ENGINEERING APPROACH TO RESPONSIBILITY FOR UNEXPECTED PROBLEMS IN FOUNDATIONS

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1. Introduction

1.1 *Example of the Unexpected*

About 1955 a developer-builder purchased several acres of urban land previously occupied by a dairy. Much of the land was known to be old fill placed at irregular intervals without engineering supervision, most during the previous 10 years. One layer consisted largely of boulders from ½ to 10 tons, wasted from blasting granite in a cut in the adjoining freeway. The boulders were covered by 10 to 15 ft of silty clay (also from the freeway cuts) which had been compacted haphazardly by the earth-hauling equipment. Shortly afterwards, the area was paved to make a parking lot for the dairy delivery trucks. Although the loads were light and the parking area only a few years old at the time the land was sold, there was no evidence of pavement distress other than a few inches of irregular settlement.

The new owner (the developer-builder) erected several light buildings on the site. No soil borings were made because his designer felt that the buildings were so light and their construction so simple that an investigation was not justified. One building was a one-story wall-bearing brick warehouse-office; another was an open shed with a bar joist roof for protecting light trucks from weather.

The structures performed reasonably well for about six years. Some of the brick walls developed diagonal cracking, but these were easily repaired by caulking. One day, without warning, one of the footings settled more than 1 ft. It was removed revealing an irregular chimney-like hole beneath. Several cu yd of concrete were required to fill the hole after which the footing was rebuilt. The only unusual condition noted was that the settlement followed several periods of short, but very intense, rain.

A few weeks later, the wall of the warehouse-office (35 ft north) began to settle several inches and tilt outward. The wall was shored up with diagonal braces until it could be rebuilt. Two days later it was beyond repair. A hole 35 ft wide and 45 ft long appeared as shown in cross-section in Fig. 1. The warehouse wall collapsed into the hole, which resembled a bomb crater. In the hole bottom was water and the dim outline of a 14 ft brick sewer. The

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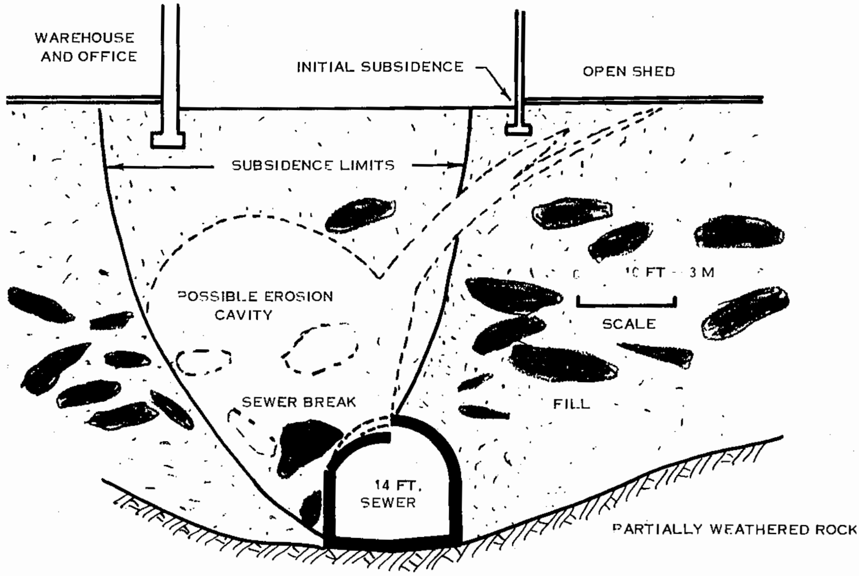


SUBSIDENCE OVER A 14 FT. TRUNK SEWER UNDER 45 FT. FILL

Figure 1 — Ground subsidence and building failure produced by collapse of a cavity generated by a damaged sewer flowing under pressure

collapse and hole appeared a few hours after an extremely intense rain that overloaded the storm drainage and flooded streets.

The failure was caused by erosion of soil into the 50-year old sewer. It was plain concrete designed only for a nominal soil cover. It was laid in an old narrow creek valley, then partially covered with soil and cinders shortly after it was built. Although the City had obtained a sewer easement before construction, it had failed to record it on the property deed. The dairy, which bought the land a decade later, was only vaguely aware of a sewer; its size and exact location had been forgotten. Thirty-five years later the ravine was filled with the boulder and soil waste and the surface leveled for parking. By that time, the sewer had been entirely forgotten. The developer-builder, who finally purchased the site, was unaware of any boulders or sewer.

The sewer had cracked from 45 ft of soil and rock cover it had never been designed to support. One boulder had punched into the old fill and had forced in a part of the crown. The sewer was far too small for the storm water loads which had increased with the increase in street and building density after a half-century of urban development. During storms the sewer water surged upward 10 to 20 ft into the fill softening the soil. After the flow subsided, the softened soil eroded through the sewer cracks and was carried away. A dome-shaped cavity developed in the soil, probably with "fingers" stretching upward. The hole found under the shed footing was probably such an extension of the main cavity. Eventually, the cavity roof became so thin that it fell in.

The total cost of sewer repair and building damage was $750,000. The warehouse occupant went bankrupt because his loss of stock prevented him from serving customers. Who was responsible? — the City?; the deceased attorney who forgot to record the easement?; the deceased sewer designer who should have anticipated future fill in the old ravine and who should have made the sewer large enough to handle future storm flow?; the excavation contractor who dumped the rock that forced in the sewer wall?; the old dairy that authorized the rock disposal in the ravine?; the development builder who built without borings?; the developer's architect-engineer who designed the buildings without knowing what was under them?; or God who is held responsible when all else disclaim their liability? Even the City's present sewer department must be included. A 14-ft main sewer 50 years old should be inspected periodically and any defects corrected. Few structures can survive that long without maintenance.

Those who were initially responsible for the sewer design and construction were dead. Neither they nor God were likely to pay. The developer-builder finally reached a financial settlement with the City; the warehouse operator began a fresh start elsewhere. All paid for the failure; none was satisfied with the settlement, but they had no reasonable alternatives.

1.2 *The Complexity of Responsibility for the Unexpected*

Although this case history may not be typical, it illustrates the complexity of the circumstances surrounding the unexpected in underground construction. Above the ground, construction problems are more visible. The builder generally constructs that which is above ground; he should know what is there. If something goes wrong, it usually can be seen before it becomes catastrophic and often corrected with limited expense. By way of contrast, the soil and rock at a site are generally pre-constructed; further their Creator may not be accountable to the owner, designer, contractor and user who eventually become involved with site problems. Those problems are likely to be more critical than those in the buildings above because if a foundation fails, all else above it fails.

The example illustrates the delayed effect of the unexpected conditions. The sewer failure was built into it 60 years before its collapse. Aggravating factors were literally added throughout its life. The final cause was a torrential rain (an act of God), but failure was the climax of all the past mistakes.

The effect of unknowns in foundation construction can be felt throughout a project. Structural changes may be required, job momentum is lost and scheduling is disrupted. The total cost of the unknown often exceeds the cost of correcting the unknown itself many times. The extra cost of a sewer strong enough to support the 45 ft of cover placed on it would have been a fraction of the cost of failure. The cost of borings to define the site conditions before building the warehouse would not have been one percent of the cost of the collapse.

The legal entanglements resulting from unknowns can be devastating. In the example cited, the attorneys involved reached a settlement out of court; the time and cost of litigation to fix responsibility, with all the poorly-defined legal positions of the various parties, might have been worse than the damage suffered. This example illustrates the usual feeling of frustration when unforeseen costs must be paid for by someone; those who are really responsible may not be able to pay; those who suffer may never be fully repaid.

1.3 *Dimensions of the Problem of Unknowns*

There are two dimensions to any problem involving unknown conditions:

1. Why was the condition unknown? Were parsimony, ignorance, inexperience or stupidity responsible?
2. Who should pay for the extra costs involved? Owners blame the architect-engineer and the contractor. The engineer blames the owner and the contractor. The contractor blames the engineer and the owner. All three may blame God and rarely does anyone but the attorneys gain anything (and statistically even the attorneys can be right only half of the time).

It is the purpose of this paper to examine the reasons for the unexpected in foundation construction and to suggest how the unknowns and the costs resulting from them can be minimized and how those costs can be paid most equitably.

2. Causes of the Unexpected

2.1 *Technical Causes*

From the technical point of view, it might be argued that nothing need be unexpected. In fact, most of the failures due to the "unexpected" that the author has investigated might have been foreseen had enough time, effort and intelligent evaluation been spent in advance. However, all three are always limited by job circumstances. The problem of why conditions were unexpected can usually be traced to some insufficiency. Table I is a reminder of the complexity of the problem.

TABLE 1 — CAUSE AND RESPONSIBILITY OF UNEXPECTED

CAUSE	RESPONSIBILITY			
	OWNER	A/E	CONTRACTOR	OCCUPANT
1. INSUFFICIENT DATA ON SOIL, ROCK				
A. Lack of time	1	2	3	—
B. Lack of money	1	2	3	—
2. WITHHOLDING OF DATA				
A. Lack of records from previous construction or investigations	1	2	—	1
B. Willful attempt to mislead in order to obtain a cheaper job	1	1,2	—	—
3. ERRORS IN DATA				
A. Location (survey) errors		1	2*	—
B. Poor investigative work	2	1	2*	—
4. IMPROPER INTERPRETATION OF DATA				
A. Lack of geologic background		1	2	—
B. Lack of local experience		1	2	—
C. Failure to consider alternatives		1	2	—
5. BAD DESIGN OF STRUCTURE				
A. Failure to fit site conditions	3	1	2**	2
B. Impossible to build	3	1	2**	—
6. POOR CONSTRUCTION				
A. Ignorance — inexperience in region inexperience in methods	3	2	1	—
B. Over optimism	3	2	1	—
C. Inadequate Design (temporary structures, contractor options)	3	2	1	—
D. Poor Workmanship or failure to follow plans	3	2	1	—
E. Failure to react to conditions	—	2	1	—
F. Inadequate Records	—	2	1	1
G. Faulty Materials	1***, 3	2	1	—

RATING SIGNIFICANCE: 1 = Major responsibility
2 = Secondary responsibility
3 = Little responsibility, but possibly some influence

***May furnish materials by separate purchase
**Should recognize problem if experienced
*Responsible for investigations involving special design for which only contractor is responsible

2.2 *Complicating Factors*

As can be seen in Table 1, the problems are complex. Moreover, there are few instances where any of the parties is solely to blame. However, the problems are often compounded, as shown in Table 2.

Table 2 — Response to the Unexpected

1. Failure to recognize that an unexpected condition exists: The ostrich syndrome.
2. Hiding an unexpected condition so that the other parties do not find out in time to fix responsibility.
3. Shifting the blame to some other party.

All three involve the response to an unexpected condition. Usually, if recognized early, the design or construction can be modified so that the problem is overcome with little added time or expense. On the other hand, the unexpected is too often ignored by the engineer who fears a claim or by the contractor who hopes it will disappear. Usually both are disappointed. A condition that could not have been expected on the basis of valid experience and a reasonable site evaluation deserves special consideration and often added compensation. It rarely goes away and often gets worse with time until irreversible damage has been done.

Unfortunately, a few irresponsible contractors use an unexpected condition as an excuse for everything that goes astray on the job. A claim for changed conditions is escalated to cover all losses because the others may be more difficult to prove. Thus, every situation must be studied promptly, in detail, by all concerned, in as objective a manner as possible. Even more important, prompt action is essential before the problem becomes a disaster.

3. Case Histories of Unexpected conditions

A few examples illustrate the complexities of the real problem, including the personal and sometimes unreasonable actions of those involved.

3.1 *Obstructions*

Many sites are underlain by natural and manmade obstructions that interfere with construction. Boulders in deposited soils, boulder-like seams in residual soils and debris in fill can obstruct excavation and damage piling. Some examples are shown in Fig. 2. Fig. 2a shows boulder-like bodies of unweathered granite within a mass of more completely weathered granite that has become a silty, sandy residual soil. In one case, the unprotected tips of H-piles were badly crumpled as shown in Fig. 2b when they hit the boulders. In a deep excavation, H-section soldier piles were deflected into sweeping curves as shown in Fig. 2c. Rubble in old fill can have similar

Figure 2 — Underground obstructions and their effects

Figure 2a — Boulder-like masses of partially weathered granite in a residual soil in Georgia

Figure 2b — Wrinkled H-pile tip, caused by absence of reinforcement

Figure 2c — H-pile bent by boulder-like mass of partially weathered rock

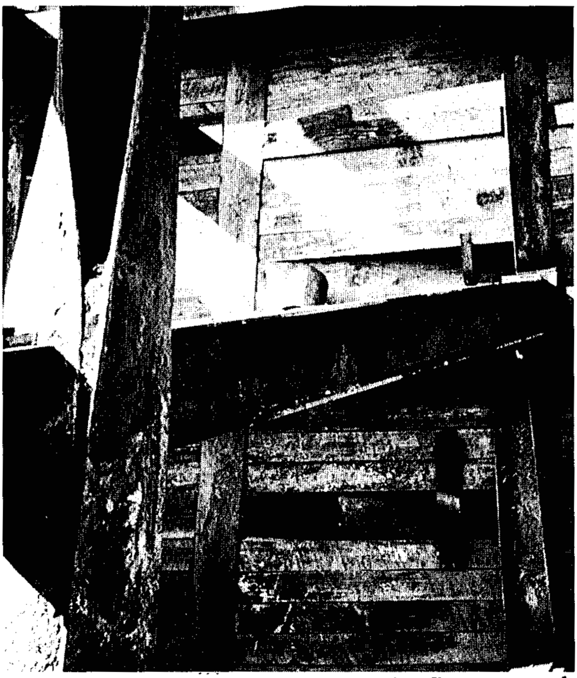
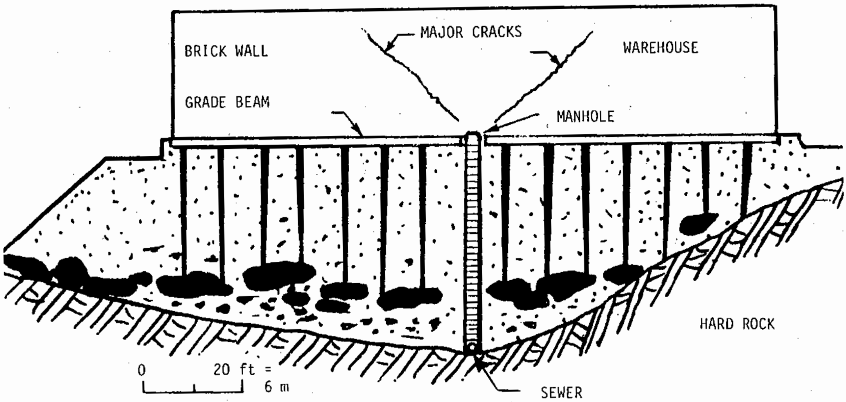


Figure 2d — H-pile twisted until opposite flanges touch due to rubble in fill effects. Fig. 2d shows an H-pile badly twisted by old masonry so that the opposite flanges touch.

The geology or history of a site, plus intensive investigation, can disclose the presence of possible obstructions. It is unlikely that their total impact on job cost and time can be determined in advance. However, the problems can be minimized by both design and good construction techniques (pre-drilling piles past obstructions or pile tip reinforcement).

One of the strongest arguments advanced in favor of design-construct or "turnkey" projects is the close coordination between the engineer and the builder and the undivided responsibility. However, this is no more true of that form of contract than the traditional form of independent design and construction contracts as Fig. 3 shows.



DIFFERENTIAL SETTLEMENT OF WAREHOUSE SUPPORTED
ON WOOD PILES DRIVEN ONTO BOULDER LAYER IN FILL

Figure 3 — Building settlement due to pile tips supported on boulders within a fill

The site was a broad ravine underlain by shallow rock. A trunk sewer was laid on the rock with 45-ft manholes in anticipation of filling for a new warehouse. The contractor-designer cut an adjoining hillside and placed the rock and soil he excavated above the sewer: First, a layer of soil to protect the sewer, then a layer of irregular boulders and, finally, soil to provide uniform support for the warehouse floor. According to his court testimony, when the owner sued him for a faulty building, he "even compacted the soil with a big sheepherder". His designer required piles driven to refusal on rock to support the building walls and columns because he was suspicious of the quality of fill construction.

Within a year, the end of the building had cracked badly with the manhole providing the most rigid support. Twenty-four-in. diameter auger holes were drilled adjacent to several of the wood piles. The tip of each rested on a boulder 10 to 15 ft above bedrock. A comparison of the engineer's record of pile lengths installed with the contours of the rock surface and the estimated level of boulders in the fill showed that most of the piles were 10 to 15 ft short of their required length. The designer-contractor was held liable; his own records showed the cause of the settlement. The design did not fit the known site conditions (boulders) and there was no follow-through between office and field. This shows that the unexpected can come from lack of good liaison between design and construction. It also demonstrates the importance of checking construction records with design data.

3.2 *Site Discontinuities*

Too often both the engineer and contractor assume that the soil and rock are ideal materials: Homogeneous, isotropic and uniformly bedded. Most formations are not. However, a few widely-spaced borings that find rock at a uniform level might delude a design engineer or a contractor into believing that the rock surface is level. Fig. 4a, for example, shows the surface of level-bedded limestone exposed in an excavation to bedrock. The surface is level, but it is cut by deep solution slots. Borings reaching the intact surface, ¾'s of the exposed area, suggest uniform rock; borings that strike a slot tell an entirely different story: Deep, wet, soft residual clay and binding of drilling tools with increasing depth.

Figure 4 — Rock defects

Figure 4a — Solution slots in hard limestone, North Georgia

Figure 4b — Solution pits in limestone in South Florida

Figure 4c — Chimney cavity in soft limestone exposed in a footing in the Bahamas

These deep slots are problems for both pile and caisson foundations. While most piles will be of nearly equal length, a few that hit the slots may be driven to extraordinary depths. One in Birmingham reached 150 ft while the adjoining piles all stopped at 40 ft. At that, it did not carry the design load. Possibly, it was twisted and poorly wedged in an irregular slot. Caissons excavated to such a mud-filled slot below the water table may defy unwatering. One project that attempted to unwater and clean two 48-in. caissons led to subsidence of the soil above rock and settlement of an adjoining building. In this case, the contractor was experienced in the area yet he continued to pump muddy water from the caisson after the soil around it commenced settling. Eventually, he was forced to complete the caisson by tremie concrete through water. The condition was unforeseen at this particular point; however, such conditions should have been expected on the basis of his past experience and from the boring data. If he had heeded the warnings of his own men, he could have used a different procedure for installing the caisson, such as pre-grouting the slot or using drilling mud to balance the water pressure in the seam.

Irregular solution depressions (Fig. 4b) and occasional deep holes in the rock surface (Fig. 4c) are typical of the soft, porous limestones of the tropics. In a site near Nassau, Bahamas, holes 1 to 2 ft in diameter were found in each footing excavation (typically 6 to 8 ft square). Each footing excavation was rejected by the resident engineer, sitting on his camp stool, watching the workmen dig. Finally, when the resident engineer checked with the structural engineer, he found that the holes had been anticipated in the design pressures. It was only necessary to plug each hole with concrete to a depth of twice its width and then pour the footing as designed. This lack of response to what the resident engineer thought was an unexpected condition caused two months delay and thousands of dollars. This again illustrates the importance of liaison between construction and design where the design was good, but its intent was not transmitted to the field, either to the engineer's resident or the contractor.

3.3 *Faulty Materials*

Materials that are too weak for the required load often produce unexpected failures that are mistakenly blamed on site conditions. For example, a 16-in. diameter grouted-in-place earth anchor failed at a test load that was a fraction of the design load. All the adjoining anchors held 1.5 times the design load with only nominal deflection. The contractor claimed that some unforeseen soil weakness was responsible. In order to verify this claim, the engineer required that the anchor be pulled out. It came out in short cylinders separated by pockets of sand and mortar so weak that it could be scraped with fingernails (Fig. 5a). The mortar used for grouting had not been thoroughly mixed; further, twice the specified amount of air entraining agent had been added to the mix by mistake.

Wood piles are highly variable in quality despite visual inspection for defects. On one project, nearly ⅓ of the piles broke when they were driven into dense sand (Fig. 5b). Sections of the new piles delivered to the job

Figure 5 — Effects of bad workmanship and materials

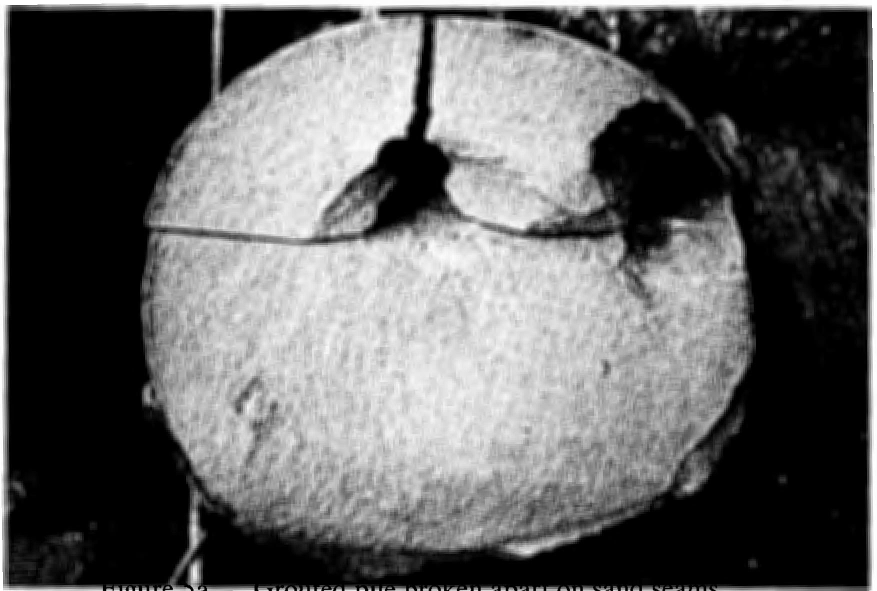


Figure 5a — Grouted pile broken apart on sand seams

Figure 5b — Wood pile tips broomed due to over-driving or poor wood quality

Figure 5c — Tops of wood piles damaged by excessive driving

Figure 5d — Reinforcing bar at edge of cast-in-place concrete pile instead of center (holes made by coring concrete) were tested in compression. Their strengths were less than half of those ordinarily expected. The cause was never determined. Possibly they had been creosoted at an excessive temperature.

3.4 *Failure to Follow Plans*

An excavation bracing system (Fig. 6) was designed to support a major city street. The rakers were steeper than ordinary because of site clear-

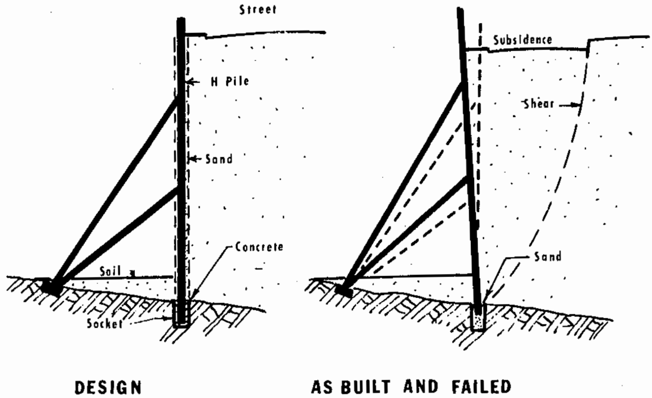


Figure 6a — Rotation of bracing system from failure to anchor soldier piles in concrete

Figure 6b — Collapse of soil under street due to failure to install specified lagging ances. Because the thrust of the steep rakers produced much uplift, the design required that each soldier pile be concreted into a socket drilled in rock just below the excavation bottom. After the first tier of rakers had been placed and while the site was being excavated to the level of the second tier, the soldier piles suddenly rose and the bracing system rotated in, an shown in Fig. 6. The street cracked and subsided 18 in. An investigation found that the contractor's foreman had substituted sand for concrete in the

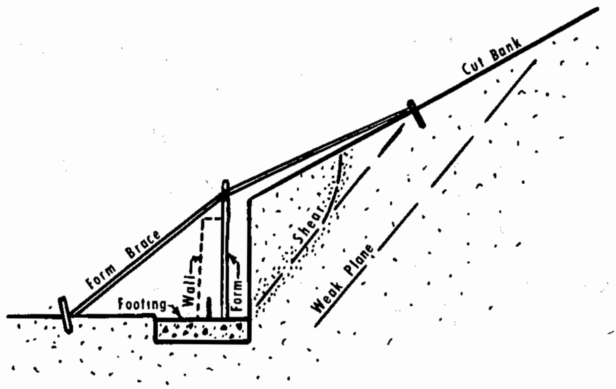


Figure 7a — Failure of toe of cut bank due to slickensided planes of weakness

Figure 7b — Collapse of soil around a concrete caisson due to pumping mud from clay seams in rock soldier pile sockets. His reason was that it would make it easier to remove the soldier piles later. Not even the contractor's general superintendent was aware of this unauthorized change.

3.5 *Failure to Recognize the Unexpected*

The toe of a cut bank was to be supported by a small retaining wall 8 ft high, as can be seen in Fig. 7. The contractor cut the bank as required and

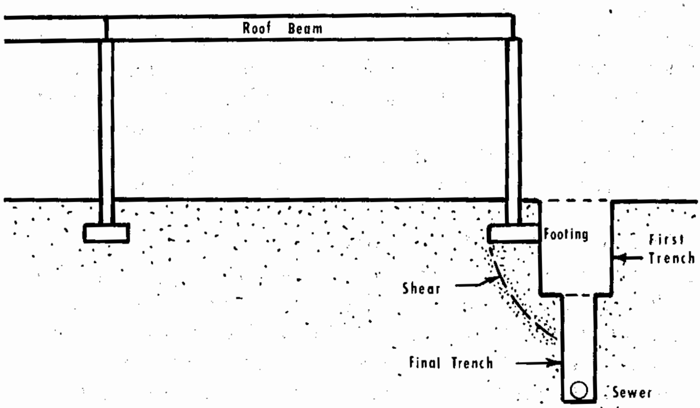


Figure 8a — Cross section of sewer trench which undermined a footing and caused a "row of dominos" collapse of 50,000 sq ft of building

Figure 8b — Photograph of trench and building remains then notched the toe of the slope to build the retaining wall. He failed to recognize several black slickensided planes of weakness in the soil that dipped steeply downward into the toe cut. A wedge of earth slid down on the slickensided surface (following a heavy rain) demolishing the formwork and the vertical steel that was being set. Local experience has shown the dangers of such black slickensided surfaces in the residual soil. The site borings showed that slickensides were present on the site. Such weaknesses should have been expected and the contractor should have been on the lookout for them. On the other hand, there was no practical way to determine in advance that those particular slickensides were present and dipping toward the toe excavation. The general condition, therefore, should have been expected; the local weakness of that point was unexpected, but was obvious to anyone experienced in local excavations once it was exposed. The failure to respond to the unexpected led to a structural failure.

3.6 *Construction Design and Workmanship*

Some aspects of design, such as excavation bracing, the wall thickness of tubular piles, jigs for positioning piles in water, are often made the contractual responsibility of the contractor. If his engineering staff is qualified, and they follow through with adequate construction surveillance, the contractor benefits by having complete control of his construction operations. If they are not qualified, disaster can result. The field engineers must be alert to hazardous conditions and capable of acting on them promptly. For example, Fig. 8 shows a sewer trench excavated in two stages along the edge of footing supporting the roof beams of the shopping center. The final excavation, nearly 15 ft below the footing, was on Saturday morning when the general contractor's forces were not working. However, despite denials, it was evident that the first, wider trench was dug on Friday when the general contractor's forces would have seen the hazard.

The wall of the deeper second trench sheared from the footing load and 50,000 sq ft of completed precast-prestressed concrete columns and roof collapsed. Three workmen were crushed to death (including the sewer subcontractor) and several more were injured. Suits for negligence totaling nearly $750,000 were filed against all involved including the architect-engineer. This failure points out that the unexpected can occur because of failure to coordinate construction activities (the sewer should have been built first) and failure to observe or take action on hazardous job conditions.

Poor workmanship plus bad design can lead to failure, sometimes years after construction, as shown in Fig. 9. The overall design for an industrial park required cutting hills as deep as 50 ft and filling ravines as much as 60 ft to provide a level site about one mile square. Storm drains were laid in the old ravines without regard to possible building sites, collecting water from a system of drop inlets from the streets and deep manholes that would eventually serve the buildings. Twenty years later a circular hole 50 ft in diameter and 35 ft deep suddenly appeared 20 ft from a large warehouse-office building. A tree 12 in. in diameter subsided vertically with the soil,

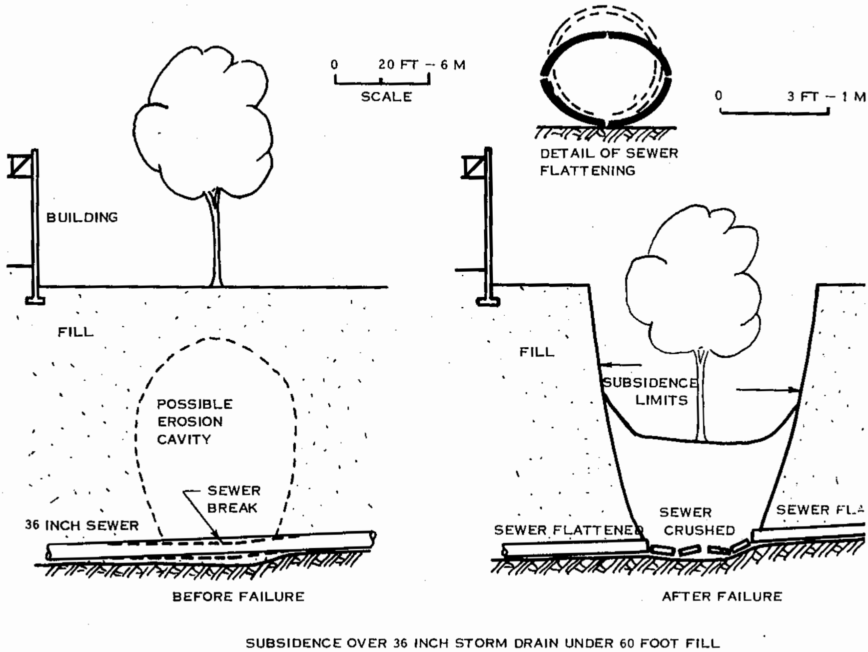


Figure 9 — Earth dropout over a collapsed sewer

its crown finally just extending above the ground surface. The building wall moved outward and settled about 1 in.

The subsidence occurred overnight following a hard rain. Immediately beneath was a 36-in. concrete storm sewer. The hole slowly filled with water to within a few feet of the ground surface and then drained even more slowly during the ensuing week. A braced steel cofferdam was constructed around the hole to protect the building and to permit excavating to the sewer. In the area of the collapse, the sewer was broken. Upstream it had been laid on rock; downstream on soil. It had not been placed on any bedding for the soil below its spring line was very loose. By way of contrast, the fill above was a compacted silty clay.

The sewer broke by shear where it went from rock to soil support. Moreover, the remaining 36-in. pipe upstream and downstream had been flattened into an ellipse with a vertical opening of only 2 ft with appropriate cracks at the top, bottom and sides. The sewer capacity was inadequate for the storm runoff. During large rains, water rose in the open cofferdam showing that the sewer was under pressure. Water pressure in the sheared zone saturated the soil above. After the storm, the water drained back into the sewer eroding the soil with it. A cavity was slowly created in the soil with the tree roots above possibly helping to reinforce the cavity roof. Eventually, it became large enough that it collapsed. Possibly preventive maintenance could have prevented failure because a 36-in. sewer can be inspected easily.

The cost of the failure exceeded a half million dollars. The cause was poor design, poor workmanship in installing the sewer and poor supervision of the work. The costs were shared by the present land owners and the original developer; the others involved were beyond the court's jurisdiction.

3.7 *The Foreseeable Unexpected Condition*

Some conditions which the contractor claims are unexpected are caused by the contractor's failure to take the necessary steps to cope with job conditions that he should have foreseen. Quicksand (Fig. 10) is the best example. It is not some mysterious type of soil; instead, it is a condition that is created by unbalanced water pressure when a contractor excavates below the ground-water pressure level without pre-drainage.

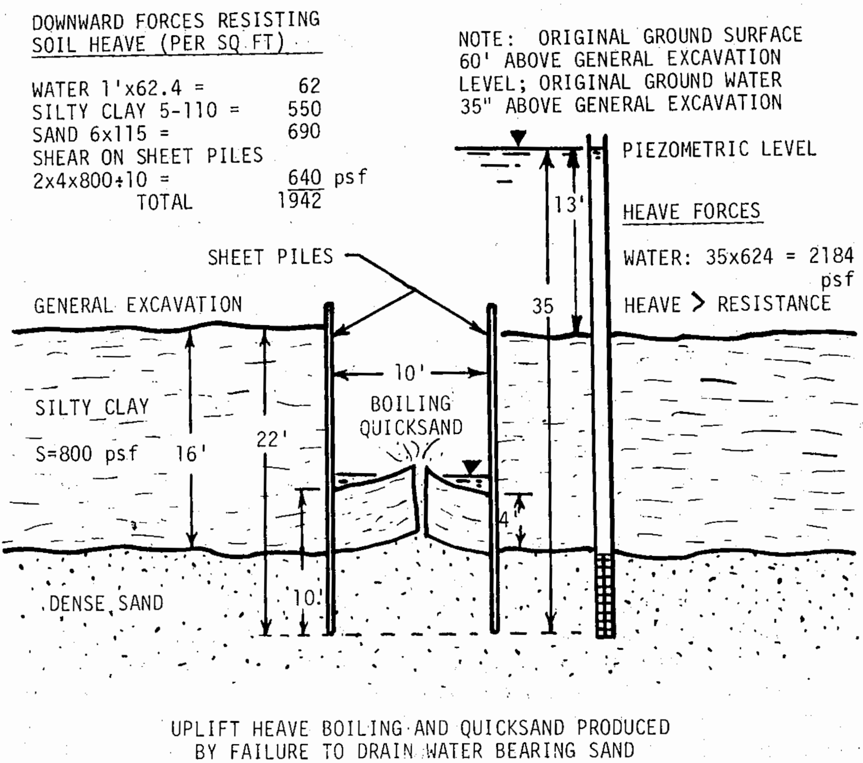


Figure 10 — Quicksand: An "unexpected" condition that should have been foreseen and easily prevented

At the site illustrated by Fig. 10, the contractor was furnished borings showing that the ground-water table was 35 ft above the general excavation. Within the general excavation were several deeper excavations, 10 ft wide and 20 ft deep, to be protected by steel sheet piling. The boring data showed a previous sand stratum 16 ft below the general excavation level. The specifications required that the contractor install piezometers to measure the water pressure level in the deep sand so he could coordinate excavation with site drainage.

Because of the low permeability of the silty clay, the ground water in the general excavation was easily controlled by sumps. Further, the water pressure level in the deeper sand fell slowly until it was only about 13 ft above the general excavation level (the combined effect of sump drainage and dry weather). When the excavation between the sheet piles reached a depth of 12 ft, the silty clay rose and sand boiled into the excavation. Two workmen (and the author) had to scramble for safety. Calculations showed that the excavation bottom was unstable. The uplift forces of water pressure in the sand below the sheet pile tips exceeded the weight of soil and water above.

Despite the contract data on ground water and the contract requirement for control of the ground water in excavations, the condition was created by lack of drainage. Wellpoints in the sand corrected the problem quickly.

The contractor's superintendent on this 10 million dollar foundation project could not understand what happened. He testified that he had been able to control water in the general excavation by "removing it with teacups" and could see no reason why this procedure would not apply to the deeper

Figure 11 — Response to an unforeseen condition: Lagging around a sewer through an excavating bracing system

excavation into the sand. Eventually, he claimed that this was an unexpected or "changed condition" for which he should be paid. The contractor was Ambassador to Ireland. The Government paid him against the advice of the consulting engineers.

4. Preventing The Unexpected and Promoting Equity

4.1 *Overview of Responsibility*

It has been said that prevention of disease is far better than any cure; the same holds true for sick construction. As can be seen from the examples, the technical failures arising from the unexpected usually begin with people failures. No single party to a construction endeavor is always right; no single party is always wrong. The owner expects perfection from his engineer and contractor, but at a cheap price. The engineer expects the highest level of experience and expertise from the lowest bidder. The contractor expects that the plans will be perfect and that the site conditions will be perfect. Such high expectations are seldom realistic. All parties must fully realize that there will be unexpected soil and rock conditions, and also some design and construction errors. Minimizing the unexpected will cost money; but usually much less than the cost of correcting failures. Ultimately, the owner pays, either directly or indirectly for all costs. This is equitable because it is the owner who provides the site and it is the owner who will eventually benefit from what is designed and built. If he is such a tightwad that he hires a poor architect-engineer, he deserves the extra cost that their errors and omissions generate. If he contracts with an inexperienced, inept contractor, he should pay for his ill-advised parsimony.

Once all parties agree to this equitable philosophy, a number of steps can be taken to minimize the unexpected and to assign responsibility.

4.2 *Disclosure of Data*

An adequate program of investigation is essential to determine site conditions, including geology, soil and rock testing and a study of the site's history of previous construction.

All data on site conditions should be disclosed to the contractor, including opinions and interpretations. While he may choose to make his own, he should have the benefit of any opinions that have been expressed. Any withholding of data could be construed as fraud — an attempt to mislead the contractor into a cheaper bid.

Some owners and attorneys object, feeling that they will be held liable if interpretations and professional opinions are wrong. However, in the long-run, good interpretation of data and sound professional opinions will minimize costs.

4.3 *Prequalification*

Many of the problems arise from bad decisions of the personnel of both the designer and the constructor. The present prequalification procedures focus on the contractor and emphasize his firm's experience and financial capabilities. Instead, the qualifications of the individuals in responsible charge of the key functions in design and construction should be evaluated. The firm's experience is worthless if the persons who gained that experience are not on the job.

4.4 *Contract Requirements*

The contract documents are the key to transmission of data, lines of responsibility and conditions for payment. Too often the documents are ambiguous, wordy and filled with meaningless, trite expressions, such as "workmanlike manner" or "trade practice" or the loaded expression "to the satisfaction of the engineer".

The documents should spell out short lines of communication with instantaneous feedback from construction to design when the unexpected is encountered. The contractor's design responsibilities should be clear, especially for selecting such permanent components as pile wall thickness or tools required such as the pile hammer weight. The objective of the designer in requiring special tools or unusual procedures should be spelled out so that the contractor can be a partner to the work rather than an opponent.

Finally, some documents should be honest. They should not provide data and at the same time disclaim any responsibility for the data. If the data are of no value, no one should consider them; if they are of value, all should heed them.

5. Conclusion

The unexpected should be expected in foundation construction. The cause is usually some human failing, generally an honest one, but a reflection that man is not all seeing, all knowing and all powerful. The unexpected can be minimized if the persons involved are skilled, but at the same time recognize their limitations. The effects of their limitations must be communicated to those concerned so that the resulting problems can be minimized. With good will and a realization that no one gets something for nothing, the unexpected can be evaluated, or even foreseen, before it becomes a disaster.

References

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