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STRUCTURES

Strengthened Parking Garage Supports High-Rise Ice Rinks

A seven-story parking garage at a shopping mall in Arlington, Virginia, provided the base on which to construct a pair of rooftop ice-skating rinks—known collectively as the Kettler Capitals Iceplex—that will serve both the public and the Washington Capitals, the National Hockey League (NHL) franchise in Washington, D.C. The two NHL-sized rinks—each measuring 200 by 85 ft (61 by 26 m)—opened in November atop the Ballston Common Mall's parking garage on a new eighth floor of the structure that includes the skating facilities along with 192 additional parking spaces. The project also added a ninth-floor mezzanine over the rinks for a total expansion of approximately 220,000 sq ft (20,400 m²) in building and parking space.

William R. Drury, the president of Architecture, Inc., of Reston, Virginia, which designed the new facility, notes that this is the third time the Ballston parking garage has been expanded. The original facility, which dates to 1950, was a five-story, cast-in-place concrete structure reinforced with mild steel. In 1981 a five-story, L-shaped addition using cast-in-place, posttensioned concrete was constructed on the south and east sides of the garage to expand the overall footprint of the structure. Then in 1986 the existing five-level structure was topped by two more levels—one portion of these levels a posttensioned concrete addition, the other a composite steel addition.

Gene Weissman, a principal with Architecture, Inc., who managed the project along with Clint Brackman, another principal of the firm, says the Iceplex's eighth-floor location—more than 60 ft (24 m) above grade—makes its elevation one of the highest in the world. But that fact also posed a temporary obstacle for the project. "We had a hard time seeking out people who actually knew what the tolerance was" for constructing an elevated rink that would remain flat and level

The Kettler Capitals Iceplex, in Arlington, Virginia, is now home to a pair of rooftop ice rinks constructed atop a seven-story parking garage. To support the two additional levels of skating rinks, parking spaces, offices, and training facilities, new steel columns were installed in the garage and preexisting steel columns were strengthened with rebar and welded shear studs. Concrete columns were wrapped in a thin layer of a fiber-reinforced polymer composite material.

Architecture, Inc.

enough to avoid cracks in the ice, notes Weissman.

By speaking with experts in the creation of rink ice, the design team eventually learned that deflections would need to be as close as possible to zero over the 200 ft (61 m) span of each rink—tolerances that would require moment connections, bolstered columns, and steel lateral cross bracing beneath the side-by-side rinks, notes Weissman. Bill Duvall, P.E., a project manager for Rathgeber/Goss Associates, of Rockville, Maryland—which was responsible for the structural engineering of the project—adds that a laser screed device manufactured by Face Consultants, of Huddersfield, United Kingdom, helped determine that the rink construction had achieved and even exceeded the design requirements for a floor flatness, F_F, of 45 and a floor levelness, F_L, of 35 as defined by ASTM International's standard E-1155-96 (*Standard Test Method for Determining F_F Floor Flatness and F_L Floor Levelness Numbers,* 2001).

The rinks also added considerable weight to the top of the existing structure, notes Duvall. Each rink represented a superimposed dead load of approximately 130 psf (635 kg/m²) in addition to the 75 psf (366 kg/m²) dead load added by the structure itself. The existing structure had been designed to accommodate one additional floor but not the two levels plus the roof and ice rinks that were added in this project, Duvall says.

Three types of columns throughout the structure were either strengthened or installed to support the new levels and the rinks. For example, 11 of approximately 126 all-concrete columns—all from the 1986 posttensioned addition beneath the new administrative areas—were wrapped in a thin layer of a fiber-reinforced polymer composite material. This process allowed the full column dimension to be used in increasing the axial load capacity, notes Duvall. Steel columns found on the two upper levels of the 1986 composite steel addition were first stripped of their concrete fireproofing and then reinforced with rebar and welded shear studs before being clad again in new concrete, notes Weissman. Finally, steel columns were added to the upper floors of the existing structure to support the new levels of the building.

Constructing the enclosed extra floors atop the otherwise open parking garage structure was "like adding a sail" to the building and required reinforcements to accommodate the wind loads, notes Duvall. The solution involved adding steel tube bracing in the form of inverted Vs that extend down through the composite steel levels of the garage to transfer the wind loads to the concrete levels of the structure, Duvall explains. Slots were cut in the concrete slabs between columns on the composite steel levels and the inverted V braces were installed between the base of the columns and the beams that support the overhead floor slabs. The cross-sectional dimensions for the bracing are 8 by 6 in. (203 by 152), and the thickness of its walls is $^3/_8$ in. (9.5 mm). The length of each segment of the V is approximately 13.5 ft (4.1 m).

The twin rinks each have a structural slab that takes the form of a 3 in. (76 mm) thick metal deck topped by 3.5 in. (89 mm) of concrete. Atop the concrete lies a 4 in. (102 mm) layer of sand that contains heating pipes to keep the structural slab warm enough to prevent condensation on vehicles parked in the open-air garage below. Atop the sand sits a 4 in. (102 mm) layer of rigid, load-bearing insulation, in turn surmounted by a 5 in. (127 mm) floating concrete slab with refrigeration piping that creates and maintains the ice. The entire structure is then crowned by approximately 1 in. (25 mm) of ice, notes Weissman.

The rinks are essentially identical, but the one designed for the public features a scoreboard mounted on the wall, while the other—which will be used primarily by the Capitals—has an NHL-style scoreboard suspended over the ice, says Weissman. The Capitals' rink also features additional steel beams underneath a bleacher section that can seat 1,000, and there is a 90 ft (27 m) steel truss above the players' boxes. The truss—chosen because the team did not want any columns in that space, notes Duvall—is approximately 10 ft (3 m) deep and supports the 120 ft (37 m) clear span of the rink's roof, which at a height of approximately 38 ft (11.6 m) creates a large, open space within the arena. The public rink features a similar 120 ft (37 m) roof supported by columns.

Locker rooms, a snack bar, an equipment store, ticket booths, and various offices separate the rinks. At the eastern end of the new addition is a 20,000 sq ft (1,860 m²) space on the eighth level that houses a training center with weights and fitness equipment, and a similarly sized space above the training center serves as the Capitals' corporate offices. These two sections feature a slanting glass facade that cantilevers approximately 14 ft (4.3 m) to suggest the blade of an ice skate, notes Drury.

Because the building is now considered a high-rise structure under Virginia building codes—and one from which several thousand people might need to be evacuated during an emergency—the design team also had to enclose the four existing stairwells that descend from the eighth floor to the ground level and add two stairwells, notes Weissman. The doorways to these exits were fitted with gaskets, thresholds, and automatic closing devices, and fans were added at the top of the building to create a positive air pressure to keep smoke out of the stairwells in the event of fire, he explains.

—Robert L. Reid