Design of Seismic Welds

An Online Continuing Education Course for Engineers

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Design of Seismic Welds

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1. Introduction

Seismic force resisting systems (SFRS) are classified into systems designed and detailed for seismic resistance with Response Modification Factor (R) > 3, and systems not precisely detailed for seismic resistance (R=3).

(R > 3) Systems accommodate severe inelastic deformations better than (R = 3) systems because these systems are designed to resist lower seismic force by dividing the elastic seismic base shear by a larger R factor value. And for that, these systems shall be detailed to provide ductile failure mechanisms in certain structural members called “fusing elements”.

The connections of the fusing elements shall be designed to resist the high seismic demands due to the ductile failure of these elements. And the welds of these connections are called “Seismic Welds.”

Welds used in steel structures are classified into three types:

- SFRS Welds, located in seismic force resisting systems but not considered “Demand Critical Welds”, are discussed in (Section 3), and following AWS D1.8/D1.8M.
- Demand Critical Welds which are located in certain locations in SFRS, are discussed in (Section 4), in accordance with AWS D1.8/D1.8M.
- Non-seismic welds, that have no special seismic requirements, following AWS D1.8/D1.8M.

Examples of the connections that contain Demand Critical Welds:

- CJP welds the beam to the moment connection of Special Moment Frames (SMF), Intermediate Moment Frames (IMF), or Ordinary Moment Frames (OMF).
- Groove welds at column splices in Special Concentrically Braced Frames (SCBF), Special Moment Frames (SMF), and Intermediate Moment Frames (IMF).
- Welds at the column-to-base plate connection in Special Concentrically Braced Frames (SCBF), Special Moment Frames (SMF), and Intermediate Moment Frames (IMF).

This course covers the following topics:

1. Classification of seismic force-resisting systems (SFRS).
2. SFRS welds.
3. Demand Critical Welds.
4. Non-Seismic Welds
5. Protected Zones.
6. Detailing os Seismic Welds.

2. Classifications of Seismic Force Resisting Systems:

Steel Seismic force resisting systems (SFRS) are classified into systems designed and detailed for seismic resistance with Response Modification Factor (R) > 3, and systems not specifically detailed for seismic resistance (R=3).

ASCE7-22-Table.12.2-1 tabulates the steel seismic force-resisting systems, and lists their design coefficients (R, Ω_o, and C_d).

The design coefficient that is important to know in this course, is the Response Modification Factor (R), which is used to determine the seismic design base shear based on the selected SFRS.

The selection of SFRS depends on the following:

- Seismic Design Category (SDC).
- Structural height (h_n).

The steel and composite systems tabulated in ASCE7-22-Table.12.2-1 are:

- Ordinary Moment Frames (OMF). [R=3.5]
- Intermediate Moment Frames (IMF). [R=4.5]
- Special Moment Frames (SMF). [R=8]
- Special Trussed Moment Frames (STMF). [R=7]

- Ordinary Concentrically Braced Frames (OCBF). [R=3.25]
- Special Concentrically Braced Frames (SCBF). [R=6]
- Eccentrically Braced Frames (EBF). [R=8]
- Buckling Restrained Braced Frames (BRBF). [R=8]

- Special Plate Shear Walls (SPSW). [R=7]
- Special Cantilever Columns (SCS). [R=2.5]
- Ordinary Cantilever Columns (OCS). [R=1.25]

- Composite Ordinary Moment Frames (C-OMF). [R=3]
- Composite Intermediate Moment Frames (C-IMF). [R=5]
- Composite Special Moment Frames (C-SMF). [R=8]
- Composite Partially Restrained Moment Frames (C-PRMF). [R=6]

- Composite Ordinary Braced Frames (C-OBF). [R=3]
- Composite Special Concentrically Braced Frames (C-SCBF). [R=5]
- Composite Eccentrically Braced Frames (C-EBF). [R=8]

- Composite Ordinary Shear Walls (C-OSW). [R=5]
- Composite Special Shear Walls (C-SSW). [R=6]
- Composite Plate Shear Walls-Concrete Encased (C-PSW/CE). [R=6.5]
- Composite Plate Shear Walls-Concrete Filled (C-PSW/CF). [R=6.5]
- Coupled Composite Plate Shear Walls-Concrete Filled (CC-PSW/CF). [R=8]

- Steel systems not specifically detailed for seismic resistance, excluding cantilever columns. [R=3]

When the building is located in a high seismic zone (SDC: D, E, or F), it is not permitted to use an SFRS with the lowest R-value (R = 3 system). The philosophy of the code is to design the structure for a lower seismic base shear to get a more economical SFRS. Still, on the other hand, the building shall be detailed to be ductile to dissipate the high seismic energy.

The structure is classified into two types of elements:

- Fusing elements, which are designed for the lower seismic force. These elements dissipate the seismic cyclic forces during the earthquake through the inelastic deformations. Therefore, they shall be ductile enough to resist these high forces without brittle failure. Examples of these elements are:
    - Braces in OCBF, SCBF.
    - Beams in OMF, IMF, and SMF.
    - Steel plate in SPSW.

- Boundary elements are designed for the amplified seismic force set by AISC341-22. These elements bound the fusing elements and should be elastic during and after the earthquake. Examples of these elements are:
    - Braces connection, column, and struts in OCBF, SCBF.
    - Beam/column connection, and columns in OMF, IMF, and SMF.
    - Columns, and beams in SPSW.

To fulfill this philosophy, the AISC341-22 sets the following requirements:

- Fusing elements shall be a highly ductile member or moderately ductile member (width to thickness ratio), to dissipate the high amounts of seismic energy without brittle failure.
- Some of the fusing elements (beams in moment frames) shall be laterally restrained to accommodate the yielding failure of the fusing elements, especially at plastic hinge zones.
- Some of the fusing elements (braces in braced frames) shall have limited slenderness ratios.
- Connections of fusing elements, or the boundary members (beams, struts, or columns) shall be designed for the amplified seismic forces set by the AISC341-22, or for the capacity of the fusing element, to remain elastic and to accommodate the inelastic deformation of the fusing elements, such as plastic yielding of the frame beams, tensile yielding of braces, or compression buckling of braces.
- Some of the boundary elements shall be highly ductile members or moderately ductile members.

3. Seismic Force Resisting System Welds:

The difference between seismic welds used in high-seismic steel systems, and the ordinary welds used in systems not specifically detailed for seismic resistance is that the welds shall be strong enough to resist the applied loads without fracture, allowing the fusing elements to deform inelastically.

The seismic welds shall have the following properties:

- Strong and ductile, which could be achieved by properly selecting filler metals and following the inspection methods set by AWS D1.8/D1.8M.
- Fracture-resistant: to accommodate the high seismic forces in different temperatures. Fracture resistance of the welds depends on the following:

- The welds shall be free of <u>cracks or crack-like discontinuities</u>, these cracks are caused by incomplete fusion, some lag inclusions, lamellar tearing, and planar discontinuities. AWS D1.8/D1.8M and AISC Seismic Provisions set the following quality inspections to check that the welds are free of cracks:
    1. Emphasizing hydrogen control.
    2. Non-Destructive Tests (NDT) after the welding process.
    3. Proper welding procedures and qualified welded workmanship.

- The welds shall be free of <u>stress concentrations</u>, such as notches and gouges from flame cutting, weld toes, left-in-place weld tabs, and weld discontinuities (undercut, underfill, and porosity).

- To elimiate the effect of stress concentrations, AWS D1.8/D1.8M sets fabrication requirements regarding the following:

1. Steel Backing:

AISC Seismic Provisions (AISC341) and Preq... IMF AISC 358 determine where the backing is requi... re required after removal of backin... g. All of these cases are

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