01 May 2013, 11:30 am - 11:50 am

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April 29 - May 4, 2013 CHICAGO
Seventh International Conference on Case Histories in Geotechnical Engineering
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RALPH PECK'S CIRCUITOUS PATH TO PROFESSOR OF FOUNDATION ENGINEERING (1930-48)

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ABSTRACT

When most geoengineers hear the name of Ralph B. Peck (1912-2008) they usually associate him with the father of soil mechanics, the legendary Karl Terzaghi (1883-1963), because of their long professional association, between 1939-63. But, Peck's professional career in geotechnics was also influenced by other engineers and geologists, whose ingenuity he admired and tried to emulate. Some of these are names easily recognized, even 100 years later, while others are all but forgotten. This article seeks to introduce the reader to some of those luminaries that played a role in shaping Ralph Peck's career as one of the founders of American foundation engineering and the father of the Observational Method, which he learned from others he worked with as well as some who preceded him. These accounts are based on a series of interviews with Dr. Peck carried out by the author, between 1991-2001.

INTRODUCTION

Ralph Brazelton Peck was born in Winnipeg, Canada on June 23, 1912 while his father Orwin Peck was working on the Canadian National Railroad. No one had more influence on Ralph than his father, who was a civil engineer.

Longing to become a bridge engineer like his father, he was educated as a structural engineer at Rensselaer Polytechnic Institute between 1930-37. He worked 10 months as a bridge engineer before being laid off. Casting about for any academic appointment, Peck was promised a teaching position at the Armour Institute in Chicago if he could learn about the emerging field of soil mechanics at Harvard University. Within a few weeks he found himself in transition, struggling to understand soil mechanics and how it influenced the design of foundations. He soon learned this foundation engineering required engineering judgment born of construction experience. At every turn he sought the advice of those nearby who were more seasoned and experienced than himself.

From the time of his arrival at Harvard in the spring of 1938, until the Second International Conference on Soil Mechanics and Foundation Engineering in Rotterdam ten years later, Peck's professional career would be shaped by a diverse assortment of professors, engineers, contractors, and geologists he was privileged to work during those formative years (Peck, 1980). These included: Arthur Casagrande, Juul Hvorslev, Ruth and Karl Terzaghi, Ray Knapp, Al Cummings, George Otto, Ralph Burke, Bill Turnbull, and O. James Porter.

These men left an indelible stamp on Ralph Peck in the circuitous path he took from aspiring bridge engineer to professor of foundation engineering. The article seeks to describe how these individuals influenced Peck's balanced view of "geotechnics," the descriptor he favored because it encompassed the innumerable subdisciplines of the geotechnical profession, such as: soil science, soil physics, clay mineralogy, soil mechanics, engineering geology, geomorphology, rock mechanics, seepage theory, hydrology, geohydrology, geoenvironmental aspects, waste geotechnics, earth and ocean systems, natural hazards, and so forth (Peck, 1962b).

Fig.1. Stationery used by Ralph Peck for his consultancy between 1974-2008, which highlighted his perception of himself as a civil engineer practicing geotechnics.

The term “geotechnics” was first applied in print by Dimitri P. Krynine and William R. Judd in their 1957 text “*Principles of Engineering Geology and Geotechnics*,” published by McGraw-Hill. Ralph Peck always held himself put to be a civil engineer first, who practiced geotechnics (Fig. 1)

ORWIN K. PECK

Ralph’s father Orwin K. Peck was born in Litchfield, Ohio on January 10, 1882, the oldest of two sons of Clark Miner Peck (1858-1943) and Emma Boyd Peck (1858-1940). His younger brother, Clark Boyd Peck, was born 13 years later, in February 1895. Clark Sr. was a missionary for the American Bible Society, who homesteaded near Mitchell, South Dakota and farmed to support himself. From time to time the family received “missionary barrels” to help sustain them. During his high school years (1896-1900) Orwin accompanied his father on trips to the Moody Bible Institute in Chicago. During these forays he observed the construction of the largest department store in Chicago, which employed the largest windows he had ever seen, of W.L.B. Jenney’s design. These sights fascinated him and he began thinking about a career in building construction.

Mitchell, South Dakota was located near the middle of the state. Ralph’s mother Ethel Indie Huyck was also raised in Mitchell and both of Ralph’s parents attended Dakota Wesleyan University. They graduated around 1904 and went their separate ways. Ethel continued her education at the University of Minnesota, from which she received a second degree in 1906. She then became a school teacher in Minneapolis.

After his graduation, Orwin got a job working for a house builder who was constructing timber truss bridges for the local county. Intrigued by the different beam and girder sizes, he began inquiring about how the sizes of the structural members of the bridge were determined, and the contractor replied that he didn’t know. Orwin decided to attend the University of Wisconsin to take a degree in engineering. He was enrolled for one and a half years, receiving his bachelor’s in general engineering in 1907. He would have received a degree in civil engineering, but instead of taking a required course in railroad curves, he chose a course in advanced strength of materials, because it addressed the new concept of conjugate beams. Because of this technicality, Orwin never enrolled himself as a member of ASCE (although he could have).

After graduation Orwin took a job with the Minneapolis Steel and Machinery Co., fabricating bridges, so he could court Ethyl. There was a general economic depression at the time he reported in June 1907, so he was turned away, even though he had a letter stating he was to be hired. Orwin showed them the letter and demanded that they honor their word, so they took him on. Then he got a job with the Northern Pacific Railroad bridge office in St. Paul. While there he designed the eastern tail span for the line’s Bismarck Bridge across the Missouri River. He employed pile bents with cofferdams excavated around them, to keep the tail span from being damaged by the enormous Bismarck Bridge Landslide. The engineers realized it was a deep-seated landslide when the lateral movements became apparent. This was an intriguing, but brief engagement. 45 years later Ralph Peck would be retained to evaluate the landslide impacting this same portion of the NPRR’s Bismarck Bridge!

Ralph’s parents were married on June 22, 1909, about two years after Orwin began courting Ethyl. Orwin then accepted a position as bridge designer for the Grand Trunk Pacific Railroad, constructing the Canadian National Railroad between Winnipeg and Prince Rupert. The Peck’s only child, Ralph, was born in Winnipeg on June 23, 1912, shortly after their arrival. After his birth, he was duly registered with the U.S. Consulate, to ensure his American citizenship.

Orwin worked in a small office in Winnipeg, from which he designed the bridges. He never actually saw the sites, but utilized survey notes for each bridge, which were provided to him. Orwin worked under an old county engineer named LeGrande. This engagement resulted in intensive training for about six years, building railroad bridges just as fast as they could be designed.

Orwin then took a position with the City of Winnipeg designing a Bascule Bridge across the Assiniboine River, just above its confluence with the Red River of the North. Ralph remembers his father tucking him under his arm and hopping around the girders of the bascule bridge, cold winters, seeing Hudson’s Bay Store sheathed in icicles, but not much else of their time in Canada.

When Ralph was six years old (1918) their family moved back to the United States, where Orwin found a position as Assistant Bridge Engineer for the Louisville & Nashville Railroad. This was during the last year of the First World War. Orwin soon discovered that the railroad’s Bridge Engineer wasn’t much older than himself, so he didn’t see much prospect for promotion. He decided to move on, accepting another bridge engineer position with the Detroit, Toledo, & Ironton Railroad, which served the iron mines south of Detroit, feeding the burgeoning automobile industry. Shortly after their move Henry Ford, flush with large war production contracts, bought the railroad. Ford had his own ideas about how to run a railroad, which Orwin found intolerable, so he quit and took a job with the Michigan Central Railroad.

While working for the Michigan Central he began writing letters of application to other railroads. One of his friends from the Louisville & Nashville had gone out west to work for the Denver & Rio Grande Western Railroad (D&RGW), and through his influence, Orwin received an offer of employment in 1921. The D&RGW went through receivership numerous times, changing the name of the line slightly each time (Athearn, 1962). The family settled in Denver, and it was the last move they ever made (Fig. 2).

Fig. 2. The Peck home at 825 Garfield Street in Denver, where Ralph spent his formative years. An only child, he lived with his parents and maternal Grandmother Huyck (Peck family).

Fig. 3. The Peck family spent most of their evenings in the living room, playing duets on the piano at left. Ralph inherited his father's knack for playing the piano by ear, but not his father's deep bass singing voice. From left: Ralph's parents Ethyl and Orwin, with Grandmother Huyck (Peck Family).

At that time the D&RGW had a fellow with the dual title of railroad structural engineer and architect, so they decided to hire a "bridge engineer." Orwin was the first to hold that title. While Ralph was in junior high school (1923-26) his father had a bridge that washed out across Fountain Creek, south of Colorado Springs, on the Pueblo line. It was a two-span truss bridge. Orwin had replaced the longer of the spans, the old piers had been there for 40 plus years. Fountain Creek had a deep alluvial bed, typical of rivers emanating from the Rocky Mountains. There was a cloudburst one afternoon up in the higher elevations and the center pier simply sank into the fluidized sand bed of the river! This event impressed upon them how deep a sand bed channel could scour itself during high flows. Wash-outs during flash floods were a common malady along the D&RGW.

<u>Ralph dreams of becoming a bridge engineer</u>

At age 6 or 7 Ralph wanted to be a street car conductor, typical of small boys of that era. The Pecks did not have a car in Denver, but both of his parents played the piano very well, and the family frequently sang hymns together, with Ralph and his father usually playing duets (Fig. 3). Ralph took piano lessons as a boy from their church organists. He could play the piano by ear, as well as by notes. After he played something once, he knew it.

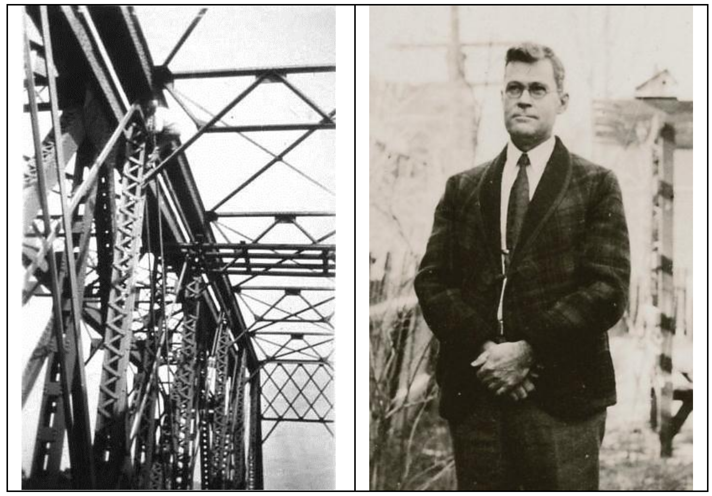

Fig. 4. Left – Ralph's father Orwin Peck inspecting the upper chord connections of a riveted truss on one of the D&RGW's bridges. Right - Orwin K. Peck as he appeared around 1934 (both images from Peck Family).

Orwin Peck loved his work and was very good at it (Fig. 4). He also loved to talk about his work when he came home. Ralph was an only child, and his maternal Grandmother Huyck lived with them, so the dinner table conversation was what went on at his father's office, what Ralph did at school that day, and what his mother and Grandmother might have accomplished as well. So, Ralph grew up hearing a lot of stories about railroad engineering, not just their bridges, but the manner by which railroads were organized and managed He took all of this information in as a matter of fact and penned his first term paper at Rensselaer Polytechnic on "*The Problems of Railroading in the Colorado Rockies*" (Peck 1930).

In the second half of his 6th grade year (1922-23) Ralph had a rather elderly unmarried teacher named Miss Knight. One day her students were given the assignment of writing essays on what they wanted to be when they reached maturity. Ralph aspired to become a bridge engineer, just like his father. After preparing the assigned essay, each student was required to read it in front of the class. Ralph thought Miss Knight would be commendatory of him, instead she landed on him about learning his arithmetic if he thought he was going to be any kind of engineer! He had only scored 61, 69, and 70 on his math semester grades. Later, during junior high school (1924-26), his algebra teacher really challenged him, and she managed to straighten him out in regards to appreciating how mathematical concepts build one upon another, and that failure to fully comprehend one math theorem could prevent understanding of more advanced concepts taught later (Fig. 5). When Ralph took a plane geometry course the next year he began enjoying math because he could visualize what he was doing.

Fig. 5. Ralph Peck at age 14 standing next to his namesake Uncle Ralph Huyck, in Denver (Peck family).

Through his father's loving encouragement and mentoring, Ralph remained fervent in his desire to become a civil engineer while he matriculated through high school. When Ralph began his senior year Orwin counseled him on where to apply for the best civil engineering programs: Minnesota, Wisconsin, MIT, and Rensselaer Polytechnic Institute (RPI). Ralph qualified for a four-year scholarship to any state school in Colorado, including the University of Colorado, Colorado State, School of Mines, Western State, or Adams State.

Ralph decided to go to RPI because he liked their promotional literature, which showed their graduates standing beside great civil works, including some of the impressive bridges around New York City. The pamphlet also pointed out that many of the most famous bridge engineers had been educated at RPI, including Washington Roebling, Leferts Buck, and Theodore Cooper of ill-fated Quebec Bridge and Coopers Loading for Railway Bridges. Orwin concurred with Ralph's preference because RPI was the oldest engineering school in the United States, which had turned out some of the finest bridge engineers in the world.

Digging ditches before heading for college

When Ralph graduated from high school in June 1930 his father suggested that he should take a summer job working for the D&RGW. Orwin had an office mate, Mr. Mullis, who was the signal engineer for the railroad, and together, they hatched up the idea of Ralph working on a 'signals gang.'

Fig. 6. Ralph (third from left) alongside the Signals Gang he worked with during the summer of 1930, between high school and college (Peck Family).

During the summer of 1930 Ralph lived in railroad bunk cars working with the rough-shod signal gang (Fig. 6). They worked on the mainline near the Malta branch to Leadville, along 10 to 13 miles of the railroad's mainline over Tennessee Pass (10,424 ft), mostly digging ditches by hand. This was Ralph's "introduction to soil mechanics." This signals gang worked hard, and they all knew that Ralph's father was an official of the road, but for several weeks he didn't have his heart into digging ditches. Then one day one of his fellow workers came over and grabbed his shovel and dug a ditch about 10 feet long in two minutes and threw the shovel back at Ralph. The message got through: he needed to show a bit more enthusiasm for the work at hand. The biggest compliment he ever received came towards the end of his time with the signals crew that summer, when they were working in eastern Utah, near Helper. Out of the blue, the same fellow who had tossed his shovel at him weeks earlier remarked: "*Look at old Ralph there making the dirt fly*." That was the greatest compliment he could have been paid by his co-workers.

The railroad paid him 55 cents per hour. The signals crew hated to see him go because they had a heavy equipment job coming up the following week. Seven years later, with bachelor's and doctorate degrees in civil engineering, Peck would be making 75 cents an hour working at the American Bridge Co. Looking back at his summer digging ditches, Ralph reflected that the long days of manual labor made college look pretty good by the end of the summer. He thinks that was his father's intent!

College years at RPI

Orwin Peck continued mentoring his son after he departed for college in September 1930. It took Ralph 2-1/2 days on various trains to travel from Denver to Rensselaer in upstate New York. He was afforded the privilege of a train pass because of his father's position with the D&RGW Railroad, but he could not ride on the express trains, so he spent considerable time sitting on sidings, waiting for higher priority trains to pass.

Fig. 7. Ralph's summer breaks usually included a site-seeing and camping trip to some part of the Rocky Mountains. From left to right: Ralph, his mother Ethyl, a Hyuck cousin, and his father Orwin. Taken in July 1935 (Peck family).

Ralph's summer vacations from RPI were filled with surveying camps of six weeks duration and a 'summer thesis,' which required the students to search out some engineering work in their home state, make proper investigation of it (including interviews, photos, sketches, etc), and describe it in engineering terms. He would come home to Denver for six to eight weeks, but he had to prepare the summer thesis. His summer break would typically include a brief family vacation, sightseeing somewhere in the Colorado Rockies (Fig. 7).

During his first summer break (1931) he prepared a term report on Cheesman Dam, an arched cyclopean masonry gravity dam 221 feet high built by the Denver Water Department in 1900-05. Thus began Ralph's life-long romance with dams, which grew with age. The following summer he interviewed Shankland and Rusteen in Denver, who had just designed a multi-story flat slab parking structure. Their firm's home office was in Chicago. Years later, he would renew his acquaintance with them.

In the fall of his senior year Ralph took a class in bridge design, which was emphasized at RPI. When Ralph came home for the Christmas break his father asked "*well, you want to come into the office and design a bridge for me?*" The job was a 60 foot span deck plate girder over the Animas River, about four miles from Aztec New Mexico, on the D&RGW's Farmington Branch, along the Animas River between Durango and Farmington. It was laid down in 1905 as a standard gage extension of an older narrow gage system, but the D&RGW had covertly converted it to narrow gage in 1923. When he got to the office they gave him the span design for Coopers E-40 loading (referring to an 1891 article in the ASCE Transactions by Theodore Cooper titled "American Railway Bridges"). The other engineers then showed him some drawings of how his father liked to detail bridges, etc. It took Ralph about three days to figure out the moments from the loads and so forth, but he enjoyed the process. His father had developed a system of moment charts for various Coopers Loadings that made it easy to determine the moments on a bridge, particularly trusses.

Ralph then designed the new span using Coopers Loading, but the D&RGW had some locomotives that might stress the bridges even more, so they had developed their own loadings. (Coopers E-40 was not very heavy loading, at that time the D&RGW mainlines were designed for E-72, which equated to 72,000 lbs on the driving wheels). How these loads affected bridges depended on the spacings between the main driving wheels and their diameters. Ralph also learned that his father favored ballasted deck bridges which employed a steel tray to support the ballast. Orwin felt this reduced the impact forces in the unlikely event of a derailment or crash, because the bridge frames don't have same resilience as ballasted track.

It took Ralph three days to draft the structural details for three 60-foot spans, one for the Animas and the other two nearby, along the same line. The bridges were to be set on the original piers, which had been constructed on 1904-05. The railroad built the spans according to Ralph's designs. A few years later, he was surprised to learn that the center pier had washed out during a flood, dropping the span.

Orwin's responsibilities with the D&RGW expanded considerably during the 1930s because the D&RGW acquired the bankrupt Denver and Salt Lake Railroad (D&SL), their principal competitor, which was a narrow gage line. This acquisition obliged the D&RGW to convert everything structurally, as the Rio Grande's engines and rolling stock were much heavier. Part of these acquisitions included the 6.2 mile long Moffat Tunnel, which had been completed in February 1928 at an elevation of 9,239 feet, eliminating 2,421 vertical feet of climb over Corona (Rollins) Pass.

Orwin soon learned that there were structural challenges in the tunnel where it passed through the Ranch Creek fault, which caused a condition known as "squeezing ground." Orwin battled the fault gouge for an entire decade (1933-43) before finally solving the problem by installing steel H sections embedded in concrete not only around the tunnel, but beneath the tracks, in the invert. All of this was very expensive, and the final solution was only made possible through federal wartime assistance to help alleviate bottlenecks that were occurring in the tunnel. His father's 10 year battle with the Ranch Creek fault had a significant impact on Ralph's evolving appreciation of geotechnics.

Fig. 8. Orwin and Ralph Peck around 1935. Note Tau Beta Pi key on Ralph's watch chain (Peck Family).

ASPIRING BRIDGE ENGINEER

Ralph's graduation from RPI coincided with the height of the Great Depression, in June 1934 (Fig. 8). Unable to find any sort of engineering job, Orwin counseled his son to return to RPI for graduate work, hoping to make his resume more attractive to the major bridge building concerns in New York City. Ralph and his classmate Bert Ingells accepted the only two fellowships available for graduate study at RPI, and became off-campus roommates, while sharing their doctoral research and dissertation, working under Professor Leroy Clarke between 1934-37. The Pecks later named their son James Leroy Peck in honor of Professor Clark because he had been Ralph's principal advisor during his seven years at RPI.

Fig 9. Ralph standing on the west tail span of the Oakland Bay Bridge with the eastern portal of the Yerba Buena Tunnel behind him. The tunnel measured 56 feet wide with a height of 76 feet, making it the largest tunnel in the world at that time (Peck family).

Fig. 10. Ralph and Orwin Peck standing atop the north tower of the Golden Gate Bridge on July 30, 1936, while it was under construction. This was a special honor not accorded to very many visitors. Note early model "boiled" hard hats (Peck family).

During the summer of 1936 the Pecks ventured farther west for their annual summer vacation, visiting San Francisco. While there Orwin used his professional connections to wrangle visits for himself and Ralph to the Golden Gate and San Francisco Bay Bridges, which were under construction (Figs. 9 and 10). These visits were a real inspiration to Ralph, who was working on the stress distributions of suspension bridges for his doctoral research.

Renowned bridge engineer David B. Steinman (1886-1960) came up to RPI once a year to lecture and review their work, which was an outgrowth of a paper of the same title he had published a few years previous. After three years of non-stop work their thesis on the "Stiffness of Suspension Bridges" was reviewed and approved by Clark and Steinman. Both men were awarded Doctor of Civil Engineering degrees on the morning of June 14, 1937, the 3rd and 4th engineering doctorates awarded by RPI. There were probably only 12 or 18 doctorates of civil engineering in the USA at that time, as very few engineering programs offered more than a year of post-graduate work and very few that offered doctorates.

It was the only time that Orwin Peck made the trip to Troy, New York to see the college where his only son had labored for seven years. That afternoon, Ralph married his longtime sweetheart Marjorie Truby (Fig. 11), and the young couple spent their honeymoon at a cottage on a nearby lake, owned by one of Ralph's other structures profs at RPI.

Fig. 11. Ralph and Marjorie Truby were married on June 14, 1937 in Troy, New York, a few hours after Ralph's received his Doctor of Engineering degree (Peck family).

Structural detailer at American Bridge Co.

During the year previous to receiving his doctorate Orwin Peck had been lobbying the American Bridge Company of Ambridge, Pennsylvania to invite his son to attend a class they convened each summer for potential employees. The course taught junior engineers how to draft details for fabrication of various bridge elements. The course had been cancelled in 1935 and '36 because of the Great Depression, but business had picked up a bit in 1937 because the D&RGW had contracted with American Bridge to build seven bridges for the upper Colorado River along the new Dotsero Cutoff. This project of the federal Reconstruction Finance Corporation connected the old DS&L line with the D&RGW mainline at the head of Glenwood Canyon, shaving off 175 miles of mainline between Denver and Salt Lake City (Athearn, 1962). Those were some of the few bridge contracts that American Bridge had going at the time, when many of their competitors closed down. American Bridge appreciated D&RGW's business, so Orwin succeeded in getting Ralph enrolled in the 1937 bridge detailing course.

Orwin and Ralph both hoped that his performance in the course would net him a permanent position with the firm, designing bridges. Ralph received the coveted invitation, which cut his honeymoon to just three days. He had to be at the American Bridge Company the following Wednesday. They were located downstream of Pittsburgh in Ambridge, Pennsylvania, about 2.5 miles from the Swickley Bridge, the first crossing of the Ohio River downstream of its confluence in Pittsburgh.

The bridge course was six weeks long and paid just 75 cents an hour. He had made 55 cents an hour digging ditches on D&RGW seven years previous, with just a high school diploma. Now, after seven years of engineering school and a doctorate degree he was only making 19 cents per hour more than he had back in 1930!

Ralph worked as a structural detailer at American Bridge for 10 months, until the following April of 1938. During that interim the company didn't receive a single new order, so one by one, the employees were let go. Despite his disappointment, he learned a great deal, some of which had to do with practicality of putting a bridge together he had to be able to "reach in and pick a point," assembling various steel shapes to fabricate the individual components. In those days everything used riveted connections.

He also learned to think on his feet, thanks to an experienced squad boss named P. T. Wheeler, an old veteran of the company. They would send one of Ralph's drawings down to the shop and the steel workers would call P.T. and inform him that one piece or another Ralph had sketched up wouldn't fit, preventing the assembly of the component parts. P.T. amazed Ralph with his ability to look at Ralph's drawings while talking over the telephone, and quickly ascertaining which pieces did or did not fit. He would then dispatch Ralph down to the shop to see the problems first-hand, so he would learn from the experience. Sometimes they were supposed to fasten two pieces together and another piece was in the way. There were always ways to fix these problems, but everything seemed to depend on experience, not on formal education.

One of the projects Ralph was tasked to detail were pieces of the curved portion of the tower of the Bronx-Whitestone Suspension Bridge. It had a large number of rivets in it and had to fit with other pieces around it, just like a glove. The designer would specify ¾-inch rivets, so many per joint, etc. He also worked on the second deck of the Henry Hudson Parkway Bridge, north of Manhattan. All of the detailing was drawn by hand using India Ink on Vellum. Ralph felt very comfortable drafting these because he had excelled in the drafting courses he had taken at RPI, where he always received the highest marks.

In his later years Ralph reflected that the 10 months at American Bridge was a crucial cog in his technical training because he was surrounded by talented and gifted problem solvers, none of whom had attended college. He learned that no engineer can really become a great designer until he has worked in fabrication and construction. The great engineers are those who design things that are intrinsically simple and straight-forward, without blemish, so they are easy for the workers to fabricate in the factory, or at the job sites. He said that one of Terzaghi's most valuable traits was his inherent tendency to listen carefully to construction workers, because he had been a construction worker in Europe and America early in his career, between 1906-13.

During this time Ralph and Bert Ingalls tried to publish their doctoral thesis work in the ASCE Proceedings. They had written their thesis as if it were going to be a journal paper, using the same format. But, ASCE politely turned it down, saying they would "keep it on file in the Engineering Societies Library in New York." This was a tremendous disappointment and Bert never joined ASCE because he felt snubbed.

Orwin was named Engineer of Structures at D&RGW in 1939, and his responsibilities expanded to include design of other structures, such as icehouses and water tanks. He continued working on an array of dynamic and challenging projects, including a second tunnel over Tennessee Pass. At an elevation of 10,221 feet, it was the highest mainline railroad grade in the United States. In 1948 Orwin and Ralph co-authored a pair of short articles for the Second International Congress on Soil Mechanics in Rotterdam (Peck and Peck, 1948a and 1948b). Both articles described D&RGW structures that had been damaged by differential settlement for different reasons. Orwin Peck continued working for the D&RGW until he retired at age 73, in 1956. Ralph's mother Ethyl died in 1965 and Orwin died in Albuquerque in 1974 at the age of 92.

BECOMING A HARVARD MAN

Armour Institute of Technology

While Bert Ingalls and Ralph were finishing up their theses at RPI, they were thinking of securing teaching jobs because the Great Depression had all but eliminated domestic construction activity. They both wrote to Linton E. Grinter, who was teaching down in Texas. He was the founder of the American Society of Engineering Education. Grinter had received the first Ph.D. in civil engineering from the University of Illinois. He replied that he didn't have jobs for them, but to keep in touch. Peck wrote to everyone else suggested to him, but his circle of acquaintances was very limited.

Months later he received a follow-up letter from Grinter, who had recently moved to the Armour Institute in Chicago as the new Dean of Engineering. The Armour and Lewis Institutes were in the process of trying to work out a merger of the two schools. In the meantime Grinter was focused on acquiring a "high-powered staff," which in those days meant people with advanced academic credentials (Armour's new President, Henry Heald, later became President of the Ford Foundation). Grinter related to Ralph that although they didn't have any openings for structural engineers, they would consider hiring him if he could attend the University of Iowa and learn hydraulics, or go to Harvard to learn about soil mechanics.

Peck had heard a little about soil mechanics because he had taken two courses at RPI in harbor engineering. One of his professors had told the students about an Austrian engineer named Terzaghi who was developing the new discipline of soil mechanics. Peck had read Professor Terzaghi's five articles on earth pressures which ran in *Engineering News Record* in 1934. Terzaghi reported the results of new experiments. He had actually written a dozen articles, but ENR thought these were too theoretical for the readers, so they published the six as a condensed version (Goodman, 1997).

In those days numerous experiments had been staged in large tanks at several universities, while students attempted to measure the various soil and water pressures. One of these tank tests had been carried out at RPI by Tommy Lawson, working for Harry DeBerkeley Parsons (1862-1935), brother of General William Barclay Parsons, Jr., founder of Parsons-Brinckerhoff. Lawson's work had been described to the RPI students in a seminar course, and the subject intrigued Ralph because of all the bridge wash-outs that had plagued the D&RGW. So he decided to go to Harvard. At that time the study of soil mechanics seemed to be little more than the application of elastic theory to soils and foundations problems.

The only problem was finances, Harvard being one of the most expensive colleges in the nation. Peck estimated that he needed approximately $5000. Marjorie had been born in Oil City, Pennsylvania while her father, Lester George Truby, worked in the oil industry as a self-taught stenographer and accountant. He moved to Denver when he became secretary of Midwest Oil Company, a subsidiary of Standard Oil of Indiana. This firm was involved in the Teapot Dome scandal in the early 1920s. When they moved Midwest headquarters to Oklahoma City, Mr. Truby decided to remain in Denver. He became assistant purchasing agent for the City of Denver, then secretary to Colorado Governor John Vivian. Mr. Truby agreed to lend $5000 to Ralph, but asked him to take out a life insurance policy for the same amount, in case something happened to him, because the sum represented the Truby's 'nest egg' for their retirement.

Turning down his 'dream job' at Waddell & Hardesty

The day before Ralph and Marjorie departed Denver for Ralph to attend Harvard he received a letter from Shortridge Hardesty (1884-1956), RPI Class of 1908 (Fig. 12). Famed bridge designer John Alexander Low Waddell (1854-1938) had taken Hardesty on as a junior partner in 1927. Waddell and Hardesty were one of the country's most prestigious bridge engineering firms, based in New York City. Though of middle age, Hardesty had already accomplished much, having been credited with inventing the vertical lift bridge.

The letter was a formal job offer from Waddell & Hardesty, offering him a position paying $159 a month (he had only earned $126/month at American Bridge). But, two days earlier Peck had sent Arthur Casagrande a letter informing him that he was on his way to Harvard. Ralph felt duty bound to honor that commitment. This was tough news for his father, who had so hoped Ralph would land a job with a 'name firm' in New York City, but he felt that the unusual timing of the various events was God's will for his son.

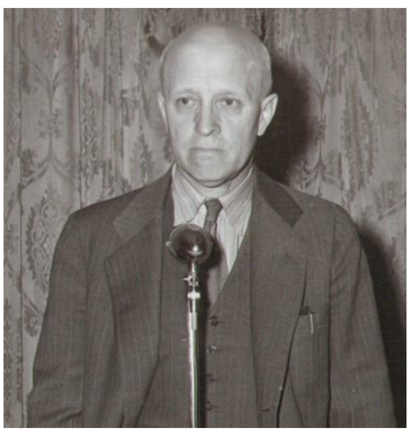

Fig. 12. Shortridge Hardesty (1884-1956) was a graduate of Rensselaer Polytechnic Institute in 1906 and a partner in the prestigious firm Waddell & Hardesty. He would lecture at RPI once per year (Niagara Falls Public Library).

ARTHUR CASAGRANDE

Arthur Casagrande (1902-81) was born in Austria in 1902 and educated at the Technical University in Vienna, receiving his civil engineering degree in 1924 (Fig 13). Between 1924-26 he worked as a research engineer in hydraulics at the university in Vienna. In 1926 he accepted a position as Research Assistant to the U.S. Bureau of Public Roads, working with Karl Terzaghi at MIT while Terzaghi was a visiting professor. In his early years his principal focus was on soil testing, and he developed testing apparatus' and techniques for determining a soil's liquid limit, the hydrometer test to measure grain size distribution of silt and clay, a horizontal capillarity test, consolidation tests, and the direct shear tests. He also undertook studies focused on understanding frost heave beneath pavements.

When Karl Terzaghi departed MIT in October 1929, Casagrande took a leave of absence to construct a new soil mechanics laboratory for Terzaghi at the Technical University in Vienna. He returned to MIT the following year (1930) and set to work designing and fabricating a triaxial testing apparatus. He began concentrating on ascertaining the shear strength of clays and their characteristics of consolidation, which he eventually discovered were influenced by preconsolidation, including desiccation and glacial loading.

Fig. 13. Professor Arthur Casagrande (1902-81) of Harvard University, as he appeared in 1947 (Peck Collection-NGI).

During the early 1930s he felt slighted by Terzaghi's choice of Glennon Gilboy to teach soil mechanics at MIT, while Casagrande labored in the laboratory and was unable to please the Bureau of Public Roads because he wasn't producing reports that were of a sufficiently practical nature to help solve the various pavement problems that had hoped it would. Throughout his career Casagrande would be perceived as something of a difficult personage to carry on with, but for those who listened reverently to his lectures and exposes, he was simply a "*complex personality with a noticeable bias, probably born by years of experience*" (quoting Peck).

In mid 1932 Casagrande accepted a lecturer position at Harvard, where he began teaching a year-long course on soil mechanics and a course on foundation engineering. He used the soil test data he had been accumulating for the previous seven years to show that excess pore water pressure develops in fine grained soils during shearing. He also developed a graphical procedure for estimating the pre-consolidation pressure exerted upon fine grained soils from consolidation (odometer) tests. These important discoveries were sufficient for Terzaghi to award him a Doctor of Engineering degree from Vienna in 1933. The following year Harvard promoted him to Assistant Professor (1934), and his academic career officially commenced. He would remain on the Harvard faculty until his retirement in 1971.

In 1935 he began teaching a course on seepage (Casagrande, 1937) and accepted his first consultation with the U.S. Army Corps of Engineers, heralding a relationship that would continue for the next half century. During that time he influenced the professional judgment of around 1000 students stretched across three generations, many of whom influenced the emerging discipline of soil mechanics and foundation engineering practice in the United States and overseas.

<u>Peck arrives late, but proves himself valuable</u>

Ralph Peck arrived at Harvard past the middle of the spring semester, much to Arthur Casagrande's chagrin. The professor wasn't pleased to have a new student arrive so late in the academic year because his soil mechanics sequence was taught over the course of nine months, beginning in the fall semester. Despite these difficulties, Peck found an empty seat at the back of Casagrande's class and tried to learn as much about soil mechanics as possible.

Casagrande was the principal teacher, assisted by graduate students Ralph Fadum and Bill Shannon, who had already earned their master's degrees (Fadum in 1936 and Shannon in 1937). Peck had to borrow Bill Shannon's lecture notes from the fall and spring semesters just to try and figure out what was being discussed. Casagrande would later state that Peck was the only student he ever had that learned soil mechanics in a "backward sequence," and that it was to his credit that he "turned out so well." Peck soon learned that Bill Shannon's father was a consulting engineer in Seattle. Young Bill worked for the New England District of the Corps of Engineers. He had attended the University of Washington in Seattle, receiving his BSCE degree in 1936.

When Peck arrived that spring Casagrande, Fadum, and Shannon were engaged in building the first universal testing machine for soils in the lab at Harvard. The machine required fabrication of a steel frame. When Fadum heard that Peck had worked for American Bridge & Iron, he asked Ralph to draft up the details of the new testing machine, because they were machining the various parts in the shop at Harvard. Ralph detailed the channel supports, which employed two supports with a couple of bolt holes through the opposing channels. The original design had staggered the bolt holes, a common mistake Ralph had seen at American Bridge. He showed them why the detail was incorrect and how the bolt holes had to face the same directions. The machinist at the Harvard needed to cut two more bolt holes, and the two holes that were not used appeared rather conspicuous. Ralph Fadum didn't like the looks of that, neither did Ralph, so they were both embarrassed. Peck completed all of the drawings in one long evening. The following day the other graduate students were mightily impressed!

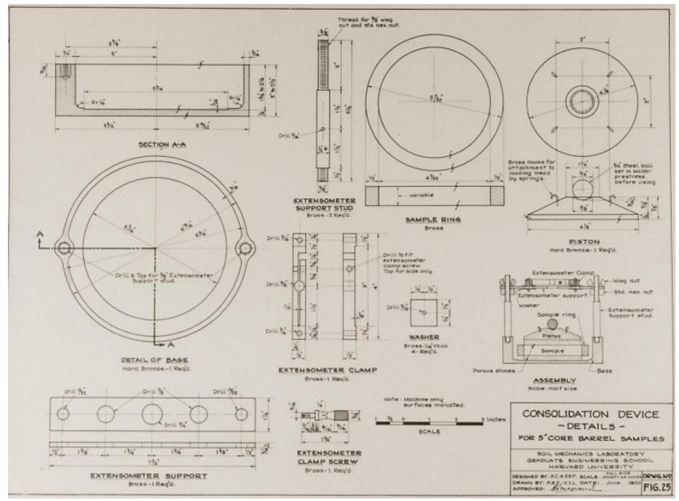

Fig. 14. Ink on vellum drawing by Ralph Peck illustrating the various components of Casagrande's consolidation device at full size. This shop drawing was prepared in June 1939, while Ralph was working on the Chicago Subway (Peck Collection-NGI).

The next day Peck began working for Arthur Casagrande, becoming part of his "inner group," comprised of the most promising grad students. From that point forward, he was given the job of drafting all of the drawings and shop plans for Casagrande's testing equipment. The students called Casagrande "Cassie," and he was very well liked by his students, in part because they shared in his lucrative consulting work.

Peck received an additional assignment as lab assistant. His duties included washing and maintain all of the glassware and set out the various components for the student's soil mechanics laboratory sessions. He worked side by side with Bill Shannon, who showed him what needed to be done. Before he knew it, the spring semester was concluded. Peck surprised Casagrande by doing very well on his final exams.

<u>New England Mutual Building</u>

During the summer of 1938 Arthur Casagrande was serving as a consultant on the New England Mutual Life Insurance Building in downtown Boston. It was the first project that used two-inch diameter soil samples taken with steel Shelby tubes. They also took some five-inch diameter samples, which Casagrande christened "undisturbed samples." The larger samples turned out to be more disturbed because they had employed an elaborate cutting shoe on the tip of the sampler to cut the sample off. The walls of this sampler were too thick to allow a truly undisturbed sample. One of Terzaghi's former doctoral students from Vienna, Juul Hvorslev, eventually convinced Casagrande of the futility of using the cutting shoe. The students were wary of criticizing anything their master had so cleverly designed.

Peck spent the summer of 1938 running consolidation tests in the soils lab at Harvard, six tests at a time. The samples were loaded once per day, and he finished a new series of tests each week. Even in those early days they began recognizing what later came to be known as "secondary compression." At that time their consolidation tests were run on "wafer samples," 4.5-inch diameter and just ¾-inch thick! They placed porous stones over the top and across the bottom of the wafers to elucidate drained conditions during odometer tests on Boston blue clay. That summer Ralph completed 36 consolidation tests, which took him nine weeks.

Fig. 15. The New England Mutual Life Insurance Building, constructed between 1939-41 (MIT Libraries).

The procedure Peck used was described in Casagrande and Fadum's January 1940 article *Soil Engineering Testing for Engineering Purposes* (Casagrande and Fadum, 1940). This was the first publication of any kind that mentioned Ralph Peck's name, in the acknowledgements. These data also formed the backbone of Phil Rutledge's Ph.D. thesis, shortly thereafter. Phil had completed his coursework at Harvard in 1937 and was teaching soil mechanics at Purdue. Ralph plotted up the consolidation data and Rutledge manipulated it for his dissertation, and his doctorate was awarded in 1939.

The New England Mutual Life Insurance Building was subsequently built as a 'floating' or 'compensated foundation,' without piles, with a central tower with wings (Fig. 15). There were lots of possibilities for future differential settlement problems, so extensive excavations were undertaken, which sought to balance the weight of excavated soil with that of structure. The whole substructure was a system of open trusses (without diagonal members). This support system became a model for the new era of soil mechanics (Casagrande and Fadum, 1944).

<u>Continuing to work for Casagrande (Fall 1938)</u>

In the fall semester of 1938 Ralph enrolled in the fall graduate courses in soil mechanics, soils mechanics and seepage, and H. M. Westergaard's elasticity course. He also audited Gordon M. Fair's statistics course (Fair was a famous sanitary engineer). This seemed to Peck like Fair's course was the only one that had much relevance to soil mechanics After a month of futile effort, he was obliged to drop out of Westergaard's course, finding himself in way over his head, even though it was described as a "structures" course.

Ralph also went back to working as a lab assistant with Bill Shannon and as a reader for Arthur Casagrande, who paid him $1 an hour. He would routinely work five to six hours per day when the labs were running and classes were full. The lab sections didn't meet every day, but lasted all afternoon certain days of the week. The students were required to describe the various tests they ran, what they were for, and the practical applications of the results.

Peck also did side jobs with Ralph Fadum, such as measuring settlements in the Liberty Mutual Building in Boston, using a water level manometer. They surveyed the building twice, checking their forward and backward readings to be within 1/10 mm. The employed a closed loop, and always ended back where they started from.

Ralph's other duties focused on running various soils tests, mostly consolidation tests, beginning on Monday morning and continuing the remainder of each week. He started one test every half hour and worked it up until he was running 8 to 12 tests at a time. He also ran identification tests for all the samples collected for the Massachusetts Mutual Life Insurance building.

On some days he worked as many as 12 hours, which equated to $12. He and Marjorie soon learned that they could live on Ralph's earnings in Cambridge, living in a one-room apartment on Dana Street, between Harvard and MIT. They later moved to another apartment by Harvard Square, also a one room apartment. That fall he and Marjorie returned her parent's $5000 nest egg.

In Cambridge, Ralph and Marjorie attended a Baptist Church few blocks down from Harvard Square. They had a large Sunday school and evening group all graduate students, almost all engaged in post-doctoral work, but Ralph was the only engineer among all the church's members!

JUUL HVORSLEV

Mikael Juul Hvorslev (1895-1989) was born in Denmark to a Jewish family on December 25, 1895 (Fig. 16). He attended the Technical University of Denmark, graduating in 1917. He found his way to the United States where he found employment working on the design and construction of dams, mostly for water supply and hydropower schemes in California, Washington, and Colombia, South America. He became an American citizen in 1929. In 1933 he returned to Europe to study soil mechanics under Terzaghi at the Technical University in Vienna, receiving his doctorate in 1936. He contributed two papers for the First International Conference on Soil Mechanics convened at Harvard in May 1936. He had a difficult time completing any sort of report or article because he was a perfectionist.

Fig 16. M. Juul Hvorslev perfected the various soil sampling and testing methods used by the geotechnical engineering industry from 1940 onward (U.S. Army Corps of Engineers).

Concerned about the rising tide of anti-Semitism in Europe, Hvorslev began lobbying Terzaghi and Casagrande for some sort of position in the United States. He returned to the United States in the summer of 1937, and Casagrande gave him what lab work he had derived from miscellaneous consultations. Hvorslev managed to survive, but not by much. In February 1938, he began working for the ASCE Committee on Sampling and Testing, under the direction of Joel Justin. It was one of the few ASCE activities that secured external funding through annual research grants from The Engineering Foundation. The purpose of this committee was to develop accepted standards for site exploration, soil sampling, and testing, which were wholly unorganized at the time, each firm doing whatever they chose to do. Hvorslev was given the title of 'Research Fellow' by Harvard because he had a doctorate degree.

At the time Peck arrived in April 1938, Hvorslev had only been working on the ASCE-Engineering Foundation project for a few months. He was stuck on the drawings of the various pieces of equipment that he was trying to design and fabricate there at Harvard. Ralph Fadum told Hvorslev about Peck's technical abilities with drafting structural details. Ever the cautious scientist, Hvorslev approached Ralph with a proposition to make a "shop drawing" of a piece of equipment he handed to him. Peck assumed that his purpose was to provide this to one of the machinists in the Harvard machine shop. Hvorslev didn't tell Ralph that he already had a shop drawing of the part, with which he could compare with Ralph's.

Peck worked on it for a day or so and brought the detail he inked up to show Hvorslev. There were all kinds of things Hvorslev didn't like about it. He was very polite to Ralph, not outwardly critical, but he made it clear that he didn't like the drawing. He said that it was a "mechanical drawing," not a "structural drawing," but this is what Ralph thought he had requested. Ralph had been taught that mechanical drawings were the appropriate means by which to instruct a machinist charged with fabricating a particular part. So, Peck tried again, but once again, Hvorslev didn't like it, so they agreed that Ralph would not prepare any more drawings for him. He was paid for the time he had put into the trial drawings at the rate of $1/hour. Despite this initial setback, the two men remained cordial and actually became friends as the years passed, continuing to see one another off and on with some regularity over the next three decades.

At the time Hvorslev and Casagrande were obsessed with finding a suitable method of obtaining undisturbed soil samples. ASCE, the Engineering Foundation, the Corps of Engineers, and Harvard were all supporting this work. But, they did not feel that they were receiving tangible results on their annual investment. The project's sponsors were pushing Hvorslev to complete the assigned tasks and produce useful reports. The sponsors complained, kicked, and cajoled Hvorslev to complete his reports, but Hvorslev could never seem to complete a written project, constantly focusing on the details that either remained unsolved or demanded more precise and careful assessment. In Terzaghi's words, Hvorslev "*was a brilliant engineer inside a scientist's body*" (e.g. he loved studying things).

The intense pressure eventually resulted in a "progress report" which Hvorslev titled "The Present Status of the Art of Obtaining Undisturbed Samples of Soils," released as Harvard University Soil Mechanics Series #14 in March 1940. Hvorslev released a more comprehensive summary of his research in an 88-page appendix in the Proceedings of the Purdue Conference on Soil Mechanics and Its Applications in early September 1940, which became the seminal document establishing standards for soil sampling until Hvorslev's final report appeared nearly a decade later.

Peck felt that Hvorslev was a genius, and that his tenacity to "get at a problem" was admirable, so long as one wasn't hoping for quick results. He said that Hvorslev knew "something about everything," not just the technical data, but the actual history of how all the various theorems evolved, and what assumptions many of these theorems were based upon. When he spoke of Henri Darcy he sounded as though he actually knew the man, describing in vivid detail the various challenges he faced.

What Hvorslev loved doing was helping others solve their problems. What he hated doing was writing reports. In 1946 Hvorslev was offered a research position at the Waterways Experiment Station (WES) of the Army Corps of Engineers in Vicksburg. His initial task was to complete the comprehensive report on subsurface exploration and sampling of soils that he began in 1938. He completed this task in November 1949.

Peck felt that Hvorslev's would never have succeeded at a consulting company or at a university, but was perfectly suited to the Corps central research facility for soil mechanics at WES, because he was superbly managed by their chief geotechnical engineer, Bill Turnbull (described below). Turnbull assigned various tasks to Hvorslev associated with developing field and laboratory testing apparatuses for soils, which could be used at remote sites around the world (the major focus in those days being on overseas air bases). Hvorslev was fortunate to be given considerable latitude, exploiting his penchant for problem solving while avoiding his fractious tendency for perfectionism.

In the last decade of his professional career he received several recognitions, including the Karl Terzaghi Award from the ASCE in 1965, and honorary membership in ASCE in 1979. He officially retired in 1965, but continued consulting work until age 80, in 1976. He died in North Carolina in 1989.

RUTH DOGGETT TERZAGHI

Ruth Doggett Terzaghi (Fig. 17) was born on October 14, 1903 and raised in Chicago. She attended the University of Chicago studying geology, and received her bachelors (1924) and masters (1925) degrees. Her master's thesis focused on the origin of abnormally steep dips in the Niagaran reefs in the Chicago area, working with famed geology Professor J Harlen Bretz. She then taught geology at Goucher College in 1925-26 and at Wellesley College from 1926-28, after which she enrolled at Radcliffe to work on her doctorate in geology, under Professors E. S. Larsen and R.A. Daly at Harvard.

During her studies in Cambridge she met Karl Terzaghi on a geology field trip in October 1928. She followed up with a visit to solicit Terzaghi's advice one evening shortly thereafter, and he was soon smitten by her. They began dating and continued corresponding after his departure for Austria a year later, in October 1929. They decided to marry one another in absentia in Cambridge, then have Ruth sail for Europe upon conferment of her doctorate.

They were reunited in France on June 7, 1930. From that juncture she became her husband's helpmate on an all-encompassing scale, accompanying him on field work in foreign lands, editing his papers, doing necessary library research, and attending to his personal needs. Ruth gave birth to the couple's first child, a son they named Eric, on September 5, 1936. Terzaghi was 53 years old and Ruth 33. Five years later, in May 1941, the Terzaghi's welcomed a second child they named Margaret (Peggy).

Fig. 17. Ruth Doggett Terzaghi as she appeared in 1956, while she and Karl Terzaghi were living in Winchester, Massachusetts (Association of Engineering Geologists).

These blessed events limited Ruth's ability to accompany her husband on his travels, but also came on the heels of a series of bitter skirmishes at the Technical University in Vienna, where one of Karl's colleagues named Paul Fillunger, grew jealous of his increasing notoriety, and was seeking to discredit him publicly (deBoer et al., 1997; Goodman, 1997; de Boer, 2005). He accused Karl of making scientific errors in his theorems on the internal stability of dams. An academic tribunal was convened in Vienna to settle the dispute and Karl and his colleague Otto Frohlich assembled their defense of soil mechanics. Midway through the proceedings Fillunger discovered an error in his own accusations of Terzaghi, but was felt too deeply committed to walk away from the tribunal he had insisted upon. On March 7, 1937 Fillunger and his wife committed suicide. Peck felt that at this stage in Terzaghi's life he felt a desire for rest and recuperation, and possibly moving to a place where he would be more appreciated loved and admired, rather than envied, for his talents.

Unknown to Ralph or the other students, Ruth Dogget Terzaghi (1903-92) had arrived in the United States with the

Terzaghi's young son Eric in the summer of 1938. Karl was obliged to remain in Vienna for the time being so that no one would become suspicious of his intent to immigrate to the United States, should the opportunity to do so arise. He felt uncomfortable because he was being pressured to work with the German-Austrian war effort. He sent Ruth and Eric with everything they could carry in their allowed baggage.

During the Second World War Ruth became interested in expansive concrete problems occurring in the drydocks of the Newport News Slipways in Virginia. Karl secured this consultation for her and she performed some pioneering work on concrete deterioration and aging from load cycling, using thin sections viewed in a petrographic microscope (Terzaghi, 1948, 1949).

After the war Ruth also did some consulting for the Association of American Railroads (AAR) on expansive concrete problems. Years previous Orwin Peck had replaced many short-span timber trestles with concrete structures, using prefabricated decks and cast-in-place piers, which he had personally designed and supervised the construction thereof. They began to deteriorate markedly after about 25 years.

Ruth was doing similar work at the time for the AAR, so Orwin arraigned for her to come out to Colorado to examine his deteriorating bridges. Ruth and Karl were then entertained by the senior Pecks, each couple enjoying the other's company. Only a year apart in age, Orwin and Karl both came down with cataracts around the same time and corresponded with one another on this topic.

Karl sent Orwin a copy of Holmes book "*Elements of Physical Geology*," which he used as the text for his engineering geology course at Harvard. It mentioned the alkali aggregate reaction being associated with porcelaneous chalcedony reacting with normal Portland Cement. Ruth suggested they replace the deteriorating beams using low alkali cement, which had recently been developed to combat alkali aggregate reactions in the concrete at Parker Dam. These contributions were acknowledged by her selection as a Fellow of the Geological Society of America in 1948, the first woman so recognized.

Between 1957-61 Ruth was a Lecturer in Engineering Geology at Harvard, and continued as a Research Fellow between 1963-70. During these years Ruth performed some pioneering research on the various sources of errors in surveys of rock joints. Her article on joint surveys, published in *Geotechnique*, became the seminal paper on the subject (Terzaghi, 1965). She fulfilled numerous requests for speaking at various conferences in the years after Karl passed away in September 1963. She was the 5th person elevated to Honorary Membership by the Association of Engineering Geologists in 1972, and the first woman so recognized.

The Terzaghi's son Eric became a molecular biologist and moved to New Zealand, while their daughter Margaret Terzaghi-Howe became a physician engaged in cancer research at Oak Ridge National Laboratory. Ruth passed away on March 2, 1992 in Winchester, MA, at 88 years of age.

KARL TERZAGHI

A few weeks before seeing Ruth and Eric off, Karl Terzaghi had begun to transfer his savings deposits to western banks and began crating up some of his most valuable possessions and sending them to America, bit by bit, so as not to arouse suspicion. He left everything in his university office in Vienna except the manuscript of a new book he was working on, which was in English. Officially, he was traveling to Paris to deliver some invited lectures. In reality he was hoping to layover for a few weeks and slip away to the coast, to take passage on a trans-Atlantic steamer, from Cherbourg. When the Terzaghi's whereabouts sifted back to Vienna, many surmised that Ruth, whom they knew to be American, must also be Jewish. She was not, but some of their Austrian colleagues continued believing that for years thereafter (Goodman, 1997).

In late September Karl Terzaghi (Fig. 18) arrived in Cambridge, encouraged by verbal guarantees of financial support from Arthur Casagrande and Al Cummings, who worked for the Raymond Concrete Pile Company in Chicago. Despite these entreaties, Terzaghi was unsure if he could secure sufficient work to sustain himself and his family to actually settle for the duration in America. He had left his options open back in Vienna. If little work materialized he supposed they would all head back to Austria after three to six months. Peck felt that without Al Cummings and Arthur Casagrande's connections, Terzaghi would have had a much more difficult time establishing himself as a much sought after consultant in such a brief period of time.

Casagrande secured him a title as Lecturer in Engineering Geology (he took the title of Professor of the Practice of Civil Engineering at Harvard in 1948). He was not provided any salary, but they did manage to find an office for him at Harvard. That fall Terzaghi delivered a series of lectures on Rankine's Earth Pressure Theory (Rankine, 1857), after Casagrande had derided Rankine's theory as being of little use (without Terzaghi's knowledge). After that single guest lecture, the Harvard students saw very little of Terzaghi.

Peck meets Terzaghi

While Ruth was visiting her relatives in Chicago, Karl lived at the Harvard Faculty Club. He set about re-doubling his efforts to complete the first book on soil mechanics in English, which he hoped would stimulate demand for his services as a consultant (the first soil mechanics text in English appeared in 1941, written by Russian émigré Dimitri Krynine at Yale). At that time he was thinking of including a chapter on grain size analyses, which would describe grain size distribution in statistical terms. He wrote the chapter, but he didn't know the English equivalents of the statistical parameters he sought to describe, which were in German.

In December 1938, Terzaghi asked Casagrande for English help on his manuscript, and Arthur suggested his senior graduate student Ralph Fadum. Fadum declined and deferred to Peck, asking Ralph to "*do it for that difficult, smoky old Austrian.*" Terzaghi's chapter on grain size analyses used probability curves to describe the variations in particle size, but he didn't understand the English technical terms for such things as mean, average, standard deviation etc.

Fig. 18. Karl Terzaghi striking a pose during a visit to the University of Illinois in 1939, during the Chicago Subway project. He is smoking one of his ever present five-cent cigars (Peck Collection-NGI).

One afternoon Peck called on Terzaghi in his smoke filled room at the Harvard Faculty Club. Terzaghi was a chain smoker of cheap cigars, usually two to five cents apiece. Being wintertime, the windows were closed and the room heavily pervaded by his cigar smoke. Despite this distraction, Peck enjoyed an hour of conversation, which whisked by very quickly. He learned that the private Terzaghi was an entertaining conversationalist, quite different from the pugnacious public Terzaghi, who sat in the front row of most lecture halls, seemingly eager to pounce on anything the speaker said that he felt worthy of "comment." When Peck left the meeting he had felt "at the top of the world," having gotten to spend an hour with such famous engineer!

<u>Opportunity in Chicago</u>

Between periods of writing, Terzaghi was planning a cross country lecture tour that he hoped would bring in lucrative consulting assignments, so he could support his wife and son, who had arrived the previous summer. The only possessions they had were being stored with friends while they basically lived out of their suitcases.

After three decades of planning, Chicago had just begun construction of a subway system. The merchants and the city fathers were both concerned about costly litigation that might occur if the excavations triggered damaging settlement of adjacent structures. Terzaghi's confidant was Al Cummings of the Raymond Concrete Pile Co. in Chicago. Al orchestrated a presentation by Terzaghi to the various parties involved in the Chicago subway project, bringing them all together at one venue, hosted by the Western Society of Engineers.

On the evening of December 1, 1938 Terzaghi delivered a terse lecture titled "*The danger of excavating subways in soft clays beneath large cities*." The lecture focused on his recent experiences with construction of the Berlin Subway, which was hampered by a high water table in running sands. These conditions had contributed to the sudden failure of a shored excavation which killed 20 workers in August 1935. He made a convincing case for proper geotechnical oversight during construction if similar tragedies were to be avoided in Chicago.

The lecture with its graphic images of the dead bodies beneath the collapsed bulkhead along the Hermann Goring Strasse succeeded in scaring his audience to death, and promptly found the State Street Property Owners' Association and City of Chicago bidding for Terzaghi's services. The City wanted him to advise them on how best to monitor progress of excavations and ground settlement, differentiating what structural or architectural damage was caused by subway construction. The City envisioned periodic visits by Terzaghi, maybe every four to six weeks. Terzaghi felt such infrequent visits were too few and far between to forestall the onset of any serious problems that might develop, the consequences, of which, might prove serious (Peck 1975).

Terzaghi made a counter-proposal to Ralph Burke, Chief Engineer of the Chicago Department of Subways and Traction (profiled below). He suggested that they place a junior engineer of Terzahi's choosing onsite full-time, who would make the measurements Terzaghi requested, and routinely report these to him for his ongoing review. Terzaghi would be able to review these progress reports as often as he wished, but only visit Chicago every four to six weeks in the first six months, then every few months, as the City originally proposed. The relatively low cost of such an untried engineer was acceptable to Burke, and the arraignment was agreed upon.

Early in January 1939 Terzaghi received a telegraph from Burke informing him to "*send your man*." At Harvard the word went out that someone was needed in Chicago, but it would require them to depart immediately, foregoing any chance of completing the graduate program in soil mechanics. Peck was the only grad student at Harvard that wasn't working towards a degree, so he could pick up and leave if he felt "opportunity knocking."

Peck had other motivations as well. He recalled how the Armour Institute seemed to have a commitment with the City of Chicago, as one of their professors had taken Casagrande's soils course after the First International Conference on Soil Mechanics at Harvard in 1936. This fellow was not well suited to teach soil mechanics, but Armour was the only institution in Illinois who could lay claim to some measure of expertise in this new field of soil mechanics. Peck reasoned that it might be possible to serve as Terzaghi's on-site assistant and teach soil mechanics in the evenings at the Armour Institute. He hoped this would provide a foothold for a faculty position.

Peck asked Ralph Fadum if he thought he should offer his service to Terzaghi for the position in Chicago. Fadum responded "*That's the sort of opportunity we've all been hoping for*." So Peck told Casagrande that he would be willing to drop out of Harvard and head for Chicago. Casagrande passed this information along to Terzaghi, who immediately asked Peck to come see him at his room at the Faculty Club.

As soon as Ralph sat down, Terzaghi asked him "*So, what tests do you propose we should run in the soils laboratory that is going to be set up in Chicago?*" Peck replied "*water content, Atterberg Limits, um uh, consolidation tests?*" After a long pause, Terzaghi replied: "*What about unconfined compression tests?*" These were considered a passé test at Harvard at the time. Terzaghi replied "*Well the biggest problem will be the settlements of tunnels associated with clay. We need to assess soil stiffness, and see if we can correlate stiffness with unconfined compression tests*." Terzaghi then asked Peck "*When are you going to be there?*" Peck responded he could leave the following week. So concluded the "interview." The date was January 14, 1939, a day Ralph would never forget.

<u>Reports to Terzaghi</u>

In preparation for his new duties in Chicago Terzaghi summoned Peck to his apartment two evenings before his departure. Terzaghi lectured him on what he expected of him. He was to essentially serve as Terzaghi's "eyes and ears" on this most important of jobs. The one thing he described most carefully was what sorts of data and information he wanted recorded on a *daily basis* in a formal journal.

The following Monday Ralph boarded a train heading for Chicago. During the trip he quietly contemplated the direction he was suddenly heading, realizing that a new career would shortly commence. Years later Peck would recall that the train ride was probably similar to what a young army officer would feel on their journey to the front: part dread, part excitement, interspersed with prayer, beseeching the Almighty for wisdom not to make any careless mistakes, and thereby betray the trust his commander had placed upon him.

Peck's new job title was "Assistant Subway Engineer." At the end of each day Terzaghi expected Peck to send him a progress report summarizing what occurred, what sorts of data had been collected that day, with the data plotted in a consistent form and pattern, so that discrete changes would be noticed. Although the regimen seemed odious, it taught Peck to become an astute observer of what Terzaghi viewed as important details, which he would likely have overlooked, had he not been tasked to note them.

Terzaghi visited the Chicago Subway job (Fig.19) frequently during the first six months Peck was on the job. He would typically spend a week at a time, about once every four to six weeks.

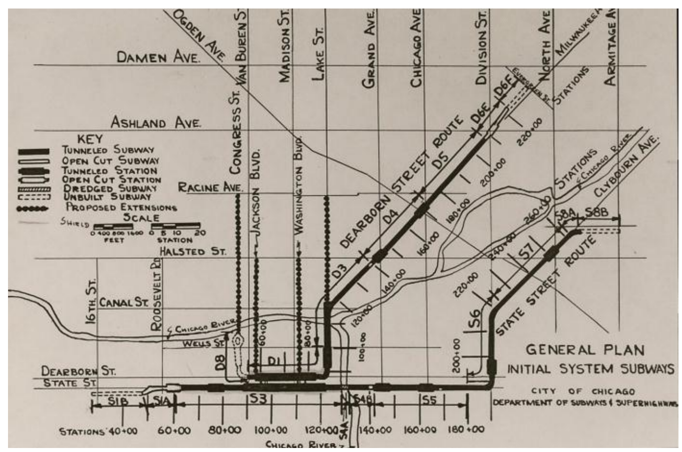

Fig. 19. Peck's hand drawn map of the Chicago Subway project with the principal routes along State and Clybourn Streets and Dearborn Street-Milwaukee Avenue (Peck Collection-NGI).

During Terzaghi's periodic visits he and Ralph would discuss all aspects of the subway construction, the various measurements, and all of the intricacies of the systems of monitoring they might employ to understand the mass reaction of various soil types to the massive excavations. Peck would reconstruct notes of these discussions in his journal. He would also show Terzaghi the sketches he made in the journal.

Terzaghi required that Ralph prepare typed reports every day, so Ralph hired a qualified typist and taught her all of the technical terms common to these missives. He was a bit surprised to receive formal replies from Terzaghi, almost every day! If he missed a day, he'd often receive a complaint from Terzaghi, inquiring why he had not received his daily report! This was occasionally demanding, and more than once Ralph had to stay up till the wee hours of the morning to keep pace with his reports if they had experienced an unusually busy day, as often occurred if there was any sort of problem.

When Ralph began working in Chicago, Terzaghi sent him a big pile of *Annual Reports of the Boston Subway Commission* "to study." The Boston project had been carried out between 1908-16. Most of these reports dealt with financial information, and very little engineering data of any value was contained therein. Terzaghi dumped these on Ralph's desk during his first visit to Chicago, a few weeks after Ralph arrived. There was very little published about the Boston Subways and they didn't measure any soil pressures, or anything similar to what Terzaghi hoped to achieve in Chicago.

AL CUMMINGS

In 1939 Albert Edward Cummings (1894-1955) was the District Manager for Raymond Concrete Pile Co. in Chicago (Fig. 20). Al was a pile peddler in daytime, but his evening hobby was exploring the theory of elasticity as it applied to soils.

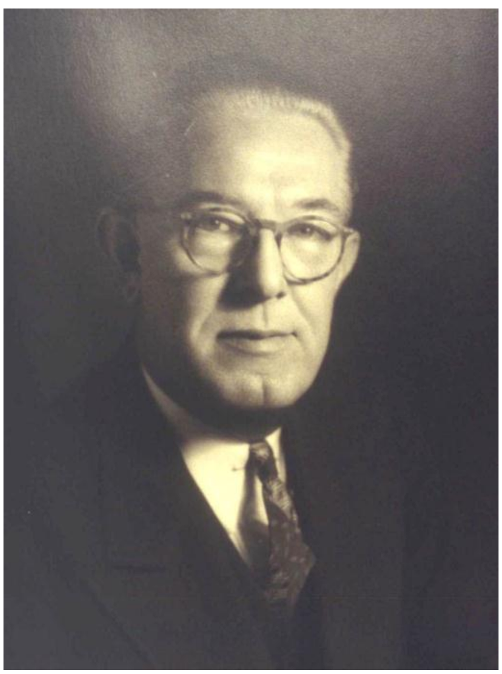

Fig. 20. Al Cummings served as Midwest Regional Manager of the Raymond Concrete Pile Company in Chicago. He was instrumental in bringing Terzaghi and Peck to Chicago to work on the subway in 1939 (Peck Collection-NGI).

A native of Wisconsin, Cummings had attended the University of Wisconsin in Madison, majoring in civil engineering. He paid his way through college by working for different contractors one semester and attending school the next. During his senior year (April 1917) the United States entered the First World War. Al enlisted in the Army the day after war was declared. Many students enlisted believing that they would receive some sort of financial support when they returned, as veterans of the largest war in world history. Sadly, no financial support was approved by Congress, only hiring preferences for government positions and the right to resume their positions with private corporations that soldiers held previous to their service. These perks were of no value to former students who had dropped out to serve their country. As a consequence, Al never completed his civil engineering degree, but he did get to see much of the United States and the devastation to Europe, picking up several European languages in the process.

The Raymond Concrete Pile Company

In 1888 Alfred Augustus Raymond (1848-1908) started a firm specializing in bridge construction in Omaha, Nebraska with his older brother Edmund W. Raymond (1843-1923). During their work in Omaha Alfred noticed the deterioration of wood pilings and began investigating what non-perishable substitute might be used in place of timber piles. By 1897 Alfred had perfected a reinforced concrete pile that could be driven just like a timber pile, without rupturing. In 1900 the firm moved to Chicago, where pile foundations for increasingly taller buildings reigned supreme.

It took the Raymonds more than a year to convince any of the city's engineers or architects that concrete piles could safely be driven without incurring inadvertent damage. This only occurred through the judicious employment of "demonstration" projects where the guests could watch the concrete piles being driven without any apparent damage, then be provided with data collected from subsequent pile load tests. One of Raymond's biggest selling points was that concrete piles were not subject to dry rot if the local water table was drawn down, a common problem that plagued timber piles. In June 1901 the Raymond Concrete Pile Company landed their first paying job in Chicago, driving the first concrete piles in America. This success was reported in *Engineering News*, and later, at a Municipal Engineers Association meeting in 1905.

The initial success soon led to more work elsewhere, and the company soon opened up offices in New York (1905) and Pittsburgh (1908). They were being given contracts all over the Eastern and Midwestern United States, including New York, Pittsburgh, St. Louis, Kansas City. By 1908 they had also opened an office in Montreal to open up the Canadian market, and had licensed their piles in Great Britain (to J. W. Stewart).

Edmund Raymond moved to Montreal to expand the business into Canada. He called Alfred to come up to Winnipeg, Manitoba in the summer of 1908 to assist with a difficult foundation along the Assiniboine River, followed by a large bridge contract in Regina, Saskatchewan. On September 12, 1908 Alfred died unexpectedly in Regina, and his son Gordon assumed supervision of the project. His other son Howard continued as the firm's assistant treasurer in Chicago.

By 1915 the firm had three main offices, in Chicago, New York, and Montreal (Fig 21). In 1922 they acquired the Gow Construction Company of Boston, establishing an office there. The Gow Division of Raymond continued refining the one-inch diameter pipe sampler pioneered by Charlie Gow (1872-1949) in 1902, which was refined during the succeeding decades. In 1924 they set up a new branch office in Philadelphia.

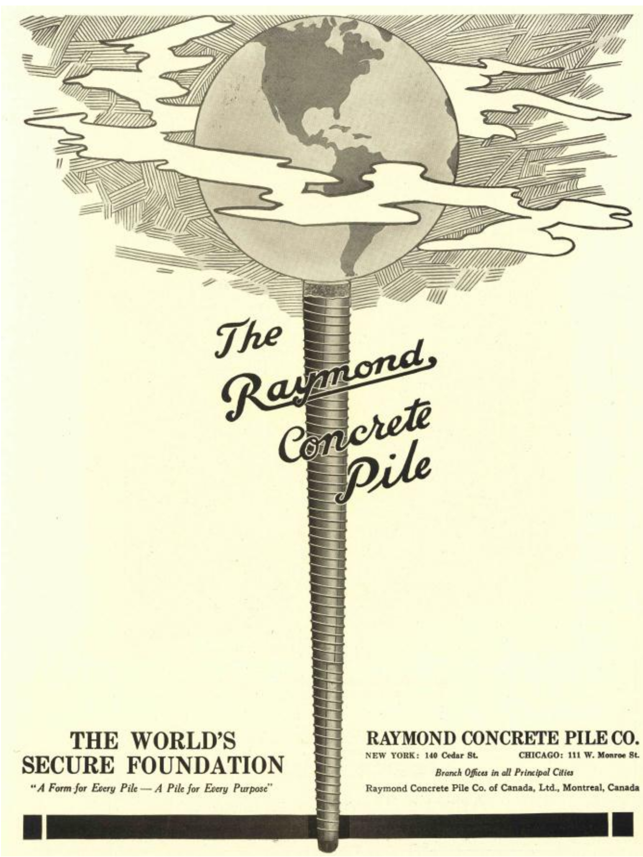

Fig. 21. Advertisement for the Raymond Concrete Pile Company that appeared in Architecture magazine in 1915. Raymond patented many different piling systems, including the tapered steel cased concrete pile shown here.

In 1927 Raymond opened a western regional office in San Francisco. In June 1928 they drilled their first power-excavated caissons for the Phoenix Assurance Building on Pine Street in San Francisco. These caissons were 38 feet deep and extended through running sands 10 feet beneath the water table. The difficulty of this site in the old Yerba Buena Cove accounted for their decision to excavate and backfill the excavations as quickly as possible. All previous caisson excavations had been carried out by hand.

During the 1930s and '40s three Gow Division engineers, Harry Mohr in Boston, Lincoln Hart in New York, and Gordon Fletcher in Philadelphia, settled on standardized drilling apparatus and input energy, so they could begin correlating recorded blowcounts with soil type (Rogers, 2006). Harry Mohr was based in Boston, so he had more access to Terzaghi than the others, and the two men would periodically meet to see what correlations they might draw from the recorded blowcounts. Their hope was to develop meaningful correlations that would help predict soil behavior when excavating caissons and straight-shaft cylindrical piers.

Terzaghi viewed what he felt to be consistent and meaningful correlations using the Gow Sampler in all three cities and their surrounding environs. In 1947 he decided to rename the Gow drive sampler data as the "Standard Penetration Test." This assertion was made during in an invited presentation on "Recent Trends in Subsoil Exploration" at the 7th Conference on Soil Mechanics & Foundation Engineering at the University of Texas at Austin. The name was then used in the first edition of *Soil Mechanics & Engineering Practice*, (Terzaghi and Peck, 1948) which appeared the following year.

Terzaghi's relationship with Raymond

When Cummings came home from the First World War in early 1919 he was obliged to support himself, and soon found a position to his liking with the Raymond Concrete Pile Company in Chicago. He started out as a field clerk, recording blow counts as the piles were driven into the ground. He soon found that he relished challenges and loved to improvise, a critical talent for a foundation contractor in those days. Within a few years he had been promoted to field superintendent.

Possessing much more theoretical training that the typical contractor, Cummings devoured everything he could find in the engineering and construction literature on foundation engineering, amassing a sizable library (over 5,000 pieces), which he bequeathed to his protégée Ralph Peck. By 1927 he was the firm's district manager in Chicago, responsible for the firm's work in the Midwestern United States.

Al Cummings, Harry Mohr, R. V. Lebarre, and Lazarius White were four of the American foundation contractors who most appreciated the potential of the emerging science of soil mechanics to give them a competitive edge in their everyday work. In 1929 Cummings went to Boston to meet Terzaghi when he was lecturing at MIT. He foresaw how soil mechanics would likely have an enormous impact on the pile business and he wanted to be at the leading edge of the practice (Cummings, 1936, 1937, 1938, 1939). The Raymond Pile Co. was beginning to work all over the Western Hemisphere, in Europe and elsewhere. Like Terzaghi, Al had a flair for languages, so when someone brought an out-of-town expert in to prove Raymond piles wouldn't work, Al was promptly dispatched by the firm to straighten them out!

After Terzaghi moved to Vienna Al Cummings traveled to Austria to visit him at the Technical University there, endearing himself to Karl and Ruth. Terzaghi asked Cummings to critique the manuscript of what eventually became *Theoretical Soil Mechanics*, which he began to write in 1936, with an eye towards publishing it in English in the United States (Terzaghi, 1943).

<u>Cumming's role as mentor</u>

About three weeks after Ralph's arrival, Terzaghi returned to Chicago for his first visit. Ralph was soon introduced to Al Cummings, who asked him "if he needed anything?" Ralph responded that he needed drilling rigs and experienced crews. Within a few days Al had the Raymond Concrete Pile Co. import three drilling foremen who had just come off the New England Mutual job in Boston to make the borings Peck needed using two-inch diameter Shelbys tubes with three rigs (Fig 23). The new soils lab Ralph set up began testing soils on February 15, 1939, one month after his arrival.

Fig. 23. Ralph Peck (in light colored jacket at middle right) logging his first boring for the Chicago Subway in February 1939 along the State Street Route (Peck Collection-NGI).

Cummings took Peck under his arm and mentored him. Al encouraged Terzaghi to allow Ralph to edit his manuscript of *Theoretical Soil Mechanics*, so this was another one of the bonds that developed during the Chicago subway days between Terzaghi, Cummings, and Peck. No one in the United States had a greater appreciation of pile foundations than Cummings, and his impact on Peck's development of engineering judgment over the next 16 years was enormous. It was Al Cummings who invited his protégé Peck to come down to the University of Illinois with him to lecture to the civil engineering students about the new field of soil mechanics and foundation engineering. The two men would take turns, Cummings lecturing on the theory of pile foundations, while Peck would lecture on the new science of soil mechanics. This liaison eventually led to Ralph being offered the faculty position at Illinois.

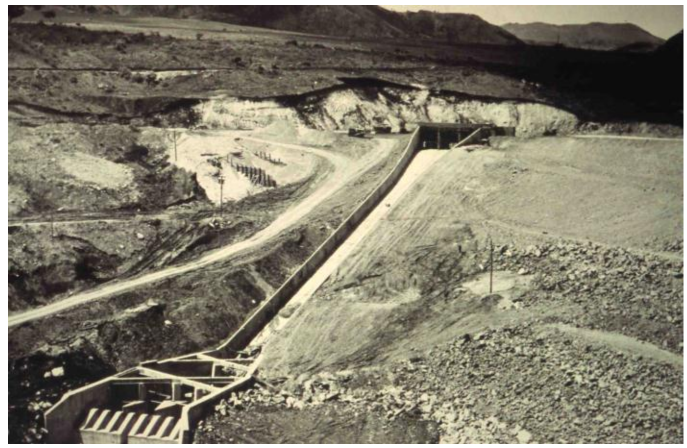

Fig. 24. Spillway chute and right abutment of Neusa Dam near Bogota, Columbia. The embankment was comprised of halloysitic clay laid on a thick mantle of landslide debris (Peck Collection-NGI).

Peck's first international consultation was orchestrated by Al Cummings in January 1950 after he had become Director of Research for Raymond and had transferred to their corporate headquarters in New York City. The job involved the design of the 120-feet high Neusa Dam near Bogota, Columbia (Fig.24). The two men designed an embankment dam comprised of halloysitic clay, utilizing as much judgment as data. On the return leg through New York City, Peck was instructed to dictate the entire report to Al's secretary. This consultation also was the first time Peck performed slope stability analyses of an earth dam and presented these results in his report for Raymond.

The dam was constructed with a core of compacted soft shale because the intended borrow pits proved to consist of troublesome halloysitic clay. Peck consulted with renowned clay mineralogy Professor Ralph Grim at Urbana, who helped him identify the type of clay, which exhibited a strange consistency and behavior he had never seen previously.

At the seeming height of his professional career Al suffered a fatal stroke and died on July 20, 1955, at age 60. His technical library, containing over 5,000 references, was bequeathed to Ralph, who cared for it until passing his personal library to the Norwegian Geotechnical Institute (NGI) in 2000.

RAY KNAPP

Early in February 1939 a new fellow came into Ralph's office one morning and said: "*I'm going to be your new boss*." His name was Ray Knapp, newly appointed Head of the Survey Section within Chicago's Department of Subways and Traction (Fig. 25). Knapp was about 15 years older than Ralph and exerted enormous influence on him, because he was the perfect combination of manager and leader, a rare combination. According to Peck, managers keep their subordinates focused on the tasks at hand and help them to accomplish those tasks, but leaders educate and inspire those below them to become excited about what they are doing.

Raymond S. Knapp (1895-1985) was born on March 3, 1895 in Huron, Ohio. He attended Denison University in Granville, Ohio, majoring in civil engineering. Like Al Cummings, he worked his way through college, taking surveying and construction jobs to earn sufficient funds for college, then returning to school. When the United States entered the First World War in April 1917 Ray continued his studies through the end of that semester, in June 1917. He then joined the Army and was assigned to the field artillery school at Camp Taylor, Kentucky and was advanced to the rank of Corporal on October 15, 1917. In December he was promoted to sergeant and assigned to artillery training, serving at Camp Jackson, South Carolina. In August 1918 he was promoted to Second Lieutenant in the 85th Field Artillery at Camp Sheridan, Alabama, where he remained until discharged from active duty in December 1918. After the war he retained his officer's commission in the Army Reserve, drilling one evening per week and two weeks of active duty each summer.

Fig. 25. From left, Juul Hvorslev, Ray Knapp, Ralph Peck, and Arthur Casagrande examining soil samples taken from the Chicago Subway project, around 1940 (Peck Collection-NGI).

After the First World War, Ray got married and settled in Ashtabula, Ohio, never completing his degree at Denison. Around 1923 he began working for R.C. Smith, who was known as "Mr. Foundation Engineer" in Chicago. In 1907 Smith and A. D. Graham pioneered the use of wash borings combined with dry sampling to evaluate foundation conditions in Chicago. Previous to this all borings in the area had been made using soil augers. Smith and Graham determined the consistency of clay by the "feel" of the drilling rods and the appearance of the recovered samples. In 1921 Smith formed his own company and developed his own penetration test to evaluate the stiffness of clays they encountered in the Chicago area. The firm made good borings and developed a suitable procedure for soil classification and consistency, and all in all, did quality work. Ray became Smith's junior partner.

By the time Ralph arrived in January 1939 Smith was still living, but had retired and moved to Texas. He had sold his company to G. A. Nordgren, another contractor who had more assets than Ray, so they parted ways. Smith had read about Terzaghi and was intrigued by the correlations he was drawing between soil moisture content, consistency, stiffness, and bearing capacity. Smith had assessed these same properties, using water content as a key indicator of consistency. Smith would run hundreds of water content determinations to ascertain which clay layers he was penetrating at the various horizons. They used the yellow hard pan as their "marker layer" across most of the downtown area. Ray learned a lot from him.

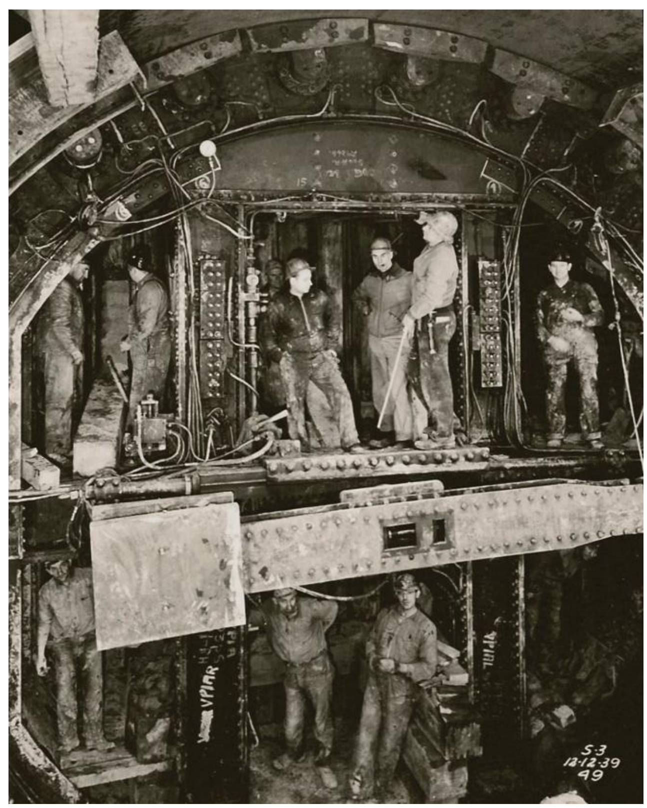

Fig. 26. Miners standing on the working levels of the tunnel shield, which was used primarily in soft clays. The soils were excavated by hand with clay knives (Peck Collection at NGI).

Ray also told Ralph all about William Sooysmith, his introduction of "Chicago Caissons" in 1894, and the evolution of building foundations prior to 1920. He also provided background on A. A. Raymond and how the Raymond Concrete Pile Company had evolved and become a nation-wide entity. This historical background proved invaluable in Peck's subsequent career, and he always felt blessed to have worked under Ray Knapp during his first professional assignment, which lasted 3-1/2 years.

When the Chicago Subway project got underway Knapp was appointed "Head of the Survey Section." Engineering services for the Chicago Subway project were divided into three sections: 1) design, 2) construction; and 3) surveys. Surveys included alignment settlement surveys, as well as "soil surveys." Ray's knowledge of Chicago made him the perfect choice for this assignment and his background as an Army officer made him a formidable persona. Ralph initially felt that Knapp was a bit officious, but he soon discovered that this trait allowed the survey section to get just about everything they asked for, which was critical to their success.

Ray Knapp would come around every morning and ask his men what they were doing and why, and then, made suggestions. This was because he was expecting to be asked questions by his immediate superior, Ralph Burke, with whom he'd meet every morning around 10 AM. Ray would have his engineers go out and observe what was going on in the tunnels (Fig. 24) prior to his morning meetings with Burke. He always wanted to find out what they had observed the previous day. He had a knack for anticipating what Burke would want to know, and always tried to 'stay ahead of Burke.' It all made for a very nice, cooperative way of working together.

Fig. 27. Settlement of sidewalk induced by subway construction along the S-5 section of the State Street Line, between Grand Ave. and one block south of Division St. (Peck Collection-NGI).

According to Ralph, the most impressive thing about Ray Knapp was that he could walk into the basement of any building in Chicago, and after a few minutes of inspection, would ascertain when it had been constructed, by whom, and what sorts of frailties such structures might have in regards to the adjacent subway excavations. Ralph later reflected that Ray Knapp had an incredible ability to predict what sorts of problems they might have [with particular buildings] and would direct his men to monitor key elements of each structure, to determine if and when they felt some measure of distress. He wasn't wrong very often (Figs. 27 and 28).

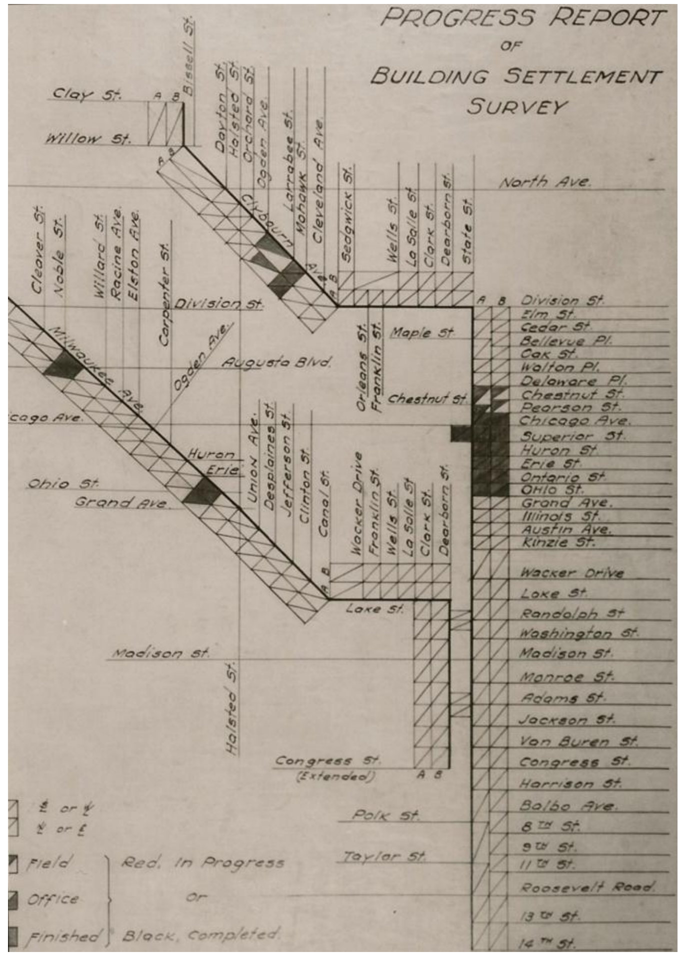

Fig. 28. Ray Knapp had a penchant for developing 'graphical controls' for the various activities the Survey Section carried out, such as the building settlement survey tabulations, shown here. Ralph was influenced by these in developing key elements of his Observational Method (Peck Collection-NGI).

Ray Knapp also co-authored the first two publications on Ralph Peck's resume, both for *Engineering News Record* (ENR). These were: *Open-Cut Soil Pressures on Chicago Subway* in the November 20, 1941 issue, and *Response to a Letter to the Editor* regarding their article, in the March 26, 1942 issue of ENR.

When America entered the war in December 1941 Ray was recalled to active duty in the Army, so he left the tunnel job about six months before Ralph. During the war he rose to rank of major and was given command of one of the ordinance plants near Chicago.

After the war he and Sydney Berman founded the Subsurface Engineering Company of Chicago, and Ray built a soil mechanics lab in his basement. That company existed for awhile doing a few jobs before Syd Berman became the Soils Engineer for City of Chicago. Ray then brought George Otto aboard to cover the engineering geologic aspects of the firm's projects.

After Ray's first wife died he married a lady from New Mexico. About ten years after Syd departed, Ray retired and found contentment doing woodworking projects in his basement. He outlived both of his wives and most of his contemporaries, quietly passing away at a hospital near his home in the Calumet Park section of Chicago on January 4, 1985, at age 89.

Ralph felt that Ray was good for his young college fellows who thought that, because of their education, they were pretty important. Ray had a way of reminding them they were lucky to have jobs. In his later years Peck reflected: "*I learned as much from Ray Knapp as I did from Terzaghi, not about soil mechanics, but about how a geotechnical engineer can go about doing some good in an organization. Ray Knapp served as the consummate interface between job site and management, facilitating whatever needed doing.*"

GEORGE H. OTTO

During the subway job Ralph Peck was also introduced to the importance of engineering geology, working with Professor J Harlen Bretz (1882-1981) and his doctoral student George Otto (1908-99). George Herman Otto (Fig. 29) was born in Brookville, Indiana on April 24, 1908. He grew up in Brookville, Pasadena, and Cincinnati. George loved southern California, where he spent his is family spent his sophomore year of high school, in 1924-25. Not long after his high school graduation in Cincinnati, the family moved to Oak Park, a Chicago suburb. George spent his freshman and sophomore years as a chemical engineering student at the Armour Institute of Technology. In early 1928 his intense fascination with geology led him to transfer to the University of Chicago, where his senior thesis examined the *Late Quaternary Geology of Chicago*, and he received his bachelor's degree in June 1931.

In 1931-32 he enrolled in graduate study at the California Institute of Technology (Caltech), and served as a teaching assistant. The following year he returned to Chicago, taking a full-time, but temporary position with the Illinois State Geological Survey and continued his graduate studies part-time at the University of Chicago, while living with his family in Oak Park. His research would focus on unraveling the subsurface glacial geology of the Chicago area, working with Professor J Harlen Bretz (Fig. 30). In September 1933 he moved into the International House on campus, where he met his future wife, Ruth McDonald, a fellow graduate student studying economics. His work for the Survey involved the collection of stratigraphic information from water well drillers in the Chicago area, which was the subject of his research. In the winter quarter of 1934 funds for his work at the survey were assumed by the Civil Works Administration, but this support ceased at the end of March 1934, leaving him without any means of support to complete his dissertation.

In May 1934 George headed for Saginaw, Michigan, where he worked 60 hours per week as a secretary to Dr. Virgil R.D. Kirkham, his first geology teacher at the University of Chicago. Kirkham had started his own oil company, drilling in the Michigan Basin. This paid well, but only lasted 3-1/2 months. George returned to Chicago, where he found temporary employment with the State Survey and settled back into International House.

Fig. 29. George Otto and his wife Ruth, in 1952. His senior and doctoral theses under J Harlen Bretz examined the Late Quaternary Geology of Chicago. Otto was the first engineering geologist cross-trained in modern soil mechanics (Anne Otto Earle).

George had remained in touch with former colleagues at Caltech and in the spring of 1935 learned that the newly formed Soil Conservation Service was going to fund the establishment of a fluid mechanics lab, where experiments in soil erosion would be performed. George collected and sent them samples of glacial sands from the Chicago area, and indicated his interest in any position they might have for him.

In late August 1935 he received an offer as assistant geologist in the new hydraulics laboratory at Caltech, working with two giants of hydraulics, Hunter Rouse and Vito Vanoni. On September 15th George and Ruth were married in Oak Park and headed for Pasadena. George worked at Caltech during the academic year, and during the summer breaks he would return to Oak Park to visit his family. George hoped to gain a faculty position at Caltech and he penned several articles on geology of the Chicago area for publication, as well as co-authoring research reports with Hunter Rouse.

During Otto's summer visit in 1939 J Harlen Bretz told him about the subway project and the subsurface exploration being carried out along the proposed alignments. Bretz contacted Burke, who passed Bretz onto Ray Knapp. Knapp extended an open invitation to Bretz and Otto to 'drop by the office' to pour through their boring logs, and see if they could glean any geologic information that might be useful to the project.

This initial visit was soon followed by tours of the Chicago Subway excavations, so Otto could view the exposures first-hand and explain the geology, which was often very puzzling, to Knapp and Peck, especially when they approached the crossing of the Chicago River, which required special provisions.

Otto's visits had another benefit. He and Bretz became excited about correlating what they regarded as a "treasure trove" of geologic data to unravel the late Quaternary and Holocene evolution of the Chicago area with a degree of detail not previously possible, because exposures were almost non-existent due to the density of development.

Fig. 30. University of Chicago geology Professor J Harlen Bretz achieved notoriety for his hypothesis of the Great Missoula Flood, his work on glacial geomorphology, and on the evolution of karst and cavern systems in the Midwest. He served as an ad hoc geologic consultant on the Chicago Subway. In the mid 1920s he had also served as Ruth Doggett Terzaghi's advisor on her master's thesis (University of Chicago).

In June 1940 Otto left his position at Caltech, taking a two month assignment in Houma, Louisiana, followed by a six month appointment as a researcher in Greenville, South Carolina. In March 1941 he moved back to Chicago to re-enroll in doctoral studies with J Harlen Bretz, using the subsurface data gleaned from the Chicago Subway project to unravel the glacial stratigraphy of the metro area. The Ottos secured an apartment in student housing near the University of Chicago. George's work turned into a major coup for the subway project, with Otto and Bretz serving as ad hoc geological consultants to the city during the subway construction. In addition, the stratigraphic correlations and geomorphic boundaries discovered by Otto proved invaluable in future years as Chicago grew.

Like Hvorslev, George Otto was a perfectionist. He spent weeks at Peck's soils laboratory examining all of their accumulated data. He found their subway data very intriguing, and he soon detected the impacts of glacial preloading on soil properties, as well as the retreat of glacial Lake Michigan eastward (these are easily discerned today in LiDAR imagery, but were unknown at that time).

According to Peck, Otto may have been the first geologist cross-trained in modern soil mechanics. From his formal training in hydraulics, he possessed a solid understanding of pore pressures and hydrodynamic theory. He began correlating physical properties of the soils and found that overconsolidation ratios of the various clay beds were uniquely tied to their load history. He derived this history from hydrostatic pressures exerted on the lacustrine clays by glacial Lake Michigan and subsequent sequences of desiccation, as the waters of the lake deepened with westward advances and diminished during eastward recessions. Otto also studied the unit densities of sand dune deposits, noting that each dune was comprised of smaller units, one much like the others, but separate from the one adjacent to it. Using Ralph's lab data, he was able to derive the relationship for densification of the aeolian sands with depth.

In June 1942 Otto completed his doctorate at the University of Chicago, titled: "*An Interpretation of Glacial Stratigraphy of the City of Chicago*." This was the same month that the subway job shut down. In the fall of 1942 the Ottos found a three bedroom apartment at 5753 Drexel Avenue, about a block from the university. Here they remained for the next two decades. J Harlen Bretz used his influence to land Otto an appointment teaching in the Army Specialized Training Program established at the University of Missouri in Columbia. Otto's Caltech connections then helped him secure a position as research scientist for the Navy at Scripps Institute of Oceanography in La Jolla, California. He spent the balance of the war interpreting salinity data to aid the acoustic detection of submarines in the Pacific Ocean.

When the war ended in September 1945, Otto returned to Chicago, accepting a position with the Armour Research Foundation. In 1947 he was contacted by Ralph Peck to see if he would be interested in serving as consulting geologist to the

Ralph Burke Company for the O'Hare Airport expansion (described later). This allowed Otto to leave his salaried position with Armour and establish his own consultancy as a consulting geologist, based in the Monadnock Building at 53 West Jackson in downtown Chicago. Peck solicited Otto's geologic input on a wide range of consultations during the next 30 years, including the foundations for the John Hancock Building.

Peck felt that the O'Hare Airport job established George Otto as Chicago's premier expert on engineering geology. George began by examining aerial photos, followed by walking the site noting the soils he found and recording their locations on acetate overlays of the photos. He mapped the various types of soils conditions in the maze of old mushroom houses and corn fields that blanketed the area. He could discern little hills and ground moraines as well as terminal moraines across the area, and he pointed out where the glacial outwash streams had been.

One of the troubling things he found was a buried sphagnum bog, filled with compressible peat along the western side of the project along York Road. This was where engineers had hoped to relocate two rail lines crossing the proposed airport (described under O.J. Porter, below). Otto determined where he wanted soils borings drilled and laid out the desired sampling intervals. There wasn't much that escaped his rigorous examinations.

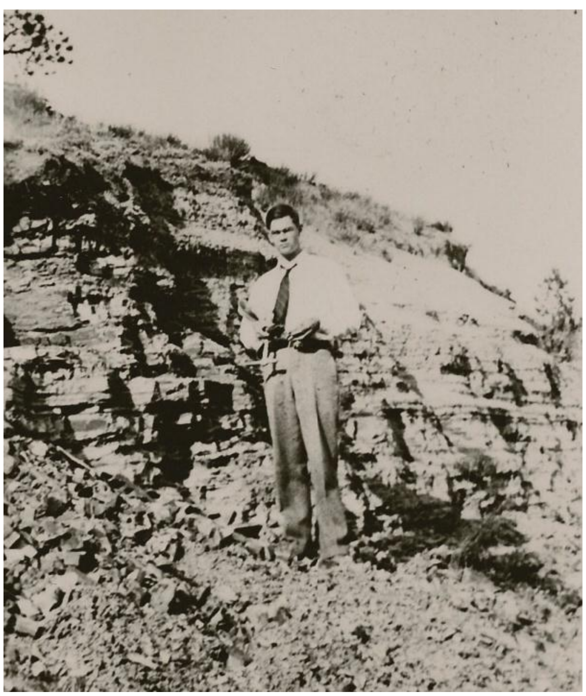

Fig. 31. Ralph Peck with pick in hand during his first geology field trip, to the Saratoga, New York area on May 8, 1935, while he was a graduate student at RPI. Note clothing worn by graduate students of that era, even for field trips (Peck family).

Most of time George Otto predicted exactly what they would find. This impressed Ralph, whose formal training in geology was scant (Fig. 31). He later reflected that George Otto was probably so successful because of J Harlen Bretz's emphasis on glacial geology, which is what had shaped the Chicago area. Otto said you had to "*learn to think like a glacier*." Peck was amazed with Otto's surficial soils map of the O'Hare Airport area, which guided the entire project, from start to finish. The map was not only used for laying out the borings, but also for extrapolating the information recovered from the borings. One of the most important discoveries was the existence of highly compressible peaty soils, which proved to be a daunting geotechnical problem that had to be mitigated.

When Sydney Berman left the Subsurface Engineering Company, Ray Knapp brought George Otto into their firm to provide engineering geology and testing expertise. Otto shared a three room suite with Subsurface Engineering in the Monadnock Building. This relationship lasted about a decade. Subsequent consultations included a few overseas projects, such as the exploitation of low grade iron ore near Belo Horizonte, Brazil; hydroelectric power projects in Peru; and determining the cause of a grain elevator collapse with Ralph Peck in Canada.

In 1971 Otto opened a second office in Linton, Indiana, where he began working on underground gas storage sites for Citizens Gas of Indianapolis. He closed down his Chicago office in 1975. In May 1992 he sold his business to Swager & Associates of Lawrenceville and Robinson, Illinois. In February 1997 he moved to Evanston, where he remained until he died on August 27, 1999.

Years later Peck would remark: "*It is absolutely essential to understand the geologic framework and geomorphic expression of the underlying stratigraphy when attempting to make realistic correlations between boreholes. Without that framework, erroneous assumptions are inevitably made, which may lead to significant problems.*"

RALPH BURKE

Ralph Haney Burke (Fig. 32) was born on May 22, 1884 in Chicago, the son of Edmund W. Burke (1850-1918), who served as Cook County Circuit Court Judge, Appellate Court Justice, and later, as Dean of Chicago's Kent College of Law. Young Ralph graduated from Northwestern in 1904, and continued his studies at MIT, receiving a bachelor's degree in civil engineering in 1906. His senior thesis at MIT was on "*A Study of Failures of High Masonry Dams.*"

Burke found employment with the City of Chicago through political connections, and gradually rose through the ranks of the sanitary district, then left the city's employ to become a tunneling contractor, then returning to the city when he was named Chief Engineer of the city's Southern Park District in the early 1930s.

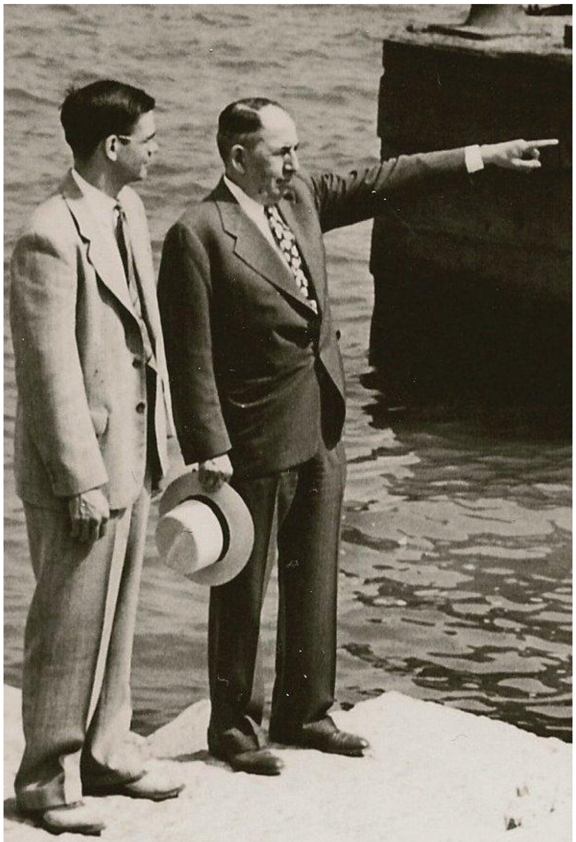

Fig. 32. From left, Ralph Peck and Ralph Burke (1884-1956) standing on the seawall adjacent to the future site of the Chicago Filtration Plant in 1947. This was around the time that Burke enticed him to become a partner in his firm (Peck Collection-NGI).

The Subway project was launched during the tenure of Democratic Mayor Ed Kelly, who, according to Peck, "ran a highly organized town." Kelly himself was a tunnel man with the sanitary district before becoming mayor. So everybody who went to work for the subway project had to be "screened" by a ward boss or precinct captain.

Charlie DeLeuw was the Chief Engineer of the subway project during the design stage. This was actually a part-time position while the Subway Master Plan was developed by his consulting firm, Kelker and DeLeuw. They did all of the necessary plans and specs to secure funding from the Public Works Administration (PWA). When the PWA money came through, the project needed a full time chief engineer.

In those days politics played a role in every aspect of life in Chicago, but Burke was somewhat above the politics because he lived in Evanston. Burke was the only Republican that seemed to thrive under either political party because everyone knew him to be a competent engineer who didn't play favorites and who stood up to contactors. Burke the engineer had also attended Kent College of Law, where his late father had been the dean. He took a leave of absence from his permanent position with the City Park District. Before their consolidation in 1934, Chicago had 22 separate park districts. The three largest were the Lincoln Park District on the north side; South Park District, and the West Park District.

Burke's view was that as long as people could actually do the work, he used them, regardless of their political affiliation. During the subway project new civil engineering graduates with any sort of soil mechanics training were detailed to the soils lab in the Survey Section. Early on Ralph Burke told Peck: "*You'll need a soils lab. Search out a couple of places to lease, choose one, sign a lease, and start tracking down the equipment you need*." Burke then asked "*How many men do you need?*" And Peck responded with "*Six or seven would be nice*."

Peck soon received six to eight new fellows to assist him during the subway work; one even had a masters in soil mechanics from Purdue. Another was a University of Illinois graduate who had taken a soil mechanics course. The rest had bachelors degrees in civil engineering, but without any formal training in soil mechanics. All of them were bright fellows, thankful to be employed and eager to learn.

Peck found a basement to rent for a soils lab in Chicago. He spent first few weeks buying platform scales and making compression test device and constructing an enclosed humid soil storage room. Chicago's credit wasn't good with the landlord, but this was a federal Public Works Administration job, so it all worked out.

<u>Burke sends a message to the building owners</u>

The Unity Building (Fig. 33) was the first 17-story building in the world, completed in 1892 (Condit, 1952). It was located at 127 North Dearborn Street, near Washington Street (it is no longer standing). It was originally supported on spread footings. With the construction of newer buildings on either side, by 1940 it had settled differentially about 18 inches (Peck, 1948). The building's owner didn't want to spend the money to underpin the old structure. Two sides of the building had been supported on caissons to the hardpan layer, but the west wall, facing the subway, had not been underpinned.

At that time (1939) Illinois law stated that if someone excavated 10 feet or less (termed the "standard depth of foundations") alongside a property you were responsible for any damages to those structures. But, if the adjacent excavation was deeper than 10 feet, you were only obliged to give notice to the adjacent property owners. The way Burke interpreted the law was that the property owners had to take care of their own underpinning when the shields for the subway passed by their structures, so long as they were given prior notice.

The width of Dearborn Street was only 80 feet, from building line to building line. Each subway tunnel was 25 feet in diameter, with 2-1/2 feet between, for a total width of 52-1/2 feet, from side-to-side. That left 27-1/2 feet to work with to avoid damaging adjacent structures. The tunnel excavations employed two 25-foot diameter shields, one out in front of the other (Fig. 34). The first to pass the Unity Building was the one closest to the building.

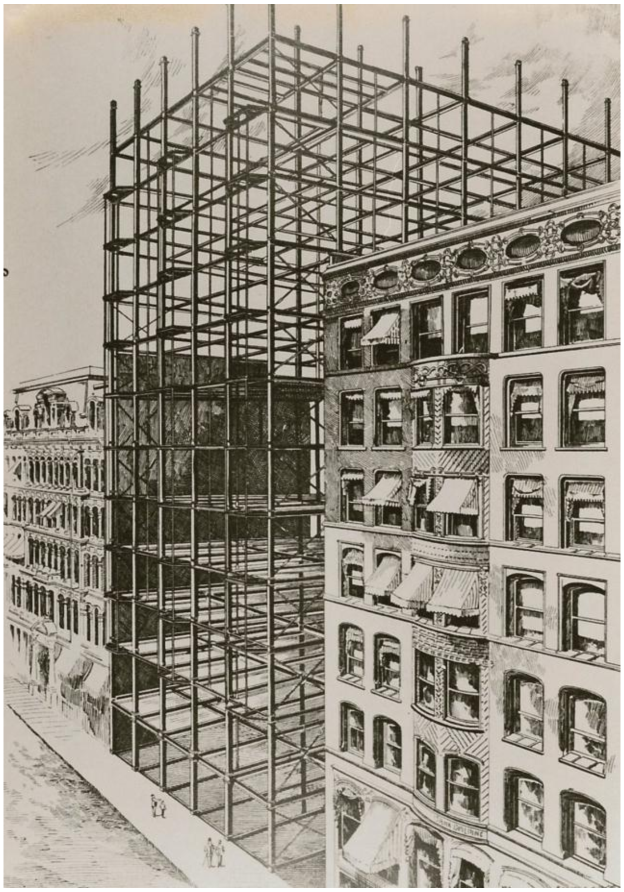

Fig. 33. Postcard view of the Unity Building in Chicago as it was being constructed in 1892 (Peck Collection at NGI).

Ralph Burke told them that he wasn't going to underpin, and that the subway was coming on by, no matter what they did or did not do, that was up to them. At first they thought he was bluffing, just to save money. When the first shield got about 100 feet away or less then they decided to underpin. They let an 'emergency contract' to underpin the west wall with four hand-dug "Chicago Caissons," like those developed by William Sooysmith in 1894 (Fig. 35). They were only able to excavate one caisson and get it concreted. They found that the caissons had to extend 65 feet below street and 50 feet below basement level to reach the desired hard pan layer.

The second caisson was being hand excavated, but was not yet concreted when the first shield went by. The shields were advancing around one foot per hour and the job was going 24 hours a day. Peck went down to the second underpinning caisson. He could hear the miners and other noises from the shield as it approached and went by. The caissons employed steel rings on two foot vertical intervals to retain the vertical boards, which were of the tongue-and-groove type (Fig. 35).

The bracing in the caissons consisted of vertical lagging boards generally about 4 feet long, then when the workers closed a circle of these, they would install channel rings against the lagging, one above and one below. These were channel sections, with fishplates on their ends, pre-formed for the correct curvature. The assembly was just tight enough to stay put. They poured concrete down the hole from top, which was not reinforced.

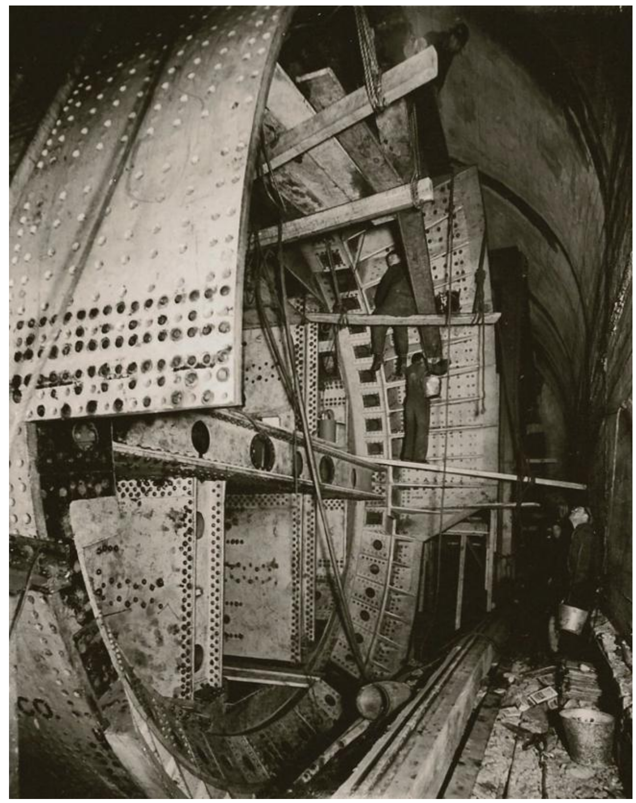

Fig. 34. One of the tunnel shields used on the Chicago Subway project, which were 25 feet in diameter. Two parallel shields were driven simultaneously, offset by no less than 50 nor more than 300 feet, along the tunnel alignment (Peck Collection NGI).

Much to Ralph Burke's relief, nothing dramatic happened to the Unity Building. His intent was to send a message to the building owners and this came through loud and clear! One of the caissons was still unconcreted after the second tunnel shield passed by, while another was being concreted as the shield passed. The shields were supposed to be staggered not less than two diameters (50 feet) apart, but most of the time they were a couple hundred feet apart. The Unity Building was the only structure that left their caissons open by the time the subway excavation passed.

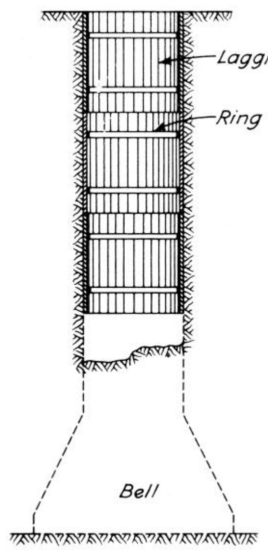

Fig. 35. Hand-excavated 'Chicago Caissons' were developed by William Sooysmith (1830-1916) as alternative supports to driven piles for the Chicago Stock Exchange Building in 1894. They were commonly employed for underpinning up through the 1950s (from Peck, Hanson, and Thornburn, 1953).

Peck's crew made some measurements of other underpinning caissons to see what they could learn (Fig 36). They even installed some Carlson stress meter cells in the side of the caisson to measure the earth pressure and pressure change as the shields went by. They then concreted in the hole with the pressure gage in place. In other places they would install Carlson gages through basement sub-sidewalk space walls, against the clay, and record measurements from those.

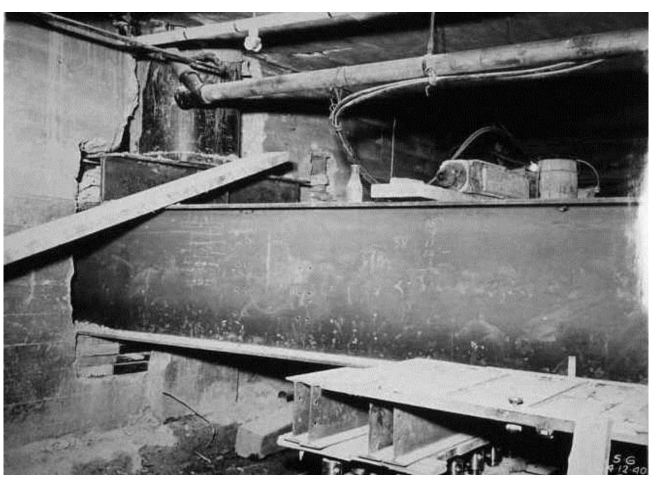

Fig. 36. The Subway Survey Section instrumented some of the underpinning caissons and needle beams, like those shown here, to ascertain the changes in load they experienced as the tunnel shields passed by the structures (Peck Collection-NGI).

The soil pressures weren't anywhere as high as they were expecting using Rankine theory. In one instance, the shield passed within a few feet of a curb wall, and a Carlson cell was installed in a basement wall, at an elevation about six feet above basement floor level and the curb wall had been underpinned with needle beams connecting them. The cell picked up from nothing to 4,750 psf when the shield was closest, then settled back down to 2,500 psf, due to relaxation of the void area just behind the shield, as it passed by. The sub-sidewalk spaces tended to heave when the shield went by.

A Chinese restaurant on Dearborn Street had its kitchen in the basement. This one had a kitchen work table in the sub-sidewalk space beneath the street, with a big kettle of soup on one end of the work table. When the shield came along it heaved the floor several feet and the kettle went sliding down the work table and the cook got pretty excited. This was a pretty impressive sight by the time Peck arrived!

<u>Impacts on soil mechanics</u>

Terzaghi's method of working was very structured, likely because of his military training and his family's military background. He demanded daily reports that were typed and appended with ink drawings and annotated photos. He would then respond to each one with written memoranda. As the project progressed he was charging Ralph Burke for every hour he worked. Sometimes Burke would say "that's too much" and Terzaghi would be obliged to reduce his bill.

Fig. 37. *Braced open cut on Contract S-1A of the Chicago Subway. This view was taken in July 1940 and shows the transition between the elevated and below ground sections of the State Street line, towards its north end, near the intersection with Clybourn Ave. (Peck Collection-NGI)*

Terzaghi took all the individual reports with the data gleaned from loads measured on the open cuts (Figs. 37 and 38) and drafted a progress report for Ralph Burke, the man that had responsible charge for the entire project, weaving the theoretical framework of what had been learned about soil mechanics on the subway project to date, which was considerable.

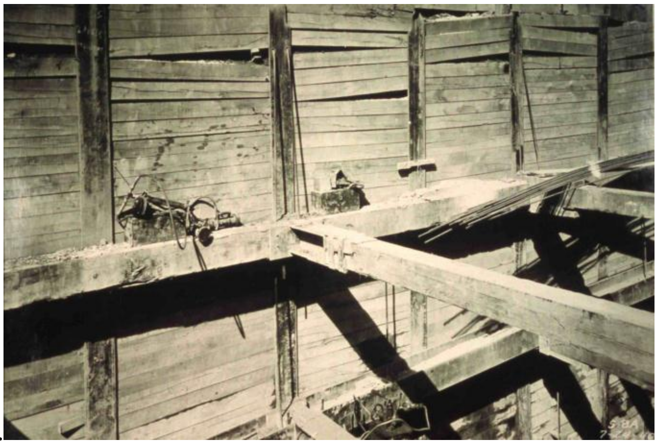

Fig 38. In 1940 Peck began measuring loads on timber struts of the braced excavations using hydraulic jacks, as shown here (Peck Collection-NGI).

In mid October 1941 the ASCE Soil Mechanics and Foundation Engineering Division sponsored a conference in Chicago to allow other engineers to see and hear about what was being learned on the subway project (Terzaghi, Peck, and Housel, 1943). Terzaghi wrote three articles based on the data being collected and sent to him by Peck. Terzaghi penned the original draft of the open cut article with Peck as a co-author, but decided to remove his name because Peck had collected all of the field and lab data it contained. He then removed Peck's name as a co-author from the companion article on tunnel liner plates.

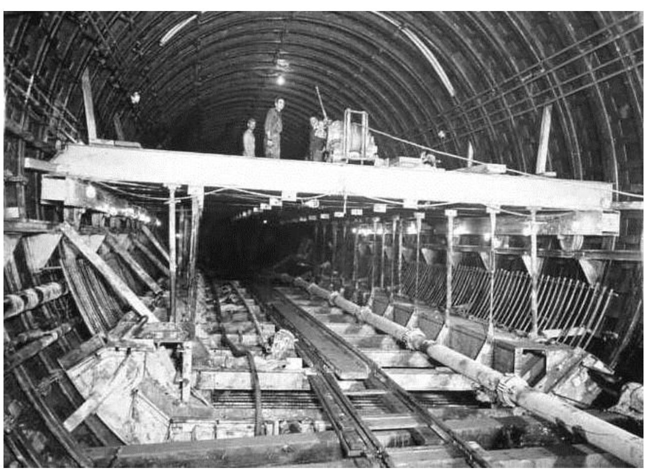

Fig. 39. View inside one of the driven tunnels showing the steel ribs and liner plates, as crews were getting set to begin concrete lining. The measurement of deflections and soil loads confirmed that soil arching was occurring, significantly reducing the anticipated loads (Peck Collection-NGI).

Terzaghi was unable to complete a third article on the tunnel shield excavations (Fig. 39) in time for the October 1941 conference. In part, this was because he had never worked on soft clay tunnels before the job in Chicago! This third article was subsequently published by Boston Society of Civil Engineers in July 1942 (Terzaghi, 1942). The two conference papers were published in the June 1942 ASCE Proceedings and the 1943 Transactions (Terzaghi, 1943; Peck, 1943).

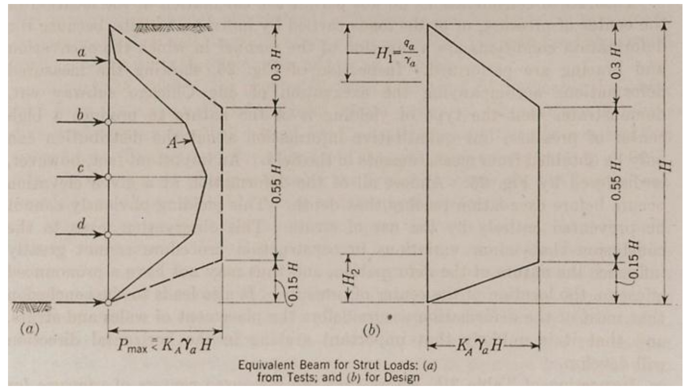

Fig. 40. First apparent pressure diagrams, as they appeared in Ralph Peck's article for the ASCE Proceedings in June 1942, which, after its publication and discussions in the society's Transactions, received the society's Norman Medal.

In Peck's article on braced excavations for open cuts (Peck, 1943) he and Terzaghi had overlayed the measured strut loads and plotted the total earth pressure versus the unconfined compressive strength of the clays (Fig. 40). They obtained what appeared to be a nice correlation, which suggested that cohesive soils acting against a braced excavation tend to exhibit a trapezoidal distribution in lieu of the traditional hydrostatic (triangular) distribution proposed by Rankine in 1857. Peck concluded that the lower soil pressures were likely due to arching. This article was subsequently selected for ASCE's Norman Medal in 1944.

Working for Ralph Burke after the subway project

The week after the Japanese attack on Pearl Harbor (Sunday December 7, 1941) Ralph Burke was quoted in the newspapers advising the City of Chicago to complete all necessary projects within eight months, due to the onset of war. Burke was the first public figure to perceive likely shortages in materials and manpower that could be expected as the nation mobilized for war, and he acted accordingly. By the middle of February the city could no longer purchase steel or cement. These commodities were being rationed for critical war-related industries and transportation corridors for projects that conveyed war material.

The two tunnel shields were left in the ground in front of the Old Colony Building (407 S. Dearborn Street) from May 1942 until the project resumed, in 1947. Ralph Burke resigned his position and returned to the park district. During the war (1942-45) Burke was placed in charge of civil defense in Chicago as an adjunct responsibility. He had a lot of innovative ideas that he was able to test because of restrictions, like the blacking out all visible lights at night. Burke figured it was pretty impractical for a city the size of Chicago, and he proposed that the city string floating lights out across Lake Michigan to resemble the city's street layout. This required Army Corps of Engineers review and approval, but by the time it was approved, the aerial threat was judged to be inconsequential and the funds to construct the ruse were not forthcoming.

Burke's last major project for the park district as its Chief Engineer was a public amphitheater proposed for Grant Park, along the lakeshore. This was the first use of the torvane in the United States (1946). It was employed to save time and money on characterizing the shear strength of clay at the site, which was to be surcharged with considerable fill. They measured shear strengths with the vane but failed to draw conclusions similar to lab-derived data, so decided that it was not such a good idea, and the amphitheater was never built.

Burke was likely the most well-known civil engineer in the Chicago during the 1940s. After the war he left the Park District to form the R.H. Burke Co, which won the contract to serve as the Airport Engineer for the City of Chicago. Burke & Co. simultaneously designed a new airport at the site of the 1933 Century of Progress World's Fair along Lake Michigan (which became Meigs Field) and an expanded commercial airport many miles northwest of downtown, called O'Hare Field. This had previously been known as Chicago Orchard Airport or the National Guard Airport, in what is now the northeast corner of O'Hare International Airport.

Fig. 41. Rendering of O'Hare Airport, as envisioned by the Ralph Burke Co. in 1952. The new airport had ample space for future expansion. Commercial aircraft began using the facility in 1956, and by 1962, it was the nation's busiest airport.

When the O'Hare Airport project got underway in 1947 Burke foresaw that it would likely become the largest and busiest airport in the world (Fig. 41). The project was full of geotechnical challenges, so he brought in Ralph Peck to characterize the soils conditions. Peck engaged geologist George Otto as a subconsultant and they moved quickly to characterize the site (described previously). Peck was able to make dozens of California Bearing Ratio (CBR) tests, which had recently been inculcated into a rational design methodology for flexible asphalt pavement design. The CBR values were very low, mostly 3, 4 or 5. Burke's pavement designers were obliged to employ large quantities of aggregate subbase and aggregate base for the runways and taxiways.

The geotechnical problems were sufficiently serious to convene a small board of consultants, comprised of Ralph Peck, Illinois Professor Nathan Newmark**,** and Robert Philippe, Director of the Corps of Engineers Ohio River Division's Soil Mechanics Laboratory (the Corps' first soil mechanics laboratory was assembled by Theodore Knappen for the Muskingum Project early in 1934). The three men collaborated to prepare a report suggesting an acceptable methodology for the design of the airport's runways, taxiways, and parking aprons.

Fig. 42. Laying down aggregate base rock for one of the runway expansions at Chicago's O'Hare Airport (from Chicago Sun Times).

These recommendations were implemented by Burke, but not quite as thick of a pavement section as had been recommended, due to budgetary pressures. They employed a pavement section with 12 inches of concrete and 24 to 40 inches compacted gravel subbase (Fig. 42). They didn't even try to compact the natural clays comprising the soil subgrade. It was the first project in Illinois that employed the new Modified Proctor compaction method recommended by the Corps of Engineers for runway construction (Porter, 1946).

<u>The lure of consulting work</u>

After the O'Hare Airport project Ralph Burke tried to get Peck to leave his faculty position at the University of Illinois and join his company as a principal. He promised that he could triple his annual salary, which did not include any summer support. Ralph asked Karl Terzaghi what he thought of the proposal. Terzaghi responded that, even though he liked Ralph Burke very much, he didn't think it was a good idea because projects like O'Hare Airport only occur once or twice in a lifetime, and Burke's clout was centered in Chicago, but not beyond. He feared that when Burke passed on the firm would likely close its doors.

Ralph continued doing consulting work for Burke's firm each summer. These consultations included the expansive Chicago Water Filtration Plant built between 1951-57. It was constructed on an enormous man-made peninsula extended out into Lake Michigan (Fig. 43). The fill was dredged lake clay, using clamshells to dump large chunks of soft clay to form the bounding dikes, using 2:1 (horizontal to vertical) side slopes. The design team assumed these chunks of soft clay would drain themselves and that they could expect some localized slumps and differential settlement, here and there. Most of the dike was laid down without too much trouble. But in some places, they couldn't bring the dike up to grade before it would suffer a slope failure.

Fig. 43. The Chicago Central District Filtration Plant and Navy Pier built on dredged clay fill along the shores on Lake Michigan between 1947-50 (Peck Collection-NGI).

The water district started to get worried about the job's progress, but Peck was satisfied that the fill was consolidating itself. He invited Bill Turnbull from the Waterways Experiment Station in Vicksburg to come up to Chicago to offer a second opinion. He chose Turnbull because of his experience with the soft Mississippi River levees, which often employed 8:1 (horizontal to vertical) side slopes, much flatter than what Peck had recommended. Turnbull thought Peck's slopes were far too steep.

Fortunately, it was not a crash program schedule-wise. They sauntered along and finally brought the fill to design height. Ralph was happy with the results and proud of the job. It was an early use of the Observational Method, which he would refer to countless times in the decades ahead. The bottom line was that circumstances were such that it was possible to wait.

<u>Lessons from unanticipated failure modes</u>

In 1952-53 Peck worked for Burke on the Grant Park North Garage along Michigan Avenue in downtown Chicago. The project began as a two level parking garage 600 feet wide and 2000 feet long, built for the Chicago Park District. Ralph Burke, Inc. was the project's designer. It was intended to park 2,359 cars. The idea was to have the roof of the garage serve as the driving surface for Michigan Avenue. That portion along the lake side of Michigan Avenue would be covered by a reinforced concrete roof covered with a few feet of topsoil to create a scenic parkscape.

The clay underlying the site was among the softest in the downtown area, beginning at a depth of around 15 feet below the original ground surface. George Otto informed Ralph that the boring logs penetrated three more glacial moraines, and that reasonably stiff clay was not encountered until reaching depths of between -45 to -50 feet. They tried to stay just above this soft clay layer.

Burke prized himself as an imaginative engineer with an innovative staff. The garage was built in two longitudinal strips: first the Michigan Ave side, about 300 ft wide, with the street traffic diverted to the east. Then, the traffic was switched onto the new Michigan Avenue right-of-way while the eastern half was excavated and constructed. Things went smoothly and construction proceeded according to schedule, though there was a little flap about frost heave that might occur during an exceptionally cold winter.

Ralph didn't expect frost action in clay, but he knew they might have ice lenses, to a depth of maybe 12 inches, beneath the floor of the expansive excavation. Someone on the team asked if they should allow for these lenses to thaw before finishing the overlying slab. They set the last frozen floor surface about 3/4" higher and it didn't go all the way back down. The garage opened on September 1, 1954.

It was a successful job, except for one little detail: the Chicago Fire Marshal demanded that the eight-inch diameter fire mains be buried in a trench excavated in the clay, beneath the garage slab. There was drainage in the floor slab to take out moisture from vehicles. Years later they experienced a particularly cold winter. For two to three weeks the weather hovered between zero and -19 degrees F below zero. The buried fire main froze, expanded, and caused the central floor to heave about six inches. Crossing shear cracks formed in the adjacent columns, below the capitals. These damaged columns had to be jacketed with steel. The floor drainage system was independent of the fire main trench. The hard freeze lifted the entire garage floor, and about half of the supporting columns were affected across the garage's 600 foot width. Most of the damage occurred on the portion lying beneath Michigan Avenue because it was more lightly loaded.

Peck would often refer to this case in his later years when attempting to describe the burgeoning field of "risk analysis." He loved to tell his audiences that the most difficult task we faced as civil engineers is to consider what he termed the "risk of the oddball occurrence," which is a failure from a cause that nobody anticipates. His feeling is that in many of these risk analysis consultations, especially, with dams, some oddball events that never gets factored into the risk analysis are the very things that will cause a failure.

<u>Burke comes to Peck's rescue in his hour of need</u>

On July 10, 1954 five workers were killed by two cave-ins, 580 to 750 feet from the south portal of the first Wilson Tunnel, on the island of Oahu in Hawaii (Peck, 1981). Ralph was retained by the City and County of Honolulu to evaluate the likely cause of the cave-in. He brought Terzaghi to Hawaii to look at the situation, but he authored the causation report that blamed the contractor for the collapse of the tunnel roof. This report was leaked to the media and published in the local newspapers. The date was April 2, 1955.

Shortly after the story appeared in the papers, Ralph submitted a letter of resignation to the Mayor of Honolulu and boarded an airliner for the trip back to Illinois. As his aircraft was taxiing to takeoff, it was intercepted by the Honolulu Police, who informed him that he could not leave Hawaii because he was being served with a summons. The summons was from tunnel contractor E.E. Black, suing him for $1.5 million over statements he made in his report on the Wilson Tunnel collapse. This claim later rose to $3 million, making it the largest legal action ever taken against an American civil engineer up until that time. Three years and many sleepless nights later, the case was dismissed, with the City paying Peck's legal fees.

In the midst of this uncomfortable case Peck was repeatedly deposed about his experience and knowledge of tunneling, in particular, with the type of rock encountered in the Wilson Tunnel (weathered basaltic klinker of the Koolau Volcanics). After all the required delays, he was allowed to return home. On his return trip he stopped in Chicago and called on Ralph Burke because he knew Burke had a law degree. He asked Burke what he thought he should do. Burke's response was very brief, "*Defeat the Action!*"

The lawsuit droned on for three long years. The City and County of Honolulu were defending Ralph in the lawsuit, but were holding him as a sort of hostage, requesting that he develop engineering plans for permanent support for the cave-in area, which extended 90 feet above the tunnel's crown. The city then requested that he furnish plans and specifications for the structural support along the entire tunnel, designs of the portal and ventilation structures, and the design package for a second, parallel bore. This involved considerable structural and mechanical engineering expertise pertinent to tunneling. Such work was far beyond the capability of a moonlighting university professor.

Once again, Peck turned to Ralph Burke. Burke enlisted the services of the former chief mechanical engineer of the Chicago Subway project, who then reassembled the key figures of the original Chicago design team to perform all the necessary work. Based on Peck's geotechnical input, they designed all the appurtenant structures and structural supports, using the loading theorems in Proctor and White (1946) for both bores of the Wilson Tunnels. All of the work was completed under the liability umbrella of Burke's company, much to Peck's relief. Years later, he would remark that this was his most difficult consultation and that he owed Ralph Burke a debt he could never repay.

Sadly, in the midst of all this Ralph Burke suffered an aneurysm in his aorta, and was informed that he was going to die. Everyone kept working to complete the tunnel plans and specs, even after Burke passed away on August 30, 1956, at age 72. Had Ralph gone to work for Burke, the responsibility of running the engineering firm would have fallen upon him, and he felt he may not have been up to such a Herculean task. The company reformulated as Ralph Burke & Associates and continued doing business for many years thereafter. Peck recalled that "*Ralph Burke was the sort of fellow you wanted by your side if you ever got sued because he wasn't scared of attorneys; he exuded the sort of confidence you would expect from military man who had seen years of combat*." Working his entire career in the political environs of Chicago politics was somewhat akin to combat.

WILLARD J. TURNBULL

The Corps of Engineers' Waterways Experiment Station in Vicksburg, Mississippi was established in 1929 to aid in designing and constructing the Mississippi River & Tributaries Project, a monumental program of flood control enacted by Congress after the devastating 1927 Flood of the Mississippi River. WES became the defacto 'national hydraulics laboratory,' supplanting the planned facility of that name approved by the Senate, but not the House of Representatives in 1924. It was to have been operated by the Bureau of Standards in Washington, D.C., a concept adamantly opposed by the Corps of Engineers.

Thanks to WES founding director 1st Lieutenant Herbert D. Vogel, USA (1900-84), a soil mechanics laboratory was established at WES in August 1933 when he hired Spencer J. Buchanan. Buchanan was on his way back to his home state of Texas after completing his master's degree in soil mechanics at MIT, working under Glennon Gilboy. He stopped to see the new hydraulics laboratory and Vogel found the funds to support the new position from the Mississippi River Commission (Rogers, 2012). The following summer he set up a soil mechanics laboratory at WES, and the program began to grow and expand beyond levees and embankments to service other challenges, such as pavement problems with highways and airfields.

In the spring of 1940 Buchanan came up to Chicago to visit the subway construction sites and see first-hand how soil mechanics was being used to benefit the project. He was a reserve officer in the Corps of Engineers, and was recalled to active duty in October 1940, leaving his position at WES vacant. He dropped Peck's name as a potential candidate to replace him. In 1941 the Corps interviewed candidates for the newly established position of Chief, Embankment and Foundation Branch at WES, overseeing the work of about three dozen people (this expended dramatically during the Second World War, which began a few months later). Ralph Peck and Bill Turnbull were the two finalists vying for the new position. They were treated to a series of on-site interviews and a VIP tour of the WES facilities in September 1941 (shown in Fig. 44). Turnbull was offered the position and remained at WES until his retirement, in 1968.

Fig. 44. From left, Ralph Peck and Bill Turnbull met one another for the first time at Vicksburg, Mississippi when both of them were interviewed for the position of Chief of the Embankments and Foundations Branch at the Waterways Experiment Station in September 1941 (Peck Collection-NGI).

Willard J. "Bill" Turnbull (1903-97) was nine years older than Peck. He had grown up in Nebraska and matriculated through the civil engineering program at the University of Nebraska, graduating in 1925. He took a position with the U.S. Coast & Geodetic Survey working in the Philippines. After a year he returned to Nebraska and began working on highways and irrigation projects. Nebraska was full of "soils contrasts." It had more lakes than any other state, with countless miles of sand hills and dunes that presented formidable engineering challenges. Turnbull described Nebraska as being "humid in the east and 'dry as desert' in its western settlements," offering "a bit of everything" when it came to foundation conditions. In the end the Corps chose the more mature Turnbull for the Chief's position, but Turnbull and Peck remained friends for the rest of their lives.

After the publication of Juul Hvorslev's 88-page appendix titled "*The Present Status of the Art of Obtaining Undisturbed Samples of Soils*" in September 1940 (mentioned previously) the Army Corps of Engineers increased their interest and level of support for his research. This sustained Hvorslev for another six years at Harvard. The Corps also began drawing upon his expertise on issues of soil sampling and testing, which was expanding at an almost exponential pace during the war, as every Crops district and overseas command were tasked with developing their own soil mechanics labs. They were sending hundreds of engineering officers to Harvard for training by Casagrande and his stable of graduate research and teaching assistants, such as Ralph Fadum, Bill Shannon, Nabor Carrillo, Raul Marsal, and Jim Gould.

After the war (1946) Turnbull hired Juul Hvorslev to continue his research at the Waterways Experiment Station in Vicksburg. Twelve years of research on how to obtain undisturbed soils samples finally culminated in WES publishing the classic tome "*Subsurface Exploration and Sampling of Soils for Civil Engineering Purposes"* in November 1949. It was so popular, the Corps reprinted it twice (it was used as the basic text for graduate soil mechanics laboratory classes for 20 years). In 1962 and 1965 The Engineering Foundation reprinted the same volume, making it available to a new generation of geotechnical engineers.

Ralph Peck felt that the publication of Hvorslev's comprehensive report in late 1949 was a real tribute to Bill Turnbull's "managerial genius." Nobody, not even Terzaghi or Casagrande, wanted Hvorslev working for them because he rarely completed a project. Turnbull knew that Hvorslev rarely finished writing projects, but he soon discovered that he loved mentoring the younger engineers who were less experienced than himself.

Turnbull created a position at WES expressly for Hvorslev, which he called the "Special Technical Consultant to Soils Division Chief." Turnbull would assign projects to Hvorslev where he could help the younger engineers develop a strategy for investigating various problems the Army set before them, which were often very challenging (e.g. pavement grooving of airfield taxiways used by B-47 Stratojet bombers). Hvorslev would immerse himself in the other engineer's project and thereby help them solve whatever problem they were facing. He often conjured up with a program of field testing and verification that became the hallmark of WES, earned it the enviable reputation of everyone in the Corps of Engineers as their premier problem solving entity.

PECK'S ACADEMIC APPOINTMENT

Ralph taught evening courses at Armour Institute while he was working on the Chicago Subway (January 1939 to May 1942). In July 1940 Armour merged with the Lewis Institute of Chicago and that fall the school's name became the Illinois Institute of Technology (IIT). By the time the subway project shut down in May 1942, Linten E. Grinter had moved onto the University of Florida at Gainesville. He was the person to whom Ralph was committed, so Ralph no longer felt any obligation to the school. But, he also found that teaching was a good exercise.

His first night class in soil mechanics for IIT had seven master's students and eight practicing engineers in the Chicago area, including his boss, Ray Knapp! The practicing engineers wanted to see what soil mechanics was all about and Ralph was curious about what his students wanted to learn and how they could apply the new information in practice. Ralph would later reflect that his first stab at teaching "*fit nicely within his unplanned education in geotechnics*." He taught two nights per week for about five semesters, and had a long drive home each evening after teaching until 9:30 or 10 PM.

While working on the subway he met a number of sharp engineers through evening meetings and presentations at the Engineer's Club. Two fellows in the audience were outspoken supporters and alumni of the civil engineering program at the University of Illinois: Chester P. Seiss and Sydney Berman. They contacted the civil engineering department head Whitney Clark Huntington (Fig. 45) and encouraged him to invite Al Cummings and Ralph to come down to Urbana and give some lectures on the soils and foundations aspects of the subway project.

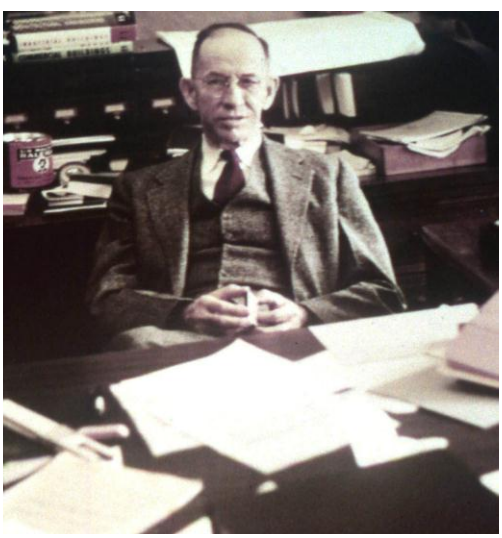

Fig. 45. Whitney Clark Huntington (1887-1965) was Head of the Department of Civil Engineering at the University of Illinois between 1926-56 (Peck family).

In the fall semester of 1940, Al Cummings and Ralph traveled the 90 miles to and from Urbana on alternate weeks to lecture anyone interested in hearing what they had to say about the subway project. Ralph lectured on soil mechanics while Al lectured on piles and pile foundations. Their classes were enormous, with several hundred attending. It seemed like everyone, including the CE faculty, wanted to hear about the various challenges being faced on the subway project. Given the level of interest, they continued teaching throughout the course of the subway work.

During the fall of 1941 Professor Huntington wanted to sponsor a big conference on soils mechanics and foundations, but this never occurred because of America's entry into the war when Pearl Harbor was attacked on December 7^{th}. Al Cummings continued lecturing at the University of Illinois through the 1941-42 academic year. The content of these lectures were subsequently published by the university as an Engineering Experiment Station Circular No. 60, *Lectures on Foundation Engineering*.

Ralph's lectures had impressed Professor Huntington (Fig. 42). In June 1942 he offered Peck a faculty position, much to the delight of Ralph and Marjorie, who were now sharing their cramped apartment with their one year old daughter, Nancy. Huntington was keen on developing a first class program in soil mechanics because his specialties were construction materials and retaining walls (Huntington, 1957).

Peck felt obliged to ask Terzaghi for his views on the appointment since the two men had begun writing a series of articles summarizing what they had learned on the subway project. Terzaghi rebuffed Huntington's offer, stating that Ralph "*did not have sufficient professional experience yet to be teaching foundation engineering at such a prestigious institution.*"

Part of this decision may have been because Terzaghi had tremendous respect for the civil engineering program at Illinois because of Arthur N. Talbot (1847-1942), who had recently passed away, after teaching at Illinois since 1885! Talbot had championed the university as an entity that could help industry solve real-world problems. Illinois had been the first American university to partner with the railroads, opening an Engineering Experiment Station in 1903. Talbot used the facility to test various designs of reinforced concrete beams for those railroads that sponsored the research. Talbot's model of universities interfacing with industry to implement state-of-the-art technology was the university model promoted by Terzaghi his entire career. So, it was no accident that Ralph Peck ended up teaching there.

Although disappointed, Peck's loyalty to Terzaghi was akin the respect that he felt for his own father, so he reluctantly declined Huntington's offer. He took a position as 'chief engineer of testing' with the firm Holabird, Root & Burgee in Marion, Ohio. Like the subway, this position was orchestrated by Terzaghi, who was consulting on the ore yards in the Marion and Cleveland areas. With wartime production going 24/7, the ore yards were increasing their capacity each month, which demanded larger and heavier piles of iron ore. Some of the ore piles had grown so high they were triggering differential heave that prevented the gantry cranes from being able to process the ore and shutting down production (Fig. 46).

Fig. 46. Ore Storage Yard at Republic Steel's Blast Furnace No. 5 in Cleveland, where Terzaghi made a grievous error in settlement calculations. If it hadn't been caught by Peck, the ore piles to have been stacked so high they would have suffered bearing capacity failures (Peck Collection-NGI).

Peck was assigned the task of figuring out how much ore could safely be stored at these facilities without engendering excessive ground movements. This involved subsurface exploration, laboratory testing, theoretical calculations, and lots of field measurements. Terzaghi was to be called upon as a consultant whenever problems arose that were unanticipated or without explanation. Each ore yard sat on slightly different stratigraphy, with different loading histories. Ralph soon learned that it was dicey dealing with differential settlement of glacial tills and overconsolidated glacial clays underlying the ore yards, especially those along the glacial Cuyahoga River Valley near Cleveland, where each clay horizons exhibited different overconsolidation ratios (Peck and Raamot, 1964).

In the late fall of 1942 Ralph discovered a significant computational error Terzaghi had made in some settlement and bearing capacity estimates for the Ore Storage Yard at Republic Steel's Blast Furnace No. 5 in Cleveland (Fig. 46). He respectfully brought it to Terzaghi's attention while they were traveling on a train between Chicago and Cleveland. He prayed that this news wouldn't upset Terzaghi too much. Terzaghi silently reviewed the calculations in dispute for several minutes, to verify the accusation. He then paused and silently contemplated what to do. After what seemed like an eternity to Ralph, but was probably no more than 10 or 15 minutes, he calmly informed Ralph that he had "*garnered sufficient experience that he could now accept the position at the University of Illinois!*"

This was six months after he had declined Dean Huntington's offer, but he wrote to Huntington informing him of his unexpected "availability." Huntington did some adroit juggling and came up with 7/8 time appointment as Research Assistant Professor, with a starting salary that was $3500 per year. In December 1942 Ralph joined the faculty at the University of Illinois.

JAMES "PAPPY" PORTER

During the Second World War another of Terzaghi's long-time 'correspondents' burst onto the geotechnical scene. His name was Omer James Porter (1901-67). Professionally he went by "James," but most everyone called him by the nickname, "Pappy" (Fig. 47).

Porter was a third generation Morman, born in Mt. Pleasant, Utah on November 28, 1901. He attended Alberta Agricultural College in Olds, then transferred to the University of Alberta, where he received his bachelor's degree in civil engineering in 1924. After graduation he took a part-time position with the California Division of Highways in Sacramento, mixing and testing concrete specimens. The quality of his work and his enthusiasm for tinkering soon landed him a full-time position in materials research and testing. For 16 years Porter worked under Thomas E. Stanton, Jr., (BSCE 1904 U.C. Berkeley), the senior Materials and Research Engineer with the Division of Highways. Their collaboration was one of the most prolific in the early years of pavement design, which began incorporating the new principles of soil mechanics.

Fig 47. O. James "Pappy" Porter (1901-67) was a clever innovator and problem solver, with a penchant for marketing and entrepreneurship. Between 1942-66 he formed more than a dozen different consulting companies from California to New Jersey, with numerous partners (image from the O.J. Porter Co.).

Between 1927-30 Porter developed the California Bearing Ratio (CBR) and soil swell tests. The CBR test measured penetration of compacted soil to evaluate the relative stiffness of pavement subgrades and basecourses, by comparing the penetration resistance of these materials with that of crushed limestone. The intent of the CBR test was to evaluate the load bearing capacity of the pavement subgrade (Porter, 1939).

In 1928-29 he developed the nation's first compaction test procedure using a simple device and scheme that measured a soil's wet unit density in comparison with a maximum figure determined from hand compaction of a soil sample in a cylindrical mold. This procedure was similar to the scheme Ralph Proctor developed in 1933 using dry bulk density, so decisions about adding or decreasing soil moisture could be made quickly. Porter's procedure was termed the "California impact compaction test," and is still used by Caltrans as California Test Method 216 (Stanton, 1938a, 1938b).

In the early 1930s Porter also pioneered the use of wick drains, which were installed on the eastern approaches to the San Francisco-Oakland Bay Bridge in 1933-35, along with standpipe piezometers to record pore pressure induced by the fill surcharge. This was one of the first successful employments of wick drains in the United States. It attracted the attention of Karl Terzaghi and Arthur Casagrande, who invited Porter and Stanton to contribute several papers for the First International Conference on Soil Mechanics in May 1936 (Porter, 1936).

Between 1930-47 Porter developed a series of retractable plug piston samplers in an array of sizes, between one and four inches in diameter, and between 1.5 and three feet long. They were initially known as "Porter Type Soil Samplers" (Porter, 1947). The design was so successful; it stirred competition to develop more efficient soil samplers, such as the M&P Sampler developed by Moran & Proctor, the modified Gow Sampler of the Raymond Concrete Pile Co., Sprague & Henwood's standard drive sampler, Dames & Moore's Soil Sampler, and the Pitcher Barrel sampler patented by South San Francisco driller John Pitcher. Pitcher's was the only other sampler that employed a retractable plug.

Soon after the United States entered the Second World War (spring 1942), Porter formed his own consultancy, O.J. Porter & Co., specializing in soils, pavement design, and foundation engineering, based in Sacramento. Porter did a lot of consulting work for the Navy's Bureau of Yards & Docks and the Army Corps of Engineers (which continued through 1964). He also became the central figure of the Corps of Engineers Airfield Pavement Design Advisory Council during the Second World War. This group oversaw Porter's program of pavement testing at Stockton Airfield, south of Sacramento. This work led to the development of Flexible Pavement Design Manuals and the Modified Proctor Compaction Test in 1945 (Stanton, 1938c, 1940; Porter, 1942, 1946; Porter Co., 1949).

During the war, Porter was dispatched to Guam, Saipan, and Tinian in 1944 to advise the Corps of Engineers on airfield construction for the B-29 Superfortress bombers. In 1946 Porter began submitting patent applications for a number of devices, including a massive 240 ton rubber-tired "supercompressor," intended to increase the insitu density of pavement subgrade for airfields.

Wick drains for O'Hare Field (1947)

In 1946 Porter established an east coast office in Montclair, New Jersey to work on the soil settlement problems in the New Jersey Meadows area, during construction of the New Jersey Turnpike. Porter employed sand drains and surcharge embankments to allow development of settlement-prone wetlands, similar to the technique he used on the eastern approaches to the Oakland Bay Bridge in the early 1930s. His business quickly expanded. In the spring of 1947 Porter was contacted by Ralph Peck about the possibility of mitigating anticipated settlement problems across peat deposits near Chicago's new O'Hare Field, just beginning construction.

One of the most interesting aspects of the O'Hare Airport project involved the relocation of two railroad lines. These had to be relocated to the west side of the airport property, near York Road. Engineering geologist George Otto determined that this area was underlain by a peat bog, about 20-23 feet thick (described previously). York Road was almost impassable because of severe differential settlement and pavement distress. The railroads objected to the planned relocation effort, so Ralph Burke promised them that he would provide a "stabilized roadbed." The railroads agreed, thinking that Burke's forces would remove the objectionable peat and replace it with engineered fill.

Ralph felt that they might use wick drains to pre-settle the proposed railway alignments. Ralph Burke knew that Peck did not have any first-hand experience with wick drains, but both men had recently read of Porter's using wick drains in the Jersey Meadowlands, so Burke sent Peck to Montclair, New Jersey to meet Porter and feel him out about the possibilities of employing wick drains at O'Hare Airport.

Peck arrived at Porter's office shortly before noon on a Wednesday and Porter welcomed him with a martini in hand, inviting Ralph to have a drink. It seemed obvious that he had imbibed in a few drinks already, so Peck declined and they went out to lunch. During lunch Porter consumed several more martinis, making Ralph uncomfortable. He wondered if Porter would recall any of the technical details being described during the lunch.

Peck didn't feel that his clients (Burke and the airport authority) got their money's worth out of that initial conference. He returned to Chicago and briefed Ralph Burke about what he had seen, but Burke decided he wanted Porter to come out to Chicago to examine the situation, and once there, he would 'size him up' to see if he was up to the job. He told Ralph that "*the construction industry is filled with brilliant alcoholics; you just have to know what sets them off. If everything goes well, he'll probably be OK. If he misses something and takes a big stumble, we'll be on our own to finish whatever it is that he starts*." Taking such a gamble on someone like this was a new experience for Ralph, and he admired Burke's confidence.

Porter came to Chicago and soon opined that he felt he could supervise the installation of sand wick drains and pre-loading of the proposed railroad right-of-ways. He then added that he could train Ralph to monitor the settlements until they were convinced the old peat bog was 100% consolidated. The railroads were pretty upset because they had never heard of wick drains, and objected to leaving the peat beneath their relocated lines. Peck wasn't too sure either, he was concerned about the secondary consolidation that might occur over the long term.

During construction they had some problems with 'mud waves' (loss of bearing capacity because of elevated pore pressures by the embankment surcharge) developing along the toe of the new railroad embankments, but on the whole, the job went quite well. The surcharge fill was allowed to sit for over a year, while measurements of pore pressures and settlement were being made every few weeks. When they were satisfied that the primary consolidation was complete, they removed the surcharge. It was the first time wick drains had been used in Chicago.

Peck later related that the elegant aspect of all this was Porter's decision to not only remove the surcharge, but overexcavate the upper few feet of native soil overlying the compressed peats, thereby reducing the overburden load that had been acting on the peats for several millennia. This obviated any fears of future problems because the as-built situation posed *less load* than had originally been on the site. Peck then realized how clever Porter really was!

On Peck's advice, Burke's team continued making observations for several years, but very small settlements were observed. The settlement of the peat horizon ceased when Porter removed the surcharge, followed by some small rebound. One of Peck's Harvard classmates, George Bertram (MSCE '39 Harvard), and his colleague Reginal Barron of the Army Corps of Engineers, went on to perfect the art of sand drains, building on the pioneering work of Porter in the 1930s and 40s.

Ralph Peck observed that Pappy Porter was a gifted entrepreneur and natural born problem solver. Within five years of going out on his own, Porter's consulting business was a coast-to-coast entity with regional offices, doing considerable overseas business for the Department of Defense, mostly on air bases. Peck admired Porter's problem solving skills, which he began to emulate when he started accepting consulting assignments in the coming years.

CONCLUDING REMARKS

Professor of Foundation Engineering

The 18 years following Ralph Peck's high school graduation were filled with varied and stimulating experiences. He often remarked that he could never have envisioned how so many disparate opportunities could combine themselves so eloquently to develop his character and engineering judgment. He felt blessed beyond measure to have worked with the people that the Lord placed next to him, especially those who became his professional mentors during his first decade associated with soil mechanics. Foremost among these was his father, who served as his best friend and confidant throughout his formative years, up until his marriage to Marjorie in June 1937.

Ralph flew through the academic ranks at Illinois with lightening speed. He received tenure in the second semester after he arrived. He became registered as a civil engineer in Illinois in 1941, and as a licensed structural engineer in April 1943, by oral examination (he later served on the Illinois Structural Engineer Examination Board for 10 years). In September 1943 his salary was raised to $4000 per annum, and he and Marjorie finally felt some measure of financial security. In 1944 the university was delighted with the prestige he brought their program when he was selected for A.S.C.E.'s Norman Medal. He remains the youngest recipient to ever receive the award by himself. He was promoted to full professorship in 1945, with the title "Research Professor of Soil Mechanics."

1948 was something of a watershed year for Ralph. He and Terzaghi released their new book "*Soil Mechanics in Engineering Practice*," which soon became the best-selling textbook on soil mechanics, translated into 17 languages. This established Ralph as the heir apparent in America to the old master of soil mechanics. Ralph also published eight articles in the Proceedings for the Second International Conference on Soil Mechanics in Rotterdam, including two co-authored with his father, something he had hoped to do since he was a boy.

In 1948 Ralph also completed a multi-year project that became the classic reference on Chicago foundations, titled "*History of Building Foundations in Chicago*," published by the University's Experiment Station as Bulletin 373. It contained 70 years of information compiled by a group of Chicago engineers, many who were drawn from the Chicago Subsoils Committee assembled during the subway project. These included Peck, Fred Reichert, Chester Seiss, Ray Knapp, Al Cummings, and Frank Randall. Frank was in his early 60s at the time and he had participated in construction of many of the Chicago buildings. Much of this information would have been lost if not for the efforts of the older engineers to document their experiences and lessons to pass this onto the next generation. Ralph felt that this was one of the seminal contributions of his professional career, which has influenced the geotechnical input for every significant foundation in the downtown area since that time. In the fall of 1948 Ralph's academic title became "Professor of Foundation Engineering," which it remained until his retirement in June 1974.

Encouragement and collaboration essential to success

Ralph was eternally grateful to Bill Shannon (1914-2006) for 'getting him through' the first half-semester at Harvard, when Casagrande was sure he would falter, not having any background in soil mechanics. After Bill co-founded Shannon & Wilson in 1954 in Seattle (Fig. 48), he and Stan Wilson always preferred graduates of Peck's geotechnical program at Illinois because they felt it offered a more balanced program of study, with six faculty teaching geotechnical courses (Shannon and Wilson had both received their graduate training at Harvard, under Casagrande).

Ralph was also thankful that Ralph Fadum (1912-2000) turned down the offer to work with Terzaghi in Chicago because of his aversion to the old master's omnipresent cigar smoke. Ralph often pondered what direction his life might have taken had he not been available to drop out of Harvard and head for Chicago on a few days notice in January 1939.

Like Peck, Fadum (Fig. 48) had secured undergraduate (BSCE at Illinois in 1935) and graduate degrees (MSCE at MIT in 1936), but found work opportunities scarce during the Great Depression. He had returned to Harvard in 1938 to work on his doctorate, in hopes of securing an academic position.

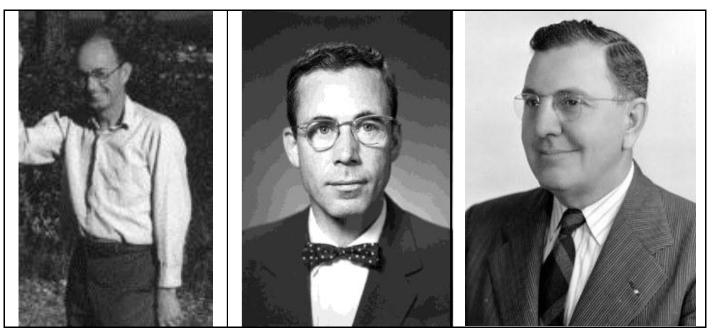

Fig. 48. From left: William L. Shannon, Ralph E. Fadum, and Willard J. Turnbull (from left: Shannon & Wilson, North Carolina State University, and U.S. Army Corps of Engineers).

After Peck left for Chicago Fadum remained at Harvard working closely with Casagrande. He completed his Sc.D. in 1941, but remained at Harvard helping Casagrande teach soil mechanics to Army Engineers. In July 1943 he landed a faculty position at Purdue when Phil Rutledge departed to join Moran, Proctor, Freeman & Mueser in New York. Fadum moved onto North Carolina State in 1949 to become chairman of their civil engineering program. In 1962 he became the Dean of Engineering at NC State and remained in that capacity until his retirement, in 1978.

Peck's professional association with Bill Turnbull (Fig. 48) at the Waterways Experiment Station (WES) continued for three decades. He marveled at Turnbull's managerial talents, which he compared to those of his first boss, Ray Knapp. Turnbull was constantly working to create balanced teams of engineers and geologists to solve the various problems thrown at WES. Oftentimes, the people he needed for one team were already assigned to another, so it required a great deal of shuffling to keep the various projects on track.

In 1951 Turnbull asked Ralph to be one of the members of a board of consultants being organized by the Corps of Engineers to advise them on the foundation investigations for the new Savannah River Plant being built by the Atomic Energy Commission. In addition to Peck and Turnbull, the other members of that first geotechnical advisory board were Arthur Casagrande of Harvard, and Tom Middlebrooks and Bob Philippe of the Corps. This was the first of numerous WES consulting boards that Ralph served on from that time forward, including soil dynamics, earthquake engineering, and too many dams to list.

In 1978, nine years after Bill Turnbull's retirement, the Carter Administration eliminated consulting boards by federal research agencies to review their general research efforts. Ralph never got over this decision, feeling that the very slight cost of the boards had proven immensely valuable in identifying errors in procedures, outdated design methodologies, and programs of research or field application that have, all-too-often, been carried out by someone else. This was something he had learned early in his career from Al Cummings (Peck, 1980). The members of these advisory boards were often aware of parallel these activities overseas because of their international associations. He predicted that the Corps would come to regret the decision to save so few dollars when "so much was at stake."

Peck's advice to young engineers

Peck repeatedly told audiences of young engineers that it was essential for them to "move around a bit," and to "work for at least three different entities during their professional careers." The reason he gave was so that that would learn that there are innumerable ways to solve engineering problems. Peck also believed that "the people that mentor us are the most important in shaping our destiny."

Upon reaching his 86th birthday in 1998 he reflected on how blessed he had been to have worked with so many luminaries of their respective fields, a few of whom were profiled here, which focused on the decade 1938-48 (structural engineer Charlie DeLeuw was another influential figure he met during this same time).

Perhaps the most important legacy Ralph Peck left us was his humility. He lectured frequently on his mistakes, not on his triumphs (Peck, 2006). He did this purposefully, so his audience would learn important lessons without having to suffer their consequences.

Like a great military leader, he grew wary of overconfidence, which he observed in so many of the young Ph.D.'s he encountered. He said that the great majority of geotechnical failures could be grouped in three "bins:" 1) inadequate geologic characterization (Peck, 1962a); 2) bias and overconfidence (Peck, 1962b; 1980); and 3) failure to consider "extra-geotechnical" factors, such as conditions or activities beyond geotechnical engineer's normal practice to consider or control (Peck, 2006). These would include "the dumb things that some people do" after completion of the foundations and the geotechnical engineer has "left the job."

All of us who are geopractioners could benefit from hearing about how our predecessors faced the geo-challenges of their respective eras, and how our life experiences shape our view of things. Each of us has a unique pedigree of experience, shaped in large measure, by whom we have been fortunate enough to have worked with in our families, our academic training, and during our professional careers.

ACKNOWLEDGMENTS

The author is indebted to Ralph Peck for granting a series of week-long interviews at the Peck home in Albuquerque between 1991-2001. The author also wishes to thank Ralph's daughter Nancy and her husband Alan Young for their kind hospitality during his many visits. Others who contributed anecdotes for this article included: Anne Otto Earle, Pamela J. Bolton, Dick Goodman, Tor and Joyce Brekke, Tom Leps, Claude Fetzer, Bill Swiger, Harry Horn, Ray Miller, Alberto S. Nieto, Tom O'Rourke, Walt Hanson, Jack Rolston, John Lowe, Don Deere, Frank Patton, Ed Cording, Dick Meehan, Tom Keusel, Eric Savage, "Red" Robinson, Bob Holtz, Gary Brierley, Ron Perisho, Shamsher Prakash, George P. Earle, and William Earle.

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