INNOVATIVE *Design*

Using Composite Steel Joists

121 SEAPORT BOULEVARD

By Michael Martignetti, P.E.

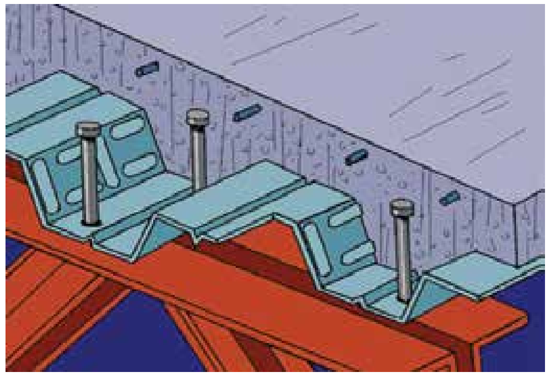
Innovation is evident in the Boston skyline. A talented group of architects and engineers have designed the structures built in the last 30 years in Beantown. These creative firms continue to incorporate new design concepts that meet their client's needs. Clients get a great, sustainable structure that utilizes the best materials and the most economical design. The public – well, they get to look at and utilize the buildings. One engineering firm has done its share of design in Boston: McNamara·Salvia Structural Engineers.

One structure of particular note is the recently completed 121 Seaport Boulevard in the Seaport District of Boston. The McNamara·Salvia (McSal) team, under the guidance of Principal John Matuszewski, P.E., worked with CBT Architects on this 17-story, 440,000 square foot, Class-A office building. Per McSal's website, "121 Seaport's unique design is carefully choreographed to promote innovation and collaboration, and increase employee productivity in the workplace." The building features a three-story lobby, dedicated fitness center, views of the harbor and skyline, and wide-open office space to meet the changing requirements for commercial office layouts. The structure's elliptical shape avoided underground tunnels and zoning issues and reduced the lateral wind load on the aerodynamic structure. This, in turn, reduced costs and allowed for a very open concept with minimal columns and floor-to-ceiling glass windows. The open concept utilized plenty of natural light and helped the building achieve LEED Platinum Certification. Top-down construction meant that the superstructure was built while the underground parking garage was simultaneously excavated. This added to the design challenge, but ultimately saved millions of dollars and six months of schedule.

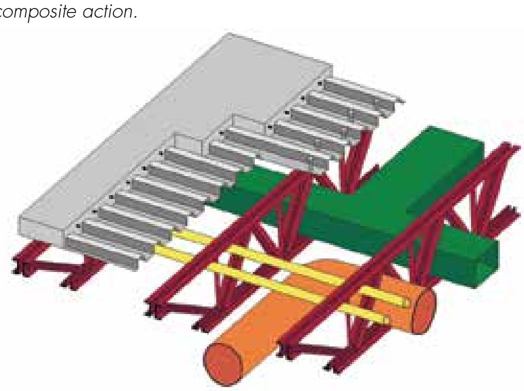
At the core of this beautiful building are CJ-Series composite steel joists. McSal has used CJ-Series joists successfully in several mid-rise buildings throughout Boston. CJ-Series steel joists support the composite steel deck and the concrete slab poured on top. Similar to composite beams, shear studs are welded through the deck and to the joist's top chord to develop shear transfer from the joist to the concrete slab. The composite action between the joist and concrete allows the concrete to act as the compression chord element of the joist. As the slab works compositely with the joist, the moment arm or distance between the tension force in the bottom chord and the compression force in the top chord increases. This reduces the required angle sizes in the joist chords, which lightens the overall joist weight and cost.

Composite steel joists offer several advantages compared to composite beams. The open web steel joists can span long distances to create wide-open spaces. At the same time, they offer an excellent span-to-weight ratio, which decreases the overall weight and cost of the steel structure. A maximum span-to-depth ratio of 30 is greater than the typical roof joist span-to-depth ratio of 24 and allows even shallower joists to achieve the wide column spacing. A typical 22-inch-deep composite joist spanned anywhere between 30 feet and 48 feet on the project, accomplishing the elliptical shape. The joists were spaced 10 feet part given their strength and were topped with 2-inch composite deck, ¾-inch-diameter shear studs, and a 5¼-inch lightweight slab. Camber in the joists was designed to offset construction dead load deflection. The efficient design reduces the overall number of members required, speeding up the erection of the structure. Minimizing the joist count also reduces the amount of spray fireproofing that must be done to achieve the required fire rating for the floors. The open web construction of the joists allows MEP trades to run plumbing, electrical, and mechanical equipment through the joists rather than under the beams. This minimizes the overall floor depth, maximizes ceiling heights, and/or reduces overall building height.

The office tower's wide-open spaces created a need for extensive ductwork to heat and cool the spaces. Vierendeel openings were created at the midspan of the joists to accommodate the ductwork. Vierendeel openings are designed by the joist manufacturer, eliminating joist webs for a section of the joist so that there is an unobstructed space between the top and bottom joist chords. The joist's midspan is an ideal location as the shear forces are significantly less at this point of the joist. The Vierendeel openings were strategically aligned from joist to joist to create a wide-open passage where all of the ductwork was concentrated, avoiding putting anything below the joists. With all of the MEP organized within the joist envelope, the structure afforded the fit-out that architects desired with the ability to leave the ceiling exposed to view.



Shear studs welded through the deck to the top chord create the composite action.



Open web steel joists allow MEP to easily route through them to minimize floor envelope.

Given the goal to minimize the floor envelope, McSal presented the concept of flush frame connection to attach the composite joists to the girders. The joist engineer and steel connection designer then coordinated to finalize this connection's design details, which offered several advantages. Typically, open web steel joists sit on top of the girders with 5-inch-deep seats. By dropping the joist between the girders, that 5-inch depth was not added to each floor envelope. The flush frame connection design allowed the erector to utilize a bolted connection, significantly reducing the amount of welding in the field.

Additionally, the overall length of the joists was shortened, making it easier to maneuver the joists into place. The flush frame connection meant some additional shop work for the production of the joists and girders, but this cost was controlled in the shop environment. Ultimately, the ease of erection saved both time for the overall construction schedule and cost for the superstructure.

Bryan Hilton, P.E., Senior Project Manager for McSal, served as a key member of the design team throughout the project. When asked about why composite joists were chosen for the project, Hilton commented, "the selection of the composite steel joists with composite beam girders was the optimum framing system for the project because of its long-span capability, the economy of weight, enhanced flexibility with the building's MEP system, reduced floor-to-floor height, and its successful performance in past projects." The McSal team worked hard to optimize the benefits that the composite joists offered for the structure. Hilton stated, "a design challenge was the incorporation of a simplified and comprehensive approach to specifying the composite steel joist's required moment of inertia to satisfy the building's office vibration criteria given the elliptical shape of the floor plate." The behavior of the building with this shape, combined with varied member lengths, made the analysis complex. Ultimately, a single minimum moment of inertia was provided for the joist designer to keep the design simple while ensuring that the lightweight members met the vibration requirements.

Cives Steel Company – New England Division, the structural steel fabricator, and James F. Stearns Co, the steel erector, constructed the main steel superstructure over a period of six months. When asked about the composite joist design, Brock Bessey, Project Manager for Cives, stated, "Composite joists worked great for this project due to the need for the design team to pass the MEP trades through the support members. Creating openings in a wide flange beam would require a good deal of shop reinforcing, especially for large web penetrations." The joists were connected directly to the concrete core at the center of the building and varied in length at the perimeter to create the "football-shaped" structure. Soft shoring was placed at the edge of each side of the opening to maximize the size of the vierendeel opening while minimizing the joists' weight. Soft shoring means that the shoring posts are set to a height that allows the joists to deflect to the elevation that results in a level slab of consistent thickness due to the self-weight of the slab before supporting the midspan of the floor until the concrete cures and composite action ensues. For this project, the shoring was only needed for three days, allowing construction to move quickly.

121 Seaport Boulevard has left an imprint of innovation on the Boston skyline with its curves and creative design. It offers its tenants state-of-the-art open spaces full of natural light and flexibility by utilizing composite steel joists rather than a typical composite beam design. This was all done while minimizing the structure's weight and utilizing an innovative construction sequencing saving both time and money for the project. Looking to the future, this project sets a new bar that will challenge designers to continue to innovate in the years to come.▪

Michael Martignetti is the Vice President of Sales for Canam Steel Corporation, a Steel Joist Institute member company. (michael.martignetti@cscsteelusa.com)

Bolted flush frame connections for joists to girder.

Vierendeel openings at midspan allow for a large chase of ductwork.