Petrography as a Concrete Repair Tool

By Laura J. Powers

It's usually pretty easy to tell when concrete is damaged or distressed. Most common concrete problems produce visible signs—such as cracks, efflorescence, or discoloration—that tell you something is wrong. The trouble is, these signs don't necessarily indicate the cause of the problem, because many different mechanisms can lead to distress that is visually similar. Without knowing specifically what went wrong on a given project, you can't design or execute an effective and durable repair. Petrographic analysis is a tool that can help determine the underlying problems and thus improve the chances of a successful repair.

What Petrographers Do

Petrography is defined as the description and systematic classification of rocks, especially through microscopical examination. Using methods borrowed from geology, metallurgy, and ceramics, concrete petrographers prepare extremely thin sections of concrete (20 to 30 microns, or about one-quarter the average thickness of a human hair). They examine samples using a variety of microscopes (including polarized light, or petrographic, microscopes and scanning electron microscopes) to obtain information about the material's composition and condition. Petrography is painstaking and exacting work that requires a good visual memory and the ability to recognize patterns.

Concrete petrography is not new. The techniques have been applied to concrete since at least the 1890s to study cracking and sulfate attack. In addition to concrete, petrographers routinely examine related materials such as mortar, grout, stucco, shotcrete, plaster, terrazzo, synthetic stone, and coatings. Their work on all of these materials is covered by ASTM C856, "Standard Practice for Petrographic Examination of Hardened Concrete." Other specific standards apply to the examination of masonry mortar (ASTM C1324) and aggregates (ASTM C295), and to microscopical air-void analysis (ASTM C457).

Getting the Most from a Petrographic Examination

Think of petrographic analysis as a diagnostic test, such as a physician might order to help determine the appropriate treatment for a patient. Just as a person can suffer similar physical symptoms caused by any of a number of diseases, concrete can exhibit visible signs of distress that don't clearly indicate their origins. And just as a physician must gather detailed information about the patient's habits, complaints, and medical history to determine the best course of treatment, a concrete repair specialist should seek similar background information to develop an appropriate repair strategy.

The process starts with a good field investigation, which includes surveying the condition of the concrete and providing detailed descriptions and photographs of distressed areas. Follow ASTM C 823, "Practice for Examination and Sampling of Hardened Concrete in Constructions," to collect the proper quantity and quality of samples for analysis. Be sure that samples exhibit the distress being investigated.

Gather as much background information as possible—it's always better to have too much than too little. Some examples of useful data include: the original mix design; results of any previous testing; technical information on other components of the concrete, such as admixtures, coatings, or reinforcement; weather conditions during placement of the concrete; and unusual exposure or service conditions. Communicate with all the relevant parties on the project, including the owner, engineer, and original contractor, to find out what light they can shed on the problem. When you can provide this information, the petrographer will better know what to look for, how to account for certain findings, and what results will be relevant for your purposes.

What Petrography Can Tell You

The first goal of petrographic analysis is to help determine the nature and extent of distress or failure (and sometimes, just to determine what other tests are needed). But by carefully examining samples of a particular concrete, a skilled petrographer can learn a surprising amount—about its composition, the quality of workmanship employed in placing and finishing it, its present condition, and its likely future performance. Following are some areas of inquiry and the types of questions you might expect petrographic analysis to answer:

Composition

- Does the aggregate consist of gravel or crushed stone? What type of stone was used?
- Does the mix include natural or manufactured sand? What is its texture?
- What is the nature of the interface between the aggregates and the cement paste?
- What type of cement was used in the mix? Does it contain fly ash or other pozzolanic materials? Pigments? Dispersed fibers?
- Does the concrete contain entrained air? What size are the air voids, and how are they distributed through the concrete?
- What size of reinforcing steel is embedded in the concrete? Where is it located? Does it have an epoxy coating? How well embedded is the steel? Does it show signs of corrosion?
- Are there foreign objects or other unintended items embedded in the concrete?

Workmanship

- Was the concrete placed correctly and with the proper degree of consolidation?
- How was the surface finished? Was it finished too soon or too late after placement? Were any surface treatments applied?
- Was the concrete properly cured?

Present Condition

- What are the physical characteristics of the concrete?
- Is there evidence of distress present in the sample?

Future Performance

- Based on its current condition, is the concrete likely to perform well for its planned use?

Case Studies

The following case studies represent three projects where petrographic analysis was used to develop different kinds of information for different purposes. Together, they illustrate a range of applications in which petrography can be helpful.

Case 1: Fire Damage Evaluation

A fire in this industrial facility caused serious damage to the building and equipment. As part of the post-fire investigation, petrographic analysis of the concrete was used to help determine the extent of fire damage to the concrete. Figure 1 shows evidence of distress where the floor was exposed to the fire—spalling, some blue-green discoloration that can result from exposure to high temperatures, cracking, and stains. By examining prepared samples under the microscope, the petrographer was able to determine that the

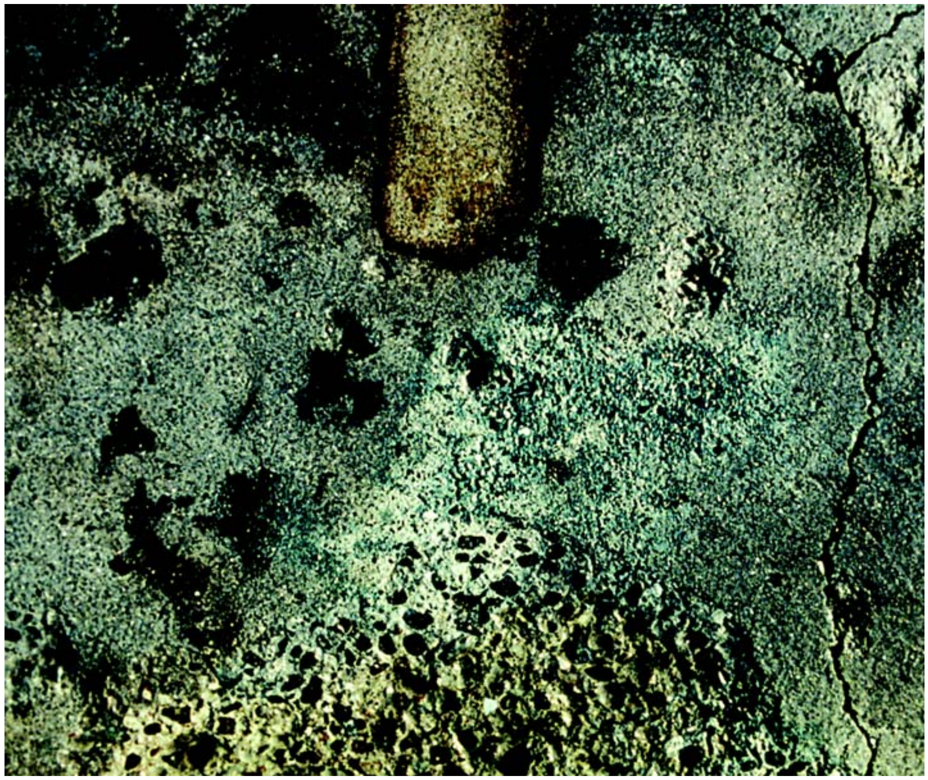

Fig. 1: Concrete exposed to fire shows signs of distress

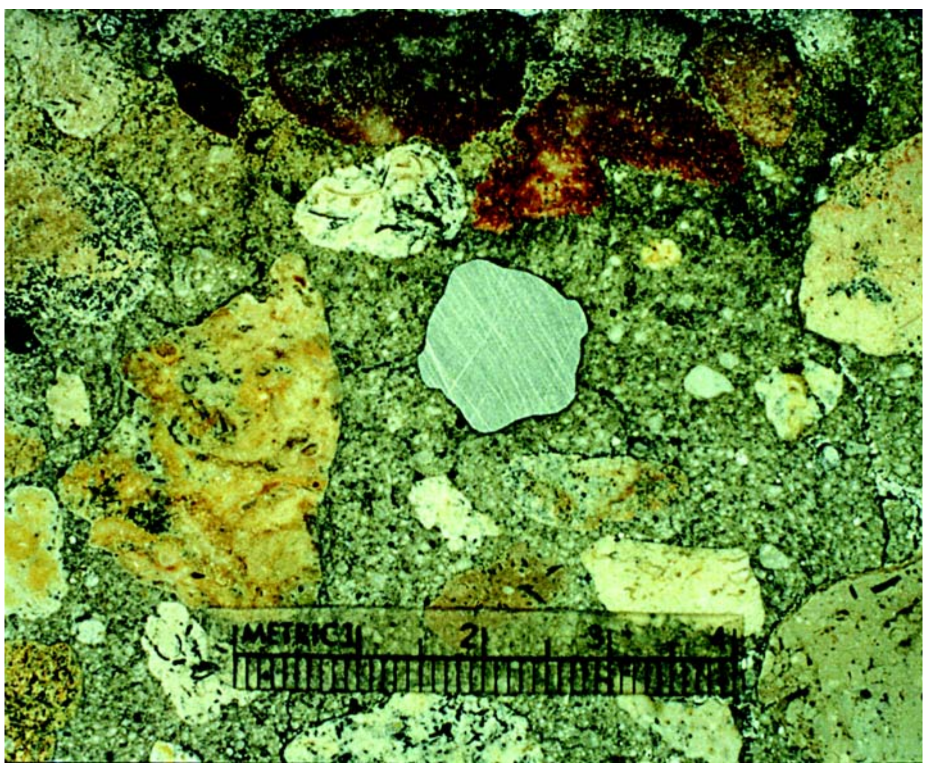

Fig. 2: Color of aggregate in photomicrograph shows exposure to temperatures between 570 and 1100 degrees F, the range at which the color change from pink to brick red occurs

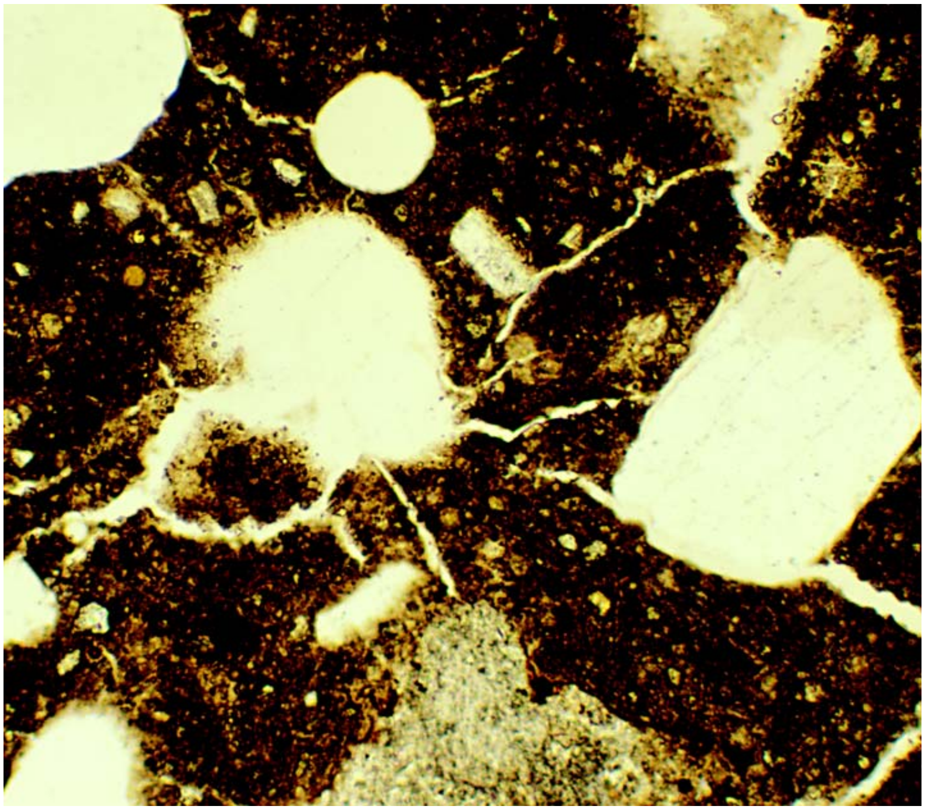

Fig. 3: Cracks in cement paste resulted from fire exposure

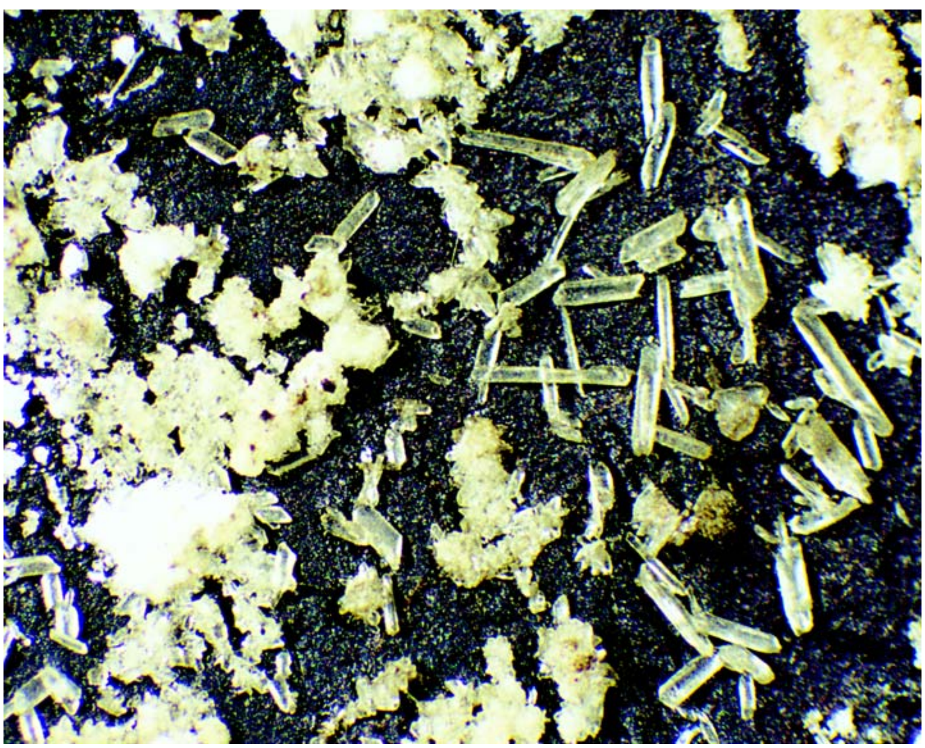

Fig. 4: Photomicrograph shows presence of gypsum crystals on the back surface of failed coal-tar epoxy coating

sedimentary rock used as aggregate had changed color, first to pink and then to brick red—a transformation that takes place between about 600 and 1100 degrees Fahrenheit (Figure 2). The cement paste also had changed color (Figure 3), but more significantly, it exhibited cracks that indicated volume changes in some of the minerals comprising the fine aggregate and loss of water from the hydration products comprising the paste. Examining other samples provided clues to the condition of the reinforcing steel, which was damaged because it was embedded too close to the fire-exposed surface. Petrography results helped the engineers to decide which areas of the concrete needed to be removed and which could be repaired.

Case 2: Coating Failure

The interior surface of this concrete sewer pipe had been treated with a coal-tar epoxy coating that was failing and delaminating in large sheets. Petrographic analysis was used to help determine the cause of the failure. Examining a sample of the failed coating (Figure 4), the petrographer identified gypsum crystals that would not ordinarily be present. Samples taken from areas with relatively intact coating showed chemical degradation of the coal-tar epoxy and sulfate attack on the underlying concrete. A layer of gypsum crystals (Figure 5) was present at the interface between the concrete and the coating. Further investigation showed that a combination of factors had led to the failure. Insufficient slope in the sewer line slowed the flow of sewage through it, allowing gases to collect. An industrial effluent discharged into the sewer contained sulfides. Microbial activity in the moist environment of the sewer converted hydrogen sulfide gas to sulfuric acid, which degraded the coating and attacked the concrete. A layer of gypsum crystals formed at the interface between the coating and the deteriorated concrete. This buildup of gypsum at the interface eventually pushed the coating off the deteriorated surface of the pipe.

Case 3: Concrete Statue Restoration

Over several decades, a number of folk art concrete statues had suffered damage due to the elements, which included a tornado. A self-taught artist had created the figures using some unconventional materials, including wooden armatures instead of metal reinforcement (Figure 6). A petrographer, consulted to analyze the concrete and provide a mix design for repairs, was able to identify a sand with characteristics similar to the original, recommend cement with similar color, and approximate the water-cement ratio and aggregate-cement ratio used in the original work.

A Valuable Tool

Petrographic analysis can be a valuable tool in deciphering concrete problems and designing effective repairs. It can uncover evidence of defective or poorly chosen materials, unusual service conditions such as environmental attack, or special circumstances such as fire or flood that may have contributed to concrete failure.

To derive the greatest value from a petrographic examination, engage a petrographer with extensive experience and access to a broad range of diagnostic tools. Then, provide as much background information on the project as you can.

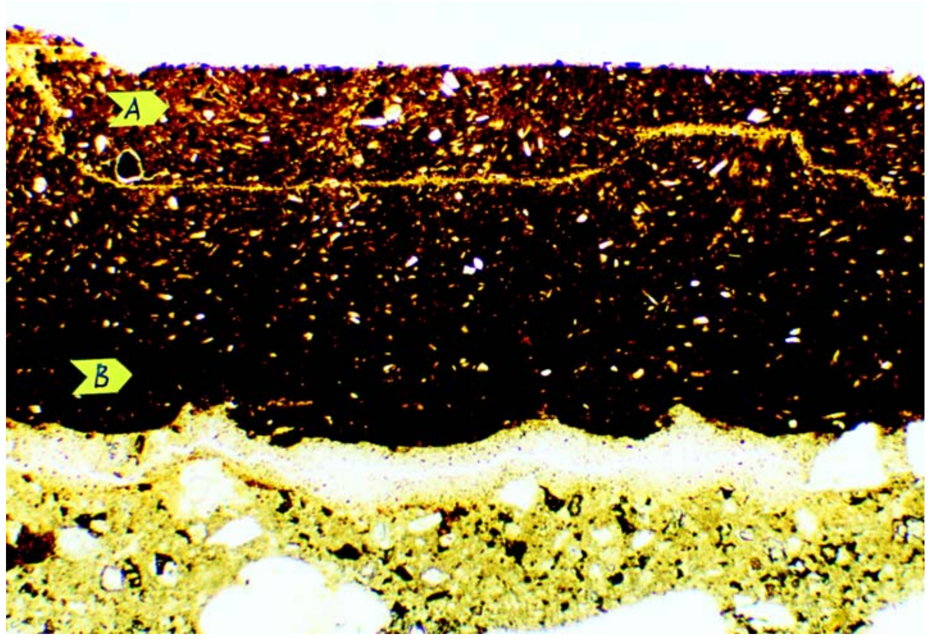

Fig. 5: Gypsum crystals fill the gap between deteriorated concrete surface and delaminated coating

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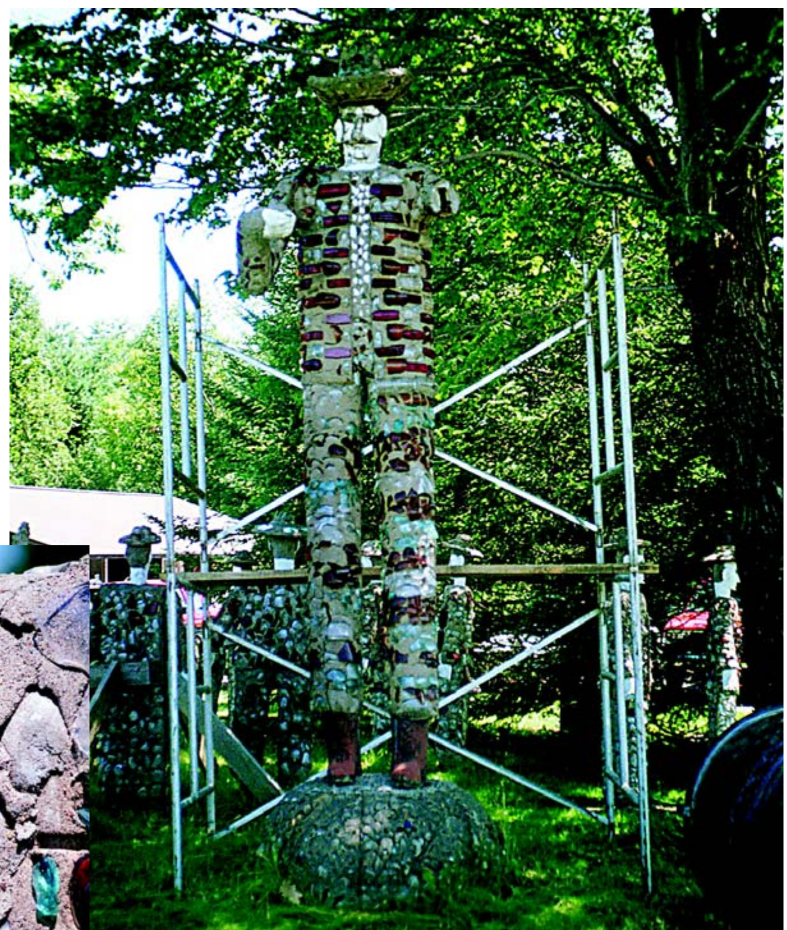

Fig. 6: Concrete folk art figures required repair after tornado damage

Fig. 7: Self-taught artist used unconventional materials, including wood reinforcement