Minimizing Cost Overruns in Repair Projects

Estimating the cost of a repair job can be difficult without the right tools and techniques

By Ron Heffron and Douglas Burke

At a recent American Concrete Institute meeting, the speaker asked who had been involved in repair projects that had significant cost overruns. Nearly every hand in the room went up. Major repair projects often exceed budget by up to 500%, forcing the design engineer and the contractor to go back to the owner or funding source with hat in hand. You can avoid such a situation if you determine repair requirements and costs systematically and logically, and closely monitor the work. Here we will review the mechanisms of deterioration and discuss various tools to minimize cost overruns.

What happened?

Why are large cost overruns so common on repair projects? The obvious answer is that the estimate was poorly conceived—the work needed was far more extensive than the engineer anticipated, and the bid quantities were underestimated. The other common reason for overruns is inadequate oversight during construction. The engineer or quality control inspector has to make sure the repairs are being made as specified. Cost overruns are common in government and private sector projects, for example. Let's look at a couple examples.

At an old Navy dry dock in Pearl Harbor, repair quantities far exceeded the engineer's estimate, despite adding an extra 1 to 2 feet around each spall and 20% more to the field observations.

At a major West Coast port, repair projects had to be stopped and re-bid when project funding was depleted, even though the work was only 1/3 complete. This led the port to pursue the development of new tools and techniques to deal with the problem.

Types of defects

It is common to find that more than one type of deterioration mechanism is responsible for the concrete defect. To arrive at a good estimate you have to start by defining the most likely ones. Typical defects are:

- *Breakage,* structural distress caused by sustained or impact overloading, resulting in noticeable deviations from the main axes or general shape of a structural component.
- *Mechanical damage,* loss of a concrete fragment, typically resulting from an impact, and limited to reducing the cover without exposing the reinforcing steel.
- *Overstressing cracks,* caused by external loads that generate high inter-

Left: The method chosen to repair an open corrosion spall must be considered when developing an estimated cost. Below: Repair projects often experience cost overruns due to inexperienced inspectors who underestimate the extent of the damage.

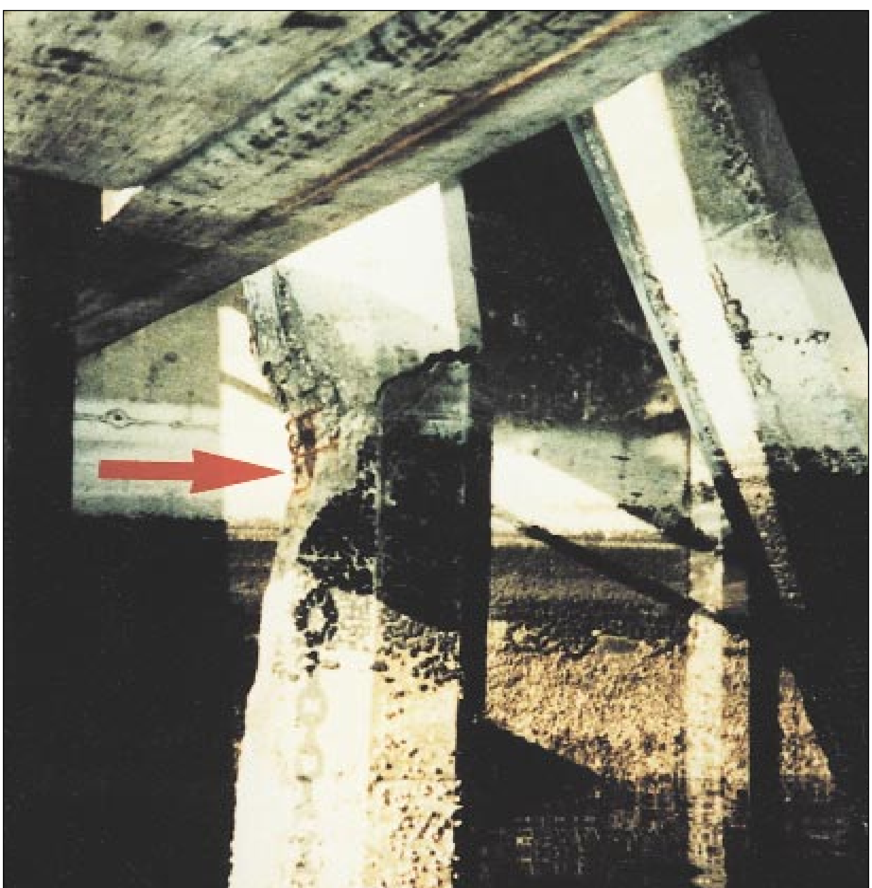
nal stresses that exceed the strength of the member.

■ *Corrosion cracks,* splitting cracks that occur in concrete due to the expansion of chemical products generated as the steel reinforcement corrodes. Typically corrosion byproducts from the reinforcing steel have stained the surface of adjacent concrete.

■ *Closed corrosion spall,* the result of incomplete separation of a fragment of concrete cover due to corrosion cracking parallel to the concrete surface. Typically the corrosion byproducts from the reinforcing steel have stained the adjacent concrete surface.

■ *Open corrosion spall,* a recess in the concrete surface caused by complete separation of a fragment of concrete cover. This, too, is the result of corrosion cracking parallel to the concrete surface. Typically the reinforcing steel is exposed and severely corroded.

Left: Chemical reactions, such as sulfate attack, DEF, or ASR, can cause extensive damage. Below: An important consideration with breakage defects is restoring the load to the member after it's been repaired.



Some less common defects are:

- *Erosion/chemical deterioration,* a general reduction of a component's cross-sectional area due to deterioration of the cement matrix or the aggregates.
- *Underwater cracking,* longitudinal cracking of an underwater component, such as a pile, attributable to delayed ettringite formation (DEF) or alkali-silica reaction (ASR). The cracks generally extend into the intertidal zone.
- *Sulfate attack,* a softening and/or disintegration of the concrete matrix due to chemical reaction with an external source of sulfates.
- *Volumetric expansion,* disintegration of the concrete matrix due to chemical reaction, such as sulfate attack, DEF, or ASR.
- *Differential settlement,* a defect caused by subgrade failure. Since this type of defect is not actually a concrete problem, it requires a different solution.

Repair issues to consider

Each type of defect requires the inspector and estimator to carefully consider a number of factors that might affect the ultimate extent and cost of the repair. Once you've identified the type of defect, consider the following:

Breakage

- Is the overload source still present?
- Should the member be replaced or repaired?
- Should the dead load be restored to the member after repair? How can this be accomplished?
- How should the repair be executed?

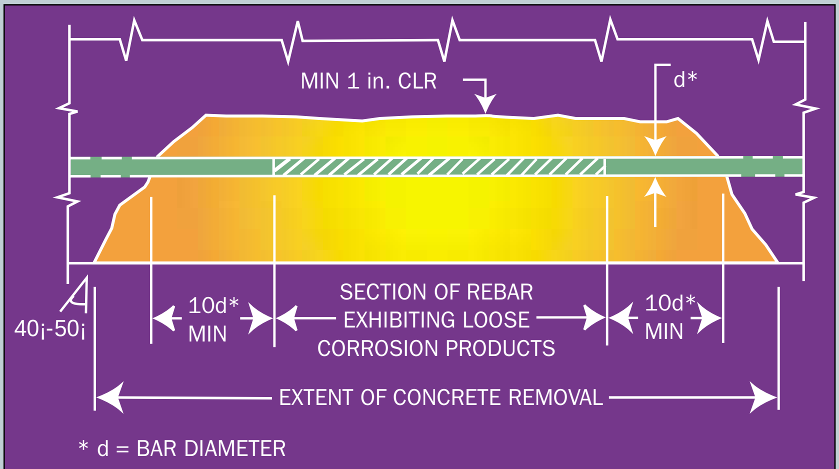
Mechanical damage

- Estimating the repair size of such defects is relatively easy since there should be no hidden damage.
- The repair strategy focuses primarily on restoring the protective cover over the reinforcing steel.

Overstressing cracks

- First establish if the crack is active and if the source of the overload is still present.
- In estimating the crack length, what you see is what you get. As with mechanical damage,

Extent of concrete removal



The amount of concrete that must be removed on a corrosion-damaged beam can be considerably greater than what is exhibiting distress.

there is not likely to be hidden damage from an overstressing.

Chemical reaction

■ Start by identifying the root cause of the deterioration.

■ Is the structural capacity of the member affected?

■ Does the member need to be protected only, or does capacity need to be restored?

■ Are the reactive constituents spent?

■ Should the member be repaired or replaced?

Corrosion deterioration

■ Is the member prestressed?

■ Is the corrosion isolated to certain areas or components?

■ What is the chloride-ion concentration profile to the depth of the rebar? Will chloride extraction be considered?

■ Which repair methods will be considered: shotcrete, trowel-applied mortar, replacement of the member, cast-in-place repair, and jacketing or encasement?

■ Will cathodic protection be considered?

The solution: better estimates

That the solution to cost overruns is better estimates may sound simplistic, but that's really what it amounts to. Better estimates are developed by considering the issues noted above and by recognizing that defects can grow significantly during the repair process. The best way to generate realistic estimates is to have a qualified inspector perform the inspections and estimate based on experience, sound, and engineering judgment. An understanding of the repair materials and the application method is important. The following rules of thumb may be helpful, but they cannot substitute for the onsite first-hand judgment of a qualified inspector.

■ The estimated length or width of "lineal" defects should not be increased.

■ The estimated size of "areal" defects should be increased by 6 inches to 24 inches across the defect in each direction.

■ Soundings are always essential, and trial chipping by the inspector can significantly improve the estimate.

■ For reinforcing bars still embedded in concrete, the estimated depth of repair should be the sum of the actual cover distance measured in the field (which may be different from what's shown on the drawings), plus the diameter of the reinforcing bar, plus a minimum of 1 inch behind the bar. If there are two layers of reinforcing steel, include both bar diameters.

■ For reinforcing bars that are completely exposed or detached, the depth of repair is similar to that for reinforcing bars still embedded, except that the distance behind the bars can exceed the 1-inch minimum.

■ If the existing concrete cover is inadequate, it is important to decide if the cover will be built up over the repair area, since this can dramatically affect repair quantities.

■ The extent of longitudinal corrosion repair should be to the end of any obvious deterioration at the level of the steel, plus a minimum of 10 bar diameters on each end of the deteriorated section. Some additional concrete may also be removed at up to a 50-degree angle from the bar to the face of the member.

General rules are helpful, but the inspector's judgment is paramount since direct visual evaluation is always more reliable than general rules or formulas. The inspector must have sound judgment, based on experience.

Tools and techniques

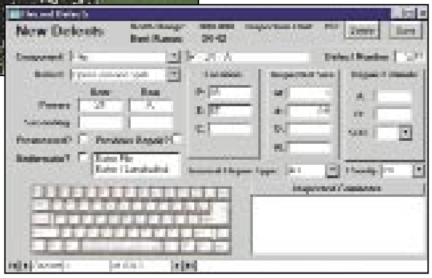
A valuable tool in estimating repair costs is a database developed by Han-Padron Associates, Long Beach, Calif., called the Automated Inspection and Repair Information System (AIRIS). You can use this system from initial inspection to closeout of the repair work. The inspector makes the initial field entries directly into a laptop or hand-held computer. Back in the office, the defect data is downloaded to the database, and the system quickly and efficiently generates repair plans. The advantages of this approach are:

■ The program prompts the inspector to enter both the inspected and estimated size of the repair.

■ A qualified inspector can assign a repair method to each defect while in the field. Direct observation is usually the best judge of the proper technique.

■ The actual repair sizes and methods are tracked during construction, thereby continuously improving the estimates over time.

The data entered in the field by



The inspector inputs data for each specific defect, allowing systematic development of an estimate using the AIRIS program.

the inspector are used to systematically develop an estimate for the project. Each individual defect is sized, a repair method is assigned, and the repair is given a priority. For each defect, the inspector notes any special factors that might affect the estimate. When the data are complete, AIRIS generates an estimator's report with user-defined unit pricing. Once the estimate is developed, if the project's cost exceeds the owner's budget, the data can be sorted such that only higher priority defects are repaired, deferring the rest to a later date. Finally, during construction, the actual repair method and extent of repair are entered so that the inspector and estimator can hone their judgment on subsequent projects.

Proper oversight

The need for attentive inspection during the repair process cannot be overstated. If the contractor will be paid on a unit price basis, it is important to decide how and by whom the repair volumes and lengths will be measured and documented. Equally important is the timing of such measurements. The best approach is to have the inspector verify the quality of the surface preparation and measure the repair volume just before the repair. In some cases, low-priority defects may intentionally remain unrepaired. The onsite inspector must therefore actively respond to contractor questions, interpret the bid documents, and ensure the quality of the job.

Summary

Cost overruns are all too common on concrete repair projects and are giving our entire industry a black eye. The solution is to provide better estimates and inspection oversight during construction. Sound judgment by the field inspector is critical; by systematically comparing the initial repair estimate with the actual repairs, the inspector can rapidly refine judgment. An automated process helps achieve the systematic accounting that is necessary. On repair projects, there will always be some unexpected conditions that can lead to cost overruns, but a logical and systematic approach can lead to much better estimates. ■

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