# Design Example 3
# Three-Story Light-Frame Multifamily Building Design Using Cold-Formed-Steel Wall Framing and Wood Floor and Roof Framing

## OVERVIEW

This example will be reviewing the design of a three-story apartment building sitting on a raised structural reinforced concrete podium deck, with one level of subterranean parking.

1. The design of this example will be limited to the lateral design of one of the three-story apartment buildings and does not investigate the design of the raised first-floor structural concrete podium deck that the three-story apartment buildings sit on.

2. The adequacy of the building's gravity system also is not evaluated except where required as part of the building's lateral-force-resisting system.

## OUTLINE

1. Building Geometry and Seismic Criteria
2. Roof and Floor Gravity Loads
3. Lateral Loading: Seismic
4. Diaphragm Flexibility
5. Flexible Diaphragm Condition
6. Building Classification: Regular or Irregular
7. Redundancy Factor
8. Redundancy Check for Building B
9. Selected Analytical Procedure
10. Distribution of Seismic Forces to Shear Walls
11. Sheathed CFS-Stud Shear Walls: Framing Materials
12. Shear Wall Design Example: Building B
13. Shear Wall Deflection
14. Discussion: Framing with Cold-Formed Steel

15. Discussion: Seismic Joints
16. Discussion: Elevators
17. Items Not Addressed in This Example
18. References

## DESIGN EXAMPLE BUILDING

Figures 3-1 through 3-5 illustrate the apartment building complex's front elevation, first floor, second floor, third floor, and roof plans used in this design example. Figure 3-6 shows an elevation cut through the building of stacked cold-formed steel (CFS) framed shear walls. The building complex is cut into a sloping grade, which is very common for these types of buildings. The first floor, podium level, is an elevated reinforced concrete structural slab over the partial subterranean parking level. There are two light-frame three-story buildings that sit on this podium deck: Buildings A and B. Building A has a single-story community room wing, which has a green roof. This roof, as well as the direction of the decorative wood slat siding on the exterior walls of the building, can be seen in the front elevation of Figure 3-1.

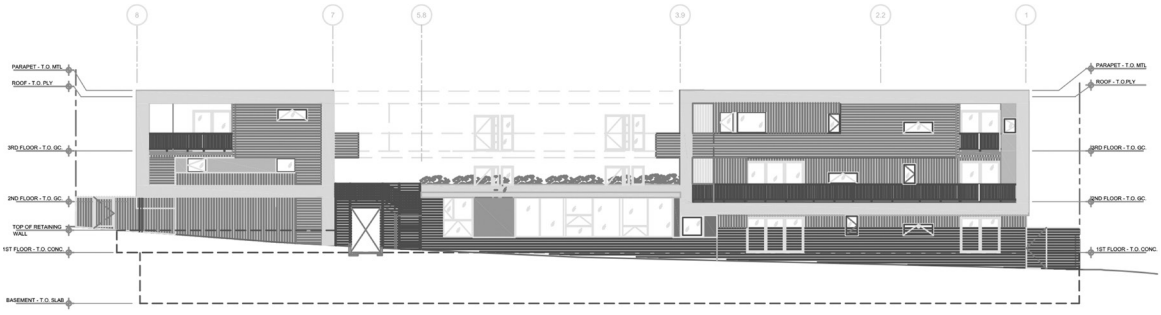


*Figure 3-1. Apartment complex front elevation*

The two three-story Buildings A and B are interconnected by a pedestrian bridge that has a seismic joint (see Figures 3-3 and 3-4). Access to the residential units is by means of exterior stairs and cantilever walkways. The walls of the residential units at each floor level stack vertically, so there are no horizontal offsets of the load-bearing walls and shear walls between floor levels. Engineered wood I-joists are used for the floor system, and prefabricated metal-plate-connected wood trusses are used for the roof members. Rated wood structural panel (WSP) sheathing is used for the floor and roof diaphragms.

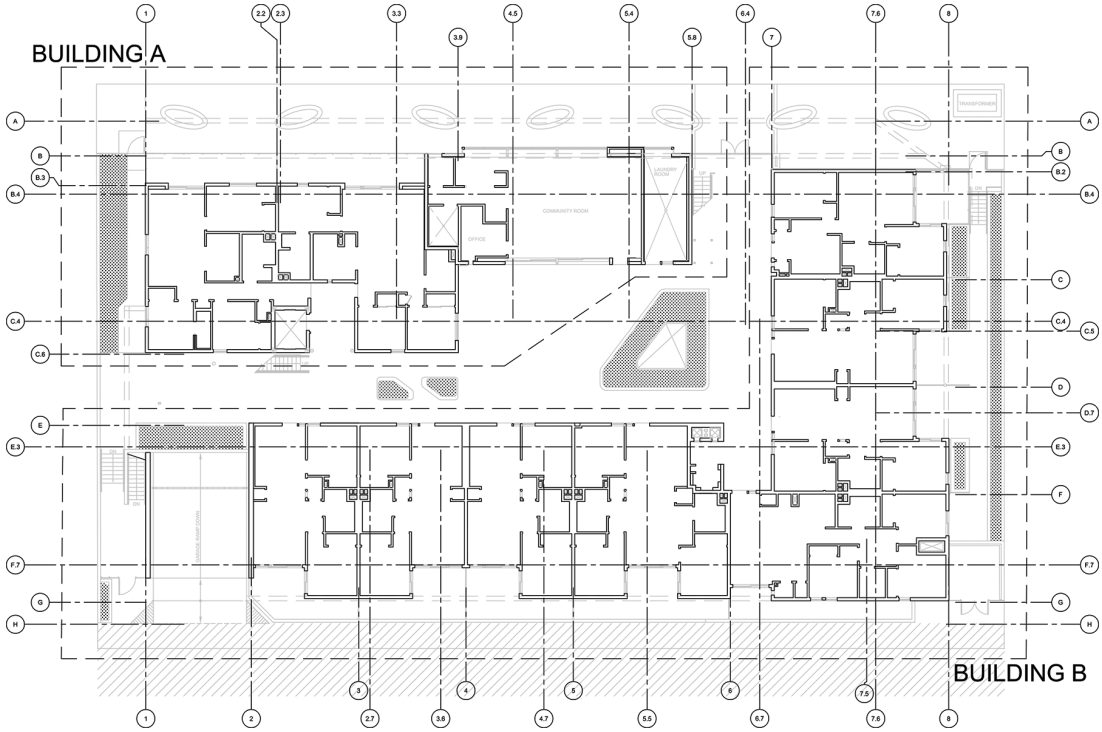


*Figure 3-2. First-floor plan—Buildings A and B sitting on a common podium deck*

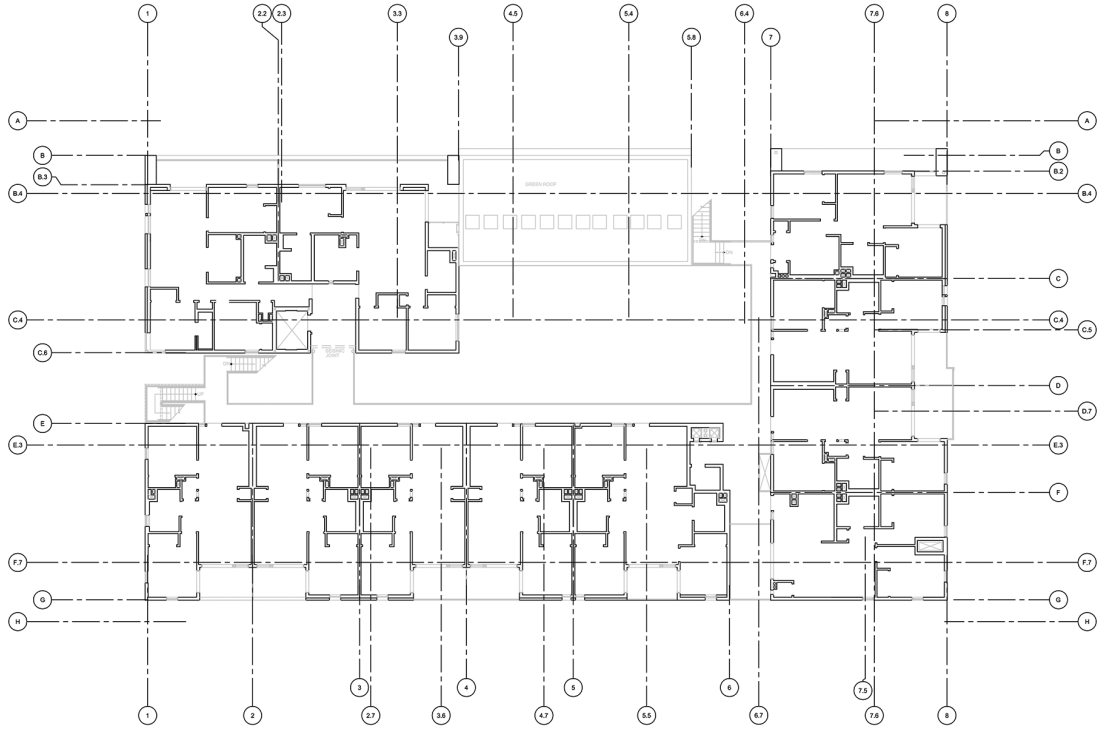

*Figure 3-3. Second-floor plan*

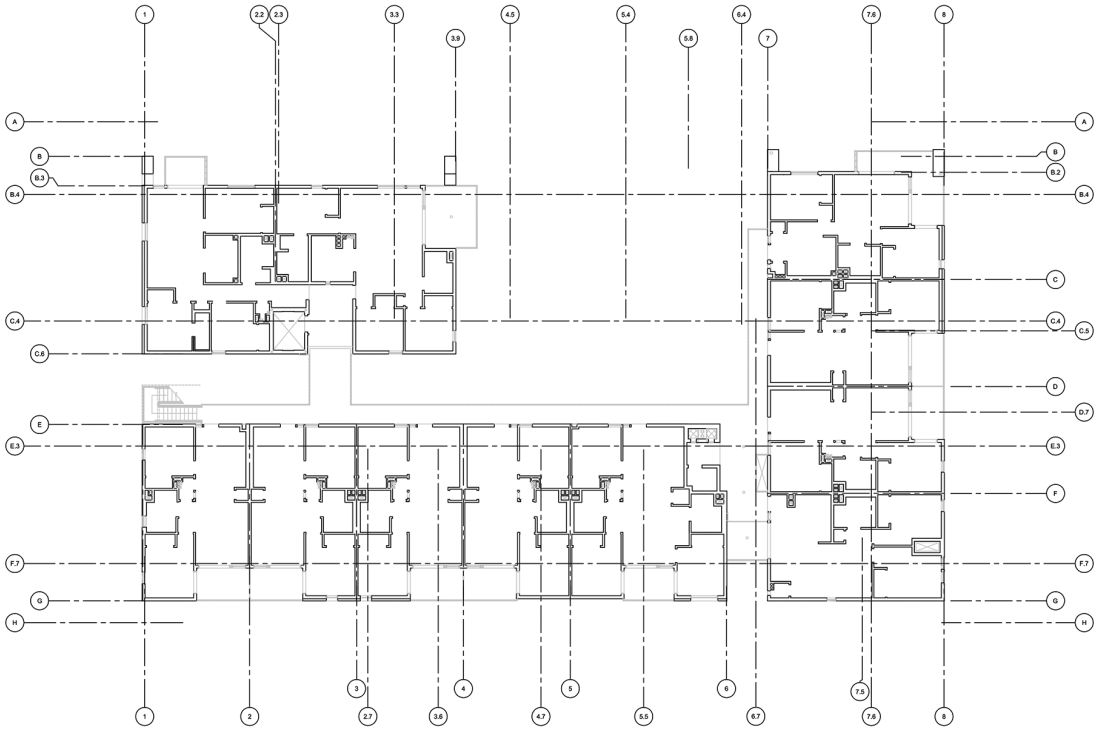

*Figure 3-4. Third-floor plan*

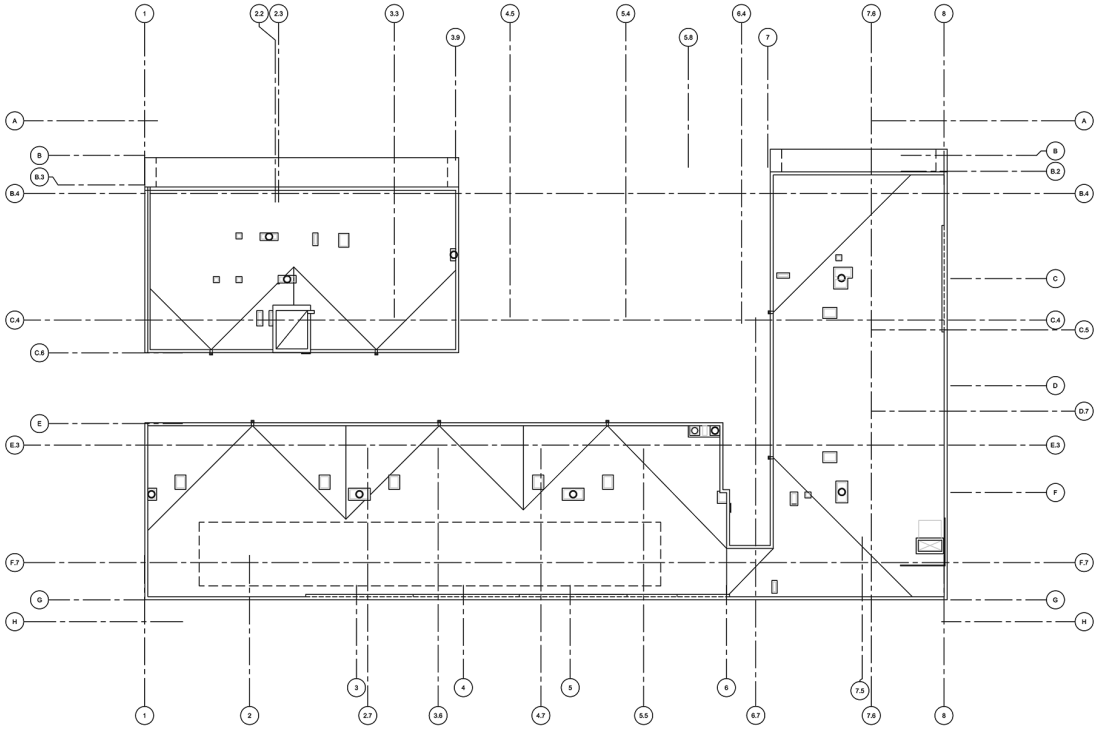

*Figure 3-5. Roof plan*

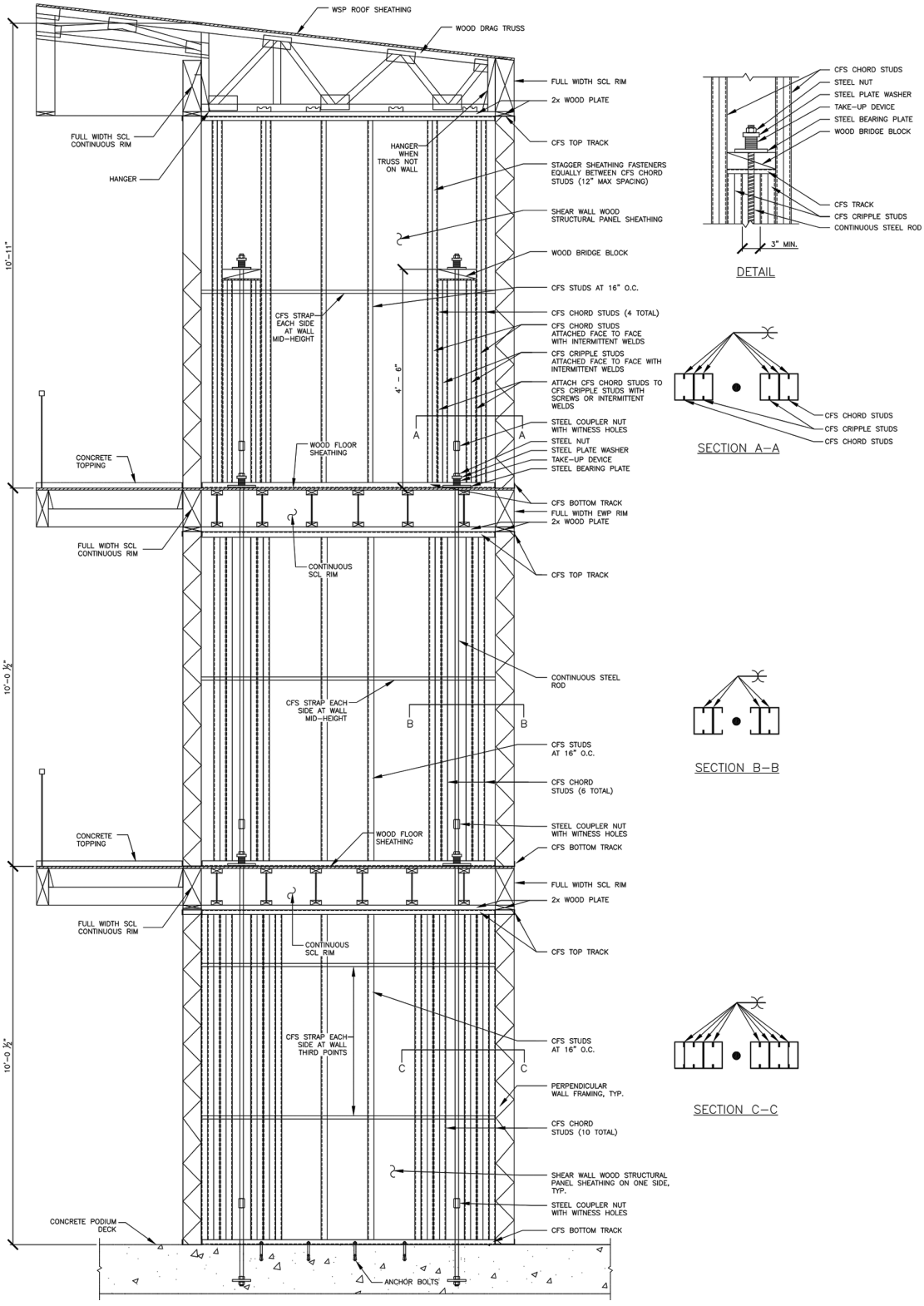


*Figure 3-6. Shear wall elevation using mixed framing materials—cold-formed steel (CFS) light-frame shear wall and wood-frame floor and roof*

The unique aspect of this building is that CFS wall framing is used for the building's wall gravity and lateral framing (wood structural panel-sheathed shear walls), while the roof and floor system is framed with wood members. The use of continuous wood rim joists along the top of CFS stud bearing walls in wood floor and roof framing systems allows for flexibility in the floor- and roof-joist layout, regardless of where the CFS studs align. The wood floor and roof framing is supported by hangers from the wood rim joist, which acts as the vertical load distribution member to the CFS studs. If the floor or roof framing is to bear directly on the wall, then the CFS stud wall top track or wood top plates must be designed for flexure and shear to support the wood I-joist reactions and transfer them to the CFS studs.

Where CFS floor joists and metal-plate-connected wood roof trusses are used with CFS-framed bearing walls, the alignment of the CFS studs within the wall with the CFS floor joists and wood roof trusses is much more critical. Regardless of the floor system selected, CFS floor framing or wood floor framing, the design of the CFS stud walls' top track or wood double plate, or combination of both, must be designed to transfer the floor gravity loads to the wall studs.

## MIXED-USE, MULTIFAMILY, MULTISTORY PROJECTS

The apartment complex is no longer just a relatively simple structure built from wood or CFS studs sitting on a concrete slab-on-grade with continuous and isolated reinforced concrete pad footings.

The apartment building is now typically just one component of a larger mixed-use, multifamily, multistory complex that includes retail spaces, office spaces, loading docks, and above- and below-grade parking in addition to the apartment units. The apartment/rental units typically occupy the space above the uppermost podium deck, while the concrete podium structure contains the parking, retail, delivery, and commercial functions. The concrete podium deck can occur at grade level over multiple levels of subterranean parking or be several stories tall above grade. These mixed-use projects commonly contain anywhere from just five or six individual rental units to several hundred apartment/rental units, and the supporting concrete podium footprint can extend for hundreds of feet in each direction.

Apartment buildings constructed during the 60s, 70s, and 80s typically were smaller, and the designer only worried about the street-front appearance since the sides were obscured by adjacent buildings, and not much emphasis was placed on the alley elevations. These larger mixed-use projects often take up the majority of the block, stretching from street to adjacent street, to taking up the entire block, requiring very elaborate street-front appearances on all exterior elevations of the building complex as opposed to just the single street-front elevation of the apartment building of past years.

## FIRE-RESISTIVE CONSTRUCTION

The demand for residential housing (apartment rentals/condominiums) since the 1980s has led to an increase in the typical number of residential floors being provided in these residential projects from three stories and less, to typically four and five stories, and in some jurisdictions to six stories using light-frame construction. Along with increasing the number of floor levels being utilized in residential housing have come additional building code requirements regarding use of noncombustible construction framing members (CFS studs, fire-treated lumber, etc.). Light-frame buildings that are three stories or less typically fall into the category of Type V construction, but once the designer goes above three stories, the building may now fall into the category of Type III construction, which has more stringent fire-rating requirements. In Type III construction, the fire rating of the exterior wall assembly has now become more important, often dictating the direction of the floor framing to minimize exterior wall fire-rating requirements, depending on whether the exterior wall is a bearing wall or a nonbearing wall.