

Achieving **LOW** Floor-to-Floor Heights

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Boston's Seaport Hotel.

Minimizing floor-to-floor heights is a method of reducing construction costs and adding additional square footage without exceeding height limitations. The desire to minimize floor-to-floor height is driven by several factors, such as:

- ✓ Height limitations imposed by zoning regulations;
- ✓ Matching floor-to-floor heights of additions with the existing building; and
- ✓ Reducing the overall height of the building to save on façade cost for a given gross floor area.

Traditionally, concrete has been looked to as the material of use for minimizing floor-to-floor heights, but in many areas concrete is not cost effective. Certain techniques, applied to structural steel framing systems to achieve the benefits of low floor-to-floor heights, can make structural steel costs competitive with concrete.

Floor-to-floor height is defined as the distance from the top of a floor to the top of the next floor. This height consists of three elements: the distance from the top of the floor to the architectural ceiling, depth of the floor construction and the “sand-

wich” space for various building systems such as: HVAC, electrical, communications, plumbing and fire protection. Floor-to-floor height may be reduced by focusing on these elements and either minimizing each one independently or integrating them so they may share functions in the same spaces.

Building usage and codes will dictate the floor-to-ceiling requirements for a particular building; for instance, hotels and apartments need 8' where office buildings commonly require 8'-6" and luxury condominiums require 9'. Because this height is set, the depth of floor construction and “sandwich” space are the few elements that can be modified to reduce floor-to-floor height.

The depth of construction includes floor slab thickness and the depth of supporting steel beams. Achieving minimal construction depth for a floor system does not require a high level of analytical skill on the part of the structural engineer, elementary engineering concepts may be applied to achieve a desired reduction in beam depth. Some of the techniques available to the engineer in minimizing beam depth are: reduced span lengths, beam continuity and selecting beam sizes for depth instead of least weight. It should be pointed out, that these techniques may increase the cost of the structure by adding more members or increasing the weight and should be applied judiciously. To avoid being penalized for beam depth reduction in additional weight, the structural system can often be reorganized so that span lengths are also minimized and optimum beam depth vs. span length is achieved.

“Sandwich” space, reserved for mechanical ductwork and piping between the bottom of steel beams and the architectural ceiling, offers an opportunity to the structural engineer to reduce the floor-to-floor height even further. The elimination

or reduction of this space requires understanding of the architectural and MEP elements competing for the same space as beams and girders. One method of integrating these elements is the use of beam web penetrations.

Penetrations in the beam and girder webs permit ducts and pipes to pass through beams rather than beneath them, thereby eliminating the “sandwich” and reducing the depth of construction. However, beam web penetration, either reinforced or unreinforced, is generally expensive and may further escalate if the penetrations are executed in the field rather than at the fabricators. The use of beam penetrations requires careful coordination between the structural and mechanical disciplines in the conceptual stage of the project. Understanding how all the systems need to be accommodated within the ceiling space allows the structural engineer an opportunity to play a creative role in integrating beams and girders with the other elements housed within the space, such as: ductwork, piping, conduits and cable trays. Of these elements, the ductwork requires the greatest space within the ceiling and should be coordinated with the structure during the design phase.

Some very good examples of integrated approaches that have been used successfully to achieve low floor-to-floor heights through structural steel framing can be found in: Boston’s Seaport hotel, the Logan Hilton Hotel and the Wellesley Gateway Center.

Seaport Hotel

Completed in 1998, the Seaport Hotel is an 18-story, 500,000 sq. ft building housing 427 guest rooms, six levels of meeting rooms, ballrooms, restaurants on the lower six levels and a three level underground parking structure.

Due to the Seaport’s close proximity to Boston’s Logan Airport, the FAA imposed height restrictions on the building. These restrictions challenged both the developer and the design team to maximize the number of floors and to achieve the least possible floor-to-floor height.

The design team achieved a floor-to-floor height of 9’-3/8” with an 8’-6” ceiling height on the upper guest room levels. The floor bay dimensions are 25’x24’, with 14” deep beams and girders. The two rows of central columns are 11’ apart and were positioned on either side of the central corridor to allow for

sprinkler pipe in the ceiling space. Typical floor construction consists of 5½” composite slab on metal deck with the composite slab spanning the full width of a room between floor beams centered on the guest room partition walls. The ceiling within the guestrooms is supported against the underside of the deck to achieve an 8’-6” floor-to-ceiling height.

The mechanical system consists of a vertical four pipe system that feeds each guest room separately. Horizontal ductwork penetrates the beams of the penthouse level framing and travels down through the slab openings and into the guest rooms. With the exception of non-reinforced 3” diameter beam penetrations required through the girders to access the ceiling of the corridor, no other beam penetrations are required in the guest rooms.

The choice of structural steel for the hotel building was driven by two considerations: first, the presence of 65’ transfer girders that carry 14-story columns to accommodate an open ballroom space and second, an “up-up” construction approach that shortened the construction time. This method of construction relied on 35’ unbraced steel columns and a ground-level steel framing, which were erected prior to construction of the below-grade post-tensioned slabs. The “up-up” construction method enabled faster steel erection and expedited the construction of the superstructure, thereby saving on construction time and cost.

The structural solution for the Seaport’s floor framing relied primarily on the repetitive fixed layout of the partition walls in the guest rooms. The ability of the floor slab to span 12’-6” to 13’-9” permitted for unshored construction with a 3” 18-gauge composite deck. Hotel room widths larger than 15’ require temporary shoring or a stronger deck.

The vertical nature of the mechanical system and the typical bay column layout allowed for the



Typical section of the Seaport Hotel.

short slab span in the central corridor space and played a major role in optimizing the ceiling height. The girders supported by the central corridor columns are outside the guest rooms and span over doors or bathroom facilities, where a ceiling height of 7'-6" is acceptable.

Logan Hilton Hotel

The Logan Hilton Hotel, completed in 1999, is a 10-story 425,000 sq. ft structure with 600 guestrooms on eight floors and two public levels that will accommodate future connections to airport parking, central processing and terminals. Facilities include: 45,000 sq. ft of ballroom space, a restaurant/lounge and an indoor swimming pool/health club. As with the Seaport, the FAA imposed height restrictions on the building, therefore encouraging the owner to minimize floor-to-floor height in order to achieve the maximum number of rooms within the restricted building height.

Since the Logan Hotel was designed with a repetitive room layout, comparable to the Seaport Hotel, Weidlinger Associates chose a similar structural steel composite construction scheme for the hotel. The floor slab construction was a 3" composite deck with a 2½" lightweight concrete topping slab. Typical floor beams were spaced at 13' on center to align with the guestroom partition walls, thereby hiding the W14 steel beams inside the walls. The 3" 18-gauge composite steel deck permitted the use of unshored construction. The architectural ceiling in the guest rooms is attached to the underside of the composite deck that allows for a 8'-9" ceiling height within a floor-to-floor height of 9'-3".

In the corridors, where a lower ceiling height is acceptable, the slab spans across the corridor with the only steel framing members being W6 beams located on the column grids. The low ceiling height allowed



Wellesley Gateway Center under construction.

for the placement of piping between the bottom of the slab and the architectural ceiling, this piping was used to serve the guest rooms.

Wellesley Gateway Center

Finally, the Wellesley Gateway Center, completed in 1999, serves as the corporate headquarters for Harvard Pilgrim Health Care. The building consists of a 4-story, 270,000 sq. ft office space.

The structural system of the building consists of composite steel construction with typical bay dimensions of 30'x45'. The typical floor construction consists of a 3" composite metal deck and a ¾" lightweight concrete topping slab. The concrete slab spans between 14" deep beams that in turn are supported by 45' span girders.

Zoning restrictions limited the overall building height to 50', thereby challenging the design team to use a maximum floor-to-floor height of 11'-6" for the office spaces. With a floor to ceiling requirement of 8'-6", a maximum girder depth for the 45' span was limited to 24" deep.

The variable nature of the interior office layout demanded a high degree of flexibility in the mechani-

cal and architectural systems. With spans ranging from 30' to 45' for a typical office layout, it was a challenge to achieve a structural steel framing system to accommodate a ceiling height of 8'-6" with a floor-to-floor height of 11'-6" and provide flexibility to distribute ductwork to all habitable spaces.

An innovative variation of typical steel composite construction allowed minimizing both girder depth and the number of beam penetrations while maintaining the ceiling height limitations. "Half-tree" columns, each consisting of a steel wide-flange column with 24" deep cantilever "branches" on one side of the column, were used for the main gravity structural system. Shallow wide-flange beam segments (14" deep) spanned between the "branch" tips to complete the span. This enabled the MEP ductwork to run beneath the shallow beam while keeping the ceiling height within a few inches of the typical bottom steel elevation.

The key factor that contributed to the cost efficiency of structural steel for the "half-tree" system was the efficiency in both fabrication and erection cost. Each "half-tree" column was shop fabricated and erected in one piece from the ground up to

the roof. Furthermore, fabrication costs were significantly reduced due to the identical size and dimensions of the half-tree frames.

The choice of structural steel for this project was driven not only by cost consideration, but also to provide structural flexibility to accommodate interior design requirements for future tenants, including reinforcing of the structure for heavier floor loading, if required. A concrete option, although shallow in construction depth, would have entailed either a reinforced concrete or post-tensioned slab with drop panels for the 30'×45' bay, which would make it difficult to incorporate future changes. This structural solution also relied on concentrating the location of the MEP system within the middle 30' section, under the W14 girders that linked the half-tree columns.

As had been illustrated, Weidlinger has utilized the concept of low floor-to-floor construction on several projects in the New England area to help our clients achieve maximum use out of buildings where conditions restrict heights. These techniques have proven extremely effective in the design of hotels and apartment buildings where developers try to maximum every available square foot. Through the implementation of a detailed conceptual design, the use of structural steel can be achieved with wonderful results in projects requiring low floor-to-floor heights.

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