Who Reads Instructions Anyway?

The Case of the Failing Floor Coating

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Several years ago, an upgrade was slated for the warehouse of a distribution facility. Part of the upgrade included recoating the concrete floor. The specification for the project required the concrete floor to be abrasive blast cleaned or scarified to remove laitance and surface contaminants. Additionally, before applying the coatings, the surface was to be tested to ensure it was free of moisture. The testing followed the plastic sheet method as described in ASTM D 4263, Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method.

The specification called for a three-coat system: an epoxy primer applied at 150 to 200 sq ft per gallon, a base coat of 100% solids epoxy applied at a thickness of 20 to 30 mils, and a two-component epoxy topcoat applied at a thickness of 20 to 30 mils.

The painting subcontractor submitted an alternate coating system from a different manufacturer as a substitute to the specified system. The alternate system, which was approved and eventually chosen for application to the floor, consisted of a coat of epoxy primer applied at a recommended dry film thickness (dft) of 3–5 mils, a modified polyamine epoxy intermediate coat applied at a recommended dft of 6–12 mils, and a topcoat of a two-component aliphatic polyester polyurethane applied at a recommended dft of 2–3 mils.

During application of the topcoat, the painting subcontractor experienced problems with its adhesion to the intermediate coat. Within weeks after the application was completed, problems also arose with the adhesion of the topcoat, and scratches appeared in the floor coating. The owner of the facility requested an independent evaluation of the floor coating problems.

Fig 1: Most scratches on warehouse floor were parallel to length of aisle. Photos courtesy of the author

The Site Investigation

A visit was made to the distribution facility to examine the floor.

The floor had been coated with a gray-colored coating material. In various areas, there was also yellow striping on the gray floor. The floor was scratched and marred to various degrees throughout most of the facility. Most of the scratches were aligned in the direction of the forklift traffic flow (Fig. 1). For example, most of the scratches in any particular aisle were parallel to the length of the aisle. There were also areas where it appeared that the wheels of a forklift had spun on top of the floor, and, in some cases, had left a black mark on the surface of the floor coating. In other cases, the wheels appeared to remove the top layer of the coating, uncovering a gray intermediate coat. The degree of marring on the floor varied; the damage was minimal in some of the areas where the coating had been newly applied, while in other areas, the marring was quite extensive.

The floor was also relatively dirty at the time of the inspection. During the inspection, a floor cleaner was used on one area. The floor cleaner removed most of the dirt, but a moderate degree of scratching was still visible.

The topcoat was delaminated in many areas. Although both the topcoat and the intermediate coat were gray, the delamination was clearly visible because the topcoat was generally dirty and therefore darker than the intermediate coat. The delamination generally occurred in small patches.

The floor coating was closely examined in many areas. The degree of hardness of the topcoat varied considerably. According to the product data sheet for the topcoat, the coating was an "extremely hard, chemical-resistant polyurethane floor coating." During the site investigation, it was found that an impression could be made in the topcoat with a fingernail. In at least one spot, the

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topcoat was slightly tacky and could be removed easily with a fingernail and rolled into small balls. In most of the areas examined, the topcoat could be removed from an intermediate coat by scratching the surface with a fingernail. In a few areas, the coating was harder, and could not be removed with fingernail gouging.

Fig 2: ASTM Tape Test revealed poor coating adhesion

The adhesion of the coating system was assessed in accordance with ASTM D3359, "Measuring Adhesion by Tape Test," Method A (X-cut). This method involves making two intersecting cuts through the coating to the substrate with a sharp blade. The smaller angle of the cuts is between 30 and 45 degrees. A special pressure-sensitive tape is then applied to the X-cut area and rapidly removed.

In many of the areas tested, the coating adhesion was extremely poor (Fig. 2). In some cases, the coating could be removed simply by applying the tape to the uncut topcoat and sharply pulling off the tape. In some other areas, the coating adhesion was rated good (4A), yet the topcoat could be removed by scratching at the surface with a fingernail. In a few areas, the tape adhesion was found to be good and the topcoat could not be removed with fingernail pressure.

In areas where delamination was observed, the topcoat could be removed easily by cutting the surface with a utility knife and slipping the blade of the utility knife under the topcoat. In some cases, by continuing to tug at the coating, large sections could be removed in one piece (Fig. 3).

During the site visit, several coating samples were removed from the floor for laboratory analysis.

The Laboratory Investigation

Visual and microscopic examination of the samples was performed using a stereo zoom microscope with magnification to 45x. The investigation revealed that the samples generally consisted of four coats. The first coat was clear and the backside was dirty. There were three off-white coats applied to the clear coating. The topcoat could be removed from the other three coats in areas on some of the chips.

Fig 3: Large sections of coating delaminated with minimal manipulation.

Infrared spectro-

scopic analysis was performed with a Fourier transform infrared spectrometer. Sample scrapings were combined with potassium bromide powder and formed into pellets under high pressure. The pellets were then placed in the optical path of the spectrometer and spectra were obtained.

The infrared analysis indicated that the top two coats that were applied to the floor were the urethane topcoat. The primer and the first intermediate coat were determined to be epoxy coatings.

The analysis also revealed that the softer topcoat samples had slightly different spectra than the harder samples of topcoat and a control sample of a properly mixed topcoat. Specifically, one of the bands in the spectra of the soft topcoats was significantly smaller than the same band in the spectra of harder topcoat.

Putting It All Together

The site investigation and the laboratory analysis indicated that the cause of the excessive marring and scratching and of the scattered delamination of the topcoat from the floor in the distribution facility was improper mixing of the urethane topcoat. The topcoat was described as an "extremely hard chemical resistant polyurethane floor coating" in the product data sheet. As noted above, the topcoat on the floor was soft enough in many areas to deform with fingernail pressure. In some other areas, the coating was relatively hard and well adhered.

Laboratory microscopic analysis indicated that there were two layers of topcoat on the samples. When the coating had poor adhesion or had delaminated, it was found that the plane of separation was sometimes between the first layer of topcoat and the epoxy intermediate coat, and sometimes between the two layers of topcoat. The topcoat that separated from the rest of the coating system was found to be soft, regardless of whether it was the first layer or the

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second layer of polyurethane topcoat.

The topcoat applied to the warehouse floor is a two-component coating. Polyol in the second component reacts with the isocyanate in the first component to form a hard film. The two components must be mixed thoroughly and in their proper proportion for the coating to obtain its proper hardness. The laboratory infrared analysis provided strong evidence that the coatings were not consistently mixed in the proper proportions.

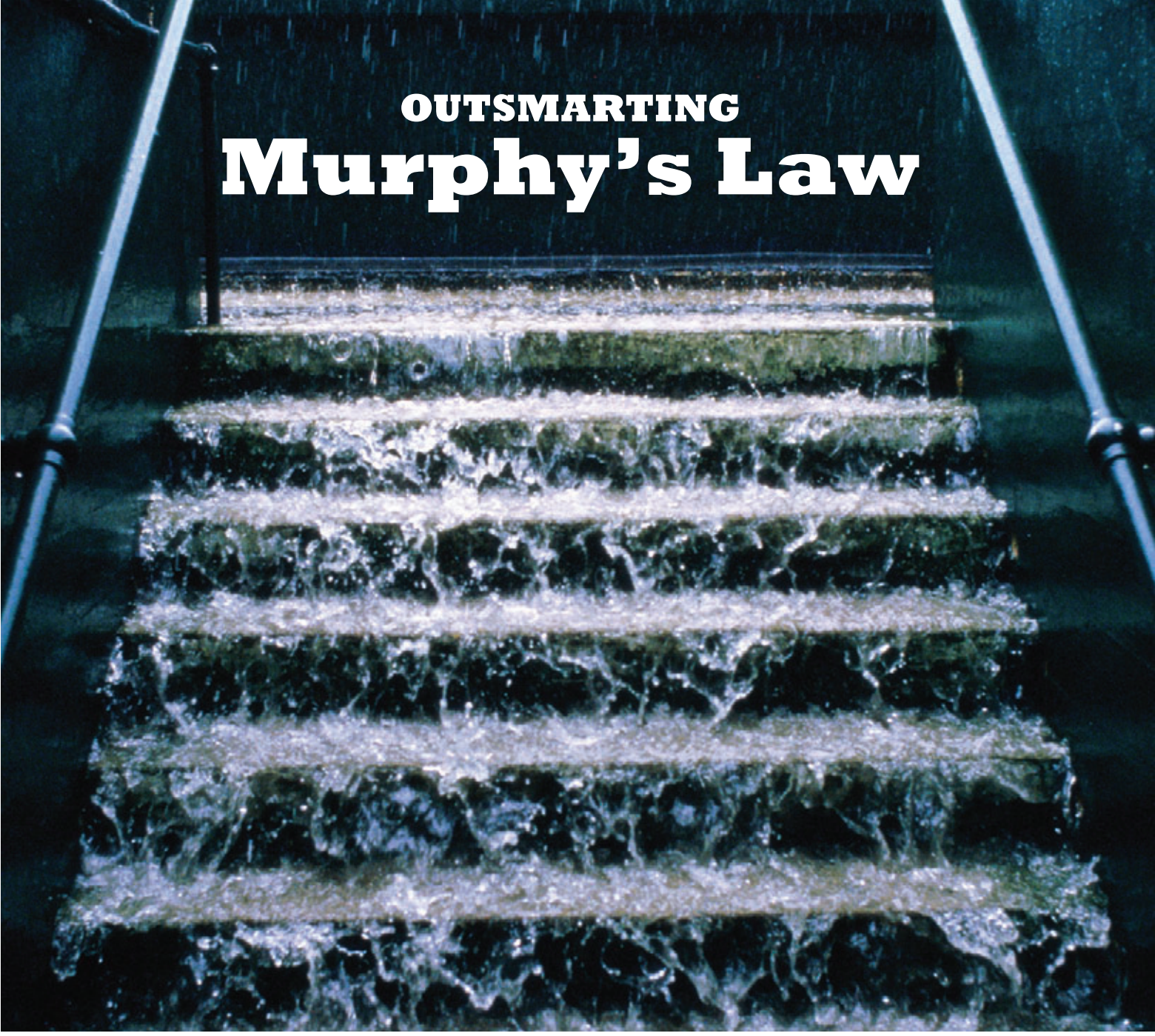
When several samples of a properly mixed two-component coating are compared using infrared spectroscopic analysis, there is usually very little difference between the spectra. In this case, the difference was very noticeable. The mix ratio of the coating varied considerably from location to location.

The softer coatings were found to adhere poorly to the underlying harder coatings. In some cases, the underlying coating was the epoxy intermediate coat. In other cases, it was an underlying second layer of the polyurethane topcoat. In all cases, the poorly adhered layer was soft.

Some degree of scratching and marring will occur with any organic floor coating exposed to forklift traffic. The degree of damage to the floor was significantly greater than should be expected for the coating system applied. The excess damage was a result of the softness of the applied topcoat. A floor coating that is soft enough to be scratched with a fingernail cannot be expected to withstand forklift traffic. If the coating had been properly mixed, it is likely the damage would have been significantly reduced and adhesion much improved.

The Fix

In a vast majority of the facility, the primer and the epoxy intermediate coat appeared to be in satisfactory condition. Unfortunately, the topcoat could not be overcoated without great risk of further failure. As a result, all of the topcoat had to be removed. Removal was accomplished using pressurized water and in some areas, a scarifying machine. In areas where the topcoat was removed by pressure washing, the uncovered intermediate coat was thoroughly abraded to break the gloss and roughen the surface. A properly mixed coat of the polyurethane was then applied to the prepared intermediate coat. The contractor had to perform the work—which also included temporary relocation of equipment and storage racks—at no cost to the owner. Additional work caused by improperly mixing the topcoat added more than 50% to the total cost of the job.



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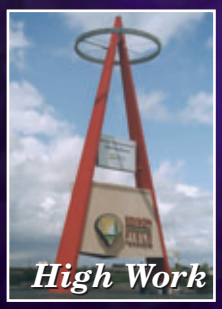

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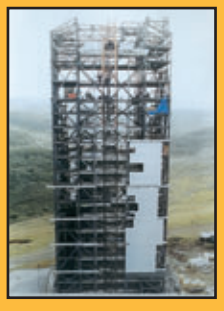

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