Quality Control in Concrete Repair: Does It Exist?

VIEWPOINT

By Gail S. Kelley, P.E.

Over the years, articles in various magazines have highlighted problems with quality control on cast-in-place concrete construction projects. Although these articles typically address new construction, similar issues occur in concrete repair. On many repairs, it is not clear whether the work has restored the integrity of the structure or whether it has just covered up the problem. On some repairs, the work may actually have made the structure more prone to deterioration in the future. Even on "successful" projects, there are likely to be problems with quality.

Why do these problems happen?

Project Communication

Communication is essential to the success of any project. On a major post-tensioning repair project in Washington, D.C., the superintendent was unable to communicate with many of the workers because they spoke no English and neither he nor his foreman spoke any Spanish. Some of the workers were bilingual but these individuals were not always around when it was necessary to give instructions. Most of the workers were very conscientious and hard working. If they were not sure what they were being directed to do, they tended to chip out an extremely large area, to make sure they had done at least what was necessary. Unfortunately, this is generally not a good practice in concrete repair; it is usually best to minimize the amount of chipping and removal of the existing structure. This is particularly true in post-tensioned concrete repair. Most of the overhead patches were pumped; several of the larger ones started cracking soon after the forms were removed.

Reading the Project Specifications

It is also essential that the contractor read the project specifications. As is customary for post-tensioned construction, the project specifications for this job required testing field-cured cylinders to ensure that the concrete had sufficient strength for stressing tendons that had been spliced. The bid form contained a line item for the cost of concrete testing. The project specifications were as follows:

A. Prepare and test concrete test cylinders as listed below:
   1. For each day's work, make and store four cylinders in accordance with ASTM C 31 and C 172.
   2. Test cylinders for compressive strength in accordance with ASTM C 39 as follows:
      a. Two cylinders at 7 days; and
      b. Two cylinders at 28 days.

B. Take four additional test cylinders for each day of post-tensioned concrete work. Cure cylinders on the job site under the same conditions as the concrete they represent.
   1. Test two cylinders prior to stressing to verify that concrete has reached required strength.
   2. Test the second set of two cylinders in the event that the first set does not have the required strength. If the first set of cylinders has the required strength, the second set may be discarded after the tendons are stressed or may be held as backup for the 28-day tests.

Although the project specifications required the contractor to submit the results of the concrete testing to the engineer within 24 hours, results were typically submitted 2 or 3 weeks after testing, and sometimes not at all. Well into the project, it was noted that the testing agency was reporting some of the 7- and 28-day tests as "Field" and was also occasionally doing 14-day breaks. In addition, it was noted that all of the cylinders were being picked up the day after they were cast.

When the contractor's project manager was questioned about this, he indicated that at his request, the testing agency was leaving cylinders outside in their yard to test as confirmation of the lab-cured cylinder breaks. These were the tests marked "Field." The project manager was told that this was not in accordance with the project specifications; in particular, these were not replacements for cylinders cured on the job site. He responded that having the testing agency come down a second time to pick up field-cured cylinders represented an extra expense. There was quite clearly no basis for this claim; the project specifications state "cure cylinders on the job site." Furthermore, during the preconstruction meeting between the contractor, engineer, and testing company, the engineer had indicated that the contractor's personnel could deliver the cylinders to the testing lab, provided it was marked on the test report whether the testing agency had picked them up or the contractor had delivered them. Finally, the project manager's claim did not make sense because the extra testing he had chosen to do was, in fact, an unnecessary expense.

The contractor instituted changes in their testing procedures, but still failed to submit reports in a timely manner. "Clerical errors" on some of the reports from the testing company resulted in 28-day cylinders breaking at 2000 psi less than their companion 7-day cylinders as well as random 7- and 28-day tests marked as "Field."

Compliance with the Project Specifications

The contractor, in addition to reading the project specifications, must comply with them. The contractor's supervisory personnel must be responsible for ensuring that this is done; the individuals carrying out the work will usually not have read the specifications and may not know what is required.

As is common on post-tensioned concrete repair projects, many of the concrete pours on this project were small (less than half a yard). As a result, these pours were done with bag-mix concrete repair material. It was agreed that testing the repair material every time it was used was unnecessary. The contractor was directed to test each bag-mix repair material being used on the project at least once every 2 months. This would allow for changes in personnel, changes in the areas where work was being done, and changes in the weather. All materials were to be mixed in strict accordance with the manufacturer's instructions and with strict control over added water and aggregate.

One day about a year into the project, it was noted that concrete repair material was being batched in a mortar mixer by a worker adding water with a hose and a garden sprayer. An entry-level engineer standing approximately 5 ft away either didn't notice what was being done or was unaware that the worker had no idea how much water he was adding. When questioned by a senior engineer who was on site, the worker replied, "Hey, we have been doing this for a long time. We know what we are doing." The contractor's project manager was directed to stop the work immediately and institute proper procedures. When asked about the incident later, the project manager indicated that the worker had said he "felt comfortable in taking a shortcut."

Poorly Written Specifications

The above discussion assumes that the project specifications are written to correctly address the work that is required. Very few engineers like writing

Fig. 1: Patch repairs like this one are all too common

project specifications, though. As a result, specification writing is often delegated to junior engineers. Many of the specification sections for the project discussed above were actually written by a college student working as a summer intern. He had no experience in the work for which he was writing the specifications, and simply copied other specifications he thought might be appropriate.

The ground floor of the building included a large exterior plaza with an exposed aggregate topping slab that was to be removed and replaced as part of the project. The specification section the student wrote for the new topping slab indicated that it was to be reinforced with 2 x 2 - 16/16 mesh. It is not clear what specification the student copied from, but it must have been fairly old because the designation for wire size in welded wire reinforcement changed from wire gage to cross-sectional area in the early 1970s.

The reinforcement called out in the specification (16 gage wire) is essentially chicken wire. Its main use, other than for fencing chickens, is in the construction of concrete canoes made by engineering schools. It is sometimes used for very thin, interior-topping slabs where temperature and shrinkage stresses will be minimal. The spacing and gage called out result in a mesh that has an area of only 0.018 in^2 of steel per foot—this is far less than what is typically used for topping slabs. The contractor ordered a roll of the mesh but indicated that they were concerned about it floating up in the slab and being exposed when the aggregate was exposed. This was reviewed by a senior engineer and the contractor was directed to use a 6 x 6 mesh with larger wires.

The specification section did not indicate how the mesh was to be supported or where it was to be located in the slab, however. The college student, having graduated and returned to work for the company, was doing construction administration. He reviewed the steel placement the day before the first pour and noticed that the mesh was lying on the waterproofing membrane. He then instructed the contractor to put reinforcing bars under the mesh to get it off the membrane. A senior engineer reviewing the pour the next morning noted that the mesh was supported on, and tied to, 20-ft long pieces of No. 4 bars laid out on the membrane. The project manager for the engineering firm was contacted; he indicated that the contractor would be pulling the mesh up as they proceeded with the pour and then removing the support bars. This was not how the contractor understood the directive to support the mesh, and they obviously could not remove the bars once the concrete had been poured, especially since the mesh was tied to them.

The contractor therefore removed the bars prior to the pour. An entry-level engineer was assigned to watch the pour; his sole responsibility was to ensure the mesh was being pulled up. The subcontractor's workmen did, in fact, pull up the mesh as directed; but they pulled it up by hand as the concrete was being placed. Because it was then stepped on by at least three, if not four, other workers during the finishing operations, it almost certainly went back down to the bottom of the slab.

Supporting mesh on pieces of concrete block ("dobies") is a fairly common way of ensuring that the mesh is at approximately the mid-depth of the slab. (Block is preferable to clay brick because incompatibilities between the brick and the fresh concrete may cause the brick to expand and crack.) The subcontractor was asked to support the mesh on pieces of block but indicated that he did not want to do this. Another option that can be used to place mesh is to "walk it in." This entails pouring approximately 2/3 of the slab depth, laying out the mesh, and then pouring the remainder of the slab. This does not provide positive support to the mesh, but it is better than trying to pull it up. The contractor indicated that this would be considered extra work, which was legitimate because neither the mesh location nor the support method was indicated in the specifications.

As a compromise, the subcontractor agreed that on subsequent pours, they would pull the mesh up with a hook after the concrete had been struck off. Although this reduced the number of workers stepping on the mesh, it is extremely hard to pull up mesh through wet concrete and it likely that the mesh ultimately settled to the bottom of the slab. Mesh at the bottom of the slab does nothing to stop shrinkage cracking, and water trapped on top of the membrane will cause it to rust. From a durability standpoint, it would have been better not to put the mesh in at all. In addition, the confusion and problems surrounding this work had a negative impact on the overall project atmosphere.

Qualifications of Inspection Personnel

Inspectors who know, and understand, the specifications are also essential. A common method of replacing deteriorated post-tensioning anchors is to chip a full-depth hole about 3 ft from the anchor, detension the strand by cutting the wires with a hand grinder, then chip out back to the anchorage. A new anchorage device is installed and a new section of strand is spliced to the existing strand. If there is no access to the anchorage for stressing, an in-line stressing coupler ("dogbone") must be used, and the area around the coupler must be blocked out to allow access for stressing. The concrete around the anchorage device is poured back and allowed to gain sufficient strength for stressing. After the strand is stressed, the blockout around the coupler is poured back. This results in a construction joint between the pour for the anchorage and the pour for the coupler.

A junior engineer inspecting the work at the start of this project informed the contractor that this was not allowed because the project specifications prohibited cold joints within a patch. Despite the fact the engineer had worked on a number of reinforced concrete repair projects that had this statement about cold joints in the specifications, he was apparently unaware of what a cold joint was. (A cold joint is when the concrete within a pour begins to harden before the adjacent concrete is poured. On repairs using bag-mix material, this can happen if the mixer is not large enough to produce the amount of material required or if the material has to be transported a considerable distance. On pours using ready-mixed concrete, it usually happens because the mixer truck is stuck in traffic.)

To avoid further confusion, the junior engineer was asked to confine his inspection to areas that did not involve post-tensioning repairs.

Summary

And the list goes on and on….these were among the least serious problems on the job. Providing increased protection to the tendons by enhancing the waterproofing systems was a major component of the project. Errors and omissions on the drawings and in the specifications for the waterproofing work led to continuous changes, considerable "field-engineering," and numerous disagreements over the scope of the work, however. Such problems are almost guaranteed to compromise the quality of the repair.

Does quality control exist on concrete repair projects?

On some projects, obviously not. Although all of the problems discussed in this article were on the same project—a post-tensioned concrete office building—similar issues arise on many repair projects. Figure 1 shows a patch on the roof level of a post-tensioned parking garage in Detroit. The patch, completed 3 years before the picture was taken, clearly shows the outlines of the corroding reinforcing bars over the columns. The same picture could probably be taken in any city where deicing salts are used.

Guidelines, training programs, and certification by the International Concrete Repair Institute (ICRI), the American Concrete Institute (ACI) and other organizations are good first steps to achieving quality. They are *just* first steps, though. Quality also requires that the contractor reads, and complies with, the specifications. More importantly, it requires that the engineer writing and enforcing the project specifications understands the work. It is unlikely that a project will be a success if individuals without the proper qualifications and experience are making decisions. At the very least, this can cause delays, confusion, and claims for changes. In too many cases, it results in a project that does not really achieve the owner's objectives.

Engineers often tend to avoid bringing problems to the attention of the owner's representative. The owner's representative, in turn, may not want to tell the owner about problems. Acknowledging that there are problems may cause the owner to question whether these individuals are doing their job correctly; addressing the problems is certain to result in additional work for everyone. It thus comes as a "surprise" when the repair starts to fail. In many cases, repairs are done in anticipation of selling the building. It is then the new owner who has to deal with the problems.

This Viewpoint article has been selected by the editors as an offering to the interest of our readers. However, the opinions given are not necessarily those of the International Concrete Repair Institute or of the editors of this magazine. Reader comment is invited.

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