THE QUEST FOR QUALITY IN DEEP FOUNDATIONS

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OVERVIEW: A three-part series.

Part 1: The natural desire to improve the way we design and build deep foundations provides a fundamental motive for achieving excellence and high quality. Unfortunately, perceived high cost and the lack of rewards or incentives to make the effort that quality work demands, often leads us to complacency and mediocrity. This complacency can result in substantial reductions in bored pile capacity that dwarfs the potential improvements available from high quality engineering design and construction.

Part 2: Examples from case histories illustrate how seemingly minor factors can cause capacity reductions of 80% or more. Faced with the daunting risks and uncertainties associated with deep foundations many engineers fall back on code-value engineering and from there to unnecessarily expensive foundations. A review of the impact of shaft diameter on measured side shear resistances leads to cautionary advice about how relying too much on intuition can affect the quality of our analytical work.

Part 3: The engineer and the contractor do have several options for improving and maintaining quality including but not limited to - better assessment of the high cost of risk and uncertainty, changing the low-bid approach to awarding foundation contracts, including a special bid item to encompass all of the QA/QC work on a project and generally making a greater effort to focus on the value that high quality brings to any deep foundation project.

PART 1-INTRODUCTION TO QUALITY BASICS

The history of the human race provides clear evidence that striving to do better, to improve the quality of life, exists as a natural human instinct. When we do something well, we feel good (I have yet to see anyone who feels good after doing anything poorly). A key element of most successful endeavors whether in business, academia, the arts, or science involves improving and focusing on the quality of what they do. As we at Loadtest have progressed in the deep foundations testing business, Dr. Schmertmann has provided us with a great standard for quality in our work. "Will your report pass muster if reviewed by Schmertmann?" has become the mantra and incentive for our engineers when completing a report for a client. The Schmertmann review process has resulted in the continuing improvement of our analyses and reports. In his Key Speech Ove Arup (1970) emphasized that *"for our own sake we need the stimulation produced by excellence." ……"We must therefore strive for quality in what we do, and never be satisfied with the second-rate."*

But before we get too far on the subject of quality we need to have some acceptable definitions. In reality, the perception of "quality" varies a lot. (For example in the world of high fashion clothing some see quality in the "grunge" look where others see only rags) Many of us see quality, subjectively, in things that are unique or better than anything else commonly available (a hand-painted scarf for example). In engineering, we usually see quality, more objectively, as something that significantly exceeds a minimum acceptable standard. We believe that we can measure quality and therefore that we can use "Quality Control" (QC) to maintain a desired level or standard. Or we test things to satisfy ourselves and others that a desirable level of quality exists via Quality Assurance (QA) programs. In the deep foundation industry we would like the contractor to provide the QC while we engineers do the QA testing. But having a definition of and paying lip-service to QA and QC does not mean that you will get any; that depends largely on the attitude toward quality.

QUALITY AND ENGINEERING ATTITUDES

Clearly, making any change for the better requires effort and when we make it, things generally do get better. Although we might believe that good engineering characteristically evolves from the innate desire to do things better, it does not follow that engineers will make the effort that quality requires. . Often, after a period of progress, we have a subsequent period of Contentment or Complacency (C^2). Too many engineers fall into this cycle of Mediocrity, Complacency and Contentment. (The MC^2 trap, which has absolutely no connection to Einstein's formulation for energy.)

Those that fall into this trap then begin to design by code, use standard specs, make no effort to investigate new processes for design or construction, make no effort to evaluate the benefits of higher quality, make no effort to put a value on higher quality and become satisfied with the mediocre. (If it ain't broke, don't fix it; let sleeping dogs lie etc.) Indeed, some engineers begin to resist any non-standard, non-code process or idea and ultimately get caught in the MC^2 times Code trap or the MC^3 trap (***M***ediocrity X ***C***ontentment X ***C***omplacency X ***C***ode).

In his address to the Ohio River Valley Soil Seminar Professor Jorj Osterberg (1999) had this to say about the lack of quality or value engineering in foundation design practice – "*The reasons for the present situation are many: the tendency of designers ....to "play it safe" by being overly conservative; the reluctance to deviate from "accepted practice" for fear of later being sued; the antiquated and inflexible building codes; the attitude that "it's not my money, so why would I care"; do it the way it was always done; the ignorance or indifference of the owner about potential savings.*"

As evidence of the global nature of the issue Professor Heinz Brandl (2004) in his state of the profession paper offered these observations- "*Young engineers and especially professionals of a low qualification frequently stick slavishly to codes, standards and guidelines. If a theory finds its way into a textbook, it is considered by many readers a law. Moreover, too many regulations, standards or codes, which are too confining hinder innovation in geotechnical engineering. They act like a brake, slowing down new development. …………Engineers are increasingly afraid to design outside of standards or codes because they fear legal problems in case of a failure. This also has been dramatically reducing the willingness to take responsibility. Fear for liability or litigation is stifling innovation in civil engineering, especially in geotechnics, and pushing engineers towards over-reliance on standards. But over-reliance on standards or codes hampers also engineering judgment and kills "engineering intuition". The tendency to do things as we've always done is another hindrance to innovation and development in construction.*" Codes by their nature tend toward the lowest common denominator and these minimum standards often become maximum standards.

Looking outside our own profession we generally find important quality assurance and quality control procedures well-established in most manufacturing and service industries. Most successful companies have very good internal quality control systems which have contributed measurably to their success in the same way that good safety programs have been net contributors to corporate profitability. Why then, does quality control in the deep foundation (bored pile) industry seem so difficult to establish? I have suggested that most companies involved in the bored pile industry do not think of themselves as manufacturers (Hayes, 2002). Because of that we often find that poor attitudes toward quality assurance (QA) and quality control (QC) lead to making it someone else's problem. ("We have a job to do – don't slow us down with testing.")

The consequence of that attitude during construction along with the concern for structural integrity leads to a situation where designers attempt to improve quality by means of detailed specifications. This process may work if the design engineer has a great deal of expertise in the construction and/or manufacturing aspects of bored piles (unfortunately not a common occurrence). A detailed and rigid specification, written by a designer who does not understand the manufacturing process for a bored pile foundation, becomes an open invitation to either high costs or poor workmanship (or perhaps both depending on the nature of the contractor/manufacturer doing the work).

QUALITY, RISK AND UNCERTAINTY

Those of us with even a little experience in the deep foundation industry know of its perils and inherent risks. Not only must we deal with all the vagaries and variability of Mother Nature but also with the impact of construction technique on foundation capacity. There are many ways to deal with this but again as Brandl (2004) points out- *"A courageous engineer is willing to take a calculated geotechnical risk, which involves detailed ground investigation, geotechnical prognoses, "active" design (i.e. adaptable), proper risk assessment, and monitoring with back analyses. The more [the] prerequisites of such a serious geotechnical risk are missing, the more it approaches a "Geopoker" (or "Geo-Gambling"). Geopoker is favored by brutal competition, time pressure, economy and lack of knowledge (thus underestimating risk and danger). Geopoker has led to the paradox that the number of geotechnical failures has continuously increased during the past years (statistically confirmed), despite the advanced geotechnical education at the universities. The opposite of "Geopoker" is costly overdesigning, which is definitively not an engineering art."*

In the author's opinion the unfortunate adoption, and continued use, of Factor of Safety (FS) as a design concept in geotechnics lies at the root of our apparent inability to handle the risk and uncertainty associated with deep foundations in a rational way, mainly because the many uncertainties in deep foundation geotechnics do not permit accuracy in "factor of safety" estimates. It would have been much better to have admitted in the beginning to a *F*actor of *Unc*ertainty (FU_{nc}). This would allow a much more rational discussion and review (at the design stage) of the inherent risks or uncertainties that exist when dealing with deep foundations. As it now stands there becomes a psychological barrier when an engineer actually has the temerity to suggest spending money on testing, or QA/QC, to *lower* the factor of safety. Why should an owner get excited about lowering the "safety" of his foundation, especially when he will have to spend money to do it? If, on the other hand, we had started by considering the high FU_{nc} (and therefore higher risk) the rationale for funding a program to mitigate risk and lower the FU_{nc} becomes much more palatable to both the owner and his insurance company.

Geotechnical engineers often do not show much interest in the risk management approach to design. Usually we handle the uncertainty of resistance capacity by "cheating" on ultimate resistance estimates. (This would qualify as a Geopoker bluff). We carry out the bluff with a straight face by underestimating the ultimate capacity, using the lowest measured resistance values or by falling back on code values (usually, and necessarily, very conservative). When we don't have to "show our cards" (no prototype testing) no one knows that we have just saddled the owner with the big "E" (a very expensive foundation). If the specifications do call for testing, the bluff can still succeed by ensuring that the test load does not exceed twice the design load.

All of this neatly follows from my “Theory of Elusive Design Deception” (or “Theory of Elucivity” for short) expressed as an acronym in Equation 1.

$$\Delta E = MC^3 \tag{1}$$

where ΔE = Extra Expense, M = Mediocrity and C = Code values, Contentment and Complacency.

An Example of MC^3 Engineering

From our load testing experience with different agencies around the world we often encounter the MC^3 phenomenon when trying to carry out an O-cell test in the most effective way. Because the upward and downward movements at a given loading generally differ, the preferred test procedure requires small regular load intervals carried out to the ultimate resistance load with no intermediate unloading and reloading. This generally conforms to the “Quick Test” under the ASTM Standard D 1143.

The basic ASTM Standard D 1143 load test for conventional top loading describes procedures for carrying out maintained load tests with loads held for particular time intervals (usually, but not necessarily, equal time intervals) and then requires unloading and reloading at one or more intermediate load levels (usually at multiples of the design load). Most project test specifications include this basic Standard.

When originally written, these standards appear to have given little consideration (probably because of a lack of related knowledge) to the impact of residual stresses on the measured performance of the test piles. Fellenius (2002) has described the important effect that residual stresses can have on the interpretation of test data. Unload-reload sequences, although now widely recognized as providing little if any value, (in fact they tend to complicate the analysis of pile performance) still get included in most static pile test specifications. The superior method, we now know, has constant interval maintained loads up to the maximum test load. Even maintaining loads of irregular intervals without unloading complicates the analysis of the test data. We rarely succeed however, in convincing the C^3 engineer that slavishly following such outdated standard procedures actually reduces the quality and value of the testing.

The Widening Gulf between Analysis and Construction

Ralph B. Peck (1991) predicted this gradual widening of the gap between theory and practice: *"Researchers will take refuge in increasingly esoteric investigations; practitioners will pay little attention to the research results. Reading learned journals will become less interesting and profitable to practitioners, scientific oriented workers will find themselves more or less writing to each other."*

Engineers often get absorbed in analytical techniques, fuss and fret over factors that might change things by 5% while ignoring factors that probably affect capacity by 50% or more. The evidence continues to mount suggesting that many engineers fail to appreciate the importance of construction technique on bored pile capacity. We will examine this evidence in more detail in PART 2.

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