Design of Seismic Bolts

An Online Continuing Education Course for Engineers

Course Number: MA-2013

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Design of Seismic Bolts

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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 specifically detailed for seismic resistance (R=3).

Seismic bolts are the bolts used in seismic force-resisting systems (SFRS) designed and detailed for seismic resistance with (R > 3).

(R > 3) systems severe inelastic deformations larger than (R = 3) systems because these systems are designed to resist lower seismic force by dividing the elastic seismic base shear by a larger value of R factor. 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.

The seismic bolts used in seismic force-resisting systems with (R > 3), studied in this course, shall be designed and detailed to resist the high cyclic forces resulting from the earthquake.

AISC341-22 sets the requirements for the design of these bolts to ensure the following:

- The bolts can transmit the tension and shear forces of the seismic loads.
- The bolts have satisfactory slip resistance to decrease the effect of connection slip on the seismic force-resisting system.
- Control the deformation of holes during earthquake events.
- Proper selection of hole types.

This course is prepared in conformance with AISC341-22, AISC360-22, and RCSC 2014/2020 (Specification for Structural Joints Using High-Strength Bolts).

This course covers the following topics:

1. Classification of seismic force-resisting systems (SFRS).
2. Types of bolts.
3. Bolt designation.
4. Types of bolted joints.

5. Types of holes.
6. Available strength of bolted joints.
7. General seismic requirements of bolted joints.
8. Specific seismic requirements of bolted joints.
9. Required strength of bolted joints.
10. Inspection of high-strength bolts.

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 precisely 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).

This course's design coefficient essential to know 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, but 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 pliable 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 malleable member or moderately ductile member (width to thickness ratio) to dissipate the high amounts of seismic energy without brittle failure.

- Some 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 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. Types of Bolts:

According to the specifications of the Research Council on Structural Connections (RCSC), bolts are classified into the following types:

a. High Strength Bolts:

High Strength Bolts are classified into 2 groups:

- Group 120: ASTM F3125/F3125M Grades A325, A325M, F1852, and ASTM A354 Grade BC.
- Group 144: ASTM F3148 Grade 144
- Group 150: ASTM F3125/F3125M Grades A490, A490M, F2280, and ASTM A354 Grade BD
- Group 200: ASTM F3043 and ASTM F3111

The most commonly used grades are ASTM A325 & ASTM A490.

b. Unfinished Bolts:

The most commonly used grades are ASTM A307.

4. Bolts Designation:

When identifying bolts on design drawings, it shall be identified with the following designation:

a. Designation of threads in case of b... ype (snug tighten... ned):

- A490-X: as (X) mean ... ions of bolt stren...
- ... of bolt

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... on the shear acting on bolts and bearing acting on ... shown in Figure (01)