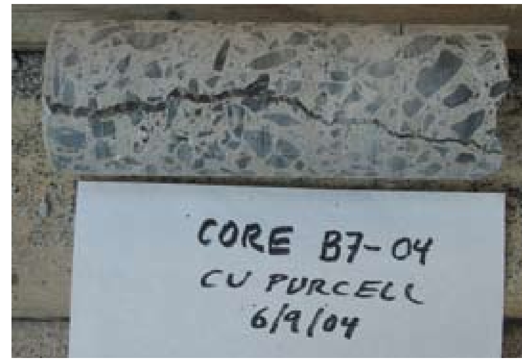
Exterior Repairs to University Building

Exterior of the Robert Purcell Community Center



Concrete core

The Robert Purcell Community Center (RPCC) is a student center constructed in 1970 on the campus of Cornell University, Ithaca, New York. It comprises dining, conference, and student recreation facilities. RPCC is a three-floor structure built around a concrete frame. The exterior walls are brick veneer backed by 8-in. (20-cm) thick, load-bearing brick walls. The third floor features projecting bays supported by cantilever beams. The beams support masonry sidewalls, projecting floor bays, and the sloping roofs above. The cantilever beams are exposed concrete on the exterior.

In 1983, the engineer of record participated in an investigation of the RPCC as part of a building-wide review of problems the facility was experiencing. Based on photo reviews, the concrete in 1983 was experiencing some cracking, but to much less of an extent than current levels. The 1983 report attributed the cracking to freezing-and-thawing deterioration along with generally poor quality concrete. This was compounded by roof drainage patterns that saturated the exterior exposed concrete and poor flashing details. The corrective actions from 1983 to 2001 largely focused on minimizing the infiltration of moisture by the application of protective coatings on the concrete.

Inspection/Evaluation

In 2001, the structural engineer initiated a new investigation to assess the progressed cracking. The investigation included visual inspection using aerial man lifts, coring, and laboratory analysis of the cores. The visual investigation determined that map cracking was prevalent in all exposed faces of the cantilever beams, with the worse typically being on the front face of the beams. In addition, concrete spandrels between the beams were experiencing map cracking. Crack widths varied from hairline up to nearly 1/4 in. (0.6 cm). The coring operation proved that many of the cracks extended the full depth of the core and several of the cores pulled not only broke, but also exhibited extensive crumbling. Water used during the coring exited the beams at opposite sides or bottoms in several locations indicating interconnecting of the cracks.

Core samples were analyzed by petrographic examination using methods from ASTM C 856. The examinations showed that the concrete had minimal air entrainment and contained four types of alkali-silica gel. These findings are consistent with the map cracking patterns in the concrete. The examination also identified secondary gel deposits, which are typical for concrete with long-term moisture exposures.

Cause of Deterioration

Exterior exposed concrete cantilevered beams and spandrels of third floor projecting bays on all four sides of the building have been damaged by cracking of the concrete caused by cyclic freezing-and-thawing action of moisture entering the cracks in the concrete. The damage was further exacerbated by alkali-silica reaction (ASR) between silica of certain concrete aggregates and alkalis in portland cement, in the presence of moisture entering the concrete.

Concrete damage appears to be most severe in the front-end sections of the cantilevered beams. There were several primary sources of moisture in the concrete:

- rainwater entering the beams via cracks in the exposed exterior concrete surfaces;
- vent slots in soffits of roof overhangs and cavities of masonry walls supported by the beams; and
- penetration through brick masonry walls and moisture condensation inside wall cavities.

Moisture penetration into concrete through cracks in the top of beams was possible because of an apparent lack of through-wall flashings and weep holes at the base of masonry walls supported by cantilevered concrete beams. Delamination and spalling of the concrete posed a potential hazard to the property and public.

Based on observations and findings, the damaged concrete beams appeared to have adequate structural strength to support imposed floor, wall, and roof loads. Left in disrepair, however, the concrete beams and spandrel deterioration would continue to accelerate, leading to an eventual loss of concrete integrity and adequate structural capacity, which could ultimately result in a structural collapse.

Injection ports

Vacuum injection of resin

Repair System Selection

Two repair options were considered to address the deteriorated concrete. The "conventional" method was based on mass removal and replacement of the deteriorated concrete and would provide the most comprehensive repair to the building. Removal of the cantilever beams, however, would create extensive shoring requirements that would significantly impact the building occupants. Because many of the interior spaces were dining related and would tolerate virtually no down time, measures to construct temporary walls would be required. This was complicated by the alarms and electrical services that were located on exterior walls and would need to be relocated to the temporary interior partitions for code requirement. Building managers also were concerned about the potential impact of noise during the concrete repairs.

An alternative method proposed by the structural engineer was based on a process of vacuum injection/impregnation. This method creates a vacuum simultaneous with injection on isolated sections of beams. The vacuum process draws resins into cracks much smaller than through conventional injections. Because of the extensive cracking, much of it on a micro scale, the technology appeared to be worthy of consideration.

Repair Process Execution

A trial repair project was used to further assess the effectiveness of the vacuum injection/impregnation process. Repairs were conducted on two bays of severely impacted concrete. The repair methodology consisted of the following:

- removing and shoring bricks bearing on the top of the beams;
- sandblasting previously applied coatings, surface sealing cracks;
- setting a network of ports to create a vacuum, then drying the internal cracks via the vacuum;
- injection of the epoxy resin;
- test coring;
- application of the finish coating;
- adding flashing and weeps; and
- brick replacement.

Test cores were taken from six locations and analyzed petrographically. Cores were located in the areas experiencing the most severe cracking. Acceptance criteria from the specification required a minimum of 80% crack fill. Although not a 100% success, the trial repairs were positive enough to accept the vacuum injection/impregnation repair method for the remainder of the building with some modifications to the protocol. The primary change was to increase density of injection ports to achieve the maximum level of fill. In addition, a QA/QC protocol using impact-echo testing was requested to minimize the number of cores.

The final repair scheme was based on the vacuum injection/impregnation techniques coupled with shallow and deep patching where needed. Additionally, measures were taken to better manage water penetration into the building envelope such as soffit upgrades, flashing, spot brick replacement, expansion joint additions, joint sealing, and elastomeric surface coatings.

QA/QC measures were implemented to minimize the number of cores and to identify core locations. Early attempts using the impact-echo testing yielded limited results because the testing was conducted post-injection. There was no pre-injection testing because of the belief that the crack networks were so intensive there would be very limited results. The testing was complicated by the geometry of the cantilever beams and depth-to-width ratios that created boundary effects. Because the results were inconclusive, a full coring program was pursued.

Coring results taken after the initial vacuum injection procedure showed a wide variance in the fill of interconnecting cracks and voids. Because the cores were taken from the most severely cracked areas, results demonstrated the need for an additional round of injection.

Prior to reinjection, a much more intensive impact echo-testing program was implemented that enabled a comparison between pre- and post-injection results. Although the difficulties of beam geometry still existed, comparison of before and after results gave indications of successful crack filling. This method is largely based on the interpretation of results that require a trained individual in the testing technique.

The repaired concrete has been in place for 12 to 18 months and has experienced winter and summer weather extremes. To date, the performance is good and no new cracking or old cracks reopening have occurred through the elastomeric coating.

RPCC

Owner
Cornell University
Ithaca, New York

Project Engineer/Designer
Stophen Engineering
Syracuse, New York

Repair Contractor
Balvac, Inc.
East Aurora, New York

Material Supplier
Fox Industries
Baltimore, Maryland