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It's Not What You Pay; It's What It Costs You. A Geotechnical Engineering Case Study

J. Richard Cheeks
Stokley, Cheeks and Associates, Inc., Nicholasville, Kentucky

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IT'S NOT WHAT YOU PAY; IT'S WHAT IT COSTS YOU A GEOTECHNICAL ENGINEERING CASE STUDY

J. Richard Cheeks, P. E.
Stokley Cheeks and Associates, Inc.
Nicholasville, Kentucky - USA - 40356

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ABSTRACT

The project consists of a middle school constructed on a previously undeveloped site. Site development required leveling a mountain ridge and perimeter fills up to 150 feet deep to create the relatively level 15 acre building site. Access to the site required a 1000 foot long side hill road from the adjacent main highway. Neither the owner nor the design team obtained geotechnical investigations of the site. As a result, they failed to consider the impact of the geologic setting on seepage, ground water flow, and slope stability. Near the end of construction, slope instabilities occurred in a cut section of the entrance road and one of the major embankment sections. The owner, the county school board, hired the writer to determine the cause of the instabilities and provide testimony in their on going litigation. This paper summarizes the site conditions and project history, describes the writer's investigation, describes the dispute resolution processes, and presents two procedural lessons learned from the case; the importance of qualified professional geotechnical advice, and the inherent and sometimes unrecognized value of ADR procedures.

KEYWORDS

Geotechnical Engineering, Professional Practice, ADR, Litigation, Ethics, Colluvium, Failure, Faults, Seepage

INTRODUCTION

Geotechnical engineers make important contributions to the design and construction process for design fees typically less than 0.2 percent of construction cost. When properly used, geotechnical engineers save the owner many times more than the 0.2 percent fees by suggesting appropriate foundation systems and identifying subsurface conditions peculiar to the site that require attention during design and construction.

In this case, the design team undervalued geotechnical advice. One factor that possibly led to this attitude was that the building would be entirely rock supported in a major cut section. However, the conclusion that geotechnical engineering was not needed for this project was misguided and, as a result, critical subsurface conditions such as the seepage and historical landslide activity were not identified. These factors resulted in slope failures, protracted litigation, and damages estimated between $800,000 and $1,000,000.

SITE CONDITIONS AND GEOLOGIC SETTING

The owner selected the middle school site due to its proximity to the county's relatively new high school. The site is located in mountainous terrain. The mountain tops occur at elevations of approximately 2000 to 2300 feet Mean Sea Level (MSL), approximately 1000 feet above the major valleys. The original site grades ranged between 1450 feet MSL along the axis of the ridge at the north end of the site to 1220 feet MSL at the base of the ridge at the southern end.

Gently dipping beds of sandstone, shale, siltstone, coal and underclay of Pennsylvanian age underlie the site. There are two faults, first on the north end of the site, and second along the highway alignment east of the site. The first fault has experienced a relative displacement of about 160 feet, with the south side of the fault being up thrown. The east end of this fault intersects the second fault, a reverse fault with the west side up thrown. The relative displacement along the second fault is about 200 feet south of the first fault, and about 40 feet to the north. No faults in this region have been seismically active in recent geologic time.

The displacement at the first fault truncated water bearing sandstone and coal layers and blocked these zones with up thrown siltstone and shale units. This blockage and the gentle regional dip of about 400 to 500 feet per mile from the northwest into the fault cause seepage discharge at the fault and historic slope instabilities due to the seepage on the east slopes north of the fault.

DESIGN PHASE

In 1986, the owner hired the same architect who had designed the high school located on the opposite side of the highway. At the owner's suggestion, the architect hired a local civil engineer for the site development design including the grading, access road, and utility service from the property boundaries to the exterior building lines. The architect was responsible for the design of the structure, the paving and side walks.

As required by the owner/architect agreement, the architect asked the owner to provide a geotechnical report for the site. In response, the same local civil engineer offered to provide a soils report even though he had no geotechnical training or experience. The civil engineer's proposal to the owner included two test pits, two Standard Proctor compaction tests, determination of the soil bearing values, and a written report for a fee of $1,215. The owner submitted this proposal to the architect for his review and approval.

This work culminated in a one page, undated, unsigned report on plain paper (no letterhead) with two Standard Proctor laboratory compaction tests appended. The report tersely summarized the site geology. Regarding slope design, the report states,

> Similar materials were encountered and utilized in the construction of US25E and the ... County high school site. Since the adjacent construction sites are within the same geologic formation, it is felt by the engineer that cut and fill slopes previously utilized can be applied to this proposed site...

The report did not address important site specific geotechnical issues such as seepage, the existence of colluvium on the natural east slopes, the impact of the faulting on hydrogeology and slope stability, or special handling procedures for slaking shale used in the embankments. Furthermore, the report did not address common geotechnical engineering concerns of site preparation and construction monitoring such as proof rolling the subgrade, benching the sloping subgrade before embankment construction, fill placement, compaction, or compaction testing.

This project included cuts and fills totaling over 400,000 cubic yards of soil and rock. The excavated material was placed in fills around the perimeter of the ridge to balance quantities and produce a 15 acre building site. In addition, an access road was built on a side hill condition using 20 foot cuts and fills. Construction was divided into two phases. Phase I provided access to the site, site grading, and utility construction to the building. Phase II paved the access road and parking lot, and constructed the school building. The civil engineer developed the Phase I plans and specifications, but the architect issued these documents under the architect's name. The architect developed the Phase II plans and specifications. The owner hired two separate contractors.

The Phase I plans indicated 2:1 (Horizontal:Veritical) slopes for all fill and cut slopes in soil. However, the Phase I plans and specifications for the project contained several deficiencies. For example,

- there were no provisions for benching the natural slopes prior to placing fill
- there were no provisions for internal embankment drainage
- the specifications defined two earth materials, "Earth" and "Rock" However, the definition of "Earth" allowed the inclusion of large boulders as well as debris such as tree stumps, etc.
- the testing and monitoring requirements in the specifications were not adequately defined

PHASE I CONSTRUCTION

The Phase I contractor submitted a total of 31 field density test reports for the entire project. The first of these tests was performed on April 30, 1987, and the last of the tests was performed on June 5, 1987. However, filling continued on the site through August 1987, and most of the fill was untested.

The thirty-one field density tests are inadequate for a project having 400,000 cubic yards of fill. Furthermore, of the 31 tests, improper testing procedures were used for many, an inappropriately low Proctor density was applied to the field densities, and no retests were performed after obtaining failing test results. About two thirds of the tests are either unbelievable or indicate inadequate dry density. For example, some of the reported test results had a combination of dry density and moisture content that plot above the zero air voids curve in a range that can not occur in nature.

The Phase I contractor observed seepage in a major fill area near the first fault. The contractor had already placed a considerable volume of fill in the area before observing the seepage. The civil engineer did not conduct any investigation of the seepage to determine its source or extent. None the less, he directed the contractor to install a drain to collect water from the actively seeping area. However, the drain discharged the water onto the face of the previously placed embankment slope and only collected water from the single point source that had been observed.

On August 8, 1987, the Phase I contractor reported a landslide had started along the entrance road and requested a plan to resolve the slide problem. However, he received no response, and before demobilizing, he regraded and revegetated the slide area, ending Phase I.

ACCESS ROAD LANDSLIDE

The slide at the entrance road noted previously by the Phase I contractor began to move again in June 1988. This landslide is not related to the Phase II contractor or activity except that it occurred during Phase II construction. Without determining the cause of the slide or the subsurface conditions at the slide area, the design team proposed a 200 foot long cantelevered retaining wall to stabilize the road slide area. The retaining wall "design" specified a rock supported footing with a shear key. Anchors, 3 feet long and 1 inch in diameter, extend out of the shear key into the rock. The remedial plan also specified the total removal of the soil to rock 15 feet behind the wall. This 1500 cubic yard excavation would be backfilled with cyclopean durable rock material. Upon completion, the reconstructed slope behind the wall would be a maximum 2:1 inclination.

Implementation of this remedial program began in September 1988. By late October, the contractor determined that the depth to rock along the wall footing was neither uniform nor at the assumed elevation. In January 1989, just after the wall was completed, new movements occurred in and next to the original slide area. These new movements damaged the wall and broke a water main. The movements also placed an existing natural gas transmission line located just above the active slide area at risk, and the gas company relocated the main to reduce the risk of rupture. The Phase II contractor responded to these problems by calling for an engineering review of the slide conditions to determine its cause and develop appropriate corrective active plans.

In mid February 1989, a geotechnical firm provided a proposal to evaluate the landslide and develop recommendations for corrective action. The proposal represented a typical geotechnical approach to characterize the soil, rock and ground water conditions with borings, observation wells, laboratory tests and analysis culminating in a written report. The estimated fee for this work was $13,600.

The Phase II contractor had employed a local grading subcontractor on the project to implement the original corrective action plan. Upon learning about the geotechnical proposal to investigate the slide, this subcontractor wrote the owner and, in part, said,

> It is my understanding that a geotechnical firm offered a proposal for drilling the area at a cost of approximately $13,000.00. I believe we can find an explanation for less expense.

The subcontractor circumvented the usual job communication protocol by writing directly to the owner and bypassing the Phase II contractor. Furthermore, the subcontractor's message was in direct conflict with the Phase II contractor's recommendation to perform the geotechnical analyses before doing any additional work on the slide. The owner never authorized the geotechnical study of the slide.

The subcontractor worked with the owner and the design team by continuing to excavate the slide material over the next six months. These activities caused the movements to spread up the slope and into adjacent areas of the slope. By the following October, the subcontractor reports removing over 15,000 cubic yards of soil and rock from the slope area with about 13,000 cubic yards of crushed rock required to finish the work. By this time, the subcontractor declared bankruptcy, and the owner finished the work with its own resources

PARKING LOT LANDSLIDE

In April 1989, embankment failure occurred near the first fault again placing the natural gas transmission line located just below the active slide area at risk. The gas company relocated the line to reduce the risk of rupture. The civil engineer stated that he was unable to determine the cause or total extent of the slide. About 11 days later, the civil engineer notified the Phase II contractor of this new slide and demanded the Phase II contractor's immediate attention. The Phase II contractor responded by reminding the civil engineer that "it is difficult to understand how work can go on if you don't know what is required."

On May 24, 1989, the architect directed the civil engineer to "proceed with haste in contacting" the same geotechnical firm that had prepared the proposal to evaluate the access road slide. On May 31, 1989, a principal of the geotechnical firm visited the site to observe the conditions. On June 5, 1989, he submitted a proposal to the owner in care of the civil engineer. On June 19, 1989, the civil engineer met with a second geotechnical firm. On June 21, 1989, this second firm submitted a proposal to evaluate the parking lot slide. The first firm's proposal was for about $20,000 and the second firm's proposal was for approximately $30,000.

While the civil engineer was still obtaining the geotechnical engineering proposals, he was also soliciting quotes to repair the new slide area from the local grading subcontractor mentioned previously. On June 21, 1989, the local subcontractor bid $35,900 to repair the slide. On June 22, 1989, the Owner "put on hold any actions on" the parking lot slide or the geotechnical evaluations of the slide. However, on July 6, 1989, the civil engineer met at the site with a technician employed by a third geotechnical engineering firm. Subsequently, this third firm drilled eleven (11) auger borings into the slide area. This work culminated in a written report on August 4, 1989. If one compares the scope of work performed by the third firm to the scopes of work proposed by the first two firms, clearly the third firm performed a greatly reduced scope limited to the auger borings and a report of the findings.

These borings encountered wood fragments at several locations. Furthermore, the fill material was very wet and consisted of a mixture of soil and weathered shale. Standard Penetration Test N Values within the fill zone ranged from 1 to 20 blows per foot. Given that rock fragments and other obstructions within the fill distorted these test results upward, one can conclude that the phase I contractor had not adequately compacted the fill. This report concluded that seepage within the fill was the basic cause of the failure. However, the lack of compaction, the absence of stability benches, and the burial of trees and other similar materials near the toe of the slope also contributed to the failure.

As noted above, the specification defines "Earth" as "dirt, debris, loose rock of one cubic yard or less, soft rock or other materials which can be removed by hard (sic hand) tools, power tools or by ripping with a bulldozer." It should not be surprising that borings drilled into the failed embankment encountered wood fragments. The civil engineer then admitted that he had allowed the contractor to bury trees, stumps and related matter in the toe area.

The civil engineer developed a corrective action plan for the parking lot slide based upon the third geotechnical engineer's boring data and report. This plan specified the complete reconstruction of the failed embankment to restore the site to its original design configuration. However, the engineer's construction cost estimate for the work was about $410,000, and the owner directed a redesign to reduce the cost. The redesign included the removal of the fill material from within the failure zone, regrading the area on 2:1 slopes with benches every 40 to 50 feet in elevation, and the installation of horizontal drains on each bench to relieve the seepage pressures. This revised approach reduced the size of the parking lot. The owner initiated litigation and bid this remedial work in the spring of 1990. The contractor completed the project in early 1991 at a cost of $219,000. In spite of these efforts, slope movements continue to occur in this area.

WRITER INVESTIGATES SLOPE INSTABILITIES

The owner's lawyer contacted the author in June 1990 to observe the landslides and determine their cause, and provide testimony in their litigation. Initially, the writer reviewed the project documentation and the various geotechnical proposals and reports. The author then conducted an independent investigation of the access road slide, the parking lot slide, and the general stability of the colluvial mountain slopes.

The investigation included twenty-one (21) borings that determined the range of subsurface conditions. The author drilled these borings according to ASTM D-1586 using hollow [illegible]

bedrock and verify its nature and continuity. At several of the boring locations, the author converted the bore holes to standpipe monitoring wells and slope inclinometers. The author also established a lateral movement monitoring program by setting surface points along the crest of the reconstructed parking lot slide area. The report addressed:

- the range of thickness and engineering properties of the colluvium on the natural slopes,
- the location of the phreatic surface within the colluvium and embankments,
- the geometry of the natural and as built slopes,
- the Standard Penetration Resistance of the colluvium and compacted fill materials,
- the probable cause of the slope failures,
- estimates of slope safety factors, and
- recommendations for remedial construction.

DISCUSSION OF THE CASE

The owner, designers, and contractors designed and built the middle school project without the benefit of geotechnical or geologic engineering. In addition, the attempts to correct the various slides during and after the construction period were done without the benefit of geotechnical engineering. As a result, the parties never understood the subsurface conditions including but not limited to the following oversights.

- The types of material that would be encountered in the excavations and their engineering properties were not determined.
- The existence and significance of the colluvium on the existing slopes was missed.
- The specified handling, placement and compaction criteria for the major fills were unacceptable for the soil or shale that represent the vast majority of fill constituents.
- The natural slopes were not benched prior to fill placement.
- Internal drainage provisions were not included in the design of the embankments and field attempts to control seepage discharge were inadequate.
- Attempts to correct the landslides were done without determining the subsurface conditions or the cause of the slides, and, as a result, the repair attempts failed.

Throughout this process, the owner incurred financial obligations to construct the retaining wall, to relocate the natural gas transmission line, to reconstruct the parking lot slide, and to repair the access road slide. Total estimated damages were $800,000 to $1,000,000. In the writer's

From a technical perspective, the seepage from the sandstone and coal beds along and north of the fault line produced a high phreatic surface within the embankment and natural slopes that reduced the safety factors sufficiently to cause failure. However, the owner and design team chose not to seek qualified geotechnical advice during design, construction, or after the landslides developed. This general lack of regard for geotechnical engineering constitutes the primary procedural shortcoming that produced the failures.

LITIGATION RESULTS

The owner initiated litigation in this case in the spring of 1990. The complaint named the Phase I and Phase II contractors, the architect, and the civil engineer as defendants. Discovery lasted about 5 years. During this period, the civil engineer's office burned and all of his project files were lost. The civil engineer also died unexpectedly, leaving his mining engineer partner to defend the suit.

In the summer of 1994, the parties attempted to resolve this dispute through mediation. During the mediation, the defendants agreed to pay about \$120,000 directly to the natural gas company for the gas transmission line relocations. After this extended day of mediation, subsequent attempts to settle the remaining elements of the case were unsuccessful, and the case went to trial in February, 1995.

The jury trial began in the county seat of the owner school board. In their opening statements, the owner argued that he had hired design and construction professionals and trusted them to perform properly. He further argued that the failures clearly demonstrated their respective negligence. The architect argued that the slope failures were unrelated to the architect's responsibilities on the project. The deceased civil engineer's partner argued that the services his former partner had provided were consistent with generally accepted engineering practice. The Phase I contractor argued that he followed the plans and specifications and the design was deficient. The Phase II contractor argued that he had no responsibility for the failures or the expansion of the failure area during the owner and design team mandated repair attempts.

While the first witness was giving testimony, a juror's family member became ill, causing the trial to recess for one day. During this recess, the parties settled the remaining elements of the case for \$500,000. The writer is not aware of the relative contributions to this settlement by the various defendants.

This litigation took five years to resolve and cost the parties substantial sums. Considering the limited information available to the author, the owner's litigation costs were probably over \$200,000. The defendants each mounted substantial defenses that included expert consultation and deposition testimony. The total combined litigation costs for this case probably exceeded \$400,000.

LESSONS LEARNED

Engineers Should Only Work In Their Areas of Expertise

Of course, this should go without saying. All engineering codes of ethics familiar to the writer clearly restrain engineers from offering to work outside their areas of expertise. However, as this case clearly illustrates, some design professionals do offer to provide services beyond their training and experience. Owners, who often have no technical background, have a right to rely upon the professional engineer's ethical compliance and thereby trust that the engineer has the requisite experience and training to provide all offered services.

In our example, the owner had a bias in favor of working with the local engineer if possible. Local tax dollars spent with local businesses; a widely held political view. However, the owner certainly wanted sound, reliable advice from any professional working on the project. The owner urged the architect to include the local civil engineer on the design team. However, from the architect's perspective, this simple request implicitly meant that the owner would probably hire an architect who would agree to hire the local engineer. Therefore, the architect complied with the owner's request and placed the local engineer on the design team.

The local engineer may have had the required experience and training to provide the specific design services assigned to him by the architect. However, the same engineer also offered to provide the required geotechnical services even though the local civil engineer was clearly not qualified to provide geotechnical engineering services. However, the architect continued to feel the owner's pressure and, as a result, failed to indicate that the owner should hire a qualified geotechnical engineer to conduct the subsurface investigation instead of the local civil engineer.

The owner forwarded the local engineer's proposal for the soils report to the architect for his review and advice. The owner wanted the architect's counsel because the architect had specifically invoked the owner's obligation to provide a soils report to the design team under the terms of the owner/architect agreement. This act by the owner created a related duty for the architect to use his expertise and experience in assessing the proposal's adequacy. The architect responded with a written approval.

This particular architect was nearing the end his career. Over the years, he had many opportunities to review geotechnical proposals and reports, and to interact with practicing geotechnical engineers. He either knew or should have known that the proposal submitted for his review was inadequate. Furthermore, when the engineer submitted the "soils report", its inadequacy was apparent on its face. However, the architect decided not to advise the owner that the proposal and the report were inadequate and inconsistent with geotechnical work.

Do Not Be Discouraged If Early Pre-Trial Settlement Attempts Appear To Fail

Construction industry disputes usually involve complex issues, large amounts of money, and multiple parties. These factors can magnify the disputants' differences and discourage any face to face discussions. As a direct result, they place greater reliance upon their lawyers and sometimes their experts to resolve the matter on the disputant's behalf. However, the lawyers tend to adopt the adversarial postures required for litigation, and these positions are not consistent with the conciliatory approach that is usually required to achieve a fair out of court settlement.

Furthermore, the disputants, whether they are owners, design professionals or construction professionals, tend to view the issues from their unique perspectives. Their narrow vision limits their ability to seriously consider the validity of the opposing views. For example, at the end of this dispute, neither the owner nor the architect was able to admit their respective contributions to the overall problem even though the decision to hire the local civil engineer for the geotechnical work clearly set the gears of failure into motion. The owner was not able to understand that his early intervention on behalf of the local engineer applied undue pressure on the architect. Likewise, the architect could not admit that he had yielded to this pressure in the face of an inadequate geotechnical study.

Alternatives to the process driven and adversarial litigation/binding arbitration can often overcome the obstacles to communication and reasoning by introducing a neutral party into the discussions. The neutral party listens to each disputant's position, distills the core issues in dispute, and forces each disputant to seriously address the opposing views. While mediation or other ADR processes may not resolve the case during the allotted time, the disputants will usually leave the process with a better understanding of not only their positions, but those of the other parties as well. As the trial date approaches, the parties frequently settle virtually on the court house steps. These 11th hour resolutions have often grown from previous "unsuccessful" settlement discussions.

Mediation, Mediation/Arbitration, and other ADR procedures should be implemented by the disputants as soon as possible. Even if early attempts to resolve the dispute appear to fail, the parties should continue to explore every possible avenue to resolve their differences before engaging an adversarial process. Even then, the parties should be receptive to any attempt to settle throughout discovery.

Experience suggests that over ninety percent of all construction disputes are settled prior to trial or arbitration. Furthermore, data suggests that of the money consumed by these disputes, about two thirds is spent on lawyers, experts, discovery, and other related systemic costs. Only about one third of the money is available to "fix" the problems. In this case, the writer estimates that the owner spent about $200,000 or more to obtain the $620,000 +/- settlement paid to the plaintiffs,. The various defendants probably spent another $200,000 or more in litigation expenses. Therefore, total settlement and dispute resolution costs of $1,020,000 or higher were incurred, and at the end of the day, the owner netted about $420,000 or less to apply to the $800,000 to $1,000,000 estimated damages.

CLOSURE

The design team and owner can only determine an appropriate level of geotechnical service after discussing the geotechnically significant project parameters with an experienced geotechnical engineer. Then the geotechnical engineer can fully discuss the risks and provide recommendations for exploration, testing, and analyses to determine the significant subsurface conditions and develop a written report that provides engineering recommendations for design and construction to mitigate against the risks. The bottom line is that a geotechnical engineer should be included on the design team early during design for any project involving earth supported structures or earth construction.

When no geotechnical advice is obtained, or inexperienced engineers attempt geotechnical engineering, significant site and subsurface conditions often remain undetected. As in this case, these unidentified conditions often become known during or after construction, resulting in project delays, failure of project structures, increased construction costs, damages to third parties, and allegations of negligence.

The decision in this case to try saving the $10,000 to $20,000 that may have been required for a design phase geotechnical evaluation resulted in $800,000 to $1,000,000 in estimated damages and litigation costs totalling over $400,000. The failure to have construction monitoring and testing by an experienced geotechnical engineer during the earthwork resulted in a major embankment failure and important site conditions being misunderstood. The decision to attempt the landslide repairs without investing the $13,000 and $20,000 to determine the causes of the failures resulted in unsuccessful and more costly repairs. This project proves the old adage,

It's not what you pay; it's what it costs you.