Robert Purcell Community Commons

Saving a Building from Alkali Silica Reaction

By Peter Paradise, P.E.

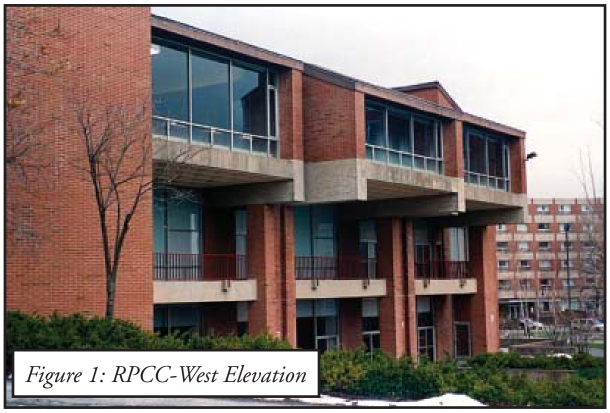

Figure 1: RPCC-West Elevation

The Robert Purcell Community Commons (RPCC) is a student center on the Cornell University campus constructed in 1970. It contains dining, conference, and student recreation facilities. RPCC is a three floor structure built around a concrete frame. The exterior walls are a brick veneer backed by 8-inch 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 (*Figure 1*). The cantilever beams are exposed concrete on the exterior. The concrete was exhibiting significant cracking.

Investigation

J. P. Stopen Engineering Partnership (J.P.Stopen) participated in an investigation of the RPCC in 1983 as part of a building wide review of problems the facility was experiencing. Based upon photo reviews, the concrete in 1983 was experiencing some cracking but to a much lesser extent than current levels. The 1983 report attributed the cracking to freeze thaw deterioration along with poor concrete qualities. 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 by the application of protective coatings on the concrete.

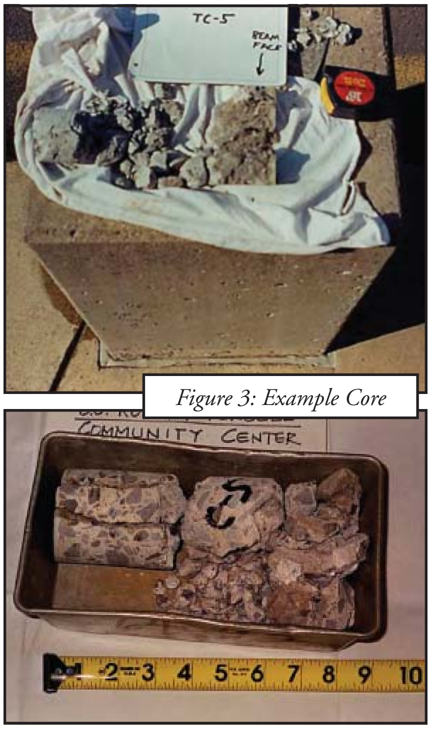

Figure 3: Example Core

Figure 2: Trial Repair Location

In 2001, J.P. Stopen initiated a new investigation to asses the progressed cracking. The investigation included visual inspection using aerial manlifts, 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 (*Figure 2*). Also, concrete spandrels between the beams were experiencing map cracking. Crack widths varied from hairline up to nearly ¼ inch. The coring operation determined that many of the cracks extended the full depth of the core and several of the cores pulled broke and were exhibited extensive crumbling (*Figure 3*). Water used during coring exited the beams at opposite sides or bottoms in several locations indicating interconnection of the cracks.

Core samples were analyzed by petrographic examination (ASTM C856). The examinations determined 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.

Repair Options

Two repair options were considered to address the concrete deteriorated by alkali-silica reaction. The first was a "conventional" method based on mass removal and replacement of the deteriorated concrete that would provide the most comprehensive repair to the building. However, removal of the cantilever beams would create extensive shoring requirements that would significantly impact the building occupants. Because many of the interior spaces were dining related and virtually no down time could be tolerated, measures to construct temporary walls would be required. This was complicated by the alarm systems and electrical services that were located on exterior walls and would need to be relocated to the temporary interior partitions to satisfy code requirement. Building managers also were concerned with potential impacts from noise during concrete repairs.

An alternative method proposed by J. P. Stopen was based upon a process of vacuum injection/impregnation. This method creates a vacuum simultaneous with epoxy injection on isolated sections of beams. The vacuum process draws resins into cracks much smaller than conventional injections. Because of the extensive cracking, with much of it on the micro scale, the technology appeared to be worthy of consideration. The primary supplier of the vacuum injection/impregnation process in the project geographic area was Balvac Inc. The primary properties of the injection material were extremely low viscosity, high bond strength to concrete and adjustable pot life.

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Figure 4: Vacuum Injection/Impregnation In Progress

Figure 5: High Percentage Crack Fill

Trial Repairs

In order to further assess the efficacy of the vacuum injection/impregnation process, a trial repair project was undertaken. Repairs were conducted on two bays of severely impacted concrete (*Figure 2*). The repair methodology consisted of removing and shoring bricks bearing on the top of the beams, sandblasting previously applied coatings, surface sealing cracks, setting a network of ports to draw vacuum (*Figure 4*), drying the internal cracks via vacuum, injection of epoxy resin, test coring, application of finish coating, adding flashing and weeps, and brick replacement.

Test cores taken from six locations were analyzed petrographically by The Erlin Company. Cores were located in the areas experiencing the most severe cracking. Acceptance criteria from the specification required a minimum of 80% crack fill. Results varied from 100% crack fill to 0% crack fill in the cores. The majority of the major cracks were completely filled and the compressive strengths were within acceptable ranges.

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 minimize the number of missed cracks. Also, a QA/QC protocol using impact echo testing was requested to minimize the numbers of cores.

Final Repair Scheme

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 Impact-Echo testing yielded limited results because the testing was conducted post injection. Pre-injection testing was not undertaken 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 for the building varied significantly between 100% fill (*Figure 5*) and 0% fill. Because cores were taken from the most severe crack areas, poor fill results served as the trigger for a second 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 successfulness of crack filling. This method is largely based upon 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 (*Figure 6*). To date, the performance is good and no mirror cracking is occurring through the elastomeric coating. Ongoing monitoring of the structure will continue.

Lessons Learned

1. Future work of this type will benefit from a thorough testing program that obtains impact echo data before and after the repairs are performed, and reduces the amount of coring required for quality assurance. This testing protocol must be overseen and reviewed by an individual with experience specific to the instrumentation, as well as knowledge of the structural deformation cause in order to interpret the result.

2. Weather conditions must be closely monitored. The injection process should be performed in temperatures above freezing, and injection material viscosity should be adjusted with ambient temperatures. To much or too little viscosity will result in significant void areas in cracks.

3. The injection process appeared to favor injection with momentary pauses, followed by reinjection prior to moving on to the next injection point. Initial protocol was for injection to stop once resin was discharging from upper port holes. However, if a pause in injection occurred, and a second attempt was made, the concrete would take additional material before discharging from an upper port. This was attributed to absorption and wicking action in the micro-cracks. Although this slowed the initial injection program, it reduced the need to go back for a second round of injection after coring.▪

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Figure 6: RPCC Concrete Repairs Complete