TROUBLESHOOTING CONCRETE FLOORS WITH PETROGRAPHY

BY GERARD MOULZOLF

Petrography is a very useful tool in troubleshooting concrete floors and floor covering debonding issues. Moisture and water vapor transmission are hot topics and often major contributors to a great many flooring failures. Other issues, however, such as finishing, curing of the concrete substrate, the presence of deleterious materials, and unexpected "bond breakers" all play a significant role in floor/flooring failures. This article addresses a petrographer's perspective on the diagnosis of the properties of concrete surfaces, applied cementitious materials, and preparation leading to floor and/or flooring failures.

The standard of practice for petrography of concrete is ASTM C856. ASTM C1324 contains a section describing the petrographic analysis of hardened mortars, which can be likened to cementitious overlayments/underlayments or thin-sets. Experienced petrographers can easily identify the characteristics in hardened concrete affecting the success of the floor and/or flooring installation. The finishing profile, quality and duration of the curing process, and quality control of the various concrete-making constituents are all usually described by a petrographer. The water-cementitious material ratio (*w*/*cm*) may also be estimated. A high *w*/*cm* in the body of the concrete can induce excessive shrinkage cracking. A high *w*/*cm* at the top surface will produce a soft and friable substrate.

Moisture content and vapor transmission information are not directly determinable by petrographic means. A high *w*/*cm* can infer the source of moisture or water vapor may have been the concrete itself, especially if a vapor barrier had been provided beneath the slab. Concrete cores are usually taken by water-assisted diamond core drilling. Dry coring produces excessive amounts of heat that can alter moisture content of drilled cores. Petrographers are rarely part of a field survey and rely on the submitting forensic engineer or technician to provide a meaningful sample—one that is representative of the field conditions.

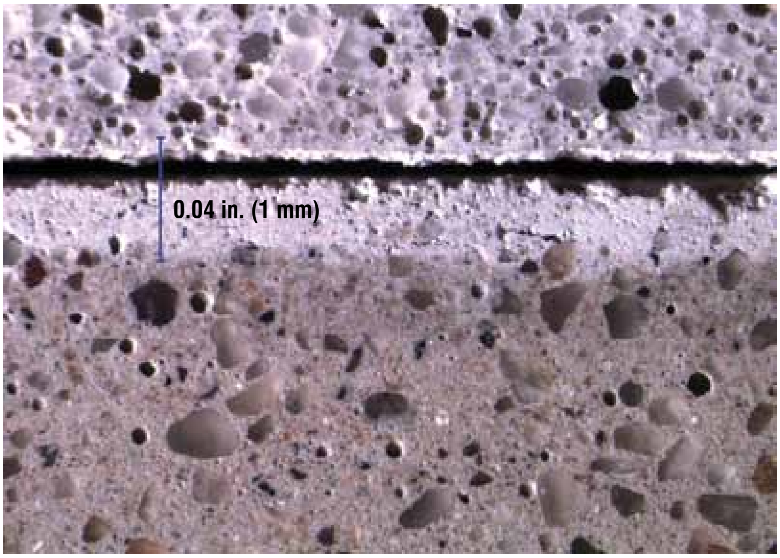

Fig. 1: Debonding of a thin-set mortar (above) along a "dusting" surface, in sawcut and lapped cross section of concrete and tile composite. Note soft, carbonated, white-colored layer of cementitious paste

FINISHING PROFILE

The finishing of a concrete slab can directly impact the need for or type of preparation required for a floor covering installation. An experienced petrographer can describe the type and duration of finishing the concrete surface has undergone. Prolonged troweling or "burning" the slab densifies the surface by removing water and creating an excessively low *w*/*cm*. Working rising bleedwater into the surface and not burnishing the water out can produce an excessively soft surface. This premature finishing coupled with carbon dioxide in the air produces the dusting phenomena commonly described as carbonation in concrete bulletins. This condition is detrimental to the adherence of flooring adhesives, coatings, cementitious overlayments/underlayments or thin-sets (Fig. 1). A finisher commonly struggles between leaving a softer, rougher finish for adhering flooring or producing a smooth, hard, dense surface by prolonged troweling. These burnished surfaces benefit from lightly sand- or shot-blasting the surface to increase bond surface area and can produce the best substrate for thin sets and adhesives. Unfortunately, burnished surfaces and low *w*/*cm* concretes are not quick to give up their moisture.

Deficiencies in power troweling procedures can produce anomalies that affect the quality of the final concrete surface. The redistribution of concrete paste late in the finishing procedure may result in thin delaminations that appear during grinding/polishing procedures (Fig. 2) or shortly after the slab is put in service. This type of delamination differs from a more common phenomenon that occurs upon planes of bleedwater trapped by delayed bleeding/premature finishing. This petrographer has also documented heavily burnished surface profiles up to 0.24 in. (6 mm) depth that have had water or a finishing aid added late in the troweling procedure—producing soft, dusting surfaces. This floor required unplanned grinding/polishing and the application of a hardener—at the finisher's expense—to produce the specified surface finish. Hardeners must be selected and tested carefully to avoid other issues such as alkali-silica reactivity (pop-outs), described further in the article.

CURING

Curing refers to the act of keeping moisture in the concrete to further develop strength and durability by continuing portland cement hydration. Early-age desiccation of portland cement hydrates at the top surface can lead to excessive shrinkage, lower strength, and carbonation. Curing compounds used to combat early-age drying must be removed before application of other cementitious materials, flooring adhesives, or coatings. Membrane-forming curing compounds and sealers may act as bond breakers. Their presence is usually easy to recognize on the top surface of the concrete under magnification (Fig. 3). Also, remnants of bond breakers are often adhered to the underside of failed flooring systems.

SURFACE PREPARATION

Surface preparation is an integral part of a successful floor covering installation. The preparation usually involves cleaning the surface of any potential organic bond breaker, removing any laitance or compromised concrete surface paste, and/or roughening the surface to provide more surface area for better mechanical bond. Standards for concrete surface profile (CSP) have been produce by the International Concrete Repair Institute (ICRI) in the form of molded rubber chips.

Surface preparation, when done, is obvious in the field; but the effects may not be so obvious. Problems created by certain types of preparation are not always obvious. Petrographically prepared samples from concrete cores taken from representative locations can disclose bruising, a condition not discernable in the field. Aggressive impacting of the surface by scrabbling, (roto)-milling, or scarifying can damage the concrete at depth in the form of incipient spalls. Micro-bruising can also be detected (Fig. 4) under microscopy of properly prepared core samples. Exposed and shattered quartz sand grains from shot-blasting can detrimentally affect the bond of coatings (Fig. 5).

Fig. 2: Very thin delaminating layer of concrete surface paste in commercial slab on grade. Paste was redistributed late in the troweling procedure

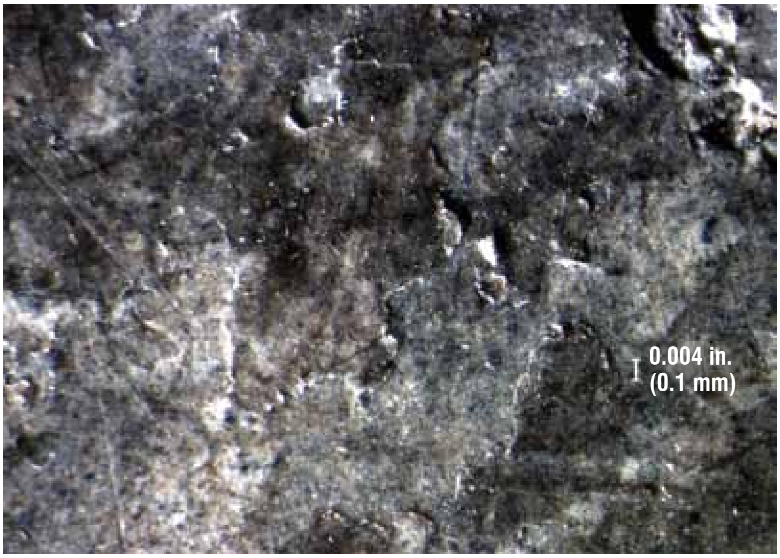

Fig. 3: Clear flakes of residual curing compound on the smooth troweled surface of concrete was implicated in VCT flooring failure

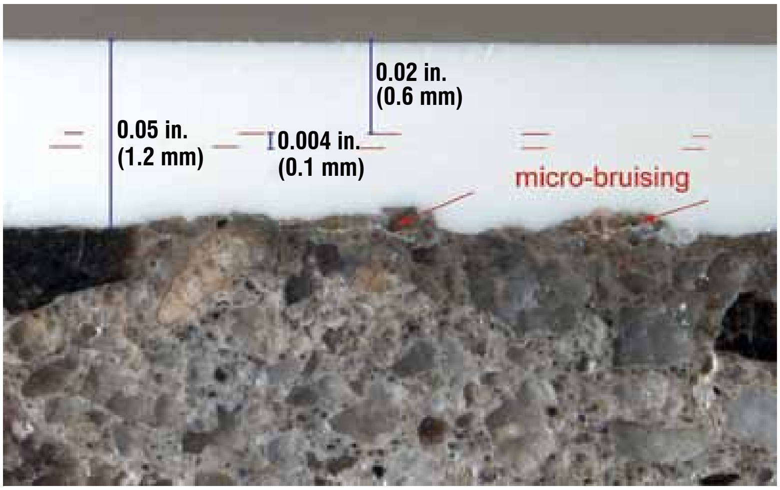

Fig. 4: Micro-bruising is evident beneath a coating system in sawcut and lapped cross section of concrete core. The base coat appears to have penetrated the cracking

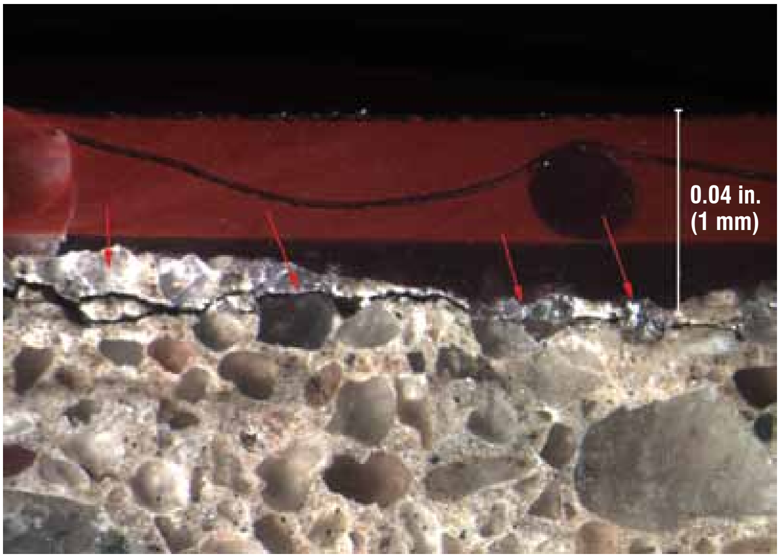

Fig. 5: Shattered quartz sand grains are marked beneath failed coating system

Fig. 6: Large, up to 0.4 in. (10 mm) diameter, concrete debris (outlined in red-dashed line) at contact between deeply recessed, hydrodemolitioned concrete surface and shotcrete repair, separated by blue-dashed line

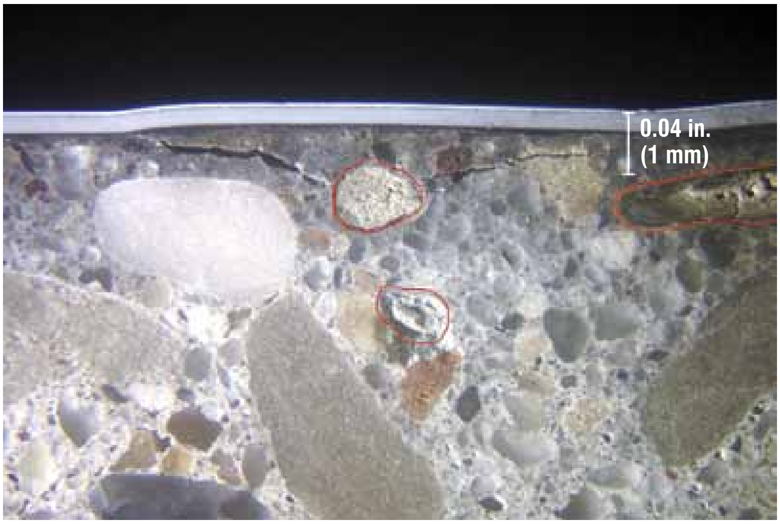

Fig. 7: ASR shale fine aggregate particles have formed protrusions in the coating system

Surface cleanliness after floor slab preparation can also be assessed under a microscope. Deep recesses in the prepared surfaces can hold large amounts of debris—especially high-/ultra-high-pressure water-jetted surfaces (Fig. 6). Failed repairs and overlayments/underlayments often exhibit debris adhered to their undersides. This petrographer has found many materials other than concrete debris at failed contacts, including steel shot, steel shavings, and sawdust. Other trades working on a project can affect previously cleaned surfaces. Protrusions in vinyl sheet goods or vinyl composite tile (VCT) have commonly been identified as construction debris and splatters of spackle or mortars. In certain geographical locations, however, especially in some parts of the Midwest, alkali-silica reactive (ASR) coarse and fine aggregate particles in the concrete expand beneath moisture-sensitive coatings and flooring (Fig. 7). These impervious coverings trap moisture and concentrate alkalis, providing a perfect environment for these expansive reactions. Alkalis can also have a negative effect on adhesives used to bond the flooring material to the concrete substrate.

COATINGS

Usually the preparation of concrete for petrography preserves the integrity of polymer coatings and traffic membranes allowing for accurate dry-film thickness measurements of various coats or layers. Even if the various coats all consist of the same polymer, application lines may be visible. Often, coatings comprise a primer, a base coat, and a finish coat. Commonly, an inorganic filler or friction media will be broadcast into the surface. These materials usually comprise natural or manufactured sands or industrial minerals, such as silica carbide. Elastic traffic membranes can also be studied, but they usually require some type of mounting and stabilization in another polymer (Fig. 8).

OTHER CEMENTITIOUS MATERIALS

Cementitious underlayments, overlayments, setting beds, and thin-sets can be reverse-engineered through transmitted light microscopy on thin sections produced from these materials. All inorganic components can be identified through this petrographer's tool for identification of rocks and minerals. Common components are a natural or manufactured fine aggregate or sand, with a binder consisting chiefly of portland cement often blended with carbonate or silica flour, hydrated lime, fly ash, or slag cement. These materials are generally highly sensitive to water content during mixing. Excessive segregation of fine aggregate and the presence of laitance or worked-in bleedwater are commonly identified deficiencies in their placement.

ORGANIC CHEMISTRY

Generally, integral organic materials are not obvious under optical microscopy. Ancillary analysis by Fourier-transform infrared spectroscopy (FTIR) can identify any organic modification of the cementitious binder. Further, FTIR can identify the composition of coatings, adhesives, and bonding agents. FTIR has been successful in revealing penetrative organic bond breakers not visible under optical microscopy. Examples of these materials include light oils, kerosene, and form-release agents.

Petrography is a very valuable asset to the forensic engineer and project owner. Field observation and traditional sampling is not always enough to successfully identify floor or flooring failures. Many factors are only visible under significant magnification. An experienced petrographer can be an integral part of the problem identification, leading to the solution of the real problem.

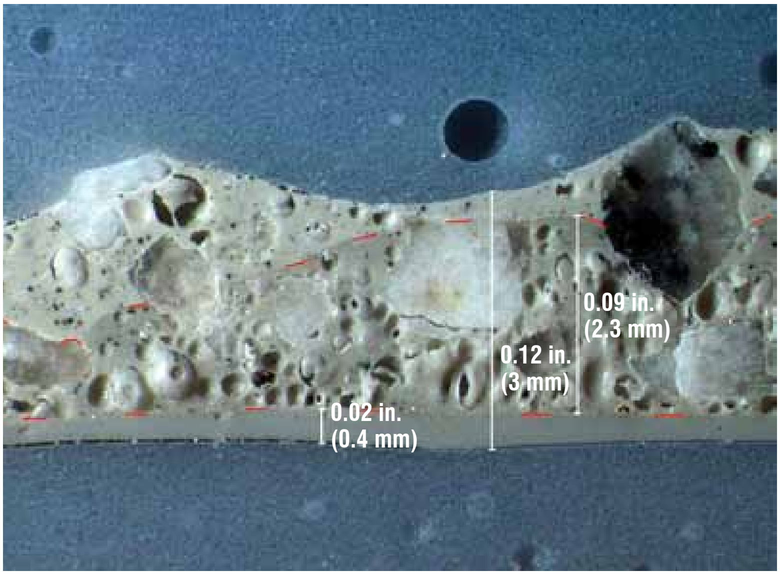

Fig. 8: Three-layered traffic membrane, with calibrated thickness measurements, was mounted in blue polymer for preparation and assessment

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