Petrography and Concrete Repair— *A Link is Needed*

BY DIPAYAN JANA

Petrography is the study of the composition, microstructure, and classification of rocks, including the man-made rock we call concrete. Because the microstructure of concrete controls its properties and performance, petrography allows petrographers to diagnose concrete deterioration (cracking, loss of mass, loss of strength, appearance degradation, or changes in chemical makeup) and engineers to choose appropriate repair strategies. This article summarizes a few case studies illustrating the important role of petrography in the concrete repair industry.

CASE STUDIES

The following examples help to illustrate the importance of petrography in the concrete repair industry.

Map cracking

Because map cracking can result from a variety of shrinkage or expansion mechanisms, execution of repairs without proper identification of its causes can increase the risk of repair failure.

In this example, investigators assumed that polygon-shaped map cracking on the surface of a concrete wall was the result of drying shrinkage. Repairs consisted of injection of epoxy resin at a series of holes drilled along the visible cracks. Because deterioration and map cracking continued after the initial repair, examination of core samples was requested. Petrographic examination helped to reveal that:

- The concrete had a network of numerous microcracks and macrocracks (from 0.15 to 1.25 mm [6 to 49 mil] in width) throughout the thickness of the wall;
- Many of the cracks, particularly narrow cracks located away from the injection points, had no epoxy filling. Some cracks were partially (less than 50%) filled, and only a few wider cracks near the injection points were more completely (more than 90%) filled with epoxy.
- Cracking was the result of expansion caused by alkali-silica reaction, facilitated by water infiltration from a brick wall bearing on top of the concrete wall.

The initial repair methods or materials were clearly not effective in filling the existing cracks or preventing new cracks. A new repair strategy was proposed that included installation of flashing to cut off the source of moisture before attempting any further epoxy-injection repairs. Had the petrographic examination been performed at the outset, the initial repairs would have been more effective and the total costs for the repairs would have been reduced.

This point of view article is presented for reader interest by the editors. However, the opinions expressed are not necessarily those of the American Concrete Institute. Reader comment is invited.

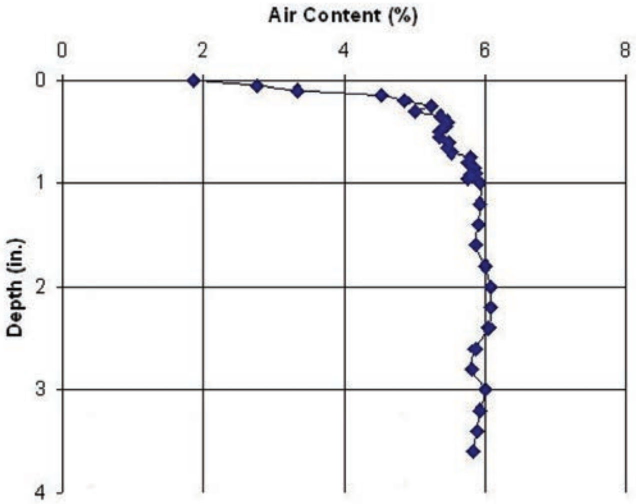

Fig. 1: Air content profile of a scaled concrete slab. Note: 1 in. = 25.4 mm.

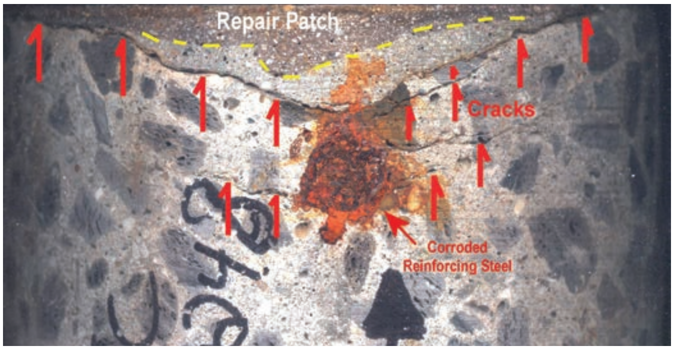

Fig. 2: Side view of a core showing ineffective repair patches and continued corrosion of the reinforcing steel in the concrete

Fig. 3: Section of a core showing delamination of a concrete overlay and severe surface-parallel cracking

Scaling

Petrographic examinations of scaled concrete slabs often reveal that the causes of the scaling are:

- Inadequately air-entrained or soft, porous concrete near the surface region with properly air-entrained, dense, and hard concrete in the body;
- Improper finishing and entrapment of bleed water underneath the finished surface; or
- A poor air-void system throughout the depth of the concrete.

Where the first two causes of deterioration are identified, a reasonable repair strategy includes partial removal of unsound material and replacement with an air-entrained concrete that is similar to the substrate. For example, Fig. 1 shows an air content profile obtained from a petrographic examination of a scaled slab. The profile not only verifies that low air content near the surface was the probable cause of scaling, but it also indicates that only the upper 1 in. (25 mm) of concrete requires replacement. The third cause of deterioration may require placement of a cementitious, polymer-cementitious, or an epoxy-based protective coating, or in worst case, replacement of the slab.

Corrosion

Chloride- or carbonation-induced corrosion of reinforcing steel in concrete causes cracking and delamination, often to the depth of the corroded steel. Repair methods involve isolated patching or complete removal of the delaminated cover. To avoid macrocell formation, a durable bonded portland cement-based overlay of similar composition as that of the substrate is beneficial.

Petrographic examinations can verify the causes of delamination, the depth of delamination, and the quality of the preexisting concrete cover or repair material. For example, Fig. 2 shows a core taken from a slab that was damaged by corrosion and delamination. Note that at least two previous repair attempts are evident. Not only was the first repair not successful in providing corrosion protection, it was also apparently not resistant to scaling!

Freezing and thawing

Cyclic freezing and thawing of bridge decks containing concrete with low or zero air entrainment causes surface-parallel cracking. Petrographic examinations can determine the cause and depth of cracking. The extent of concrete that must be replaced can therefore be properly assessed. For example, Fig. 3 shows a core through a concrete deck that exhibited continued delamination after receiving a 1-in.-thick (25 mm) repair patch. Petrographic examination showed that severe surface-parallel cracks existed throughout the depth of the slab and that the full thickness of the slab contained concrete with low air entrainment. Clearly, partial-depth repair was, and would continue to be, ineffective for this deck.

Fig. 4: Section of a core showing the extent of damage in the wall of a concrete chimney

Fire

In fire-damaged concrete, petrographic examination can determine the depth and/or extent of distress, including discoloration, spalling, and thermal cracking. For example, Fig. 4 shows a core from a chimney subjected to repeated exposure to high temperatures. Petrographic examination indicated the depth of cracking and physico-chemical alterations in the concrete and allowed development of a rational repair strategy.

PETROGRAPHY ANSWERS "WHY?"

Petrography provides information on the three common causes of repair failure: improper materials, poor workmanship, and poor design. Costly additional repairs can be avoided by a cost-effective diagnosis of the problem by petrography.

References

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SUCCESSFUL REPAIR

Clearly, the success of a repair depends on the design of the repair, the repair workmanship, and the repair material.[1,2] There tends to be greater interest in choosing a state-of-the-art repair material or method; however, the engineer must also be aware that improper diagnosis of the problem can lead to failure of the repair itself. In short, the success of a repair is founded on the proper diagnosis of why the repair is needed.

Petrography allows the investigator to:

- Identify the causes of deterioration;
- Determine the composition, texture, and current condition of the concrete;
- Determine the degree, location, and extent of the deterioration;
- Attribute the deterioration to design, materials, or environment;
- Evaluate whether the deterioration will continue; and
- Anticipate the probability of future damage.