Design Example 1
Concrete Diaphragm Design—Four-Story Building

Overview

This example illustrates the design of concrete diaphragms, chords and collectors for a four-story office building with vertical and horizontal irregularities in accordance with the provisions of the 2012 *International Building Code* (2012 IBC) for Seismic Design Category (SDC) B and SDC D. The gravity load-resisting system consists of concrete beams and girders on the interior and exterior, which are supported by concrete columns. Lateral loads are distributed to the vertical elements through a $6^1/_2$-inch-thick normal weight concrete slab at each of the roof and floor levels. Resistance to lateral loads is provided by 12-inch-thick concrete shear walls in both directions. Typical floor plans and sections of the structure are shown in Figures 1-2 through 1-8. A three-dimensional view of the structure is shown in Figure 1-4.

The following steps provide a detailed analysis of some of the important seismic requirements for the diaphragm, chord and collector design in accordance with the 2012 IBC. Semi-rigid diaphragm is used to represent the floor and roof diaphragm in the lateral analysis procedure. ETABS is used to analyze the three dimensional model of the example building. Shell elements are used to model the diaphragm.

This example is not a complete building design. Many aspects have not been included and only select steps of the seismic design have been illustrated. The following irregularities are covered in this example:

a. Horizontal Irregularity Type 4

b. Vertical Irregularity Type 4

Outline

This example will illustrate the following parts of the design process:

1. **Determination of Diaphragm Demands for SDC B**
2. **Considerations for Horizontal and Vertical Irregularities**
3. **Determination of Diaphragm Shear at Second Level for SDC B for North-South Direction**
4. **Design of Diaphragm at Second Level for SDC B**
5. **Design of Collector at Third Level for SDC B for East-West Direction**
6. **Brief Discussion of Seismic Design Categories C through F**
7. **Determination of Diaphragm Demands for SDC D**
8. **Design of Diaphragm at Second Level for SDC D**
9. **Design of Collector at Third Level for SDC D**

Given Information

Site data: Site Class D (stiff soil), by default

Building data:

The example building is Risk Category II in accordance with Table 1.5-1 of ASCE 7-10.

ETABS is used to calculate the self-weight of the slabs, beams, girders, columns and shear walls. All member sizes assumed in the analysis are shown in Figures 1-2 and 1-3. The following are the modeling assumptions incorporated into the computer analysis:

- The concrete shear walls and concrete slabs were assigned a stiffness modifier of 0.35 to model cracked section properties (ACI 10.10.4.1).
- All building columns were assigned a stiffness modifier of 0.0001 to eliminate lateral force resistance.
- All nodes at the foundation level for columns were assigned pinned supports.
- All nodes at the foundation level for shear walls were assigned pinned supports.
- Self-weight of slabs, beams, columns and walls are automatically calculated by the program.
- Static analysis was carried out to design the example building.
- Live load of 100 psf is used for floors.
- Additional dead loads:

Floor mass (seismic):	Ext. Cladding	10 psf
	Partitions	10 psf
	MEP	4 psf
	Flooring	2 psf
	Misc.	3 psf
		29 psf
Floor loads (gravity):	Ext. cladding	10 psf
	MEP	4 psf
	Flooring	2 psf
	Partitions	15 psf
	Misc.	3 psf
		34 psf
Roof mass (seismic):	Ext. cladding	5 psf
	Partitions	5 psf
	MEP	4 psf
	Roofing	3 psf
	Mechanical	10 psf
	Misc.	3 psf
		30 psf

Roof loads (gravity):	Ext. cladding	5 psf
	MEP	4 psf
	Roofing	3 psf
	Mechanical	10 psf
	Misc.	3 psf
		25 psf

Notes:

1. The exterior cladding weight (mass) was accounted for by including it as part of floor and roof mass. This is conservative and a more accurate representation would be to apply these loads as line loads applied to the perimeter beams of the analysis model.

2. Per ASCE Section 12.7.2, 10 psf is included for partition load.

3. The typical story height is 15 feet.

The following are the total seismic weights tributary to each floor level, as calculated by the computer program:

$$
\begin{aligned}
W_{\text{roof}} &= 3{,}524 \text{ k} \\
W_{\text{4th floor}} &= 3{,}720 \text{ k} \\
W_{\text{3rd floor}} &= 3{,}720 \text{ k} \\
W_{\text{2nd floor}} &= 3{,}720 \text{ k} \\
\Sigma W &= \overline{14{,}684 \text{ k}}
\end{aligned}
$$

Note: Seismic weights are equal for both the north-south and east-west directions.

The following material properties are assumed for this example:

$$
\begin{aligned}
f'_c &= 4{,}000 \text{ psi} \\
f_y &= 60{,}000 \text{ psi}
\end{aligned}
$$

Typical slab: $6^1/_2$-inch-thick with #5 @ 12 inch o.c., top and bottom in the east-west direction. Temperature and shrinkage reinforcement: #4 @ 12 inch o.c. in the north-south direction. See Figure 1-1 below.

Typical concrete framing member sizes are as follows:

Interior beams	21 × 24
Perimeter beams	21 × 24
Interior girders	24 × 28
Exterior columns	21 × 21
Interior columns	24 × 24

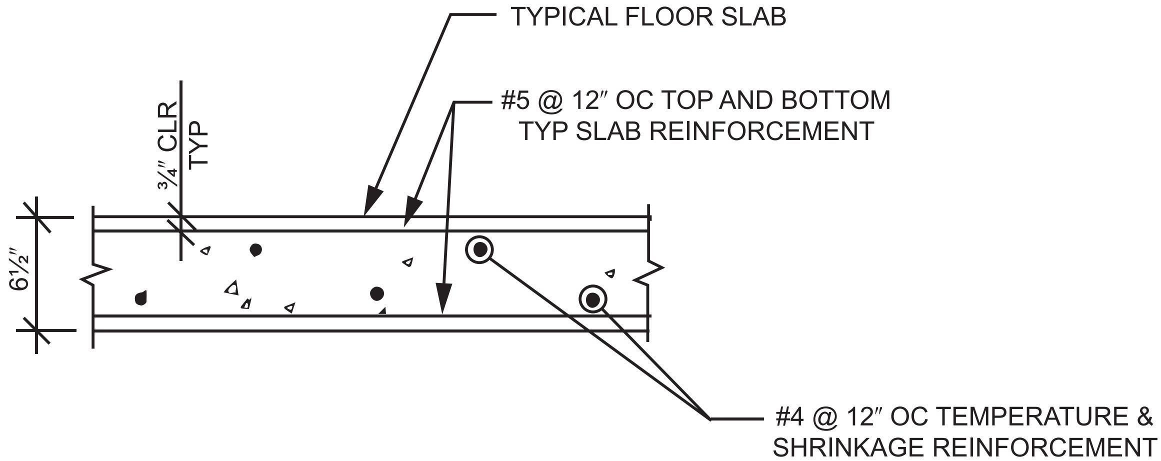

Figure 1-1. Typical concrete slab section

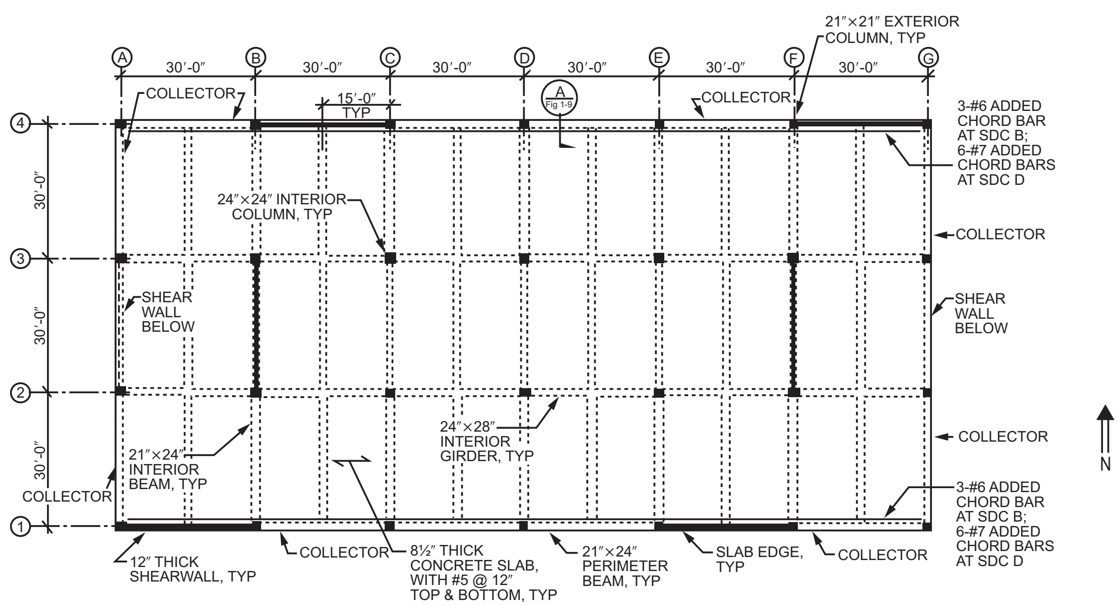

Figure 1-2. 2nd level floor plan

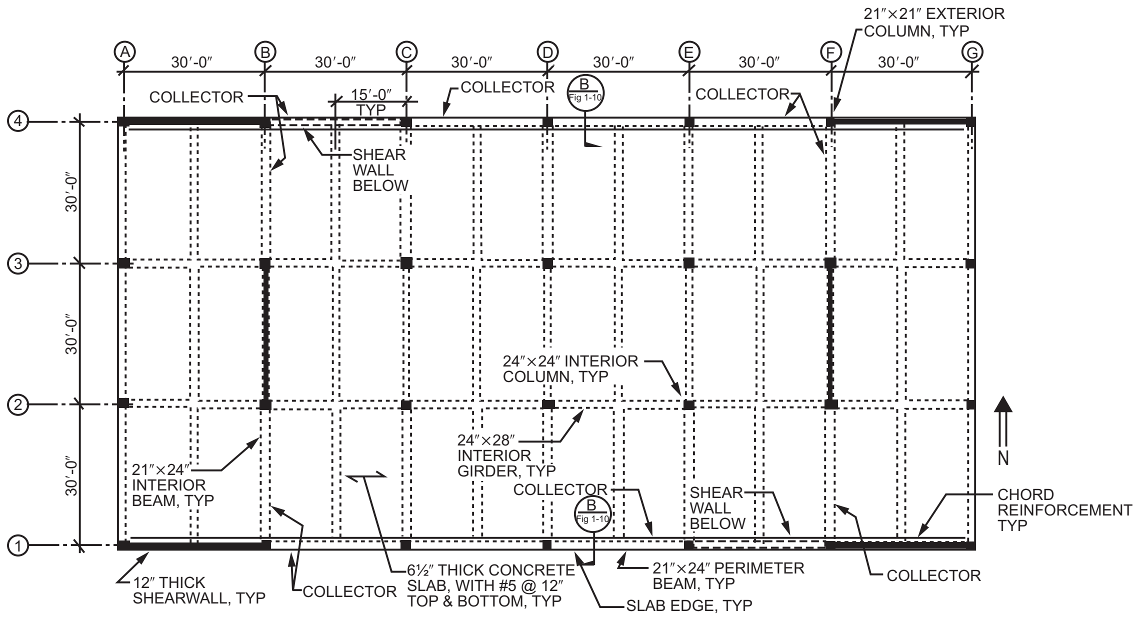

Figure 1-3A. 3rd level floor plan

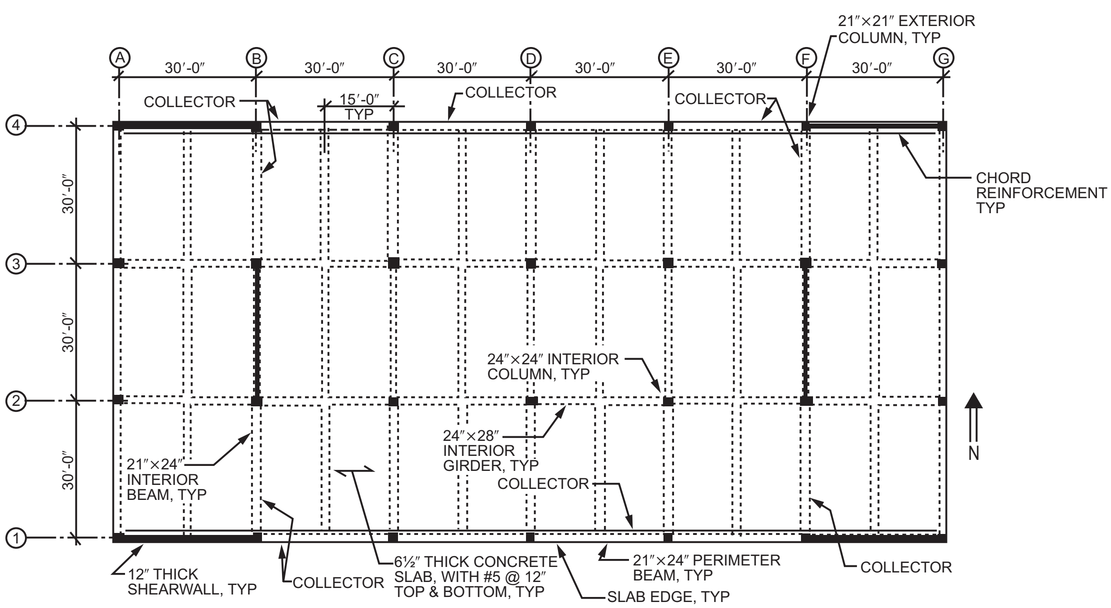

Figure 1-3B. 4th level floor plan

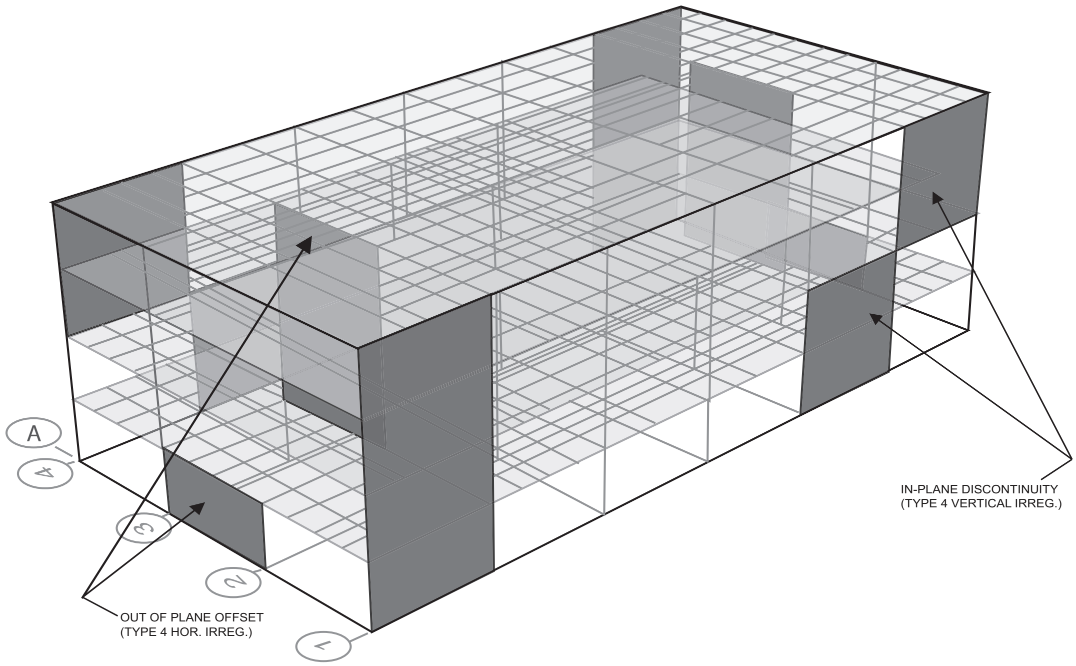

Figure 1-4. Three-dimensional view of the structure

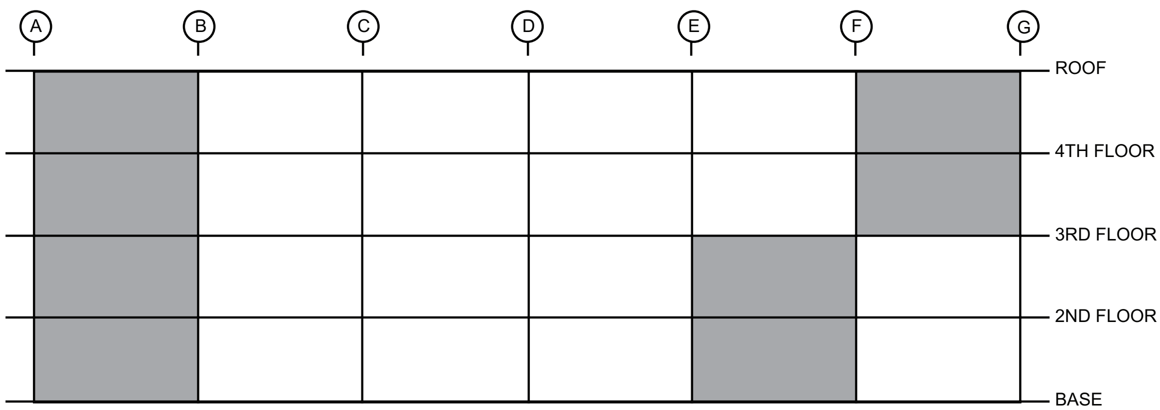

Figure 1-5. Typical E-W elevation (gridline 1)

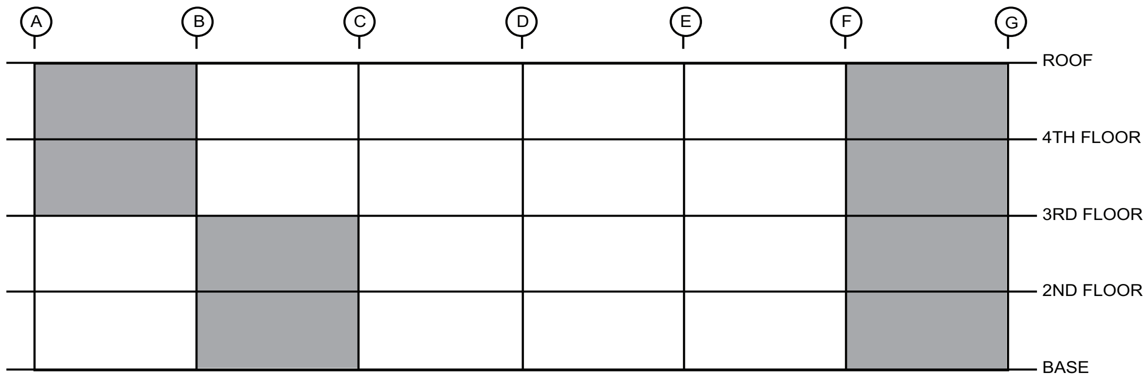

Figure 1-6. Typical E-W elevation (gridline 4)

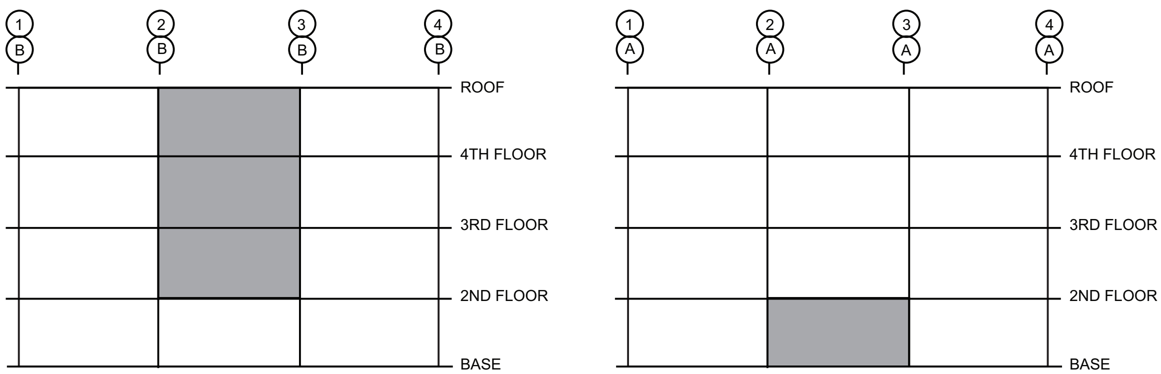

Figure 1-7. Typical N-S elevation (gridline B/A)