Reaching Higher with Cold-Formed Steel Framing for Podium Structures

By Robert Warr, P.E.

Figure 1. Concrete podium with CFS above.

Building designers are often challenged with an increasing demand for high-density, combined-use buildings in urban locations. The most common scenario is a base structure, commonly referred to as the podium. The base structure is generally used for parking or retail space, with an upper structure that is of another use, such as apartments, dorms, senior living, hotels or other private spaces. This upper structure lends itself well to individually framed walls and floor systems.

With this increased density comes the need to provide a safe, non-combustible framing system that is also strong to achieve the desired overall building height. Combining non-combustible materials such as cold-formed steel with concrete and hot-rolled steel results in higher building heights for these structures at an economical price. Building height limits also affect building material selection, the treatment of fire safety, sound considerations, architectural unit space planning, and egress. Cold-formed steel provides an ideal solution for all of these design challenges.

How High Can Cold-Formed Steel Go?

The *International Building Code* (IBC) requires the upper and lower structures to be separated for fire and other safety reasons. There are three sections in IBC 2015 Chapter Five pertaining to podium designs that describe permissible building heights and story limits and are critical to understand when designing cold-formed steel upper structures over a concrete podium to maximize the benefits of non-combustible steel construction.

The first provision, Section 510.2, allows an upper structure of any construction type to be built over a lower podium where the two structures are treated as separate and distinct structures. This permits a separate and distinct determination of each of the areas based on the allowable area limitation, continuity of firewalls, type of construction, and number of stories. This provision only applies when four criteria are met:

1) A horizontal assembly separates the building portions with a minimum three-hour fire resistance rating;
2) The building below is of Type IA construction and is protected throughout with sprinklers;
3) Shafts, stairways, ramps, and escalator enclosures penetrating the horizontal assembly have a two-hour fire resistance rating; and,
4) The maximum building height above grade is not exceeded.

Starting with the last point, Type IA, IB, IIA and IIB types of construction require non-combustible materials within a fire-rated assembly, except for IIB which does not have a minimum fire rating for the non-combustible material. However, with each increase in fire protection, the building is allowed to be taller and have a greater number of stories. For example, residential occupancy classification ranges from five stories to unlimited stories and heights ranging from 75 feet to unlimited heights for non-combustible materials in these construction types. This is achieved by providing a fire protection system for the bearing walls that meets an hourly rating between one and three hours. For cold-formed steel, there are various UL assemblies as outlined in *A Guide to Fire and Acoustic Data for Cold-Formed Steel Floor, Wall and Roof Assemblies* (**www.steelframing.org**).

Figure 2. CFS over parking structure podium.

The most common range for mid-rise non-combustible building materials is five to twelve stories and 85 feet to 180 feet. These heights are associated primarily with Type IIA and IB, which require one-hour and two-hour fire-rated assemblies, respectively. For example, by using the residential occupancy and cold-formed steel framing over the top of retail space, one could get the maximum stories of floors and still be under the overall building height limitations when coupled with a multi-story podium. *Figure 1* shows an example of a concrete podium for retail use below a multi-story cold-formed steel framed residential upper structure.

The second provision, Section 510.4, is not used as often as 510.2 but offers a similar opportunity for stacking buildings and gaining the ability to add an additional floor. Specifically, for buildings with parking below (S-2 occupancy) and any residential group occupancy above, this section allows a podium of Type I construction but only requires a two-hour fire separation that can be further reduced to a one-hour separation if sprinklered per Table 508.4. Assuming a parking level meeting Type I construction (either IA or IB), the limiting height would be based on the cold-formed steel framing assembly above. Using the construction type that limits the height the most, a building is allowed to be 75 feet with sprinklers which could be seven stories with this provision alone. *Figure 2* depicts this provision where a cold-formed steel superstructure is positioned atop a parking structure below.

The third provision, Section 510.6, governs Group R-1 and R-2 buildings of Type II-A construction. It presents a rare opportunity for a nine-story, 100-foot-tall, Type II-A building when there is at least a 50-foot lot line separation. This provision does not require a podium level separation but does require a 1½-hour fire-rated first elevated floor system. Below-ground parking would still require a three-hour fire separation. This design would likely be most cost-effective when the building has no need for a parking deck and ample space in the lot on which it is being built.

Figure 3. Nested jamb with studs and track.

Figure 4. Nested LDM with steel plate.

Figure 5. Overlapping shear straps for lateral resistance.

Seismic and Wind Load Considerations

Most podium buildings are designed for seismic loads using the Two-Stage Analysis Procedure described in Section 12.2.3.2 of ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*. The two-stage analysis procedure recognizes the unique performance characteristics of a lightweight and flexible superstructure over a stiff base which is ten times stiffer than the superstructure. This analysis procedure treats the upper and lower portions of the structure as two distinct structures, with the base shear of the superstructure applied to the base in a second analysis. The lightweight nature of cold-formed steel provides a direct benefit for seismic design (less mass) but also offers a significant benefit since the inherent stiffness of cold-formed steel makes it easy to comply with the ASCE 7-10 requirement that the fundamental period of the entire structure not be greater than 1.1 times the period of the upper structure alone.

For wind loading, the cold-formed steel framing is the building's main frame and therefore the primary wind force resisting system (MWFRS). In this case, AISI S240, *North American Standard for Cold-Formed Steel Structural Framing*, allows for the design of these elements as MWFRS (**www.aisistandards.org**). Section B1.1 allows for live load reduction of the framing along with a check for combined MWFRS loading and axial loading. Separately, there is a bending check for components and cladding loading without the effect of axial loading. This helps to clarify the use of the framing element as both the main frame of the building and a component. This is a unique and necessary check for cold-formed steel as it often receives exterior components connected directly to it, unlike other structure types that provide a skeleton frame with in-fill framing where cladding is attached to the in-fill framing only.

For the lateral force resisting system, shaft assemblies constructed from CFS could be the best option. Shaft assemblies are typically placed in the central core area of a building and are inherently strong due to the construction and fire-rating requirements. However, they alone may not be capable of providing the torsional resistance due to their dimensions and location within the building's footprint. When this is the case, cold-formed steel shear walls can be used to supplement or even provide the entire lateral force resistance. If the shear walls are non-bearing walls, the seismic forces may be significantly higher than gravity loads. This is where cold-formed steel is uniquely qualified. Since it is relatively thin, many members can be nested together, overlapped, or even built-up to form an efficient assembly to resist the loads. *Figure 3* (*page 21*) depicts an example of creative overlapping of thin cold-formed steel lateral strap bracing. In this situation, the design called for more lateral resisting elements than what was available in open wall locations, so an overlapping method was employed. This is achievable with cold-formed steel. As seen in *Figure 4* (*page 21*), connections to the podium can range from post-installed anchors to welded embed plates. More discussion on this topic is found in AISI D110-16, *Cold-Formed Steel Framing Design Guide, 2016 Edition* (**www.steel.org**).

Figure 6. Steel embed in concrete at podium to CFS wall above.

Connection and Detailing Considerations

Unlike other building materials, cold-formed steel framing is unique in its strength-to-weight ratio and connection to other steel and concrete via traditional commercial building methods, which allows it to marry well with other trades, tools, and techniques already employed in commercial applications. Cold-formed steel framing is dimensionally and geometrically stable, which can be a major consideration when evaluating the longevity and durability of a mid-rise building.

Often, it is the detailing and concentration of load into a single isolated connection that creates the greatest challenge for the designer. It is easy to achieve uniform loading that is evenly spaced, and many materials can handle this load scenario. Unlike some alternates, cold-formed steel can also resolve concentrated loads into singular or closely grouped resisting elements when appropriately detailed. As discussed in CFSEI Tech Note G200-15, *Chase the Loads: Load Path Considerations for Cold-Formed Steel Light-Frame Construction*, the goal of every framing system is to provide a concise and direct load path (**www.cfsei.org**).

Another challenge is the design of gravity framing around stacked openings like doors and windows. The loading from a single floor can be handled by the header over the opening. However, in framed walls, it is the jamb that transfers the forces vertically from floor to floor. Jambs can accumulate quite large forces in taller buildings when openings align. With cold-formed steel framing, there are many ways to keep the framing concentrated into an area that is relatively narrow in the wall without dimensional build-up that occurs with other materials. This allows more room for electrical, plumbing, and other necessary items that occupy the wall cavity. *Figure 5* (*page 21*) shows an example of nested studs and tracks to form a compact jamb condition. Once the jamb load reaches the podium level, it can be transferred via a base plate or other assembly to transfer the force to the podium efficiently. If the podium is concrete, then an embed plate is a common way to transition the force to the concrete. Likewise, with hot-rolled steel beams and columns, a plate can be employed and welded into place for a steel-to-steel connection. *Figure 6* shows a nested wall top, called a load distribution member, with a steel plate inside to stiffen the elements.

Designing with Steel

When specifying a construction material, the engineer should be prepared to educate the client on the positive attributes of the recommended materials. Cold-formed steel framing provides many benefits for construction teams and building owners.

An essential benefit of cold-formed steel is its flexibility, giving architects the opportunity to be creative in their designs. Cold-formed steel can be curved and offers many options for indoor space planning.

Steel is also a sustainable material. It is the only building material recognized by LEED as having a default minimum value of 25 percent recycled content and is 100 percent recyclable. Steel is routinely collected in aggregate quantities from construction and demolition sites and is recycled into new steel products.

Steel is a resilient material too. Resiliency is the measure of a building's ability to serve its intended purpose with minimal disruptions. Cold-formed steel framing meets these requirements of a resilient building material – safety in the face of a natural hazard; security in a man-made event; energy efficiency; reduction in environmental impacts over the life of the building; durability resulting in a long life with minimal maintenance and resistance to deterioration, predictable performance, serviceability, repairability and adaptability.

Cold-formed steel framing has a proven track record of providing cost-effective benefits over the entire construction cycle due to lower insurance rates, shorter project cycles, predictability and accuracy of components, and design efficiency.

For additional information on cold-formed steel framing, visit **www.cfsei.org**.

Conclusion

Cold-formed steel framing has both the strength and non-combustible attributes to support the increasing need for denser urban housing construction typified by podium building construction. Cold-formed steel allows for tall buildings, high capacity elements, efficient connections between the base and superstructures, and durable, quality construction.▪

The online version of this article contains references. Please visit **www.STRUCTUREmag.org**.

Part 1 of this series on podiums, Mid-Rise Wood Frame Buildings, ran in the February, 2019 issue of STRUCTURE.

Robert Warr is the Managing Principal at Frameworks Engineering, LLC in Marietta, GA, where he practices cold-formed steel framing structural engineering design. (rwarr@frameworksengineering.com)

References

International Building Code, 2015. International Code Council, Whittier, CA. American Society of Civil Engineers (ASCE), 2010.

ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, New York.

American Iron and Steel Institute (AISI), 2015. AISI S240-15, *North American Standard for Cold-Formed Steel Structural Framing*, 2015 Edition, Washington, DC.

AISI D113-18. *AISI Shear Wall Design Guide*, 2018 Edition, Washington, DC.