Engineering Ethics Cases with Numerical Problems

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Civil Engineering Case 3

The Sinking Tower

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Suggested Courses:

Soils & Capstone Design

Level:

Junior & Senior

I. Situation

In 1986 the City of Pitcher, Wyoming, formed the Wyoming Woolies Stadium Authority to build, own and operate a new stadium to accommodate professional football games and other major events. Ostensibly an independent body, the authority was known to be controlled by the Pitcher City Council. Later that year the authority retained the engineering consulting firm Matrix Engineering Associates to design the site and structure. The consulting contract with Matrix included geotechnical engineering and on-site inspection. Matrix retained sub-consultant SoilTest Geotechnical Engineers to research subsurface conditions, develop a soil boring program, supervise borings, analyze data, and make design criteria recommendations. Early in 1987 Benson-Marquardt Construction Company (BMCO) negotiated a construction management contract with the Stadium Authority to manage the project. In closing their deal, BMCO's primary selling point was their guarentee to achieve substantial completion prior to the first home game of the 1988-89 season. The Stadium Authority accepted the BMCO proposal, but required a contractural provision for liquidated damages in the amount of $10,000 per calendar day. Weather in Wyoming is often a major impediment to continuous winter construction work. The contractural provision for liquidated damages allowed no relief for weather except for catastrophic events beyond BMCO's control. Additionallly, design work by Matrix was at that time only in the preliminary stages. From the outset it was clear that each and every work day would be a precious resource.

When Matrix retained SoilTest, the testing firm already had a heavy backlog of work for Pitcher and several other governmental clients. Under persistent pressure from Matrix, on behalf of BMCO, SoilTest management sent a crew of two technicians and an old, borrwed drill rig to the site with a quickly-developed hand sketch of the boring location and instructions to complete the borings in one day. By mid-afternoon, when the rain began, all but two borings were completed; the crew then returned to the shop with good intentions of returning later in the week. The missing borings were never obtained or requested.

Dennis Snead was on-site Project Engineer for Matrix and was responsible for most day-to-day engineering decisions to provide direction and support for the fast-track project. The project was especially challenging for Dennis, since this was his most responsible field assignment to date on a project of such large magnitude. At various times throughout the project, Dennis found himself intimidated by Hardnose, BMCO's veteran construction superintendent, and uncertain about the extent of his authority as a consulting engineer to delay "progress" when technical and quality issues arose. More than once BMCO's management "advised" Matrix principals that any liquidated damages costs assessed against BMCO should be shared by Matrix if Matrix delayed construction progress without sufficient reason. Not the least of Dennis' challenges was the marginal soil conditions across the site, and the tendency of the native clay to resist compaction and impede construction during and after rains. Dennis was puzzled by his firm's selection of SoilTest to perform the geotechnical work because their reports appeared to be incomplete and inconsistent in their recommendations. Only much later was Dennis to discover that the President of SoilTest was the chairman of the political party controlling city hall and played a pivotal role in the city's selection of Matrix.

Due to the configuration of the stadium the four external stair towers were constructed after the main mass of the stadium superstructure was erected. During the course of site cut and fill Hardnose noticed water ponding in the area of the west stair tower one morning after a half-inch rainfall. He mentioned the condition to Dennis, but it didn't seem very serious to Dennis at the time.

In the afternoon of Thursday, April 24, 1988, during his normal inspection walk of the site, Dennis notes that Hardnose has directed the excavation crew to "hog out" the area of the west stair tower in preparation for digging, forming and pouring of the tower foundation. As he approaches the hole, Dennis can see Hardnose closely scrutinizing the soil material in the exposed bank, which is clearly different in color and texture from that in all other excavations on the site. Knowing that the Matrix structural design was based on SoilTest reports of reasonably uniform conditions across the site, Dennis returns to his office trailer to check the portion of the SoilTest geotechnical report, which Dennis hasn't yet found time to study thoroughly, pertaining to the area of the west stair tower. To his dismay, Dennis discovers the SoilTest report indicates their nearest boring fifty-five feet southeast of the center of the west stair tower.

Dennis returns to the excavation and discusses the situation with Hardnose, whom Dennis has gotten to know better during their occaissional fishing weekends at the BMCO cabin in northern Wyoming. Dennis wonders out loud whether he should issue a "Stop Work Order" on the stair tower area and request his office to require SoilTest to perform emergency investigation and analysis prior to allowing construction to proceed. Hardnose notes the non-native material appears to be mostly granular and well-compacted, and reminds Dennis that the Wyoming Woolies' first home game is "73 work days from today". Dennis tries to call his boss at the Matrix office, but is unable to reach him. By this time it is 4:15 P.M.; the excavation crew has completed digging the footing trench, carpenters have set the edge forms, and the rod-busters are just completing tying-up the footing steel. Dennis can't locate Hardnose, but the assistant superintendent tells Dennis that Hardnose instructed him to schedule ready mix trucks to begin arriving at 8:00 A.M. tomorrow to pour the footing. On his way to his car

Dennis hears a carpenter foreman (who has long lived nearby) talking to someone else about the gas station that once was located where the west stair tower is now being built. Dennis spends the night worrying about a decision he is reluctant to make.

Arriving at the project site at 8:00 Friday morning, he finds the situation has only become more difficult since the site has received a moderate overnight rain. Hardnose has had the footing trench pumped dry, and has his pouring crew standing ready for the trucks to arrive. When the first truck rumbles up the stone drive, Dennis stays in his office trailer pretending to do yesterday's paperwork.

The evening of the Woolies' home opener Ivan Civil, Dennis' boss, arrives at the completed stadium to attend the game. On his way to the Matrix suite via the west stair tower Ivan notices the top-of-slab elevations at the stair landings are consistantly lower than the corresponding elevations of the stadium floor slabs. The next day he and Dennis Snead have a meeting.

II. Numerical and Design Problems

The following problems assume the stair tower has a total weight of 200 tons and that the foundation is a spread footing with a radius of 12 ft.

1. Assume the surface soil was classified as CL by the Unified Classification system and that it had a plastic limit of 32 and a liquid limit of 79. What sort of compaction equipment would you recommend for the site preparation?

2. Over most of the site the clay extends 60 ft below the surface and is underlain by dense sand and gravel. It is normally consolidated with Poisson's ratio of 0.33. A plate load test gives an undrained modulus of 200 ksf. Estimate the initial elastic settlement of the stair tower.

3. After four months has passed, some vertical separation is noted between the stair tower and the stadium amounting to about 0.6". If the coefficient of consolidation is reported as 36 ft^2/yr, use Terzaghi's one-dimensional consolidation theory to estimate the total ultimate separation.

1. If the initial void ratio of the clay is 1.02 and its density is 105 pcf, use the results of problem 3 to compute the compression index C_c.

III.

Solutions to Numerical Problems

1. Since soil is primarily clay with a high plasticity index (Unified CL-lean clay), a sheepsfoot roller will likely be the most effective compactor.

2. Since foundation diameter is 24' and layer depth is 60', H/B = 60/24 = 2.5. Thus the shape factor Cs is 0.605 (see pp 170-2, Fang, Foundation Engineering Handbook, Van Nostrand, 1991)

The settlement can be computed from:

$$s = C_s q B \left(\frac{1-\nu^2}{E_u}\right)$$

$$s = 0.605 x \frac{400}{\pi 12^2} x 24 x \left(\frac{1-0.33^2}{200}\right) = 0.7''$$

Substituting the appropriate values gives:

$$T = c_v \frac{t}{H_{dr}^2}$$

3. Since c_v is 18 ft2/yr, the time factor, T, is given by:

where t is the elapsed time, and H_{dr} is the longest drainage path. Substituting values gives:

$$T = \frac{36}{12}\frac{4}{30^2} = .0132$$

This time factor corresponds to about 13% complete consolidation, therefore the ultimate settlement will be about 0.6/.13 = 4.6".

4. The initial stress at the center of the clay is (30)(105) = 3.15 ksf. From the chart 5.24 in Fang, the stress increase is 400/(π 12^2)*0.5 = 0.44 ksf. Thus since the settlement is 4.6" from problem 3, the value of Cc is given by:

$$C_c = \frac{s(1+e_0)}{H_0 \log\left(\frac{\sigma_2}{\sigma_1}\right)}$$

$$C_c = \frac{4.6 x (1+1.02)}{60 x 12 x \mathrm{Log}\left(\frac{3.15+0.44}{3.15}\right)} = 0.099$$

Substituting valus gives:

IV. Ethical Questions and Solutions

1. List the professional obligations of Matrix's principals, and identify two aspects in which they failed to satisfy these obligations.

Matrix's principals had professional obligations to the general public (taxpayers, as well as users of the stadium), their client (City of Pitcher), and Dennis. As stated in the *Code of Ethics for Engineers* of the National Society of Professional Engineers (NSPE), their obligations required them to "hold paramount the safety, health and welfare of the public". Their obligations to the City of Pitcher required them to provide a safe design at minimal cost, while meeting the schedule to allow the stadium to be ready on time. Their obligation to Dennis involved providing the necessary support/supervision to effectively do his job.

They failed to satisfy these obligations by hiring SoilTest as a subcontractor, in order for Matrix to get the contract from the City. When SoilTest performed inadequately, Matrix's ability to compel them to do so was limited. In addition, this violates provisions in sections II.1.d., II.5.a., II.5.b. and III.5.b. of the NSPE Code of Ethics, prohibiting acceptance of a contract awarded in return for financial or political considerations.

They also failed to satisfy these obligations by assigning a relatively inexperienced engineer (Dennis) to a project with such a critical schedule, then failing to provide adequate support/supervision. This assumes that, due to Matrix's workload and resources, they decided implicitly or explicitly that Dennis was the best they could do on this project, but then did not adequately support/supervise him.

2. List the professional obligations of SoilTest, assuming that their principals were engineers, and identify two aspects in which they failed to satisfy these obligations.

SoilTest had professional obligations to the general public and their client (Matrix). These obligations involved protecting the public health and welfare and meeting the specifications of the contract. They appear to have violated provisions of the NSPE Code of Ethics prohibiting accceptance of contracts in return for financial or political considerations.

They failed to satisfy these obligations by undertaking a project which they did not have adequate resources to complete and by not performing the work they were contracted to do. Given their heavy workload, they should have notified Matrix that they were likely to be unable to complete the drilling prgram (NSPE Code of Ethics section III.1.b.).

3. List Dennis Snead's professional obligations, and determine to what extent he satisfied these obligations.

Dennis had professional obligations to the general public, the client (City of Pitcher), and his employer. He failed to satisfy these obligationsin several ways. He undertook a project which may have been beyond his capabilities. This is prohibited by NSPE Code of Ethics section II.2. He failed to review the soils report at an early stage in the project, then did not require SoilTest to complete the specified boring program. He used the BMCO fishing cabin in violation of NSPE Code of Ethics section II.4.c.. He failed to issue a Stop Work Order when he was faced with a decision in which his professional judgment was required.

4. What uncertainties did Dennis face in dealing with the situation described in the case? How could he have resolved them? Why didn't he?

Dennis was uncertain about soil conditions at the site, the implications of poor soil, and the extent of his authority to stop work. He could have resolved the uncertainties by requiring SoilTest to perform drawings in the area of the stairway. Given the delay which that would have caused, he might have delayed pouring the stairway

foundations until he could analyze the sensitivity of the design to soil that was of lower quality than had been assumed.

He could have resolved the uncertainty over his authority by discussing it with a more experienced engineer at Matrix, suggesting some hypothetical situations. His authority would have been stronger had he not gone on fishing trips to BMCO's cabin.

He didn't resolve the uncertainties because:

1) He didn't review the soil report at an early stage, so was unaware of SoilTest's failure to complete the boring program.

2) He may not have consulted with a senior engineer because he did not want to appear uncertain or too inexperienced to have been assigned to a project such as this;

3) He didn't want to delay the pour because of the cost and potential liability involved.

5. How does the presence of uncertainty affect professional and ethical issues

If Dennis had been certain that soil conditions would result in unacceptable settlement of the stairway, his professional obligation would have been to delay the pour until borings could be performed and the stairway could be redesigned. Allowing the pour to proceed would have been unethical, since he would be violating his obligations to the general public and his client.

If Dennis had been certain that soil conditions would not result in unacceptable settlement, his professional obligation was to allow the pour to proceed so that the project could be completed on time.

Without being able to resolve the uncertainty, Dennis needs to consider the severity of the implications of decision alternatives. If the soil is good and the pour proceeds, everything is fine. If the soil is good and Dennis delays the pour, the stadium will not open on time and Matrix will incur damage to its professional reputation. Matrix and SoilTest will likely disagree about the cause of the delay and incur costs for delays and litigation. If the soil is poor and the pour proceeds, the stadium will open on time but additional repairs and costs will be involved and the professional reputation of Matrix will suffer. Matrix and SoilTest will likely disagree about the cause of the delay and incur costs for delays and litigation. If the soil is poor and Dennis delays the pour, the stadium will not open on time.