Shotcrete Shines in Parkade Repair

by Neil McAskill

Shotcrete has a long history of application in challenging circumstances including overhead application. Shotcrete is often the repair material of choice when repairing corrosion or fire damage to the soffits of parkade slabs because of the ability to apply and finish the material overhead.

In 2005, BC Ferry Services Inc. undertook a program to repair corrosion deterioration of the parkade slab at their Horseshoe Bay ferry terminal near Vancouver, BC, Canada. Although the cast-in-place slab was marginally protected by a deteriorated traffic membrane, the use of deicing salt on the slab during winter months resulted in significant chloride-ion contamination and corrosion-induced spalling of the soffit and delamination of the surface concrete.

At some locations, the surface delamination coincided with the location of soffit spalling, leaving only a thin layer of concrete between the delamination and spall fronts. It became obvious soon after the work started that replacement of the full slab thickness would be required at many locations. This presented the challenge of repairing the slab while keeping all three berths of the terminal operational. At times vehicles had to travel on top and beneath the slab requiring repair. Under these conditions, conventional forming and placing would have had a significant impact on terminal operations.

The use of shotcrete applied overhead was considered. The slab was typically approximately 6 in. (150 mm) thick and, therefore, would have to be shot in multiple lifts. Using a shotcrete set accelerator was not considered viable as it might have interfered with the stringent performance requirements for the hardened shotcrete as well as the requirement for minimum rebound. Previous work with high silica fume content shotcrete mixtures, applied by the wet-mix shotcrete process, has demonstrated that such mixtures can develop sufficient cohesion to allow significant overhead thickness of buildup while minimizing rebound and overspray. Based on this, it was decided to proceed with shooting the full thickness patches overhead.

Preparation

During preparation of the repair areas, it became obvious that early identification of the alignment of surface and soffit delamination was important in minimizing the concrete removal effort. If

One of the repair areas prior to intervention. Note the extensive spalling

The same area shown in the first photo, after repair. The pattern of the shotcrete in the foreground is where additional concrete was removed to get sufficient development length for the new reinforcing steel that was added delamination was aligned, removal of concrete was much more efficiently conducted from the top rather than chipping overhead. Also, heavier equipment including rivet busters and 55 lb (25 kg) jackhammers could be used for bulk removal, with the smaller 15 lb (7 kg) chippers used for final preparation only. The berth could be kept operational when necessary during the preparation process by temporarily covering the work area with steel plates. The plates were removed after ferry loading and preparation continued.

Preparation of the area included verifying that all corroded reinforcing steel and embedded conduit had been "chased" and exposed, all loose or fractured concrete had been removed, and sufficient shooting clearance was maintained around reinforcing steel. Edges were sawcut to a depth of approximately 3/4 in. (20 mm) on the top surface of the slab and slightly undercut at the slab soffit to avoid feather-edging of the repair material. The existing reinforcing steel was measured to determine its residual cross section and augmented as necessary to replace any significant section loss due to corrosion.

Final concrete surface preparation was by wet grit-blasting with a 5000 psi (35 MPa) pressure washer with grit injection. As work was near a sensitive marine environment, coal slag grit was used because it is considered free of residual metals. Immediately prior to shotcreting, a final water pressure-wash was carried out to remove any residues of blasting grit that remained adhered to the surfaces to receive shotcrete. Zinc anode pucks were electrically connected to the reinforcing steel near the perimeter of the patch to mitigate "halo corrosion." The pucks were attached after grit blasting and pressure-washing to ensure that the porous coating around the anode was not damaged in the aggressive preparation process.

Shotcrete Mixture Design

The shotcrete mixture was a proprietary blend containing silica fume; fly-ash; cement; and air-entraining, water-reducing admixtures. The aggregates conformed to ACI Gradation No. 2. The material was supplied in 66 lb (30 kg) paper bags and mixed on site with a combination mixer pump. The use of prebagged material allowed for a shooting rate that was controlled by the stiffening rate of the shotcrete rather than the availability of a ready mix truck. Mixing on site also permitted the use of fresh shotcrete whenever needed, thus eliminating the risks and costs associated with slow placement of ready mix truck-delivered shotcrete.

Shotcrete Application

Shotcrete was applied during off-peak periods when the berth could be closed to traffic for the remainder of the day. Paper-faced form plywood was placed face down to cover the patch area as necessary. The steel traffic plates 3/4 in. (20 mm) thick were placed over the plywood to restrain it against shooting impact pressures. The areas were shot from a man lift under the patch. Consistent with recognized good shooting practice, the corners were shot first, followed by approximately 2 to 3 in. (50 to 75 mm) buildup over the entire area. Generally, a number of areas were shot in close proximity to allow the applied layers to

The top formed side of a typical through-patch. The light spots at the ends are where small voids were repaired

Another typical through-patch from the top formed side

A typical patch from the bottom. Some minor restrained shrinkage cracking was noted in both the shotcrete and the cast-in-place patches

stiffen before application of successive layers. Clustering the repairs also had the advantage of making cleanup more efficient. After the final shotcrete layer had stiffened, the area was cut and finished to a smooth trowelled surface and the overspray scraped from the adjacent surface. Acrylic curing compound was applied to the soffit and wet burlap to the top of the plates to minimize moisture loss and temperature spikes during the early curing period. Cores were taken from test panels to determine strength gain. As the average ambient temperature was approximately 70 °F (20 °C), the shotcrete gained strength quickly. The structural engineer's required 3625 psi (25 MPa) compressive strength before vehicle traffic was allowed on the patch area. Earlier access for traffic was not allowed, as the wheel loads could have sufficiently deflected the steel traffic plates and damaged the immature shotcrete or bond around the perimeter of the patch. Curing compound was liberally applied to the top surface of the patch after removal of the steel plates and plywood.

Quality Control

Quality control of the shotcrete application included inspection of the patches, particularly the upper surface where any shadows behind reinforcing steel would be noticeable, and extraction and testing of cores from test panels shot during the course of the work. In some cases, small voids were noted around the perimeter of the patches where there was a congestion of reinforcing steel. These areas were chipped out with 2.2 lb (1 kg) air hammers and patched with polymer concrete.

Conclusion

Overhead shotcreting using the wet-mix shotcrete method can be a viable method of placing concrete in full-depth slab repairs. Care is required in shooting around the perimeter of the patches to ensure that full contact with the perimeter concrete and complete encapsulation of the reinforcing steel is achieved. Pneumatic placement has the advantage of dramatically reducing forming time to repair small full-depth patches.

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