Column and Beam Enlargements Using Self-Consolidating Concrete at a U.S. Ski Resort

Submitted by Structural Preservation Systems, LLC

Constructed in 2006, the condominium/hotel facility at a major ski resort offers high-quality lodging in studio through three-bedroom condominium units. The structure features an underground parking garage, which is an important amenity to patrons.

PROBLEMS THAT PROMPTED REPAIR

Upon completion of the construction and loading of the building, many cracks appeared on the underside of the garden level slab, which was also the ceiling of the upper level of the parking garage. After hiring an independent consultant to perform a structural review of the building, the owner learned that the building had been under-designed and there were construction deficiencies. In fact, the building was not in code compliance and structural remediation was needed. To ensure the safety of patrons, the owner had to shore the ceiling of the parking garage, which eliminated 75% of the parking spaces.

INSPECTION/EVALUATION METHODS

Once the structural engineer was hired to perform the evaluation of the existing structure, the first step was to perform a site survey and map all of the existing cracks and place gauges on some of the larger cracks to monitor the width. The next step was to perform a detailed review of the original design documents. Once these activities were complete, the magnitude of the design and construction deficiencies was understood. The structural engineer then began the design process for the remediation.

REPAIR SYSTEM SELECTION

Upon inspecting the repair design drawings, the repair contractor developed an innovative strategy using self-consolidating concrete (SCC) for the 59 beams and 16 columns that needed to be constructed underneath the garden level slab. For this project, SCC was the only way to place the concrete in the overhead beams. The forms for the beams were completely enclosed, so pouring conventional concrete would not have been possible. The flowability of SCC allowed the concrete to flow properly around the tight reinforcing steel. In addition, pumping SCC under pressure achieved the bond between the existing and new concrete.

Existing condition—cracks on underside of garden level slab

SITE PREPARATION

The parking garage at the structure was partially closed during the first phase of the work, which took place during the ski season. During this portion of the work, all materials and equipment had to be stored within the active work area among the myriad of shoring present so that the remainder of the garage could be used for parking. Upon completion

Example of typical formwork at the beam-column intersection

Structural shoring and formwork in place—this demonstrates the tight working area

Example of congested reinforcing steel beam-column intersection. The flowability of SCC allowed the concrete around the tight reinforcing steel

of the ski season, the entire garage was closed and the remainder of the garage outside of the repair area was used for a laydown area in addition to a large area of the outside parking lot.

DEMOLITION METHOD

At several of the basement level columns, the slab-on-ground had to be removed and the footings had to be excavated so they could be enlarged. At several of the column capitals on the underside of the garden level, portions of the capital had to be removed so that the new beams could tie into the existing columns. This demolition was performed through a combination of a remote-controlled pneumatic demolition machine and conventional chipping hammers. In addition, at all the columns that were tied into the new beams, several core holes were required so that reinforcing steel could be passed through to accommodate shear transfer from the new beams to the existing columns.

SURFACE PREPARATION

The surface preparation of the existing slab and column surfaces was a critical part of the remediation design. The interface between the new beams and the existing slabs was relied on to provide a significant portion of the shear transfer between the two, which allows for composite action. The surface preparation was done using a combination of high-pressure water-blasting and conventional chipping.

APPLICATION METHOD SELECTION

The final repair design called for a very large number of dowels between the existing slabs and columns and the new enlargements. Another unique feature of the remediation design was the use of undercut anchors along the length of all of the new beams to further aid in the shear transfer between the new and existing structures. After demolition and surface preparation were completed, a stay-in-place mockup beam was installed to ensure that components in the field would fit together as they were drawn on paper. All steps were completed on this beam from dowel and undercut anchor installation to reinforcing steel installation, formwork construction, and concrete placement. Following the successful completion and acceptance of this mockup, the work proceeded on the remainder of the project.

REPAIR PROCESS EXECUTION

Although SCC was clearly the best material for completing this strengthening project, the repair contractor had to overcome several challenges to make it work. The most significant challenge faced was that there were no concrete plants in close proximity to the project site. The nearest sizeable

town was more than 50 mi (80 km) from the resort and there are only two concrete suppliers that could deliver materials to the mountain. Of those two suppliers, one was eliminated because the structural engineer had concern with their aggregate. The remaining supplier had no experience with SCC, so the repair contractor had to work closely with them and the admixture supplier to develop a new mixture for this project to ensure proper strength properties and workability. Typically, SCC should be placed within 90 minutes of mixing. Because of the distance from the plant and the mountainous terrain, it was a 2-hour drive from the concrete plant to the job site, and the concrete would begin to set up by the time it reached the job site. To combat this challenge, the repair contractor worked with the admixture and the concrete suppliers to develop a mixture that would delay the hydration reaction of the mixture—essentially putting the concrete to sleep until it arrived at the job site.

The concrete had to be pumped from 300 ft (91 m) away and several different kinds of pumps were used to get the concrete into the forms. The forms were pressurized to allow for proper concrete placement with no voids and to achieve the required bond with the existing substrate, so special safety precautions were taken. The team carefully monitored the pumps and forms both visually and audibly to ensure there was not a catastrophic failure. The innovative formwork helped ensure that the beams were monolithic structural members.

In addition to these challenges, the facility remained open during the repairs. Crews had to confine materials to a limited laydown area and no work could be done on many weekends. The project began at the end of January, which is the peak of ski season. There were restricted work hours, but the project had a tight schedule—work had to be completed by November for the upcoming ski season. Even with the challenges, the repair contractor was able to complete the project on time and on budget. Both the owner and the structural engineer were extremely pleased with the outcome.

UNFORESEEN CONDITIONS FOUND

There were several unforeseen field conditions that required quick decisions and adjustments by the project team during construction. These changes ranged from unforeseen obstructions due to existing mechanical/electrical/plumbing (MEP) equipment and structural elements that were not clearly shown on the original structural drawings. A large factor in the overall success of the project was the ability of the repair contractor, owner, and structural engineer to remain in constant communication and work as a team to develop timely and effective solutions to these challenges.

SCC sample obtained for testing

Finished beams and columns tied together

Ski Resort Column and Beam Enlargements

OWNER
(Owner information kept confidential by request)

PROJECT ENGINEER/DESIGNER
Simpson, Gumpertz & Heger, Inc.
Rockville, Maryland

REPAIR CONTRACTOR
Structural Preservation Systems, LLC
Elkridge, Maryland

MATERIAL SUPPLIERS/MANUFACTURERS
The Euclid Chemical Company
Cleveland, Ohio

Central Supply Company
Elkins, West Virginia