SCC Proves Successful in Repair and Strengthening Projects

By Mike Miller, Ville Vainio and Jay Thomas

Self-consolidating concrete (SCC) has been used for a variety of new construction and precast manufacturing projects since its inception in the 1980s. Recently, design and construction professionals have found that the features and benefits related to SCC can solve many constructability and placement challenges that most concrete mix designs can not. The main feature of this unique type of concrete relates to having very high slump and flowability properties without segregation. Successful SCC applications are not only seen in new construction projects that present difficult placement or finish challenges, but also in concrete repair and strengthening projects where the material must be placed under pressure into confined, highly reinforced forms.

Many of the characteristics that have made SCC popular in early uses for new construction are also advantageous for renovation projects. These include reduced labor cost, ease of pumping and placement into very congested formwork, creating specialty surface finishes, as well as the high quality of the end product. The SCC mix design uses similar concepts as traditional concrete (strength, accelerated or retarded set times, aggregate size), except, specialty admixtures radically modify the slump and hence flowability.

Why Use SCC for Repair/ Strengthening Project?

Also known as self-compacting concrete, SCC is a highly fluid, non-segregating concrete mixture that consolidates under its own weight. According to the National Ready Mix Concrete Association (NRMCA), "the development of high performance polycarboxylate polymers and viscosity modifiers have made it possible to create 'flowing' concrete without compromising durability, cohesiveness or compressive strength." Translation: A concrete so flowable that when testing for slump, instead of measuring the height of the slump cone, you will need to classify the slump by measuring the diameter of the circular "blob" (20-28-inches) that pours out of the slump test cone. This is not an easy concept after years of working with standard concrete mixes.

Many repair/strengthening projects have tight forming space constraints that make concrete pours challenging. These projects usually have tighter spacing between the reinforcement and the existing concrete surface and reinforcement and formwork. SCC's flowability lends itself well to concrete beam, slab and column "form and pump" repairs that are commonly found on structural restoration and strengthening projects. Frequently, these repairs involve enclosed formwork and require the material to be placed under pressure to ensure a good bond with the prepared, "open" substrate. This placement process and material alleviate problems associated with using traditional concrete, where voids and honeycombs can occur and are often not revealed until the forms are stripped.

Installation of rebar, PT cables and anchors.

Examples could include filling a repair void created by chipping out deteriorated concrete or enlarging the sides and bottom of a beam to carry addition loads. In addition, repair projects often require crews to work in extremely tight conditions with many mechanical/electrical/ plumbing (MEP) components, mazes of existing rebar configurations and, due to access and building operations, the pumping distance can be from hundreds of feet away.

When pumping concrete for repairs on existing structures, the installation of formwork can create challenges. For example, forming and pumping new concrete on an overhead beam or slab with SCC requires stronger formwork design, as the forces created by the truly liquid material are greater than those seen in standard concrete. Also, the pressurization of the formwork adds even more stress. Traditional ready mix concrete, because of its high viscosity and limited flowability, is also inherently difficult to pump (especially over long distances) into enclosed/ pressurized formwork with tightly spaced reinforcement. Concrete contractors routinely have had challenges with clogged pump lines during a pour, and understand the loss of time and money this can create when a pour is shut-down to repair a pump line. The low viscosity of SCC makes it easier to pump and allows it to flow easily throughout a form, typically from one single port location, while preventing voids and honeycombs.

In addition to improved flowability, SCC may offer several cost savings that can easily offset the reasonable premium per yard cost as compared to traditional ready mix concrete. For example, there is a labor savings because crews can pour larger repair areas at one time all from one port location – sometimes allowing a single pump location and line set up. This minimizes the amount of hard and soft pump lines. The improved finish means crews have to spend less time on rub-out repairs after the forms have been stripped. The flowability also allows ability to have dramatic architectural finishes that will literally mimic whatever finish or shapes are inside the formwork. Forms do not have to be vibrated to consolidate the concrete.

When to Use SCC?

Before incorporating SCC into a repair or strengthening project, it is important to evaluate several factors including the size and configuration of the concrete formwork, any MEP obstructions that may require penetrations through the formwork, as well as the new reinforcement size, concentration, type and clearances between formwork and existing concrete. Seek the experience of the local concrete supplier qualified in making SCC and a specialty contractor familiar with placement is valuable. Although not a difficult process, not all ready mix suppliers have experience with SCC and it is very important to ensure a consistent product is delivered to the jobsite. There are numerous admixtures put together in an SCC concrete mix to give it the desirable flowable properties. Each of these admixtures reacts to one another in a different way, so it is crucial that the concrete supplier has performed testing with the help of their local SCC admixture supplier to be sure all bugs are worked out before the product arrives on site. In addition, the admixtures used react to the different types of coarse and fine aggregates and the aggregates can vary greatly in different parts of the country. This learning curve is easily overcome through sample batches, testing and constant communication between the concrete supplier, engineer, contractor and SCC admixture supplier.

SCC may not be appropriate for every repair and strengthening project. Typically, SCC is used for closed void "form and pump" type concrete beam, slab and column repairs where enclosed concrete formwork is necessary and/or congested reinforcement exists. Further, because SCC must be supplied in volume by a ready mix supplier, it would not be suitable for small repair areas where using a pre-bagged product would be more cost-effective.

Pumping in progress with SCC filling up the plexiglass viewing window. The window was built into the formwork at the end anchors.

Using SCC

Baltimore-based Structural Preservation Systems (SPS) has experienced challenges with pumping standard concrete on projects that are related to the pumping operation, clogged lines and sub-par repairs that only became apparent after the forms were stripped. SCC has been used in new construction projects for highly congested foundation and shear walls and in precast concrete manufacturing, but has just been incorporated into the structural repair and renovation industry in the last few years. As such, SPS began to conduct research to determine SCC's feasibility in this market.

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Close up of PT cable anchors and rebar prior to formwork installation.

Over the years, SPS has been contracted to perform many honeycomb repairs on new construction projects after the forms are stripped and voids are present due to lack of consolidation around highly concentrated rebar or segregation issues. SPS had been seeking a cost effective, highly flowable concrete that would not only address voids repairs but could also serve as a dependable form and pump material for sizable enlargement projects. Existing materials were typically custom pre-bag mixes that are cost prohibitive for large volumes. Initial results showed that SCC could easily be adapted, and would be equally advantageous to the concrete repair industry. To begin testing, SPS performed full scale mock-up pours to simulate formwork and pumping conditions, as well as rebar/MEP obstructions within the formwork to verify the feasibility prior to actual field use.

SPS learned from the testing the importance of the amount and location of bleed tubes or bleed channels cut into the formwork to allow air to escape as well as insure placement in the congested areas. On most pours, plastic widows are installed into the formwork to visibly verify placement in critical areas. In addition, a great deal was learned about the importance of the quality and strength of the concrete formwork. SCC requires stronger formwork than conventional concrete, as internal form pressures and hydrostatic pressures are higher on SCC than ready mix concrete due to the fluid nature of the material.

SCC at Work

The positive results from the mock-up prompted SPS to begin incorporating the material into a variety of projects. One such project was the strengthening of deficient cast-in-place post-tensioned reinforced beams in a Washington, DC parking garage via external post-tensioning that was subsequently encased in SCC. Initially, SPS was contracted to perform basic concrete and coating repairs in the parking garage. While performing contract work items, a significant crack was uncovered near a critical location in the structure, which prompted destructive testing. Upon opening up a probe location at the mid-span of the beam, the post-tension cables were discovered to be located toward the top of the beam, not near the bottom where it would be expected. Upon further inspection of the anchorages and their location, it became evident that the post-tensioned cables were straight inside the beam and not draped in a "V" shape and traditionally designed. Essentially, the existing post-tensioned cables were providing a compression force on the beam with virtually no uplift force at the mid-span, where the force is needed most. Therefore, the beam needed to be strengthened, requiring the addition of external post-tensioning strands, encased in SCC, which yielded and enlarged concrete sections on each side of the existing beams by 4.5 inches for a total of a 9-inches increase in width. Upon further review of the structural drawings, this condition was found to exist on five other beams.

The design team ultimately decided to use SCC, because forming and pumping of the beams was necessary to enlarge the cross-section. Concentrated reinforcing steel, post-tensioning cables and associated beams were located inside the formwork, which made this a great application for SCC. Using SCC resulted in high quality concrete, strengthening repairs with minimal voids and honeycombs requiring little rub out following the stripping of the formwork.

Another example of SCC success was a unique pre-stressed beam repair project on a new parking structure for a government office building in the Washington, D.C. area. The project required the repair of two post-tensioned beams damaged after being overloaded during construction. Although the initial repair option involved removing and replacing the damaged beams, the post-tension slab above the damaged beams would have had to have been detensioned and extensive shoring would have been necessary that would have been extended through several levels below. This approach would have been costly in both time and money. As such, SPS developed an alternate, in-place repair solution that involved enlarging the damaged beams using SCC and post-tensioning with mild steel reinforcement to add strength. The enlarged sections on the sides and bottom of the beams were placed by properly preparing and roughening the surface (¼-inch amplitude with open pores) and by using the SCC method. After initial cure, the post-tensioning cables were stressed to the specified forces and the repair was complete.

Installed rebar, PT cables, anchors and the formwork installation in progress.

Final beam – pumped, cured and stripped – prior to stress of the cables and pouring of the stress block at the end.

SCC was also used on a major courthouse in an east coast city for a blast upgrade of an existing slab. Because of increased security measures, a 15,000-square-foot, 1-foot-plus thick, heavily reinforced blast resistant slab was installed underneath the existing slab to prevent progressive collapse of the structure from a blast event. The majority of the slab was installed on the ceiling of the boiler room below that had abundant existing MEP obstructions and required very intricate formwork. The engineer's specification was extremely stringent regarding the acceptance of even the smallest void in the finished product, which led to the selection of SCC. The end result had no voids.

The Future Is Bright

The concrete repair and strengthening market is experiencing tremendous growth as owners look for ways to upgrade or extend the service life of their structures. The use of SCC for these projects will only allow the market to continue to grow. Repair and restoration contractors should evaluate each project to determine if the use of SCC is applicable to provide quality, cost and constructability benefits. SCC merits consideration as the material of choice for the "form and pump" method of placement on any sizeable project. As more contractors learn how to use SCC and it becomes more accepted by the engineering community, it has the potential to become the standard material for all form and pump repairs.▪

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Photos courtesy of Structural Preservation Systems, LLC.