Wood Flooring: Recognizing Water Damage

By Nolan Wells, Ralph E. Moon, PhD and Donald Nehrig

Introduction

Cleaning professionals are expected to recognize when wood flooring materials become water damaged. Wood flooring is observed regularly yet we can be surprised to find damages such as unexpected wear patterns, cupping, swelling, surface distortion and color changes during cleaning tasks. From the professional cleaning perspective, we were curious as to when wood flooring damage would first become visible.

Previous research efforts on floor moisture damage have focused on chemical stabilization[1], thickness swell performance,[2, 3] additives to provide improved biological resistance[4] and efforts to improve impact performance,[5] with the intent of diminishing the effects of moisture absorption. This study examined wood flooring exposed to two moisture-exposure scenarios: 1) damp concrete to reveal changes in surface appearance, mold growth, and cupping; and 2) partial water immersion to reveal the occurrence of thickness swelling and surface distortion. The responses of the different flooring types (*i.e.*, hardwood, engineered, laminate and bamboo) were compared to their inherent construction properties.

Flooring Types

There are four predominant flooring types: hardwood, engineered, laminate and bamboo. The ability to distinguish between different types of flooring may be critical for cleaning contractors or flooring professionals during damage reporting and legal testimony.

- *Hardwood flooring*. Manufacturing begins with trees cut into logs that are examined for quality. Logs destined for flooring are selected based on the

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SYNOPSIS

This study examined wood flooring exposed to two moisture-exposure scenarios: 1) damp concrete to reveal changes in surface appearance, mold growth and cupping; and 2) partial water immersion to reveal the occurrence of thickness swelling and surface distortion. The responses of the four predominant wood flooring types — hardwood, engineered hardwood, laminate and bamboo — were compared

Two moisture exposure scenarios were examined using a solid wood-framed test apparatus that also included a 1.5 inch-thick concrete slab. The chamber was maintained at an ambient temperature of 74°F with a relative humidity over 95%. Water was initially added manually during each scenario using a slow-drip system. The water level was maintained daily.

The wood flooring test specimens were obtained from samples. Specimens were cleaned lightly with soap and water followed by isopropyl alcohol to remove surface contaminants. Nitrile gloves were used during specimen handling.

The specimens were placed directly onto the concrete surface inside the chamber. The concrete slab was fully saturated for 142 days during the first exposure scenario; however, no liquid water was visible on the concrete surface to prevent direct contact between the wood flooring surface and liquid water. For the second exposure scenario, the concrete slab was fully saturated for 110 days with the specimens partially immersed to a depth sufficient to prevent floating. Each study included specimens representing the four predominant flooring types.

Experiment One — Significant Findings

Three observations were documented: cupping, underside mold growth and visible changes in topside surface appearance.

Cupping was the first visible change observed among five of six hardwood flooring samples after 6–9 days of exposure. The one that did not exhibit cupping was rift sawn. No evidence of cupping was observed among the engineered, laminate or bamboo samples. There was no evidence of surface distortion or ply separation among the engineered exemplars.

Mold Growth was observed on the bottom of all samples after nine days. The earliest growth was observed after 5–6 days. Mold growth was most prolific beneath the engineered flooring samples. The least growth was observed among the laminate and hardwood flooring exemplars.

Surface Appearance of nine of 16 flooring exemplars did not exhibit a surface change after three months of exposure to a damp concrete surface. Of the remaining seven, cupping, surface staining and surface cracking indicated a change caused by moisture exposure.

Experiment Two — Significant Findings

The immersion study examined the consequences of a "worst-case" scenario where the moisture source sustained liquid water exposure.

Thickness Swelling measurements were obtained nine times during the study. Thickness swelling reflected the composition of the wood flooring. Composite wood materials containing OSB, and compressed wood fibers were most vulnerable to moisture absorption and swelling, while solid hardwoods expressed the least.

Microbial Growth was prolific under immersion. Wood flooring materials expressed stains, cracks and discoloration within a week of moisture exposure. All samples supported extensive microbial growth by Day 142.

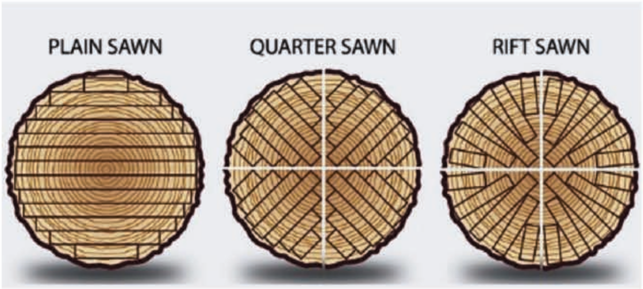

Figure 1. Three cutting methods for hardwood planks: plain, quarter and rift sawn. Source: 3-ply Engineered Hardwood Flooring, info@v3-usa.com

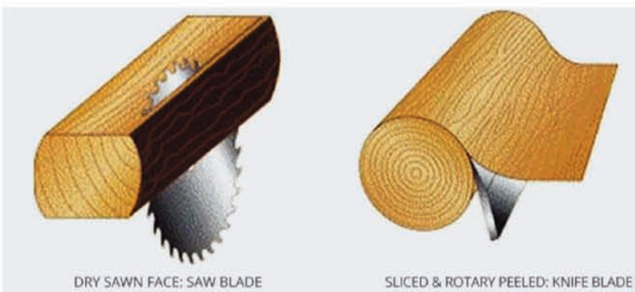

Figure 2. Veneer cutting methods, dry sawn face and sliced and rotary peeled. Source: SVB Wood Floors, 4200 Main Street, Grandview, MO 64030.

grain and absence of knots. These logs are cut into rough-sawn planks, dried, and cut into planks using one of three methods (flat or plain sawn, quarter sawn and rift sawn) that affect the stability of the plank and cost (Figure 1). The cut planks are graded and planed on both sides and the tongue-and-groove edges are cut to make the boards fit together. The tongue-and-groove edge allows the board to expand and contract without creating gaps between the planks.

- *Engineered hardwood flooring.* This product is manufactured using three to five ply layers of wood in contrast to a single plank of solid hardwood. The crisscross layer structure provides dimensional stability so that each plank is less prone to moisture expansion and contraction. The top layer of wood is decorative and provides the flooring its name (*i.e.*, hickory, maple, walnut, oak, etc.). Both solid and engineered hardwood floors are made entirely of wood, the difference is the construction method. The appearance of the top layer is achieved using one of two methods (Figure 2). A rotary cut veneer is produced by removing the top section of hardwood using a lathe that peels a thin layer of wood from the log to provide a view of the grain pattern. The slice veneer cuts a piece of wood by slicing perpendicular to the growth rings (quarter slicing), by slicing parallel to the center of the log (plain slicing), slicing in an arc parallel to the center of the log (half round slicing) and straight cuts by slicing at a slight angle to minimize irregularities (rift cut). The finish looks like solid wood and can be sanded. The flooring is intended to be installed by nailing or gluing on top of a subfloor such as a hardwood.
- *Laminate flooring.* This is a high-density fiberboard (HDF) laminate that feels soft. The upper wear layer is smooth. The flooring looks "wood-like" from a distance until examined closely. The wood appearance is a photographic layer that is coated with a clear finish "wear" layer. Laminate flooring is manufactured in a process that fuses four layers of wood together in a single press operation at high heat (>300°F) using direct pressure laminate (DPL) construction. The four layers are 1) an upper wear layer or clear topcoat, 2) a design or pattern layer of printed paper that is positioned on top of an inner-core, 3) an inner-core substrate layer made of wood pulp that is adhered together in a flat panel, and 4) a moisture-resistant backing layer that is placed on the bottom to serve as a moisture barrier and to limit warping (Figure 3). In addition to the four layers, an underlayment padding is sometimes added.

There are two types of laminate construction: Direct-Pressure Laminate (DPL) and High-Pressure Laminate (HPL). Direct-Pressure Laminate flooring is constructed using 300 to 500 pounds per square inch (psi) pressure and is intended for residential or low-traffic areas. High-Pressure Laminate flooring is constructed with an additional layer of paper sheets that are treated with a stronger resin that makes the top layer stiffer and more durable. These materials are pressed together using 1,300-plus psi to maximize their strength and are intended for commercial areas with high foot traffic.

- *Bamboo flooring.* The most common species of bamboo for flooring is Moso Bamboo *(Phyllostrachys edulis)*. Bamboo is in the grass family because it grows laterally using rhizomes. Bamboo flooring may be constructed in a horizontal or vertical orientation with a characteristic linear grain. During manufacturing, bamboo flooring is divided into long strips that are boiled and dried to remove starch, insects, and sugars. The strips are glued together to form flooring planks as thick as the width of the strips (Figure 4). Bamboo flooring is known for its strength; however, the strand-woven bamboo comprised of shredded bamboo fiber is the strongest. In the strand woven manufacturing procedure, the bamboo is treated as above to produce a pulp that is placed in a mold and pressed under extreme

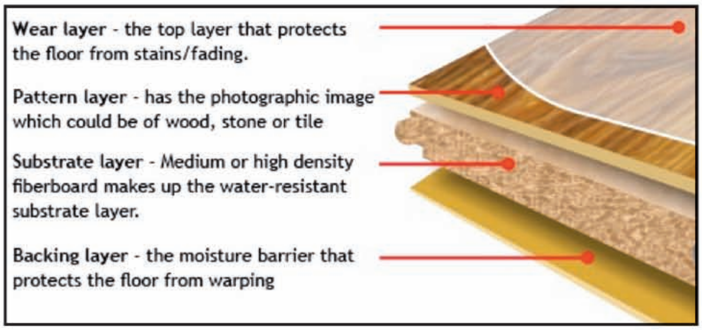

Figure 3. Laminate flooring construction with multiple layers. Source: Fuchsiadesign.com

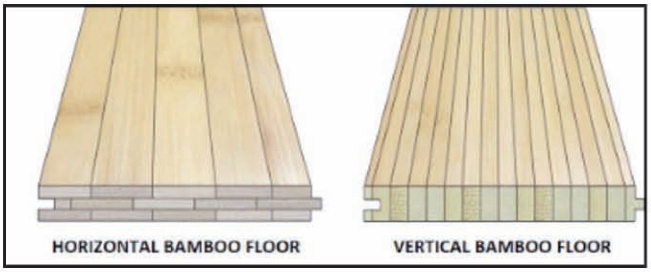

Figure 4. Horizontal and vertical bamboo flooring orientation. Source: BambooFloorCompany.com, a trading name for Kitchner Flooring LTD.

pressure into a solid block. The block is cut into planks creating a random appearance.

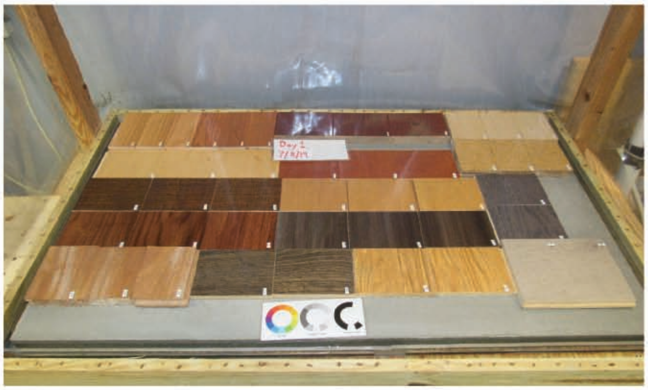

Photo 1. Test chamber with base shelf supporting concrete slab and specimens during experiment one.

Photo 2. This hardwood flooring exemplar (rift sawn) (Day 6) was the only exemplar that did not exhibit cupping after 142 days exposure to damp concrete.

Materials and Methods

Two moisture exposure scenarios were examined using a solid wood-framed test apparatus that featured layers of 12-gauge clear polyvinyl chloride (PVC) sheeting. A base shelf was constructed inside the apparatus chamber that supported a smooth, 2 foot by 3 foot by 1.5 inch-thick concrete slab (2,500 psi), for water and test specimens. The chamber interior was maintained at an ambient temperature of 74°F with a relative humidity over 95% using a stone bubbler diffuser submerged in a small tank of water suspended inside the chamber. The base shelf was lined with PVC sheeting and a layer of 3.5 mil clear polyethylene. Water was initially added manually during both moisture exposure scenarios to maintain the desired water level using a slow-drip system. The water level was maintained daily (Photo 1).

The wood flooring test specimens were obtained from samples offered in the flooring departments of Home Depot and Lowe's building supply stores. The specimens were prepared in near adherence to ASTM Method G1. Manufacturer labels were removed by hand and specimens were cleaned lightly with soap and water followed by isopropyl alcohol to remove surface contaminants (*i.e.*, fingerprints, label adhesives and manufacturing residues). Nitrile gloves were used during specimen handling.

The specimens were placed directly onto the concrete surface inside the chamber for both moisture exposure scenarios. The concrete slab was fully saturated for 142 days during the first exposure scenario; however, no liquid water was visible on the concrete surface to prevent direct contact between the wood flooring surface and liquid water. The concrete slab was fully saturated for 110 days with the specimens partially immersed to a depth (3–4 mm) sufficient to prevent floating. The first and second studies examined 12 and 18 different wood flooring specimens, respectively. Each study included specimens representing the four predominant flooring types.

RESULTS

Experiment One: Wood Flooring Exposed to a Damp Concrete Floor

Three observations were documented during examinations of wood flooring exemplars: cupping, underside mold growth and visible changes in topside surface appearance. Cupping was the first visible change

Photo 3. Engineered flooring exemplar with prolific fungal mycelium after 142 days.

observed among most (5 of 6) hardwood flooring exemplars after 6–9 days of exposure (Table 1).

The hardwood flooring exemplar that did not exhibit cupping was rift sawn (Photo 2). The rift sawn method is a premier cut that minimizes wood distortion in wet or humid conditions.

The degree of cupping varied among the hardwood exemplars and was attributed to the plank cutting method. No evidence of cupping was observed among the engineered, laminate or bamboo exemplars. There was no evidence of surface distortion or ply separation among the engineered exemplars.

Mold Growth

All wood flooring exemplars supported visible mold growth on the bottom after nine days. The earliest growth was observed after 5–6 days and was attributed

Exemplar Type	ID	Experimental Day 1	3	6	9	12	16	20	40	80	140
Hardwood	1,2,3			cupping	mold						
		No change in surface appearance									
Hardwood	4,5,6			cupping	mold						
			Slightly Darker								
Hardwood	7,8,9			cupping		mold					
			Slightly Darker								
Hardwood	31,32,33				cupping	mold					
			Slightly Darker								
Hardwood	34,35,36					mold	no observed cupping				
			Surface stains and slightly darker								
Hardwood	43,44			mold	cupping						
		No change in surface appearance									
Engineered	10,11,12				mold						
		Surface mold, same surface appearance									
Engineered	13,14,15				mold						
		No change in surface appearance									
Engineered	16,17,18			mold							
		No change in surface appearance									
Engineered	19,20,21				mold						
		No change in surface appearance									
Engineered	22,23,24				mold						
			Gradual increase in darkening after Day 40 to dark brown at Day 143								
Engineered	28,29,30				mold						
			Surface staining after Day 8								
Engineered	41,42			mold							
		No change in surface appearance									
Laminate	37,38					mold on edges					
		No change in surface appearance									
Laminate	39,40					mold on edges					
		No change in surface appearance									
Bamboo	25,26,27				mold						
			Surface splitting and mold growth in cracks								

Table 1. Wood flooring exemplar observations after a 142-day exposure period to damp concrete. The left side of the table identifies the exemplar. Each exemplar was accompanied by two rows of data. The top row showed when cupping and mold growth occurred. The second lower row described changes in the surface appearance.

Photo 4. Hardwood flooring after 142 days.

Photo 5. Engineered flooring after 142 days.

Photo 6. Laminate flooring after 142 days.

Photo 7. Bamboo flooring with surface cracking after 142 days.

to optimal moisture content (surface contact between the flooring and concrete) and consumption of available sugars in the wood. Mold growth was most prolific beneath the engineered flooring exemplars where thick fungal mycelium mats extended as much as six inches across the concrete slab (Photo 3). The least growth was observed among the laminate and hardwood flooring exemplars. A thin foam sheet elevated the laminate flooring exemplars above the concrete surface and prevented direct moisture contact and absorption. Hardwood exemplars cupped in response to moisture absorption and lessened surface contact with the damp concrete. This physical change lessened the area that attained moisture fiber saturation and microbial growth.

Surface Appearance

Nine of 16 flooring exemplars did not exhibit a detectable surface change after three months of exposure to a damp concrete surface. Of the remaining seven, cupping, surface staining, and surface cracking (bamboo only) would have indicated a change caused by moisture exposure (Photos 4 –7).

Experiment Two: Wood Flooring Immersed Above a Concrete Floor

The wood flooring immersion study examined the consequences of a "worst-case" scenario where the moisture source sustained liquid water exposure. Photographs documented the visible changes while thickness measurements recorded the thickness swell changes.

Thickness Swelling Measurements

Thickness swell measurements were obtained from control and test samples (n=8) using a micrometer (Grainger). Measurements were obtained nine times (Days 1, 7, 8, 9, 25, 36, 48, 72 and 110) during the study. Measurements taken on Day 7 and Day 110 are

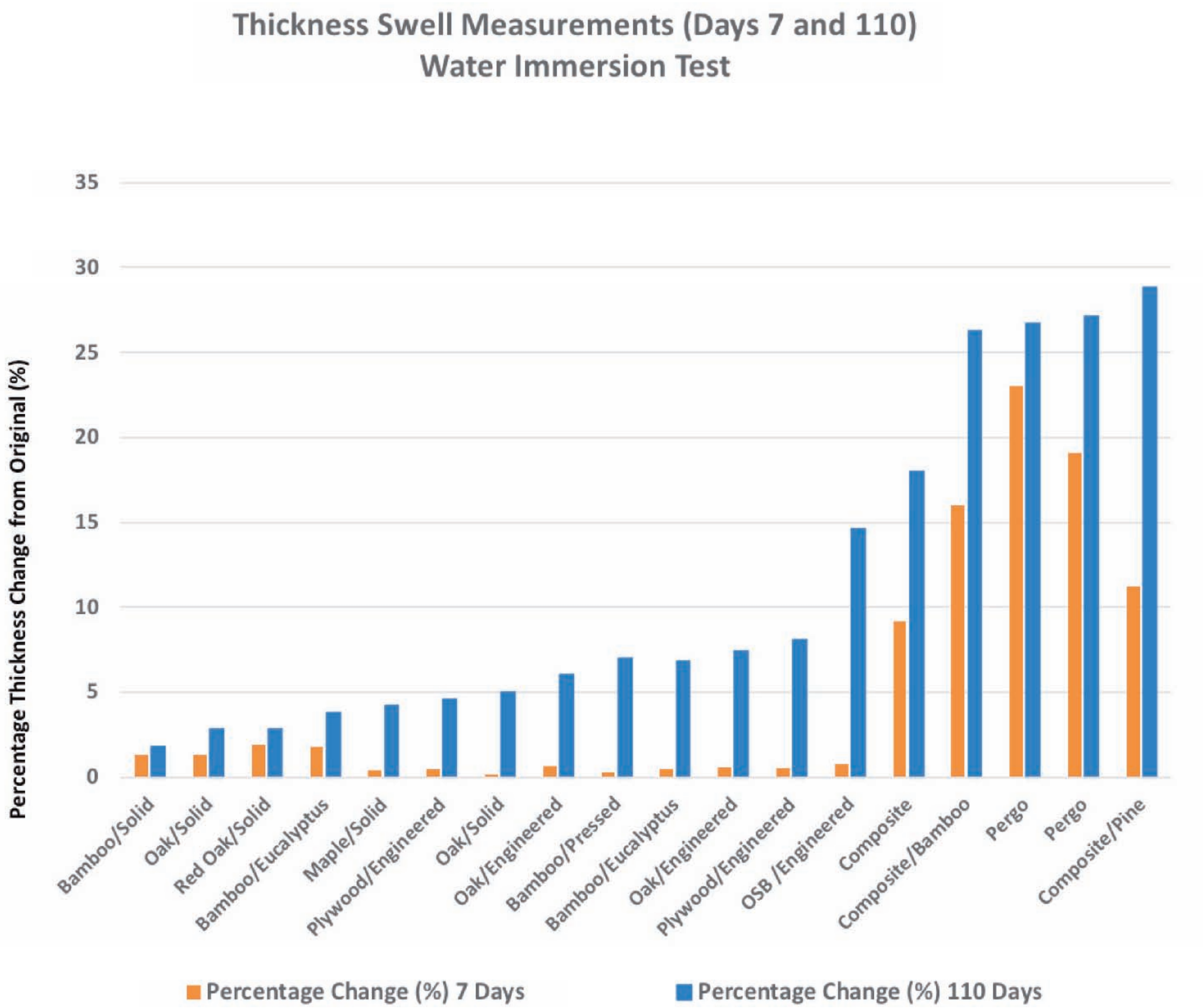

Table 2. Thickness swell measurements obtained from 18 flooring exemplars after 7 and 110 days of moisture immersion showed thickness increases with continued moisture exposure.

shown below to represent the increase in thickness swell (Table 2).

Several findings emerged from the moisture swelling measurements. Thickness measurements reflected the composition of the wood flooring. Composite wood materials containing OSB and compressed wood fibers were most vulnerable to moisture absorption and swelling, while solid hardwoods expressed the least.

Pergo®, composite pine, and composite bamboo materials expressed the highest increase in thickness swelling with measurements ranging from 10% to 25% after Day 7 to nearly 30% at Day 110. The highest swelling increase was observed among composite flooring products. The least swelling measurements were obtained among solid hardwood products with swelling measurements ranging from 1 to 5%. Engineered flooring products initially ranged from 1% to 5% after 7 days and from 5 to 9% after 110 days.

Microbial growth was prolific under immersion. Wood flooring materials expressed stains, cracks and discoloration within a week of moisture exposure. Wood flooring exemplars supported extensive microbial growth by Day 142.

FINDINGS

Findings from the two moisture exposure studies included the following:

- Wet hardwood flooring exemplars were the easiest to identify because of cupping.

- Cupping occurred in hardwood exemplars within nine days.
- Cupping only occurred among hardwood flooring exemplars when placed on a damp concrete surface. Immersed hardwood exemplars did not exhibit cupping because moisture was absorbed uniformly on the top and bottom.
- Laminate and engineered flooring exemplars were stable and did not distort when exposed to either a damp concrete surface or when immersed.
- The ability to observe whether wood flooring materials exposed to moisture depended on the type of wood flooring, not necessarily on the duration of exposure.
- Wear observed at the butted seams of laminate flooring is attributed to higher swelling at the butted ends where foot traffic tends to wear more aggressively.
- Worn butted ends on laminate flooring surfaces may mean moisture exposure.
- The plastic image placed on engineered floors and the wood veneer finish on laminate floors are deceptive and can obscure wet flooring for months.
- Most laminate and engineered flooring exemplars did not reveal evidence of moisture exposure as visible surface discoloration, staining, or discoloration after 142 days of continuous exposure to a damp concrete surface.
- Thickness swelling among immersed flooring exemplars was most prominent among composite products as is observed among composite building materials (i.e., oriented strand board, medium density fiberboard and particle board).
- Laminate and engineered flooring did not distort despite continuous moisture immersion.

Limitations

This study examined the response of wood flooring materials to moisture when placed on a concrete pad. Wood flooring materials placed on plywood sheathing over a crawlspace would presumably have a different outcome because most of the water would discharge into the crawlspace and lessen the wood moisture content. Under this circumstance, the rates of moisture absorption, mold growth, and cupping would be reduced especially if the moisture source was promptly identified and stopped.

We did not employ olfactory senses as an instrument to identify floor moisture exposure. However, the odors produced during this study were overwhelming and support the common-sense understanding that if you detect obnoxious wood decaying odors, you may have wet floors.

The study simulated worst-case conditions of high humidity and moisture. Air-conditioned living spaces with humidity values sustained at 65% or less would experience less favorable conditions for mold growth, cupping, and diminished responses from those described herein.

The study revealed that it was difficult for a cleaning professional to determine that wood flooring was exposed to water within weeks or months depending on the type of flooring. In our study, we were able to observe damages (swelling, discoloration, mold growth) within the first 14 days by simply turning over the exemplar. This option is not normally available so efforts to prevent moisture exposure must be focused on preventing potential moisture releases. JCS

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