Slab Solution

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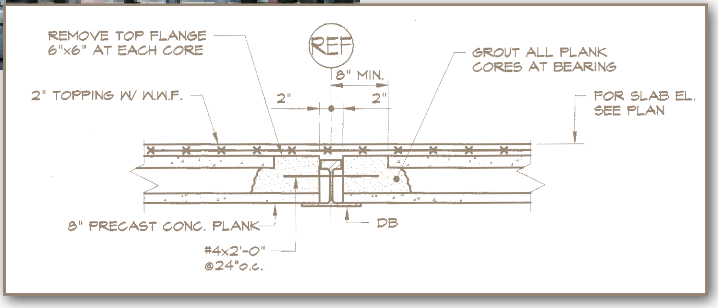


Singly-symmetric steel girders and precast concrete plank proved to be a cost-effective structural system for this Chestnut Hill, MA, condominium.

The Residences at Chestnut Hill is a two-building upscale condominium project located in Chestnut Hill, MA. The first building was delivered for occupancy in March of 2002. The second structure is now under construction.

Each building includes three levels of residential construction over a basement level of parking. Due to site geometry constraints on the building footprint, a common grid between residential and parking levels was not attainable. Nearly 60% of the three-story residential level columns were transferred at the lowest residential level to allow for an efficient layout of parking spaces and travel aisles.

The tight site was further complicated by local zoning ordinances, which limited the overall height of the building. This limit was overcome by limiting the floor-to-floor height of the residential floors to 9′-7″, constraining the structural depth of the floor system within the interior of the building to 11″. At the perimeter, architectural soffits encased spandrel beams, which were limited to 12″ in depth. The spans of the 8″ pre-cast concrete plank varied from 14′ to 28′. The spacing of interior columns ranged from 14′ to 20′. Generally, all columns with spacing over 15′ required a special detail to shorten the girder spans.

The ground level floor was framed with a conventional composite steel system. The floor deck was 2″ composite deck with a 4$^1/_2$″ normal weight cover, totaling 6$^1/_2$″ in depth. Normal weight concrete was used to minimize long term creep of composite transfer beams and provide mass for sound control between the parking in the basement and the residential units at the first floor.

The typical floor structure consisted of W14 and W16 infill beams with transfer beams ranging up to W30×138. Unreinforced holes were designed within the beam webs to allow mechanical pipe and drain lines to fit within the ceiling assembly.

Lateral bracing was provided by a system of diagonal braces of various configurations. The brace elements were steel HSS braces field welded to gusset plates, which were shop attached to the beams and columns. All of the lateral braces were terminated at the ground floor level, and the lateral wind and seismic loads were transferred to the exterior basement walls though the concrete floor diaphragm. The bracing system was concealed within walls at stairwells, corridors and between units.

The architectural program required exterior balconies with a concrete floor surface. Precast concrete balcony slabs with sizes ranging up to 20′ by 8′ were supported from the spandrel beams by galvanized seat angles welded to stiffeners on the spandrel beams. The unsupported two edges of the balcony were propped by a steel post at the outstanding corner. The post was later wrapped with architectural cladding.

The key to the economics of the balcony system was that the steel erector

Opposite (photo): One half of the partially-erected structure. Note the first floor transfer level beams, D-Beams at the roof level and the specialized "suction" lifting device for the precast plank.

Opposite (detail): Section at D-Beam with concrete topping.

Right: view of the completed building. Note the parking entrance below the structure and the precast balconies.

placed the balconies as the steel and precast were being erected. This eliminated the need for a separate crane mobilization to erect the balconies. The quality of precast concrete provides for a long-term maintenance-free balcony.

DESIGN ALTERNATIVES

After review of the architectural plans, only three structural systems were viable. The first was a cast in place concrete flat plate. The second was the use of precast concrete planks supported on conventional steel beams. The third was the girder-slab concept, licensed from Flex-Frame, LLC (www.flexframe.com).

The use of a concrete system was ruled out due to the large number of column transfers at the first floor level and the prohibitive cost of constructing flat plate concrete in the Boston area. In all there were 24 interior columns requiring transfers.

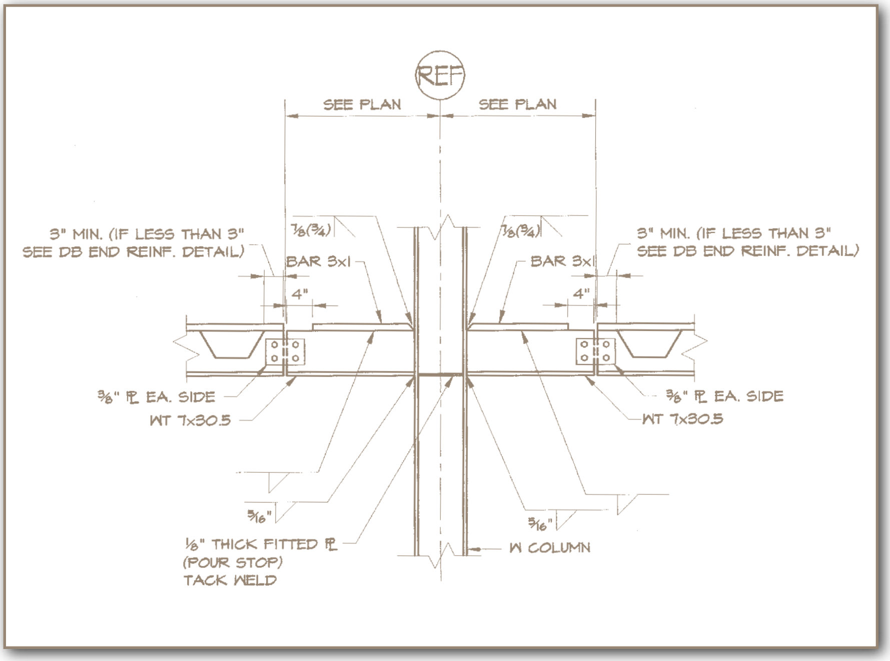
The second scheme considered was to frame the floor system with precast plank and heavy W10 to W14 column sections. The steel weight of this system turned out to be excessive. The conventional steel and precast plank scheme was eliminated because the deep steel beams projected down into the ceiling space and because of cost concerns.

A steel frame was used to construct a structure, which, due to floor-to-floor height limitations and ceiling height requirements combined with an irregular floor plan layout, could only be constructed with a cast-in-place concrete flat slab. After numerous preliminary layouts, a column grid was developed so that the building could be framed at the upper levels utilizing the 8″ deep singly-symmetric girders and 8″ precast concrete plank.

The girder-slab concept, patented by Flex-Frame, LLC, allowed the floor construction depth to be minimized to a total thickness of less than 11″. Structural bay sizes ranged up to 20′ by 28′. The key to the system is Flex-Frame's "D-Beam" (dissymmetric beam), a singly-symmetric steel shape. Precast plank rests on the top of the bottom flange, which projects less than 1″ below the bottom of the precast plank. The entire bulk of the depth of the D-Beam lies within the depth of the concrete plank.

This project was the third structure to utilize this relatively new technology. Other projects constructed using the girder-slab concept include the Somerset Hotel in New Jersey, Drexel University Dormitory in Philadelphia and the Marriott Fairfield Inn at Newark Airport.

David O'Sullivan, principal of O'Sullivan Architects, learned about the girder-slab concept at the 2000 AIA convention and decided that the system may be applicable for the Residences project. Just about eight months prior to being approached to design the project, we had enjoyed reading an article in *Modern Steel Construction* about the girder-slab concept. The story about the design of a steel framed hotel, which cloned a flat slab system in steel, left a lasting impression. After numerous phone conversations with



Detail of column "goosenecks"—beam "stubs" moment-connected to the columns to reduce the effective span of the girders.

Interior column with "gooseneck" connection welded to both sides of column.

Pete Naccarato, P.E., chief engineer for Flex-Frame, LLC, and our own due diligence, we became comfortable with the system. We accepted the assignment of the structural design for this project.

DESIGN ISSUES

Soon after design was 50% complete, the design team was informed that the owner required that a 2″ thick concrete topping be included to provide increased sound performance, as well as a high quality level concrete floor surface.

The increase in design loads of 25 psf created overstress conditions for the D-Beams. Based on the then current knowledge of the D-Beam section and behavior, the size of the beam could not be increased to overcome the overstress.

After much careful thought, we concluded that the span on the D-Beam must be reduced. Since we could not move the columns closer, a system of "goosenecks" was used to shorten the span of the D-Beams. The goosenecks were an 8″ deep beam moment connected to the columns. The columns were designed for the unbalanced moment created by pattern loading conditions.

Current designs with D-Beams use the "gooseneck" to increase the column spacing of D-Beams from a maximum span of 15′ to spans ranging from 20 to 22′. The premium on column sizes and associated costs is smaller than one would expect.

The required fire ratings for the building were two hours between the basement parking and one hour between the residential floors. The rating at the first floor was achieved by spraying the beams and using 4$^{1}/_{2}$″ of normal weight concrete over the 2″ composite deck. The floor rating of the units was achieved by wrapping the bottom of the D-Beams with sheet rock in accordance with UL design K912.

The structural system was designed with the assistance of RAM Structural System and RAM Advanse computer programs. The design of the first floor transfer beams required a bounded solution. It was not clear at the time of the design when the first floor concrete slab would be poured. These beams were designed with the residential level dead loads input as construction loads for the first floor transfer beams to induce stresses at the appropriate level of composite beam action.

LESSONS LEARNED

Both young and experienced structural engineers stand to gain much useful information from industry publications. The information gained from industry publications cannot be replicated by the experience in a single design office. Case in point, we discovered the Flex-Frame system by reading Pete Naccarato's article (*Modern Steel Construction*, September 2000). Similarly, the "gooseneck" concept was introduced to us in an article by Minhaj Kirmani (*Modern Steel Construction*, September 2000). All in all, the girder-slab system proved to be the most appropriate structural system for the project.

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