

ANATOMY OF A LEAKAGE INVESTIGATION AT A CONCRETE FLOOR SLAB

BY LONNIE HAUGHTON

An excellent guide for forensic construction professionals who investigate sources of rainwater leakage is ASTM E 2128, *Standard Guide for Evaluating Water Leakage of Building Walls*.¹ The guide lays out a purposeful, step-by-step methodology by which information is accumulated and succeeding sampling locations are identified by a skilled professional.

Even though the authors of ASTM E 2128 are specifically addressing the evaluation of water leakage conditions at vertical walls, the standard presents a forensic methodology that also is generally applicable to leakage investigations at the horizontal boundaries of the building envelope. Section 11 of the standard includes, in part, the following seminal guidance:

1. An evaluation is conducted in response to a problem situation and a nonperforming wall and may involve several techniques and procedures specifically adapted and applied in a systematic manner to diagnose a specific problem.
2. The information systematically accumulated in a leakage evaluation is analyzed as it is acquired. The new information may motivate a change in approach or focus for subsequent steps in the evaluation process.
3. The evaluator is expected to establish a cause-and-effect relationship

between wall characteristics and observed leakage. This requires an appropriate selection of activities and a logical analysis and interpretation of the acquired information.

4. The conclusions and findings from an evaluation must be rationally based on the activities and procedures undertaken and the information acquired in order to be considered legitimate and substantiated.
5. The record should be sufficiently complete so that any interested party can duplicate the evaluation program and acquire similar information. Notes on the analysis and interpretation of the acquired information should be clear and complete enough to be understood by any other building professional skilled in leakage evaluation.

In response to potential critics who might argue that the forensic methodology of ASTM E 2128 is not satisfactorily founded upon the tenets of random statistical sampling, a rigorously peer-reviewed paper² (coauthored by this writer and Colin Murphy, RRC, FRCI) recently published in the *Journal of ASTM International* demonstrates that the purposeful protocol prescribed by the standard is fully consistent with sampling methodologies validated within the social sciences.

In short, the goal of the skilled forensic professional is to produce findings of sub-

stantive significance³ that identify cause-and-effect relationships between building envelope characteristics and observed leakage and resultant damage. To this end, the building professional must provide a record of the investigation and analysis that is sufficiently complete to enable another professional to duplicate the intertwined processes of observation, sampling, and analysis.

ASTM E 2128 also accepts the many constraints (e.g., time, access, logistics, budgetary, aesthetic, and/or legal) that can be placed upon the investigation by noting that any conclusions or expectations about the substantive significance of the findings must be proportional to the defined scope of work and the effort and resources applied to this task. In determining substantive significance, both the forensic investigator and any subsequent reviewers must address these kinds of questions:

1. How solid, coherent, and consistent is the evidence in support of the expert's findings?
2. To what extent and in what ways do the expert's findings increase overall understanding of the observed conditions?
3. To what extent are the expert's findings consistent with knowledge derived from other sources?

As noted, the standard's fundamental methodology for carrying out a forensic investigation at a building wall is equally valid for a professional evaluation of prob-

lematic vapor intrusion at a concrete floor slab. Basic tools for such concrete floor investigations include an electrical impedance moisture meter and a calcium chloride vapor emission testing kit⁴ (see *Photo 1*).

However, it is important that the investigator keep in mind key differences in moisture-resistive performance properties of framed walls and concrete floor slabs. Consider, for example, that the direction of water movement within a framed wall assembly will be greatly influenced by the effects of gravity. This condition often enables an inspector to “chase” an observable trail of water damage up a wall to its original source. In contrast, a large volume of water can move a great distance laterally within a concrete slab without leaving much visible evidence of the problem.

Photo 1 shows the placement of a vapor emission test dome adjacent to an apartment wall at which excessive vapor condensation was occurring at the interior side of a window positioned within the wall. A moisture meter confirmed that the surface moisture content of the concrete floor slab was unusually high. The subsequent calcium chloride test confirmed an unacceptable level of water vapor emissions into this bedroom. Based upon this information (and known conditions of failed waterproofing at other portions of the apartment complex),

the inspectors made a preliminary hypothesis that the source of this problematic concentration of water was a waterproofing failure at the exterior courtyard opposite the walls seen in *Photo 1*.

However, after an extended series of destructive investigations and testing, the investigative team discovered that the actual source of the water was a failed plumbing connection within an interior wall behind a clothes washer located in the opposite corner of the apartment (more than 25 feet from the affected bedroom window). Leakage from the drainage piping seen in *Photo 2* was being absorbed into the floor slab under the washing machine – eventually leading to semisaturation of the entire concrete slab and resulting in vapor condensation at the distant bedroom window.

The moral of this review is that the homogeneous, semiporous nature of a concrete floor slab presents the forensic investigator with a challenge to consider alternate potential sources of hidden leakage that may be located a great distance from any observable evidence of the problem. In effect, a concrete floor slab can function as a reservoir or dam for a large volume of excess water. Any observation of “leakage” from the dam should not be construed as evidence that the source(s) of water flowing into the reservoir are located nearby.



Photo 1 – Calcium chloride vapor emission test dome installed at concrete floor slab



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Photo 2 – Hidden leakage at drain piping connection eventually resulted in vapor condensation at a bedroom window at the opposite end of the apartment.


In retrospect, at the commencement of the investigation described above, a small amount of nondestructive moisture/vapor testing at other floor slab locations might have quickly led the team toward the failed plumbing hidden behind the clothes washer. In addition to the moisture meters and vapor test domes commonly used to evaluate concrete floors, it even may have been prudent for the team to evaluate alternate areas of the floor slab with the relatively new “relative humidity probes” that entail drilling small holes into the concrete to measure the actual humidity level inside the concrete.⁵ Any such additional testing within the apartment interior certainly would have been quicker and less expensive than the destructive testing that was carried out at the building’s courtyard plaza waterproofing system in a futile search for an exterior source of the excess moisture.

However, in the end, the actual course of the investigation and its findings of cause and effect certainly were consistent with the investigative methodology and goals described by the authors of ASTM E 2128. The team’s initial hypothesis that the observed conditions were the result of a waterproofing failure at the exterior courtyard was a logical step in this particular evaluation process, because numerous comparable waterproofing failures already had been found at other locations at the project. While the information gained from this exterior testing did lead the team to retrace its investigative path back into the

unit interior, such twists, turns, potential dead ends, and occasional negative results are not uncommon for construction-defect investigations.

Such investigations often consist of a forensic professional’s puzzle-solving methodology for identifying (or eliminating) rival explanations or hypotheses. The intent of ASTM E 2128 is that the step-by-step course of this qualitative puzzle-solving process should be systematic, logical, founded upon professional expertise and knowledge, and designed to establish a clear cause-and-effect relationship between building characteristics and observed leakage.

Often, as in this case, the puzzle-solving exercise will also serve to better inform the investigator for future investigations. While statistical analysis follows precise formulas and rules, the core of qualitative analysis includes the insights, knowledge, and con-

ceptual capabilities of the experienced investigators who always are striving to expand their professional expertise. 

References

1. ASTM E 2128, *Standard Guide for Evaluating Water Leakage of Building Walls*, ASTM International, West Conshohocken, PA.
2. L. Haughton and C. Murphy, “Qualitative Sampling of the Building Envelope for Water Leakage,” *Journal of ASTM International*, Volume 4, Issue 9 (October 2007).
3. While the goal of random sampling is to evaluate levels of statistical significance, the methodology of a typical forensic investigation is to produce findings that have substantive significance, which refers to the strength and importance of a meaningful relationship. (In contrast, a finding of statistical significance does not necessarily indicate a relationship that is important or meaningful to the goals of the investigation; it simply means that enough samples were examined to rule out the effects of chance.)
4. ASTM F 1869, *Standard Test Method for Measuring Moisture Vapor Emission Rate of Concrete Subfloor Using Anhydrous Calcium Chloride*, ASTM International, West Conshohocken, PA.
5. ASTM F 2170, *Standard Test Method for Determining Relative Humidity in Concrete Floor Slabs Using in situ Probes*, ASTM International, West Conshohocken, PA.

Lonnie Haughton

Lonnie Haughton, CDT, LEED AP, is a construction consultant with Richard Avelar & Associates, a forensic architectural consulting firm in Oakland, CA. His professional Web site is www.mastercodeprofessional.com. Lonnie is one of the fewer than 500 individuals nationwide who have achieved the Master Code Professional certification awarded by the International Code Council. He is a member of the Forensic Expert Witness Association, the Western Construction Consultants Association (Westcon), and the Construction Writers Association.

