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A HISTORICAL PERSPECTIVE ON GEOTECHNICAL CASE HISTORIES COURSES

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ABSTRACT

Ralph Peck introduced the concept of using a geotechnical case histories course to teach students problem solving and technical communications skills, beginning around 1956. This course was developed as a professional practice course at the graduate level, intended for civil engineers of diverse backgrounds as well as geoscientists. Students were required to prepare one-page summaries of each case history profiled in the course, a requirement that left an enormous impression on the students. A different approach was employed by the University of California, Berkeley, beginning around 1970. Berkeley offered two graduate courses in the mold of ABET "capstone courses," graduate soil mechanics laboratory, and advanced foundation construction. These courses were intended to prepare students for geotechnical problem solving and professional practice using a single term project, which required student teams to prepare a comprehensive report, similar to those prepared by private sector consultants. The background on each of these courses, the individuals who taught them, and the techniques employed by those instructors are briefly profiled and their pros and cons are compared.

INTRODUCTION

The idea for teaching a course in geotechnical case histories emanated from the University of Illinois in the early 1950s, when Ralph Peck (Fig. 1) was engaged in building a successful graduate program in geotechnical engineering. Peck had earned his bachelors (1934) and Doctor of Engineering (1937) degrees at Rensselaer Polytechnic Institute. Peck's graduate work was in structural engineering, dealing with analysis of stiffness in suspension bridges. Unable to secure a teaching position in structural engineering, Peck was encouraged to gain sufficient understanding of the new sub-discipline of soil mechanics so he could teach that subject at the Illinois Institute of Technology in Chicago. In April 1938 Peck enrolled in the graduate program in soil mechanics at Harvard University under Professor Arthur Casagrande (1902-81).

In January 1939 Peck volunteered to go to Chicago to be Karl Terzaghi's (1883-1963) on-site representative for construction of the Chicago Subway system, then beginning construction. Peck remained in Chicago for 3-1/2 years, making many valuable measurements of earth pressures against restrained excavations (Figs. 2 and 3) as well as underground tunnel linings (Fig. 4).

These resulted in a series of famous presentations (beginning in 1941) and articles (beginning in 1944) published in the ASCE Transactions, where Peck's article introduced equivalent pressure diagrams for braced excavations, recognized by ASCE's prestigious Norman Medal in 1944. Peck joined the faculty of the civil engineering department at the University of Illinois in Champaign, IL in December 1942, and remained there 32 years, until retiring in June 1974.

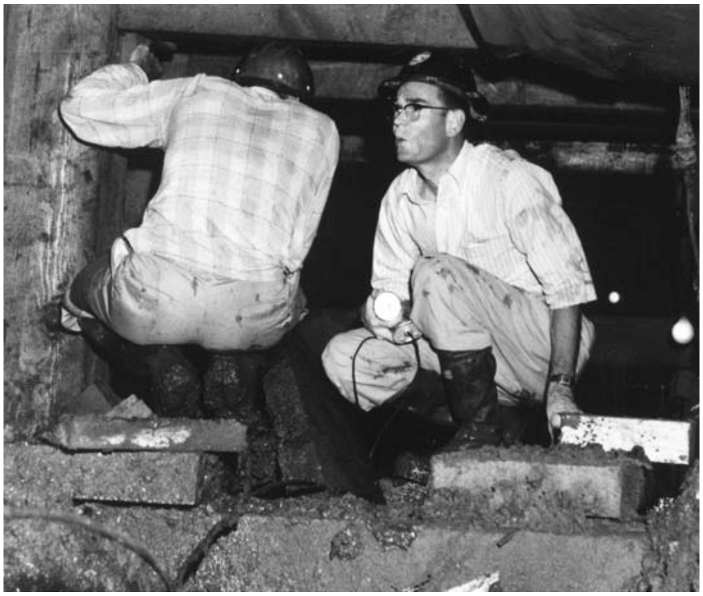


Fig. 1. Ralph Peck examining the pilot bore in the crown of the Wilson Tunnel in Oahu, Hawaii in the winter of 1954-55, after a cave-in had killed five workmen the previous summer. Peck fathered the "Observational Method" of foundation engineering (Peck, 1969a).

Fig. 2. Braced open cut on Contract S-1A of the Chicago Subway, as seen in July 1940. This view shows the transition between the elevated and below ground sections of the State Street line, towards its north end, near the intersection with Clybourn Avenue.

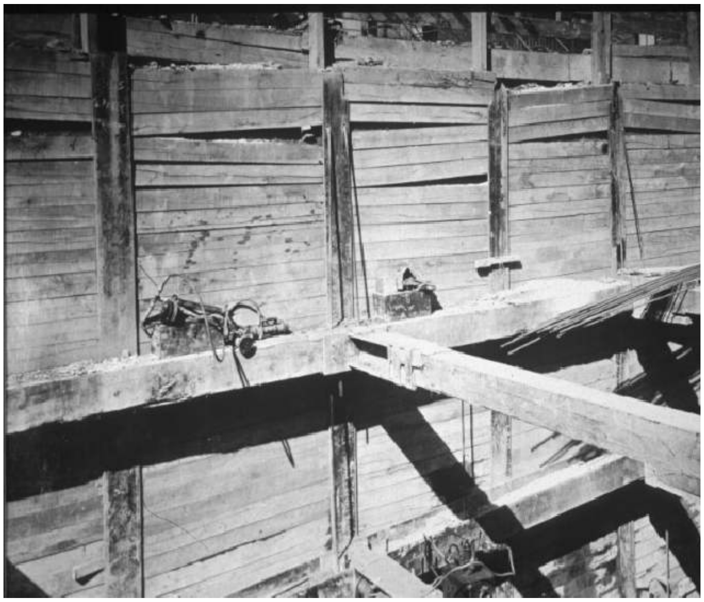


Fig. 3. Close up view of steel H-piles, timber struts, steel walers and timber lagging used to support an open cut of the Chicago Subway, as seen in 1940. Karl Terzaghi wanted Peck to measure strut loads to see if clays adhered to the wedge theory of lateral soil pressure for sands he had proposed after studying the Berlin Subway collapse in 1936.

BACKGROUND

Between 1942-48 Ralph Peck co-authored the first edition of Soil Mechanics in Engineering Practice (described in Dunnicliff and Deere, 1984), with Karl Terzaghi, who had taken a position at Harvard University. Originally titled Applied Soil Mechanics, it was intended to be a sequel to Terzaghi's first English text, Theoretical Soil Mechanics, published in 1943. The book was an instant success when it appeared in 1948 and was eventually translated into 17 languages, including Russian and Chinese. In the post-war building boom Peck grew increasingly concerned that the university wasn't equipping students to think critically about the type of geotechnical information needed when preparing proposals for foundation investigations. Few of these proposals exhibited a fundamental understanding of the likely subsurface conditions to be encountered and geotechnical testing appropriate to the projects at-hand.

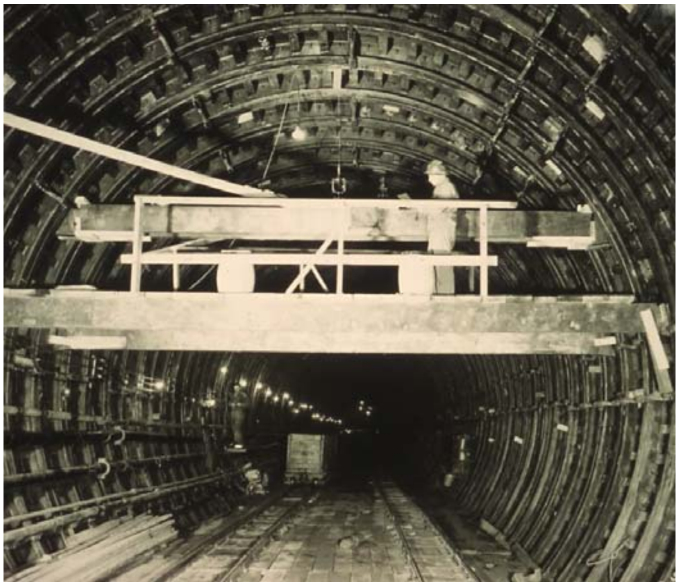


Fig. 4. Apparatus used to measure radial deflection of tunnel liner along the Chicago Subway in 1941. These results led to Terzaghi and Peck's theories about loading and support offered by flexible lining in soft ground, which were subsequently verified in the construction of the San Francisco Bay Area Rapid Transit (BART) system (Peck, 1969b).

Peck became a registered structural engineer in Illinois in 1943, and was often called upon by prestigious structural firms, such as Kelter and DeLeuw, to comment critically upon proposals for soils and foundation investigations for projects they were associated with (Peck and Charles DeLeuw later served on the Structural Engineer Examination Board for Illinois). At that time Peck began to notice that a considerable range in the scopes of proposed services, such as the numbers and locations of borings, as well as the types of lab tests. Many owners and architects felt obliged to take the lowest bidders, only to experience unnecessary problems later on.

The graduate and undergraduate geotechnical courses evolved almost simultaneously during the Post-Second World War period. Tom Thornburn had a soil science background, so he taught geologic aspects of foundation studies prior to Don

Deere's arrival on the faculty in 1955. Deere developed specific courses in engineering geology, for undergraduates and graduate students, while Thornburn taught a graduate course in engineering properties of surficial soils.

One of the vexing problems of working in the Great Lakes Region was the concept of overconsolidation, which varied considerably across the major river valleys, upon the elevated uplands, and was all but absent in many portions of the expansive outwash plains. This greatly affected bearing capacity, and led to numerous failures of "typical foundations" which had performed admirably, often in close proximity to the failures (Fig. 5).

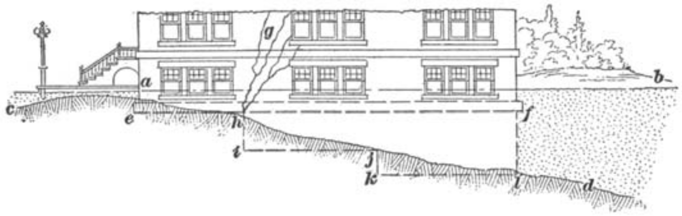


Fig.5. When Ralph Peck began teaching foundation engineering at the University of Illinois in 1949 there were few examples of foundation problems or failures he could show his students. This image of tension cracks emanating from a stepped foundation is taken from Lowndes (1928), which Peck drew upon before publishing his article on the history of building foundations in Chicago (Peck, 1948).

In the fall of 1949 Peck, Tom Thornburn, and Walt Hanson began teaching a new course in foundation engineering, which was initially taught using a series of case histories, mostly drawn from structures in Chicago. They used mimeographed notes and Peck's comprehensive article on "History of Building Foundations in Chicago," published in the Bulletin of the Illinois Engineering Experimental Station (Peck, 1948). The early course notes summarized soils information from various jobs and explained the different approaches used to design foundations for an array of structures. Claude Fetzer, one of the students in that initial course, later recalled that the students soon learned that each consultation contained a "mystery" that had to be solved; that being to come up with an adequate solution to address the problem posed by the site conditions (Fetzer, 1995; 1997). This proved too difficult for many of the students, who were bereft of any field experience, so Peck encouraged the students to discuss and debate the projects amongst themselves, integrating the more experienced graduate students with the less experienced undergraduates. These sessions soon evolved into "bull sessions," reminiscent of exchanges between staff and project engineers in a consulting company.

Between 1948-52 Peck, Thornburn, and Hanson (Fig. 6) collaborated to write the first American textbook on Foundation Engineering, published by John Wiley in time for the fall 1953 semester. Walt Hanson left the university in 1951 to work for the Illinois Division of Highways and went on to found his own consulting firm in 1954. Peck felt that the book's successful format was due in large measure to constructive comments made by fellow Professors E. J. Daily (structures) and Herbert O. Ireland (geotechnical). Foundation Engineering was used as the text for the undergraduate course of the same name for the next 45 years. While working on the foundation engineering book they discussed and critiqued the various case studies, and this led to the decision to develop advanced courses for graduate students, which they named Advanced Soil Mechanics and Advanced Foundation Engineering. A new separate course in case histories was then developed for those graduate students expecting to go into professional practice, which became CE 484, Geotechnical Case Histories.

PECK'S CASE HISTORIES COURSE AT ILLINOIS

The graduate case histories course convened for two hour sessions, twice per week. It was taught by Ralph Peck, aided by his colleague Herb Ireland (Peck and Ireland, 1974). The essential purpose of the course was problem solving: to train students how to go about analyzing and mitigating real-world geotechnical situations. The graduate students were assigned the role of being the ersatz "consulting board." Peck would present the essential elements and facts of a particular case, playing the role of the project geotechnical engineer. The briefing would include the type of information normally known at the beginning of a job, where much of the geotechnical information was assumed, based on previous experience, either with similar kinds of projects, or within the immediate area surrounding the project (similar geology).

After Peck's initial briefing the students were required to ask questions, in order to elicit additional information needed to make engineering assessments. Sometimes the student would become frustrated, unable to comprehend what Peck was asking for. Occasionally, he had to make up some information.

The students were expected to analyze all the available information, based on the initial briefing and the all-important follow-up questions. The students were then instructed to discuss the project among themselves, identifying the problems requiring solutions and debating amongst themselves what range of acceptable solutions might be offered, always keeping costs in mind.

Fig. 6. From left - Ralph B. Peck (1912-2008), Thomas H. Thornburn (1916-1986), and Walter E. Hanson (1918-) were the University of Illinois instructors who collaborated to write the text Foundation Engineering, the first edition which was published in 1953. A revised edition was released in 1974.

Professor Peck encouraged his students to tabulate unit prices for construction items, such as timber, concrete, steel, earth moving, and the like. These were usually gleaned from Engineering News Record, but students often found themselves calling contractors in the Chicago area to get unit prices for things like dewatering pumps, drilling of tiebacks, or unit prices on grouting. In their one-page reports students were asked to summarize the essential elements of the consultation and summarize their recommendations for an acceptable solution, including whatever diagrams they felt most helpful (Fig. 7).

Professor Peck would peruse these summaries for English grammar and syntax, as well as technical content. According to Peck, he "bored down in them pretty hard!" Over the years the biggest obstacle he encountered was getting everything down onto a single page. This was particularly vexing for the students who had considerable experience, and this group often complained that it was impossible to summarize all of the salient information on some of these projects in a single page. Peck summarized this difficult requirement as follows (taken from DiBiagio and Flaate, 2000): "*If you can't reduce a difficult engineering problem to just one 8-1/2 x 11-inch sheet of paper, you will probably never understand it.*" This was probably the most important aspect of Peck's case histories course.

In an interview with the author in 1997, Peck summarized some of the overarching goals of the case histories course:
"*Geotechnical engineering has become much more sophisticated than it was back in the early days, but it remains the most onerous sub-disciplines of civil engineering because it requires the most professional judgment. Geotechnical engineers are obliged to make estimates of soil behavior, based on a limited amount of data. Whether the engineer realizes it or not, these assumptions are the mainstay of our profession, and the consequences of making errors can be severe. The engineering judgment needed to make reasonable assumptions comes from experience, and the best geoengineers tend to be those who appreciate the physiographic and geomorphic setting of any given site, in the mold of Terzaghi.*"

In his retirement, Peck reflected that he received the greatest positive feedback from former students about the case histories course; insofar that any complex engineering project should be summarized in such a manner, because clients, lenders, and regulators want to read brief executive summaries, not tedious technical reports with frequent references to oversize figures and weighty appendices.

After he graded the summaries he would return them to his students at the next class session. At this juncture he would deliver a slide illustrated lecture summarizing what actually happened on the job that was just handed back to the students. Sometimes the students agreed with what was done on the actual job, but many times they did not!

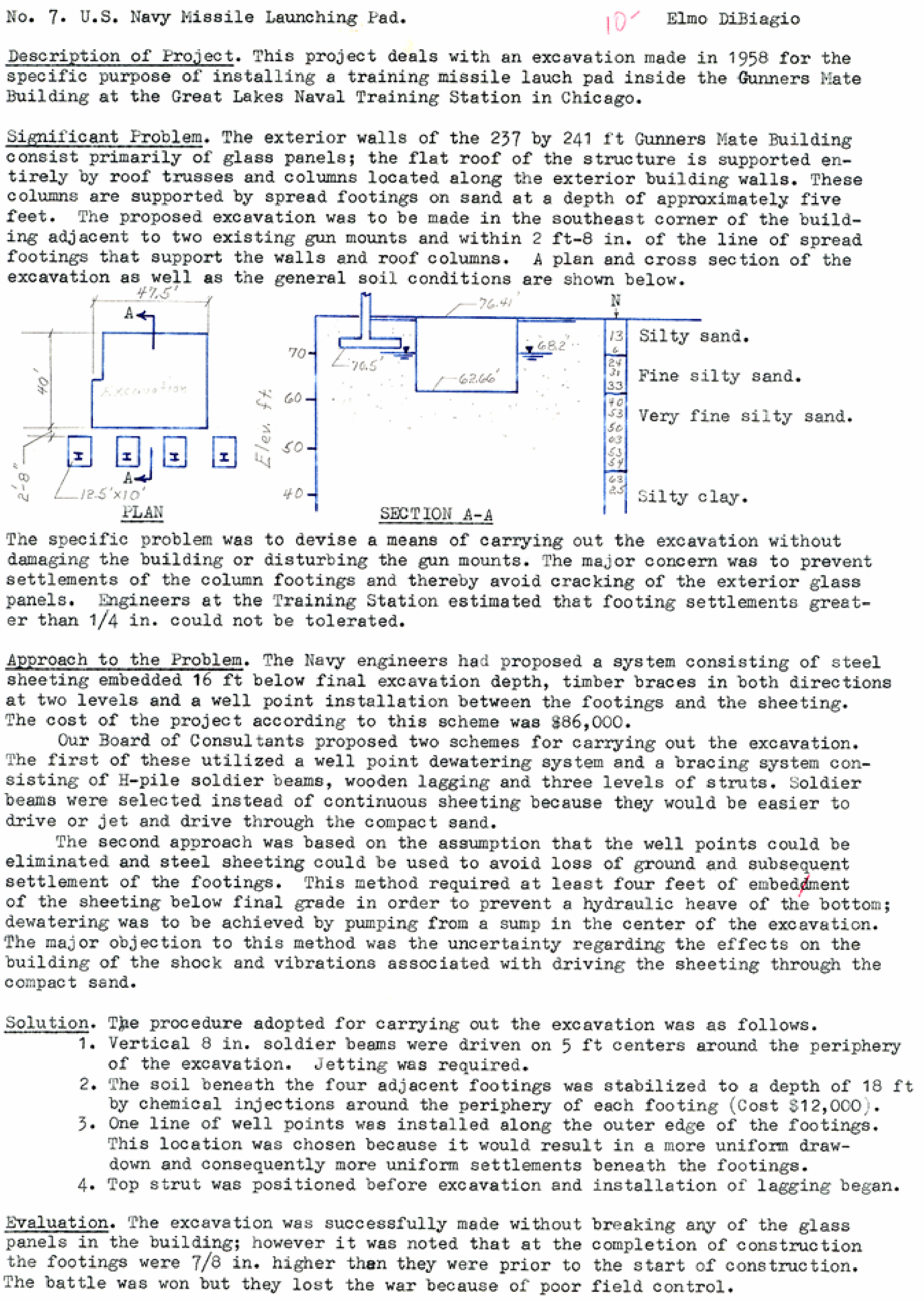
Examples of case studies profiled

The geotechnical faculty at Illinois used their consulting jobs to develop the case studies. The case histories course began with simple foundation consultations, such as spread footings, raft foundations, retaining walls, and eccentrically loaded footings. Then he would introduce settlement problems, which often involved more than one compressible unit, or drainage layer asymmetry across a site, which is often overlooked. Other common themes dealt with surcharge loads of all types, de-watering triggering settlement of adjacent structures, and basal heave of open braced cuts. Some of the projects profiled in the case histories course included:

1) Crib wall failure near Winnetka, IL, along the Chicago and North Shore Railroad suburban line. This was Peck's first consulting job, in late 1941, for structural engineer Charlie DeLeuw. Crib walls are fairly conservative gravity structures, but lack of adequate subdrainage and the dynamic loading exerted by the railroad caused a progressive failure of the wall, in overturning. Though seemingly simple, students vigorously debated what the proper surcharge values should be on the wall, and few had any idea how to handle the impact of train speed. A number of fascinating retaining wall failure case studies are summarized in Peck, Ireland, and Teng (1948).

2) The Transcona Grain Elevator bearing failure in Winnipeg, Manitoba, which obeyed Skempton's simple expression of bearing capacity: $q_d = 2.5\ q_u$ (described in Peck and Bryant, 1953).

3) The impact of pile driving disturbance on strength loss of sensitive clays, drawn from a highway job near Willow Run, MI, where piles had been driven to support a viaduct. Years earlier Professor Bill Housel at the University of Michigan had assessed the soil conditions at this site, but his observations



No. 7. U.S. Navy Missile Launching Pad. 10' Elmo DiBiagio

Description of Project. This project deals with an excavation made in 1958 for the specific purpose of installing a training missile lauch pad inside the Gunners Mate Building at the Great Lakes Naval Training Station in Chicago.

Significant Problem. The exterior walls of the 237 by 241 ft Gunners Mate Building consist primarily of glass panels; the flat roof of the structure is supported entirely by roof trusses and columns located along the exterior building walls. These columns are supported by spread footings on sand at a depth of approximately five feet. The proposed excavation was to be made in the southeast corner of the building adjacent to two existing gun mounts and within 2 ft-8 in. of the line of spread footings that support the walls and roof columns. A plan and cross section of the excavation as well as the general soil conditions are shown below.

The specific problem was to devise a means of carrying out the excavation without damaging the building or disturbing the gun mounts. The major concern was to prevent settlements of the column footings and thereby avoid cracking of the exterior glass panels. Engineers at the Training Station estimated that footing settlements greater than 1/4 in. could not be tolerated.

Approach to the Problem. The Navy engineers had proposed a system consisting of steel sheeting embedded 16 ft below final excavation depth, timber braces in both directions at two levels and a well point installation between the footings and the sheeting. The cost of the project according to this scheme was $86,000.

Our Board of Consultants proposed two schemes for carrying out the excavation. The first of these utilized a well point dewatering system and a bracing system consisting of H-pile soldier beams, wooden lagging and three levels of struts. Soldier beams were selected instead of continuous sheeting because they would be easier to drive or jet and drive through the compact sand.

The second approach was based on the assumption that the well points could be eliminated and steel sheeting could be used to avoid loss of ground and subsequent settlement of the footings. This method required at least four feet of embed~~d~~ment of the sheeting below final grade in order to prevent a hydraulic heave of the bottom; dewatering was to be achieved by pumping from a sump in the center of the excavation. The major objection to this method was the uncertainty regarding the effects on the building of the shock and vibrations associated with driving the sheeting through the compact sand.

Solution. The procedure adopted for carrying out the excavation was as follows.

1. Vertical 8 in. soldier beams were driven on 5 ft centers around the periphery of the excavation. Jetting was required.
2. The soil beneath the four adjacent footings was stabilized to a depth of 18 ft by chemical injections around the periphery of each footing (Cost $12,000).
3. One line of well points was installed along the outer edge of the footings. This location was chosen because it would result in a more uniform drawdown and consequently more uniform settlements beneath the footings.
4. Top strut was positioned before excavation and installation of lagging began.

Evaluation. The excavation was successfully made without breaking any of the glass panels in the building; however it was noted that at the completion of construction the footings were 7/8 in. higher than they were prior to the start of construction. The battle was won but they lost the war because of poor field control.

Fig. 7. A typical 1-page summary sheet prepared by students enrolled in Ralph Peck's Geotechnical Case Histories course (in this case, the student was NGI's Elmo DiBiagio). Note the small figures summarizing the foundation layout, site profile, and the respective SPT blowcounts.

and conclusions (made during the Second World War) had been overlooked by subsequent workers.

4) Preloading soft compressible soils for railroad re-location around O'Hare Airport, which required the employment of wick (sand) drains. There were two rail lines that had to be relocated to the west side of the airfield property, within a few hundred feet of York Road, which sat on a peat bog, about 20 to 25 feet deep. York Road was almost impassable due to differential settlement and rutting of the asphalt pavement. The railroads expressed anxiety about having a stabilized roadbed, assuming that the peat would be excavated and replaced. Instead they used sand drains and preloaded the site for just over a year, one of the first applications of wick drains being employed in the Midwest. There were some problems with mud waves developing adjacent to the new railroad embankments. Very small settlements were observed over the next few years, and these ceased altogether when the last of the surcharge was removed. The time settlement curve was the most intriguing aspect of this case. When the time caught up to the expected settlement curve, some secondary settlement began, but it remained quite small (flat).

5) The Zion Nuclear Plant near Kewaunee Wisconsin, just over the Wisconsin border from Illinois. This case usually fooled the most experienced students, so he kept using it for over 20 years. The project involved judging pre-consolidation of clay foundations on the basis of strengths and c/p ratios. The trick lay in the fact that some of the clays were varved (alternating layers of clay and silt), while in other portions of the site the clay was not varved (bereft of silt). He presented the class with bottled samples taken from drive samplers and extruded Shelby samples, but few would note the physical differences and appreciate their impact. He would describe the physical situation, then lay out the soil samples across the lectern table in their respective positions. The varved clays lay on one side of the site while the homogeneous clay occupied the other. When the students asked to see certain borings, Peck would retrieve the samples, and provide whatever test information the students requested. The students could examine the samples in their own hands and request further information. The students usually came up with sound recommendations about how to judge the information presented, and were invariably, intrigued with idea that because the varved clays were overconsolidated, the predicted settlements were minimal, and that all of these assessments were based on relatively crude unconfined compression tests!

6) Basal heave of the Newport News Drydocks. This case study evolved from wartime work for Dravo Corporation, while they were excavating large drydocks for constructing Navy cruisers at Newport News, VA, using cellular sheetpile cofferdams. The consultation was presented as follows: the students were to assume that they had been called to the drydock excavation while it is being dewatered. The owners had been reading piezometers and seeing fairly low uplift pressures beneath the concrete slab floor, which was only 6-1/2 feet thick. The readings appeared lower than expected. Upon arrival the consultant finds the standpipes sticking up through concrete floor with Borden gages. These gages appear to be working properly. But, the surveyors note that the sheetpile cells are tilting towards the excavation! After asking a few questions, the consultant is informed that the contractor backfilled the cells with clay, and that they began tilting when the excavation was dewatered! The question posed is: "What can be done at this juncture?" The actual case was solved by installing drain wells in the cofferdam cells, and bailing water from these, to alleviate pore pressures. The thin floor slab didn't act as an impervious blanket because the concrete slab was poured up against the sheetpile cells, and when the cells deflected, small cracks opened up between the cells and the floor, which provided pressure relief from the fine grained sand beneath the ship floor! This case was profiled in Fig. 69.1 on p. 675 in the Second Edition of "From Theory to Practice in Soil Mechanics" (1967). Other references include FitzHugh, Miller, and Terzaghi (1947), and in Jansen (1947).

7) Foundation problems for supporting heavy traveling cranes used to lift railroad locomotives in the engine shops of the Rock Island Railroad in western Illinois. This job involved variable foundation conditions with bedrock "pockets," which prevented adequate drainage. The foundations could support the static loads of the equipment, but the differential load caused by the suspended locomotives traveling along the gantry were engendering differential settlement. The gantry foundations had to either be stiffened longitudinally, or caissons installed to take the surcharge loads down to rock.

8) Clay consolidation caused by leaky brine wells in Detroit. Wyandott Chemicals had been dissolving salt from beneath their site for 50 years before adjacent buildings started sinking. Their brine wells extracted salt from Paleozoic-age limestone, at depths of 800 to 1200 feet. But, these casings began to corrode at the bedrock interface and were leaking in the glacial clays lying over the bedrock. The late Pleistocene age unit lying just above the limestone was very permeable. The leaky wells began draining the fresh groundwater down into the salt cavity, from which the company had been pumping their brine. The groundwater levels dropped about 100 feet from where they had been, because of this abnormal drainage, and this triggered ground settlement. When the students calculated the expected clay consolidation for the groundwater table dropping 100 feet, it matched the observed settlements. The leaky brine wells had to be sealed off and the groundwater table restored to its natural level. Some students habitually neglected this mitigation.

9) Sheetpile walls along depressed mainline of the Southern Pacific Railroad in downtown El Paso, Texas. Freight trains running through downtown El Paso created traffic nightmares, so the city issued a Request for Proposals to come up with a creative solution for grade separations through the downtown area. The students were given this RFP and allowed to make inquiries. The cost of relocating an active mainline railroad (four tracks) through a downtown area was daunting. DeLeuw and Cather worked up a scheme using conventional sheetpile bulkhead walls with struts across the top, which cost about 25% of a reinforced concrete open excavation alternative. The

scheme was unprecedented, so design assumptions were checked using strain measurements on the struts, at the time they were placed.

10) The frog in the tunnel lining. This case history emanated from Terzaghi and Peck's consultations in the late 1950s for BC Electric (now BC Hydro) on the Whatsam Power Plant in British Columbia. Whatsam was a small plant served by a concrete lined penstock tunnel feeding into the power plant. The reservoir was close to the cliff, so the penstock tunnel wasn't very long. Water leaking from the tunnel triggered a landslide that dumped so much material onto the powerhouse, it eventually collapsed. .

The project's designers didn't understand that pressure tunnels expand under hydrostatic loading and crack, and that these cracks allow leakage, in proportion to the hydraulic pressure head exerted on the lining. Terzaghi had come to appreciate this fact as a young engineer working in an Austrian hydro plant. When he inspected the emptied penstock tunnel feeding into the plant he did not observe any cracks, but he noticed half of a frog sticking out of the concrete tunnel lining, attesting to its having a greater diameter when it was filled with water. The solution was to collect the excess moisture that seeped through the lining and convey this to a safe point of discharge so it couldn't destabilize the adjacent slope. The pressure head from this moisture in the joints of the cliff face is what drove the raveling, not the modest volume of water.

11) Bearing capacity for the old Denver Coliseum. This site was an old gravel pit, so most everyone expected the exploratory borings to encounter gravels of high strength and bearing capacity. Peck wanted SPT values, so they fashioned some disposable conical points and secured these to a drive pipe and went probing. This succeeded in developing some nice correlations with predicted bearing capacity in some areas, but as they marched across the site, these disposable cones started penetrating without developing any meaningful resistance! The class was left to ponder this mystery until the next session.

In the actual case they soon discovered old fill in a forgotten garbage dump, dating back to the early days of Denver. The footprint of the building was pushed as far from the old dump as possible, leaving just barely enough room to get it constructed. This case was intended to emphasize the importance of doing the requisite historical research on any site, regardless of how "obvious" the site conditions might appear. It also pointed to the need for a thorough subsurface investigation across any site, even when numerous exposures and outcrops are in evidence. The case was summarized in a little-known article by Peck (1953).

12) Chewelah Chimney case. According to many of Peck's former students, this was the most memorable case study profiled in his course. It is summarized in *Judgment in Geotechnical Engineering* (Dunnicliff and Deere, 1984, pp. 177-180). In the late 1940s Peck was called out to provide input for design of a chimney structure at a site in Chewelah, Washington, just north of Spokane. The company had undertaken its own borings, extending down to bedrock within 100 ft of a proposed smelter chimney. In this boring the casing had fallen 45 feet under its own weight, and shortly thereafter, soils oozed up 60 to 80 feet within the casing! A review of the geologic literature for this area revealed that the site was located along a tributary to a valley that had been blocked by an ice dam during the late Pleistocene, creating a deep glacial lake. Not only was the site flat, but it possessed a very high groundwater table. Back-analyses of the existing 20-ft diameter storage silos on the site yielded an average soil pressure of 2 tsf (192 kN/m3).

All Peck had to work with when he arrived was a pile of drill spoils about 20 ft in diameter. This debris had been dumped on the ground when the company used a local water well driller to advance the cased hole described above. By carefully excavating this pile of drill spoils with a shovel and back-calculating the removed volumes, Peck was able to reconstruct a crude boring log! The layering of the drilling spoils suggested the site was covered by a thin veneer of wet sand and silt about 4 ft thick, underlain by blue lacustrine clay that extended 20 to 30 ft beneath the ground surface. The blue clay was underlain by fine sand, but capped by brown (oxidized) clay at a depth of about -4 ft (Fig. 8). This brown clay was the key "hint" fed to the students. The oxidized clay represented was likely caused by desiccation under subaerial exposure, which would create a much stiffer, overconsolidated crust, above the blue clay.

Peck reasoned that the conditions in a glacial lake deposit could be expected to be similar 100 ft away, beneath the proposed location of the new chimney. He cajoled the students to reason that if the bearing pressures could be maintained at or below those already exerted by the 20 ft diameter storage silos, it should support the concrete chimney. The proposed stack had an octagonal base with a diameter of 32.5 ft (9.91 m), exerting a pressure of 3,500 psf (167.65 kN/m3), about 500 psf less than that exerted by the existing silos. As a check on these preliminary conclusions, Peck recommended that a simple auger boring be extended about 25 ft deep with thin wall tube samples recovered for unconfined compressive tests. The strengths were erratic in the upper 4 ft because of freeze-thaw effects, reaching a maximum strength of 3 tsf in the upper part of the oxidized crust, and decreasing to 0.5 tsf at -24 ft. These results are summarized in Fig. 8.

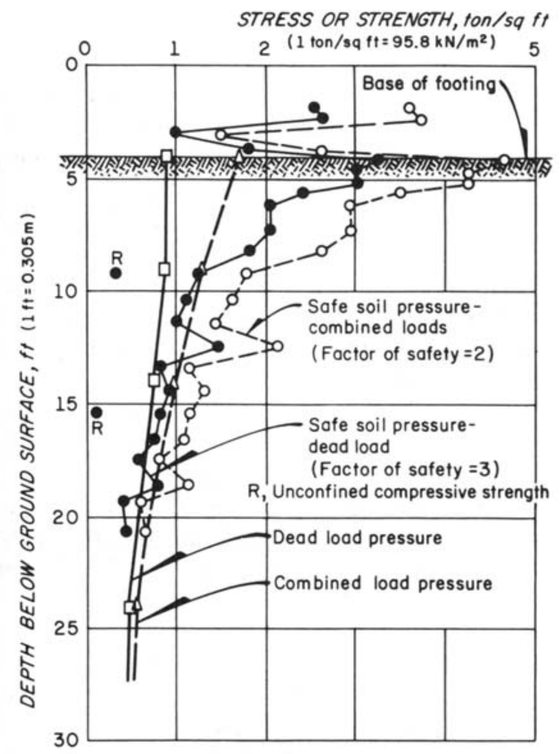


Fig. 8. Simple chart showing unconfined compressive strength (solid circles), safe soil pressures (open circles), dead load pressure (open squares), and combined load pressures (open triangles) for the proposed chimney at Chewelah, Washington.

The students were also asked to plot the stresses beneath the proposed chimney as a function of depth, with maximum wind load, using Newmark's influence chart for computation of vertical pressure (Newmark, 1942). These results are shown in Fig. 9. They allowed a visual assessment of the ratio of imposed stress to soil strength, which reached a minimum between depths of -10 and -25 ft. The students could calculate a factor of safety of 3 for bearing capacity under static conditions, decreasing to FS = 2.0 for conditions of maximum wind loading.

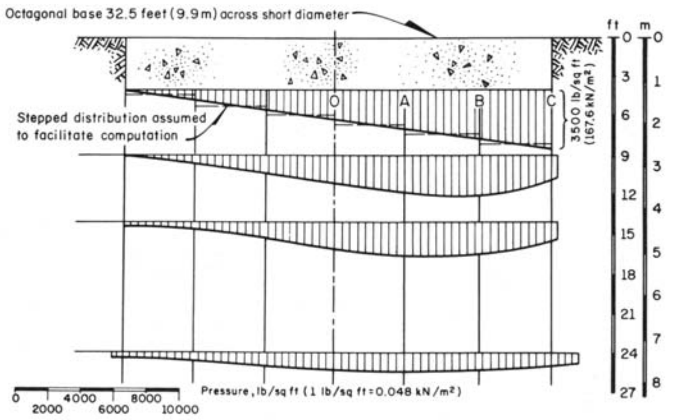


Fig. 9. Newmark pressure diagrams beneath the footing of the proposed chimney at Chewelah, Washington under maximum wind loading, versus depth. Students found this to be a valuable graphic representation of the situation, which required more than a simple check of the bearing capacity of the hardpan layer.

Many of Professor Peck's students later remarked that the Chewelah Chimney case provided them with the tools to undertake invaluable geotechnical studies at remote sites in the Third World, where modern drilling equipment and trained personnel were seldom available. Peck found that the students favored these hands-on exercises more than any other course they took at Illinois. They liked working on real jobs where they could see and feel the soil samples. As the semester wore on, Peck would introduce increasingly complex case studies. Some of these cases took several weeks to describe and provide sufficient interchange for the students to become properly appraised of the most critical issues at hand. Sometimes they would ask for information that hadn't been gleaned from the actual case, and Peck would have to inject "new information," based on his experience and judgment.

The graduate program at Illinois gradually grew to something between 300 and 400 students, of which between 20 and 25% were enrolled in geotechnical engineering. Many of these included individuals employed by the Army Corps of Engineers, because Professor Peck served on the permanent Geotechnical Consulting Board for the Corps' Waterways Experiment Station, between 1960-78. Many of the graduate students from structures and geology enrolled in the case histories course because it gained a reputation as being one of the most valuable and practical courses at the University of Illinois in the post-war era (1950-75).

BERKELEY'S CAPSTONE GEOTECHNICAL COURSE

The geotechnical engineering program at the University of California, Berkeley basically began with the hiring of Professor H. Bolton Seed (1922-89) in 1950 (Fig. 10 left). Harry Seed grew up in England, receiving his BSCE degree from the University of London in 1944 and a Ph.D. in structural engineering in 1947. Following two years as assistant lecturer at Kings College, he enrolled in graduate studies in soil mechanics at Harvard University under the tutelage of Karl Terzaghi and Arthur Casagrande. He received his S.M. degree from Harvard in 1948 and spent the next year at Harvard as an instructor. This was followed by a year as a foundation engineer for Thomas Worcester, Inc., in Boston, before joining the Berkeley faculty, where he spent the balance of his career.

Like Ralph Peck at Illinois, Harry Seed built a credible program of study in geotechnical engineering, surrounding himself with a diverse and talented stable of experts, which included Clarence K. Chan and William N. Houston, who oversaw the activities of the state-of-the-art geotechnical laboratory developed at Berkeley between the mid-1950s and early 1990s. Bill Houston (Fig. 10 middle) received his BS degree in geological engineering at Colorado School of Mines in 1960 and owned his own surveying company before enrolling in graduate study in geotechnical engineering at Berkeley in 1964. He completed his masters in 1966 and doctorate in 1967, before joining the Berkeley faculty in 1968.

Shortly after Ralph Peck retired from the University of Illinois in June 1974, Harry Seed invited him to come out to Berkeley and teach his geotechnical case histories course in a special two week summer session. Peck taught his course all afternoon each day for one week, departed the following week, then returned and completed the course the week after that, teaching each afternoon. Peck found this arrangement to be ineffective because the students didn't have time to discuss the information amongst themselves between the presentations, which is how they learn from one another. One student was a project engineer for Dames & Moore in San Francisco. He couldn't believe that Peck was serious about boiling everything down to just a single page of paper, so the first report he turned in was 12 pages long. Peck admonished him to try again, and the student whittled it down to seven pages! Peck returned the paper once again, and this time the frustrated pupil informed Dr. Peck that "*I've been writing report for Dames & Moore for ten years and I've never been forced to limit myself to a single page!*" "*Yes, I know*" Peck replied, "*I've seen some of those reports!*"

Fig. 10. Left - Harry Seed as he appeared around 1985. Middle – Professor Bill Houston, who taught at Berkeley between 1968-85, then moved to Arizona State. Right – Berkeley Professor Ben C. Gerwick, Jr., who held a dual appointment in construction and geotechnical engineering after 1984.

Despite Professor Peck's summer offering of his case histories course in 1974, the Berkeley faculty didn't feel they could offer a similar course with the breadth of experience offered by Peck. Instead, they chose to develop their graduate geotechnical laboratory class into a "capstone course," in the model presently promoted by the Accreditation Board for Engineering and Technology (ABET) to equip students to apply the various technical principles to real world situations requiring problem solving, report preparation, and verbal presentation. The course in Graduate Soil Mechanics Laboratory Procedures (CE 270L) was intended to introduce the various aspects of geotechnical testing in the field and laboratory. It succeeded in being much more than a simple lab course because of the manner in which it was organized and taught by Professor Bill Houston. The course covered the essential elements of the geotechnical engineering profession; which included field sampling, field testing, field measurements, soils classification, lab testing, deciding which analytical techniques were appropriate to different conditions of loading, engineering analysis, and report preparation. It soon became the most difficult of the two dozen graduate courses Berkeley offered at the height of their graduate program, in the late 1970s, when they enrolled almost 100 graduate students in geotechnical engineering. The course was time-intensive, employing one hour of lecture and two three-hour laboratories each week. Prerequisites included both courses in advanced soil mechanics and foundation engineering (CE 270 A and B).

The 270L course used the deactivated Hamilton Air Force Base near Novato, CA along the northern margins of San Francisco Bay as the perennial "project site." Hamilton Field was underlain by Young Bay Mud estuarine clays, with a mixture of ferruginous organic silts (from the 1862 floods) and overbank silts, which looked very similar to bay mud, but were essentially soft silts, bereft of clay. These were underlain by sand lenses and more extensive Old Bay Muds (now called the Yerba Buena Mud), of approximately 116 ka age. This soil profile was similar to what could be found elsewhere along the margins of San Francisco Bay and the

Hamilton Field test site had been probed, sampled and analyzed in great detail by the Berkeley geotechnical program over the years, and their properties were well understood (Bonaparte and Mitchell, 1979).

The class usually enrolled between 25 and 35 students. The students were divided into "design teams" of about three students apiece, the same model used in Berkeley's construction engineering courses (discussed next), which were also popular with the geotechnical grad students. Over the course of several weekends the class engaged in a day-long sessions of drilling, logging, sampling, and insitu testing (Fig. 11). Each team took turns advancing their own borings across the study site, along the bay margins. The teams used hand augers and standard 3.0-inch diameter Shelby Tube samplers, filling out boring logs with requisite information. Students were also asked to perform insitu strength tests using conventional vane shear apparatus, reporting these values on their boring logs. During some of those years, other instruments, such as cone penetrometers, and Menard Pressuremeters, would be demonstrated onsite for the benefit of the students, to gain familiarity with these techniques. At other times interpreted CPT logs would be given to the students, to supplement the information gleaned from their own borings.

The Shelby Tubes were sealed and taken back to the Berkeley campus, where they were placed in a controlled moisture room. The following week students would gain experience extruding the recovered samples and spent the balance of the semester running a battery of laboratory index tests, which varied from year to year, but usually included: USCS soil classification; wet sieve analyses; Atterberg Limits; bulk density, water content, unconfined compression; one-dimensional consolidation; and/or 1-D consolidation using strain-controlled loading; pore water pressure measurement in consolidated-undrained and drained triaxial tests; and cyclic triaxial testing. Other sites, such as the Richmond Field Station, seven miles northwest of campus, were used to accommodate pile load tests and introduce students to advanced instrumentation and measurement techniques, as well as pavement design procedures. This was an ambitious testing program and every student that completed this challenging regimen benefited immensely from the experience. Many of the tests had to be re-run because of extenuating circumstances, such as: disturbance during field sampling or sample preparation, entrained air that had not been properly bled from the vacuum lines, or errant data recordation.

Fig 11. Student recording raw blow counts from a SPT test at Hamilton Field study site, along north shore of San Francisco Bay. Students were required to calculate the appropriate corrections years before industry routinely employed such practice.

These are the sorts of issues that must be experienced on a personal level to leave their indelible mark on the student. For instance, if a geotechnical engineer hasn't personally run a series of consolidation tests at some point in his/her career, they will be hard pressed to recognize the impact of sample disturbance in the results, which often obscure meaningful calculation of pre-consolidation pressures. These were the kinds of details that Professor Houston kindly pointed out and explained in a manner that all of the students could usually understand.

The next step was to analyze the collected lab data and synthesize it. This synthesis involved a critical evaluation of the project description, which outlined what was being asked of the geotechnical engineer. This often involved behavior during construction, with undrained loading; while another aspect of the project might involve long-term, drained conditions. Houston did an excellent job of defining the various states of stress associated with different periods of construction. For instance, students were often asked to prepare apparent pressure diagrams for temporary restrained excavations, then contrast these with the long-term loads that a permanent restrained wall system would need to support (Fig. 12). This distinction is often blurred or altogether unaddressed for students matriculating through fast-paced graduate programs.

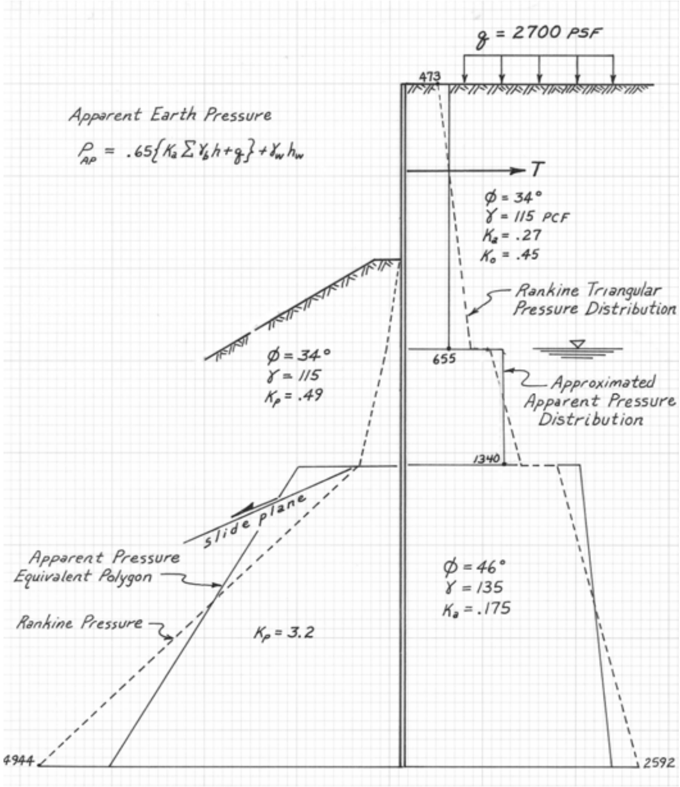


Fig. 12. Earth pressure diagram illustrating Rankine (dashed) versus Apparent Pressure Diagrasm for the retained excavation posed in the author's CE 270L term project.

Being in California, 270L term projects always required evaluations of seismic loads. This process has been in continual evolution since the mid 1960s in California, especially, if near-fault effects were considered. The Rodgers Creek Fault Zone passed within a few miles of Hamilton Field site, so those issues came into increasing consideration as the years passed. The course also introduced the students to the appropriate safety factors to apply for temporary support, such as braced excavations, in comparison to permanent walls, and the likely impacts of changing water levels on those support systems.

The most difficult aspect of the course was performing the dynamic triaxial tests. This usually involved help from Research Engineer Clarence Chan, who had designed the dynamic soils testing apparatus that was used. Dynamic triaxial tests required no small measure of experience and patience to carry off successfully. Anyone who was in a hurry usually regretted it afterwards, because their data would be unreliable. This led to considerable angst on the part of many of the less experienced students, who had fared well (~4.0 GPA) in all of their classroom coursework prior to taking CE 270L.

The course culminated with the preparation of a "consulting report" summarizing the program of field exploration, sampling, testing, analyses, and resulting recommendations. Students were provided access to actual consulting reports to gain some idea of what was expected. For many of the less experienced students these were the first geotechnical reports they had ever seen. These made a lasting impression because Bill Houston presented students with some of the best that Bay Area consulting firms had produced to date, not the "low ball" variety. The reports had to follow a prescribed format, which included the finalized boring logs and lab test results neatly arraigned in appendices. Houston emphasized that the students weren't writing the report for a soil mechanics professor. Students were encouraged to consider how the lab tests would be plotted that best summarized the results of such work. He reminded students that the data not only had to be understood by the client, but also sufficiently clear and concise to prevent it from being misused by others, including engineers designing temporary shoring for the contractor. Few of us realized at the time how profound these admonitions were, but everyone appreciated it later in their professional careers.

Professor Houston left Berkeley in 1985 to take a faculty position at Arizona State along side his wife, Sandra L. Houston. He retired from ASU in 2003, although he has remained active in research and as a consultant to GTCS Testing Systems. He is a commercial salmon fisherman out of Point Arena, CA during part of each year.

BERKELEY'S FOUNDATION CONSTRUCTION COURSE

Professor Ben C. Gerwick, Jr. (1919-2006) received his BSCE degree summa cum laude from Berkeley in 1940, on a Navy ROTC scholarship. By the end of the Second World War Gerwick had been promoted to full commander and given command of his own deep draft ship (USS Scania). This background in maritime operations and seaborne commerce served him well during his subsequent career. After his discharge in 1946 he went to work for his father Ben Sr., (1882-1977) who received his BSCE degree from Ohio State in 1906 before starting his own heavy construction firm, Ben C. Gerwick, Inc., in 1926 (based in San Francisco). The firm gained prominence a decade later when Gerwick Sr.'s patented cofferdam technique was successfully employed to construct the north tower of the Golden Gate Bridge. Gerwick Construction went on to champion the use of precast concrete piles on marine facilities and the first to construct concrete drydocks "in the wet" for the Navy during the Second World War. In 1952 Ben Jr. succeeded his father as the company's president and began developing prestressed concrete piles, pioneering their use in deepwater marine structures and in arctic regions. In the mid-1960s Gerwick was the first American contractor to employ soldier pile-tremie concrete (SPTC) systems to support the deep retained excavations, for the Bank of California building in San Francisco (Gerwick, 1967). The SPTC support technique was subsequently employed in the construction of the Bay Area Rapid Transit and San Francisco Municipal Transit system's underground stations in the late 1960s and early 1970s (Rogers, 2003).

During the 1950s and 60s Gerwick's firm served as one of the prime contractors for the caissons and supporting bents of the Richmond-San Rafael and San Mateo-Hayward bridges. Before entering academia Professor Gerwick registered six patents related to prestressed concrete piles and he was widely respected for his innovations with concrete admixtures for marine structures, having authored 90 technical articles. He joined the civil engineering faculty at Berkeley in 1971, where he helped launch their construction engineering and management program. He retired from his full-time position in 1989, but continued teaching one course per year until his death in late 2006. During his academic career (1971-2006) Gerwick wrote 126 technical papers, authored four chapters in other texts, six of his own textbooks, and his own personal memoir.

Professor Gerwick (Fig. 10 - right) developed a series of graduate courses on various aspects of heavy construction. One of these was CE 267A, Advanced Foundation Construction. Like Ralph Peck, Gerwick was world-renown for his work on deep foundations for bridges, buildings, harbor facilities, and offshore structures. Similar to Peck's case histories course, Gerwick's foundations course drew students from most of the major disciplines of civil engineering; including structures, geotechnical, coastal and marine; as well as construction engineering and management. Most of Berkeley's geotechnical graduate students were encouraged to take CE 267A. The author took his course in the fall of 1977, which was the course's third offering.

Like Houston's 270L course, the foundation construction course was delivered by Professor Gerwick in the mold of a capstone course, with the students divided into multi-disciplinary teams; usually consisting of a construction engineering and management student, a structures student, and a geotechnical student. Each of these members would be tasked with preparing their respective portions of the "consulting report" that constituted the only work product for the course. There was nothing amateurish about these reports, they were stand-alone documents suitable for submittal to any building inspection department in America. Students were obliged to visit the proposed project site on their own time to see what they could learn about the site conditions. Most of the course projects were actual jobs, so these site visits could be extremely valuable in understanding the various construction challenges posed at these locations (Fig. 13).

Fig. 13. Photos of 24-inch diameter augered caissons being excavated at the course project site along The Embarcadero in San Francisco, in September 1977. The contractor chose to employ Sonotube forms as temporary casing, using lime to improve working conditions on the excavated pad, which extended into soft estuarine clays.

Gerwick began his foundation construction course with about three weeks of historical overview, beginning with James B. Eads and the various innovations ushered in with the construction of the Eads Bridge across the Mississippi River in St. Louis in 1867-74. He then profiled the evolution of American foundation engineering, with the major emphasis on projects in and around New York City, beginning with the techniques introduced by The Foundation Company, founded in 1901 by Daniel E. Moran, Franklin Remington, and Edwin S. Jarrett. This trio developed the first cofferdam caissons and perfected many patented techniques for sinking shafts and caissons that were employed up through the 1940s. Gerwick also introduced his students to Lazarus White of Spencer, White & Prentiss, through White and Prentice's 1950 textbook, which remains one of the best collections of geotechnical case histories ever compiled. Most of these examples were for large high-value structures, like cofferdams for bridges, locks, and powerhouses.

Gerwick also profiled the development of deep foundations for buildings, beginning with hand-excavated belled caissons founded on hardpan in Chicago (from 1893 on ward), Boston (from ~1902 onward), and New York (from ~1901 onward). His emphasis then shifted to west coast projects, where he and his father had most of their experience. The earliest of these was the machine excavation of Gow belled caissons by the Raymond Concrete Pile Co. for the Phoenix Assurance Building on Pine Street in San Francisco in July 1928 (Rogers, 2006). This project had an enormous impact on other west coast contractors. This was followed by brief summaries of various foundation problems overcome during the construction of the San Francisco-Oakland Bay Bridge, Treasure Island, and most of the taller structures in downtown Oakland and San Francisco built after 1930.

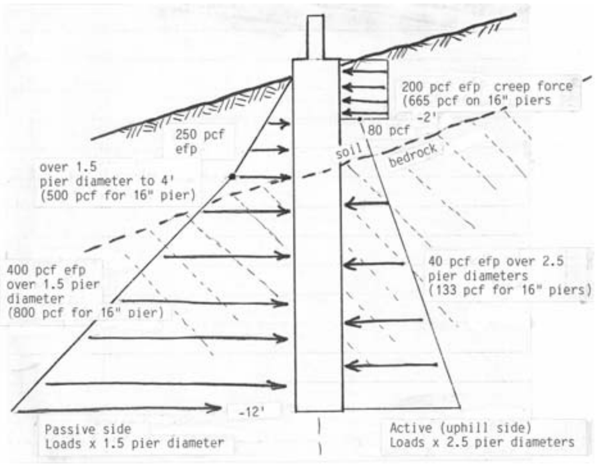


Fig. 14. Professor Gerwick admonished students to provide physical diagrams for recommended geotechnical loads, as sketched above. This decreased the likelihood of recommended loads being misinterpreted or incorrectly applied by other engineers.

Professor Gerwick's foundation construction lectures contained a great deal of practical advice, drawn from years of experience. One of the basic tenants was to show the recommended loads on a sketch, like a free body diagram, similar to that presented in Fig. 14. He felt that this simple protocol prevented mis-interpretation of the recommended soil forces, and how they should be applied by structural engineers tasked with calculating such loads. This reduces the likelihood of the geotechnical recommendations in the body of a report being misinterpreted by another engineer, such as the structural engineer designing shoring for a contractor.

Examples of case studies profiled

Gerwick's case history lectures were always interesting because they usually focused on geotechnical construction problems and the innovative solutions employed to circumvent various problems. Some of the most memorable case studies profiled in Gerwick's course are summarized below:

1) Tilting and correction of the Moran Caisson. Carlton Proctor of Moran & Proctor Foundation Engineers in New York designed and constructed the world's first open-dredged caissons, in 120 feet of water, for the Bay Bridge between Yerba Buena Island and San Francisco in 1934-35. These water depths were about 50% deeper than any constructed previously, world-wide. His firm developed what came to be known as the "Moran Caisson," a cellular caisson consisting of a series of steel cylinders that was initially sunk into the bay sediments in the proper position. During excavation, only a few of cell covers were removed at any given time, while soil within each of the cylindrical cells was gradually excavated. The caisson unit was carefully "managed" using compressed air and the excavation staged to advance downward and avoid tipping or buoyancy problems. This technique was subsequently emulated on dozens of deep caissons thereafter, world wide. Moran & Proctor had one near-catastrophe with placement of one of these massive multi-celled caissons, which gradually tipped over because of local bearing failure in the Bay Mud. It was recovered by closing off the caps on the cells, pumping in compressed air, and re-floating, then repairing, and leveling of the sea floor before attempting a second placement (summarized in Proctor, 1936).

2) Dewatering sites during construction. One of the most memorable lectures dealt with dewatering problems, which can cause a plethora of unforeseen problems, by triggering settlement of adjacent structures. The most successful dewatering job he profiled was the construction of Kaiser Engineers headquarters in Oakland, across Lakeside Drive from Lake Merritt. The contractor realized the dewatering challenges would be unprecedented, so he allowed for a full six months of pumping before excavating the basement, with numerous monitoring wells. This resulted in marked success.

3) The pitfalls of pile driving. Some of Gerwick's most colorful stories were about various experiences with pile driving, with which he was particularly well acquainted. He could have spent the entire semester discussing pile supported foundations (this was the emphasis of a companion course on construction of harbor, coastal, and ocean structures). One of his first pile driving jobs was for his father during the summer while still a student at Berkeley. He was supposed to drive some timber piles 45 feet deep for a temporary ferry mole on Treasure Island, for the Golden Gate International Exposition in 1939-40. Young Gerwick carefully supervised the setting and driving of the first pile, which was easily driven into the bay without offering any meaningful resistance (one blow for every 18 inches). When he returned to his father's office that evening, the senior Gerwick couldn't believe what he heard; it "was just impossible." Further investigation by father and son the next day revealed that young Ben had inadvertently set the pile tip on the collar of an old well casing, and that his crew had faithfully pounded the pile into the casing!

Other pile driving tales included driving steel H-piles that were deflected by an old buried seawall and ended up emerging from the ground across the street! He also described the various advantages of using steel tips when driving H-piles and how to provide cathodic protection from corrosion in the partially saturated zone, where corrosion is most problematic (Fig. 15). Some of the more memorable tales about prestressed concrete piles concerned the driving of broken piles by inexperienced personnel, and how this condition could be deduced from the pile driving records. Many of these stories later proved valuable in the professional careers of his students. Another tale concerned the vexing problem with piles on the margins of San Francisco Bay, where negative down-drag forces were exerted on the piles by consolidation of the Young Bay Muds through which they extended. Down-drag was partially alleviated by applying bitumen to the piles before driving, but was never altogether eliminated. Differential down-drag along long wharves was a particularly vexing problem, especially if these wharves supported traveling cranes on rails.

The most difficult pile driving job Gerwick described was in San Francisco's financial district, across the street from renowned plaintiff attorney Melvin Belli (1907-1996), who hired a string of experts to measure vibrations and alleged damage to his condominium building. These problems and other similar complaints eventually led to the City of San Francisco restricting pile driving to evenings and weekends in the city's business districts.

4) Rat holes along the margins of pile-supported structures. Professor Gerwick described a number of high-visibility projects around the margins of San Francisco Bay involving pile supported structures that remained fixed, while the surrounding ground settled, due to consolidation of underlying estuarine clays. When the ground dropped away, voids developed between the pile supported foundations and the sinking ground. These were commonly referred to as "rat holes," because they allowed animals and vermin to enter the newly formed spaces. Rat holes looked bad, posed a serious trip-and-fall safety hazard, and invariably, promoted separation of buried utilities serving the pile-supported structures. Some of the examples Gerwick presented included: the Bay Bridge Toll Plaza structures built in 1934-35; the Alameda Naval Air Station constructed in 1939-41; structures on Treasure Island built by the Navy after 1941; and the Watergate Condominiums adjacent to the Emeryville Marina, built in the early 1970s. Gerwick covered more advanced topics relating to pile foundations, such as earthquake resistant design, in his companion course on construction of harbor, coastal, and marine structures (CE 267C).

Fig. 15. Cathodic protection applied to steel sheetpile bulkhead wall on Sand Island Inner Harbor, Midway Atoll. Remnants of previous bulkhead wall can be seen behind the replacement structure.

5) Soldier Pile-Tremie Concrete diaphragm walls. Gerwick's construction firm had pioneered the use of SPTC diaphragm walls for supporting deep excavations in San Francisco. Gerwick took his students on a tour of slurry wall trench technology, beginning with the Italians, and profiled all the major advancements that were made between the early 1960s and late 1970s. These lectures culminated with the foundations for Embarcadero III office complex and the Embarcadero BART/MUNI Station at the foot of Market Street in San Francisco, where the excavations extended up to 40 feet (12.2 m) below the groundwater table.

6) Tie-backs and tied-back walls. Gerwick provided a brief synopsis of the kinds of tiebacks that had been used on retained excavations and permanent retention structures, beginning with prestressed tie-downs used in Europe in the 1930s to increase overturning factors of safety on older masonry gravity dams!

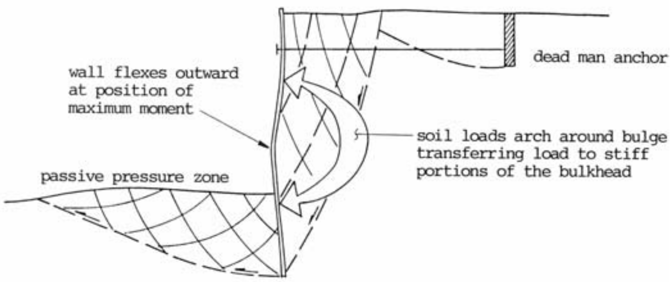


Fig. 16. Gerwick's exaggerated image of sheetpile deflections and soil arching provided valuable insights on how these support systems operated, and allowed students to visualize where deflections could be expected. A common problem with wharf bulkheads was periodic dredging removing lateral support in the passive pressure zone.

He illustrated the basic loading concepts employed on tied-back structures, such as bulkhead walls (Fig. 16) and explained where predicted anchorage levels were not achieved on various jobs, and why. These usually revolved around variances in geologic conditions and man-caused changes to the site that had gone undetected in the geotechnical investigations. He also stressed that tiebacks typically had performance specifications, which meant increased risk for the contractor and cost for the owner. His biggest warning was to beware of installing tiebacks in clayey materials, as this was where the greatest variance between theoretical anchorage and pull-test results invariable occurred.

7) Assessing basal heave. Professor Gerwick described a number of case histories dealing with basal heave and examination of critical hydraulic gradients. These included the dry docks at Hunter's Point, the North Point Sewage Pump Plant, deep excavations in vicinity of China Basin, and the Bank of California building. The lessons all devolved down to the need to think out ahead of the excavation schedule; the sooner one started dewatering, the better. But, he also emphasized that dewatering was a tricky practice, which required continuous monitoring, ongoing assessment, and resulting adjustments. Trying to circumvent or hurry this process almost always resulted in unnecessary complications.

8) Soil and site improvement. This was an area that was largely unexplored during Gerwick's professional career (1946-71), but one which fascinated him greatly because he

saw its potential for the future. His Berkeley colleague James K. Mitchell taught a graduate course on soil and site improvement (CE 272) between 1969-93. These lectures began by describing the ad hoc use of "soil additives" by contractors to achieve greater strength and workability during construction. These included adding cement, lime, and fly ash to soft soils, even one contractor's employment of flame throwers on exposed San Francisco Bay Mud to dry it out more quickly! Gerwick also exposed his students to future applications of geotextiles to accommodate low cost alternatives for certain applications, such as that sketched in Fig. 17. Another futuristic area that excited Gerwick was reticulated root piles, a technique introduced by Italian contractors. He thought that unstressed, small diameter tensile reinforcement had enormous potential for geotechnical work, stitching soil together much like the root system of a tropical banyan tree.

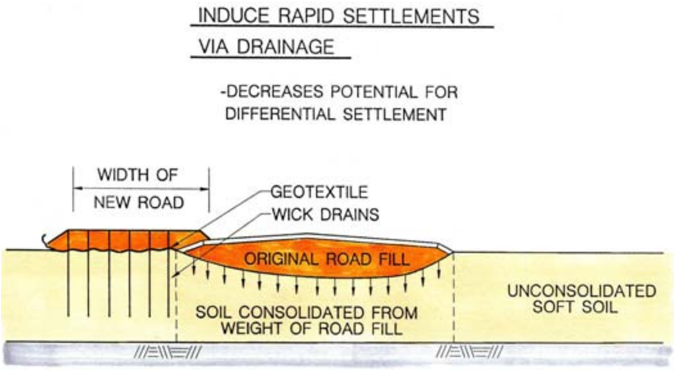


Fig. 17. In the late 1970s Gerwick saw the potential for geotextiles to be used between engineered fill and soft soils, to promote more even settlement of the surcharge.

DISCUSSION

According to university alumni surveyed more than 10 years after graduation, professional practice courses in geoengineering using selected case histories have been one of the most effective and influential components of post-secondary education. These courses introduce students to problem solving and the need to make reasonable assumptions about site conditions, based on the geomorphologic setting and "area experience" (working in areas with similar geologic conditions). Making the "right assumptions" involves considerable judgment and often involves "trade-offs," between competing factors. For instance, some conservative assumptions should be balanced by other, more liberal assumptions, or the site characterization may become over-conservative. By forcing students to struggle with these competing factors, most of them gain some appreciation of the geologic uncertainties existing at any site (both in soil/rock type, thickness and extent, as well as variances in strength parameters and behavior). This appreciation is fundamental in honing the professional judgment that is an integral part of geoengineering.

Unfortunately, few universities have professors with the breadth of professional experience profiled herein. Can professors with impressive academic credentials effectively teach courses in geotechnical case histories? Karl Terzaghi scoffed at such an idea. In May 1942, when Peck was initially offered a faculty position at the University of Illinois, he asked Terzaghi if he should accept. Terzaghi responded "*Are you kidding, you don't have any experience with foundation design. Would you take a course in artillery at West Point from some officer who's never fired a canon?*" So Peck took a job with Holabird, Root, and Burgee, as chief of field testing during the construction of an ordinance plant in Marion, Ohio. Seven months later Terzaghi changed his mind after Peck discovered a significant error in some calculations Terzaghi had made for Republic Steel's ore loading yard in Cleveland, stating "*you've gotten some quality experience under your belt now, go ahead and start teaching, so long as we can continue working together*."

Terzaghi and Peck remained active consultants the entire time they taught, asserting that it was this balance that allowed them to be such effective teachers. Between 1939-56 Terzaghi taught courses in Engineering Geology and Applied Soils Mechanics at Harvard. During that time he had just under 1000 graduate students attend his courses (Bjerrum et al., 1960). During Peck's 32 year career at Illinois about 4000 graduate students took at least one of his courses (Dunnicliff and Deere, 1984).

Karl Terzaghi, Ralph Peck, Harry Seed, and Ben Gerwick all felt that universities should maintain faculties with a balance of theory and practice; and that, practice courses should be taught by respected engineers with experience (Peck, 1958). The American model for research institutions that evolved after the Second World War has become increasingly skewed towards the pursuit of externally-funded research, at the expense of educating students in aspects of professional practice. Many faculty regards these issues as something the private sector is responsible for teaching to its own ranks. Realizing the lack of practical training, most high-profile consulting firms save training expenses by only hiring experienced personnel from other agencies or firms. This trend has led to increased bidding for, and mobility of, experienced geoengineers (Rogers, 2002).

Academia is in sore need of balance; they need researchers, but they should also promote teaching excellence and aspects of professional practice, because their fundamental charge is to prepare the great majority of their students to become professional engineers, not professors. There is little question that the enormous success of the programs at Illinois and Berkeley came about in large part because of the superior quality and balance of the education received at those institutions because the professional practice aspects were adequately addressed, by seasoned professionals with world-class experience. This influenced the university rankings, which, in turn, helps attract high quality students. Successful programs are usually built on a wise blend of balance, with mutual trust and respect (Weingardt, 2001; 2005; Haltiwanger, 2004).

Like consulting firms, academic administrators should realize that “one size doesn’t fit all.” Over the past century the most successful professional firms and institutions of higher learning have been those who recognize their own strengths and carve their own niches. All too often, corporate and academic leaders try unsuccessfully to emulate the giants of their respective industries (e.g. IBM or Berkeley), because these entities are perceived as being “successful.” In reality, some of the smallest programs, such as the California Institute of Technology (900 students) and Massachusetts Institute of Technology (4600 students) have built top-ranked programs by focusing on quality of a limited number of academic programs, rather than breadth and quantity (Rogers, 2007). It takes decades to build successful academic programs; and these are seldom accomplished by leaders obtained from “nation-wide searches;” who remain for only three to five years before moving on somewhere else, as has become the fashion in American higher education.

CONCLUSIONS

Most engineering schools could offer challenging and rewarding courses in geotechnical case histories, if the faculty and administration simply committed themselves to the task. The easiest way to begin this process would be by pooling “experience resources” within the existing faculty, to ascertain which subjects they could cover adequately. Alumni and practicioners could then be invited to fill “gaps” with additional case histories that would expose students to engineering problem solving. Unfortunately, these kinds of lectures and the follow-up discussions can’t generally be accommodated in the 50-minute seminar formats used by most universities for guest speakers. It’s the question-and-answer period following formal project descriptions that are most crucial to promote interactive discussions between the students and the teacher. This was why Ralph Peck found himself obliged to use two-hour sessions twice per week. Even with that kind of format, it sometimes took two or three weeks to profile the more complicated case studies (Dunnicliff and Young, 2006, p. 52-54).

Case studies courses could lend themselves to corporate sponsorship by seasoned practicioners and/or experienced academics. Their experiences could be packaged up and deposited in a “virtual library,” making them available for circulation to other teachers. If Peck’s course served as the prototype, the syllabus should commence with a range of smaller jobs, leading to increasingly complex assignments, often concluding with some of the higher visibility failures. Most engineers will encounter the more mundane kinds of problems, like retaining wall failures or accelerated pavement distress, in contrast to high profile catastrophes, like the 1976 Teton Dam failure or the failure of the concrete flood walls around New Orleans during Hurricane Katrina in 2005.

A virtual library of case histories wouldn’t have the same depth of realism offered by the actual ”principal” who performed each consultation, but it would introduce the concepts of engineering history, heritage, and lessons learned from engineering failures, which experienced engineers seem to value over simple theory.

In 1997 the Board of Directors of the American Society of Civil Engineers identified three principal deficiencies in undergraduate civil engineering education that they felt needed to be addressed by academic programs (ASCE, 1998; 2008). In developing Policy 463, ASCE President Luther W. Graff stated “An emphasis on history gives engineers insight into today’s design and problem-solving methods while offering practical examples of how engineers have resolved some of the tough ethical issues. Such knowledge can be invaluable to practicing engineers.”

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