



FHWA Welding Reference Manual Development

T-14 Meeting | Burlington, VT | 27 June 2018



Document:

- ***Reference Manual for Welding of Metal Structures***
- **Federal Highway Administration – Office of Bridges and Structures**

- **Team:**
 - Ronnie Medlock (High Steel)
 - Heather Gilmer (HRV)
 - Dr. Duane Miller (Lincoln Electric)
 - HDR (Tony Ream)

- **FHWA:**
 - Justin Ocel

Objective

- Comprehensive reference manual
- Welding of highway structures with an emphasis on steel highway bridges
- Explain AASHTO/AWS D1.5/D1.5M “Bridge Welding Code” and the AWS D1.1/D1.1M “Structural Welding Code-Steel”, including relationships to structural performance and design intent
- Limited coverage of AWS D1.2/D1.2M “Structural Welding Code-Aluminum,” AWS D1.4/D1.4M “Structural Welding Code-Reinforcing Steel,” and AWS D1.6/D1.6M “Structural Welding Code-Stainless Steel.”
- Target audience
 - DOT employees and their representatives and consultants involved with the welding and fabrication of steel highway structures
 - Designers, fabricators, field/construction/materials engineers and other paraprofessionals associated with structural design, material and procedure specifications, drawing approval, welding, construction, inspection, and repair.

Outline:

1. INTRODUCTION

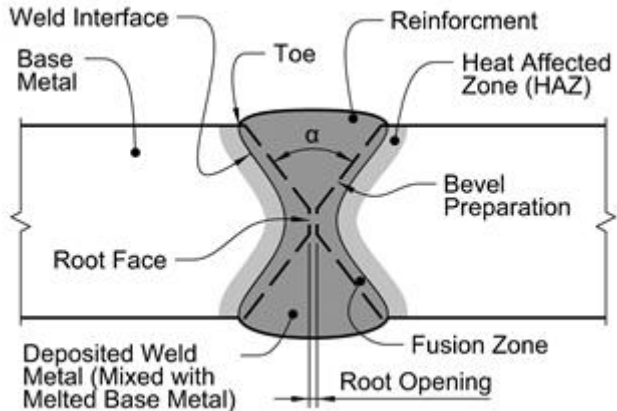
- 1.1. Manual Background
- 1.2. Welds
- 1.3. History and Importance of Welding in Bridges
- 1.4. Applicable Codes and Specifications
 - 1.4.1. Welding Codes
 - 1.4.2. Material Specifications
 - 1.4.3. Fabrication Specifications



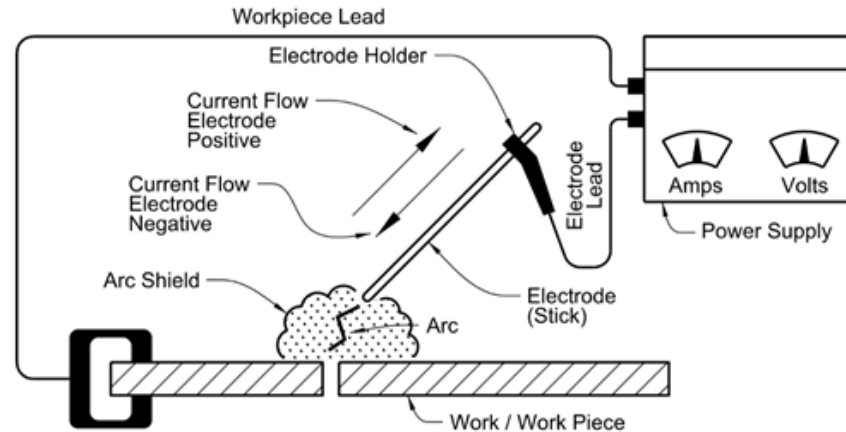
Outline:

2. MATERIALS, EQUIPMENT AND PROCESSES

- 2.1. Base Material
- 2.2. Filler Metal
- 2.3. Weld Metal and HAZs
- 2.4. Basics of Arc Welding
- 2.5. Welding Equipment



- 2.6. Overview of Welding Processes
 - 2.6.1. Submerged Arc Welding (SAW)
 - 2.6.2. Gas Metal Arc Welding (GMAW)
 - 2.6.3. Flux Core Arc Welding (FCAW)
 - 2.6.4. Shielded Metal Arc Welding (SMAW)
 - 2.6.5. Electro-slag Welding (ESW)
 - 2.6.6. Electro-gas Welding (EGW)
 - 2.6.7. Gas Tungsten Arc Welding (GTAW)
 - 2.6.8. Stud Welding



Outline:

3. QUALIFICATION OF WELDING PROCEDURE SPECIFICATIONS AND WELDERS

- 3.1. Welding Procedure Specifications
 - 3.1.1 Description
 - 3.1.2 Fabricator Research and Development
- 3.2. WPS Qualification and Creation of the Procedure
 - 3.2.1 Prequalification
 - 3.2.2 Qualification of WPSs for Groove and Welds and Multipass Welds
 - » 3.2.2.1 Heat Input
 - » 3.2.2.2 Production
 - » 3.2.2.3 Pretest / Verification
 - 3.2.3 Fillet WPS Qualification
 - 3.2.4 Electroslag Qualification
 - 3.2.5 Plug and Slot Qualification

- 3.3. WPS Qualification Tests
 - 3.3.1 Qualification Testing
 - 3.3.2 Groove Welding Qualification Test Plate
 - 3.3.3 Executing the Groove Weld Qualification Test Plate
 - 3.3.4 Groove Weld Qualification Tests
 - 3.3.5 Fillet Weld Soundness Tests
 - 3.3.6 Combinations of PQRs and WPSs
 - 3.3.7 WPSs for PJP Groove Welds
 - 3.3.8 Unlisted Materials
- 3.4. Welding Positions
- 3.5. Standard Joints
 - 3.5.1 Tolerances and Fit-up
 - 3.5.2 Joint Details
 - 3.5.3 Backgouging
 - 3.5.4 Non-Standard Joints

Outline:

3. QUALIFICATION OF WELDING PROCEDURE SPECIFICATIONS AND WELDERS, CON'T

○ 3.7. Welder Qualifications

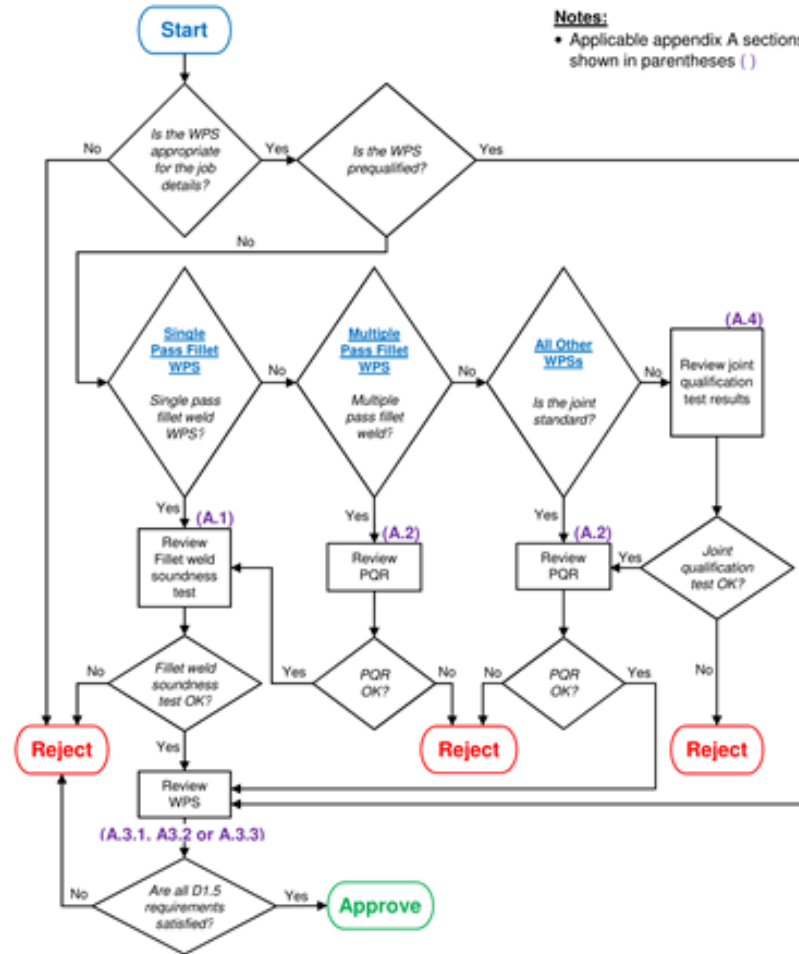
- 3.7.1 Achievement of Quality by Skilled Workers
- 3.7.2 Qualification versus Certification
- 3.7.3 Fabricator Responsibility
- 3.7.4 “Welders” versus “Operators” versus “Tack Welders”

- 3.7.5 Process
- 3.7.6 Weld Type: Groove versus Fillet Weld
- 3.7.7 Position
- 3.7.8 Qualification Frequency
- 3.7.9 Personnel Qualification Test
 - » 3.7.9.1. Materials
 - » 3.7.9.2. Groove weld tests
 - » 3.7.9.3. Fillet weld tests
 - » 3.7.9.4. Plug welds



Outline

APPENDIX A - GUIDE TO REVIEW AND APPROVAL OF WELDING PROCEDURE SPECIFICATIONS (WPSs) AND PROCEDURE QUALIFICATION RECORDS (PQRs) UNDER THE BRIDGE WELDING CODE (AASHTO/AWS D1.5)



Source: FHWA

Figure 87. Illustration. WPS approval flow chart.

Outline:

4. WORKMANSHIP AND WELD QUALITY

- 4.1. Quality and the Bridge Welding Code
- 4.2. Preheat and Interpass Temperature Controls
- 4.3. Hydrogen Control
 - 4.3.1 The Mechanism of Hydrogen Problems
 - 4.3.2 Welding Consumable Hydrogen Controls
- 4.4. Weld Discontinuities and Defects
 - 4.4.1 Planar Discontinuities
 - » 4.4.1.1 Incomplete Fusion
 - » 4.4.1.2 Incomplete Joint Penetration
 - » 4.4.1.3 Overlap
 - » 4.4.1.4 Laminations and Delaminations
 - » 4.4.1.5 Lamellar Tearing
 - 4.4.2 Cracks
 - » 4.4.2.1 Centerline Cracking

- » 4.4.2.2 Segregation-Induced Cracking
- » 4.4.2.3 Bead-shape-Induced Cracking
- » 4.4.2.4 Surface Profile Induced Cracking
- » 4.4.2.5 Heat-Affected Zone Cracking
- » 4.4.2.6 Transverse Cracking
- 4.4.3 Volumetric Discontinuities
 - » 4.4.3.1 Undercut
 - » 4.4.3.2 Porosity
 - » 4.4.3.3 Slag Intrusions
- 4.4.4 Weld Profile Requirements
 - » Excessive Concavity
 - » Excessive Convexity
 - » Inadequate Weld Size
 - » Under filled Weld Craters
- 4.5. Spatter
- 4.6. Arc Strikes

Outline:

4. WORKMANSHIP AND WELD QUALITY, CON't

○ 4.7. Distortion and Shrinkage

• 4.7.1 Types of Distortion

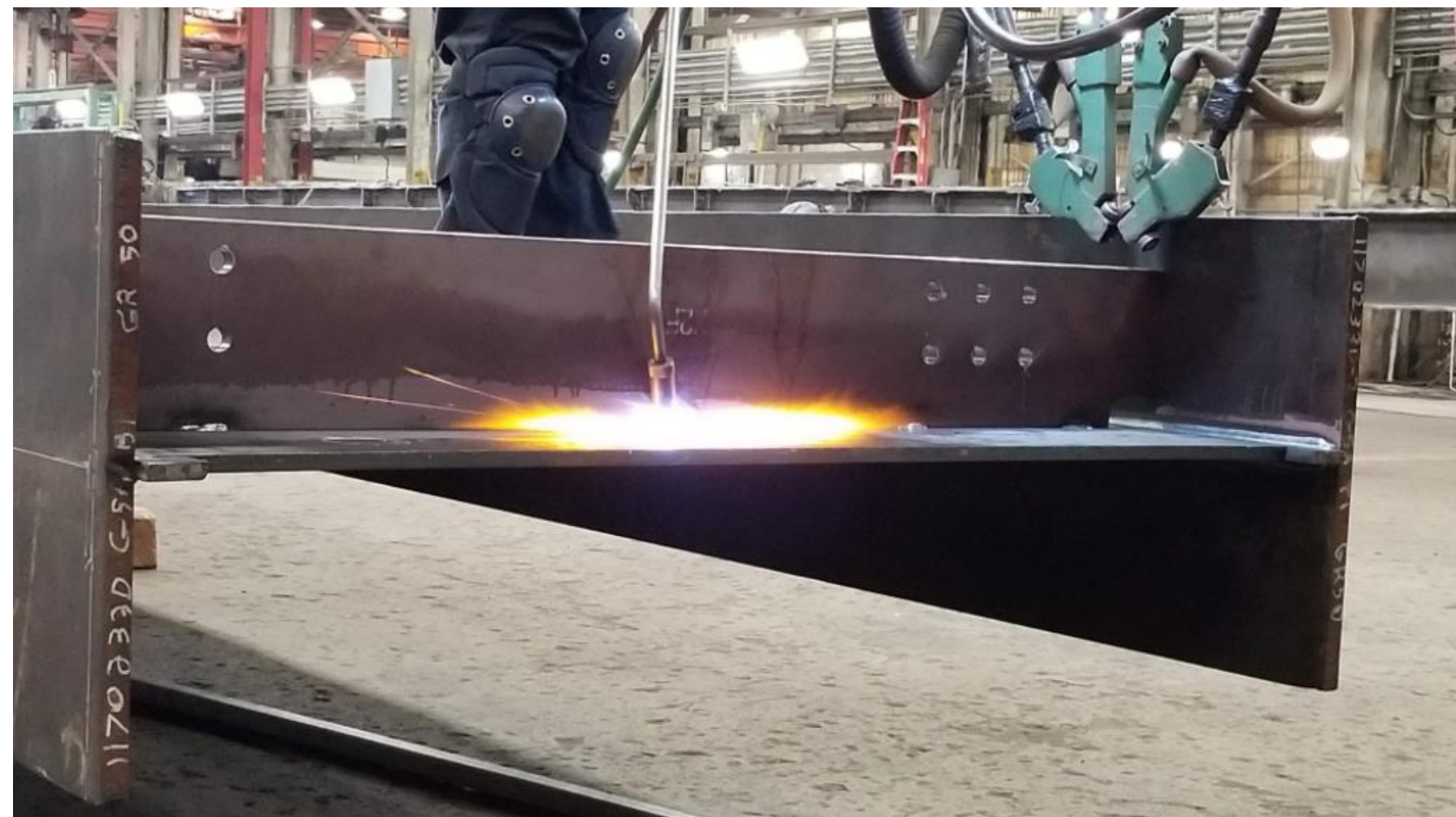
- » 4.7.1.1 Angular Distortion
- » 4.7.1.2 Transverse Shrinkage
- » 4.7.1.3 Longitudinal Shortening
- » 4.7.1.4 Twisting
- » 4.7.1.5 Longitudinal Sweep or Camber
- » 4.7.1.6 Buckling and Warping
- » 4.7.1.7 Rotational Distortion

• 4.7.2 Distortion Control Measures

- » 4.7.2.1 Adding Restraint
- » 4.7.2.2 Weld Placement
- » 4.7.2.3 Welding Sequence
- » 4.7.2.4 Stress Relief

○ 4.8. Weld Repairs

- 4.8.1 General
- 4.8.2 Internal Defects Discovered by NDT
- 4.8.3. Undercut Repair
- 4.8.4 Cracks



Outline:

5. INSPECTION AND QUALITY CONTROL

- 5.1. AISC Certification
- 5.2. Visual Weld Inspection
- 5.3. Non-destructive Examination Methods
 - 5.3.1. Magnetic Particle Testing (MT)
 - 5.3.2. Ultrasonic Testing (UT)
 - 5.3.3. Radiographic Testing (RT)
 - 5.3.4. Dye Penetrant Testing (PT)
- 5.4. Acceptance Criteria
- 5.5. Documentation



Outline:

6. AASHTO/AWS FRACTURE CONTROL PLAN (FCP) FOR NONREDUNDANT MEMBERS

- 6.1. History
- 6.2. Extent of Fracture Critical Condition
 - 6.2.1 Tension versus Compression Members
 - 6.2.2 Attachments

- 6.2.3 Design Detailing Practice
- 6.2.4 Shop Drawings
- Fracture Critical Members (FCMs)
- 6.3. Special Requirements for FCMs
- 6.4 System Redundant Members (SRMs) and Internally Redundant Members (IRMs)

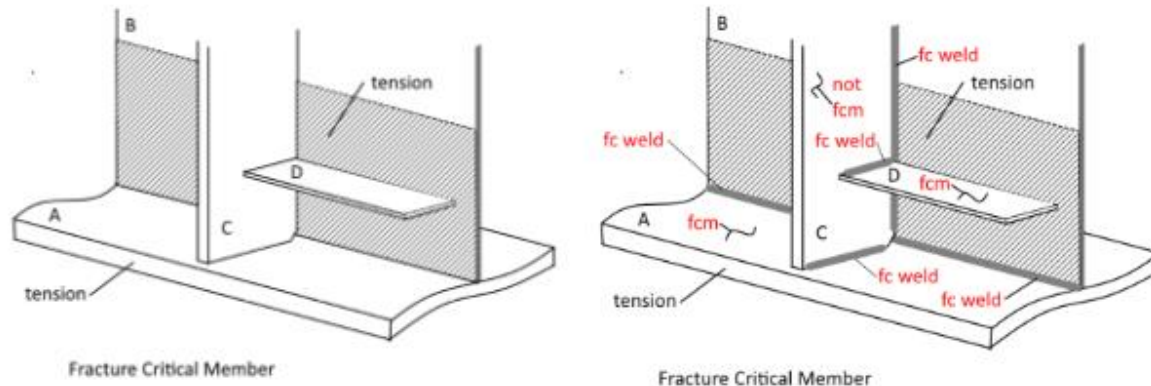


Figure X. Fracture critical detailing (left) and as-executed (right) (FHWA)

Outline:

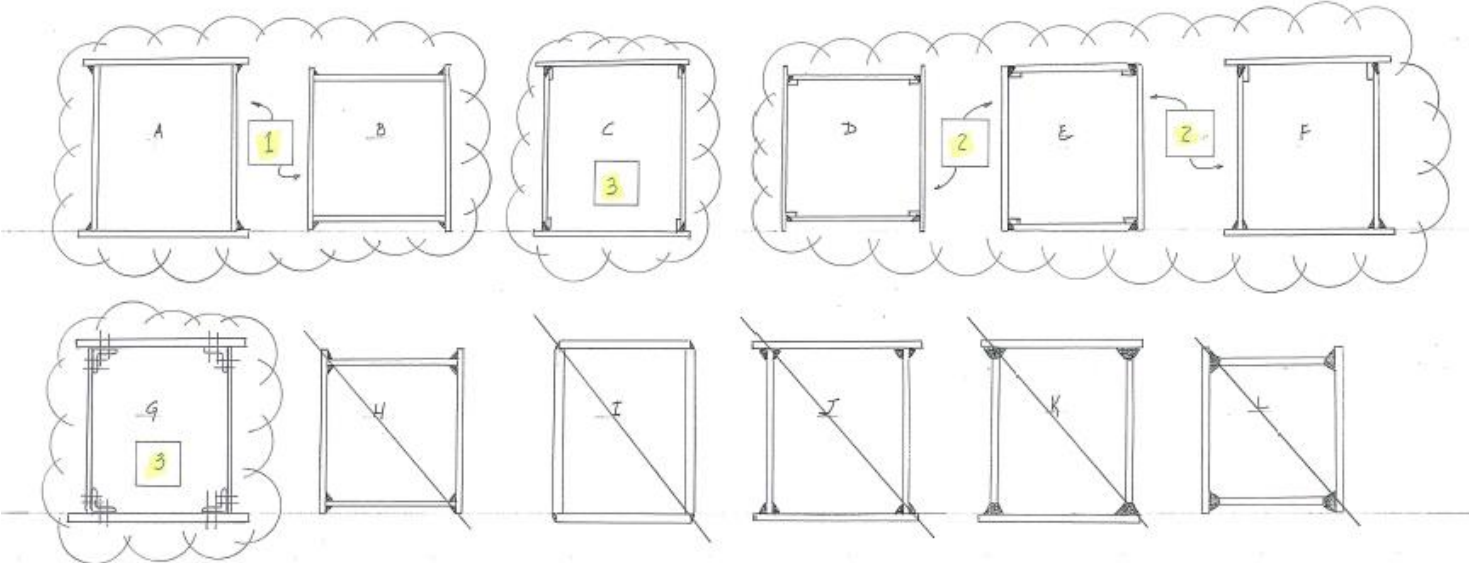
7. FABRICATION CONSIDERATIONS IN DESIGN OF WELDED STRUCTURES

- 7.1. Welding Symbols
- 7.2. Tack Welds
- 7.3. “Seal” Welds
- 7.4. Weld Backing
- 7.5. Reinforcing Fillet Welds
- 7.6. Intersecting Welds
 - 7.6.1. Structural Concerns
 - 7.6.2. Fabrication Concerns
- 7.7. Skewed Joints
- 7.8. Access for Welding
- 7.9. Weld Terminations
 - 7.9.1. Weld Tabs
 - 7.9.2. Holdbacks
 - 7.9.3. Transitions
- 7.10. Undermatching

Outline:

8. DETAILS FOR SPECIFIC BRIDGE WELDS

- 8.1. I-Girder Bridges
- 8.2. Tub Girder Bridges
- 8.3. Boxes
- 8.4. Special Situations



Outline:

9. THE ENGINEER'S ROLE IN WELDED FABRICATION

- 9.1. Introduction
- 9.2. Contract Documents
- 9.3. Approvals
- 9.4. Unexpected Circumstances

Outline:

10. ADDITIONAL TOPICS

- 10.1. Field Welding
 - 10.1.1. New Construction
 - 10.1.2. Welding of Existing Structures
- 10.2. Aluminum
- 10.3. Reinforcing Steel
- 10.4. Stainless Steel
- 10.5. Welding Coated Members
- 10.6. Innovations

Outline:

11. RESOURCES

○ AASHTO

- Mandatory:

- » Bridge Design Specification

- Consider:

- » Bridge Construction Specification

- » Traffic Structures Design

○ AWS standards

- Mandatory:

- » D1.5 - Bridge Welding Code

- » A2.4 - Symbols

- » A3.0 - Definitions

- Consider:

- » D1.1 – Structural Welding Code—Steel

- » D1.2 – Structural Welding Code—Aluminum

- » D1.5 – Structural Welding Code—Reinforcing Steel

- » D1.6 – Structural Welding Code—Stainless Steel

- » D1.7 – Guide for Strengthening and Repairing Existing Steel Structures

○ AASHTO/NSBA Steel Bridge Collaboration Standards - Include a discussion of the entire family, with emphasis on the welding related standards

○ AISC

○ Design Guide 21

○ FHWA

- Design and Construction of Welded Bridge Members and Connections

- Welding Inspection for Steel Bridge Fabrication

- HMEC Module C – Steel, Welding and Coatings Participant Workbook

○ Lincoln Electric - Procedure Handbook of Arc Welding

Outline:

12. APPENDICES

12.1. Guide to Review and Approval of Welding Procedures under AASHTO/AWS D1.5

12.1.1. Reviewing Prequalified Procedures

12.1.2. Groove Weld Procedures

12.1.2.1. High Heat Input

12.1.2.2. High-Low Heat Input

12.1.2.3. Production

12.1.3. Single-Pass Fillet Weld Procedures

12.1.4. Multi-Pass Fillet Welds Procedures

12.2. Table: Differences Between D1.5 and D1.1

Questions?

