Journal of the National Academy of Forensic Engineers®

NATIONAL ACADEMY OF FORENSIC ENGINEERS

http://www.nafe.org
ISSN: 2379-3252

Vol. 32 No. 2 December 2015

Forensic Investigation of Water Leakage Issues into Buildings, Recreating the Leaks Vs. Determining the Cause

By Kami Farahmandpour, P.E., FRCI, REWC, RRC, RWC, RBEC, CCS, CCCA (NAFE 854F)

Abstract

Forensic investigations of water leakage through building envelopes often involve complex investigation techniques and testing. In many cases, forensic investigators perform testing under controlled conditions to recreate the leaks and to determine whether design and/or construction defects resulted in leaks. However, construction-related litigation involves complex lines of contractual responsibility and multiple parties. As such, allocating responsibility to various parties requires an increased level of scrutiny. This paper provides an overview of typical construction defect cases and how the lines of contractual obligations can impact the scope of investigation by a forensic engineer. As a case history, a forensic engineering investigation of water leakage reported in a recently constructed building will be reviewed. The plaintiffs' experts performed testing to recreate the leaks, and adequately proved that the designs or construction methods of the exterior walls were defective. However, they were unable to prove causation attributed to one prime contractor who did not settle prior to trial. At trial, the defendant's expert demonstrated other potential paths of water leakage that were not attributed to the defendant, raising sufficient doubts about the liability of the sole defendant at trial.

Keywords

Building envelope, construction, project delivery, water intrusion, water leakage, water testing

Building Construction Litigation

Most construction professionals agree that the majority of building design and construction claims are related to water intrusion. In fact, one source suggests 70% of construction litigation is related to water intrusion[1].

Litigation related to building design and construction often involves several parties. The structure of each claim is dependent on the contractual relationships between such parties and the project delivery methods employed for the subject building. Understanding the contractual relationships between various parties is a key part of every construction litigation case.

Construction Project Delivery Methods

Building construction projects are typically delivered through a few project delivery methods, the most common of which include:

- Design-bid-build
- Design-negotiate-build
- Construction management
- Design-build
- Owner-build

The most traditional construction delivery method is design-bid-build. In this method, the project owner (owner) employs a design professional to design the building. The design of the building is conveyed through drawings and specifications that should detail every aspect of the construction and/or its performance requirements. The design documents are then sent to general contractors to provide bids for the work. The successful bidder is then contracted by the owner to construct the project as the general contractor. Design-bid-build consists of a simple contractual line of responsibility shown in **Figure 1.** The owner has a direct contractual relationship with the designer and a separate contractual relationship with the general contractor. The general contractor will often work with several subcontractors to construct various systems or supply materials. Having more than 30 subcontractors on one project is not uncommon for the construction of many buildings. In design-bid-build project delivery, no direct contractual relationship exists between the designer and the contractor, between the owner and subcontractors, or between the designer and subcontractors. The lack of direct contractual

Kami Farahmandpour, P.E., 1845 E. Rand Rd, Suite L-100, Arlington Heights, IL 60004; (847) 454-8814; kamif@btcpc.com

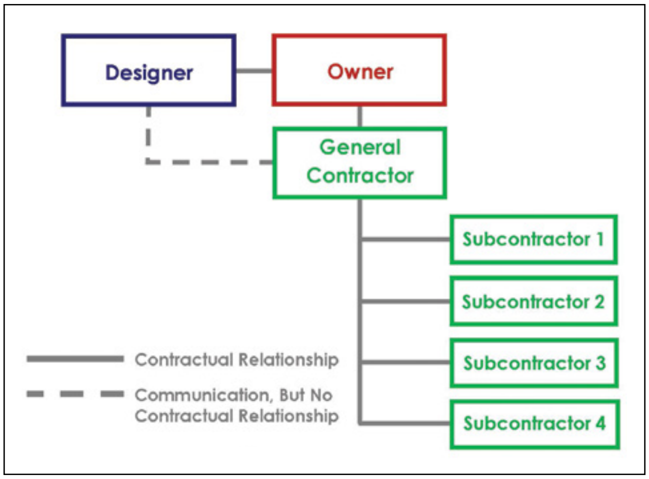

Figure 1
Design-bid-build project delivery.

relationships between these parties poses legal challenges in pursuing subcontractor and suppliers.

Design-negotiate-build project delivery is similar to design-bid-build. However, rather than bidding the construction of the project to several contractors, the owner negotiates with contractors to arrive at a mutually agreeable cost for the project. The contractual relationships between various parties are similar to design-bid-build.

When utilizing construction management project delivery, the owner retains a designer to design the project. The owner will also contract with a construction manager to assist in the construction of the project. Some construction managers also assist the owner in selecting the designer. Construction management project delivery can be further categorized into Construction Manager as Advisor (CMa) or Construction Manager as Constructor (CMc)[2]. CMc is also referred to as Construction Manager at Risk (CMr). When using CMa project delivery, the construction manager will not serve as a general contractor. Instead, the owner will contract directly with several contractors (typically referred to as prime contractors) to construct various portions of the project. This arrangement will result in the owner having a contractual relationship with multiple prime contractors. Although the construction manager will be responsible for overseeing and coordinating the work of these multiple prime contractors, it will have no direct contractual relationship with any of them. Instead, the construction manager will advise the owner on various aspects of the project and assist in managing the multiple prime contractors. When using CMc project delivery, the construction manager may serve as the general contractor. Discussing the differences between contractual responsibilities of these two categories of construction managers is beyond the scope of this paper. In either case, the construction manager's contractual obligations are usually to the owner. Typical contractual relationships between various parties for a construction management project delivery are shown in **Figure 2.**

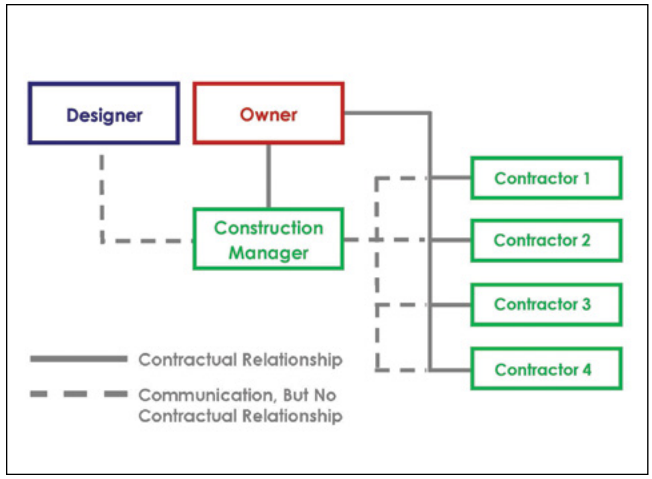

Figure 2
Construction manager project delivery.

In a project using design-build project delivery, the owner contracts with a single entity to perform the design and construction of the building. That entity is typically referred to as the designer-builder, who can then contract with various parties, such as architects, engineers, and contractors, to perform various tasks.

In many projects, a combination of these project delivery methods may be employed. For example, in the case of a residential developer, the owner (acting as the developer) will typically retain the designer and general contractor in a design-bid-build arrangement. However, in some cases, the developer may be the designer or the general contractor.

Challenges for Forensic Engineers Involved in Construction Litigation

Forensic engineers who specialize in the evaluation of moisture damage and water infiltration into buildings are often tasked with identifying the exact cause(s) of water infiltration or moisture (including condensation) in complex building envelope systems. This task is further complicated by the need to identify the responsible party (parties) and allocate responsibility.

When forensic engineers are retained by the plaintiff, their scope of investigation will likely be influenced by the contractual relationships between various parties and what the burden of proof will be. In a design-build project scenario, the plaintiff's forensic engineer may not need to allocate responsibility to the designer versus the contractor(s) because the plaintiff's contractual relationship was merely with a single entity with obligations to the plaintiff.

In building envelopes, most water leakage issues occur at interfaces between various systems. For example, water leakage can occur at the interface between the windows and the adjacent masonry walls. In such cases, allocation of responsibility will be complicated by the fact that several subcontractors may have played a role in constructing the interface. In addition, the design of the interface may have been faulty or omitted from the design documents. In the example of a window-masonry interface, the following parties may carry responsibility for the defects that led to water leakage:

1. The designer may have designed the interface improperly or specified incompatible materials at the interface.

2. The designer may have omitted the appropriate details at the interface, and one or more of the subcontractors may have constructed the interface incorrectly without seeking direction from the designer.

3. The window subcontractor may have installed the windows incorrectly.

4. The window supplier/manufacturer may have supplied defective windows.

5. The masonry subcontractor may have constructed the masonry through-wall flashings incorrectly around the windows.

6. The waterproofing subcontractor may have applied the weather-resistive barrier flashing around the windows incorrectly.

7. The sealant subcontractor may have improperly applied sealant at the interface between the masonry and the windows.

8. The general contractor or construction manager may have dictated incorrect sequence of work by the subcontractors.

9. The owner may have failed to maintain the building properly, or may have made modifications that may have adversely impacted the window-masonry interface.

In a construction defect case involving building envelope issues, it would not be uncommon to have more than 10 parties involved. This presents a challenge to the forensic engineer who may be tasked with quantifying the damages attributed to each party. While some forensic engineers render opinions regarding allocation of damages based on their judgement, there are more scientific methods for allocation of damages, including allocation by cost of repair for each component and allocation by percentage of damage caused by each source. A detailed discussion of these damage allocation methods and their potential shortcomings is beyond the scope of this paper.

Another challenge for forensic engineers is allocation of responsibility to design. In some cases, the designers may have delegated design responsibility for certain building systems to the contractor. For example, design of a curtain wall system is typically delegated to the curtain wall subcontractor because curtain wall systems are highly proprietary. However, the lines of responsibility for design of interfaces between various systems are more complicated.

All of the above challenges are exacerbated when considering that construction cases can involve hundreds of thousands of pages of background information. These documents are often provided to the forensic engineer in a disorganized manner. Sifting through the background information and finding relevant information is typically a significant challenge.

Typical Evaluation Methods Available to Forensic Engineers

Moisture issues through building envelopes can generally be divided into two categories: bulk water leakage and condensation issues. This paper focuses on bulk water leakage. Condensation within building envelope assemblies is a complex phenomenon that requires a separate discussion.

Evaluating bulk water leakage intrusion into buildings requires a thorough understanding of the building envelope systems, the as-built condition of their interfaces, and how bulk water penetrates building envelopes. Several forces drive bulk water (or snow and ice) through openings in the building envelope. These include gravity, wind pressure, capillary action, kinetic energy, and surface tension. The author has evaluated building envelope water intrusion issues caused by all of the above factors. However, most building envelope water intrusion issues are driven by gravity or wind pressure.

One of the most widely recognized standards for investigation of exterior wall leaks in buildings is ASTM E2128, *Standard Guide for Evaluating Water Leakage of Building Walls*[3]. That standard provides a good overview of the procedure a forensic investigator should follow to evaluate water leakage issues through building exterior walls. However, ASTM E2128 does not address building roofs or below-grade waterproofing.

The procedures prescribed in ASTM E2128 include background review, evaluation of the building's service history, a visual review, development of a hypothesis, confirmation of a hypothesis, and water leakage paths through testing and exploratory openings.

Background review is an important part of any forensic engineering investigation. In building construction, the as-built details often do not strictly follow the original design drawings and specifications. Many changes are made during the construction, and design intent and construction details sometimes change through multiple submittals that include shop drawings. As part of this review, a building envelope forensic engineer is often tasked with reviewing design drawings, specifications, contracts, shop drawings and submittals, test reports, reports produced by various parties during construction, meeting minutes, requests for information, change orders, payment applications, and many other forms of communication between multiple parties.

Once the relevant background information is reviewed and the service history has been established, a visual inspection of the building (or affected portions) is performed. Based on this information, the forensic engineer will develop certain hypotheses regarding potential water intrusion causes. Such hypotheses should then be verified (or ruled out) through water testing to recreate the leaks and to assess the path of water leakage through concealed components of the building exterior. In some cases, water testing may not be required. For example, where there is an obvious opening through the exterior wall at the location of a reported leak, it may be rationally concluded that the opening is one of the leak sources. However, the forensic engineer should also assess if there may be other water leakage sources.

Water testing will necessarily involve replicating the conditions that caused the water intrusion. Several water testing methods and standard procedures are available to building envelope forensic engineers. These include ASTM C1601[4], ASTM C1715[5], ASTM E1105[6], AAMA 501.2[7], and AAMA 511[8]. Discussions of these test procedures are beyond the scope of this paper. However, it is important to point out that the forensic engineer should understand the limitations of each test, and determine if the selected test procedure can sufficiently replicate the in-service conditions that caused the water intrusion.

It is also important to note that assessing the exact path of water leakage requires systematic and deliberate sequencing of testing. During such test sequences, various components of the building exterior should be isolated to evaluate their performance individually. Without such deliberate test sequencing and isolation, the leaks may merely be replicated, but their exact source or path cannot be determined.

Understanding What is Asked of the Forensic Engineer

The investigation methodology employed by each forensic engineer will greatly depend on what is asked of him/her. For example, a forensic engineer's assignment may be limited to determining if bulk water leakage occurs, or may be as detailed as determining the path of water leakage and attributing responsibility to various parties responsible for the design and construction of the building envelope.

In cases where the plaintiff files a claim against a developer who employed the designer and the general contractor, simply proving that water leakage occurs under in-service conditions may be sufficient for the purposes of convincing a jury or panel of arbitrators that the buyer (current building owner) did not get what it bargained for. However, in cases where allocation of responsibility is important, simply reproducing leaks under in-service conditions is not sufficient. In such cases, the forensic engineer will have the much more complicated task of proving that leaks occur under service conditions and determining the path that the water travels to reach the building interior. This second component of the investigation is crucial for the purpose of allocating responsibility to various parties.

Case History

In a recent case, a residential condominium association filed a lawsuit against the developer of its building due to pervasive water leakage issues throughout the building. The leaks had manifested within several residential units within a relatively short time after completion of the building.

The subject building was a concrete frame high-rise structure with a combination of punched windows, strip windows, drainage masonry walls, and barrier metal panels forming the exterior of the building. The building exterior also included cantilevered balconies.

The building was developed by a development entity (the developer) who had constructed the building under construction management project delivery method. As such, the developer had retained a design firm to design the building, a construction manager to oversee the construction as an advisor, and several prime contractors who constructed various portions of the building.

In order to investigate the water leakage issues, the condominium association retained two forensic consulting firms who assigned multiple personnel to the project. The first consulting firm focused its efforts on investigating the windows, while the second reviewed the windows and exterior wall systems. The second consulting firm also acted as the plaintiff's expert during the subsequent litigation.

Through water tests, the condominium association's forensic consultants were able to replicate the water leakage through the exterior building components: Water leakage to the unit interiors was confirmed, proving that there were design and/or construction defects. The testing performed by the condominium association's consultants primarily consisted of ASTM E1105 and AAMA 501.2 tests. ASTM E1105 prescribes procedures for testing of installed windows and doors using a calibrated spray rack applying water on the exterior face of the assembly and a differential pressure exerted across the assembly to simulate wind pressure. AAMA 501.2 prescribes procedures for testing of inoperable windows and curtain walls using a hand-held calibrated spray nozzle with no applied differential pressure. In many cases, the ASTM E1105 testing (conducted by the condominium association's forensic consultants) was performed without employing any differential pressure across the tested system to replicate wind-driven rain events.

Although the tests replicated leaks, the path of the water leakage was not determined — with the exception of one test that conclusively demonstrated water leaks along the mullion joints of the strip windows.

Following the testing, the condominium association's consultants made exploratory openings to examine the as-built condition of the wall and window systems. Through those exploratory openings, several construction deficiencies were documented. These deficiencies were related to work performed by the window, metal panel, sealant, and masonry contractors. In addition, design deficiencies were also noted.

The condominium association's consultants attributed several of the noted deficiencies (observed through the exploratory openings) to the masonry prime contractor, including a lack of mechanical attachment along the top of through-wall flashings, inadequately constructed through-wall flashing end dams, lack of through-wall flashing end dams at some locations, failed sealant joints, lack of horizontal gaps for vertical expansion of brick, and missing through-wall flashing below window sills.

Based on their findings, the condominium association's forensic consultants developed repair schemes to address the leaks. These included a series of comprehensive repairs that addressed all of the deficiencies they had observed. In many cases, no water testing had been performed to verify that the components scheduled to be repaired were causing water leakage. Nonetheless, in an apparent attempt to ensure long-term performance of the building envelope, every potential source of water leakage was addressed.

Once the repairs were designed by the condominium association's forensic consultants, they were implemented by a qualified contractor. The costs for the design and implementation of the repairs were then attributed to the developer's prime contractors and the designer based on the cost of repair of each component. As the litigation process unfolded over several years, the condominium association was forced to pursue the developer's prime contractors, and the designer was dismissed*. Subsequently, several of the defendant prime contractors settled with the condominium association shortly before trial†. Ultimately, the only remaining defendant was the masonry prime contractor.

The case against the masonry prime contractor proceeded to trial by a jury. During the trial, the condominium association's experts presented the results of their investigation. However, when challenged under cross-examination, they indicated that their water testing did not conclusively determine that the masonry deficiencies observed through their exploratory openings caused the water leakage issues. Using 3-dimensional modeling and computer-generated animations, the masonry prime contractor's expert demonstrated to the jury that other factors outside the masonry prime contractor's responsibilities were the likely cause of the water leakage issues. These factors included the windows (installed by another prime contractor), the design of the building envelope, and the sequencing of construction by the construction manager. An example of a 3-dimensional model used as a trial exhibit is shown in **Figure 3**. In addition, the masonry prime contractor's expert demonstrated that many of the repairs performed by the condominium association to address the water leaks may not have been necessarily related to the leaks.

Figure 3
3-dimensional model used to demonstrate where leaks could be due to a gap between the window frames and the window rough opening. That gap was left open by design.

* For several reasons, the developer of the building was not pursued, and under the state law, the condominium association was able to pursue its claims directly against the developer's prime contractors.

† In the author's experience, most construction claims are settled prior to trial. This is partially due to the complex nature of construction cases that cause uncertainty of outcome and the expenses related to such trials.

The jury found in favor of the masonry prime contractor, leaving the plaintiffs with no recovery from that contractor.

This case demonstrates that as the litigation process evolves, the burden of proof can change. Initially, the plaintiffs were pursuing the developer — a single entity who was responsible for the design and construction of the building. As such, their experts only needed to prove that the building did not perform acceptably without having to attribute causation to each prime contractor. The developer would then have the option of pursuing the designer and its prime contractors as third-party defendants, and allocating responsibility to each of those third-party defendants would be the developer's burden, not the plaintiffs'. However, as the case evolved over several years, the plaintiffs ended up pursuing the developer's prime contractors, making it the plaintiffs' burden to allocate responsibility among the prime contractors. To complicate matters further, since the building had been repaired, additional testing and investigation could not be performed to determine the responsible parties for the leaks.

In this case, it is not clear why the plaintiffs' experts did not determine the path of water leakage and properly formulate opinions regarding allocation of responsibility. However, evolving needs during a long construction litigation process spanning multiple years are common, and can certainly explain the process adopted by the plaintiffs' experts.

Uncertainty and confusion about burden of proof in building envelope water intrusion cases can occur due to many reasons, including:

1. In some cases, the client simply does not have the financial resources to authorize extensive testing and follow-up exploratory openings to determine the exact path of water leakage and allocation of responsibility through a thorough review of project documents.

2. In some cases, due to the long process of litigation, the initial objectives of the forensic engineer are defined properly. However, as the case evolves and burden of proof changes, the attorney or the forensic engineer fail to account for the changes in litigation strategies and the need to properly allocate responsibility to various parties.

3. In some cases, miscommunication between the forensic engineer and the attorney can lead to misunderstanding of the investigation objectives by the forensic engineer.

Conclusions

Prior to taking on an assignment, forensic engineers should thoroughly understand the client's objectives and what questions should be answered through their opinions. Based on this understanding, they should develop a scope of investigation that can yield useful and reliable results, which should then be used to formulate engineering opinions.

In building construction and water intrusion cases, a thorough understanding of each party's responsibility is often required. To determine each party's responsibility, the forensic engineer should perform a review of the project documents to understand the design, design changes during construction, and each party's role in changing and constructing the intended design. This will typically include a review of each party's contract and scope of work.

The initial document review should then be followed-up with an investigation of undisturbed conditions. This investigation will require the selection of an appropriate investigative testing protocol that can replicate the conditions that led to the water leakage, followed by exploratory openings to confirm the condition(s) that led to the water leakage and water leakage paths. Such investigative testing often involves methodical isolation of various building systems and their interfaces.

During the litigation process, the forensic engineer and client should routinely communicate and assess the need for further investigation as the case evolves.

References

1. Seward A. When it leaks it pours. Architect – The Journal of The American Institute of Architects. June 06, 2011 [accessed 2015 December 19] http://www.architectmagazine.com/technology/when-it-leaks-it-pours_o?o=1

2. The project resource manual: CSI manual of practice. 5th edition. Alexandria VA: The Construction Specifications Institute; 2005.

3. ASTM E2128-2012. Standard guide for evaluating water leakage of building walls. West Conshohocken PA; ASTM International.

4. ASTM C1601-2014. Standard test method for field determination of water penetration of masonry wall surfaces. West Conshohocken PA; ASTM International.

5. ASTM C1715-2015. Standard test method for evaluation of water leakage performance of masonry wall drainage systems. West Conshohocken PA; ASTM International.

6. ASTM E1105-2015. Standard test method for field determination of water penetration of installed exterior windows, skylights, doors, and curtain walls by uniform or cyclic static air pressure difference. West Conshohocken PA; ASTM International.

7. AAMA 501.2-2015. Quality assurance and diagnostic water leakage field check of installed storefronts, curtain walls, and sloped glazing systems. Schaumburg IL; American Architectural Manufacturers Association.

8. AAMA 511-2008. Voluntary guideline for forensic water penetration testing of fenestration products. Schaumburg IL; American Architectural Manufacturers Association.