Shotcrete Repairs to Infrastructure

By Ted W. Sofis

When considering rehabilitating vertical and overhead concrete structures, there is no more efficient way of performing the work than by using shotcrete. By its very nature, shotcrete provides the engineers and contractors several advantages. On an infrastructure repair, the shotcrete method eliminates the need for forming, so the lumber and labor costs involved in this aspect of the work are eliminated from the start. Along with the forms, the form support systems, whalers, Richmond ties, and anchors also become unnecessary. The shotcrete is easily conveyed from the gunning equipment to repair areas through hoses, eliminating the need for cranes, hoists, and hand labor of physically transporting the material. Overhead repair work on culverts, under bridge decks, or on the undersides of arches becomes much easier to perform. Forming and placing concrete for overhead spall repair is a tricky and difficult proposition even under the best of circumstances. Unless it is a full deck repair, where the forms are set from below and concrete is poured from above the deck, there are a great many obstacles to overcome. It is extremely difficult to place concrete without leaving gaps between the concrete substrate in poured overhead repairs. The nature of using a flowable material will cause it to spread out across the bottom of the form, leaving gaps along the top as gravity works against you. This is not the case with shotcrete installation. With shotcrete, you have no forms and the repair material is sprayed directly against the existing concrete surface from the open underside of the repair area. Everything you do is visible and the shotcrete is gunned from the top down, so it becomes much easier to make good repairs. On thin vertical wall repairs, forming becomes more expensive per square foot (square meter) and efficiently placing concrete becomes more difficult as it hangs up and creates honeycomb-like areas. Again, this is not a problem when gunning shotcrete directly into an open area. Shotcrete also allows the contractor to efficiently place material on rounded columns, piers, arches, cones, and other shapes that are not easily formed. When shotcrete is used, the repair material is easily and cost-effectively transported and enables the contractor to efficiently install material overhead and on irregular shapes. It allows the worker to perform the concrete repair faster and more efficiently and, in many cases, provides a better result than using cast-in-place concrete.

Nozzleman gunning dry-process shotcrete—filling the edges of the repair area first—and working toward the middle to avoid trapping rebound in the corners

Preparation Tips

After delineating the repair areas, it is essential to remove all of the deteriorated concrete back to sound concrete. It is also good to get at least 1 in. (25 mm) behind the initial mat of reinforcing bar whenever possible, as it better ties in the repair to the existing structure. Often when the reinforcing bars rust and develop heavy scale, they expand, creating cracks and fissures in the concrete. The concrete outside of the reinforcing bar is often easy to remove; however, it is a good practice to remove even sound concrete if necessary to get 1 in. (25 mm) behind the reinforcing bar to ensure a good repair.

The next consideration is the positioning of the mesh from the finished surface. The mesh or

reinforcing bar should be placed at least 2 in. (50 mm) from the exposed surface to ensure adequate cover. In overhead applications, try to position the mesh within 2 to 4 in. (50 to 100 mm) from the surface. When there is too much unsupported weight of wet material beyond the reinforcement, it tends to pull itself off. Make sure that the reinforcing steel and mesh are securely tied and anchored in place. There should be no flex or give, particularly in overhead applications. The reinforcing steel needs to support a lot of weight—approximately 146 lb/ft^3 (66.23 kg/m^3). Unlike a vertical surface where there is a great deal of lateral support, the reinforcing steel on overhead work must support the mass of the material. When tying mesh overhead, a good way to check your work is to reach up with both hands and pull on the mesh. If the mesh can support your weight without sagging, then it's usually safe to assume that it will support the weight of the applied material. If there is appreciable movement or flex in the mesh, then more anchors and ties need to be made to reinforcing bars to tighten up those areas.

The shotcrete method provides a superior bond to the substrate without the need for bonding agents when proper surface preparation techniques are used. Prior to placing the shotcrete in the repair areas, the area should be cleaned with air and water to remove any dust, sandblasting residue, or other particulates that may have collected in the corners that could inhibit the bond. Wetting the surface prior to gunning will help to reduce the amount of water that the existing concrete substrate will draw from the freshly applied shotcrete. This is important in both the dry and the wet processes because shotcrete contains a lower percentage of water than found in conventionally placed concrete, and losing moisture could ultimately affect the bond and the strength of the shotcrete. It is also a good practice to gun in the edges of a repair area first and work toward the middle so rebound does not collect in the corners. As the shotcrete initially hits the concrete surface, some of the aggregate rebounds off the substrate, leaving a thin layer of cement paste that cushions and bonds the subsequent shotcrete to the existing concrete. It is for this reason that bonding compounds should never be used for shotcrete installations. Bonding compounds, in more cases than not, are detrimental, often creating a bond breaker. Shotcrete is placed at a high velocity and therefore already provides excellent adhesion to the substrate.

Overhead dry-process shotcrete being placed on the underside of a pier hammerhead in Pittsburgh, PA

Shotcrete easily conforms to the circumference of this round bridge pier and works well with irregular shapes and configurations

Shotcrete Placement

With the dry-mix process, the shotcrete mixture is transported by air through the hoses in a nearly dry state and the water is injected through a water ring at the nozzle. This allows the nozzleman to make sensitive adjustments during placement to ensure enough moisture to properly hydrate the material, yet remain stiff enough to

stay in place without sagging or having to use accelerators. The relatively low water content of dry-mix shotcrete provides superior strengths in what is essentially a zero-slump pneumatically placed concrete. In the wet-mix process, the material is mixed with water and then pumped so it is a flowable, low-slump shotcrete mixture where the air and accelerators are injected at the nozzle. With the wet process it is easier to wrap around dense reinforcing bar mats, and one can place greater volumes in less time. There are advantages to each process. With both methods it is important to maintain proper shooting angles, as close to a 90-degree angle to the shooting surface as possible.

Conclusion

Shotcrete provides an economical and efficient method for the rehabilitation of concrete structures. The placement of shotcrete saves time and money. Shotcrete offers the ability to eliminate forming (a costly component of the repair process) and to place material more efficiently in hard-to-reach areas, it easily conforms to unusual shapes, and provides an effective method of placing material overhead. In these difficult economic times, we need to look for new and better ways to do things. The next time you look at a difficult concrete repair job, consider an alternative—a shotcrete repair.

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