RRJ INSIGHT™

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A technical newsletter by Raths, Raths & Johnson, Inc. for the construction industry.

"Insight: to see into and understand; an item of knowledge gained by this power."

The first article in this issue of *RRJ Insight* discusses an RRJ investigation of a distressed tile floor / poured underlayment system to highlight a number of the issues which can occur due to the additional demand on the conventional wood light frame structural support system. The second article focuses on moisture content of wood construction in order to avoid decay fungi.

INSIDE

Figure 1—Typically cracked and deflected tile floor system observed throughout the above grade guest rooms at the complex (as discussed in the Project Profile article).

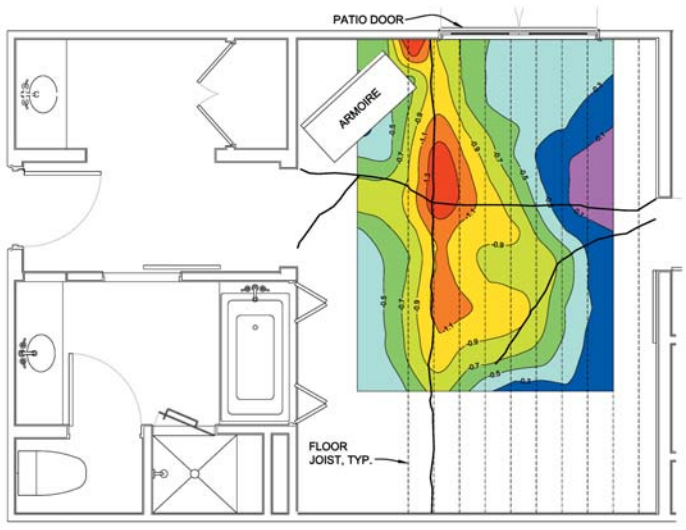

Figure 2—Crack map, floor level contour map and floor joist locations superimposed on guest room floor plan.

Project Profile

Benefits and Pitfalls of Tile Floor Construction Using Poured Concrete Underlayment

Poured concrete underlayment can enhance the performance of a floor system, particularly in conventional wood light frame construction, by adding fire resistance, reducing sound transmission, and reducing perceptible floor vibrations. However, poured underlayment adds significantly to the weight of the supported structure, increasing the demand on the building frame. Poured underlayment is relatively intolerant to deflection and susceptible to cracking. Additionally, commonly used portland cement and gypsum-based materials must be properly batched and placed in order to achieve acceptable performance. Over-watering or improper curing can diminish underlayment strength, increase shrinkage, and reduce bonding capacity for adhered floor finishes. Care must be taken during design and construction to address these issues. This article discusses an RRJ investigation of a distressed tile floor / poured underlayment system to highlight a number of these issues.

RRJ was engaged by the owner of a recently constructed luxury hotel complex to diagnose the causes of several perceived construction defects and to recommend remediation. A central focus of our assignment was the widespread cracking of quarry floor tile installed in approximately 240 above-grade guest rooms. The floor tile was bonded directly to normal weight portland cement concrete underlayment 2½ inches thick supported on ¾-inch orientated strand board (OSB) sheathing and engineered wood floor joists. A sound attenuation composite membrane was placed between the OSB and the concrete underlayment.

RRJ conducted visual surveys which indicated varying degrees of floor tile cracking present in virtually every above-grade guest room (Figure 1). Additionally, RRJ was shown instances of severe framing deterioration, reportedly caused by water infiltration. RRJ implemented an investigation involving crack mapping, detailed floor level surveys (Figure 2), invasive testing to document the condition of the wood framing and the extent of water intrusion, and removal of tile floor coverings to document the condition of the concrete underlayment. Finite element structural analyses were conducted to assess the deflection behavior of the floor system modified for reduced stiffness caused by exposure to elevated moisture levels.

RRJ's evaluation established the following facts:

- Floor tile cracking was entirely reflective of cracks in the concrete underlayment.
- Underlayment cracking was due to a combination of excessive deflection of the wood floor system and excessive shrinkage likely due to high water/cement ratios and improper curing.
- Widespread water intrusion was responsible for reduced stiffness and deterioration of the wood structure.
- The absence of control or expansion joints contributed to cracking of the tile and underlayment.

Based on the RRJ findings, the owners were able to effectively focus remediation efforts on the mitigation of waterproofing defects and on proper reconfiguration of the floor system details. RRJ developed graphics and animations which clarified the issues for the owners (Figure 3).

The findings highlight several points that designers and builders should consider to provide reasonable assurance of acceptable floor system performance.

- The high dead loads inherent with the use of poured underlayment result in increased long-term creep of wood floor framing systems. Wood floor system creep is amplified by exposure to elevated moisture levels. Special attention during design and construction should be given to assure adequate floor system structural capacity and protection from water intrusion.
- Tile floor coverings bonded directly to concrete underlayment are subject to potentially high stresses transferred across the bond line and will exhibit cracks reflective of cracks in the underlayment. Use of an "uncoupling" membrane to isolate tile from underlayment is an effective means to suppress tile cracking. The uncoupling membrane limits the transfer of stresses between underlayment and tile by stretching to absorb underlayment movement. Both the Ceramic Tile Institute of America (CTIOA) and American National Standards Institute (ANSI) provide guidelines for the use of these products. However, the guidelines advise that uncoupling membranes provide protection only against tile cracking caused by minor horizontal planar underlayment movements (shrinkage cracks) and will not protect against vertical underlayment movements (structural cracks).
- Proper spacing of control joints in concrete substrates and tile is recommended by ANSI and the Tile Council of America (TCA). Limiting the size of continuous tile installments reduces the likelihood of stress cracks forming in unwanted locations.

— W. Joseph Macicak, P.E., S.E.

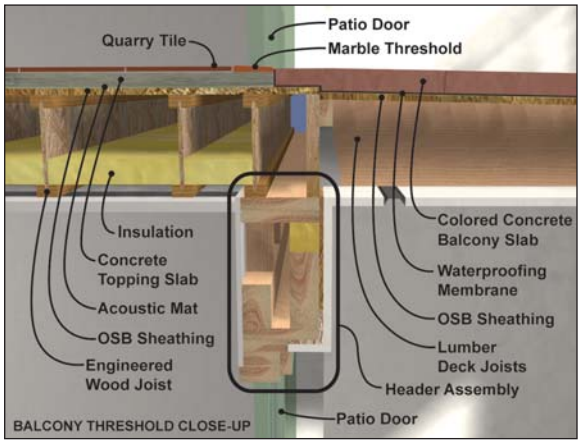

Figure 3—Color graphics were useful tools to help describe construction components for the owner.

Tech Tip

Wood-Based Building Products and In Situ Moisture Testing

Wood construction is recognized as one of the most common building practices for single-family homes, multi-family dwellings, and light commercial structures in the United States and North America. Construction methods have changed and evolved due to product developments, material availability, and demand. Guidelines, methods of practice, and safety thresholds for wood products have also evolved, including recommended moisture contents for installation and finish applications, as well as guidelines for storage and maintenance. For example, a maximum moisture content of 19% is considered a performance threshold for kiln drying and installation by some building codes and industry publications for wood products. This threshold is commonly used as a criteria for building inspectors to determine the serviceability and performance of wood components in existing buildings. However, in order to effectively apply this threshold, building inspectors must understand the derivation and fundamentals of the criteria.

Material properties of wood products can be changed by the effects of heat, moisture, organisms, chemicals, etc. Some changes to the material properties can be temporary while others can result in permanent damage or failure. Decay fungi will affect the structural performance of the wood and result in changes to material properties, whereas mold formation may not degrade the structural integrity of the wood product. Additionally, moisture problems can manifest in a variety of visible ways on wood products including staining, surface mold, dimensional changes, rot or physical deterioration, all with varying levels of permanency.

Recent laboratory studies and published findings indicate decay fungi will not result from moisture contents much below fiber saturation, at approximately 30% moisture content. Despite this, none of the studies directly contradicted the threshold to maintain a moisture content below 19%. Therefore, while 19% appears to remain a practical guideline and threshold for design and construction, it is important to recognize it does include a certain factor of safety. Moisture content alone is not an indicator of structural degradation.

Moisture content surveys of building products can be a useful tool in determining the moisture profile of the building. Careful use and interpretation of the data can allow an investigator to identify areas where moisture contents are elevated in comparison to other areas and assist in identification of building deficiencies contributing to increased moisture levels. However, moisture meters have limitations that must be understood. There are many variables and factors needed to predict the formation of fungi and deterioration of the materials that are not identified by moisture content readings alone and may require the involvement of a Certified Industrial Hygienist or other qualified professional. Therefore, knowledgeable professionals should be employed to ensure proper use of investigative tools and resultant data. Diagnosis and repair of moisture-related problems should be performed upon identification to reduce potential damage and impact to building performance.

Figure 4— Decay of wood-based construction products due to water intrusion.

For more information on this topic, refer to: "In Situ Moisture Testing of Building Products as a Predictor of Actual Conditions" published in the Proceedings of BEST I (First International Conference of Building Enclosure Science & Technology), June 10, 2008.

— Garth D. Hall, AIA
— Sarah K. Flock, AIA

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