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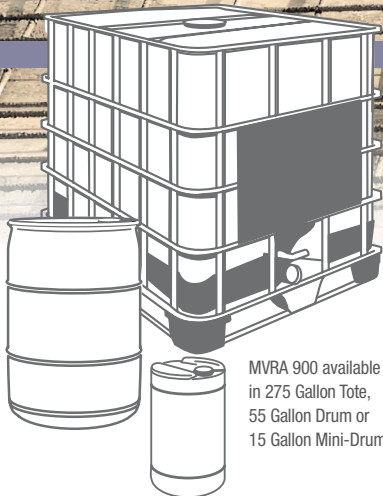


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Jason Spangler

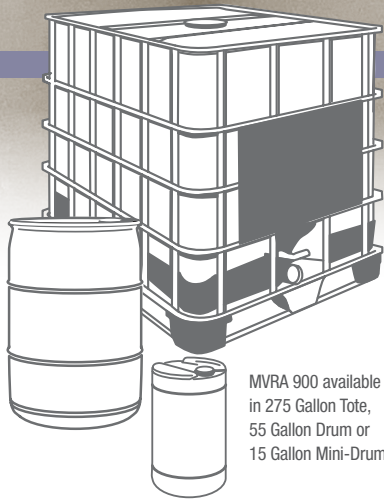


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Mark Thomas

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The Importance of Substrate Surface **Water Absorptivity**

by Dean E. Craft, DBA, CSI, CDT, LtCol USMCR (ret.)

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OFTEN REFERRED TO AS SUBSTRATE “POROSITY,” SUBSTRATE SURFACE WATER ABSORPTIVITY REFERS TO THE ABILITY OF A FLOORING SUBSTRATE SURFACE TO ABSORB LIQUID RELATIVELY QUICKLY.

TO BETTER CONCEPTUALIZE, IMAGINE A CONCRETE MASONRY UNIT (CMU) BLOCK. IF A DROP OF WATER WAS PLACED ON THE CMU, IT WOULD ABSORB THE LIQUID VERY QUICKLY. NOW, IMAGINE A HARD, SMOOTH SURFACE SUCH AS STEEL, EXISTING RESILIENT FLOORING, OR POWER-TROWELED CONCRETE, ALL OF WHICH COULD SERVE AS THE SUBSTRATE FOR MANY DIFFERENT FLOORING PRODUCTS. IF A DROP OF WATER WAS PLACED ON ANY ONE OF THOSE SURFACES, IT WOULD SIT THERE AND LIKELY EVAPORATE BEFORE BEING ABSORBED.

Historical context

Why is this of concern for porosity and how that relates to a successful flooring installation? Before addressing this question, it is helpful to provide some historical context. In the 1970s, concerns were raised about indoor air quality (IAQ). The apprehensions grew in the 1980s, and eventually, encompassed the flooring industry, too.

On January 11, 1990, the National Federation of Federal Employees (NFFE) petitioned the Environmental Protection Agency (EPA) under section 21 of the *Toxic Substance Control Act (TSCA)* to start rulemaking proceedings and focus on reducing emissions from new carpets.¹

While EPA opted to not initiate the specific rulemaking proceedings it decided to “... initiate a series of actions designed to assess and, if necessary, reduce the public’s exposure to compounds which may off-gas from carpeting.”² Upon mutual agreement with EPA, the Carpet and Rug Institute (CRI) agreed to conduct total volatile organic

compound (TVOC) emission testing on various materials, and reported the results to EPA's Office of Toxic Substances in the "Carpet Policy Dialogue Compendium Report," published in September 1991.³

Following closely on the heels of the compendium report, CRI launched a Green Label program in 1992 to test carpet, cushions, and adhesives to help design professionals identify products with low VOCs.⁴ This resulted in a fundamental, rapid, and fairly radical change in the formulation of many of the adhesives and other constituent components used for flooring.

New adhesives versus old

There is a common belief the 'good glues' or flooring adhesives of times past were insensitive to concrete substrate moisture. That is actually not true, and there is literature going back to the 1950s discussing this very topic. Building on that misconception, many believe the 'newer, water-based' adhesives, developed for their low VOCs, are the primary source of flooring installation issues. Historically speaking, the 'newer' glues are not really new anymore—many of them began their evolution almost 30 years ago. Further, over that time, there have been untold millions of square feet of very successful installations. However, there is a fundamental difference between many of those older adhesives and the newer ones, especially in how they behave once applied to a substrate surface. For example, wet-set water-based adhesives necessitate water loss through evaporation and/or absorption into the substrate for adhesive strength development. In contrast, a moisture-cured adhesive absorbs moisture from the air or substrate for strength development. Knowing whether the concrete surface is porous or not prior to the application of an adhesive and using the appropriate installation methods for the specific porosity conditions are crucial for a successful and durable floorcovering installation.

What drives surface porosity?

A major determining factor of substrate surface porosity is the density of the material. A common substrate for many flooring installations is concrete. In its fresh state, concrete is basically a suspension of solids in



An example of a non-absorptive (non-porous) concrete surface.

Photos courtesy ISE Logik

water. As consolidation occurs, the denser solids, such as large aggregates, settle. This settling, or displacement, pushes residual mix water, sand, and cement fines upward toward the surface in a process known as bleeding, which is also the process that results in the "cream" at the surface of newly placed slab. Bleeding of the free water continues until the cement paste has hardened enough to finish the sedimentation process, and often results in sheen of liquid water on the surface of the slab. Final troweling of the concrete slab surface is not supposed to occur until the concrete has set and bleeding has stopped; doing so could lead to other surface issues, such as dusting, and a weakened surface layer.

There is no definitive amount of time it takes for the bleed process to finish, as it is the result of a multitude of factors ranging from the concrete mix design to the project site environmental conditions. The amount of water in the initial mix is normally the largest driving factor and mix designs with higher water to cementitious material (w/cm) ratio, all other factors held constant, will bleed longer than a similar mix design with a lower w/cm. Mix designs with various fine supplementary

cementitious materials (e.g. fly ash or silica fume) will likely bleed slower than similar mixes without such materials. Various admixtures and fibers can also significantly alter bleed rates. Air movement and temperature and ambient environmental humidity also impact bleeding, and subsequent evaporation of surface water. For example, on windy days or when temperatures are hot, or when the ambient humidity is very low, the bleed water may not even be noticeable since the evaporation rate might be greater than the bleed rate. As a result of all these factors, and more, the time from concrete placement to setting and the stoppage of bleeding, could be anywhere from 20 to 30 minutes to several hours.

With regards to newly placed concrete, the primary influencer as to whether the substrate surface is porous or non-porous is how the concrete was finished. The accepted standard for interior slabs is for them to receive a light-steel trowel finish which will, in most cases, render the surface non-absorptive. This is simply due to the densification effect of the trowel blades on the surface concrete paste.

Even older concrete can have a non-porous substrate surface. It is often said concrete gets stronger throughout its life. This is true as long as sufficient moisture and reactive ingredients are present. So, even a decades old basement residential slab may have a non-porous substrate, and be very dense, simply due to the concrete continuing to gain strength and densify over the years.

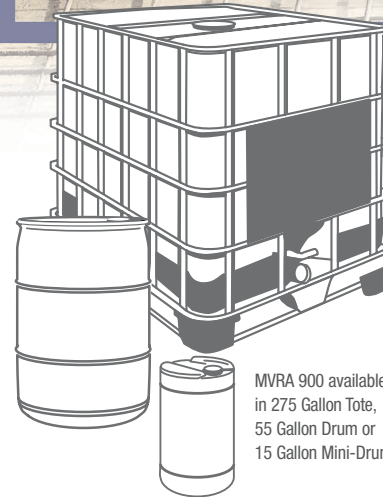
However, the density of the substrate surface will drive the absorptivity of the substrate surface, and concrete is not the only substrate encountered. Other acceptable substrates that may be encountered are polymer terrazzo, ceramic tile, existing well-adhered resilient flooring, and even steel. Each of these would be non-porous and would likely require additional surface preparation before installing new flooring.

The role of the flooring contractor

Once the jobsite is ready for the installation of floorcovering, it is the floorcovering contractor's responsibility to determine whether the substrate surface is porous or not, and to proceed with the correct methods and compatible products for the determined porosity. This is a crucial factor in the proper installation of many different flooring system components, such as flooring adhesives, cementitious underlayments, and primers.

This is not new. For years, most flooring manufacturers have said adhesive spread rate and open time, or product installation, was dependent on substrate porosity. What was missing, however, was an industry accepted standardized method for determining substrate

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surface porosity in the field. In response to this, ASTM F3191-16, *Standard Practice for Field Determination of Substrate Water Absorption (Porosity) for Substrates to Receive Resilient Flooring was developed*.⁵ ASTM F3191-16 assists the installation contractor in identifying how an adhesive should be applied. It can also help the design professional to specify the type of adhesive and where; or at least to ensure such a determination is clearly required in the project specs.

With the proper specification language in place, should the substrate surface be determined to be non-porous, the only adjustments needed might be to use a smaller trowel size, and perhaps a reduced open ('flash') time, as many of today's adhesives can be used on both porous or non-porous substrates. However, in other cases, an entirely separate adhesive may need to be used, or an entirely separate substrate preparation protocol may be required, as not all adhesives are suitable for installation on non-porous substrates. To avoid costly change orders and flooring installation delays, the design team should take great care in ensuring the specified adhesive is actually suitable for the project's substrate surface absorptivity conditions, as not all flooring manufacturers have adhesives for both. Language such as "...use an adhesive recommended by the manufacturer" may result in unexpected delays and expensive slab profiling and self-leveling, when all that may have been needed was a different adhesive. Language such as "...use an adhesive suitable for substrate conditions and compatible with flooring backing" could greatly expand the project's options. The importance of addressing porosity in the specification cannot be overstated. Installing an impermeable floorcovering on a non-porous substrate with the wrong adhesive for the porosity conditions, or with an improperly applied adhesive for the substrate surface porosity conditions, can lead to early bond failure, adhesive oozing through seams, adhesive displacement, a moisture-related flooring failure, etc.

Determining surface porosity

The first step in evaluating whether a particular substrate surface is porous or not is to consult the written instructions of manufacturers of resilient flooring, adhesive, primer, and underlayment, or combination thereof, for their acceptable test methods and time limits. In the absence of written instructions, the industry now has ASTM F3191-16. It lays out a very simple and quick process to assess substrate surface absorptivity/porosity. To begin, substrates need to be at the service temperature and relative humidity expected during normal use, or at the conditions required for installation of the floorcovering material per the relevant manufacturer's specifications. This is so the area tested best

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replicates the conditions that should exist when the adhesive (or primer, underlayment, etc.) is applied. To achieve these conditions, the interior space will likely need to be climate controlled for the test to proceed and produce accurate results. In new construction, achieving and maintaining the proper climate-controlled environment is often neglected, even during the installation of floorcoverings.

Once the space is appropriately acclimated, the substrate surface where the test is to be performed needs to be prepared in the exact manner as planned or as required for each specific floorcovering material installation. Given that many projects have different flooring systems, assessing substrate surface absorptivity/porosity is not a one-size-fits-all approach. Some areas may first require grinding to achieve the proper concrete surface profile, while other areas will only need to be clean, smooth, and surface dry.

After the space has been appropriately conditioned and the substrate surface properly prepared, the test is very straightforward. Simply place a single drop of potable water (approximately 0.05 mL) on the substrate surface using a pipette, water dropper, straw, etc., taking care that the drop is not placed from such a height that causes it to splatter, and wait. The waiting period is very brief with the cutoff time between porous or non-porous within F3191-16 being exactly one minute. If at or before a minute the drop of water absorbs into the substrate surface, then the surface is to be considered porous. If, however, a full minute has elapsed and the water has not been absorbed, then the substrate is to be considered non-porous.

It is important to understand F3191-16, or perhaps a manufacturer's own substrate surface porosity test, is not a "pass/fail" type of test. Instead, it is a qualitative assessment of substrate water absorption (porosity) and whether or not that substrate should be regarded as porous/absorptive or non-porous/non-absorptive as these terms relate to the installation of resilient floorcoverings, adhesives, self-leveling underlayments, primers, and other products. It is an evaluation to help the project team determine the proper substrate surface preparation and adhesive or adhesive spread rate for the materials to be installed. As mentioned before, depending on how the specification is worded, the resulting determination may be easily addressed simply by changing the trowel size or selecting a different product.

Installation

With a flooring adhesive, the correct method over a porous surface may be as simple as an application rate and open time difference versus a non-porous surface, instead of a

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change in the product. Installation data sheets for flooring adhesives generally include a table or chart recommending trowel size, application rate, and “open time” or “flash time” for both porous and non-porous surfaces. The working time of the adhesive may be reduced as the flash time increases, so the floorcovering installer will need to manage it accordingly. The non-porous surface flash time of the adhesive is greater than the duration for a porous surface (*i.e.* another 10, 20, or 30 minutes), and is influenced by concrete surface temperature, ambient relative humidity and temperature, and airflow. This is regardless of whether the adhesive is being applied over a porous or non-porous surface. This flash time facilitates the evaporation of moisture from the adhesive, and if flash time is insufficient, the moisture could be trapped when installing an impermeable floorcovering. This can compromise adhesive cure and strength development, thereby jeopardizing the integrity of the floorcovering bond to the subfloor surface. Adhesive migration may also develop between the seams and transition areas to the surface of the floorcovering.

The importance of evaluating substrate surface porosity is not limited to adhesives, and can encompass many other products, such as primers, thin sets, and cementitious underlayments. For such products, and even for some adhesives, a concrete surface profile (CSP), as described within the International Concrete Repair Institute (ICRI) Technical Guideline No. 310.2R-2013, of CSP 1 or more may be required if the pre-existing substrate tests as “porous.”⁶ When this occurs, the generally accepted method for preparing the substrate surface is by mechanical means. ASTM D4259, *Practice for Preparation of Concrete by Abrasion Prior to Coating Application*, is a good resource in which such mechanical methods are described in detail.⁷ In some cases, it may also be possible to install a primer specifically designed for non-porous substrates that might preclude the need to mechanically prepare the substrate surface. Also, there may be other products that do not require a porous substrate. If such products are available, they should be given significant consideration as it would reduce labor and time costs for surface preparation, and perhaps, more importantly, minimize the production of respirable silica dust, a material regulated by the Occupational Safety and Health Administration (OSHA).⁸

The role of the architect

As the author of the specifications constituting part of the contract documents, the architect (and their consultants) has considerable impact on this issue. All too often, under which adhesive to use—buried within various 09 Divisions—the phrase, “as recommended by flooring manufacturer,” is embedded into the specs. Though seemingly in the best interest



Use the correct trowel size and allow sufficient flash time.

of the project, that short phrase may actually limit the options for addressing a non-porous substrate surface, and end up causing the project significant schedule delays and cost overruns, especially if the manufacturer of the specified flooring does not offer an adhesive product that can be used over both porous and non-porous surfaces.

This recently occurred with an 18,581-m² (200,000-sf) hospital project in central Florida. The project specification for resilient flooring required, in part, the use of an adhesive as recommended by the manufacturer. The manufacturer, unsurprisingly, recommended one of their adhesive brands. Upon closer analysis, their adhesives were only for porous substrates. The flooring manufacturer’s installation instructions said if the concrete substrate surface was non-porous per ASTM F3191-16, the concrete substrate would need to be bead-blasted and self-leveled, so their porous substrate-only adhesive could be used. Upon discussion with the architect, that initial adhesive specification language was changed to “... an adhesive compatible with flooring material backing and suitable for

substrate conditions.” Seemingly a simple word change, but had that change not been made, the entire project may have required bead-blasting and self-leveling. Such a process would likely have necessitated a change order on the magnitude of \$600,000 to \$700,000 and weeks of additional time. By thinking through the ramifications of the initial specification language in conjunction with the specified flooring, the design team was able to proactively address this potentiality through a slight alteration of the specification language. This directly and materially contributed to construction team being able to stay on budget and schedule; and all applicable warranties conveyed to the project.

Success is achievable

If the submitted floor system material that will be in direct contact with the substrate surface—irrespective whether the material is a primer, adhesive, thin set, or cementitious product—is unsuitable for direct installation on a non-porous substrate surface, the project may face extra costs and time during substrate preparation; thereby creating a delay in overall project delivery. Due to this, it is advisable to research the installation requirements for such products as it relates to substrate surface porosity, and perhaps alter any corresponding specification language to allow for the selection of alternative products because, in many cases, such alternatives are readily available without compromising warranties. Regardless of the approach, the importance of assessing concrete substrate porosity before installing flooring system materials cannot be overstated and has reached the level of being balloted for inclusion within ASTM F170, *Standard Practice for Preparing Concrete Floors to Receive Resilient Flooring*. **CS**

Notes

¹ For more information, visit www.govinfo.gov/content/pkg/FR-1990-04-24/pdf/FR-1990-04-24.pdf.
² See Note 1.
³ Access the report at www.nepis.epa.gov/Exe/ZyPDF.cgi/2000IW9B.PDF?Dockey=2000IW9B.PDF.

⁴ Details at www.carpet-rug.org/testing/green-label-plus.
⁵ Consult www.astm.org/Standards/F3191.htm.
⁶ Details at www.icri.org.
⁷ Visit www.astm.org/Standards/D4259.htm.
⁸ Consult www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1153.

ADDITIONAL INFORMATION

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Key Takeaways

Often referred to as substrate “porosity,” substrate surface water absorptivity refers to the ability of a flooring substrate surface to absorb liquid relatively quickly. The coalescence of an impermeable

floorcovering material and a non-porous concrete surface not only reduces moisture from coming in, but also from escaping. Using wet-set water-based adhesives necessitate water loss through evaporation and/or absorption for adhesive strength development, whereas a moisture-cured adhesive absorbs moisture from the air or substrate for strength development. Knowing whether the concrete surface is porous or non-porous prior to applying the adhesive, and enacting applicable installation methods, are crucial for the long-term success of floorcovering installation.

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Concrete	Surface porosity
Floorcoverings	

Getting It Right

Wood Flooring Over a Concrete Subfloor

by Jason Spangler

All photos courtesy of iStock.com

THE VISUAL APPEAL OF A WOOD FLOOR IS HARD TO MATCH. MOST PEOPLE EXPERIENCE A CERTAIN JOY WHEN ENTERING A BUILDING WHERE WOOD HAS BEEN USED GENEROUSLY. THEY MAY NOT BE ABLE TO PUT THEIR FINGER ON EXACTLY WHY THEY REACT FAVORABLY TO WOOD—IT MAY BE THE TOUCH OF ELEGANCE OR THE WARM GLOW THEY SENSE, BUT WHATEVER IT IS, THE POSITIVE IMPRESSION IS INDISPUTABLE.

Wood's advantages are more than skin deep

Wood flooring offers more advantages than just aesthetic appeal in both homes and commercial settings. It is easy to clean and is significantly more stain-resistant than carpeting. Wood is also strong and durable, and if properly cared for, its hard surface can last for decades. When a wood floor shows signs of wear from years of regular use, many can simply be refinished rather than replaced entirely. Wood floors also add value to any building, increasing the resale value by as much as 10 percent or more.

A wood floor also contributes to better indoor air quality (IAQ). Unlike carpeting, or even the grout lines of a tile floor, wood floors do not trap dust, pollen, particulate matter, or other common allergens. Wood floors can even improve acoustics. For example, hardwood floors can produce a clean, clear, crisp sound as opposed to other types of flooring that may soften or deaden sound, which is one reason why hardwood gets used frequently in dance or music studios. When choosing flooring material, one should consider what type of effect they are trying to produce.



Beware of subfloor moisture

On any commercial flooring project where wood is going to be used, it is important to consider in advance how moisture could play havoc with the design goals. It is crucial to address all possible sources for excess moisture. The National Wood Flooring Association (NWFA) has estimated at least 75 percent of all flooring failures are the result of moisture issues.¹

One of the most common, but sometimes overlooked, sources of moisture is in the subflooring.

In commercial settings, wood flooring is typically installed over a concrete floor slab. Concrete slabs may look perfectly solid and feel dry to the touch, suggesting they hold very little water inside. In reality, water is always an essential ingredient in the concrete mixture, and all concrete slabs, whether freshly poured or even decades old, will harbor surprising amounts of moisture.

It is important to note, the manufacturer's specification (if applicable) for the wood product should be the guide regarding what is an acceptable moisture condition for the concrete slab. However, the typical limit for wood and wood-based products is about 75 percent relative humidity (RH) in the slab.

Indeed, without enough water, a concrete slab will not cure properly and attain its characteristic hardness. Curing takes relatively little time. Generally, concrete sets in 24 to 48 hours allowing one to walk on it. Within seven days, one can expect the slab to cure to about 70 percent of full strength and, in approximately 28 days, the concrete should be approaching full strength.

This curing process should never be confused with concrete drying. While curing happens rather quickly, concrete drying does not. Once a slab is poured, moisture begins leaving the slab from the 'inside out.' What this means is moisture within the slab migrates to the surface over time and then evaporates. Ambient conditions will affect the speed at which this process occurs, but it is never particularly fast. For a 127-mm (5-in.) concrete slab, it may take five months or more for the slab to dry sufficiently. This would be after the building is enclosed and an



One of the most common, but sometimes overlooked, sources of moisture is in the subflooring.

environment conducive for drying is established. The concrete must be fully dry before one can successfully install a finished floor product.

Failure to build this drying time into the overall project and conduct an accurate moisture assessment of the concrete floor slab may mean scrambling later to address one or more serious moisture-related problems. The initial excitement over the beauty of a project's wood flooring may rapidly wane and turn to frustration and headache instead.

Visible signs of a hidden moisture problem

Since wood is a hygroscopic material, wood flooring naturally expands when moisture is present and shrinks when moisture is absent. Excessive moisture in wood flooring can present itself in several different and problematic ways.

Cupping

Cupping occurs when the edges of a board are higher than the center. Low RH in the environment or moisture in the subflooring are common culprits. As the wood expands on the bottom (due to moisture from the

subfloor) or shrinks on the top (due to dry environmental conditions), the edges of the boards start to deform and raise. Aside from the visible warping of the floorboards, the floor could eventually fail altogether. The cupping could continue to worsen and create gaps between the boards. Eventually, if the boards do not revert to their original shape, they could buckle away from the subfloor, or even splinter or crack.

Crowning

The opposite of cupping is crowning when a board's center is higher than its edges. If a wood floor is exposed to moisture or humid conditions for extended periods of time, the moisture can saturate the wood flooring and cause crowning. Another possible cause of crowning could be when a floor was previously cupping and was sanded before the moisture level returned to a normal state.

Buckling

Buckling is an extreme reaction to moisture in a wood floor and occurs in response to prolonged exposure to excess moisture. Buckling happens when the flooring gets pulled up from the subfloor, lifting as much as several inches in one or more places. Fortunately, buckling is not a common occurrence, and if caught early, spot repair and replacement may be possible.

Cracking

Cracking, or the occurrence of separations between floorboards, is another possible sign of a moisture problem. Typically, cracking is more a response to significant (often seasonal) variations in the air's RH rather than an issue with moisture in the subflooring. Therefore, monitoring a building's temperature and RH levels and taking corrective action is all that is needed to address cracking.

Mold or mildew

Persistent moisture in the subfloor may also lead to problems with mold or mildew within or under the wood flooring. A musty smell



provides an important telltale clue mold may be a serious problem. If present, it should never be ignored because certain types of mold pose a significant risk to human health.

Discoloration

Discoloration of wood flooring due to moisture may also occur. In many types of hardwood flooring, excess moisture may cause the wood to take on a darker appearance than normal. The appearance of splotches of darker wood appearing may indicate the finished floor is in contact with moisture in the concrete subflooring.

Buckling is an extreme reaction to moisture in a wood floor. However, it is not a common occurrence, and if caught early, spot repair and replacement may be possible.

Other types of wood flooring

For engineered wood, delamination is a common issue related to moisture. When moisture penetrates the layers of an engineered wood product, the glue holding layers together can fail.

Solid wood can be susceptible to the effects of moisture. Moisture-related issues can include the ones discussed above.

Wood finishes, such as sealers, stains, varnishes, urethanes, etc., may add some degree of moisture protection from above, but they will not address the various problems stemming from moisture in a concrete floor slab.

Applying a sheet material that serves as a moisture barrier, such as a 6-mil (0.15 mm) thick polyethylene (PE) plastic sheet overlapped with taped seams, can be one way to mitigate concrete moisture. This sheet material does not negate the importance of installing a vapor barrier underneath the slab. It should serve as an additional element of protection.

Prevention is the best remedy

While wood flooring makes a great choice for a variety of commercial applications, its susceptibility to various problems stemming from moisture calls for due diligence prior to any installation over a concrete floor slab. One aspect of this due diligence is simply to wait. It takes time for a concrete slab to dry, even when specific steps are taken to hasten the drying, such as enclosing the building and turning on the HVAC.

The general rule of thumb for concrete drying is one should allow a month for each inch of thickness of the concrete slab, and this is after the establishment of environmental conditions conducive for drying.

It is important to keep in mind this must be thought of as no more than a rule of thumb. It can help guide one's

expectations but should never be used for making an installation decision.

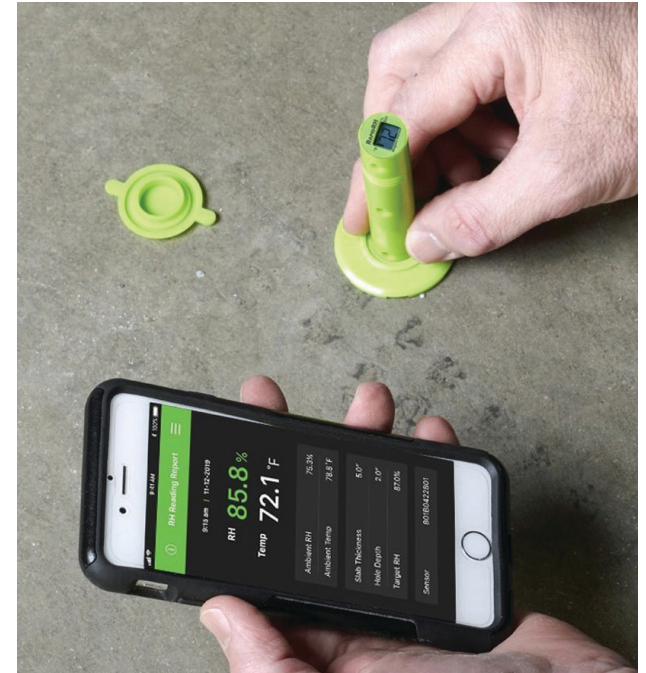
The key step to preventing moisture-related problems is always insisting on the performance of a moisture test prior to any flooring installation. Getting accurate, reliable test results provides the essential information needed for deciding when wood flooring over a concrete slab can be installed safely.

Two types of concrete moisture tests are often used in the United States. Historically, surface-based tests, such as the anhydrous calcium chloride test, were employed to evaluate the moisture condition of the slab. Today, this type of test is becoming less commonly used as more people in the industry learn about the advantages of using another type of moisture test known as the in-situ RH test.

An inherent problem with a surface-based test is it is unduly influenced by ambient conditions and can easily give false results. Another problem is this type of test is at best indicative of the moisture condition at or near the surface of the slab. It is based on the false premise this is the only information needed to make a proper decision about time of installation. The test offers no information about the level of moisture existing deeper within the slab.

This consideration is critically important. The moisture in a concrete slab exists in a gradient, with significantly less moisture at the surface than deeper down. However, once a slab is effectively sealed with a finished floor product, so moisture can no longer evaporate from the slab's surface, the moisture inside the slab will tend to even out and the moisture gradient will disappear.

The net effect is the moisture at or near the slab's surface, which is what the finished floor will now be in contact with, becomes higher than what a surface-based test would indicate. For this reason alone, one should not rely on this



The in-situ relative humidity (RH) test method provides reliable and accurate concrete moisture assessment.

type of concrete moisture test. Results from the test may mislead and this could end with flooring failure.

In-situ RH test

On the other hand, scientific studies in recent decades have demonstrated a slab's moisture condition (and how it affects installed flooring) can be best measured by looking at the RH deep down in the concrete using an RH probe

set into the floor slab. Since 2002, the in-situ RH moisture test, as standardized in ASTM F2170, *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*, has become increasingly favored as the ‘gold standard’ for moisture testing.

The RH test is useful as it is a depth-specific test that fully considers what happens to concrete moisture after a flooring installation seals off the slab’s surface. Studies at Sweden’s Lund University determined the placement of the RH probe at a depth of 40 percent of the overall depth of the slab (when drying from one side) will provide RH readings that accurately predict the moisture that the finished floor will ‘see’ once the flooring is installed.²

In growing recognition of this and other major advantages of the RH test (less vulnerable to changing ambient conditions, faster and easier to perform with test results within 24 hours, and ability to easily track and record RH changes over time), a large number of flooring manufacturers now provide specifications for their products based on the RH test’s numeric results.

In the author’s experience, no other method of concrete moisture assessment provides the same level of reliability and accuracy as does the in-situ RH test. Therefore, no other method can give the same level of assurance for avoiding costly moisture-related flooring failures and the many types of damage (such as cupping, crowning, buckling, mold, or mildew) that could otherwise occur in wood floors.

What it all means for the project’s specifications

It is imperative a project’s specifications always identify and require the exact concrete moisture test to be performed. This is an easy addition to the project’s plans given the in-situ RH specification is available for free download.³

It is important to recognize the in-situ RH test has been shown to give reliable results leading to consistent, successful project outcomes. Additionally, unless this specific test is spelled out for the general contractor (GC) and/or the flooring professional, some parties in the industry may unwittingly choose to employ another test that may place

the project at risk. Therefore, it is crucial to be very specific about which concrete moisture test is desired.

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Notes

¹ Review bsmmag.advanced-pub.com/?issueID=92&pageID=34.

² Consult www.concreteconstruction.net/how-to/construction/testing-slab-relative-humidity_o and piprolink.com/in-situ-moisture-measurement-the-correct-way.

³ Visit www.rhspec.com/download-the-rh-test-specification.

ADDITIONAL INFORMATION

Author

Jason Spangler, Wagner Meters’ flooring division manager, has more than 25 years’ experience in sales and sales management across a broad spectrum of industries. He has successfully launched a variety of products to the construction market, including the original Rapid RH concrete moisture test. Spangler, who received an MBA from West Texas A&M University, has extensive industry involvement, including the National Wood Flooring Association (NWFA) and the International Certified Flooring Installers Association (CFI). Spangler is also vice-chairman of associations for the Flooring Contractors Association (FCICA). Spangler can be reached via email at jspangler@wagnermeters.com.

Abstract

On any commercial flooring project where wood will be used, it is important to consider in advance how moisture could play havoc with the design goals. It is

crucial to address all possible sources for excess moisture. One of the most common, but sometimes overlooked, sources of moisture is in the subflooring.

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SPECIFYING THE RIGHT RESINOUS FLOORING SYSTEM

by Mark Thomas

Photos courtesy Tnemec

SELECTION OF FLOORING MATERIALS OFTEN STARTS WITH THE PREFERRED VISUAL APPEAL BASED ON THE NEEDS OF THE ARCHITECT, THE INTERIOR DESIGNER, OR THE OWNER. WHAT MATERIALS WOULD BEST MEET THE AESTHETIC NEEDS: THE WARMTH OF HARDWOODS, THE DURABILITY AND DECORATIVE OPTIONS OF TILE, OR THE ECONOMY AND CLEANLINESS OF VINYL? MATERIALS SUCH AS TILE AND SHEET GOODS ARE TYPICAL OPTIONS, BUT FOR MANY PROJECTS, HIGH-PERFORMANCE COATINGS ARE A CAPABLE AND OFTEN-DESIRED ALTERNATIVE.

Few materials meet the combined benefits of coatings. The varied chemistries tailored within a complete system provide a seamless, easy-to-clean surface that withstands heavy traffic, impacts, and chemicals, all while offering anything from a utilitarian, industrial look to something fitting for a commercial setting.

However, selecting the right coatings and specifying the appropriate system can be more difficult than picking out a type of tile or vinyl. Some knowledge on the types of flooring, the common coating chemistries, as well as the appropriate performance characteristics of these systems can go a long way in helping construction professionals specify an enduring, aesthetically pleasing floor.

Flooring options

Before selecting a flooring system, it is important to first identify its performance requirements. Will it be exposed to foot traffic, wheeled carts, or something more abusive like a forklift? Will heavy items likely be dropped on it, or will there be aggressive cleaning techniques involving hot water spray, cleaning agents, or scrubbing? If the floor will be frequently wet or damp, what kind of skid-resistance is desired? Chemicals, fuels, lubricants, and other fluids often leak onto commercial floors: Is this exposure likely in the environment and how often will this happen?

Once the exposure conditions and performance needs are identified, one of the following three basic types of high-performance flooring systems can be considered.

Thin-film flooring system

The most basic type of floor coating system is a thin-film floor, typically comprising two to three coats that will generally be between 380-1015 μm (15 to 40 mils [0.38 to 1 mm]) in total dry film thickness (DFT). This type of floor is available in a variety of colors, helping to achieve the desired aesthetic and visual requirements, while being easy to clean, especially because it is applied without the seams or grout lines found in vinyl or tile floors.

Thin-film systems can also be customized for additional skid and/or chemical resistance. Skid resistance can be tailored with the inclusion of aggregates or anti-slip particles for better traction, while chemical-resistant topcoat options make these systems a good choice for environments that will be exposed to cleaning chemicals or fuels on a regular basis. Material costs are lower for this type of floor and easy roller application also helps reduce labor costs.

The primary deficiency of a thin-film system is its resistance to point-load impacts, such as a dropped tool or other heavy item. The thinness and lack of aggregate reinforcement make a thin-film floor susceptible to impacts that not only damage the coating system, but also transfers the energy to the concrete substrate. This damage is repairable but might lead to ongoing maintenance and a visual ‘patch work,’ if they occur frequently.

Thin-film floor coating systems are often installed in commercial areas, such as offices, pedestrian corridors, vehicle bays, aircraft hangars, and production facilities.

Broadcast/laminate flooring system

If the performance requirements necessitate something more robust than a thin-film system, the next option would be a broadcast/laminate floor. These floors are usually installed at a



Thin-film floor systems can help achieve the desired aesthetics. They can also be customized for skid and/or chemical resistance.

nominal 3175 μm (125 mils [3.2 mm]) DFT and filled with aggregate. The aggregate in these systems not only helps achieve the higher thickness, but also reinforces the coating to make it more resistant to physical damage, such as abrasion and impact.

The popularity of this floor type has made installers adept at its installation. First, a coating layer is laid out by notched-squeegee after which an aggregate, or sometimes decorative flake or quartz, is broadcast into the liquid coating “to refusal,” meaning the coating cannot accept any more aggregate. After cure, loose aggregate is removed and the process is repeated providing what is referred to as a “double broadcast.” Next, these floor systems

generally receive a grout-coat to help secure the uppermost aggregate. A finish coat is then often applied (depending on the needed service requirements) and can offer additional chemical resistance, color stability, or even abrasion resistance.

Over time, flooring contractors have modified the double-broadcast floor installation by replacing the first broadcast with a loose “slurry” comprising the coating liquids and a reduced aggregate load. By substituting the first broadcast with the slurry technique, productivity is increased, and installation times are shortened. A second broadcast is still applied for additional thickness, followed by applicable grout and top-coats.

Broadcast/laminate flooring systems are commonly installed where long service life is required, such as institutional facilities like healthcare, education, or correction, as well as commercial projects and even manufacturing environments. Aesthetic options range from solid colors to decorative quartz and flake.

Mortar flooring systems

These heavy-duty systems are most often used where extreme durability is needed. A mixture of aggregates and coating liquids, these systems are typically trowel applied at a thickness of 6350 μm (250 mils [6.3 mm]) DFT and then topcoated to seal the mortar and provide additional durability.

Mortar floors are more costly due to the increased material use, and slower technique of trowel application, relegating them to areas of high abuse. Exceptional resistance to impacts, abrasion, and heavy traffic make mortar floors good choices in manufacturing and processing facilities. Mortar flooring systems are generally installed as a solid color, but decorative quartz is sometimes employed for enhanced visual appeal.

Getting the chemistry right

Once the type of system is determined, the next step is to identify the actual coating products. This is best done by categorizing them into the basic chemistry groups most often used in floor coatings, such as epoxies, polyurethanes, and other specialty products.



The aggregate in broadcast/laminate floor systems makes it more resistant to physical damage like abrasion and impact.



Aliphatic polyurethanes have excellent color stability and resistance to ultraviolet (UV) light, and tend to showcase good chemical as well as abrasion resistance.

Epoxy

Epoxyes are the workhorses of the coating world. They are known for good adhesion, compressive strength, chemical resistance, and overall durability, all at a moderate cost. Epoxy floor coatings can be solvent- or water-based, but are most commonly offered as solvent-free, 100 percent solids formulations.

Epoxyes will yellow with age and can be degraded by ultraviolet (UV) light, so aesthetic considerations should be made based on desired appearance. Often, epoxy systems are topcoated with more color stable coating types, such as aliphatic polyurethanes.

The two most commonly encountered flooring epoxyes are polyamine and novolac. Polyamine epoxyes are by far the most used and offer all the performance characteristics associated with epoxyes including moderate to good chemical resistance. For more extreme chemical exposure, a novolac epoxy may be required. Novolacs have a tighter cross-linked film, which improves chemical resistance. However, they tend to be more expensive and can be susceptible to greater yellowing, so are only used as exposure conditions dictate.

Polyurethane

If epoxyes are the workhorses of the coating world then polyurethanes or, more specifically, aliphatic polyurethanes, are the show horses. Aliphatic polyurethanes have excellent color stability and resistance to UV light, and tend to showcase good chemical and abrasion resistance. However, they are typically applied as a thin topcoat of 50-127µm (2 to 5 mils [0.05 to 0.13 mm]) DFT.

Aromatic polyurethanes are a more industrial variant of the chemistry type. Surrendering the color stability of their aliphatic cousins, aromatic urethanes gain chemical resistance and improved durability. There is a common floor product that combines the characteristics of aromatic polyurethane with the toughness of concrete. Called “urethane-modified concrete,” these products were originally developed and marketed to industrial and processing facilities where a durable floor topping with exceptional resistance to severe freeze-thaw cycling was needed.



However, over time, flooring contractors began substituting 100 percent solids epoxyes with these products in more commercial and architectural applications because of their fast cure, great adhesion, and tolerance to moisture vapor transmission (MVT). As with epoxyes, aromatic polyurethanes are topcoated to improve the system's appearance.

Specialty products

The coating industry is full of products that do not fall neatly into the epoxy or polyurethane categories.

Mortar floors are suitable for manufacturing and processing facilities because they offer exceptional resistance to impacts, abrasion, and heavy traffic.

Methyl methacrylate (MMA) is a fast curing chemistry that is tolerant to cold temperatures during application and cure. For this reason, it is often used where installation must be completed as soon as possible or if the space is unconditioned, even exterior. This cure speed comes with a very high odor, and can only be installed by a specially trained crew. Due to this, coating manufacturers have introduced alternatives to MMA, which includes polyaspartics that combine the speed and color stability of MMA without the offensive odor.

Vinyl esters are an option when specifiers need industrial coatings resistant to chemicals, particularly acids, and are sometimes used within a flooring system. Varieties include thin-film, mortars, and even mat reinforcements. This specialty niche system is relegated to industrial areas exposed to the splash and spillage of chemicals and acids.

Planning out the specifications

Presuming the specific floor coating products have been identified and developed into the type of floor system needed for the project, it is time to identify critical components of the specification that will help ensure correct installation and avoidance of potential problems.

Substrate preparation

Compared to steel, which is a fairly consistent and predictable substrate, concrete can be very tricky to coat. Its variability from project to project can produce unexpected situations affecting a coating system's bond. For the specifier, there are critical elements of substrate evaluation and surface preparation that, when properly addressed, can help reduce the potential for future coating problems.

Moisture in concrete slabs can lead to issues for all types of floor toppings, which includes coatings. The industry standard of waiting 28 days for new concrete to fully cure before coating is based on the time it generally takes for any free water that has not hydrolyzed with the cement particles to evaporate and escape the concrete.

Unfortunately waiting for new concrete to fully cure does not eliminate moisture-related issues. In fact, old, existing on-grade slabs



Vinyl Esters are an option when specifiers need coatings for industrial areas exposed to the splash and spillage of chemicals and acids.



For the Calcium Chloride Test, a calcium chloride disk is first weighed, then placed under a sealed plastic sheet and left to collect moisture vapor. The disk is again weighed after 24 hours. The difference in weight indicates the amount of moisture vapor that emerged from the slab.

also pose a challenge because of potentially high MVT conditions. Unless the project is located in the driest of climates, moisture will be present at some level in the soil on which the concrete slab is resting. Today, it is common practice to install a vapor barrier prior to concrete placement to prevent moisture from transmitting from the soil through the slab, but this is rarely the case with older slabs. Additionally, it is difficult to determine the presence or absence of a vapor barrier under an existing slab. Therefore, testing the slab prior to coating application is a key to avoiding future problems.

Testing for moisture

The most basic test is ASTM D4263-05, *Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method*. The Plastic Sheet Method, involves taping a 457- x 457-mm (18- x 18-in.) square plastic sheet to the concrete floor and waiting at least 24 hours before removing it. (A heat source, such as an incandescent lamp, is sometimes placed close to the plastic sheet to help promote moisture migration). Once the plastic sheet is removed, the concrete is inspected for darkening or other signs of moisture. Although this test has existed for decades and is still used, most flooring manufacturers do not favor its use due to several flaws. First, it does not quantify the amount of moisture; it simply indicates whether or not moisture is present. Second, it only detects moisture in the upper portion of the slab, not in the middle or lower areas where moisture is more apt to reside.

The Calcium Chloride Test, per ASTM F1869-11, *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*, is a better test because it provides a quantifiable result. For this test, a calcium chloride disk is placed under a sealed plastic sheet and left to collect moisture vapor. After 24 hours, the disk is retrieved and weighed, and compared to the disk's pretest weight. This weight difference indicates how much moisture vapor has emerged from the slab in 24 hours.

A more recent test providing the most complete data is ASTM F2170-11, *Standard Test Method for Determining Relative Humidity in*



Epoxies are known for good adhesion, compressive strength, chemical resistance, and overall durability, all at a moderate cost.

Concrete Floor Slabs Using in situ Probes. This method requires holes to be drilled into the concrete and a humidity probe inserted at 40 percent of its total depth. The quantitative result and the measurement within the middle of the slab make this test a more accurate and reliable way to measure MVT.

It is important to note results from all three tests are limited to a particular time period and may not reflect seasonal or unusual environmental conditions. Additionally, it is recommended to conduct concrete moisture tests after the building's HVAC system has operated for at least 48 hours.

Floor coatings will have varying tolerance to moisture vapor levels, and this should be reflected on the product data sheet. As a general rule, moisture vapor transmission rates should not exceed 1.3 kg (3 lb)/24 hrs or 75 to 80 percent relative humidity (RH) for most conventional floor primers. However, there are specialty primers and floor toppings designed specifically for higher MVT rates, up to 9 kg (20 lb)/24 hrs, and up to 99 percent RH.

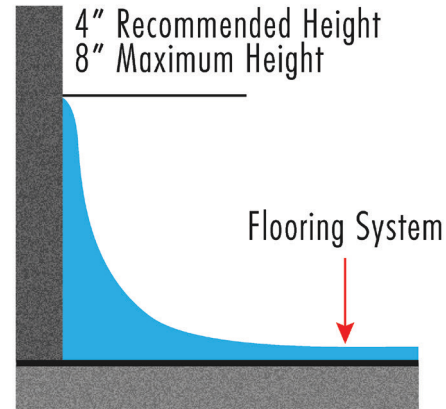
Surface preparation

The degree of surface preparation will depend on the thickness of the flooring system. A thinner system requires less preparation than a thick, mortar one. In all cases, specifications should include clear language addressing the removal of "laitance, curing compounds, hardeners, sealers, and other contaminants," and should reference NACE No. 6/ Society for Protective Coatings (SSPC)-SP 13-2018, *Surface Preparation of Concrete*, which outlines minimum acceptance criteria of the concrete substrate and relevant test methods.

The floor coating industry relies on the International Concrete Repair Institute (ICRI) visual reference standards for degrees of surface preparation from lightest (CSP 1) to heaviest (CSP 10). Thin-film systems generally require an ICRI-CSP 1 to 3, which can be achieved through light shot blast or diamond grinding. (Acid etching is discouraged as it is difficult to assure sufficient profile and full neutralization of acid). Broadcast/laminate and mortar systems

Figure 1

ROLLED RADIUS COVE



A rolled-radius cove is usually 100 mm (4 in.) high and resembles the plastic, rubber, or wood bases commonly used to trim a room.

accommodate a more aggressive anchor profile, usually listed as minimum of ICRI-CSP 3 or greater and achieved by shot blast, diamond grinding, or scabbling.

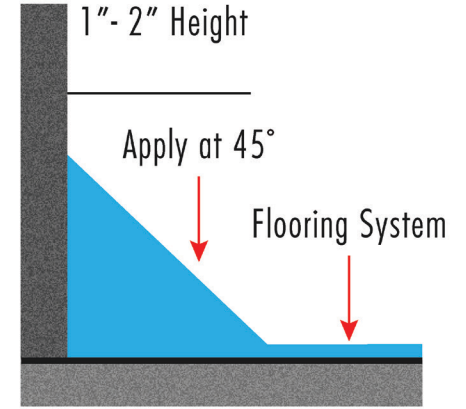
Relevant tests for floor coatings

Determining what products to select can be challenging, especially since many floor coatings products look similar on published literature and documents. Specifiers should consider the following performance tests prior to product selection:

- abrasion, per ASTM D4060, *Standard Test Method for Abrasion Resistance of Organic Coatings by Taber Abraser*;

Figure 2

CANT COVE



A cant cove base is installed at a 45-degree angle from the floor to wall for easier cleaning by eliminating hard right angles.

- compressive strength, per ASTM C579, *Standard Test Methods for Compressive Strength of Chemical-resistant Mortars, Grouts, Monolithic Surfacing, and Polymer Concretes*;
- impact, per ASTM D2794, *Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation*; or MIL-D-3134, *Military Specification for Deck Covering Materials*;
- slip resistance, per ASTM D2047, *Standard Test Method for Static Coefficient of Friction of Polish-coated Flooring Surfaces as Measured by the James Machine*; and
- cleaning agent resistance, per ASTM D1308, *Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Coating Systems*.

There are many more tests that may be relevant depending on the actual exposure conditions expected on the project. These could include specific physical attributes such as chemical resistance, UV resistance, and ability to withstand severe free-thaw cycles. A careful review of the project with the coating supplier will identify these parameters to ensure the right product is selected for long-term durability and performance.

Floor to wall transitions

A major benefit of fluid-applied floor coatings over other materials is the ability to tie directly, and seamlessly, into the wall coating system by the creation of a cove base. This continuous transition is durable, hygienic, and creates a “bathtub” effect suitable for wet conditions or frequent cleaning. Often, the same floor coating materials used for a broadcast/laminate or mortar system can be used to build the cove base, or the coating manufacturer may offer a specialized material designed with enough viscosity, or bulk, to properly build the base.

The two most common cove bases are rolled-radius (Figure 1, page 23) and cant cove (Figure 2, page 23). A rolled-radius cove is usually 100 mm (4 in.) high and resembles the plastic, rubber, or wood bases commonly used to trim a room, whereas a cant cove is installed at a 45-degree angle from floor to wall for easier cleaning by eliminating hard right angles. To tie seamlessly into the wall, the cove is either installed

before the wall coating, in which case the wall coating is carried down to the cove/wall junction or after the wall system is applied.

Conclusion

The ability to tailor a floor coating system—whether for physical wear, mechanical abuse, or chemical contact—makes high-performance coatings a viable choice for a variety of facility floors. By keying in on the expected physical exposure conditions and aesthetic requirements, thickness and coating types can be determined and specified as a complete system based on their relevant performance data.

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ADDITIONAL INFORMATION

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Mark Thomas is a vice-president for Tnemec Company, where he is responsible for marketing the company's various coating products and brands. Since joining the company in 1996, he has worked extensively on new product technologies with research and development, technical service, and sales department personnel. He is a NACE CIP Level 2 Coating Inspector. Thomas holds a bachelor's degree in journalism and a master's degree in integrated marketing communications, both from The University of Kansas.

Key Takeaways

Materials such as tile and sheet goods are typical flooring options, but for many projects, high-performance coatings are a capable and often-

desired alternative. Selecting the right coatings and specifying the appropriate system can be more difficult than picking out a type of tile or vinyl. Some knowledge on the types of flooring, the common coating chemistries, and the appropriate performance characteristics of these systems can go a long way in helping construction professionals specify an enduring, aesthetically pleasing floor.

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