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Interdisciplinary Forensic Engineering As a Result of Substantial Completion Request: A Case Study

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Abstract

A project owner commonly relies on the contractor and design professional to determine substantial completion of a construction project. If the need arises, the owner may engage independent reviewers. The potential for forensic consulting arises when the contractor fails to provide construction in conformance with the contract documents or when the designer errantly designs, observes, approves, or omits work during the process. If a forensic consultant is engaged near or at completion of the work and reports substantial deviation from the contract documents, the owner must determine how to handle the need for corrective action. The deviations must be categorized and allocated to the responsible parties, and a means and cost to cure such defects are necessary. This paper provides a case study of the forensic review process under Colorado Rules of Evidence, although the rules are substantially similar in other states and on the federal level.

Keywords

Forensic, investigation, inspection, substantial completion, punch list, building code, NFPA, testimony, cost

Background

In 2016, approximately one year from the beginning of the construction of a dormitory addition and renovation to a private school in Colorado, the project owner engaged an engineer to perform a preliminary observation to verify substantial completion and authorize final disbursal of payment to the contractor. The site is a 25,000-square-foot school and residential dormitory for private use.

During the site observation, the engineer identified a number of details in the construction of the building that did not comply with code or industry standards. Review of the owner-provided punch list verified that not only were items beyond simple cleanup, but these items would also require substantial modification to cure the multitude of non-conforming work related to the construction of the building and site development. The discovery of issues gradually increased the magnitude of the original scope, leading to the need for additional information gathering about the design and construction of the project. The nature of the discoveries triggered additional document analysis, code reviews, and site investigations, including intrusive examination, all of which were necessary to provide the owner and litigants a complete understanding of the issues noted on the property.

Analysis

Forensic engineering requires a thorough understanding of the local, state, and federal laws regarding construction defects to provide proper analysis and reporting in the event that the substantial completion reporting begins the process of construction defect litigation. Also, since the scope of work could ultimately become a basis of action under the provisions of the contract, the forensic engineering process must include a review of the agreements, modifications, and addenda between the owner and contractor in order to evaluate the claims and their impact on the standards of work as set forth within the contract. In the project profiled herein, uncompleted work that was accepted by the owner via the owner's architect, or other third party, created a number of potential issues surrounding the determination and allocation of the damages, the costs to cure the work, and, in some cases, the acceptance of the work despite the damages.

Two-Prong Approach

In order for the engineer to evaluate the work against the contract documents and determine if such work

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resulted in either a non-conformance or a construction defect, a methodology has to be utilized in order to more clearly and consistently position opinions within the subjective field of forensic analysis. Understanding of the forensic engineer's long-standing and consistent position with respect to the origination and evolution of construction defects, as well as the resultant damage, is necessary for building and site analysis. This position is ultimately developed out of the forensic engineer's experience, education, and training specific to the design, construction, and validation of compliance. This position has become known as the "two-prong approach" and is the foundation for the findings and opinions utilized in the case study presented herein. The two-prong approach is founded on the following precepts:

- The first prong of damage is the inability of a product, component, or system to perform its intended function. If the constructed condition cannot perform its intended function throughout its expected useful life, then it is first-prong damage. Thus, it satisfies the definition of damage commonly used within the legal framework of construction. The first prong of damage analysis, the ability of the system or element to perform the intended function, is defined by the code requirements, site-specific construction documents, manufacturer product information, and relevant industry standards.

- The second prong of damage is defined as the resultant manifestation of physical damage or distress that stems from the first prong. The observable distress or loss of use resulting from the inability of the system to function as intended is a result of the original inability of the product or system to perform. The manifestation of damage may create further resultant damages to the product, component, system, or adjoining systems that would otherwise be undamaged.

First- and second-prong damage may be readily observable, latent, or expected and depends on a combination of the forensic engineer's education and experience, as well as access to the first- and second-prong damage via visual or intrusive examination. **Figure 1** graphically displays the relationship of damage characteristics of the two prongs and also introduces a causal relationship into the overall process using water intrusion as an example.

First-prong damage initially occurs near substantial completion when the non-compliant construction is installed and/or becomes a part of the completed system. The result is a system that cannot function as it was intended. The first-prong damage, standing alone and absent a causal event, yields no resultant manifestation of damage. However, the current condition also does not necessarily result in loss of use, voidance of product warranties, or apparent damage to the property. Simply stated, improperly assembled construction, despite lack of physical damage, does not (and will not) work in its constructed state. Any conditions that include this first-prong damage should, therefore, be repaired so that the product, component, or system can function as intended.

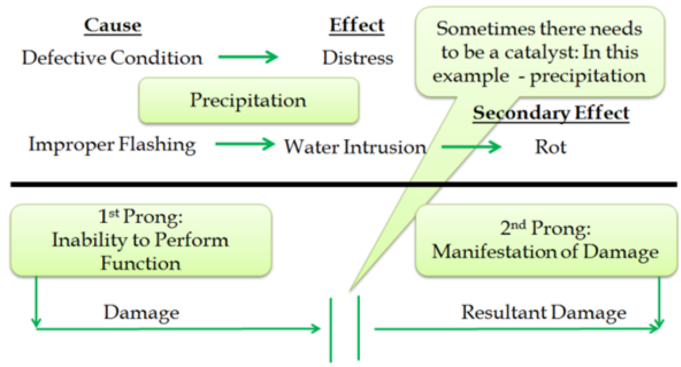

Figure 1
Damage manifestation timeline.

The second prong, as discussed above, is the actual resultant manifestation of damage. This is when first-prong damage becomes observable. In **Figure 1**, the manifestation may not be observable until such items as visible biological growth are noticed by an owner. Here, it is important to emphasize the distinction of observations by an expert trained to recognize construction defects compared to a less sophisticated person without the education, experience, and knowledge of an expert in the field.

To further explain the **Figure 1** graphic, the defective first-prong condition (improper flashing) results in the second-prong water intrusion damage. After repeated rain events, the moisture builds up in the underlying products causing material deterioration to occur. Further, resultant damage will typically occur after substantial completion of a project.

During construction, the developer and contractor have the ability to remedy any discovered defective conditions. For example, an exterior cladding drainage system may be installed in a manner that directs water inward toward moisture-sensitive materials. This is a prong one condition that, with a high degree of engineering certainty, results in second-prong damage. However, if that damaged condition (first-prong damage) is identified and corrected prior to completion of the project, then the condition is no longer at risk of resultant loss of use. In theory, the developer and contractor are able to correct any deficient conditions until the end of the construction warranty terms of the project. The forensic services should include communication with the owner's counsel to verify whether the defective construction is a breach of contract versus a claim of defective construction.

During the design and construction process, the owner may make choices based upon the acceptance of risk. The substantial completion request does not fully address the entirety of the design and construction process. The forensic engineer could inherently question the use of products or systems without the knowledge of predetermined decisions. This information should be provided to the forensic engineer to ensure that previous decisions that modified the construction were properly and thoroughly documented and entered into the files.

For example, with the case study herein, one of the issues in the punch list that had been provided by the owner and developed with the architect in August 2016 included isolation of the door trim from the concrete slabs. Review of the file found that while the original geotechnical report was provided for the site in July 2014, after the first site reporting, a second geotechnical report was issued in August 2014. This second report allowed a change of the foundation system and altered the bidding as part of the guaranteed maximum price (GMP) contract in February 2015.

This request to modify the foundation and floor systems was made with the design team and builder's input with the sole intent of reducing the cost of construction. In review of the structural engineering documents and architectural finishes, this change in the foundation system resulted in substantial risk acceptance, detailing changes and architectural impacts on the property that required substantial modification to the fire walls and finishes, and owner acceptance of the risks associated with slab-on-ground and expansive soils. This decision had to be connected to the understanding of the change from a cost-savings issue to one of building damage and associated repairs due to the expansive soils on the site.

Review Format According to Discipline

In order to comprehensively review the project for final compliance, engineers must employ a methodology based on organized engineering disciplines. Following such a review structure also aids in allocating and attributing responsibility for defects to the various trades involved with the construction. With this project, engineers analyzed substantial completion based on the following general interdisciplinary fields:

- Geotechnical
- Structural
- Civil
- Building envelope
- MEP systems
- Accessibility
- Acoustics
- Fire protection

After initial observation of the subject project and identification of non-conforming construction, this review structure was customized to the specifics of the project. The following list of non-conformances was used over one year of proceedings in negotiations with the owner's attorneys:

- Geotechnical
  - – Geotechnical report review
- Structural
  - – Foundation system – spread footings
  - – Floor system – slab-on-ground
  - – Superstructure – conventional wood frame
- Civil
  - – Grading and drainage
  - – Streets and roadways
  - – Concrete flatwork
- Building envelope
  - – Façade (exterior cladding and sealants) Type 1
  - – exterior insulation and finish system (EIFS)

– Façade (exterior cladding and sealants) Type 2 – adhered brick veneer

– Moisture-management system (barriers, flashings, drainage, etc.)

– Fenestrations (windows, doors, curtain walls, etc.)

- Workmanship issues
- Owner noted items
- Fire-resistance rated construction

Applicable Codes, Contracts, and File Disclosure Challenges

All parties involved in the construction project are bound by the contract documents. This contract should be the main focus of the substantial completion request. The contract documents are comprised of the legal agreements between the various construction parties, design drawings, specifications, and construction communications, such as requests for information, change orders, meeting minutes, and correspondence with the authorities having jurisdiction (AHJ) over the project. The contract documents form the fundamental minimum requirements set forth for the project. Since the contract documents evolve during construction with the inclusion of ongoing clarifications and change orders, the forensic engineering review must include a review of the current set of contract documents, including all changes to or clarifications of the contract, drawings, and specifications, as well as reviewing as-built drawings prepared by the contractor. The construction process requires that changes to the contract documents be carefully recorded and preserved.

Because of varying recordkeeping practices, the gathering of contract documents can be a lengthy, disorganized, and incomplete ordeal. The primary way to acquire contract documents is through voluntary tender or subpoena of the involved parties.

Forensic engineers should exercise their best ability to gather the information, compare changes from original work, and validate that such changes were properly submitted to the design team, owner, and AHJ. Establishing the applicable codes involves contacting the local AHJs and verifying the codes used in the review, inspection, and design of the project in order to accurately review the contract documents and construction.

Local AHJs often store physical copies or scans of submittal documents and are a secondary source of AHJ-approved construction drawings and approval communications; however, contract provisions can require the on-site parties to maintain these records. Owners usually desire to have an as-built set of the drawings and specifications (including operation and maintenance manuals) at the completion of the work.

On some projects, the disarray of documents can reduce the forensic engineer's ability to comprehensively review a file within the necessary timelines of the project. The expert's need to review the disclosed files in a timely manner can be impacted by the failure of the parties to provide full disclosure. When this doesn't occur, seeking legal remedy through retaining counsel is likely necessary to gain access to the entirety of the records. Corrections, updates, and supplemental reporting due to an incomplete file can result in the need for additional discovery, which can drastically lengthen the resolution process and ultimately increase the cost of the legal proceedings.

In the case of the subject private school project, the builder's file of documents was provided in a haphazard manner. In addition, the engineer noted within the reviewed contract documents numerous drawing revisions that, unfortunately, were not provided at the beginning of the engagement. This lack of provided information resulted in additional numerous report revisions and increased testimony time. Ultimately, the file in this case required an arduous forensic re-creation. Thus, information that was provided in late disclosure resulted in correction of claims against the design and construction of the property.

Four sets of disclosed documents were ultimately produced during the scope of work. The owner had 10,094 pages in the initial disclosure and 2,597 pages in the supplemental disclosure, in comparison to the builder, who disclosed 13,283 documents originally. The owner had provided a punch list developed with the architect in August 2016 and a field observation report from a third party that was dated one month after the punch list. After completion of the first engineering report, and even during the first arbitration period, the builder continued to produce documents. This late discovery further hampered the forensic engineer's ability to provide timely reporting. The second and third round of disclosed documents from the builder in early December 2017 included an additional 13,065 and 6,191 documents, respectively.

Ultimately, more than 50,000 pages of disclosures were produced. These disclosures were done with little to no means to identify fully all parts of the construction process. Documents were undated, misplaced, or generally out of order. During review of the documents, the engineer ultimately determined there were no less than eight drawing revisions. Having multiple designs ultimately became an underlying issue specific to the fire separation construction that involved many noted deficiencies.

Had the builder, as required per contract, created and provided an as-built set, the file review process, reporting, testimony, and overall clarity of the proceedings would have been substantially improved — both with reduced time and efficiency of efforts. Even in the final arbitration, the defense expert (who replaced the original defense expert used in the first hearing) relied on the incorrect drawings, which showed an assembly that was never actually constructed.

The main references that were used in the evaluation of the work for the substantial completion — and ultimately for both the breach of contract and construction claims — were drawn from the American Institute of Architects standard A102 documents[1], including the use of the general requirements set forth in A201. The architect was contracted under standard B101 forms and engaged the mechanical, electrical, plumbing, fire suppression, civil, and structural sub-designers. The owner independently contracted with the geotechnical firm. The selection of the contractor was made after for GMP agreements, with four addenda being incorporated during the bidding process. The forensic engineer had to carefully review the entirety of the contracts, modifications, and associated documents. Following are the specific non-conformances that were discovered by the engineer during review of substantial completion organized by the engineering disciplines outlined above and the consequent repairs that were proposed.

Geotechnical Review

The original foundation system at the subject site (as shown in **Figure 2**) originally included deep-drilled cast-in-place concrete piers. The uplift of the expansive soils in the active zone required that the lower concrete shafts be keyed into the claystone bedrock. This is not a typical design for two-story buildings and likely did not match the original building, which was founded on spread footings. During the cost review, a decision was made to change the foundation system to spread footings and a slab supported on ground. This change clearly reduced the cost of the project; however, the costs associated with the upkeep of a building that is more prone to movement would have to be absorbed by the owner. The change in the design and construction would require the contractor, designer, and owner to review, acknowledge, and accept the risks versus the cost savings. Unlike value engineering, this change would not provide similar functions to the deep-seated foundation systems, including the inability to maintain below slab MEP systems.

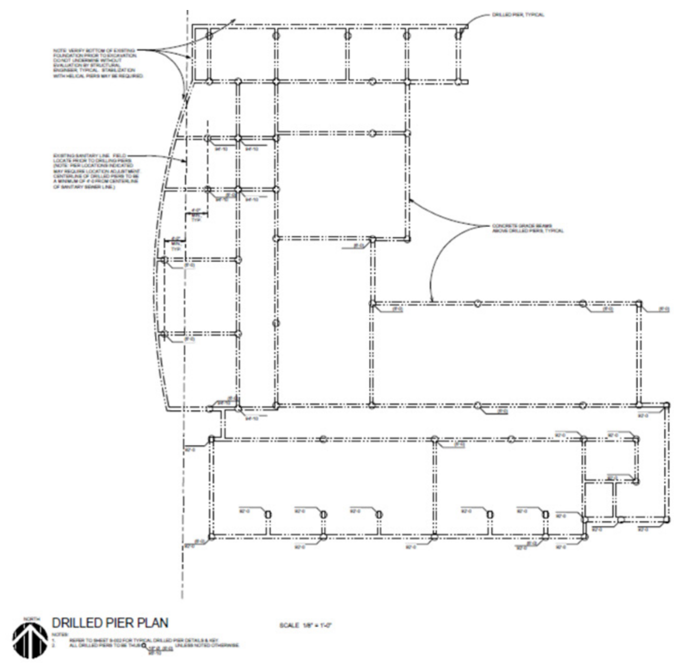

Figure 2
The original project documents included a foundation design using shear ring piers, which was consistent with the geotechnical report. An addendum changed the foundation to spread footings. No documentation exists evidencing the owner was apprised of the change in risk tolerance to the finish materials and structure due to the change in foundation type.

An updated geotechnical report was provided to relay the relevant information to the structural and architectural designers with respect to the foundation change; structural and architectural plans were updated to reflect the reduced foundation. As described above, the use of a two-prong analysis is important in properly analyzing the building and performance. The updated geotechnical report indicated that the movement of the soils could result in upwards of 3 inches of vertical rise. It is important to analyze this movement on the foundation- and slab-supported elements of the building and below grade non-accessible MEP systems. The interior demising walls, which are explored further in this paper, do not have the ability to absorb this type of movement. The structural engineer passed the information to the architect via a general note on the structural drawings. The architect created slip-jointed fire separations in order to handle the anticipated movement. This fire wall, as described in this report, has inherent maintenance issues as the floors move. The architect, however, omitted any special detailing needed to accommodate the additional floor-to-foundation wall movement or better protect brittle surfaces, door frames, wall-to-wall connections, plumbing below the slab, or any other movement-sensitive areas. In addition, this decision contradicted opinions from the geotechnical report, which stated and illustrated: “In our opinion, a straight shaft pier (caisson) foundation should be used for the proposed building structure at the site. The piers should be drilled at least 6 feet into the bedrock. Shallow foundations are a riskier option for non-occupied features.”

During observations, the forensic engineer noted several issues throughout the building. First floor dormitory room door frames were separating from the hallway drywall, and cracks had developed in the brick veneers and flooring. These manifestations of physical damage, or second-prong damages, occurred because the building systems were not constructed with tolerance or ability for movement that was expected in the secondary selection of the slab-on-ground and footing systems.

The inability of the foundation system to perform under the known movement parameters was the first-prong damage. Rather than suggesting a reconstruction of the building to provide a system that could perform on the expansive soils, a systematic means for maintenance was established and a capital expenditure account set up for the anticipated damages. Repair recommendations developed by the engineer after the forensic evaluation included implementation of a capital expenditure program that would deal with damages to the floor, walls, appurtenances, and fire assemblies. Ultimately, a knowledgeable contractor and design team should have informed the owner that movement issues may surface as part of switching to a more movement-prone foundation system.

Structural Review

Since the forensic work had to include both review of the construction as well as the potential breach of contract issues, not only did the engineer consider the change of the foundation system and its effect on the architectural and MEP systems but also found that the rebar had been wet-stabbed into the footings (as shown in **Figure 3**). This method of placing reinforcement after the concrete pour is improper and was not provided in accordance with the specifications. The structural notes in the documents issued for permit for the project stated, “All reinforcing shall be accurately placed and adequately supported prior to concrete placement (no wet stabbing) per IBC Section 1907.5.”[2] Since there is not sufficient lateral load issues on this foundation system, it would be expected that no second-prong damages associated with this poor workmanship were observed or expected, thus no costs to cure this issue were assigned to the claim. The issue was used, however, in establishing an opinion of the overall quality of work provided by the general contractor.

Figure 3
Owner-provided photograph (Nov. 6, 2015), showing concrete placement for footings. Note that the dowels necessary to connect the footing to the foundation walls are not in place prior to the pour. The stabbing of dowels is a violation of the code, and was strictly forbidden by the structural engineer of record.

The foundation system change was not the only indicator of the unusual construction. The educational building was being constructed as an R-2, Type V building[3]. Although wood framing is allowed in the R-2 setting, it is much more common to see fire-resistant materials (such as masonry or steel) in the construction of educational buildings. Making the decision to sidestep more commonly accepted building materials presents additional coordination challenges to the design team.

The structural engineer required both horizontal and vertical slip joints to allow for the movement of the structure independent of the slab system. However, the architect omitted such detailing for vertical connections, and the contractor constructed the walls improperly at both vertical ends. Upon discovery of the non-conforming issues by a jurisdictional fire inspector, the contractor deconstructed the work and reconstructed the room demising walls to allow movement at the top of the walls with a floating connection, also known as a site-fabricated deflection track.

The design and construction team had originally sought a metal deflection track system manufacturer for incorporation of wood-frame walls with floated assemblies while the construction continued. The jurisdiction would not accept this metal track as a means to provide one-hour assembly to the demising walls.

With a constructed wood-floated track, no tested assembly of this construction exists, and the contractor sought an engineering decision from a proprietary group to establish the construction of the joint. Although that decision was not provided, the walls nonetheless were constructed. Upon the issuance of the engineering letter, the contractor moved the item to the resolved list even though no inspection, verification, or other work was done to validate the already completed work.

As the issue was tabled, it ultimately resurfaced through meeting minutes. None of this was noted in the disclosed file for over a year, and once it was determined, had to be carefully admitted during the arbitration hearings to lay foundation to each element. Had this been provided in the as-built, resubmitted set of drawings, it would have provided a clear means to the analysis necessary to determine the substantial completion of the building. The investigation showed that the wall had been constructed in general conformance with the Engineering Judgment Letter. But in review of the floating connection, other floor/ceiling assembly fire-resistance rating issues were found to be improperly constructed. It should be noted that the plan revisions indicated ultimately a callout to the Engineering Judgment Letter; however, those plans and modifications were not disclosed until very late in the case.

In consideration of the movement of the floor that was cost shared between the owner and contractor, and the foundation-supported frame walls, the floor will move independent of the foundation, and this float connection will require ongoing drywall seam repair each time the slab-on-ground floor system moves. This would include door tracks on the slabs and foundations, the vertical joint between the slab-supported demising wall and the foundation-supported corridor wall, and all ceiling float joints that are above the ceiling lid and thus non-observable.

Lastly, another issue came to light in review of the Engineering Judgment Letter and the comments from the original plan review of the fire department. The fire department noted that the engineered wood joists would require proper installation of the drywall to comply with one-hour assemblies. As is typical, that included either two layers of Type X drywall or a single layer of Type C drywall[4]. However, it was discovered that only a single layer of Type X drywall was used in the construction of the floor-ceiling assembly that attached to the one-hour demising and corridor walls; thus, the contractor failed to provide a rated assembly for the Type V construction. The substantial completion observation could not have determined this condition as it was latent and not accessible without intrusive testing.

Civil Review

The use of a slab-on-ground on expansive soils, as well as site appurtenances, requires that the builder provide proper drainage in accordance with the site-specific geotechnical report. In addition to the need for proper grade, the increased risk of building damages due to the foundation change and connection of the slab-on-ground to existing foundation-supported elements presents the likelihood of future damages and higher maintenance obligations. The builder and designers should have provided clear direction to reduce the likelihood that the soil movement would damage the building. Grading on sites that will move should consider not just the minimum standards, but increased standards that will allow discrete maintenance, such as additional fall in the backfill zone, structural landings and walks near the building, and drainage conveyance that can be easily manipulated to provide discrete repairs, such as inlets and storm drainage in bounding areas. Failure to consider maintenance in the design and construction does not allow owners a reasonable means to ensure their site is functioning as necessary to avoid first-prong damages that will ultimately result in second-prong damages.

The site drainage plan was provided by a civil engineer under contract through the architect. The builder, architect, and engineer all had the opportunity to understand the potential associated effects that are the result of poor drainage around the building, and the change of foundation and floor types increased those associated risks. The site observations conducted during the substantial completion revealed two primary conditions with the grade: the first was the lack of effective slope within the backfill zone, also referred to as the “protective zone;” the second condition was ponding water near the building’s foundation (as shown in **Figure 4** and **Figure 5**).

During construction, the builder attempted to remediate bad work where ponding was occurring by adding a small yard inlet located in the east courtyard. This modification to the contract documents would require that the

Figure 4
Substantial completion observation (July 24, 2018) showing storm drainage water accumulation at the backfill zone of the foundation.

Figure 5
Substantial completion observation (July 24, 2018) showing storm drainage water accumulation at the backfill zone of the foundation.

owner be willing to accept deficient, non-conforming work without cost reduction in the GMP and that the owner be willing to accept additional risks associated with water migration toward the structure and site. Building code and the geotechnical report both required that 5 percent minimum grading be maintained for 10 feet from the foundation perimeter[5]. This slope is visually apparent as 6 inches of fall in 10 horizontal feet, and the use of a perforated landscape edge is easily recognizable.

The original reporting for substantial completion included this visual assessment of the failure to provide code- or contract-compliant grading. During the arbitration, the argument from the builder's expert was that the forensic evaluation did not include a topographical survey and that an assessment of grading could not be provided without a surveyor's information. In defense of the visual approach to observation, the report included photographs showing ponding water; hence, a survey would not be needed to show this failure to meet the requirements of the plans, codes, or specifications. The contract required as-built plans. Had the contract been adhered to, the survey would have been provided by the contractor prior to the request for substantial completion.

Building Envelope Review

As constructed, the cladding system at the subject site incorporated an expanded polystyrene rigid insulation board (XPS) that was clad with adhered brick, a modified stucco system, and metal panels, depending on location. In all cases, the construction of the system provided no provisions for drainage of moisture that would accumulate behind the claddings.

Other non-compliant items were also observed during the substantial completion observations, such as the failure to provide proper joints at dissimilar materials, no separation of the claddings at water table systems, and the failure to provide for changes in façade based on the backup systems such as the foundation and framing elements. The construction attempted to create a barrier exterior insulation and finish system (EIFS). The code clearly does not allow barrier EIFS on Type V construction[6] and, thus, both the contractor's substitution and the architect's silence resulted in a non-compliant assembly.

The only viable means to cure the first-prong condition (the defective moisture-management system) and provide a tested fire protective assembly was to de-clad the structure back to the exterior wall sheathing, allowing the proper creation of the fire and moisture systems. Although the substantial completion scope identified missing components, the forensic investigation required intrusive examination of the building envelope. This intrusive examination revealed numerous flaws even in the constructed assembly, such as fastening, lapping, and coverage of materials. As constructed, in no instance could the building perform its intended function regarding drainage behind the architectural veneers. Based on the age of the building at substantial completion, observation of second-prong damages would not be expected, and the opposing side used that as its argument — since no damage had been found on the less than one-year-old building, it must in fact be performing. The first-prong argument states that the expectation of failure of performance — hence, the loss of the intended use — is, in fact, damage.

Fire Protection Review

Ultimately, what became one of the most contested matters in the case arose during the first substantial completion observation. Per the project documents, the building was to be constructed with an NFPA 285-compliant cladding system, and this was clearly specified in the project manual. NFPA 285 requires that the cladding system be subjected to testing to determine its resistance characteristics to fire[7].

As discussed above, a decision was reached during the design phase to construct the addition out of wood framing, or Type V construction, in lieu of a safer and more typical application in this building's use of a Type III construction. The Type III would include non-combustible exterior walls as part of the inherent passive strategy. NFPA 285 testing is not specifically considered as part of Type V wood-framed construction. However, the question remains that if NFPA 285 was, in fact, considered in Type I to Type IV construction, there is no reason the veneer assembly could not comply with the standards.

The use of a more combustible product on combustible construction is allowed within the parameters of the code because combustible construction is typically not associated with institutional construction. The allowed classification of the dormitory renovation as occupancy type R-2 instead of the arguably more appropriate educational or institutional occupancy type is, in part, to blame for the exclusion of NFPA 285 requirements and the allowance of Type V construction in this setting.

The decision to construct the dormitory out of combustible materials did not result in the elimination of the NFPA 285 requirements in the specifications. However, two items must be investigated in the substantial completion of the project and in the review of the specifications in light of the GMP contract.

The contractor provided the GMP bid based on the drawings and specifications, which required components that complied with the NFPA 285 rating. During construction, the contractor submitted a hybridized system consisting of NFPA 285-compliant and non-compliant materials. Although the architect, via specifications, demanded a verifiably safer system, the architect did not exercise the diligence to reject the proposed materials and thus construction continued. No deductive change order was provided to the owner for the lack of compliance with the drawings and specifications. The owner was not informed about the reduction in the protective class of the building, its components, or its assembly.

Upon discovery of these issues, it was noted that the plans indicated specific areas for fire-retardant treated plywood (FRT). These requirements were in the bid set of construction documents and thus should have been incorporated into the construction cost prior to the contract award. During the substantial completion observations, no FRT was found on the building, and this was later confirmed in the testimony of the contractor's agents. Contractor construction photos showing the various layers of the building were only produced after intrusive testing confirmed the lack of FRT on the building, contrary to assertions from the other side's experts. Earlier disclosure of the construction photos could have significantly reduced the need for intrusive testing.

The FRT would have provided additional protection in the lobby, parapets, and stair areas on the Type V building; it would be logical that such increased level of protection would be advised in a dormitory setting, and inclusion of this material was understood as an essential component in the fire-protection scheme for a higher-risk residential dormitory. Ultimately, the architect testified that the specification in the manual and on the drawings was likely a mistake. However, this issue is complicated for two reasons. The first is the cost deduction for not installing the FRT should have been reflected in the GMP bid. The second is that the permit set, as required by the AHJ (local building department), requires documentation of any detail changes, especially those concerning life-safety features. Omission of the FRT should have been submitted via an RFI, a cost deduction, and a resubmittal of the plans to the AHJ for review and incorporation into the file.

Lastly, coordination with the sprinkler system design for NFPA 13 or 13R compliance would require such information to be reviewed in the determination of the layout and selection of the appropriate sprinkling systems for the building. None of these necessary tasks were completed in this project, leaving the issue open for the arbitration and requiring substantial time and testimony to determine a proper resolution. The original architect's conclusion is compromised by the fact that on-site construction observations were provided, and this framing would have been open and obvious during the observation. The architect failed to note that the framing systems were not in compliance with the architectural plans, and admission of this issue could indicate fault on the architect's behalf.

Design of the dormitory, lobby, education areas, recreation areas, library, storage, retail, and other areas requires that the designers review the applicable construction type, the allowable areas for each use, and the restrictions associated with the prescriptive code for each of the occupancy groups. The fire provisions included appropriate egress considerations, active and passive fire protection features, and many other design aspects that are related to the safety and well-being of the building occupants. According to the plans, a one-hour fire separation was to be constructed between the old educational wing and the new lobby, between renovated assembly areas and the old educational wing, between the residential dorm room wing and the lobby, and, albeit not required as a one-hour separation because of the sprinkler, between each individual residential dorm room and the adjacent hallway. Because the dormitory wing consists of two floors, floor/ceiling separations also required review.

At first review, the architectural plans indicated adequate separation between identified occupancy groups. However, concerns arose due to unconventional combining of non-residential uses as part of a gross residential area. These areas included the bookstore, conference rooms, student lounges, commercial-style laundry, and utility and maintenance rooms — all of these spaces were combined within the gross student residential occupancy group. Inclusion of spaces that are an accessory to the host occupancy group is generally allowed; however, the size and use must fall within allowed parameters defined within the code and industry[8].

During substantial completion observations, area calculations determined that the amount of accessory spaces included in the residential occupancy was approximately twice the allowed limit, included non-residential equipment and uses, and exceeded occupant loads expected under the residential category. The building codes establish required fire separation ratings according to generally understood uses, elevating separation requirements where the risk of fire increases. Interpretation of the building code through a formal International Code Council review was sought, specifically to address the overstepping of non-residential functions and risks that were included within the residential occupancy designation.

The life-safety protection features in the codes are primarily founded on failure-based precedence and are matters that should always be carefully considered in any project — not taken advantage of or misinterpreted for the sake of reducing material costs by a comparatively insignificant amount. The difficulty in the interpretation included non-utilized space for normal activity, such as closets. The forensic review should anticipate the ambiguous portions of the code in relation to the industry knowledge and acceptance of how these spaces are considered in area calculations.

Repair Recommendations

Arbitration- and trial-based rulings rely on carefully composed cost estimates provided from both plaintiff and defendant to arrive at accurate damage valuations based on the acceptance of the arguments. In this case, the repairs for curing the non-conforming, non-accepted work were prepared by an outside estimating firm that based its work on the forensic reporting.

For most items, a scope of work was prepared that would provide resolution. In some instances, no costs were provided because although the work was non-conforming, no repair scope was provided. The costs included both correction to poor workmanship as well as defective work. This cost analysis, with multiple repair scopes encompassing the litany of damages, would allow the arbiter to review the case under both legal claims: one of breach of contract and one of defective construction. The cost analysis provided to the client in some cases must take into account independent repair costs to each potential party, thus needing to be separate and distinct for each party.

These scenarios must include separate costs for rip and tear items. An example is if the stucco was placed over a non-flashed window, the costs associated to remove the necessary components to get to the missing head flashing and the costs to replace the removed components have to be separated from the cost of the missing flashing. The policy language may not include coverage for that missed component but would include coverage for the costs to resolve the damage. A similar point can be made if there are two trades that share a cost to repair. The repair estimate may include a cost for each trade separately, as though the dual work never existed. The job-specific understanding and communication with the legal team are essential in developing appropriate segregated repair costs.

Summary

In summary, interdisciplinary forensic engineering can provide the necessary tools to help finalize outstanding contractual obligations. However, as noted in this report, lack of documentation and other challenges can derail a smooth substantial completion process. The forensic expert should have knowledge both via education and experience to provide an understanding of the various engineering disciplines or engage others to review the multitude of potential issues. The engineer must weigh the building use, construction types, foundation types, occupancy types, and impact of each design and construction decision against the adjoining work, areas, and impact on other trades. Review of the provided documentation must be thorough and completed with meticulous attention. It must be fully separated by each trade and trade interface. Job file communications, such as the RFI responses, change orders, supplemental instructions, field directives, and even emails, should be reviewed to determine who, when, and where such needs impact work product.

References

1. American Institute of Architects (AIA), A102 "Standard Form of Agreement Between Owner and Contractor" A201 "General Conditions of the Contract for Construction," and B101 "Standard Form of Agreement Between Owner and Architect," 2007.

2. International Code Council, Inc. (ICC), "International Building Code" (IBC), 2009, Chapter 19 "Concrete," Section 1907 "Details of Reinforcement," subsection 1907.5 "Placing reinforcement."

3. International Code Council, Inc. (ICC), "International Building Code" (IBC), 2009, Chapter 6 "Types of Construction," Section 602 "Construction Classification," subsection 602.5 "Type V."

4. Gypsum Association, Underwriter Laboratories Rated Assemblies.

5. International Code Council, Inc. (ICC), "International Building Code (IBC)," 2009, Chapter 18 "Soils and Foundations," Section 1804 "Excavation, Grading and Fill," subsection 1804.3 "Site Grading."

6. International Code Council, Inc. (ICC), "International Building Code" (IBC), 2009, Chapter 14 "Exterior Walls."

7. National Fire Protection Association, NFPA 285 "Standard Fire Test Method for Evaluation of Fire Propagation Characteristics of Exterior Non-Load-Bearing Wall Assemblies Containing Combustible Components," 2012.

8. International Code Council, Inc. (ICC), "International Building Code (IBC)," 2009, Chapter 5 "General Building Heights and Areas."