Practical patching

How to perform durable partial-depth repairs of corrosion-damaged concrete

By Martin S. McGovern

For partial-depth concrete removal, use 15-pound chipping hammers to avoid excessive impact to the concrete surface.

Patching of corrosion-damaged concrete is by far the most common concrete repair procedure, comprising a significant portion of the total repair market. Each year, billions of dollars are spent to repair deterioration in bridges, parking garages, building facades, and a host of other reinforced-concrete structures. The popular term "crumbling infrastructure" is synonymous with concrete damage caused by corrosion of reinforcing steel.

In some cases, rebar corrosion has progressed to a point where the structural integrity of the reinforced concrete is affected. Appropriate shoring may be required, and concrete members may need to be replaced or strengthened. But in many cases, repair is required to prevent further deterioration, extend the service life, and improve the function and appearance of the structure. For much of these repairs, partial-depth patching is sufficient.

To install durable partial-depth patches, however, contractors must adhere to several tenets of good concrete repair practice: proper concrete removal, thorough surface preparation and rebar cleaning, careful material selection, and adequate curing. Failure to follow these steps contributes to what many consider an unacceptable failure rate of partial-depth repairs.

Figure 1. Chain dragging is a simple yet effective way to locate delaminations in reinforced concrete.

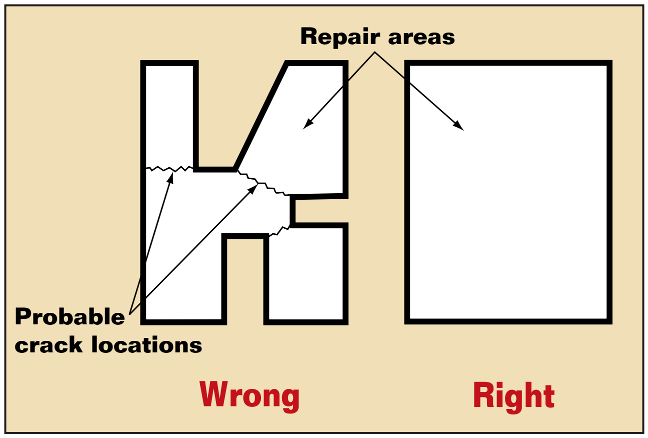

Figure 2. Create patches with simple geometric shapes. Patches with re-entrant corners and abrupt changes in width are susceptible to cracking caused by differential drying shrinkage.

Concrete removal

There are many ways to locate corrosion-damaged concrete, including visual observations and nondestructive testing. A common and effective way to locate deteriorated concrete that may not be visible is to "sound" the concrete by dragging a chain across the surface or tapping it with a hammer (Fig. 1). Areas with delaminations—subsurface cracking caused by the expansive force of corrosion—make a dull or hollow sound. ASTM D 4580 is a standard test method for detecting delaminations.

Once damaged areas are determined, you must decide the proper shape of the patch. Deteriorated areas can wander in different directions, and it's tempting to remove only the deteriorated concrete to save on removal and material costs. But it's better to create patches with simple geometric shapes because patches with abrupt changes in width and re-entrant corners are susceptible to cracking caused by differential drying shrinkage (Fig. 2). Simple patch shapes also minimize perimeter sawcutting.

Along the patch perimeter, make perpendicular sawcuts ½ inch deep, assuming that the rebar is below that depth (Fig. 3). The primary reason for sawcutting is to avoid "featheredging" the patch, which creates an area susceptible to failure.

Many specifications recommend sawcutting before chipping to establish definite concrete removal boundaries. But some contractors prefer to remove concrete within the patch first. "I like to chip first to see the position of the rebar so we don't cut them," says Dave Dorsch, a Baltimore-based consultant.

Many contractors also prefer to chip first because delaminated areas often extend beyond the boundaries indicated by sounding. "If you sawcut first then find that the deterioration extends beyond the sawcuts, you have to sawcut again," says Dorsch.

How can workers with chipping hammers distinguish between sound and unsound concrete? One rule of thumb is that deteriorated concrete often fractures at the interface of the coarse aggregate and mortar, whereas the coarse aggregate in sound concrete will often fracture when hit with a chipping hammer. However, in some lower-strength (but otherwise sound) concrete, the aggregate may not fracture (Ref. 1).

In short, most engineers and contractors agree that the best way to find and remove as much deteriorated concrete as possible is to com-

Figure 3. Sawcutting the perimeter of the patch establishes concrete removal boundaries and prevents featheredging.

bine the inspection and testing expertise of the engineer with the field experience of the contractor.

For partial-depth concrete removal, use 15-pound chipping hammers to avoid excessive impact to the concrete surface. Using heavier hammers, workers are more prone to punching all the way through the member. Lighter hammers also minimize microcracking, or "bruising," of the concrete surface that remains.

In some cases, rust develops only on top of a rebar, while the rest of the rebar remains firmly bonded within sound concrete. Because removing concrete from beneath rebar is difficult and costly, it's tempting to not undercut the exposed bar. But current guidelines recommend undercutting all exposed corroded bars. "Years ago, we specified removing only cracked and delaminated concrete above the bar," says Pete Popovic, principal of Wiss, Janney, Elstner Associates Inc., Northbrook, Ill., "but we found that these repairs were not durable and would begin delaminating after a few years."

The benefits of undercutting the rebar are two-fold: the rebar provides mechanical anchorage for the patch, and the bar is completely encapsulated in a chloride-free, alkaline environment to help prevent future corrosion. Undercut corroded rebar at least ¾ inch or ¼ inch more than the largest aggregate in the repair material, whichever is greater (Ref. 2).

Surface preparation and rebar cleaning

After the bulk of the deteriorated concrete is removed, the newly exposed surface will contain loose concrete fragments and microcracks caused by the impact of the chipping hammer. Don't place repair material directly onto this unsound surface. Further preparation is required.

Abrasive blasting is the most effective way to remove the remainder of the unsound material left in the patch as well as the rust from the rebar. However, cleaning the backside of the bars can be difficult. In some cases, small blast nozzles will fit between closely spaced rebar, allowing workers a better angle for cleaning the backside. Another way is to blast the concrete behind the bars so the abrasive rebounds off the concrete and hits the backside. Placing a steel plate beneath the bars can improve the rebound of the sand and speed cleaning of the backside.

Some specifications require cleaning the steel to a near-white metal condition, but a light, tightly bonded rust buildup on the surface is usually acceptable (Ref. 1). If the rebar will be coated, follow the coating manufacturer's recommendations for rust removal. After abrasive blasting, use compressed air to blow dust out of the repair area.

The moisture content of the concrete surface affects the bond of the repair material to the base concrete. Most experts discourage placing repair concrete onto a dry surface because the base concrete will suck water out of the repair concrete, robbing the cement of the water it needs to hydrate. Manufacturers of repair mortars usually recommend that the base concrete be in a saturated surface-dry (SSD) condition (the surface is saturated but contains no standing water).

Material selection

Many factors influence the type and amount of cement, aggregates, and admixtures for the repair concrete, including patch thickness, rate of strength gain required, and installation and service conditions. In general, the repair concrete and the base concrete should be *compatible*—they should respond similarly to loads and changing temperatures. For example, the compressive strength (and, therefore, the modulus of elasticity) of the repair concrete should not be substantially higher or lower than that of the existing concrete.

Partial-depth repairs are susceptible to shrinkage cracking because they usually are thin and fully re-

Bonding agents and rebar coatings: Are they needed?

Bonding agents and rebar coatings are two other potential components of partial-depth patches. But experts disagree on where and when these components should be used. Here are some common arguments for and against bonding agents and rebar coatings.

Rebar coatings

Why you need them: The rebar corroded in the first place because it received insufficient protection. Additional rebar protection is warranted, especially in areas with shallow concrete cover.

Why you don't: An appropriate repair material should provide sufficient protection for the rebar. Achieving full rebar coverage with a coating, especially at intersections and on the backside of bars, is very difficult, reducing coating effectiveness.

Bonding agents

Why you need them: Low-slump repair concrete does not contain enough free cement paste to adequately fill the pores of the concrete substrate to establish a strong bond. A separate bonding grout is required.

Why you don't: Adequate bond can be achieved by simply placing the repair material against a properly prepared substrate. Using bonding agents is risky because if the bonding agent dries before you place the repair material, it can inhibit bond.

strained by patch boundaries and by their bond to the substrate. Therefore, use a repair material with low shrinkage. Shrinkage can be minimized by proportioning a mix with as little water as possible. This is achieved by using low-slump concrete and as much coarse aggregate as possible. Avoid excessively high fresh-concrete temperatures and high fine-aggregate contents (Ref. 3).

Admixtures also can be used to improve material properties. Polymer modifiers reduce the permeability of the concrete and improve bond strengths. Water reducers and superplasticizers reduce the amount of water required for a given workability. Pozzolans such as silica fume and fly ash also reduce the permeability of concrete.

Curing

Proper curing is important to prevent water loss from the repair concrete after placement. Curing prevents early shrinkage of the concrete, allowing it to gain strength to withstand the tensile stresses brought on by subsequent drying shrinkage. It also improves other important properties, such as freeze-thaw and abrasion resistance (Ref. 3).

Most experts recommend wet-curing repairs for as long as is practical. A common method is to cover the repair with wet burlap and a plastic sheet. When wet curing is not practical, use a liquid-membrane curing compound. ■

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