# Multi-Unit Residential Construction Over Podiums

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*Figure 1. Cold-formed steel construction above a steel podium.*

Multi-unit residential construction continues to see an increasing demand for living units above a one- or two-story podium. The demand is primarily driven by maximizing residential unit density within permissible building heights for a particular construction type. Architecturally, the podium's primary purpose is a horizontal separation between different occupancies, creating open space for parking, retail, or amenity space on the lower floor(s). Yet, for the structural engineer, the podium level is expected to transfer significant loads from the density of the program above the podium to a different structural system below. While "stick-built" construction is historically wood-framed, the prevalence of cold-formed steel is increasing the structural demands on the podium level due to the ability to construct as many as ten stories of residential (*Figure 1*). While the design focus is often the structural efficiency of the residential units, due consideration is required for a properly designed, detailed, and constructed podium structure.

## System Overview

The podium structure is typically structural steel (*Figure 2*) or cast-in-place reinforced concrete, though regional variations and/or construction cost models might lend themselves to post-tensioned concrete and even precast/prestressed concrete; the latter is not discussed in this article. Design considerations for these structures are unique – they can be items required for architectural expression, mechanical, electrical, plumbing, and fire protection (MEP/FP) coordination, or the structural system's analysis and design.

*Figure 2. Structural steel podium.*

Podiums can be used to create a tall story at the ground floor for lobby, retail, or restaurant occupancies. However, the tall story can create complexities for the facade support design. Secondary structural steel may be required to support the facade, either through structured mullions or continuous horizontal framing to support the vertical structure of the exterior wall system. Contract documents should either provide fully designed details for the secondary steel or clearly identify the performance requirements and delegate the design to the contractor. Similarly, canopies, overhead doors, louvers, signage, entry vestibules, and other architectural elements may dictate additional steel if they require support between the ground floor and podium level.

With any structure, MEP/FP distribution is a critical coordination step for the design team. Reviewing duct, pipe, and conduit size, plan location, and elevation is essential in designing the structure. It can require structural elements to move, change depth, or be locally strengthened. This is the same for podium structures and even more critical. Because gravity loads from the residential units accumulate at the podium level, structural members are highly loaded and typically very large. Similarly, mechanical systems are often their largest and/or most densely congregated at the podium level. Gravity-fed plumbing may run horizontally from the vertical chases in the building to the outlet location at this level. Plumbing lines have slope requirements with minimal flexibility, so the structural system must typically accommodate the plumbing. There can be penetrations through steel or concrete beams or rearranged framing layouts to accommodate these needs. The complexity and density of MEP/FP at the podium level play an important role in deciding the structural system of the podium level.

Some factors impact the podium analysis, independent of the structural systems used, that should be considered in developing system concepts. Serviceability requirements can be one of the governing factors. Instantaneous and long-term deflection (if applicable) can create cracking in bearing wall finishes if the deflection is not minimized with an appropriate construction sequencing. From the authors' experience, limiting the podium level combined superimposed dead and live load deflection to L/1000 effectively minimizes the risk of cracking and other serviceability issues. When analyzing the podium, how and if the walls above are modeled in 3-D analytical software can significantly impact the analysis. If bearing walls are modeled, it is important to confirm that the bearing wall in-plane stiffness does not artificially stiffen the podium structure. Reducing the in-plane stiffness in the analysis model or applying loads as line loads to the podium level are possible solutions to confirm loads are accurately applied to the podium structure.

*Figure 3. Beam web penetrations in structural steel podium framing. Framing bears on top of the perimeter columns.*

## Structural Steel

Structural steel podiums provide many benefits compared to other structural systems; however, like all structural systems, there are limitations. Loading configuration can impact both the steel tonnage and the number of steel members required. If bearing walls above are arranged in a linear, orthogonal, and regularly spaced pattern, steel girders can be located directly below the walls and designed to meet the requisite strength and serviceability limits, allowing the remaining framing at the podium level to be designed only for a single level. Vertical and horizontal plan offsets, and complex loading patterns from the structure above, can necessitate additional steel beams or the slab construction to support each section of wall or applied load; this can lead to a large number of total pieces, complex framing geometry, increased material, and increased number of highly loaded connections.

Structural steel systems are not susceptible to additional long-term deflection considerations. This can be a benefit when considering the likelihood of cracked finishes and other serviceability considerations.

For structural steel podiums, there will be a combination of deep beams sized to support accumulated loads from the structure above and shallow beams to support just the slab of the podium level occupancy. Since ceiling elevation is typically dictated by the elevation of the bottom flange of the deepest beam, in the absence of soffitted ceilings, these shallow floor beams can create a zone for MEP/FP distribution in the space between the bottom flange of the shallow and deep framing. Inevitably, there will be zones where MEP/FP distribution is required to pass by deeper beams; in these cases, if located near the mid-span of the girders and away from high point loads, beam web penetrations can be designed and incorporated into the fabrication of the steel framing (*Figure 3*). It is crucial to have a dialog with other design team members and the contractors and key trade partners, if possible, to determine if additional web penetrations should be included in the design. Web penetrations are typically easier to fabricate in the shop than in heavily loaded girders in the field.

*Figure 4. Concrete podium with cast-in-place anchor rods and embedded conduit.*

Structural steel podiums are typically lighter than concrete solutions, an additional benefit that can reduce foundation loads. Therefore, it is a valuable exercise to compare the total foundation demands for the building with a structural steel podium against alternate podium solutions to determine if cost savings in the foundation systems will be a significant factor in structural system selection.

Though often governed by stiffness considerations, girders supporting multiple floors also accumulate significant loads at their connections. Contract documents should specify actual connection forces at each member if delegating the connection design. Relying on conventional beam reaction tables may underestimate the connection demand. For single-story podiums, detailing steel beams to bear on top of the columns will simplify connection design, improve constructability, and reduce eccentricity in the steel column (*Figure 3*). Continuous beams over columns are also more efficient than single spans; comparable deflections can be achieved with less steel.

## Reinforced Concrete

Reinforced concrete (RC) podiums offer a great deal of flexibility in the arrangement of the supported superstructure. Still, they require important considerations related to both initial detailing and long-term performance (*Figure 4*).

Like structural steel, RC podiums can be designed and detailed with beams and girders at the bearing walls or columns above. However, the reinforcement details and significant formwork requirements are rarely cost-effective. Alternately, a deep flat plate can be a cost-effective option for the transfer of discrete line or point loads from the structure above. Forming is much simpler, and reinforcement can be increased locally to accommodate high loads due to bearing walls and/or individual columns. Flexibility can be designed and detailed to allow walls/columns to move marginally as the design develops. Typically, the overall flat plate RC podium is shallower than other materials. The flat plate also allows for reasonably impediment-free distribution of MEP/FP systems below the slab.

The primary concern with RC podiums is long-term deflection, particularly where vertically stiff, multi-story bearing walls are supported. Providing additional reinforcement to increase the transformed area, increasing the concrete strength to increase the modulus of elasticity, and extending the duration of shoring can mitigate some of the concerns. However, regardless of the additional measures, the importance of long-term deflection to the serviceability of the structure above must be explicitly considered.

There are several secondary considerations for RC podiums. For discrete systems, such as structural steel columns or hold-downs in wood-framed or cold-formed steel shear walls, detailing of the base plate and exposed anchors is a consideration – providing box-outs to recess the baseplate in the slab to not impact floor finishes should be clearly detailed (*Figure 4*). Concrete levelness should be considered for pre-fabricated bearing wall systems detailed and assembled in the shop to design, not as-built, dimensions.

## Post-Tensioned Concrete

Post-tensioned (PT) concrete is the preferred structural system for podium slabs in certain regions because of cost savings. However, the added economy accompanies heightened trade coordination and, for many practitioners, analytical complexity.

PT concrete slabs are generally more economical than non-prestressed RC when the slab span exceeds 25 feet, a common scenario for parking or retail below a podium. PT slabs can be 10% to 20% thinner and contain 40% to 60% less reinforcement than RC slabs for the same span and loading. Whether these savings offset the additional post-tensioning material and labor costs is highly dependent on the local market, project scale, and contractor experience. A thinner slab at the podium level also translates to less load on foundations, more space for MEP/FP distribution, and taller ceiling heights, if desirable. While long-term deflections can be the Achilles heel of RC slab design, PT slabs are inherently powerful at minimizing deflections and controlling cracks due to their precompression and load balancing.

PT podium design is generally governed by two-way (punching) shear strength at slab-column joints. Increasing the slab thickness to improve shear strength offsets the economy of a PT slab; increasing column sizes may have programmatic impacts. Shear reinforcement is typically a reasonably cost-effective compromise. However, there are instances where shear reinforcement is impractical for heavy loading. In these cases, shear caps are an effective way to increase shear strength. For PT slabs, shear caps can also be used to reduce flexural stresses because the American Concrete Institute's *Building Code Requirements for Structural Concrete* (ACI 318) prescriptive limitations on drop panel dimensions only apply to non-prestressed slabs. Therefore, practitioners should be aware of significant reductions in precompression stress at shear caps and ensure they stay above the 125-psi code-required minimum.

Trade coordination makes the list of challenges for any structural system, yet PT podium slabs are particularly vulnerable to costly coordination mistakes. With MEP/FP systems collecting and redistributing at the podium level, openings should be coordinated and clearly detailed to avoid banded tendon lines, anchorage zones, and slab-column joints. Electrical engineers also view the PT slab as a viable location for conduit, leading to congestion and heightened risk of either conduit damage, or worse, poor slab performance. Early efforts should be made to hang conduit below the slab or embed it in a concrete drop slab, if necessary, for fire ratings. The podium is also the interface between the PT subcontractor and carpenters or ironworkers building the residential structure above. Ideally, steel embed plates or shear wall hold-down anchors should be cast into the PT slab to avoid post-installed anchors that might damage the PT tendons.

Analytically, PT podium design is likely the most challenging system for practitioners. Load application from the residential floors above can be the most troublesome part of the design process. Bearing walls can be irregularly spaced, staggered with plan offsets and feature concentrated loads from posts and hold-downs. Design is iterative – walls move, framing orientation changes, and wall openings are modified. Prior to modeling and designing for distributed line loads or concentrated loads, practitioners should study if a conservative equivalent uniform load, supplemented with localized checks, is appropriate for the PT design. As PT design is usually governed by punching shear at the columns, the flexural design for the wall loading pattern may be less critical, allowing some flexibility in design evolution.

## Closing

The podium structural system for a multi-family residential development can impact nearly every part of the project. System selection, design, and detailing should balance structural efficiency with serviceability, architectural needs, MEP/FP coordination, local contractor experience, and constructability.▪

References are included in the PDF version of the article at **STRUCTUREmag.org**.

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## Additional Reading

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*Mid-Rise Wood-Frame Buildings*. McLain, STRUCTURE February 2019.

*Reaching Higher with Cold-Formed Steel Framing for Podium Structures*, Warr, STRUCTURE, March 2019

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## References

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