

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Listen to the Steel!

Special Welding Applications

- Welding HSS
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- Practical Connection Design for Economical Steel Structures
  De-mystify connection behavior and design
- Listen to the Steel – Duane Miller on Welding

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- Introduction to Seismic Steel Design and the AISC Seismic Provisions
  December 10, 2009
  Presented by Thomas A. Sabol

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