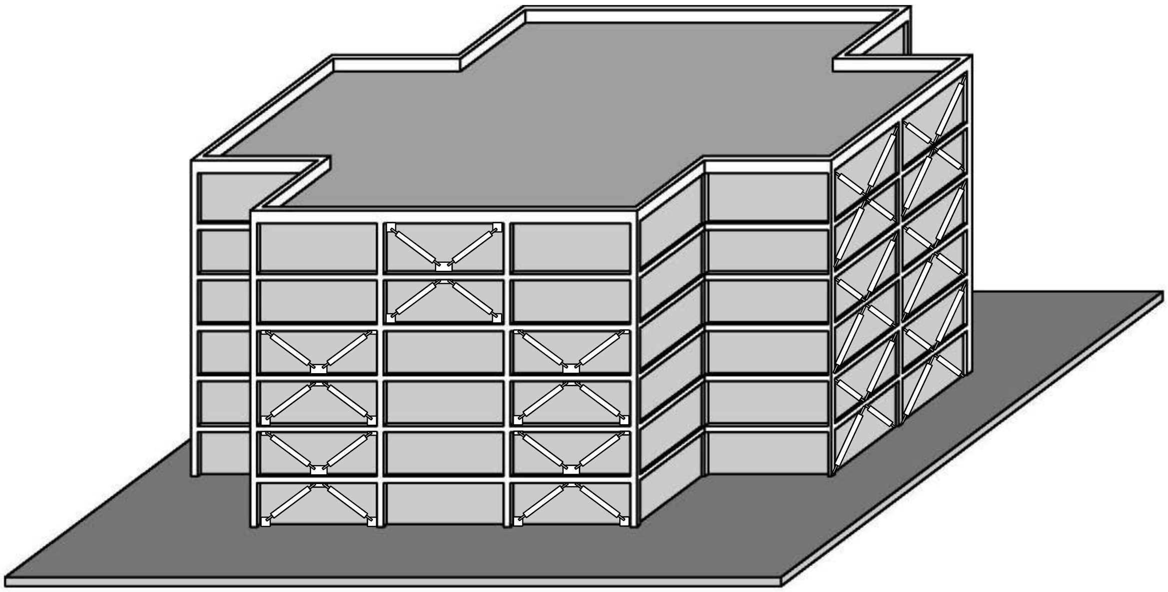
Design Example 2
Special Concentrically Braced Frame



OVERVIEW

This example shows procedures for the design of special concentrically braced frame (SCBF) buildings. It is intended to provide specific methods for the design of braced frames that comply with the *International Building Code* and the AISC *Seismic Provisions for Structural Steel Buildings* (AISC 341), guiding designers toward the careful consideration of the performance of concentrically braced frame structures under severe seismic loading. Certain recommendations provided are considered best practice; nevertheless, the calculation methods illustrated are applicable to a wide range of designs.

The SCBF system has been developed over several cycles of building codes as a moderately ductile system that can withstand moderate inelastic drift while maintaining strength. In order to provide this performance, SCBF braces must accommodate significant compression buckling demands. In addition, the system must be able to realize the strength and stiffness of braces subject to tension as the strength and stiffness of buckled braces in compression diminishes.

Thus, SCBF are intended to have post-elastic behavior that differs significantly from the elastic distribution of forces. A simple linear analysis of force distributions is insufficient, and an amplification factor is, in many cases, insufficient as well. Design rules for SCBF have thus always contained some form of requirement for consideration of post-elastic conditions.

The 2016 edition of AISC 341 has gone further than previous codes in making this latter requirement an explicit requirement. The provisions require that beams and columns have sufficient strength to withstand forces corresponding to two different conditions: the maximum forces the frame can resist (with frame forces corresponding to braces reaching their expected buckling strength and expected tension strength) and the post-buckled condition (with frame forces corresponding to braces reaching a low estimated post-buckling strength and expected tension strength). These are essentially plastic-mechanism analysis requirements and are illustrated in this example.

As important as determining design forces for frame members is the detailing of connections to accommodate building drift and ductility demands. To accommodate building drift, the effect of gussets on the beam-to-column connection and the column base-plate connection must be considered. These gusseted connections should be considered fully rigid unless special detailing is used to allow for relative rotation. (The use of typical “simple” connections in combination with a gusset plate is insufficient to guarantee adequate rotation capacity.) Connections considered rigid will develop large moments at the design story drift, and AISC 341 requires that the connection have flexural strength corresponding to the strength of the beam or of the column.

In this example, a fully rigid beam-to-column connection is employed. This connection is a combination of the gusset plate with an SMF welded unreinforced flange-welded web (WUF-W) connection. The design of alternative connections (including the accommodation of rotation) is illustrated in the AISC *Seismic Design Manual*.

Accommodating brace compression ductility demands entails detailing the gusset plate to allow for brace rotations or designing the connection as a fixed end for the brace. In this example, the former approach is taken, with a hinge plate oriented to allow for in-plane rotation. Alternative designs are illustrated in the AISC *Seismic Design Manual*.

This example does not include the design of a base-plate connection. However, Design Example 9 illustrates a base-plate design for a buckling restrained braced frame and can serve as a guide for SCBF base plates.

For more information on the SCBF system, see *SEAOC Blue Book* article 08.03.050: “Concentric Braced Frames”; August 2008.

OUTLINE

1. Building Geometry and Loads
2. Design Base Shear and Load Combinations
3. Vertical and Horizontal Distribution of Load
4. Brace Sizing
5. Plastic Mechanism Analysis
6. Beam Seismic Forces
7. Column Seismic Forces
8. Detailing and Design of Connections
9. Additional Considerations
10. Items Not Addressed in This Example

1. Building Geometry and Loads

1.1 GIVEN INFORMATION

The building is a six-story office building located in San Francisco, CA, in Seismic Design Category D. See Appendix A for the following information:

- Building dimensions.
- Floor and roof weights.
- Latitude and longitude.
- Soil type.
- Spectral accelerations.
- Load combinations including the vertical seismic-load effect.

1.2 FRAME LAYOUT

Early design decisions that should be made include:

- Location of frames.
- Configuration of frames.
- Relationship of braces to the architecture.

1.2.1 LOCATION OF FRAMES

In this example, the frames are located at the building perimeter, which is more efficient in controlling building torsion and ensuring redundancy. The plan layout of frames at floors 1–4 is shown in Figure 2-1.

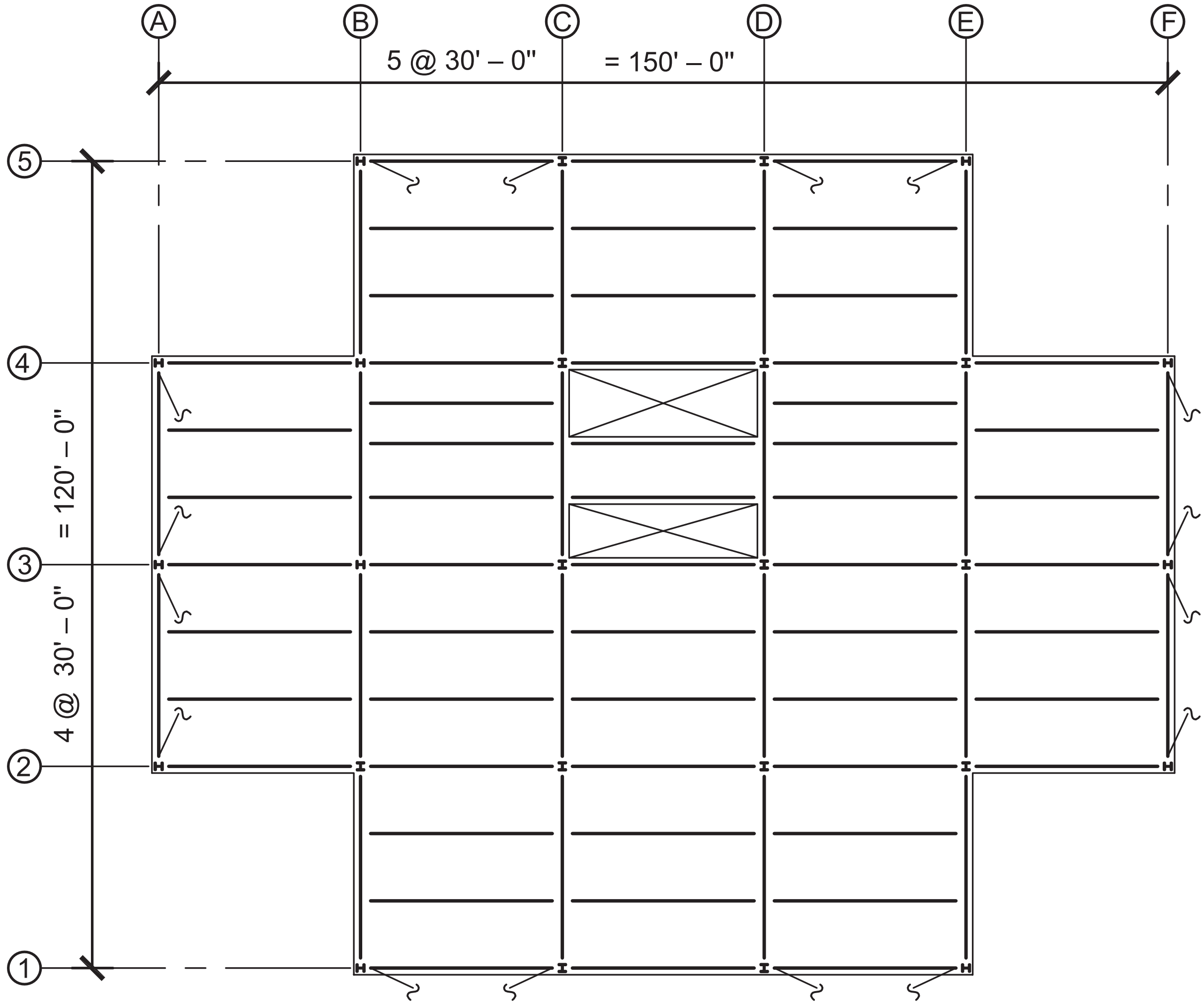


Figure 2-1. Plan

1.2.2 CONFIGURATION OF FRAMES

Frames are configured in a two-story X configuration, which is advantageous in limiting beam flexural demands in the post-buckled condition. Additionally, the frames are offset at floors 5 and 6. This reduces the column overturning demands, which is especially beneficial for column size (and consequently column-splice demands), base-plate demands, and foundation demands. This constitutes an irregularity, but this irregularity does not represent a dramatically different collector beam demand from those in similar regular configurations. A typical frame elevation is shown in Figure 2-2.

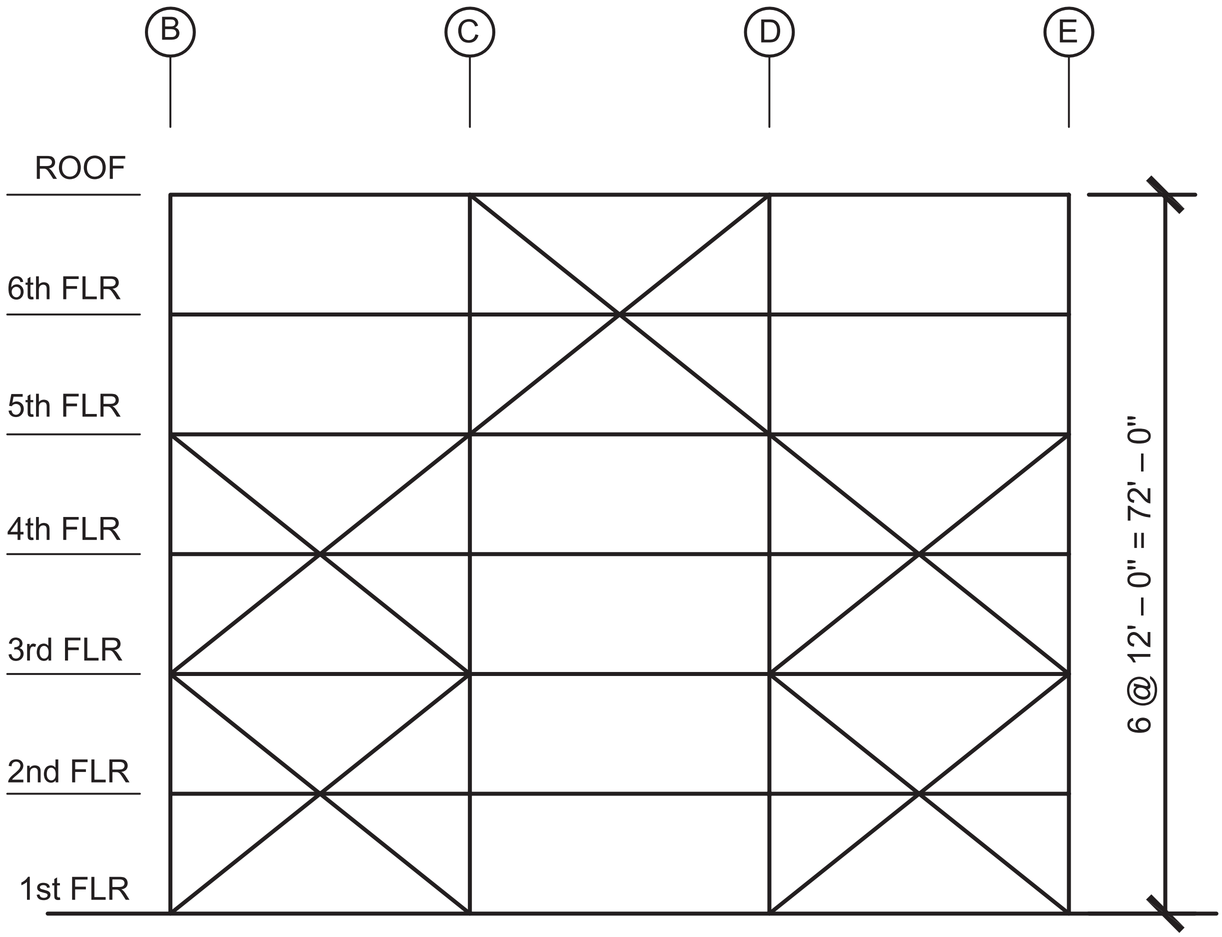


Figure 2-2. Frame 1 elevation

1.2.3 RELATIONSHIP OF BRACES TO THE ARCHITECTURE

Braces in this example are exposed. Thus, no special wall detailing is required to allow for brace buckling deformation. However, braces are located within 8 inches of the exterior glass, potentially leading to a falling hazard should braces buckle out of the plane of the frame, causing damage to the façade. Such a hazard could be mitigated in several ways, including increasing the physical separation or treating the glass to prevent falling debris. In this example, the hazard is eliminated by configuring braces to buckle in the plane of the frame by using a round section in combination with end detailing that favors in-plane over out-of-plane rotation. The detail employed at the beam-to-column connection is shown schematically in Figure 2-3.

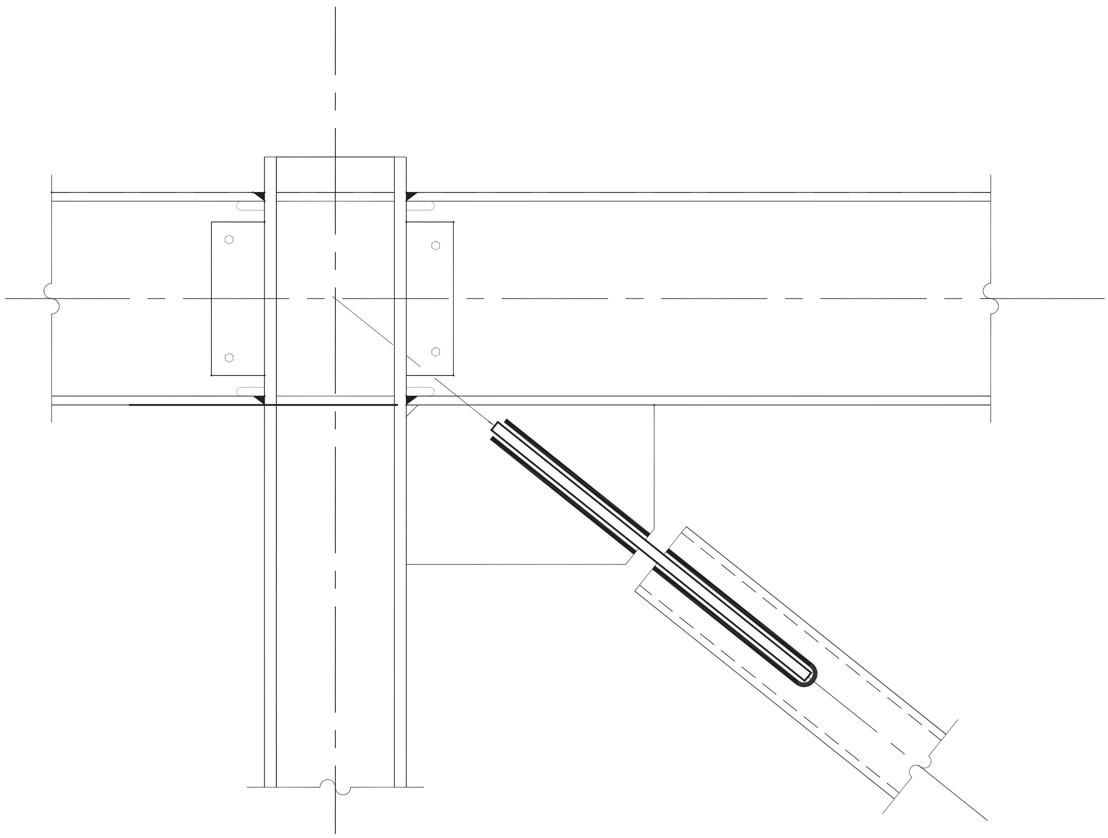


Figure 2-3. Typical gusset configuration

This detail has many advantages over more typical single-gusset-plate details. In addition to avoiding out-of-plane brace deformation, the detail avoids potential conflict between the composite deck and the hinge plate as the latter bends as a result of brace buckling. The detail is also highly adaptable to special conditions, including connections to sloped beams.