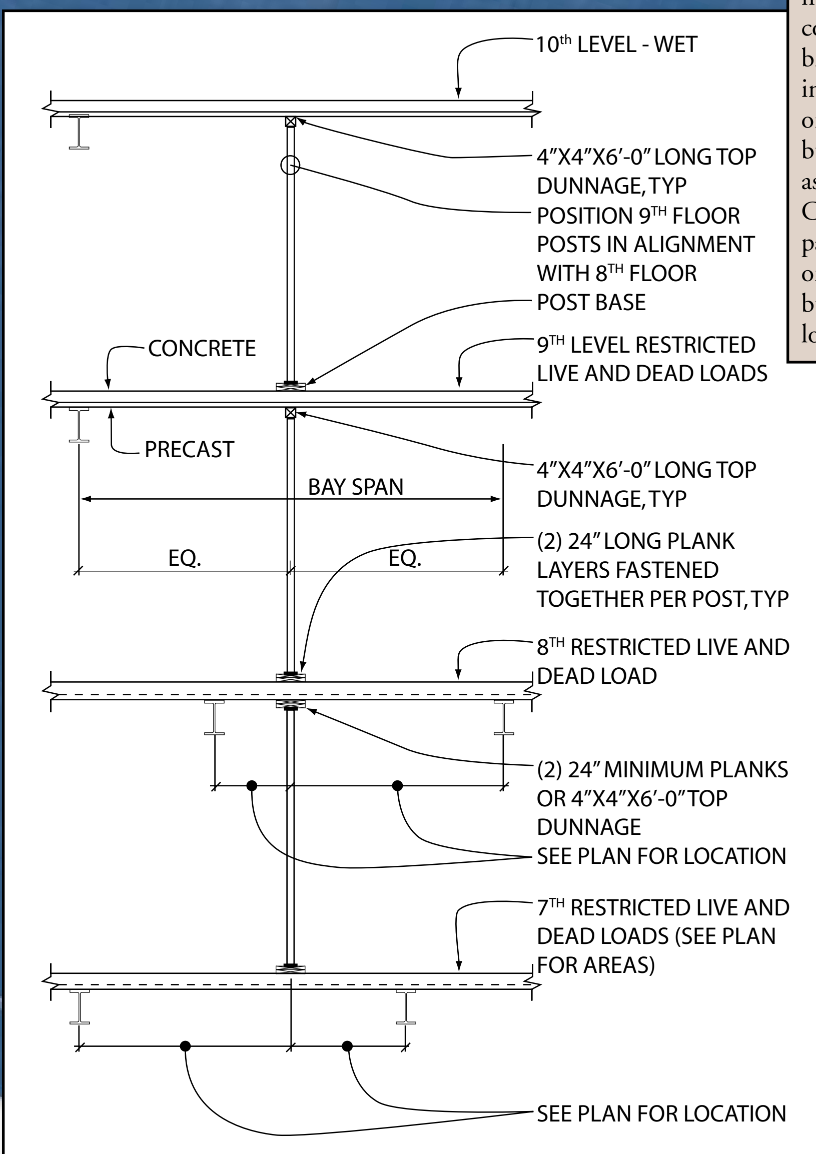
Mandarin Hotel Shoring

By Stephen A. McDermott and Craig E. Barnes, P.E., SECB

The Mandarin is a condominium and hotel project in the Back Bay section of Boston, MA also know as the Prudential Center. The Mandarin has an eight-story hotel base from which two mid-rise towers extend, each with six floors. Steel wide flange columns and beams are the basic structure for this pile supported braced frame. The Prudential Center Complex started building in the mid-1960s and, when completed, provided a 52-story office tower, 18-story hotel, two high-rise condominium buildings and a grade level complex of retail shops and eateries, as well as a large supermarket. Locals considered the Prudential Center Complex to be a city within a city. Several levels of parking occupied the entire complex footprint below grade. The only remaining above ground area, with space sufficient for a building the size of the Mandarin, was a rectangular automobile loading and discharge area parallel to Boylston Street.

CBI Consulting Inc. (CBI) was engaged by the concrete subcontractor, S&F Concrete, to provide a shoring design to support concrete topping onto pre-installed shallow pre-cast concrete filigree panels. The Mandarin floor design consisted of composite steel deck and concrete from floors 2 through 8, pre-cast filigree panels from floors 9 to 14 plus the roof. CBI shoring design began at the 9th floor. Shoring design for the filigree panels required coordination among McNamara Salvia Inc., the Structural Engineer of Record (SER); Suffolk Construction, the general contractor; Mid State Filigree Systems, the pre-cast manufacturer; and the concrete placement contractor (S&F Concrete). The parties had their own interests relating to the shoring, panel placement, speed and size of area to be covered at one time, plank capacity, and surface finish of topped panels.

CBI assumed several roles during the construction phase of the project. Engaged first by Suffolk Construction, the general contractor, CBI provided engineering for various means and methods of construction. Subsequently, CBI was hired by the crane subcontractor, to review ways to bring heavy equipment to the site. As construction progressed, service to Suffolk Construction continued as scheduling advice for construction cycling was provided. Lastly, and the subject of this article, CBI became engineering subcontractors to S&F Concrete, Hudson, MA, who were responsible for all concrete placement for the project. S&F Concrete are concrete placers and finishers, providing related form work.



Proposed Shoring Section.

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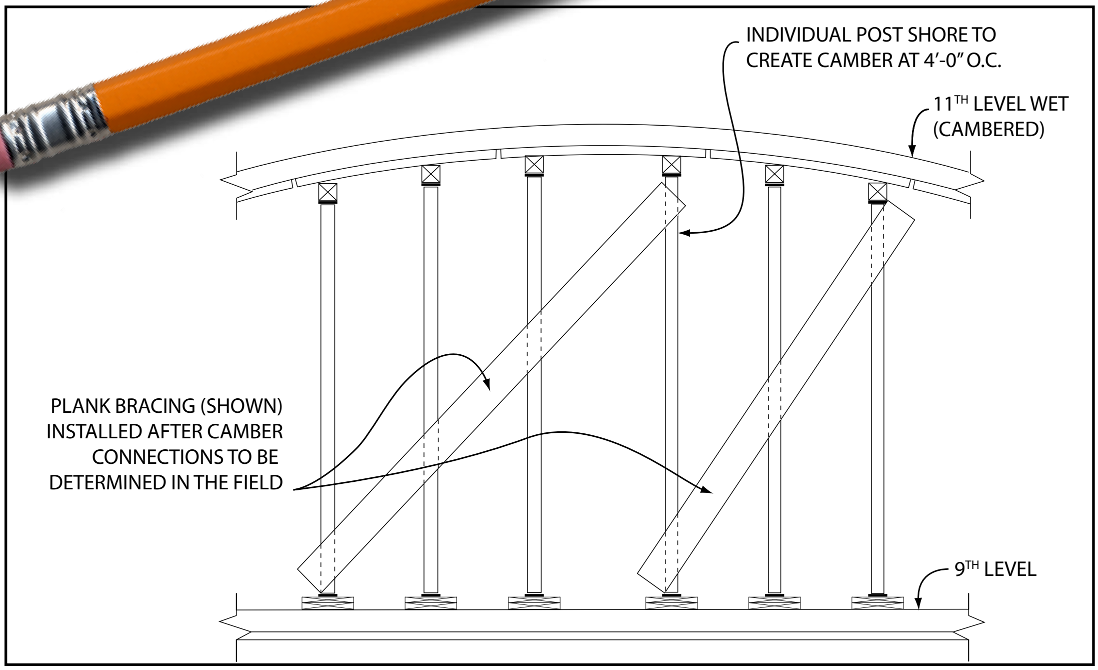

Schematic Elevation.

A filigree panel is nothing more than a thin piece of precast concrete, in the case of the Mandarin, 2¼ or 4½ inches thick, which functions as form work. Filigree can be used as beam and column forms as well. The finished surface is of acceptable architectural quality. The filigree panel needs to be shored before concrete placement, as the inherent filigree capacity has little more than self-weight ability. Generally, spans exceeding fifteen feet require intermediate shoring, even for self-weight.

The shoring was designed to support the topped panel gravity loads and construction loads. In addition, the team had to create a positive floor chamber from relatively flat pre-cast panels for spans varying from 15 to 30 feet. Ultimately, adjustable post shores with top and bottom dunnage wood pads and timber transfer beams were used. Generally, the shoring was centered mid-span of the panel and ran perpendicular to the length of the pre-cast filigree. The panel shoring at mid-span allowed slight jacking of the filigree panel to create a positive floor chamber.

In most construction situations, at least in New England, the SER establishes on the contract documents general guidelines for the SER's involvement in the construction process. It is generally a hands-off approach to the contractor's means and methods.

In the case of the Mandarin project, for a variety of reasons to be noted herein, the SER maintained constant involvement until the last slab was cast. CBI took its initial guidance from the contract documents. It was assumed that the uniform live load capacities contained in the General Notes of the contract plans were not to be exceeded. From their own design experience, CBI knew this was a conservative approach, perhaps not so much in the actual strength of the member but more so in what constituted the miscellaneous loads to be applied.

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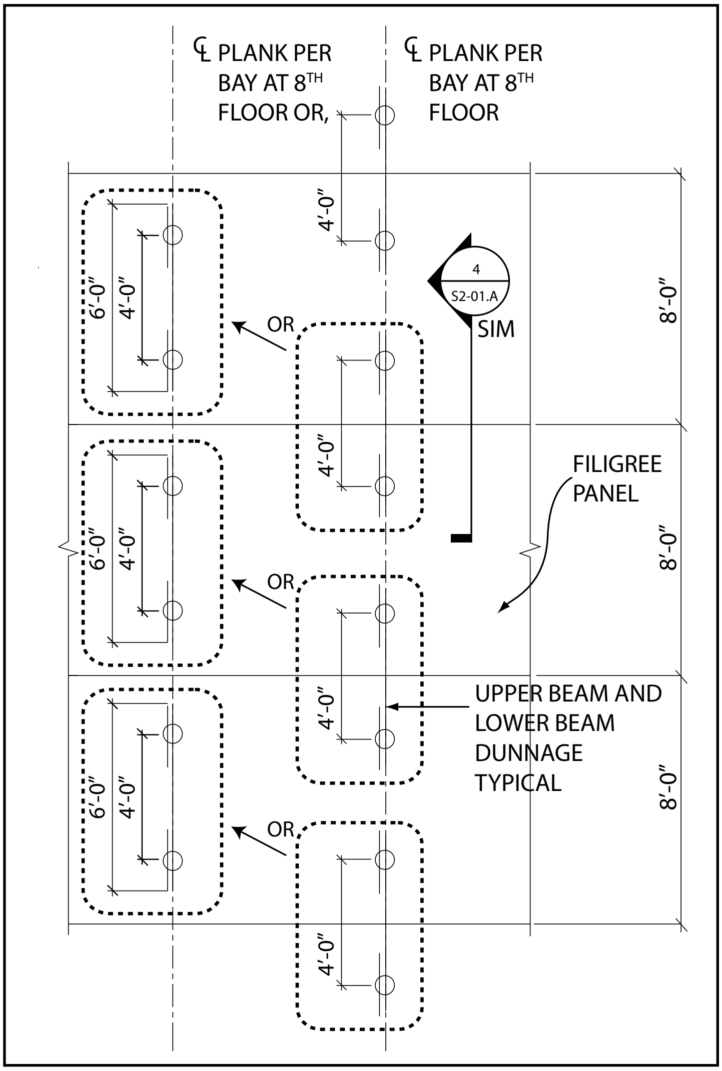
During the shoring design process, which began in August 2006 and concluded in May 2007, and to some extent during the construction process underway within that period, construction ideas were tested with the contractor, such as varying topping strength, varying the plank dead load capacity, controlling construction loads, etc. When something "more" was needed out of the system that would be a departure from the initially established criteria, such as reducing construction loads or increasing miscellaneous live load capacities, the advice of the SER was sought.

Application of the centerline shoring typically was carried stacked downward two levels onto various aged green concrete. As the floor placement continued upward, the centerline shoring locations differed from floor to floor as plank span changed. This required realignment of the stacked shoring posts below the concrete placement floors. This shore/reshore arrangement continued throughout the project.



Typical Plan View.

The span direction of the filigree panel changed 90 degrees at the 12th floor creating a shoring centerline atop a single panel versus perpendicular distribution across the width of a series of panels. The change in direction of the pre-cast panel required the shoring of all the preceding floors to be removed and realigned to create a new stacking effect. The reconfigured shoring required three lower floors to distribute the change in plank direction. After placement of the 12th floor, the upper levels remained consistent with two shoring levels below.

Each level of shoring construction was defined by a set of shoring plans for the working level (the level being cast) and as many levels below as were reshored. Each submission of plans contained a full set of calculations for the shoring plans being submitted. Plans and calculations were sealed by a Massachusetts registered structural engineer. Regularly scheduled meetings were held at the job site with the general contractor, concrete subcontractor, concrete subcontractors, SER and CBI.

The job contained some unusual intricacies. The first shored level, the 9th floor, was above a metal deck and concrete system with slightly greater load capacities than the residential floors of the filigree system. The filigree plank needed to allow for a steel wide flange beam frame system below that contained members which were cambered to various degrees. The beams of various size and spans had varying non-composite and composite capacities. To maximize placement efficiency, planks were cast in some areas to be laid down as one piece over one or two intermediate supports. How would a beam, with a particular set height, curve to match a plank with a mind of its own? Where multiple levels of shoring and reshoring were being supported on members at those levels, which had different deflection characteristics, stiffness compatibility became an obstacle to be dealt with. When the plank layout of the 12th floor changed direction, the reshore layout between 9th and 10th, and 10th and 11th floors had to be supplemented with shoring in the orthogonal direction. At one point, an attempt was made with a field test to determine if the plank with an eight (8) foot width and two span lengths could be "made" to drape or conform to the parabolic shape created by the cambered beams pegged to a zero relative grade at the columns. The plank would not cooperate; however, the grade difference was not substantial enough to change the design intent.▪

Stephen A. McDermott, Project Manager for CBI Consulting Inc. is responsible for forensic investigations, design, waterproofing evaluations, building envelope studies, and field observations. Mr. McDermott can be reached via email at ***smcdermott@cbiconsultinginc.com****.*

Craig E. Barnes, P.E., SECB, is principal and founder of CBI Consulting Inc. As an engineer registered in both the civil and structural fields, Mr. Barnes has over 40 years experience designing, coordinating, and managing structural and civil engineering projects throughout New England. Craig also serves on the STRUCTURE® Editorial Board. He can be reached via email at ***cbarnes@cbiconsultinginc.com****.*