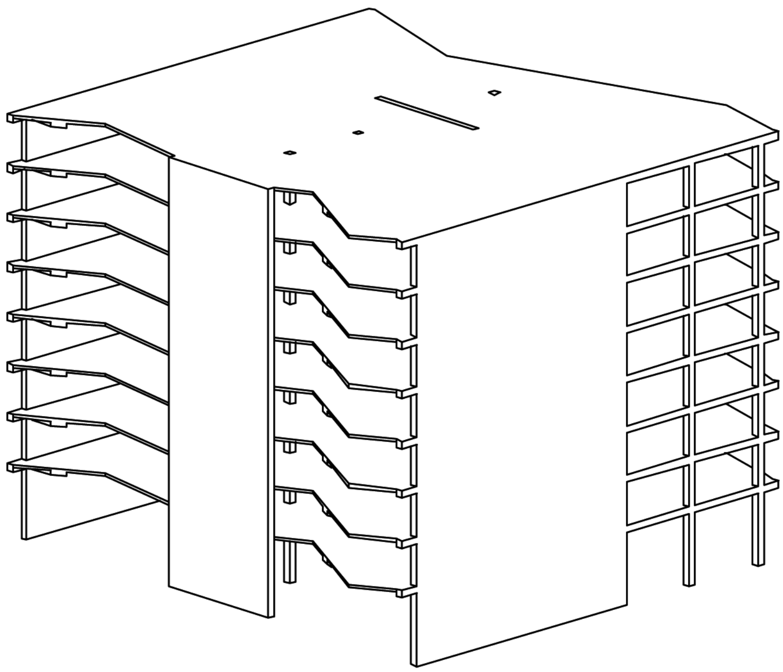
Design Example 1
Reinforced Concrete Wall



OVERVIEW

The structure in this design example is an eight-story office with load-bearing reinforced concrete walls as its seismic-force-resisting system. This design example focuses on the design and detailing of one of the 30-foot, 6-inch-long walls running in the transverse building direction.

The purpose of this design example is twofold:

1. To demonstrate the design of a solid reinforced concrete wall for flexure and shear, including bar cut-offs and lap splices.

2. To demonstrate the design and detailing of wall boundary zones.

The design example assumes that design lateral forces have already been determined for the structure and that the forces have been distributed to the walls of the structure by a hand or computer analysis. This analysis has provided the lateral displacements corresponding to the design lateral forces.

OUTLINE

1. Building Geometry and Loads
2. Load Combinations for Design
3. Preliminary Sizing of Wall
4. Flexural Strength at Base of Wall
5. Flexural Strength and Lap Splices over Height of Wall
6. Shear Strength of Wall
7. Shear Friction (Sliding Shear) Strength of Wall
8. Detailing of Wall Boundary Elements

1. Building Geometry and Loads — ASCE 7

1.1 GIVEN INFORMATION

This design example follows the general building code requirements of the 2012 *International Building Code* (2012 IBC) and ASCE 7. For structural concrete design, the 2012 IBC references the *American Concrete Institute Building Code* (ACI 318) as indicated in Section 1901.2. This example follows the requirements of ACI 318-11. Discussions related to the SEAOC Blue Book recommendations refer to the document *Recommended Lateral Force Recommendations and Commentary* (SEAOC, 1999) as well as the Blue Book online articles on specific topics (SEAOC, 2009) as applicable.

Figure 1–1 shows the typical floor plan of the structure. The design and analysis of the structure is based on a response modification coefficient, R, of 5 (ASCE 7 Table 12.2–1) for a bearing wall system with special reinforced concrete shear walls. The deflection amplification factor, C_d, is 5. The SEAOC Blue Book (2009, Article 09.01.010) expresses the opinion that the R value for concrete bearing-wall systems ($R = 5$) and that for walls in building frame systems ($R = 6$) should be the same, which may be justified based on detailing provisions. To be consistent with the current code requirements though, this design example uses $R = 5$.

Mapped spectral response acceleration values from ASCE 7 maps (Figures 22–1 through 22–11) are

- $S_1 = 0.65$
- $S_S = 1.60$
- Site Class D
- Risk Category II

- Seismic Design Category D
- Redundancy factor, ρ = 1.0
- Seismic Importance factor, I = 1.0
- Concrete strength, f'_c = 5000 psi
- Steel yield strength, f_y = 60 ksi

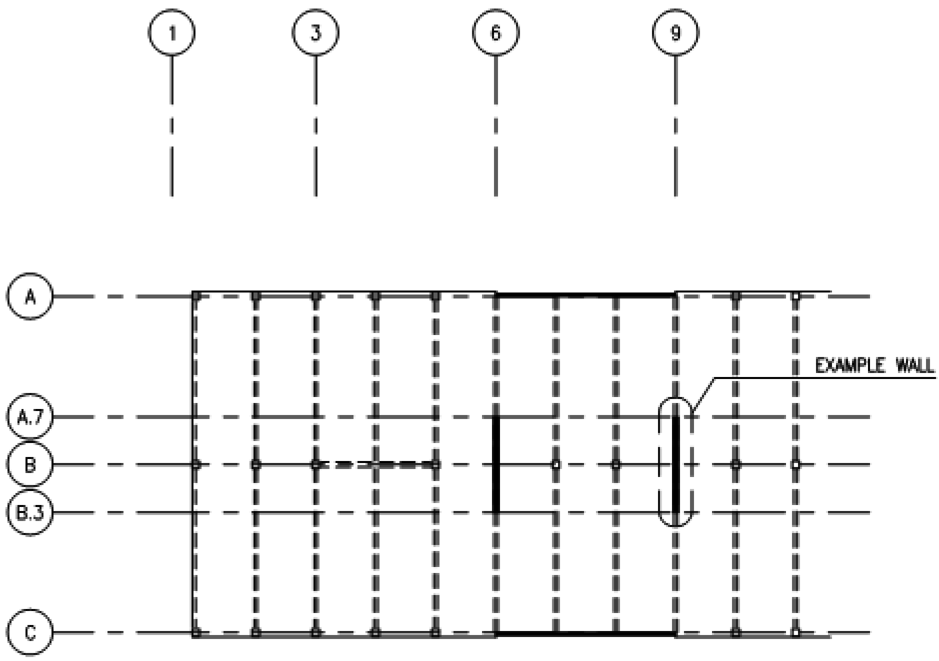


Figure 1–1. Floor plan

1.2 DESIGN LOADS AND LATERAL FORCES

Figure 1–2 shows the wall elevation and shear and moment diagrams. The wall carries axial forces P_D (resulting from dead load including self-weight of the wall) and P_L (resulting from live load) as shown in Table 1–1. Live loads have already been reduced according to IBC Section 1607.10. The shear, V_E, and moment, M_E, resulting from the design lateral earthquake forces are also shown in Table 1–1. The forces are from a linear static analysis.

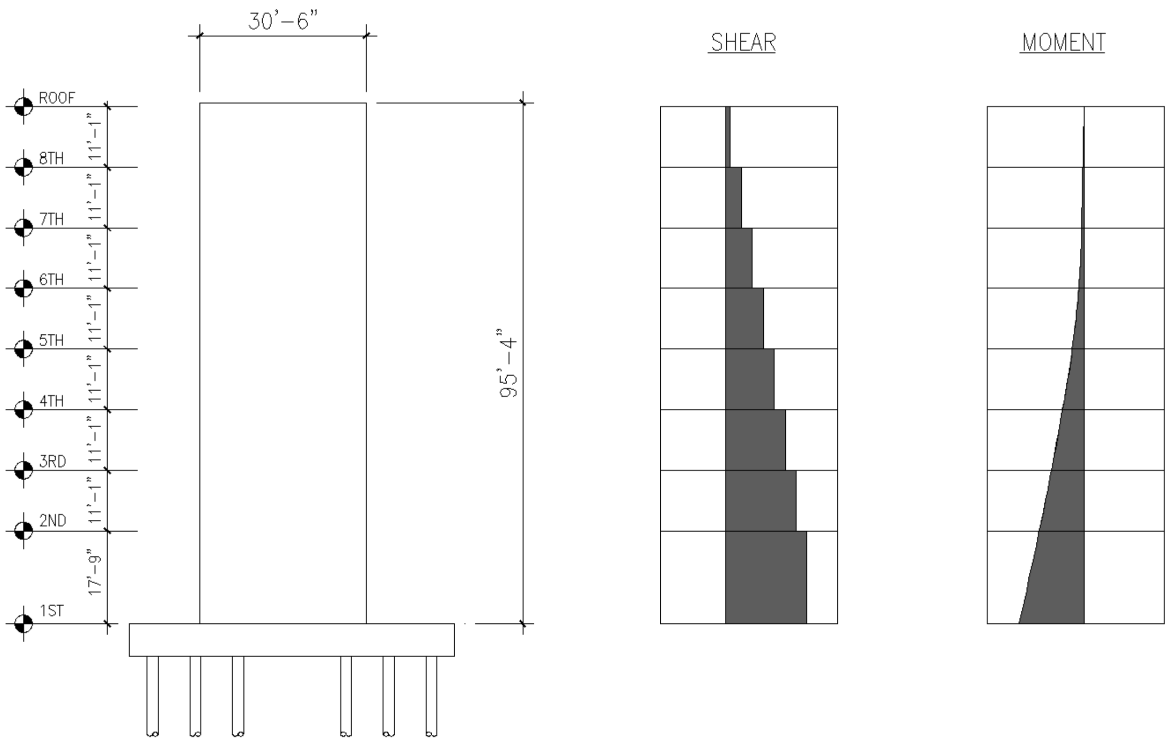


Figure 1–2. Wall elevation, shear, and moment diagram

Table 1–1. Design loads and lateral forces

Level	P_D (kips)	P_L (kips)	V_E (kips)	M_E (kip-ft)
Roof	193	37	84	0
8	388	72	244	928
7	573	108	414	3630
6	758	144	595	8210
5	945	181	785	14,800
4	1130	217	987	23,500
3	1310	253	1220	34,400
2	1540	290	1420	48,000
1				73,000

For this design example, it is assumed that the foundation system is rigid, and thus the wall is considered to have a fixed base. The fixed-base assumption is made here primarily to simplify the example. In an actual structure, the effect of foundation flexibility and its consequences on structural deformations should be considered.

The analysis uses effective section properties for the stiffness of concrete elements. Example 2 includes a discussion of effective section properties for use in analysis.

Using the fixed-base assumption and effective section properties, the horizontal displacement at the top of the wall corresponding to the design lateral forces is 1.55 inches. This displacement is needed for the detailing of boundary zones according to ACI 318 Section 21.9.6, which is illustrated in Part 8 of this design example.

2. Load Combinations for Design — ASCE 7

2.1 LOAD COMBINATIONS

Load combinations for the seismic design of concrete are given in Section 2.32. (This is indicated in Section 12.4.2.3.) Equations 5 and 7 of Section 2.3.2 are the seismic design load combinations to be used for concrete.

$$1.2D + 1.0E + L + 0.2S$$
$$0.9D + 1.0E.$$

Load combinations for *non-seismic* loads for reinforced concrete are given in Section 2.3.2, Equations 1, 2, 3, 4, and 6.

2.2 HORIZONTAL AND VERTICAL COMPONENTS OF EARTHQUAKE FORCE

The term E in the load combinations includes horizontal and vertical components according to Equations 12.4–1 and 12.4–2 of Section 12.4.2:

$$E = E_h + E_v \qquad \text{Eq 12.4–1}$$
$$E = E_h - E_v \qquad \text{Eq 12.4–2}$$

where E_h and E_v are defined according to Equations 12.4–3 and 12.4–4 of Section 12.4.2.1 and Section 12.4.2.2 as follows:

$$E_h = \rho Q_E \qquad \text{Eq 12.4–3}$$
$$E_v = 0.2S_{DS}D. \qquad \text{Eq 12.4–4}$$

Substituting this into the seismic-load combinations results in

$$(1.2 + 0.2S_{DS})D + \rho Q_E + L + 0.2S$$
$$(0.9 - 0.2S_{DS})D + \rho Q_E.$$