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Ethical Responsibility: When the Forensic Engineer is Faced with Notifying Occupants to Vacate

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Abstract

Holding the obligation to protect life, safety and welfare paramount required the forensic engineer in this case to notify the homeowner to vacate her new home constructed in an active landslide. The forensic engineering evaluation of a four-year-old home revealed extensive damages caused by active soil mass flow in glacial lake deposit soils and a natural spring that imposed excessive hydrostatic pressure on the front foundation wall. The homeowner remained in the home for nearly four years during the investigations while insurers and their engineers argued over coverage. The structural analysis revealed significant probability of imminent collapse, threatening the safety and welfare of occupants and creating both a compelling necessity and an ethical obligation to notify the homeowner of grave peril to the occupants and their need to vacate and abandon the premises.

Keywords

Safety, unsafe conditions, landslide, construction defect, ethics, obligation, ethical responsibility, tunnel vision, forensic engineering

Introduction and Background

A medical professional invested her life savings into a two-level home she believed was her dream home (see **Figure 1**). As part of the deal, she was offered and accepted the purchase of the new home warranty through the builder in 2010. Soon after occupying the home with her son and daughter, cracks began forming in drywall surfaces, and the lower level (a walk-out basement with a wood-joisted floor system above the crawl space) became unleveled. She contacted the builder in September 2011. In November 2011, she initiated her claim of defects in the construction with the home warranty company, seeking answers into the cause of problems in the home.

Figure 1
Street view of the subject home's south face.

The builder's engineer ("B-E"), who also had provided foundation design guidance early in the project construction, responded after notice was given. B-E concluded there was no differential settlement but that there was differential movement in the foundation. The home warranty company dispatched a forensic civil/structural engineer ("HW-E") to evaluate the structure in December 2011, who concluded the damages were caused by differential foundation settlement and that movement in the brick veneer (along the right side of the structure) was attributable to lack of brick ties. The homeowner retained an engineer ("O-E") in 2012 — who also provided home inspections — to inspect the property. O-E provided two reports, the final (submitted in August 2013) of which concluded that the home suffered from significant movement, and additional movement would threaten the safety of occupants.

However, O-E did not make a determination about

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the habitability or the potential threat to the safety, health, and welfare of occupants or the public. None of the three engineers (B-E, HW-E, or O-E) identified the imminent threat to the occupants through a sudden catastrophic failure, nor was that threat conveyed to the home's occupants.

In 2014, the homeowner's attorney retained a forensic engineer ("A-FE"), the author, to inspect and complete a forensic analysis. That analysis revealed that the home was located in an active landslide that had damaged the home and was threatening the safety of its occupants. Upon identifying the imminent risk, A-FE had an ethical obligation to notify the occupants to vacate.

Codes of Ethics Are Foundations for Engineer's Conduct

The first fundamental canon of the engineering *Code of Ethics* published by the National Society of Professional Engineers ("NSPE") states, "Engineers, in the fulfillment of their professional duties, shall hold paramount the safety, health, and welfare of the public[1]." Other technical societies have similar codes of ethics[2,3]. A library of cases has been developed by NSPE's Board of Ethical Review ("BER"), many providing direct guidance regarding the ethical obligation of engineers to notify their supervisors, clients, other affected parties, and authorities having jurisdiction when conditions manifestly threaten the health, safety, and welfare of the public.

This paramount foundational tenet is similarly embodied within many state laws. Regarding the practice of engineering, for instance, Alabama states: "In order to safeguard health, life, safety, welfare, and property, the practice of engineering in this state is a learned profession to be practiced and regulated as such, and its practitioners in this state shall be held accountable to the state and members of the public by high professional standards in keeping with the ethics and practices of the other learned professions in this state[4]."

Other state laws are similarly written, such as: Minnesota §326.02; Nebraska Rev. Stat. §81.3402; and Oklahoma §59.475.1. New York promulgates, "The practice of the profession of engineering is defined as performing professional service such as consultation, investigation, evaluation, planning, design or supervision of construction or operation in connection with any utilities, structures, buildings, machines, equipment, processes, works, or projects ***wherein the safeguarding of life, health and property is concerned***, when such service or work requires the application of engineering principles and data" at §145-7201[***emphasis added***][5]. The health, safety and welfare of the public, which includes affected parties, is the paramount foundational concern of the forensic engineer when reviewing, analyzing, and reporting conditions manifest in structures, systems, or works.

Earlier Engineering Evaluations

In the subject case, the owner's initial 2011 call to the builder of her home expressed concern over cracks and other damage to the drywall surfaces. The owner's call initiated a series of site visits and investigations. The first investigation was conducted by B-E, who reviewed conditions in October 2011 and issued a written report stating, "structurally it does not appear to be a differential foundation settlement issue." However, in apparent contradiction, B-E concluded the report with, "To repair the settlement in the back corner, I recommend a helical pier be installed under the footing… . " B-E also indicated that nothing should be done to the structure until the following spring to determine if further movement occurred.

In November 2011, following review by B-E, the builder notified the home warranty company ("HWC") of the owner's claim of structural damages (**Figure 2**). The builder included a copy of B-E's report with the warranty claim.

HWC engaged the services of a national forensic engineering firm, who assigned a forensic civil/structural engineer ("HW-E") to review conditions in the structure. HW-E's initial investigation was a "Distress Inventory Report" of the subject home that occurred in December 2011.

The HW-E report included notation of the following, generally: in the front right bedroom, a bowed and inoperable window, cracks present in the bedroom ceiling, and uneven margins for the bedroom closet doors; cracks in the tile floor and raised tiles in the main (right) bathroom; drywall repairs to cracks at the kitchen with the east hallway; in the stairway, drywall cracks in the ceiling and at vertical corners as well as interface between the walls and ceiling; in the basement, wall and ceiling cracks in the hall and left rear bedroom; and, in the garage, separation and cracks at wall and ceiling locations. Exterior observations included: separations between the brick veneer and right (or east) face window frames at their forward (south) sides with the rear (north) sides noticeably bowed; a vertical crack through the brick veneer at the right rear (northeast) corner with up to 1 inch of lateral movement observed; stair step cracks from the head and sill of the north window of the east face; and, at the crawl space access,

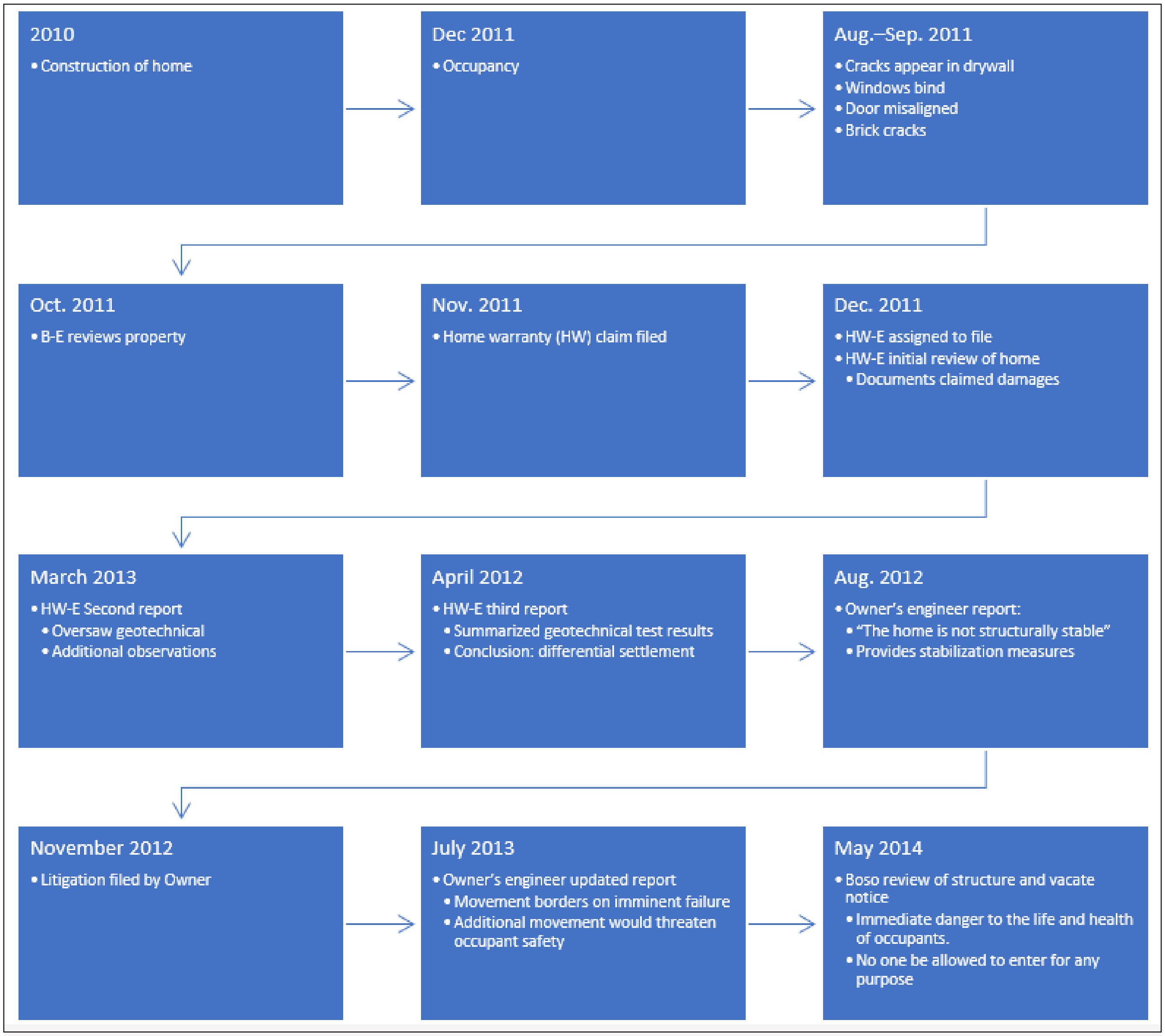

Figure 2
Timeline of events leading to May 2014 determination.

hairline crack above the opening with uneven "reveals" or margins. Within the crawl space, HW-E observed: a stair step crack in the north portion of the east crawl space masonry wall; moisture present in the east and south walls at the southeast corner; and the ground beneath the plastic vapor barrier was very soft and muddy with standing water present. No conclusions or recommendations were presented in the December 2011 report.

HW-E made two subsequent site visits and generated corresponding reports with the last report dated April 2012. The last HW-E report described geotechnical investigations at the right rear corner and concluded that settlement of the structure at that corner, caused by improperly consolidated fill material, was the root cause of problems being experienced. The HW-E's report also concluded that the lack of adequate brick ties between the brick veneer and wood-framed structure contributed to the "brick movement." No investigation of soil conditions at the front or along the sides of the subject home was conducted.

In August 2012, the owner engaged O-E to inspect the property to help understand accumulating damages as well as newly developing damages. O-E observed movement in the front foundation wall sufficient to cause heaving of the crawl space floor at the footing. O-E further stated, "significantly major foundation movement has occurred within the home, concentrating at the right rear areas of the foundation resulting in a one inch horizontal movement within the right side crawl space foundation with additional lateral movement occurring along the rear crawl space foundation wall… This lateral movement is literally pulling the interior of the basement and main floors apart with majors [sic] cracks in the walls and ceilings."

During a return visit one year later, O-E documented an additional ¾ inch of movement at the right-side bedroom window in a year. Movement within the structure was described as "rearward." O-E initially concluded that the structure was, "not structurally stable with ongoing structural movement." O-E went on to say, "Significant repairs and reinforcement along with an interior crawl space foundation drain will be required to stabilize the foundation and interior of the home." O-E's updated 2013 report added, "This home continues to suffer significant and major ongoing movement. Although there did not appear to be any major failure in the structure at this time of the inspection, the home demonstrates significant stress and movement that boarders [sic] on immanent [sic] structural failure." However, O-E did not declare the structure to be unsafe.

Both B-E's and HW-E's report concluded that the structure was being affected by differential settlement at the right rear corner. O-E's 2013 report was the first to express concern about the safety of the structure and its occupants. However, O-E's report suggested a remediation plan without consideration of sequencing of demolition, stabilization of retained soils, or any temporary measures to assure worker safety while accomplishing remediation. Photographs from HW-E's and O-E's reports were used as comparisons for A-FE's investigation to document the movement of the structure and to confirm progression of the structure's movement — and its perilous and compromised state that threatened occupants.

Tunnel Vision

Tunnel vision is the mental constriction of the field of vision during an engineering evaluation. The consequence of this phenomenon is a limiting of the observations and evaluation of the investigator. As a result, the observer focuses and reports on a limited area of observed damage without regard to the whole.

In the matter of the subject property, the first three engineers reviewing the location focused on the conditions at the right rear corner of the premises and what they perceived as differential settlement. B-E began by focusing on the settlement at the right rear corner that needed to be monitored. He stated in his 2011 report, "to repair the settlement in the back corner… ." The HW-E continued that narrow focus, evaluating only the "differential settlement." The first two engineers identified the conditions at the right rear corner "differential settlement" and focused on repairing that corner of the home. None of them appeared to have asked themselves the true forensic question: "What is causing the movement?"

Even the O-E focused on stabilization and repair. In 2012, the O-E stated that, "significantly major foundation movement has occurred within the home…, this lateral movement is literally pulling the interior of the basement and main floors apart with majors [sic] cracks in the walls and ceilings, and [the] home is not structurally stable with ongoing structural movement. Significant repairs and reinforcement, along with an interior crawl space foundation drain will be required to stabilize the foundation and interior of the home."

O-E was the first engineer to make observations beyond the right rear corner. Although O-E acknowledged that the front foundation wall was moving, neither the safety of the building nor the occupants were addressed in O-E's opinions, nor was stating the obvious — that the wall had failed. In his subsequent report of August 2013, O-E opined, "The home continues to suffer significant and major ongoing movement. Although there does not appear to be any major failure in the structure at this time of this inspection, it demonstrates significant stress and movement that boarders [sic] on immanent [sic] structural failure. Time is now critical to the stability of this home and the safety of the owner and occupants."

There was no indication by O-E that the homeowner needed to have urgent concern about the safety and well-being of herself and her family and should leave — or, at the very least, consider leaving the premises. After that non-specific warning, O-E refocused on repairs.

It was a matter of significant forensic concern that none of these engineers seemed to comprehend that the front basement wall had failed. The fact that it had not yet collapsed did not mean that it had not already failed. The very fact that the basement wall supporting the front wall of the house had slid meant that the factor of safety was less than 1.0 from the outset.

B-E and HW-E focused only the right rear corner of the house. O-E recognized the movement of the front basement (crawl space) wall. All three engineers focused on remediation. Tunnel vision prevented all of them from recognizing the imminent threat to the safety of the owner and her family.

Review of the Subject Property

A-FE was retained in May 2014. Initial review found a wood-framed, single-family dwelling constructed on a full basement foundation system. Facing the south with the ground surface downgradient to the rear (north) of the lot, the street providing access to the property was approximately 4 feet above the main floor elevation. A constructed lake was situated along the northern property boundary approximately 25 feet below the street and 60 feet to the rear of the structure.

A sanitary sewer for the development extended across the rear yard — approximately 15 feet from the northwest (rear left) corner of the subject structure. Repair of the sanitary sewer was completed the previous month as a result of a 2-foot ground shift that separated the 8-inch PVC sewer line joint near the left rear corner of the home.

The front and left side yards presented as a "washboard" where the soil surface was folded with 2- to 3-inch wrinkles (**Figure 3**). Repairs to approximately 80 feet of the north side of the concrete paved street had been made, evidenced by the newer concrete appearance. However, the north side of the street, which was previously repaired, had moved to the north by approximately 1½ inches, and soils along the vehicle recovery area of the street cross section beyond the northern curb had settled approximately 12 inches at several locations on the subject property and the lot to the west. Damage to the replaced concrete street segment was observed at the eastern end of the repair along the curb.

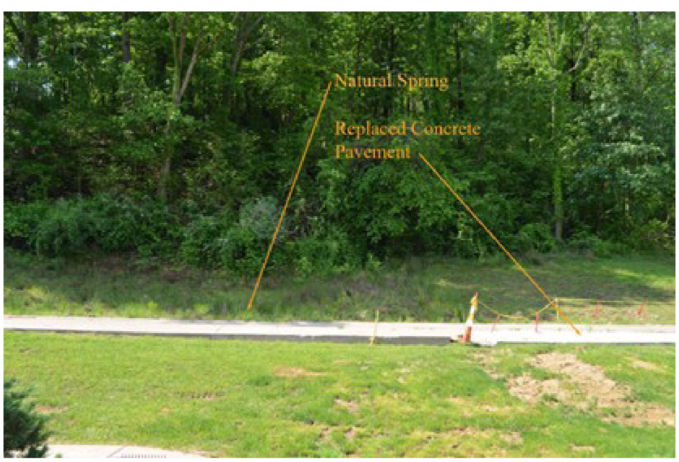

Figure 3
View of street and spring area at the southern boundary of the subject property from the front porch.

Water from a natural spring was found pooled in a depression across the street from the southwest corner of the subject structure. Water from the spring flowed westward approximately 45 feet in a poorly constructed swale before crossing via culvert under the street. A 6-inch water main extended with the street across the property frontage.

Because of previous experience with like properties in the area, A-FE was aware of problematic soils at the home site. It is this author's opinion that the local knowledge was beneficial to a more broad forensic approach in determination of the ultimate findings. A review of the soils conditions at the home site was conducted using the NRCS Web Soil Survey for the geographic location.

This review revealed that the site soils were of the Gilpin-Upshur (GRF) complex and Vandalia (VdD3) soil series that are fine-grained, well-drained soils with high plasticity indices and low strength and liquid limits on steep slopes (**Figure 4**)[6]. Gilpin-Upshur soils are clay loams, and Vandalia soils are loamy clays that each have high shrink-swell or linear extensibility characteristics. These soils are common on hillsides in the geographic region of the home and have a propensity for absorbing and retaining water that weakens the interior soil strength while increasing unit mass until failure as a debris flow-type landslide. The site was thus situated in a defined debris flow area. This activity should have been reviewed and the foundation/site conditions designed and constructed around the peril.

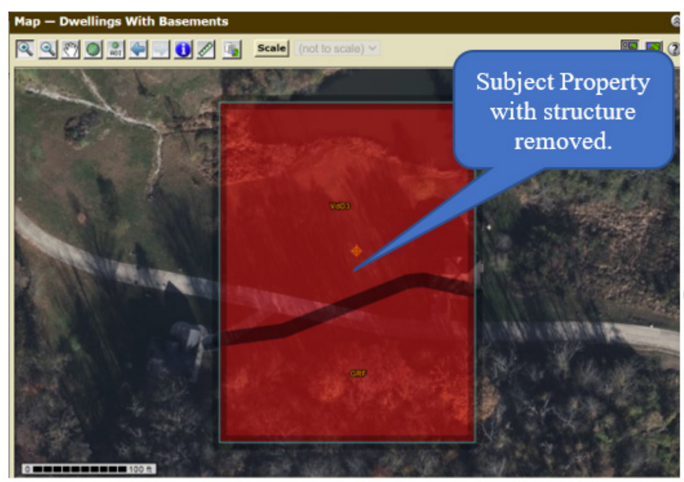

Figure 4
NRCS Web Soil Survey of soils on and around the subject parcel, "Soil Slippage Potential" hazard class "High" (red).
(U.S. Department of Agriculture, NRCS Web Soil Survey)

Wood platform framing techniques were used in constructing the home's structure. Due to the approximate 18-foot to 20-foot drop in elevation relief from the front street to back of the home, the walkout basement level floor system was constructed on a crawl space foundation with a platform framed floor system (**Figure 5**). The front basement (crawl-space) foundation wall utilized 12-inch concrete unit masonry on a poured concrete footing. Veneer masonry techniques were used to apply the brick exterior and construct the left and right basement walls. The crawl space floor was covered with a polyethylene vapor barrier.

The construction methods used resulted in an unbalanced load on the foundation system where the uphill foundation wall received the backfill equivalent fluid pressure, and the side walls provided active shear resistance. Based on the foundation configuration, the front foundation wall was under active conditions, and the lower walkout wall had to resist forces expressed through the structure with passive resistance — the pressure which the soil and wall developed in response to movement toward them.

Figure 5
Elevation relief from street to rear of home
was approximately 20 feet along left side.

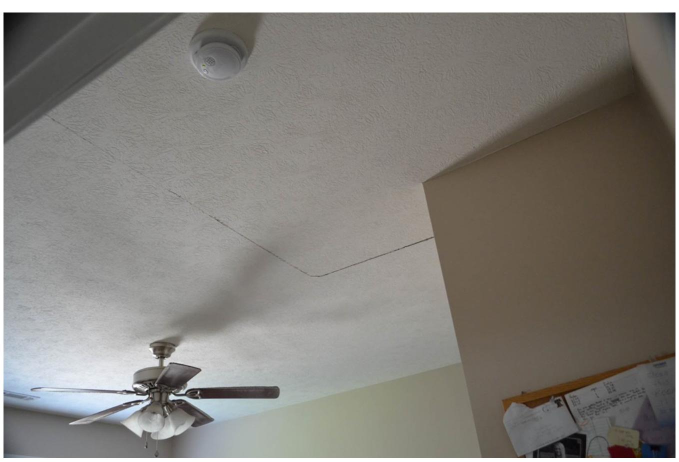

Figure 6
Ceiling of bedroom at right end of the structure with
gapping between joints in the drywall field; joints had
been previously repaired post-construction.

Cracking was observed in the drywall surfaces of the main level, particularly at the intersection of wall and ceiling surfaces, but occurred at most drywall joints in rooms on the right side of the structure (**Figure 6**). Walls extending left-to-right in the room were displaced rearward approximately ¾ inch at the base with drywall corner tape detached and stretched diagonally. The rear sashes of the front right bedroom's twinned window were broken out and filled with board insulation (**Figure 7**). Review of the window's exterior exhibited rearward displacement of the framed wall with an increased gap between aluminum frame at the front edge of 2 inches. The rear window frame jamb was distressed and distorted as the first level framing platform was forced rearward past the right side brick veneer.

Damage to the right side masonry veneer was not realized until viewing the right rear corner of the subject structure. Rearward movement of the wood framed basement level and main level floor platforms and associated rear wall framing fractured the brick veneer vertically at the corner and pushed the rear wall against the multi-level,

Figure 7
Right bedroom window jamb rolled beneath the right-side
brick masonry veneer, buckled window screen and board
insulation filling the sash space as protection against glass breakage.

wood-framed rear deck system. The structure of the wood deck system provided additional resistance to movement of the platform framing system toward the rear yard and lake (**Figure 8**).

Uneven gaps occurred at window and door openings of the rear wall plane. Doors of the rear elevation bound in their openings due to twisting of the jambs caused by movement of the structure.

Interior damages to the basement drywall surfaces resulted from rearward displacement of the front basement wall with vertical corners along the right side torn. Drywall applied to the right side wall remained generally in place while the drywall applied to lateral interior walls was drawn away from the corners by 2 or more inches.

The basement stair treads and risers connected the basement and main floor along the front basement wall. The front basement wall also provided foundation support for the rear garage wall. The stairway was twisted with an approximate 2-inch gap along the front foundation wall near the base (**Figure 9**). Though the garage foundation walls provided limited passive resistance to the active lateral pressure of the landslide soil bearing on the front wall, the passive resistance of the foundation and internal wood-framed structural system had succumbed and was succumbing to horizontal movement caused by the excessive active lateral pressure.

Distortion of interior doorways in the right half of the basement level was manifested as twisted door headers and jambs pinching the door leafs, causing binding of the doors. Floor elevations of the wood-framed basement floor were rippled under the compressive and torsional stresses from the front wall movement with variations exceeding 3 inches (either above or below level) in central floor areas of the right basement half; variations were less pronounced over the floor girders.

The front basement foundation wall included an offset in the medial region based on the room configuration and location of the front wall of the upper level. A divergent, tapering crack had developed in the inside corner between the front right wall segment and the rearward offset with an approximate $^1/_8$-inch gap at the top of the wall intersection and nearly ½ inch at basement floor level. The conditions indicated that the left wall was being pushed rearward at the base at a greater rate than the left segment with the opening crack, indicating that the central region of the basement retaining wall was forced rearward more

Figure 8
Right rear corner with vertical veneer fractured at the down-spout.

Figure 9
Lower stairway landing at the front foundation wall with an approximate 2-inch gap.

extensively than the left or right ends. The lower level floor system was being crushed as the front basement wall was twisted and forced back. Gaps between the floor sheating longitudinal butt joints caused each sheet's left corners to be tight against the front wall with the right edge of the sheathing ends gapped by approximately ¾ inch with the next sheet — a ratio of ¾:48.

Crawl Space Review

Basement level floor joists extended right to left and were found bowing in the crawl space — most notably along the right region of the home. The central floor girder supporting the right basement floor system was rotated with the top chord displaced to the right, the forward end forced out of the beam bearing pocket in the front block basement wall (**Figure 10**), and the wood fibers were crushed at the interface between joists and girder or the girder and piers.

Interior foundation piers in the right crawl space area leaned rearward approximately 2 inches, measured using a 29-inch level (**Figure 11**). Active water movement was observed beneath the polyethylene vapor barrier in the right crawl space region such that the soils of the floor were saturated, soft, and incapable of supporting load. As an example of the soil's condition, while gathering data, A-FE's knees sunk into the mud between 4 and 6 inches throughout most of the right side of the crawl space, while crawl space soil on the left remained reasonably firm and provided resistance to movement. The front foundation wall was broken at interior and exterior wall corners as well as vertical cracks in the field of the wall. Active water movement through the crawl space had eroded soil from beneath the rear foundation wall, leading to settlement in the foundation and breakage of the rear masonry wall and footing approximately 10 to 12 feet from the right rear corner below the lower deck.

Figure 10
Right-side floor system girder displaced from its bearing seat in the front foundation wall.

Figure 11
Right-side floor system pier measurement from plumb with active water surrounding the column.

Garage Observations

The effects of the structure's movement were exacerbated at the garage. Gaps between the driveway and structure caused by the foundation's lateral movement exceeded 3 inches to the left (west), away from the driveway and 1 inch rearward (**Figure 12**), were observed at the front corner along the right side of the garage. Caulking placed in the joints between the driveway and garage walls or floor was found torn and stretched. Inside the garage, a 1- to 1½-inch gap existed between the left and rear edges of the garage floor slab and adjacent foundation

Figure 12
Front right corner of structure at the garage with displacement of structure to the west manifested by gap with driveway and roof drainage down-spout leader connection.

walls (**Figure 13**). The gap at the garage door entrance increased from the rear jamb to the front jamb, indicating that the right-side masonry of the structure was somewhat restricted from movement as compared to the wood framing (**Figure 14**).

The drywall corner at the right rear of the garage was gapped by more than 1 inch, resulting from the living space and front foundation wall being moved away from the garage by the slipping front yard soil mass that extended beneath the garage. Electrical service to the property entered the right side underground with the distribution panel on the right garage wall at the right rear corner (**Figure 15**). Distribution wiring for the home extended from the panel through the corner to other areas of the home; condition of the wiring was not observable due to the wall finishes.

Figure 13
Garage floor separation of 1 to 1½ inches from rear and left foundation walls.

Figure 14
Front garage door jamb separation from brick masonry veneer because first level framing system was being forced rearward by connection to the front foundation wall.

Analysis of the Structure

Water from the spring upgradient from the subject structure provided constant water flow that had three cumulative consequences: increased the unit density of the restrained soil behind the foundation wall; reduced the internal friction of the soil structure; and increased hydrostatic pressure bearing on the front foundation wall. The home was not only forced rearward on its foundation but also rotated about the driveway retaining wall, generally at the right side based on the tapered gap between the garage floor slab and driveway slab (viewed north to south). Estimated movement by the structure was approximately 1 inch along the left side wall, approximately 3 to 4 inches of movement at the central region of the basement floor system, and 2 to 3 inches of movement rearward along the right side wall (**Figure 16**).

Considering all the observations and measurements of:

1. The separation of the garage floor from the adjacent foundation walls measuring more than 1 inch;

2. The separation of the garage from the concrete driveway;

3. Lateral movement measuring over 2 inches rearward of the first level platform framing along the right side wall in relation to the brick masonry;

4. The rear brick wall broken vertically at the corner as opposed to corbeled brick separation in the mortar joints about the right rear corner;

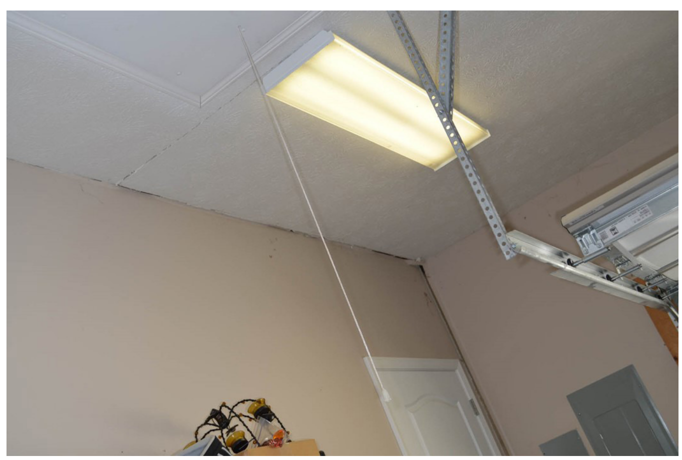

Figure 15
Right rear corner of the garage at the ceiling with displacement of structure manifest by gap with the ceiling and wall at the electrical distribution panel.

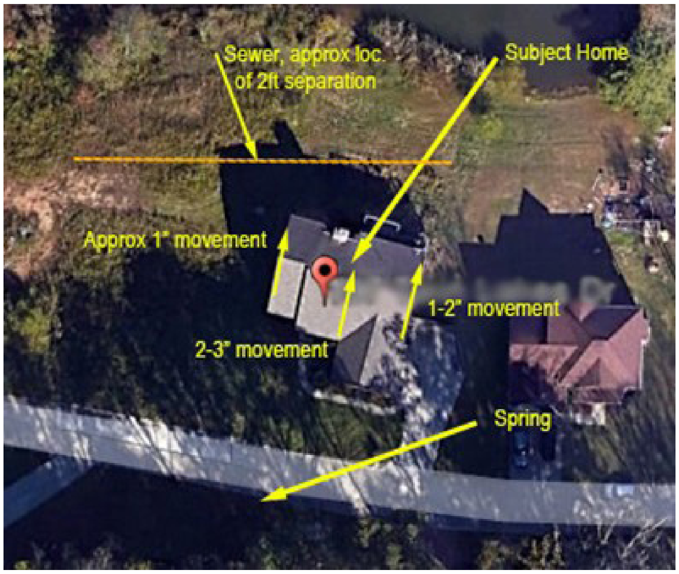

Figure 16
Site plan showing spring, street and lake in relation to structure and movement observations. (Aerial imagery from Map West Virginia, mapwv.gov)

5. Over 2½ inches of rearward displacement of the basement level framed floor system at the floor system girder support piers;

6. The distorted basement level floor system in the right half;

7. The extensive drywall damage with laterally stressed joint tears and gaps; and,

8. The tapered drywall joint cracks in the ceilings resulting from torsional stress,

the combination of movements demonstrated that the entire structure was enveloped in active soil mass movement. The manifestation was further that the home was resisting a debris flow landslide that, by their very nature, can result in catastrophic landslides that are sudden and deadly and capable of moving houses[7].

Since the front foundation wall was actively moving, the factor of safety was less than 1.0, based on the physical evidence — though a typical factor of safety for the design of retaining walls is 1.5 or greater for cohesionless backfill soils and 2.0 for cohesive backfill[8]. In the year following the initial visit and notification, the right side of the structure actively moved rearward over an additional 1½ inches.

Within the structure, the front basement wall (with the upper-level platform attached) was being driven rearward through the home and the rear wall of the structure. The wood deck system constructed at the rear of the structure and interior wall system of the basement level provided some additional resistance to total collapse of the structure. The two wood floor platform framing systems were also providing restraint against movement through the diaphragm effect across the field of the floor from end-to-end but were experiencing significant stress that extended beyond normal design parameters.

Structural support for the lower level platform was drastically reduced as the framing system was displaced by the differential sliding of the front foundation wall, and the tops of the supporting piers were driven rearward, causing point loading and localized fiber crushing of the wood girders as well as displacing supporting soils from beneath the pier footings. Basement floor joists were displaced and bowed from their installed alignment. The floor joist bowing and displacement resulted in undulation within the basement floor system with variations from level exceeding ±3 inches — values that exceeded acceptable deflections of L/360 under the loads applied for the nominal 13-foot span joists; deflection values of less than ½ inch would be acceptable under normal design loading. The central girder supporting the right side of the basement floor system was dislodged from its bearing in the front wall as the floor system slid and rotated.

Perpetual water movement through the crawl space was strong evidence that the natural spring affected a broad area, burdening the entire frontal region of the subject structure — not just the soil along the left side of the home. Water-inundated conditions of the crawl space floor weakened the soil structure sufficient to significantly minimize bearing support for the structure. Moreover, the supersaturated, soft, and yielding soil of the crawl space floor eliminated the possibility of using cribbing and shoring to provide safe work conditions for the workers conducting stabilization and/or remediation operations.

The rearward debris flow along the west side of the home caused a more than 2-foot lateral displacement in the sanitary sewer line just 15 feet away and downgradient from the northwest corner of the structure. Repair of the sewer occurred just a month before the site visit and was strong evidence that the debris flow was active. Northward movement of the northern half of the concrete street west of the home evidenced the head of the active slide area by the soil elevation drop and lateral concrete street displacement as compared to the southern half of the street.

The 6-inch water line serving the development followed the street and passed through the slip zone at or about the visible head of the landslide (at the center of the street) but geologically downgradient from the natural spring.

During the nighttime weather news of May 14, 2014, 1½ inches of precipitation was forecast to fall in the region of the home that triggered a series of questions for the author: (1) What if rainfall approaching 1½ inches fell on the development? (2) What if the 6-inch water line broke or separated? (3) What if the home's framing system ruptured?

The answers, which were terrifying, were: If 1½ inches of rain fell over most of the day, soil moisture content would be increased at the front of the home that would probably accelerate the debris flow along the west side of the home with the head extending across the street. Additionally, the soil moisture at the front of the home would increase the burden upon the already stressed front basement foundation wall and framing systems.

If the 6-inch water line in the street separated or broke in front of the home — much like the sewer line at the rear of the home had — water flow across the surface would increase the soil moisture content (already saturated to or near the liquid limit by the spring) at the separation site and within the front lawn of the home by two to five percentage points, enough to exceed the liquid limit of the soil since the natural spring provided continual wetting of the deeper, subsurface soils. Note: Liquid limit is the percentage of water contained in the soil whereby the soil changes from a liquid state to a plastic state based on the Atterburg Limits procedure, also known as the upper plastic limit. The resulting deep liquefaction could readily trigger a debris flow landslide, overwhelming the restraining capabilities of the foundation wall or structure.

If any component of the floor or rear deck framing systems ruptured or failed, a failure of any one of the components could probably trigger a chain reaction resulting in catastrophic failure and collapse of the structure; there would be nothing to resist the sliding movement of the front foundation wall and the retained soil with the house being pushed down the hillside in seconds.

Because the home:

1. Was directly involved in an active landslide;

2. Was moved, rotated, and damaged by the active landslide;

3. Was exhibiting significant and uncharacteristic stress within the wood framed structure that restrained added movement caused by the active landslide;

4. Could not be immediately stabilized safely;

5. Was downgradient from a 6-inch water line that passed through the active landslide area and would be subject to damage by the active landslide; and,

6. Was within a landslide that could be exacerbated by changes in environmental conditions.

collapse of the subject structure was probable, with the difference between possible and probable being that probable is that the statistical probability of an event occurring exceeds 50 percent. Because debris flow landslides can release suddenly without warning and are dangerous to life and property[7], the occupants were in immediate peril if they remained in the home. On the morning following the inspection, verbal notice was promptly given to the property owner's attorney of the determination of the structure's perilous conditions and of the threat to the occupants should they remain.

Verbal notice to the owner's attorney was promptly followed with a letter, which stated: "conditions in the home have deteriorated such that there is now an immediate danger to the life and health of the residents or occupants of the subject property. The health, safety and welfare of the home's occupants will be in peril when the structure, now deformed under severe stress and strain and resisting movement by an active landslide as well as being subjected to the effects imposed by differential settlement, succumbs. This home is unsafe for anyone to occupy for any purpose."

The letter described the observed conditions and hazards that existed and the probability of structural collapse. After the owner received notification from her attorney, she and her family immediately vacated the property. Had the owner not heeded the warning and vacated the property, this engineer had a duty to notify authorities having jurisdiction of the danger for the building occupants. It's not something you ponder; it's something you do as an engineer.

Despite the notice to vacate by the author, HW-E persisted in planning repairs to the home by contacting the writer, asking for recommendations for a contractor to assist. A letter responding to the request was sent in the days following that stated: “Unfortunately, I am not able to provide any recommendations pertaining to contracting firms who can stabilize this structure, without threatening the personal safety and well-being of their employees. Due to the level of instability observed during my visit on Wednesday, May 14, 2013, and the magnitude of movement induced stress within walls and each of the two wood framed floor platforms — manifest as bowed floor joists, displaced floor girders, twisted and shifted floor sheeting, and distorted wall surfaces and doors, to name a few — this home is unsafe for anyone to occupy the home for any purpose.” After receiving the letter, HW-E relented to the author’s findings, and the HWC paid the policy limits.

The engineers’ creed says, “as a professional engineer, I dedicate my professional knowledge and skill to the advancement and betterment of human welfare. I pledge to give the utmost of performance, to participate in none but honest enterprise, to live and work according to the laws of man and the highest standards of professional conduct, to place service before profit, the honor and standing of the profession before personal advantage, and the public welfare above other considerations. In humility and with need for Divine Guidance, I make this pledge[9].” We have to live the creed of the engineer and seek to protect life, health, and welfare first and foremost when evaluating a structure and faced with the question: “Should I notify the occupants to vacate?” We have to demonstrate concern for people more than property. Property can be replaced; people cannot.

Summary

During the four-plus years of occupancy, adverse conditions within the subject structure developed and deteriorated, ultimately presenting a threat to the life, safety, and welfare of occupants in the home and to the public visiting the property. The structure was constructed in an active landslide. It was being subjected to forces not considered in the design and to which it was not capable of restraining, resulting in the home being twisted and moved from its constructed location.

Engineers engaged by others to review conditions of the structure developed tunnel vision and focused on stabilization or repairs without comprehensively considering the structure’s stability and the safety of its occupants. The owner’s own engineer stated that the home was not structurally stable and presented options for stabilizing the structure; however, he did not, at that time, clearly indicate to the owner that there was an immediate threat to the health, safety, and welfare of the resident(s) or urge the owner to vacate to safety.

The notice issued to the owner’s attorney following the investigation of this home warned the occupants of a threat to their lives and stated that the home was unsafe for anyone to occupy for any purpose. The owner’s attorney notified the owner. Wisely, the owner and her family immediately vacated the premises. The notice continued to others unchanged, stated the peril, and urged others not to enter. Ultimately, the structure was razed. Had the attorney not notified the owner or had the owner not vacated, A-FE had an obligation to take further steps to protect the owner, her family, and other members of the public, including notifying authorities having jurisdiction.

Conclusions

For engineers applying their engineering training and science in design and construction of projects, experience is vital in developing critical thinking skills. These skills are needed in the field to systematically analyze process or system failures in order to safeguard life, health, and property and to promote the public welfare. Engineers must guard against focusing on a limited area or aspect of a problem without considering the entirety of the system, often known as “tunnel vision,” and must consider the whole system or structure in their evaluations.

Engineers must recognize when observed conditions in a structure or system threaten the life, safety, or welfare of the general public, the normal occupants, and those who might be engaged to effectuate repair. When engineers recognize such circumstances, they must give notice to all potentially at risk as a result of the imminent peril. Recognizing conditions that threaten to harm people requires engineers to broaden their perspectives, evaluate potential threats to the life, safety and welfare of the public, and consider the failure probabilities within the structure or system. When such threats are identified, the engineer must notify the client, occupants, and authorities having jurisdiction. When the question “Is the structure at risk?” is answered “yes,” then the engineer must recognize that the question “Should I give notice to vacate?” must also be answered “yes.”

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