GEOSTRATA

NOVEMBER // DECEMBER 2019

GEOTECHNICS OF FAMOUS STRUCTURES

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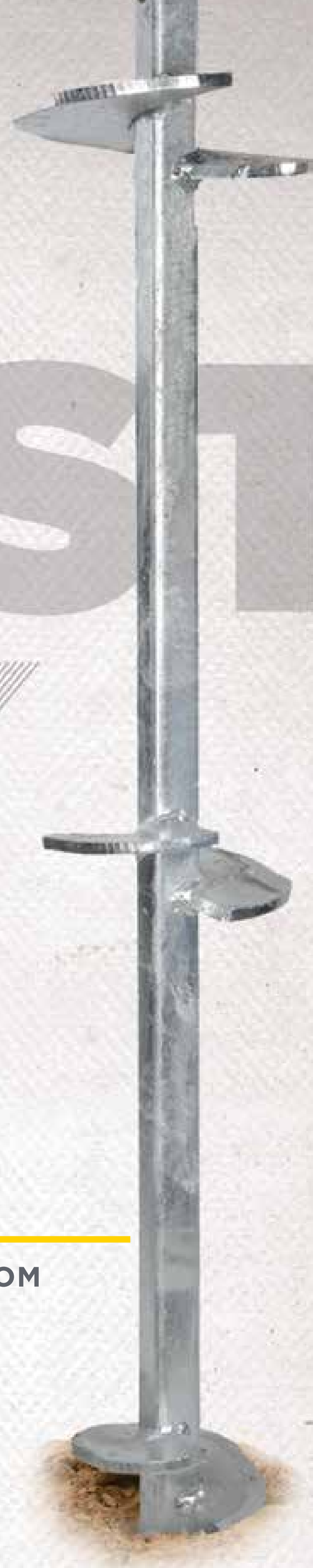

GEOSTRATA November // December 2019

Features

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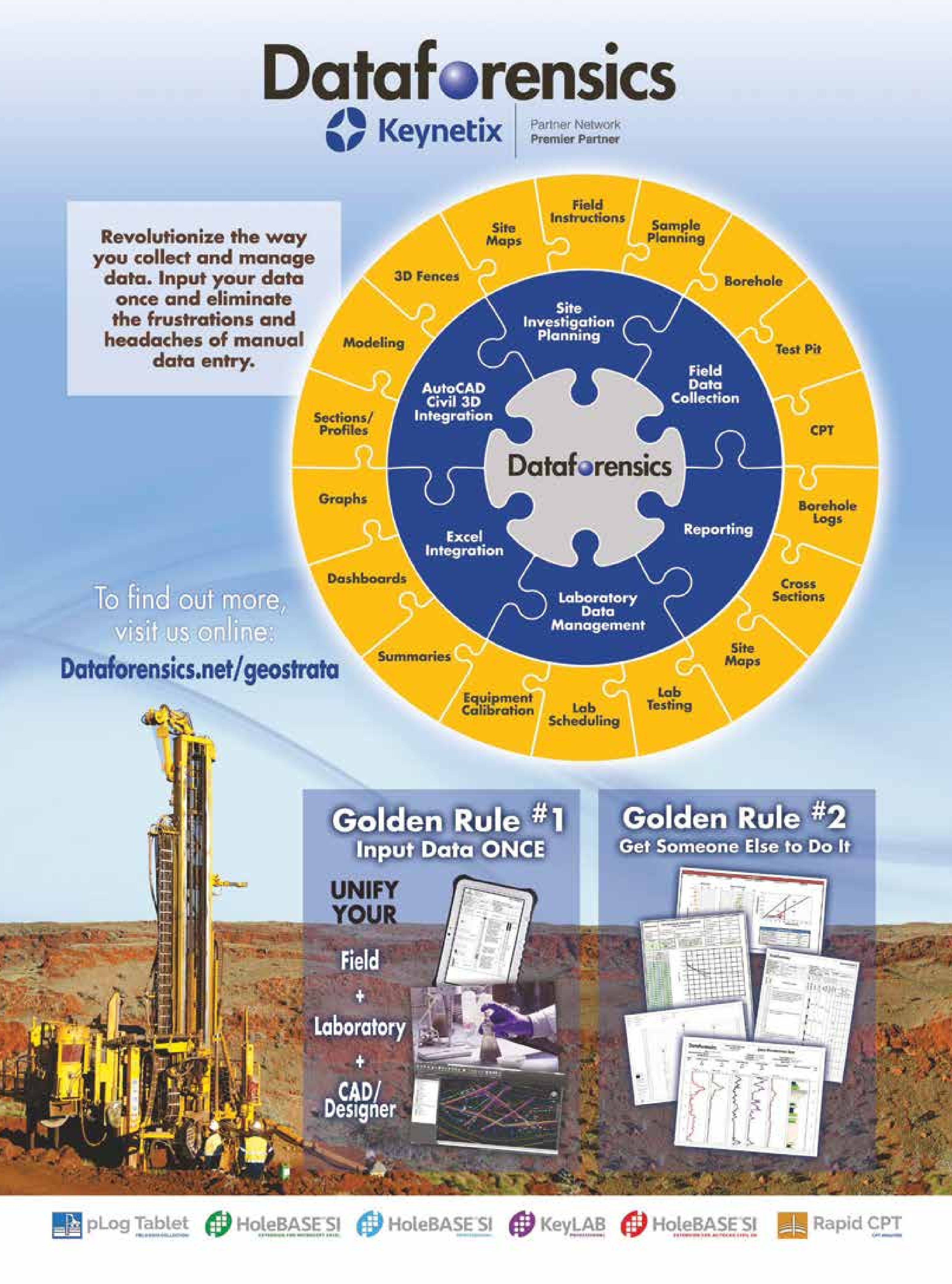

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A New
Digital Era.

From the President

Changing of the Board

PATRICK J. FOX

Greetings from Happy Valley, PA! It is a great honor to write this, my first President's Column, at the start of a one-year appointment as president of the Geo-Institute of the American Society of Civil Engineers. I have been a member of the G-I Board of Governors since 2014, and held the position of editor-in-chief of the *Journal of Geotechnical and GeoEnvironmental Engineering* for five years prior to that. I also have served the G-I in several other capacities, including the Geoenvironmental Engineering Technical Committee, several conference organizing committees, chair of the Technical Publications Committee, and chair of the 2010 Geo-Congress. For my other job, I currently hold the John A. and Harriette K. Shaw Professorship and serve as the head of the Department of Civil and Environmental Engineering at The Pennsylvania State University. Two great positions for two great institutions — what a year ahead!

Every G-I president relies heavily on the path laid by their predecessors. In my case, I want to acknowledge the great work done by our past president, Beth Gross, and her predecessor, Youssef Hashash. I am inspired by their outstanding contributions, along with those of the many other past G-I presidents, who have elevated the G-I to its current position and continuing leadership in the geoengineering profession. In addition, I would like to acknowledge our new vice president, Jim Collin, new treasurer, Bob Gilbert, and Board members Sissy Nikolaou, Domniki Asimaki, Chuck Black, and our newest Board member, Stan Boyle. I look forward to working with them, and our outstanding staff led by G-I director Brad Keelor, to provide leadership, innovation, and excellence for our 12,000+ members, including 50 G-I local chapters and 35 G-I graduate student organizations.

Looking to the year ahead, the G-I Board is working on a number of priority activities and initiatives to increase the value of your G-I membership. They include:

■ ***Outstanding conference events.*** We are looking forward to the 2020 Geo-Congress — Vision, Insight, Outlook — in Minneapolis, MN, in February 2020, the 4th International Symposium on Frontiers in Offshore Geotechnics (ISFOG) in Austin, TX, in August 2020, and the 10th International Conference on Scour and Erosion in Arlington, VA, in November 2020.

■ ***Excellent technical publications.*** The G-I provides journals, books, and conference publications of the highest quality, including the *Journal of Geotechnical and Geoenvironmental Engineering*, *International Journal of Geomechanics*, and, of course, *GEOSTRATA*, which will be celebrating its 20th anniversary in the spring.

■ ***Robust awards program.*** Our awards program recognizes the achievements of individuals across the geoengineering profession, including practice and research contributions. Please consider nominating a colleague for a G-I award.

■ ***The digital G-I.*** The Board is in the process of significantly upgrading the G-I website (*geoinstitute.org*) to make it more functional and better serving to our committees and membership at large.

■ ***GeoTechTools.*** As of this writing, a total of 47 technologies, ranging from earth support, to liquefaction mitigation, to bio-augmentation of soils, are described in the GeoTechTools section of the G-I website. Each technology is complete with rating scales, fact sheet, design guidance, cost information, case histories, and specifications. It's impressive. Check it out!

■ ***IDEA.*** The IDEA program provides technical evaluation of earth retention systems and is now administered by the G-I (formerly by HITEC and ASCE). The goal of the program is to foster innovation with proven technologies, encourage the development of new technologies, improve the delivery of these technologies to highway infrastructure projects, and assess the continued efficacy of previously evaluated systems. The G-I website provides more details.

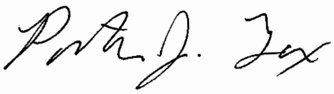
■ ***Professional practice issues.*** The Board continues to be centrally involved in geoprofessional licensure policy and post-PE credentialing initiatives, including collaboration with the Structural Engineering Institute (SEI) and the Academy of Geo-Professionals (AGP).

■ ***Guidelines for risk-informed design.*** For the last several years, a G-I task force, chaired by ASCE President-Elect Jean-Louis Briaud, has been developing a guidance document on risk-informed design. The document is intended to serve as a basic reference for geotechnical engineers and will be available to G-I members in the coming year.

■ ***Re-imagining the G-I.*** The Board continues to consider innovative concepts to re-imagine the structure and increase the efficiency and impact of the G-I, to better promote the profession and serve its members.

In closing, I would like to express my sincere gratitude for the outstanding and dedicated service of our Board of Governors, Board-level committees, technical committees, task forces, journal editors, local chapters, student organizations, and G-I and ASCE staffs. Over the next year, I look forward to working with many of our members in these various roles, and others, who help keep the G-I at the highest levels of excellence worldwide.

As president, and on behalf of the Board of Governors, I welcome your comments and suggestions on ways in which we can improve our ASCE Geo-Institute. GS



Patrick J. Fox, PhD, PE, D.GE, F.ASCE
President, ASCE Geo-Institute
pjfox@engr.psu.edu

From the Editorial Board

BRIAN A. HUBEL

For the holidays, we at *GEOSTRATA* are happy to provide our loyal readers with a geoprofessional "world tour" of sorts, as our authors share with us geotechnical and geological challenges of famous structures around the globe. Our greatest challenge was narrowing the number of structures to the few we have space to present.

What's Inside?

Who better to introduce the topic "Geotechnics of Famous Structures" than a commentary by the same name from noted educator and consultant John B. Burland, who is known for his work on iconic structures like the Tower of Pisa and the Big Ben Clock Tower. He points out the importance of clear communications with clients, project-team members, and the public, and clarity of responsibility during project decision making.

The article "Geotechnics of the Suez Canal Construction" by Mamdouh Mostafa Hamza tells the story behind the planning and construction of this critical waterway linking the Mediterranean and Red Seas. The author recounts how, more than 60 years before soil mechanics became a recognized discipline in civil engineering, the canal's engineers somehow dealt with problematic ground conditions that continue to challenge today's geotechnical engineers.

Do you know what kind of foundations the beautiful Taj Mahal marble structure is supported on? In "The Taj Mahal – Immortal and Ethereal Beauty in Stone," Madhav R. Madhira and Venkata Abhishek Sakleshpur discuss some of the structure's construction history, the foundations it bears on, some relatively recent subsurface characterization of the area, and environmental issues that pose concerns for the Taj Mahal's long-term viability.

Writing to the true geoprofessional nerds, Jim Lambrechts takes a different approach in writing an article around this issue's theme, "Geotechnics of Famous Structures." His article isn't about the foundations for a famous structure, but rather the famous ground conditions of Boston. In "What Lurks Below — The Geotechnical Intrigue of Boston's Back Bay," we learn about the geology, history, and geotechnical challenges this ground has posed for developments over Boston's blue clay.

Even structures we consider famous today were not always so recognized. Getting there depended on many factors, but meeting a public need has always been crucial. So while it's not yet achieved the accolades of decades-older structures, the Eurasia Tunnel crossing of the Bosphorus Strait in Istanbul, Turkey, is a likely future contender. In their article "Connecting Continents — Challenges of the Eurasia Tunnel in Istanbul," Ray Castelli and Dave Smith share some of the geotechnical and geologic challenges that had to be faced during the design and construction of the 3.4-km tunnel linking Europe and Asia.

Early concerns about the lifespan of geosynthetics rightfully subjected them to careful scrutiny, but these issues have been largely dispelled by ever-improving polymer formulations, research, and field evidence of good performance. In our periodic feature *What's New in Geo?*, Ming Zhu, Marco Isola, and Jorge Zornberg take a look at three relatively new applications of geosynthetics in their article "Advances in Geosynthetic Solutions for Sustainable Landfill Design."

And don't miss the GeoLegend interview with Dr. W. Allen Marr. The article covers a wide range of topics related to professional experiences, including the influence of Marr's mentors on his career, some lessons he's learned along the way, future advances he envisions, and his simple, but powerful, winning approach to business and life. Many thanks to the Temple University PhD candidates Alireza Kordjazi and Arash Hosseini, and PhD graduate Siavash Mahvelati, for conducting this interview.

As one of the world's foremost experts in geostructural instrumentation, John Dunnicliff has lectured worldwide and helped train thousands of engineers in the lessons he's learned. In his *Did You Know?* article "It's All About Communication," John offers sage advice we should all follow when we make presentations to professional and lay audiences alike.

Mary Nodine gets to rest for this issue, which offers an opening for guest poet Katherine Zadrozny and her poem "Big Reputation," a truly fitting piece for this issue.

Enjoy the issue, and Happy Holidays! GS

This message was prepared by **BRIAN A. HUBEL, PE, GE, M.ASCE**. He can be reached at *Brian.A.Hubel@usace.army.mil.*

// GeoCartoon

20 *GeoStrata* Will Turn 20 Years Old In 2020!

Has the magazine been helpful? Have you learned something new? What do you like or not like? What pages do you turn to first, i.e., Feature articles? GeoCurmudgeon? GeoPoem? GeoLegend? We'd enjoy hearing from you with the idea of publishing a few of the comments in the March/April 2020 issue. Please send your comments of 150 words or less to our editor-in-chief at *jlwithiam@dappalonia.com.*

Board of Governors Update

It's time for the annual changes in the G-I Board of Governors (BoG). On October 1, the G-I presidency transitioned from Beth Gross, PhD, PE, D.GE, F.ASCE, to Pat Fox, PhD, PE, D.GE, F.ASCE, and the BoG welcomed its newest member, Stan Boyle, PhD, PE, M.ASCE. With this transition, Beth became past president, while the 2017-18 past president, Youssef Hashash, completed his service and transitioned off the BoG.

As a mover and a shaker, Youssef leaves behind a legacy of an innovator who changed the way we communicate, especially with the reformed website, digital G-I, and other new initiatives. Youssef was available around the clock for any issue that arose, and he would not rest until a satisfactory solution was found. As an exemplary leader who embraces diversity, Youssef contributed to making our Board more in sync with the emerging needs of the younger and more demanding generation of geoprofessionals. We are immensely grateful for Youssef's contributions, endless energy, and dedication to the G-I and its BoG, and look forward to his wise advice and counsel for years to come.

G-I Board of Governors

Patrick J. Fox, PhD, PE, D.GE, F.ASCE
President
pjfox@engr.psu.edu

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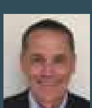
Operations: TBA
Committees: TBA



James G. Collin, PhD, PE, D.GE, F.ASCE
Vice President
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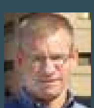
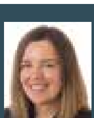
Initiatives: FHWA - IDEA, GeotechTools
Operations: Finance
Committees: Local Involvement, Regional Conference



Robert B. Gilbert, PhD, PE, D.GE, M.ASCE
Treasurer
bob_gilbert@mail.utexas.edu

Initiatives: Post-PE Credentialing, Risk-Informed Design Task Force
Operations: Technical Committees, Activities, and Research
Committees: Codes and Standards, Geo-Congress Organizing, Geo-Legislative, AGP Liaison



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Past President
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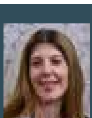
Operations: Governance and ASCE Relations, Conferences



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Initiatives: Digital G-I
Operations: Communications, Outreach, and Collaboration
Committees: International Activities, Technical Coordination

Charles W. Black, Jr., PE, M.ASCE
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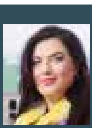
Operations: Membership
Committees: Outreach and Engagement, Organizational Member

Stan Boyle, PhD, PE, M.ASCE
Governor
srb@shanwil.com

Initiatives:
Operations:
Committees:



Sissy Nikolaou, PhD, PE, D.GE, F.ASCE
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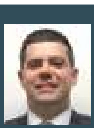
Initiatives: Ideas and Innovation Committee
Operations: Professional Practice Issues
Committees: Awards, Continuing Education, Technical Publications, Open Access (Task Force)



Brad Keelor
Secretary and G-I Director
bkeelor@asce.org

Manages the day-to-day activities of the G-I

Stan Boyle, the BoG's newest member, is a vice president with Shannon & Wilson in Seattle, WA. He has more than two decades of analysis and design experience in a broad range of geotechnical engineering problems, including retaining structures, highway and railroad embankments, excavation shoring systems, dams, levees, impoundment dikes, trenched and tunneled pipeline installations, and structure and bridge foundations. Stan holds a PhD in geotechnical engineering from the University of Washington (1995), a master's degree in structural engineering from Carnegie-Mellon University (1984), and a bachelor's degree in civil engineering from the University of Vermont (1983). He is a registered Professional Engineer in the states of Washington, Colorado, and Alaska, and serves on the G-I's Organizational Member Council.

The most recent BoG meeting was held in New York City on October 14-15, 2019, and included meetings with representatives from agencies, organizations, and private firms from the tri-state area. As a follow-up, the BoG received and addressed feedback from the regional representatives, especially regarding ongoing and new G-I initiatives on emerging technologies, continuing education, digital G-I, codes and regulations, and issues of the geoprofession.

Did You Know?

It's All About Communication

By John Dunnicliff, PE, Dist.M.ASCE

Editor's Note: John Dunnicliff is one of the world's foremost experts in geo-structural instrumentation, the author of *Geotechnical Instrumentation for Monitoring Field Performance*, referred to by its users as the *Red Book*, and a leading lecturer and author on the topic. Beginning in 1994, John began writing "Geotechnical Instrumentation News (GIN)," feature articles that appeared in 93 issues of *Geotechnical News* from BiTech Publishers, Ltd. of Richmond, BC, Canada. Over the years, GIN became a forum for articles useful to its readers in engineering practice. As such, practitioners, product suppliers, educators, researchers, and John contributed case histories, new technologies, and best practices that became a go-to resource for geoprofessionals. Unfortunately, *Geotechnical News* will cease publication at the end of 2019, and so, too, will GIN. John has directed more than 100 continuing education courses about geostructural instrumentation and monitoring during the past 40 years. From these experiences, he offers some communications lessons he's learned to help shorten for others the path that he has taken. Let us know if you have similar lessons to share.

Content of Professional Lectures

During my career, I've learned a few lessons about how lecture content should be presented to be the most effective. Here are my Top 5 tips:

1. Be clear in your own mind about your objective, and fulfill that objective during your presentation. This will usually be to provide guidelines to the audience about how your lecture will improve their professional practices.
2. Will your presentation keep you focused on those "clear guidelines" so your audience will understand and remember them?
3. Will you present so much information that the "clear guidelines" will be obscured?
4. Think of your primary theme as "Main Street." During your presentation, define Main Street and *stay on Main Street*! Turning left or right will detract from your primary theme.

5. My Golden Rule for articles in GIN is a quotation by Joseph Pulitzer that applies to both written and spoken communications:

   "Put it before them briefly so they will read it,
   clearly so they will appreciate it,
   picturesquely so that they will remember it
   and, above all, accurately
   so that they will be guided by its light."

PowerPoint Slides

When watching (enduring!) a PowerPoint presentation, I've often wanted to shout out "Your slides are terrible!" Here are my suggestions:

1. Use light colours on a dark background. Dark on light causes glare. The worst is non-bold black on a white background, and this seems to be highly popular, hence my stifled shouting! Consider using yellow, white, and/or light blue on a black background.
2. Use a clear font. Verdana bold is good. The font should be large enough to be seen clearly at the back of the room. I prefer using Verdana 28 bold for titles and Verdana 20 bold for text below.
3. To avoid attempting too much, limit the number of slides to about one per minute. If you have more slides than this, you'll likely run out of time and may need to speak too quickly at the end.
4. Avoid too many words on a slide. If you have too many words, the slides are no longer visual *aids*. It's far better to have just a few words on a slide to remind you what to say and to elaborate during your presentation.
5. Use a simple title of six words or less.
6. Avoid the trap of having words on the screen while you're speaking other words. If the people listening to you try to read the words, they'll be distracted from what you're saying. This tends to happen when the slides are too wordy.
7. Slides with multiple graphics take time to explain, often leading to time problems.
8. No busy slides! Use pictures and clear, concise schematics rather than detailed drawings and graphs.
9. Keep the flow of slides simple. I use "Appear" for animations, and "None" on the Transitions tab.
10. Unless publicized as a commercial presentation, avoid any commercialization, except perhaps for your company logo on the first slide.

And One Last Thing

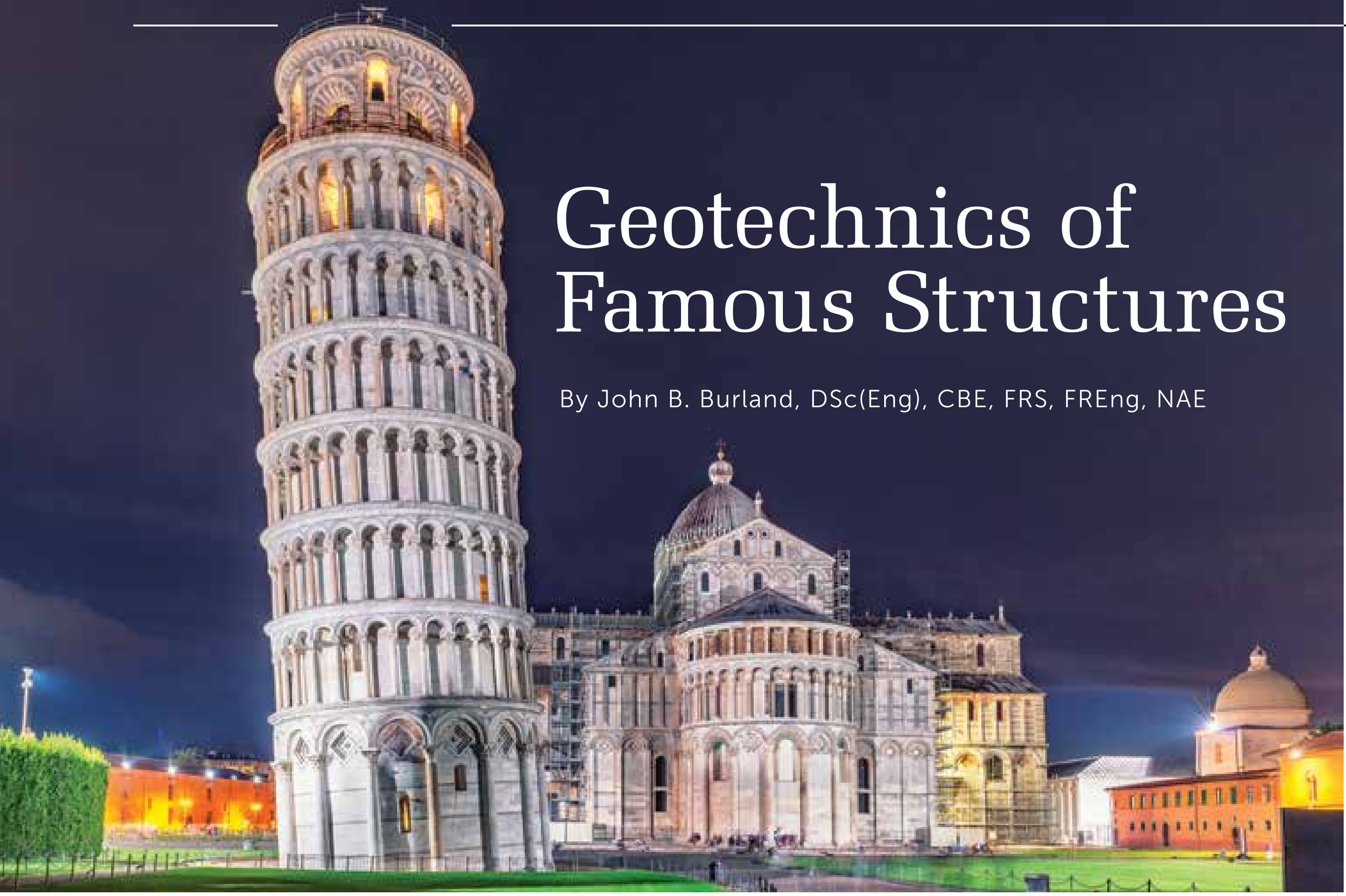
To make yourself heard and actively engaged with your audience, try to arrange for a "Lavalier-type" microphone at the podium. This device has a small microphone that attaches to clothing or hangs from a ribbon around your neck, together with a transmitter that goes in your pocket. A Lavalier-microphone is far preferable to a conventional microphone beause the latter tends to be positioned too far or close to the speaker's mouth, which distorts or lowers the volume. Regrettably, the introductory graphic shows I haven't always been successful in arranging for the right microphone! GS

JOHN DUNNICLIFF, PE, Dist.M.ASCE, is a geotechnical instrumentation consultant located in Bovey Tracey, Devon, UK. He can be reached at *john@dunnicliff.eclipse.co.uk*.

"Put it before them briefly so they will read it, clearly so they will appreciate it, picturesquely so that they will remember it and, above all, accurately so that they will be guided by its light."

— Joseph Pulitzer

// As I See It



Geotechnics of Famous Structures

By John B. Burland, DSc(Eng), CBE, FRS, FREng, NAE

I am delighted to have been invited to contribute a commentary for this issue of *GEOSTRATA* on the theme of *Geotechnics of Famous Structures*. Having been associated with the geotechnical aspects of a number of famous civil engineering projects, including the stabilisation of the Leaning Tower of Pisa and protective works for the Big Ben Clock Tower, I am keen to share some of the key lessons I have learned.

By definition, a famous structure is well known and inevitably attracts considerable public interest. Therefore, the ability to communicate with the public and the press is vital. These situations also provide a golden opportunity to highlight the excitement and challenges of engineering — something we engineers are often not very good at. Frequently it is the size of the structure or project that attracts considerable public interest — for example, a major tunnel. On large, complex projects, I've found that the responsibility for decision making during construction can become diffused, potentially leading to very dangerous consequences. Therefore, the two topics that immediately came into my mind in writing this commentary are *communication* and *clarity of responsibility*.

Communication

It has been my experience that the general public holds the view that engineering is an exact science and that everything can and should be calculated. As engineers, we sometimes reinforce that view, particularly with the advent of very powerful geotechnical computer programs. But, as we know, the real geotechnical world is not like that. The ground is seldom so well behaved and well defined that we can be confident in making accurate predictions of ground and ground-structure behaviour. This is particularly true when the construction involves processes such as grouting, tunnelling, and ground treatment.

The late Dr. Hugh Golder, an international soil mechanics icon, once wrote: "A design that relies for its success on a precise calculation is a bad design" — a saying that I treasure and pass on to my students. In geotechnical engineering, we seek robustness and resilience in our designs, and an ability to accommodate a degree of uncertainty in them. I believe that this is the real challenge of good geotechnical design.

In geotechnical engineering, we seek robustness and resilience in our designs, and an ability to accommodate a degree of uncertainty in them. I believe that this is the real challenge of good geotechnical design.

In dealing with the public, I've found that people generally respond well to being upfront about the challenges that a geotechnical project presents and how these are being tackled. I certainly found that this approach paid off when I talked to the press while the stabilisation works were being implemented at Pisa, communicating the very real challenges that this work presented.

By analogy, have you noticed how often the public responds to a sportsperson who faces and overcomes challenges? As a golfer, I used to ask myself why Arnold Palmer was such a crowd pleaser. Some golfers play like machines, but Palmer was different. When he got into trouble, he would play amazing shots to get himself out of it. Sports fans and the public relate to someone who faces and overcomes challenges! In general, the press and the public respond well to having the challenges of a project, and how they will be faced, explained — explanations of sophisticated calculations are a switch-off.

Clarity of Responsibility

I learned some very important lessons at Pisa. In September 1995, we undertook ground freezing as a preliminary step prior to installing some ground anchors on the northern side of the Tower, which leans to the south. The freezing gave rise to some ground movements that were not easy to control, and these caused the tower to move further southward. We had to abandon the operation. Inside our engineering team, the episode came to be known as "Black September."

Later we implemented a geotechnical process known as soil extraction, or underexcavation, that could be tightly controlled and rigorously monitored. Professor Carlo Viggiani, from the University of Naples, and I were given the responsibility for interpreting the monitoring results daily and specifying each extraction intervention. I often liken this to riding a bicycle by email! Over a period of two years, the inclination of the Tower was successfully reduced from 5.5 degrees to 5 degrees, which, with some additional measures, stabilised the Tower. The experience with the Pisa Tower and the Big Ben Clock Tower, together with direct experience in other major geotechnical projects, has made me realise how vital it is to have very clear and transparent lines of responsibility. Responsibility concentrates the mind wonderfully!

It is now becoming common practice to carefully monitor the behaviour of major geotechnical projects during construction. This growing practice has been enhanced by the huge advances that have been made with a wide variety of monitoring instruments and techniques. This development is providing excellent benefits, and is particularly important when the work involves one or more geotechnical processes that are largely dependent on human operator control. But the lingering issue that really concerns me is: Where does responsibility lie for interpreting the results, deciding when and what actions are needed, and ensuring that these actions are implemented?

Some years ago, I was involved in the design of a major urban underground metro scheme. The Owner proposed that responsibility for monitoring ground movements should lie with the contractor. This worried me a great deal. At a meeting with the Owner, I showed a picture of the Nicholl Highway collapse in Singapore and asked, "If this were to happen on your project, who do you think the press and the public would hold responsible?" The Owner accepted my suggestion to establish an independent organisation responsible for carrying out essential ground and building monitoring, interpreting the results, and conveying them to the contractor and the client team for decision and action, if necessary.

Too often I have been involved with large projects where extensive monitoring is carried out and the results processed. But the responsibility for interpreting the data and acting when trigger levels have been exceeded is often not clearly defined or understood. Frequently, the pressure of meeting project deadlines takes precedence over monitoring and the interpretation of the measurements. I am of the opinion that for famous and not-so-famous geotechnical projects, it is vitally important that the lines of responsibility for monitoring, interpretation, and responding appropriately be very clearly specified and understood by all parties involved. GS

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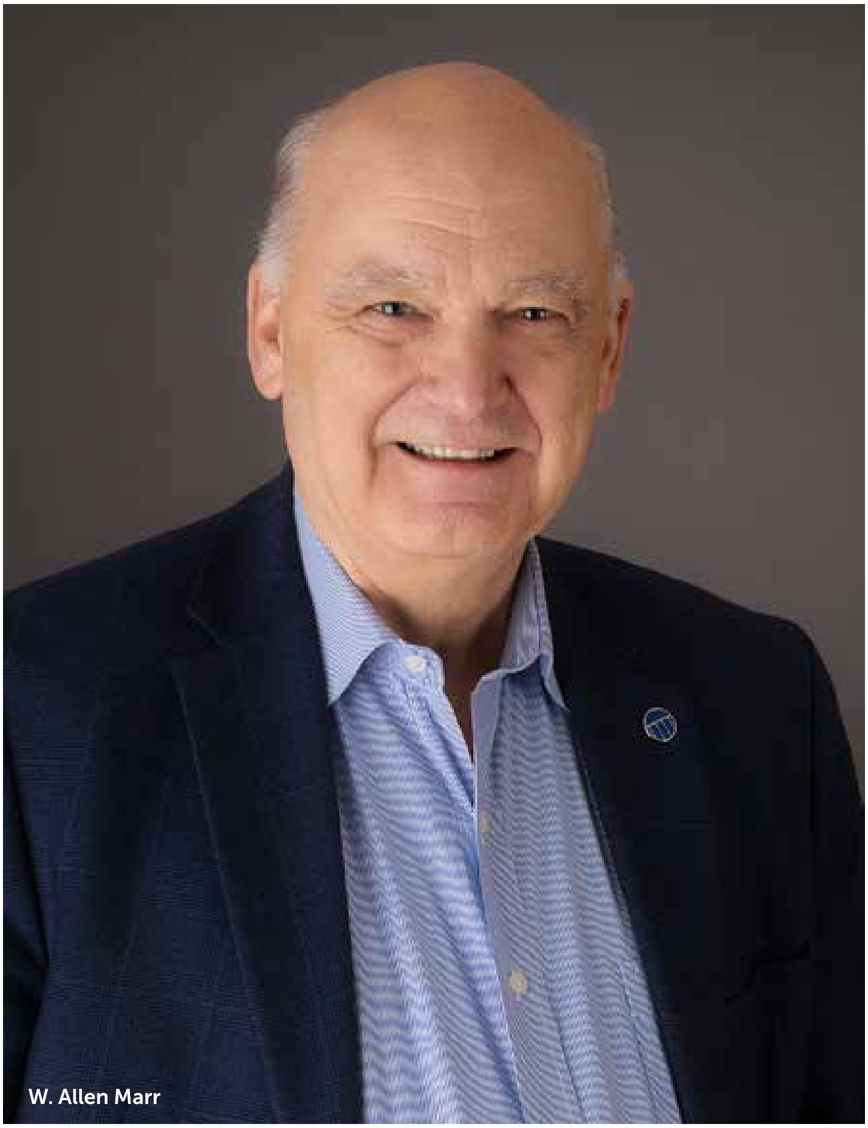
W. Allen Marr, PhD, PE, D.GE, NAE, F.ASCE

By Siavash Mahvelati, PhD, EIT, Arash Hosseini, and Alireza Kordjazi, EIT, S.M.ASCE


W. Allen Marr

With almost half a century of experience, Dr. Allen Marr is one of the most influential experts in the field of geotechnical engineering. He is the founder and CEO of GeoComp Corporation, a leading provider of geostructural design and performance monitoring services, where he leads a team of engineers to incorporate the latest engineering and scientific advances into geotechnical engineering practice.

Some of Marr's expertise includes field instrumentation for real-time monitoring, soil and rock testing, soil and rock improvement, and risk assessment and mitigation. He has applied his expertise and skills on major projects such as Boston's Central Artery Tunnel, subway construction in Los Angeles, and the new World Trade Center in New York City. He has also made great contributions to the geotechnical engineering literature. "Stress Path Method: Second Edition" and *A History of Progress: Selected U.S. Papers in Geotechnical Engineering* are just a few examples.

Due to his dedication to the advancement of geotechnical engineering, Marr has received numerous prestigious awards. He is the recipient of the Distinguished Alumnus of College of Engineering from the University of California at Davis. This was followed by his election to the National Academy of Engineering (NAE). He is also a past president of the Academy of Geo-Professionals, where he is currently a member of the Board of Trustees. In 2019, Marr was awarded the H. Bolton Seed Medal that was accompanied by his lecture on Geotechnical Risk and Judgment.

Q: Please tell us about your academic journey, the universities you attended, and major career milestones.

My father was a tunnel contractor, and we would move from one project to another. This meant changing schools, but also developed in me a great love for underground construction. I went from high school to UC Davis and enrolled in civil engineering. My passion right from the start seemed to be much more aligned with civil engineering. I did my four years at UC Davis, a great school with 10,000 students and a young civil-engineering faculty. I owe the UC Davis faculty a lot.

Approaching graduation, I felt a need for more education, so I applied to graduate schools. In 1970 I was accepted at MIT, when it arguably had the best geotechnical program in the country. For my master's, I worked with Professor John Christian, a leading theoretical researcher who was working on a NASA grant to develop finite-element programs to build structures on the moon. While finishing my master's, I was introduced to Professor William Lambe. I became interested in his work on ground-performance predictions, so I chose to work with him for my PhD studies. About halfway through, I became an instructor at MIT. I also started working with Lambe on his consulting projects, and by 1973, as a young

Marr with John Christian (l) and Demetrious Koutsoftas (r) at an ASCE event. All are members of the U.S. National Academy of Engineering.

> Today, many clients come to us because we do something we call "best practices." By this I mean using the best tools and the best knowledge that we can, within the constraints of the project.

Marr (r) with Dr. Philip Lambe (l) and Professor Tom Brandon (center) of Virginia Tech. The photo was taken during the post-failure investigation of New Orleans levees following Hurricane Katrina.

Marr (l) with Professor Pedricto Rocha (Catholic University of Rio de Janeiro) during inspection of the Pereira Passos Dam in Brazil.

engineer, I was working on projects in Japan, Venezuela, and Holland. By 1975, Lambe formed "T. William Lambe and Associates," and I was essentially the technical director of that group. That experience was a huge opportunity and wonderful training for me.

Q: What's special about geotechnical engineering?

The challenges; every project is different, each one bringing a new experience, a new learning opportunity, and a new set of people. I've always been fascinated by how, throughout my career, I've been so fortunate to meet and work with people from all different kinds of backgrounds. I've just found it really interesting. I've been working in geotechnical engineering for 50 years, and have never done the same thing twice.

Q: The influence of Professor Lambe and your father on your career is clear. Is there anyone else?

You got it right! My father and Professor Lambe made major impacts on me. Professor Whitman at MIT was also a very inspirational and intelligent man who taught me a lot about looking at different sides of the problems.

Q: You've made a significant effort to bring applied research into your practice. Which of these concepts has had the most influence on geotechnical engineering?

Three come to mind. First, Professor Lambe influenced me to focus on performance prediction to make rational decisions about design. Not just plugging numbers into an equation and doing standardized cookbook design using conservative engineering, but really trying to anticipate the behavior. That's a more interesting and challenging undertaking, so his training has served me really well all my life. Today, many clients come to us because we do something we call "best practices." By this I mean using the best tools and the best knowledge that we can, within the constraints of the project.

Marr (r) performs a site inspection at Naghlu Dam in Afghanistan.

We had almost no structural damage during the Big Dig, and that was a huge step forward. Today, every major tunneling project in urban areas requires real-time monitoring.

The second is instrumentation and performance monitoring in tunneling projects. When I started Geocomp, one thing we focused on was becoming more engaged in real-time performance monitoring. We implemented this approach during the Big Dig project in Boston in the mid-1990s. We went from situations where data wouldn't be available until days later and not be very helpful in monitoring tunneling operations, to producing data the same day and being able to give that feedback to the contractor. We had almost no structural damage during the Big Dig, and that was a huge step forward. Today, every major tunneling project in urban areas requires real-time monitoring. I think we had a big impact on that.

Third would be the whole area of geotechnical testing. Testing for mechanical properties like strength was dying in the U.S. in the early 1980s. It would take months to get some testing programs done. We got involved in building automated test equipment to make the process go faster. I believe we were the first to build a commercial device to do automated, incremental consolidation testing that reduced the required time from four weeks to one week. That was a big step forward, improved the quality of the test results, and brought life back to laboratory testing in the U.S. Then we started a commercial lab, GeoTesting Express, a name we selected to emphasize that we could do quality geotechnical testing *fast*. It's probably the most comprehensive soil- and rock-testing laboratory company in the U.S. today.

L to r: Allen Marr, Francisco Silva-Tulla, and Professor T. William Lambe investigating levee failures along the Inner Harbor Navigation Canal in New Orleans in 2011.

Marr with the planning committee for the Chinese International Geotechnical Conference for 2019. He was an invited keynoter on the topic "Using Performance Monitoring to Help Manage Risk for Infrastructure."

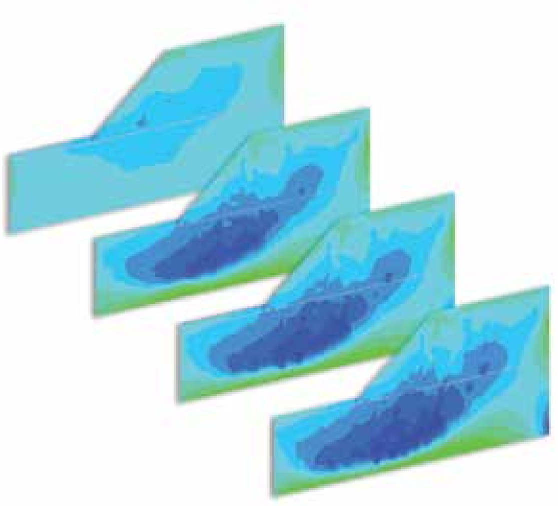
Marr (4th from right) with the AGP Board of Trustees at a planning meeting.

Q: Among your Geocomp projects, was there an extremely challenging one that forced you to learn a lesson the hard way?

Our work in Japan was a real challenge. It was for TONEN, a Japanese company that was then the third-largest oil products producer in Japan. It had built three major refineries on reclaimed lands in an area with very high seismicity.

Dr. Lambe was contacted in 1973 by the company's CEO to ask our help at a tank farm site that was subject to possible earthquake loading and liquefaction. Standard practice using some of the liquefaction methods would have said that you have to take down the whole site, redo all the foundations, and rebuild it, which would be extremely disruptive. And the risk was unclear. This was the time when risk analysis hadn't been developed that well. We knew that the whole problem was driven by how big a potential earthquake might be. The bigger the earthquake we try to design for, the bigger the cost and the more challenging it would be. We put together a team of experts, including Dr. Whitman, to quantify the risk. What's the probability of an earthquake of different sizes occurring, and for each of these what is the probable performance?

The first concern was what was the most serious failure consequence, and it turned out we had thought it would be damaging tanks and disrupting the refinery operations. But that wasn't it. It was totally unexpected that the bigger risk was spilling oil off-site into the Tokyo Bay. So we could have, in fact, gone in and done a lot of work to treat the foundations of the tank, but never actually solved the real problem. We asked ourselves what's the cheapest way to reduce the risk? It turned out to be a method that had never really been successfully done anywhere around the world — lowering the groundwater levels across the whole site. It was all done in the 1980s and early 1990s at three sites. I visited one site 1-1/2 years ago, and fortunately all was working great. The client loves the solution, and the sites survived



Excess pore pressure build up timelapse at 1, 10, 20, and 40 seconds the 2011 Tokohu earthquake without damage. There's been some liquefaction around the area, but our work seems to have stood the test of time.

Q: What must researchers consider to make the research applicable to practice?

I know it's very popular today to make research practical and to be entrepreneurial. But we don't need every researcher to be commercially focused. There's a very strong need for good fundamental research. The most important thing for a researcher is to have a clearly stated objective, a clear work plan, and dedication to stick to it. And maybe an ability to understand when something's not working, and being able to change course when necessary. These things are necessary so you can remind yourself as a researcher where you're trying to get to.

> Have confidence in yourself. Take on opportunities, but be sure to deliver. Be on time, on budget, and deliver a dependable work product. That's what I did and why I was mostly successful along the way."

Q What's missing in today's geotechnical engineering education that could help new graduates in their careers?

Learning more about judgment and its importance, how we make judgments, and how we improve our judgment abilities. I've hired a fair number of young college graduates, asked them all to watch Professor Peck videos, take good notes, and commit to do good work like he says. Peck says to have a clear purpose in mind, and take notes so you can keep on track.

It's so easy to sit down to do something, say you don't know much about this, decide to go to the Web, and four hours later you're off track, having actually forgotten the problem you were initially trying to solve. Staying focused is important so you can sort through all the information, which, regrettably, is mostly junk.

One thing I try to get our engineers to do before advanced numerical analysis is define the problem on paper. Don't even open the computer! First define the problem, inputs, and expected outcomes. And for consulting assignments, check with the client because they're going to pay the bills. Is this the problem you're really going to spend money on? Don't crank the computer right at the start… slow down! Be sure you're on the same page with the client. You and the client must agree on everything, even incidental stuff like what units to use. Once you've gone through all these steps, only then can you start using some of the fantastic computer tools that we have today. If you don't go through these steps, it's very easy to get lost in the iteration process, and that means time and money. And in the consulting world, money and time are short!

Q: What topics are not adequately emphasized, or perhaps overemphasized, in academia?

Mastery of fundamentals is crucial. Some academic programs tend to capture the latest industry trend at the expense of making sure students really get the basics of strength of materials and mechanics. I've had people come to work for me who cannot draw free-body diagrams or Mohr's circles! If you can't do that, you don't have a good understanding of the basics. So, when you get a complicated problem, you don't have the tools to support your analytical approach to think it through, step by step. I'd like to see more teaching in the undergraduate and graduate levels on what the civil engineering profession is all about. When I was teaching, we had many students who had been in civil engineering 6-7 years, but they didn't really know what it would be like when they graduated. Clearly, courses that teach critical thinking about data will become even more important.

Q: How will scientific and technological advances influence the geotechnical engineering profession over the next 10 years?

I see really exciting possibilities coming from all these tools that we have. When we get a chance to use them, it's a lot of fun, and we can do great work for our clients. Unfortunately, the commercial side of the business drives us to the lowest common denominator, where the budgets are tight.

The business of geotechnical engineering is too often commodity-driven, where it's "who can do the least work for the cheapest price?". It's a big contradiction that, frankly, I don't see being resolved. I think the future is cloudy, although it has a lot of bright aspects. I get concerned that the real world is a commodity business. The question is, what are all these tools going to do when they hit the reality of the world, constrained by the highly competitive environment?

Q: How have you encouraged students and young engineers to learn more about the origin and historical advancement of their profession?

First of all, learning the history of how things evolve is fascinating, and should be something people do when they can find some time. One of the best things to do is to get a copy of Don Taylor's textbook, *Fundamentals of Soil Mechanics*. Other tremendous sources are the papers and works of Terzaghi, Casagrande, Skempton, Bishop, and Lambe. Reading those papers tells the story of geotechnical engineering's evolution and helps readers develop a very strong appreciation for the field. I found it hard to locate some of the early works, so I assembled 75 papers in two volumes and re-published them (with permission) in *A History of Progress: Selected U.S. Papers in Geotechnical Engineering, GSP No. 118*. Unfortunately, ASCE put a big price tag on it, so it wasn't a big seller. I was greatly disappointed that it was not more readily available to students. I intend to write up my Seed Lecture from Geo-Congress 2019, primarily to make it available for students. I hope it will have a positive impact on them in developing good judgment skills.

Q: What closing remarks do you have?

Have confidence in yourself. Take on

L to r: Alireza Kordjazi, Arash Hosseini, Marr, and Siavash Mahvelati.

opportunities, but be sure to deliver. Be on time, on budget, and deliver a dependable work product. That's what I did and why I was mostly successful along the way. When I was 30 years old, I was involved in major projects around the world. That didn't happen because I was any different than others, with the exception of having my construction background. But I had learned the importance of doing what you say you'll do, being on time, and delivering good work. It's a winning approach to business and life.

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GEOTECHNICS OF FAMOUS STRUCTURES

Geotechnics of the Suez Canal Construction

150 Years Old, but Nearly Four Millennia in the Making

By Mamdouh Mostafa Hamza, PhD, M.ASCE

Construction of the Suez Canal created one of the most important waterways in the world, connecting the Mediterranean and Red Seas. Its construction from 1854 to 1869 created three cities, Port-Said, Ismailia, and Suez, and two main ports, Port-Said and Suez. But today's Suez Canal is not the first waterway to link these bodies of water.

Ancient Canal Construction and Operation

As long ago as the 19th century B.C., the Pharaoh Sesostris I dug a canal connecting the Nile River to the Red Sea. But building a canal in the middle of a desert requires constant maintenance and repair to keep the desert from smothering it. Lack of maintenance meant the canal wasn't always in the best working order; at times, it was abandoned because of siltation. Amazingly, however, this canal survived, in one form or another, for over 2,500 years because of interventions by:

Canal Builder	Reopened	Comment
Siti I	1310 B.C.	Engraving in Karnak Temple provides evidence that the canal remained in service for at least 600 years
Necho II	610 B.C.	Cleared/redug canal from Pelusiac Branch of Nile to Wadi Tumulat
Darius I	510 B.C.	Construction restarted, but was then discontinued because people feared Egypt would be flooded by sea water (the Red Sea was believed to be higher than the mainland)
Ptolemy II	285 B.C.	Canal completed by extending it from Bitter Lakes to Red Sea
The Romans	98 A.D.	Navigable for about a century
El-Moemeneen	640 A.D.	Reopened to transport wheat from Nile Valley to Mecca

It's likely that these earlier canals were only navigable during the seasons when the water level in the Nile River was high. Traces of these early canals were found both by Napoleon Bonaparte's surveyors during the French occupation at the end of the 18th century, and 55 years later by Ferdinand de Lesseps' engineers during their preliminary surveys.

19th-Century Canal Planning

Serious contemporary Suez Canal efforts date back to the days of the French expedition. In 1798, Napoleon Bonaparte, accompanied by an impressive body of French scientists and engineers, formed the "Institut d'Égypte" to study, document, and make recommendations about aspects of Egyptian life and culture. Among the modernization schemes was to reconstruct the ancient canal. Bonaparte appointed engineer Jacques-Marie Le Père to make a detailed preliminary survey.

The plan perpetuated a serious surveying error made 23 centuries earlier about the relative levels of the Red and Mediterranean Seas — the same error that would affect future thinking about the canal for the next 50 years. Le Père erroneously reported that the level of the Red Sea at high tide was 9 m above that of the Mediterranean Sea. Reasoning that a direct cut between the water bodies was impracticable, he concluded that a new canal must follow, more or less, the route of the old canal and join the Red Sea to the Mediterranean Sea via the Nile. (Note: A survey carried out in 1830 corrected the surveying error and proved that a sea-level canal was feasible. Later, in 1847, surveyors confirmed that the difference between the two seas was negligible, about 0.8 m.)

In 1840, Egyptian government engineer Linant Pasha directed publication of a design report on the proposed canal design whereby the canal would be constructed as a direct cut between the two seas. Assuming Le Père's survey about the relative levels of the Red and Mediterranean Seas was correct, he proposed a canal with locks and strong banks to prevent flooding. In 1847, three teams of engineers from the Société d'Études du Canal de Suez (Société) investigated the Gulf of Suez, the Bay of Pelusium, and the interior of the Isthmus. They recommended a route from Alexandria to Suez via the Nile, ignoring Pasha's direct-cut proposal.

In 1851, the Société supplied French diplomat Ferdinand de Lesseps (Figure 1) with information about the work of the group's investigations. They believed that de Lesseps would put his negotiating ability at the disposal of the Société, but de Lesseps disagreed with them on two fundamental points. Technically, de Lesseps was convinced that a canal scheme via the Nile was impracticable due to the ever-increasing size of ocean-going steamships that the canal would have to accommodate, and as a result a direct cut across the Isthmus was the only choice, following the recommendation of Linant Pasha's design. Politically, he seems to have realized that financial backing from the great European banks was unrealistic due to the known British opposition. De Lesseps' opportunity came in September 1854, when Abbas, the viceroy of Egypt, died and was succeeded by his uncle, Mohamed Sa'id, an old friend of de Lesseps.

Canal Profile

Topography, Morphology, and Geology

Figure 2 shows a diagram of simplified topography along the

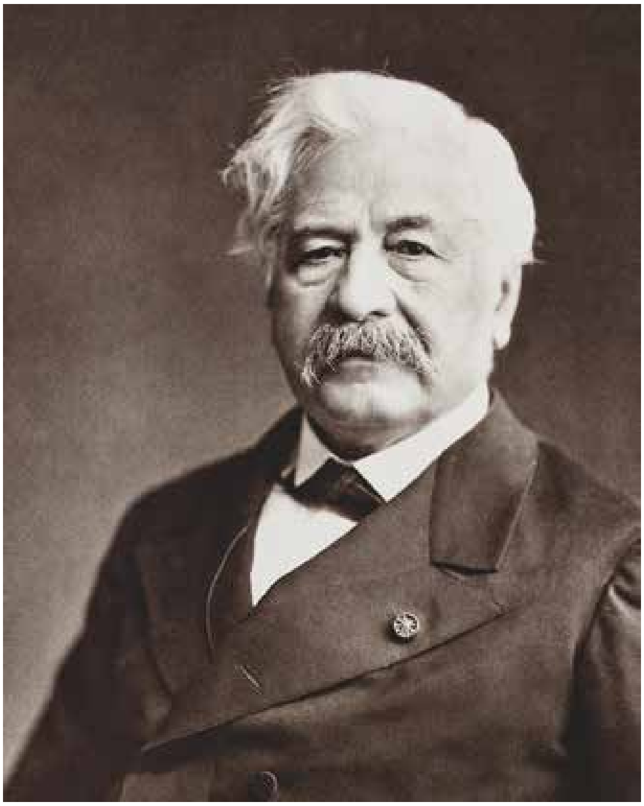

Figure 1. **Architect of the Suez, Ferdinand de Lesseps.**

canal route and an overlay of the design depth of the waterway. All along the course of the canal, there is a natural depression, the lowest portion of which is the basin of the lakes that had long been dry. At only three locations does the ground rise much above the level of the sea: Chaluf (10.7 m), Serapeum (11.3 m), and El Guisr (16.8 m).

Planning/Design-Phase Borings

The initial soil investigation was two boreholes by M. Lepere as part of the work done by the Egyptian commissioners. It was followed by 19 boreholes by de Lesseps' engineers along about 160 km of the planned canal alignment. Executed between 1854 and 1855, the 19 boreholes were advanced at locations that include the following:

- Roadstead of Suez
- Ridge separating Suez from the Bitter Lakes
- Basin of the Bitter Lakes
- Ridge of Serapeum
- Ridge of El Guisr
- Highest point of the Isthmus
- Lake Manzalah

The boring locations and their depths along the proposed canal alignment as they relate to the base of the canal are presented in Figure 3a. Figure 3b displays a similar profile, but instead shows the subsurface stratigraphy along the proposed canal alignment.

Construction-Phase Borings

During the construction, additional and confirmation boreholes were drilled at an average interval of 150 m. Sir John Hawkshaw, then president of the Institution of Civil Engineers, reviewed the soil investigation campaign and declared that borings at a spacing of 150 m would not offer a guarantee of ground conditions between them.

These borings showed that the subsoil conditions along the canal alignment consist principally of two kinds: hard clays, from the Suez to the Bitter Lakes to the south, and sand, from the Bitter Lakes to the Bay of Pelusium to the north. In general, the soil profile along the canal consists of two portions. The North portion from Lake Menezelah to about the middle is formed mainly of sand and soft clay, which is easy to excavate. The South half is mainly hard, clayey gravel. Near Serapeum, a layer of rock was found, which in one 73-m section increased suddenly from a few centimeters to a thickness of 2.1 m. Then, at the bottom of the Bitter Lakes, a 1.8-m-deep deposit of crystallized salts was found, which supports beliefs that the Red Sea had formerly flowed over this basin.

Canal Geometry

At opening, the canal's minimum cross-sectional breadth was 21.9 m for approximately 35 km. For the remaining 124 km of its length (i.e., 78 percent of the total), the width was double the minimum. The smaller dimensions were adopted to reduce excavation and construction cost. At its opening on November 17, 1869, the canal had been excavated to one of the following section geometries:

- Narrowest width: Width at surface – 60 m; width at bottom – 22 m; depth – 7.9 m; side slopes – 2H:1V, with one or more 3.0-m-wide horizontal benches, depending on channel depth.
- Widest width: Width at surface – 100 m; width at bottom – 22 m; depth – 7.9 m; side slopes at lower depths are 2H:1V, but 5H:1V at shallower depths connected by an 18-m-wide horizontal bench.

In 1863, Hawkshaw conducted a design review that resulted in flattening the canal slopes at El Guisr and Lake Menezelah because of the presence of very soft clay.

Geotechnical Engineering

Canal construction began in 1859 and ended in 1869. Figure 4 summarizes the many geotechnical challenges and obstacles engineers met along the canal's route during construction. And yet, more than 60 years before soil mechanics became a recognized discipline in civil engineering, the canal's engineers somehow dealt with problematic ground conditions that continue to challenge today's geotechnical engineers.

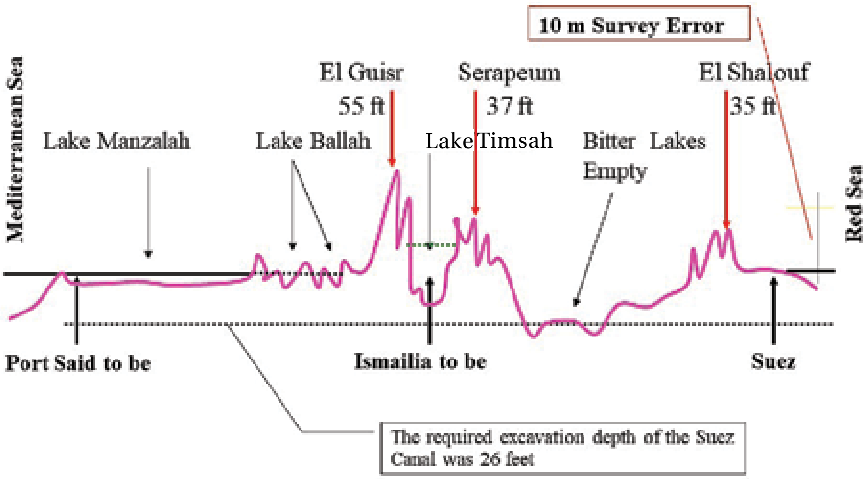

Figure 2. **Topography along the canal alignment.**

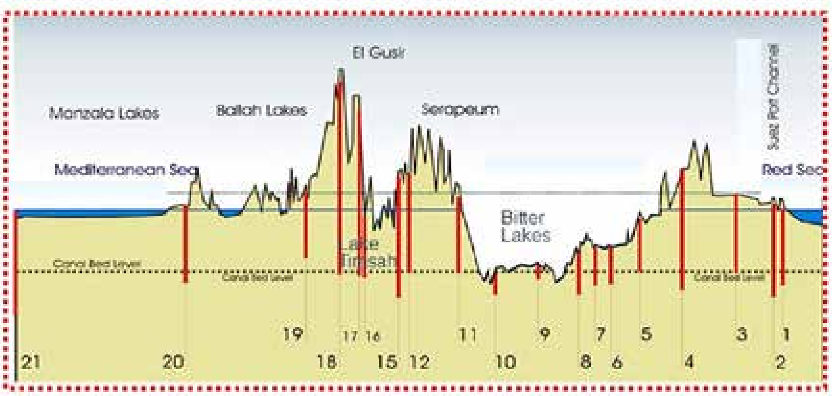

Figure 3a. **Borehole locations.**

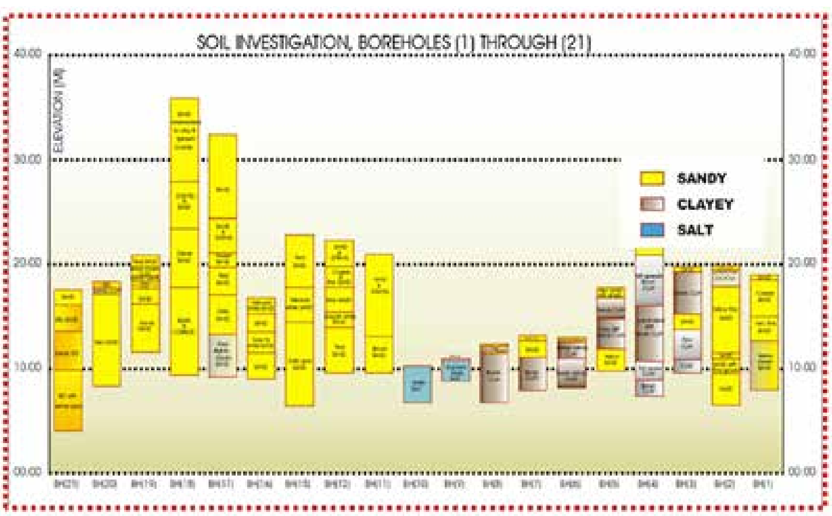

Figure 3b. **Soil profile along the Suez Canal alignment.**

Soft Clay Engineering

The 32-km distance from Port Said to Lake Menezaleh represented the first engineering challenge. This section was about 1.5 m deep, with a lake bottom consisting of mud resulting from the rich Nile deposits. The problems were: (1) excavation of the mud, (2) construction and stability of the canal banks on very weak soil, and (3) use of the excavated material for bank construction.

The unique solution was to use local fishermen to scoop up large masses, squeezing the water out by pressing them against their chests, then laying them in lumps one over the other. By doing this, a 3.7-m-wide channel was formed that allowed dredgers to work and operate below the mud to the excavated clay. The excavated mud and clay were dried in the sun before another layer was added. This process increased the soil's cohesion, which allowed the banks of soil to stand 1.8 m above water level. The sun cooperated and baked the whole thing into a firm, solid mass; so firm, in fact, that the banks could be used as roads even when heavy loads were transported.

Reliability of Soil Investigation at Serapeum

During his project site visit in 1863, Hawkshaw warned about the danger of encountering rock layers in this cut section between Lake Timsah and the Bitter Lakes, and declared that soundings at 150-m intervals were not a guarantee. This warning was prescient because after months of excavating nearly 6 million m^3 and more than 90 percent of the total estimated excavation, two rock layers were discovered at km 87 and 93.

Just 15 days before the canal's opening, engineers told de Lesseps that they had discovered a hard rock layer that had broken the buckets of the dredgers. De Lesseps rushed to the site, where rock was as much as 4.6 m above the proposed canal bottom, leaving only 2.4 m of water for navigation. Fearing a delay, de Lesseps shouted, "Go and get powder at Cairo. If we cannot blow up the rock, we will blow ourselves up!" At explosion, the rock layers at the two interfering locations were dislocated and broken to produce satisfactory results following excavation by dredgers.

Slope Stability of Sand at El Guisr
The El Guisr plateau is a series of sandy hills. At the time, it was feared that cutting through sand would cause the excavated slopes to fail and bury the workmen alive. Even though excavations were made to depths, side slopes of 2H:1V proved to be safe and stable.

Salt Band at Bitter Lakes
At the bottom of Bitter Lakes, an extraordinary band of salt — 11 km long by 8 km wide — was found. Fearing the salt would behave like rock, it was dissolved.

Drifting Sand
Knowing that sand storms can bury an object in a very short time, engineers feared that loose sand could fill up the canal. But this concern was not evident at the large natural depressions at Ballah and Timsah Lakes. At these sites, it was found that some banks formed by these whirlwinds protected the natural depressions from being buried. This observation suggested that artificial banks all along the canal would be needed to operate as a protective measure against filling the canal.

Using records from two nearby canal sites, however, Hawkshaw concluded that the sand lying adjacent to the canal was generally compacted and often covered with small gravel to prevent the sand from shifting. Again using information about drifting sand from the nearby canals, Hawkshaw estimated that drifting-sand annual infilling of the Suez Canal would be 118,000 m^3, which he considered insignificant.

Rock Engineering
During excavation for 15 km in Lake Ballah, an irregular, almost dry swamp, workers found the excavated soil was gypsum, which cracked and decomposed when used for embankments. Other material, a combination of mud and plaster, had to be carried from some distance away to be used for bank construction.

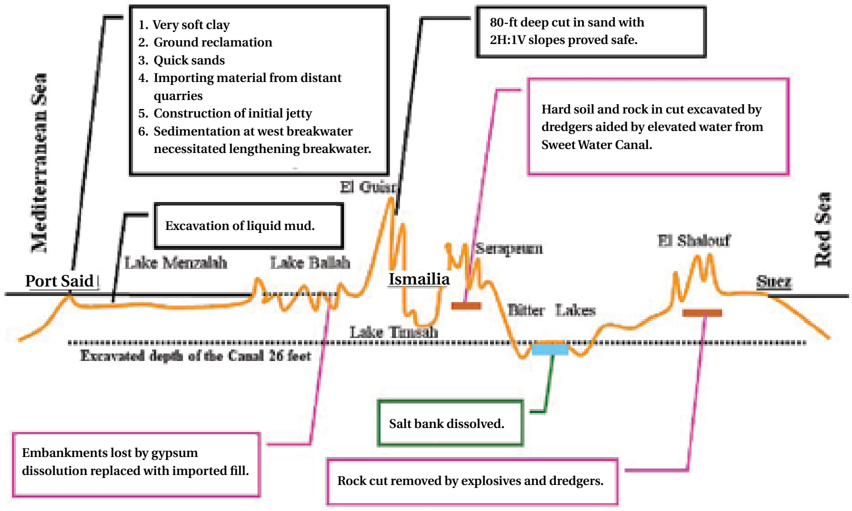

Figure 4. **Geotechnical and canal construction challenges.**

More than 60 years before soil mechanics became a recognized discipline in civil engineering, the canal's engineers somehow dealt with problematic ground conditions that continue to challenge today's geotechnical engineers.

In 1865, de Lesseps concluded that during the eight years they had been exploring and working the line, they had never encountered a single layer of rock, unless it had been very friable marl in the El Guisr cutting. He also confessed that a regular ledge of rock was encountered in the Chalouf cutting, but the engineers had made a short curve to avoid it. There was also, as already mentioned, the last-moment discovery of a mass of rock in the Chalouf cutting just before the canal's opening.

Dredging

Dredging Equipment
When difficult conditions were encountered during canal

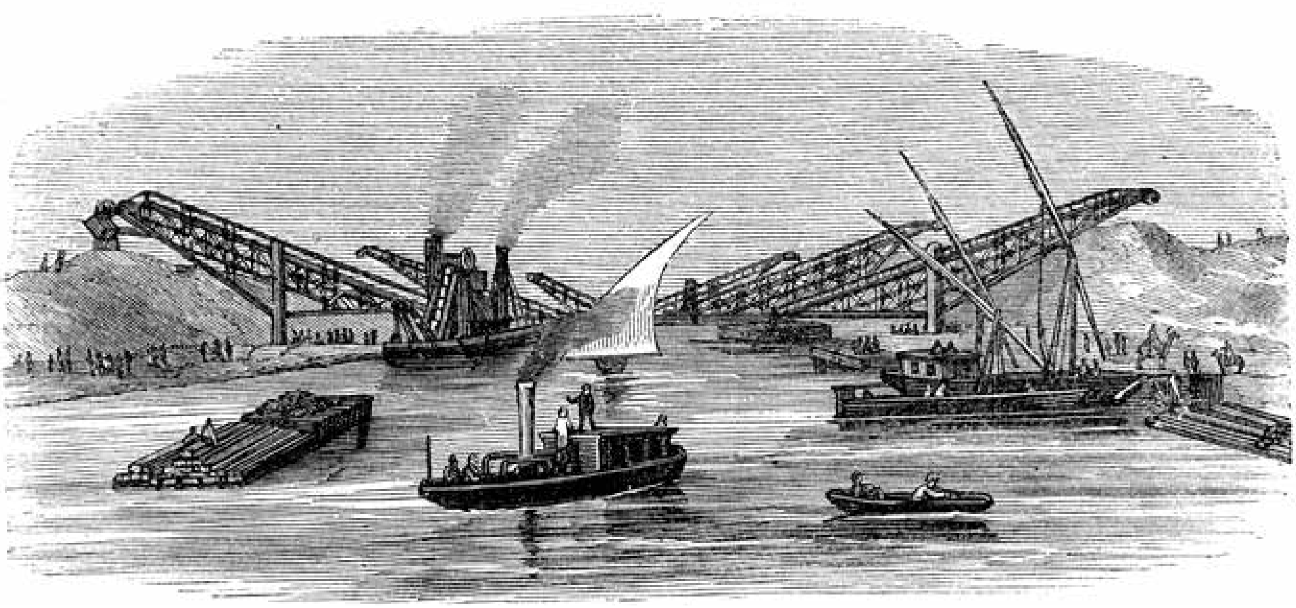

Figure 5. **Dredges at work.**

excavation, there were many opportunities for trying new solutions to overcome them. The contractors recognized that the dredging could only be achieved with the aid of machinery, so they devised extraordinary dredgers to tackle them (Figure 5). The dredgers ranged from 11 to 56 kW machines, with the largest dredgers 34 m in length, an 8.2-m beam, and 15-m-diameter drums above the waterline.

The dredging machine carried from 2,000 to 3,000 m^3/day, and with 60 such machines, succeeded in extracting as much as 2 million m^3 each month. The dredged materials were:

- Used to build embankments to laterally confine the canal
- Used to reclaim land or for making concrete blocks
- Conveyed onto large barges for deep water disposal some four or five miles out to sea

Cutting through the Serapeum Plateau

The cutting in the Serapeum plateau posed extraordinary difficulties that the contractor simply could not overcome. Manual labor failed to make a dent in the enormous cuttings. An intelligent idea was to excavate using dredgers, and to overcome the high-ground elevation problem by:

- Banking the canal at the point where it met the Mediterranean Sea
- Scooping out loose cuttings by manual labor
- Banking up at the end next to Bitter Lakes
- Turning the Fresh Water Canal into an excavation
- Moving the dredgers through the Maritime Canal from Port Said to Ismailia, and passing them through the locks into the Fresh Water Canal, which raised them 5.2 m above sea level
- Making a cross-cut from the Fresh Water Canal to the line of the works on the Maritime Canal, into which the machines were floated into their respective positions
- Conveying the dredged materials by lighters into large artificial lakes that had been formed for this special purpose in close proximity to the Maritime Canal

When these dredgers had reached the required depth, the connection with the Fresh Water Canal was closed, and the dam in the line of the Suez Canal was removed. In this way, the level of the Fresh Water Lake fell to sea level. The dredgers descending at the same time continued to dredge the canal to its final prescribed depth.

That portion of digging the canal presented the most ingenuous piece of engineering in the project.

The Suez Canal is considered the most useful project for humanity for the 19th century. The project was the driving force for the evaluation of the art of dredging. During the construction of the Suez Canal, two pioneering procedures took place: First, the BOT (Build–Operate-Transfer) mode of project was realized. Second, the first international arbitration in the field of construction ended with elimination of forced labor from the project concession.

The Suez Canal Today

As recently as five years ago, the canal was too narrow for free, two-way traffic, so ships would pass in convoys and use bypasses completed in 1980. To overcome this constraint, the Egyptian government oversaw an $8 billion expansion project that widened the Suez Canal from 61 m to 312 m for a distance of 34 km. In August 2014, Egypt selected a consortium to begin construction of a new canal section from km 60 to km 95, combined with expansion and deepening of another 37 km of the canal. Opened in August 2015, this expansion now allows navigation in both directions simultaneously in the 72-km-long central section of the canal. Today, an average of 50 ships navigate the canal daily, carrying more than 300 million tons of goods per year. GS

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THE TAJ MAHAL

Immortal and Ethereal Beauty in Stone

By Madhav R. Madhira, PhD, D.Sc, FNAE, and Venkata Abhishek Sakleshpur, S.M.ASCE

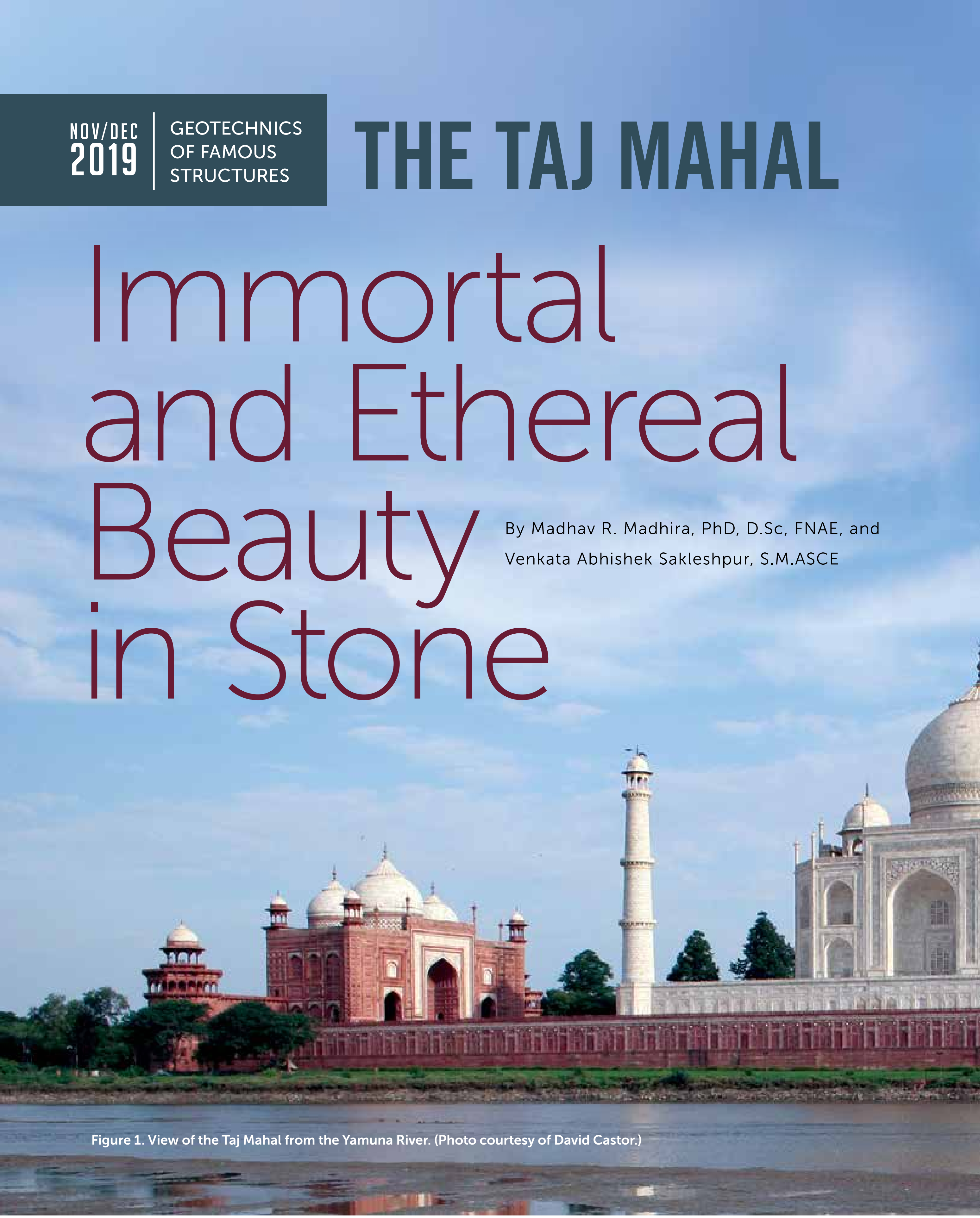


Figure 1. View of the Taj Mahal from the Yamuna River. (Photo courtesy of David Castor.)

The Taj Mahal, probably one of the most beautiful structures in the world, has withstood the vagaries of history and the environment. Lengthy tomes have been written on its beauty and the details of the above-ground structure, but very little information is available regarding the foundations or the geotechnical aspects of the site. This article compiles some available information gleaned from historical records and some recent studies.

Civil engineering structures are famous for a variety of reasons. For example, the Pyramids of Giza are admired for their huge size at the time of construction, the Great Wall of China for its tremendous length, and the Roman aqueducts for their seemingly delicate, yet durable, stone arches. In recent times, man has competed to build super-tall structures, such as Burj Khalifa (the world's tallest building), and other famous structures that came before it, such as Taipei 101, the Petronas Towers, and the Empire State Building. But the Taj Mahal (Figure 1) remains unsurpassed as a beauty set in stone that no other structure comes close to, despite the distinct technological advantages available in the 21st Century.

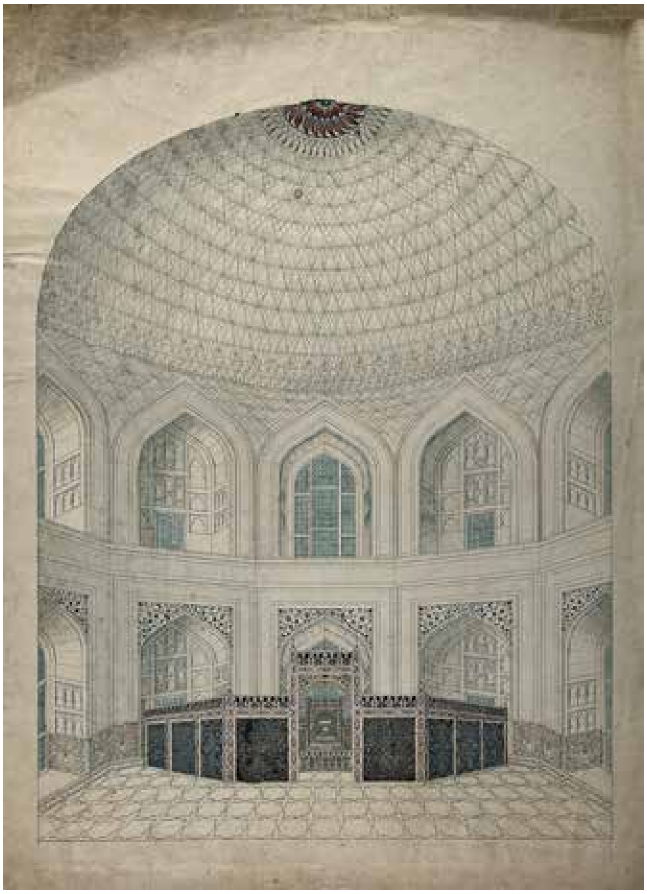


Figure 2. **Interior view in Taj Mahal of vaulted dome over the tombs of Shah Jahan and Mumtaz.**

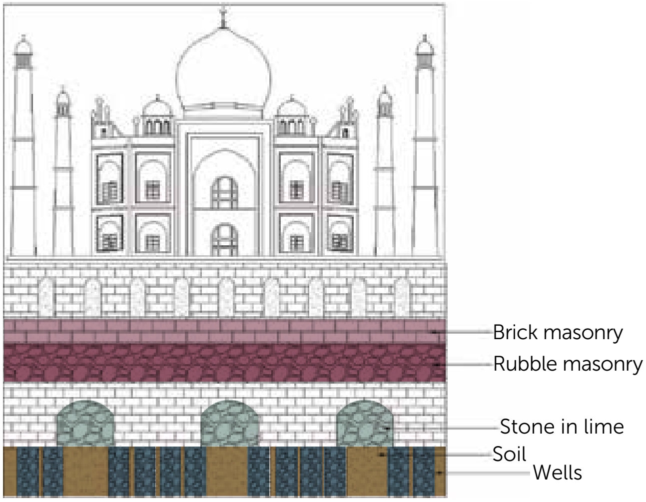


Figure 3. **Conceptual view of the Taj Mahal foundation (Sharma, et al., 2018). (Graphic courtesy of ICE Publishing.)**

The Taj Mahal is located on the south bank of the Yamuna River in the city of Agra in the state of Uttar Pradesh, India. The mausoleum was constructed with translucent white marble in memory of Mumtaz Mahal, second wife of Mughal Emperor Shah Jahan, who ruled for 30 years from 1628 to 1658. Mumtaz Mahal died in 1631, and the monument was commissioned by Shah Jahan a year later in 1632; a major part of it was completed by 1643. The entire complex is built over an area of 17 hectares and includes, apart from the mausoleum, a mosque, a guest house, gardens, and a crenellated wall on three sides. Apart from Mumtaz Mahal, both Shah Jahan and the builder of the complex are also buried there (Figure 2). The cost of construction was 32 million rupees (≈ \$0.5 million); in 2019, the same structure would be about \$1 billion.

The base platform of the mausoleum is 95.5 m^2, and the main structure housing the tombs is a square with chamfered corners (effectively making an octagon). The width of the main structure through its center is 55 m. Four, 40-m-tall minarets, each facing the chamfers, frame the tomb and provide immeasurable beauty to the 74.4-m-high mausoleum. A spectacular centerpiece feature of the mausoleum is the 35-m-high dome that rests on a 7-m-high cylinder. The massive structure is estimated to transfer an enormous load of about 7,000 MN to its foundations. The minarets were built slightly outside the plinth and were designed in such a way that they would fall away from the mausoleum should a catastrophe occur. The garden complex, called Charbagh, covers a square area 300 m on each side and has 16 sunken flower beds.

Site Development

The Yamuna River is located immediately north of the complex. To protect the complex from floods and subsurface seepage, an area of 1.3 hectares was excavated to a depth of about 50 m and backfilled with stone, bricks, mortar, and fine-grained soil. A 15-km-long earthen ramp was constructed to transport construction materials to the site. Two spur dikes were constructed upstream of the complex to protect the structure from scour. The dikes seem to have worked well for over 350 years to protect the Taj Mahal from the ravages of the Yamuna River.

Foundations

Limited information is available regarding the type of foundation used to support the Taj Mahal. The remains of some structures, believed to be about the same age as the Taj Mahal, can be found on the opposite side of the river bank and feature a "well" type of foundation, a common practice in India — made of bricks and lime mortar filled with rubble and mortar. Professor Alfred Jumikis made the earliest mention about the foundations of the Taj Mahal in 1962, when he stated that cylindrical caissons were sunk at close intervals to serve as the foundations, and that the terrace and the main structure rest on a strong and stiff masonry raft, and bear on stiff subgrade soils. Consequently, settlements have been negligible, and the minarets continue to maintain their original profiles (i.e., verticality).

The Taj Mahal foundations (Figure 3) are wells sunk at close intervals, over which the supporting platform, consisting of brick arches/vaults in lime mortar, was constructed. Based on limited historical and archeological data, the base of the well-type foundations are estimated to be located at a depth of 15 m below the ground surface. Thus, the foundations bear on a dense sand stratum located below the estimated maximum scour depth corresponding to the maximum flood discharge of the Yamuna River. The thick masonry platform functions as a semi-rigid raft and distributes the load from the Taj Mahal over a wider area, thus reducing the net stress transferred to the bearing stratum.

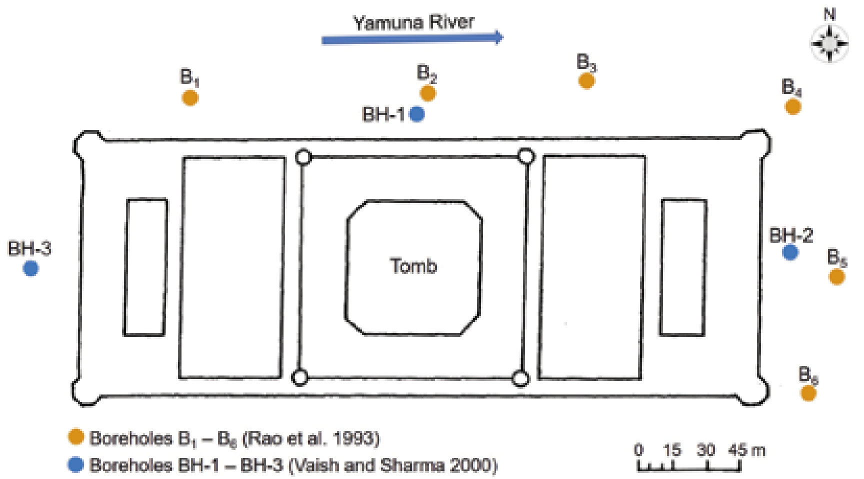
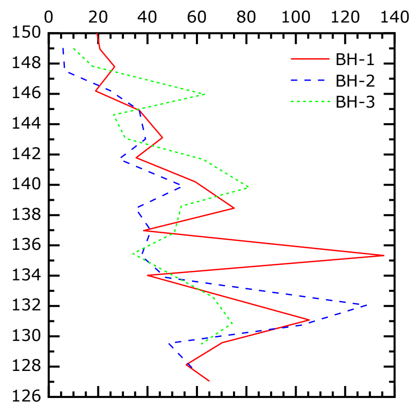


Figure 4. Plan of borings near Taj Mahal (redrawn from Rao, et al. (1993) and Vaish and Sharma (2000).

Reduced Level (m)		Nature of Soil Strata
From	To	
149	133	Clay of low to intermediate compressibility (CL-CI) — Stratum 1
133	124	Non-plastic sand to silty sand (SP-SM) — Stratum 2
124	107	Clay of intermediate compressibility (CI) — Stratum 3



Groundwater level located at approximately 4-5 m below the ground surface.

Figure 5. Generalized soil profile at Taj Mahal. Note: SPT profile redrawn from Vaish and Sharma (2000).

Geotechnical Characterizations

Before the early 1980s, there were no historical records of the subsurface conditions at the site. Since then, explorations have been conducted around the perimeter of the Taj Mahal. These explorations show that the subsurface comprises an alluvial soil profile, typical for the region, consisting of silty clay and sand layers that include kankar nodules.

Over more recent years, a total of nine borings have reportedly been advanced along the north, east, and west sides of the Taj Mahal at the approximate locations shown in Figure 4. Rao, et al. (1993) presented soil profiles obtained from six boreholes (B_1-B_6) drilled along the periphery and away from the plinth of the Taj Mahal to depths of about 40 m. Four boreholes (B_1 to B_4) are located between the Taj Mahal and the Yamuna River, whereas boreholes B_5 and B_6 lie to the east of the Taj Mahal. In 2000, additional borings were advanced to support ground-probing radar investigations of the foundations and other subsurface features at the Taj Mahal. Those investigations included standard penetration tests (SPTs) to depths of about 26 m on the north, east, and west sides of the Taj Mahal (labeled borings BH-1, BH-2, and BH-3 in Figure 4).The depth of the groundwater table ranged from 4–5 m below the ground surface when the borings were advanced.

The soil profile corresponding to boreholes B_1 to B_4 along the riverfront consists of 12-16 m of clay of low to intermediate plasticity, above 7-13 m of nonplastic, poorly graded sand to silty sand. Below this layer lies a layer of clay of intermediate plasticity, which extends down to the borehole termination depth. A similar soil profile exists on the east side of the monument, but with layers of slightly different thicknesses due to spatial variability. Figure 5 presents a generalized soil profile based on the logs obtained from the borings. The SPT N-values increase linearly with depth from about 10-20 blows/30 cm (i.e., blows/ft) in the top 5 m, to about 70-100 blows/30 cm at a depth of 20 m below the ground surface. Based on the blow counts, the substrata are considered very competent, generally low-compressibility soils, attesting to the fact that the upper silty clay layer is generally stiff and the sand stratum is dense.

Table 1 summarizes the geotechnical material properties of the soil layers at the Taj Mahal site from laboratory testing of soil samples collected from boreholes B_1 to B_6. Unit weights are fairly high, approximately 20 kN/m^3, and water contents are correspondingly relatively low, ranging from 19-25 percent. The undrained shear strength of the clay layers, based on unconfined compression test results, ranges from 45-50 kPa, whereas the angle of shearing resistance of the sandy material, based on triaxial compression testing, is 42°. The modulus of elasticity of the two lower layers ranges from 50-55 MPa. The hydraulic conductivities of the upper fine-grained layer and the intermediate coarse-grained layer are of the order of 10^{-5} and 10^{-3} cm/s, respectively, whereas the lower medium stiff

Figure 6. **The Taj Mahal is located near a bend in the Yamuna River that causes erosion along the monument's north side.**

Figure 7. **Garbage piled up along the polluted banks of the Yamuna River.**

clay layer is relatively impervious, with a hydraulic conductivity of about 10^{-6} cm/s.

Significance of the Kankar Nodules

The layers in the top 18-20 m of the soil profile have kankar nodules within them. Kankar nodules form due to the precipitation of cementing agents, such as calcium carbonate and sodium chlorate, around soil particles as groundwater levels drop during the dry season. As a result, the soil particles are cemented/bonded and become very hard. The fact that these nodules exist up to depths of 20 m suggests that groundwater levels must have been lower than that depth in the past.

Alternating cycles of wetting and drying due to seasonal fluctuation of the groundwater table and changes of temperature introduce capillary forces in the soil. The net effect is a gain in strength and a reduction in compressibility of the soil due to the phenomenon of desiccation or pseudo-overconsolidation. The upper strata of the Taj Mahal site may have become pseudo-overconsolidated over time, thus precluding the Taj Mahal from damaging total and differential settlements.

Trouble May Be Lurking

While the Taj Mahal still retains its ethereal beauty thanks to the stable ground conditions, the seemingly strong foundations that bear its weight, and the materials and skills employed by the builders in creating such an iconic structure, environmental conditions could pose future dangers. As mentioned before, the Taj Mahal is located close to the point where the Yamuna River makes a sharp bend away from the monument (Figure 6). The photo clearly shows ongoing erosion along the north side of the monument, as evidenced by the resedimention of the river's bed load on the inside bend of the river. Erosion has been resisted by the dikes and modified ground around the Taj Mahal's foundations, but this process will need to be monitored closely and protective actions taken when conditions warrant.

Another environmental concern is pollution (Figure 7). Unfortunately, Agra, where the Taj Mahal is located, is rated as one of the most polluted cities in India. As the region's population continues to grow, many cities in the Indo-Gangetic plains are becoming increasingly contaminated with solid and liquid industrial and municipal wastes, which are sometimes dumped directly into streams and rivers, including the Yamuna River. The problem is complex because of social, economic, and political issues and aspects. But with efforts by India's government and several technical institutes studying

Property	Layer 1 (CL–CI)	Layer 2 (SP–SM)	Layer 3 (CI)
Unit weight (kN/m^3)	19.8	20.0	20.2
Water content (%)	25.0	19.0	23.4
Specific gravity (—)	2.65	2.65	2.67
Undrained shear strength (kPa)	45	—	50
Angle of shearing resistance (°)	—	42	—
Modulus of elasticity (MPa)	—	55	50
Poisson's ratio (—)	—	0.25	0.40
Hydraulic conductivity (cm/s)	2.0×10^{-5}	2.0×10^{-3}	1.5×10^{-6}

Table 1. Geotechnical material properties of soil layers at the Taj Mahal Site (after Rao et al., 1993).

these problems, the issues are being addressed and will hopefully be resolved in the near future.

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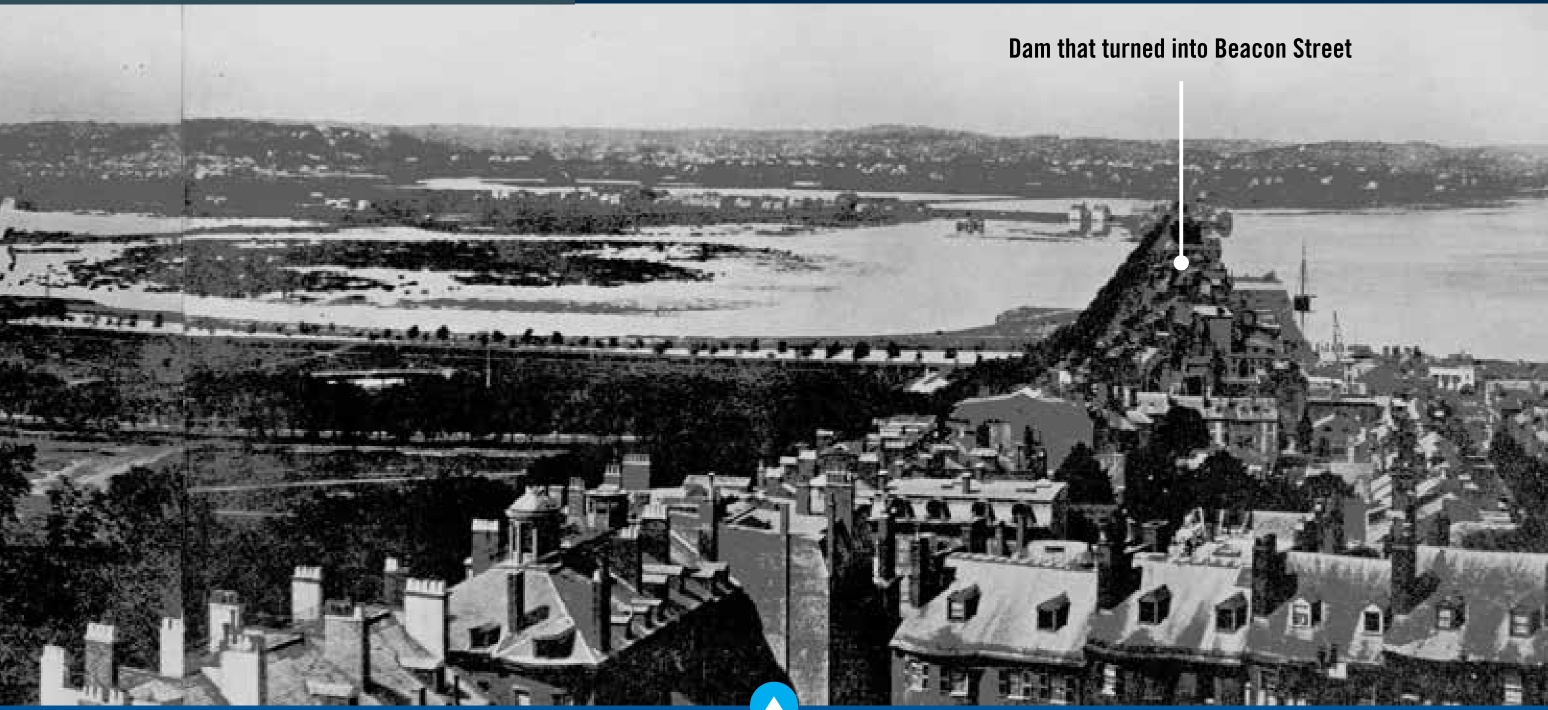
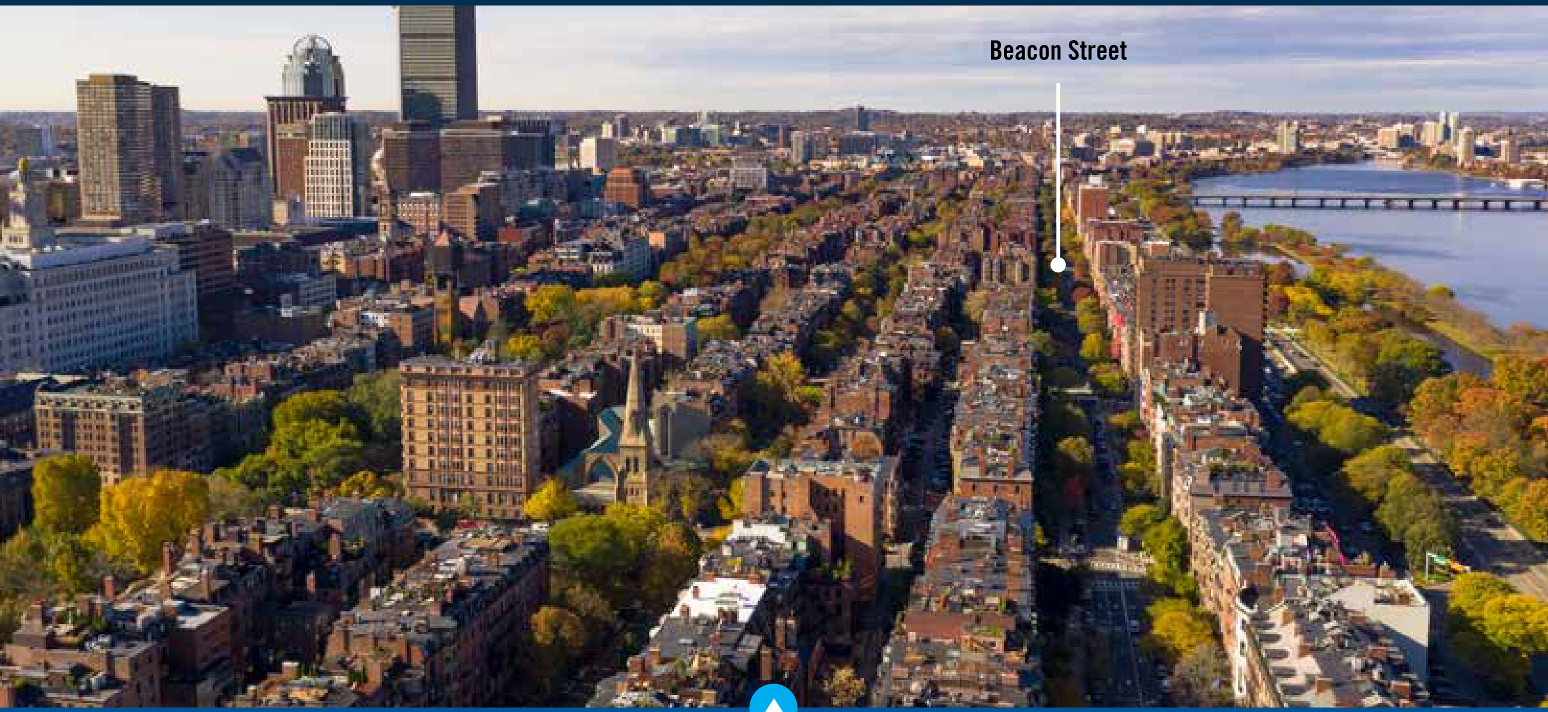


Boston Public Library

1857

WHAT LURKS



PRESENT DAY

The Geotechnical Intrigue of Boston's Back Bay

By Jim Lambrechts, PE, M.ASCE

BELOW

In 1858, the great filling of Back Bay began. Completed in about 20 years, it led to nearly 100 city blocks of iconic 4- and 5-story brick rowhouses. In the past 60 years, about 50 high-rise buildings have sprouted along the "spine" of Back Bay. No matter the size, all have had to accommodate the geotechnical intrigue of Boston's Back Bay.

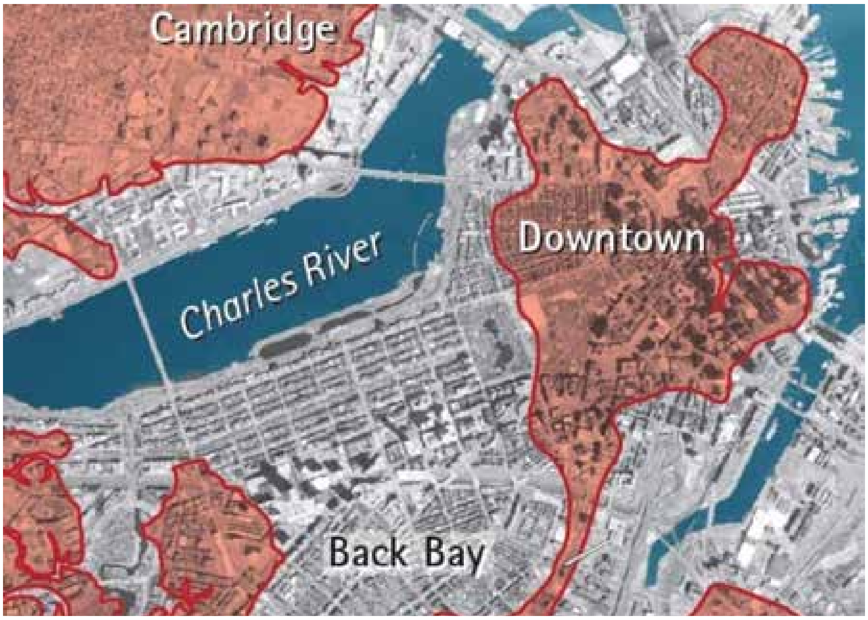


Figure 1. Colonial Boston was small, surrounded by water. (Courtesy of Weiskel, Lora, and Smieszek, USGS Circular 1280, 2005.)

The more than 700 people who set sail from England in 1630 to found Boston had no idea that their choice of location would be so influenced by geologic events that began nearly 600 million years earlier. Back then, a long, rather narrow volcanic island was depositing sediments in a long trough off the coast of present-day northwest Africa, when both were near the South Pole. The settlers were simply in search of a new land that would provide the essentials: fresh water, a workable harbor, and land that was defensible against invaders. The hills and unique geologic setting of Boston offered all three. When Boston was founded, Back Bay was no more than a swamp, mostly underwater at high tide (Figure 1). Two hundred years later, however, the Back Bay would have a great deal to do with the continuation of Boston as the major city in Massachusetts.

Bedrock Origin – Making the Boston Basin

Stepping back in time about 600 million years, sediments were being eroded from the mountains of a more than 600-mile-long volcanic island. These sediments would turn into the Roxbury Conglomerate (coarse sediments left largely above water) and the Cambridge Argillite (finer sediments deposited underwater) of today's Boston Basin. Plate tectonics then moved the island across the vast ocean to collide with the continent called Laurentia, the core of North America. Together, these units formed the bedrock of eastern Massachusetts and elsewhere. Through tectonic movement processes, igneous intrusions have occurred — some as massive volcanoes and granite batholiths, and others as narrow basalt dikes pushing through the already existing bedrock.

Boston's present-day bedrock surface reflects the resistant nature of the granite and metamorphic rocks that surround the Boston Basin. The conglomerate is also fairly strong, and stands prominently as hills next to its lifelong neighbor, the more readily erodible argillite, which has seen valleys eroded to depths of more than 200 ft. It's the presence of this easily weathered and erodible argillite that has given Boston and the Back Bay its geotechnical intrigue.

Glaciers and Boston Blue Clay

Nature's great bulldozer essentially scraped the New England bedrock landscape bare within the last two million years, and provided a new layering of soils for our geotechnical amusement. Over a period of about 3,000 years, the glacial till, outwash, rock-flour sediments (i.e., blue clay), more outwash, lacustrine, and alluvium were deposited. Glacial filling in Boston began about 14,500 years ago, with a later episode of glacial re-advance that bulldozed up hills of the original peninsula and provided fresh-water-bearing strata to attract the colonists of 1630.

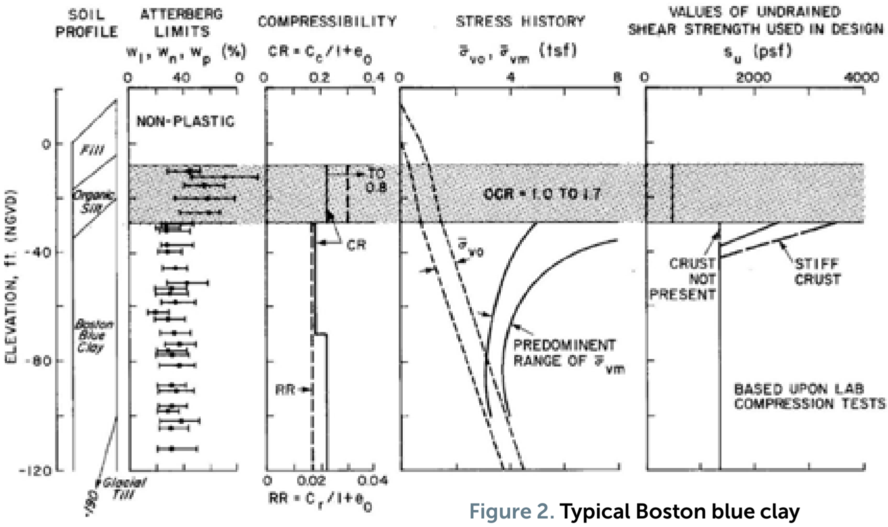


Figure 2. **Typical Boston blue clay properties across Back Bay.**

Blue clay was deposited in a marine environment, filling the deep valleys previously carved into the soft argillite by streams and further deepened by the glaciers. In some areas in and around the Back Bay, the clay is nearly 200 ft thick, but it's more usual thickness is in the 50-80 ft range.

Owing to its marine deposition, numerous small shells are often found in samples of the clay. It's not unusual to find a cobble or boulder embedded somewhere in it, a remnant stone dropped from ice rafting. On one occasion early in my career, it appeared that a glacial till high had been discovered when, after about 60 ft of blue clay, a 10- to 20-ft thickness of dense glacial till was encountered in a number of preliminary test borings over more than a 2-block-long area. Upon drilling the design-phase borings, another 10 to 20 ft of blue clay was discovered below this upper "fake" till. The hoped-for "shorter" piles then had to become exceptionally long to reach firm end bearing on the real till or bedrock.

Boston's blue clay was exposed to air when glacial re-advance again lowered sea level. Weathering, desiccation, and freeze-drying caused the blue clay to develop a stiff, yellow crust in the top 5 to 10 ft, with OCR values of 5 to 10 and N-values commonly greater than 20 blows/ft. N-values decrease with depth, and 40 to 60 ft into the clay, single digit to WOR N-values are typical. Consolidation tests show the precipitous decline in maximum past pressure, such as those shown in Figure 2 from tests made along a mile-long length of a subway alignment across part of Back Bay. But throughout its depth, some minor overconsolidation is present in the blue clay; how much is part of the geotechnical intrigue.

Making Land in the Back Bay

By 1800, Bostonians recognized they needed more land. As ships required deeper anchorage berths, harbor front was filled, and longer wharfs were constructed with soil taken from the hills. The 1630s Mill Pond was filled in because silt had accumulated, rendering it no longer effective in harnessing tidal power. However, developers saw a chance to make a new tidal pond west of the Boston peninsula by enclosing the Back Bay and part of the Charles River estuary. By 1821, the tidal Back Bay was harnessed to become a huge Mill Pond system as seen in the 1857 photo on the first page of this article. The mile-long, 50-ft-wide earth fill dam with granite block walls eventually became today's Beacon Street.

By the mid-1830s, the Mill Pond system was obsolete with the advent of steam power. The new railroads entering Boston necessitated that engineers construct long embankments that created isolated lagoons; these became stagnant and then polluted with sewer outfalls and waste dumping. The need to expand Boston's land area and eliminate the lagoons led to a massive, 30-year-long land-filling project that would create the area now known as Boston's Back Bay and the adjacent Fenway area.

Granular fill was imported from glacial hills more than 9 miles away by three, 35-car trains, sometimes working around the clock. Steam shovels loaded the trains from the sand and gravel hills, and then the train cars were side-dumped to unload the fill over the mud flats. Horse-drawn spreaders then distributed the fill. A regular planned grid of streets was filled up 5 ft higher than house building lots. The 10- to 20-ft thickness of fill caused as much as 3 ft of compression of the organic silt stratum over the following two decades, along with some compression of the blue clay. Some secondary compression continues today, at about 1 in. every 20 to 40 years.

Early Foundations – Only One "Game" in Town

Building development quickly followed the filling, as illustrated in Figure 3. Four- to five-story-tall brick rowhouses were constructed on wood pile foundations driven by drop hammer 25 to 40 ft through the new fill and organic silt strata to substantial end resistance on the stiff clay crust or outwash sand above the blue clay. Granite blocks were used as pile caps, which limited pile spacing. Timber piles were used to support more than 2,000 buildings constructed throughout Back Bay in its first 30 years. Under the famous Trinity Church in Copley Square, 700 wood piles were reportedly used to support each of the church's four massive stone pillars, with about 4,500 piles required for the entire church.

Engineers knew that to keep wood piles preserved, their tops had to be submerged. Top-of-pile elevation was generally slightly below mean sea level, or at about the average level of the then-tidal Charles River.

Figure 3. **Development quickly followed Back Bay land filling. (From the collection of Edmund Johnson of Haley & Aldrich, received 1995.)**

In 1929, while investigating the cause of cracking and settlement of the Boston Public Library building in Copley Square, severely rotted tops of wood piles were found in fill that was no longer saturated. One-third of the massive library needed the tops of its wood piles repaired.

In 1929, while investigating the cause of cracking and settlement of the Boston Public Library building in Copley Square, severely rotted tops of wood piles were found in fill that was no longer saturated. One-third of the massive library needed the tops of its wood piles repaired. A major inquiry determined the cause of groundwater lowering to be leaks into the St. James Avenue sewer, because groundwater levels quickly rose when it was plugged and filled. In response, more than 700 observation wells were installed in the 1930s throughout Back Bay and other filled-land areas of Boston, and monitored through 1940 to determine groundwater levels. Unfortunately, no records exist as to the actions taken when or where groundwater was found to be below commonly used top of pile El. 5, and the program's funding from the depression-era Works Progress Administration (WPA) ended.

In the 1980s, 21 contiguous row-houses at the edge of Back Bay near the Charles River were found to have rotted wood pile tops, and the issue of lowered groundwater again made headlines. The cause was eventually determined to be a change in the manner of operation of a nearby 8-ft-diameter combined sewer overflow (CSO) collection conduit that had been made necessary by the construction of the new Charles River Dam over a half-mile away. Today's Boston Groundwater Trust is a result of the 1980s problems, with an active program to monitor and report groundwater levels in over 800 observation wells, and to actively pursue remedy when low groundwater levels occur. Old, leaking sewers are often found to be the cause, and the Boston Water and Sewer Commission aggressively acts to find the leaks and implement repairs. More geotechnical intrigue.

A Wide Choice of Foundations over the Past Century

The use of concrete and steel for foundations at the turn of the last century opened a new window on foundation design and construction. The single focus on wood piles ended, although wood pile use continued into the later 20th century. The wide variety of different foundations used in Back Bay is illustrated in Figure 4.

Hand-dug caissons were adopted early on, with 3-ft-diameter shafts and expanded belled bases to make use of higher bearing capacity afforded by the crust of Boston's blue clay. Concrete frame buildings of 10- to 12-stories were constructed using such foundation systems with 4 to 5 ton/ft^2 allowable bearing pressures supporting 6- to 8-ft-diameter caisson bells. Eventually, machines took over the bulk of the drilling process, but "sand hog" workers still had to manually clean the bearing surface for the geotechnical field representative to inspect and verify clay bearing capacity.

The "floating" foundation came about in the 1930s with the construction of the 12-story New England Mutual Life building, which had a basement excavation depth great enough to relieve the clay of a load greater than the new building would apply. This foundation was a triumph for modern soil mechanics, with significant involvement by Arthur Casagrande.

The 30-story Hancock Clarendon Building was built in 1946. The first true "high-rise" in Back Bay, it is notable today for its lighted mast, which indicates approaching weather. Here was the first use of deep end-bearing steel H-piles, driven to glacial till or argillite bedrock. Just 14 years later, redevelopment of a huge railroad yard in the middle of Back Bay began to produce the now iconic Prudential Center. A variety of foundation systems was used. The 52-story main tower is founded on 30-in.-diameter, concrete-filled shafts drilled to a depth of 200 ft to penetrate 30 ft into the argillite bedrock. Other foundation types used for Prudential Center buildings have included deep concrete filled-pipe piles, precast-concrete piles, and drilled shafts. Pressure injected footings (PIFs) and wood piles extend to the outwash sand above the blue clay to support lightly loaded stores and the two-level parking garage. Recent buildings constructed at the "Pru" have used high-capacity drilled micropiles penetrating into the deep bedrock and a floating foundation.

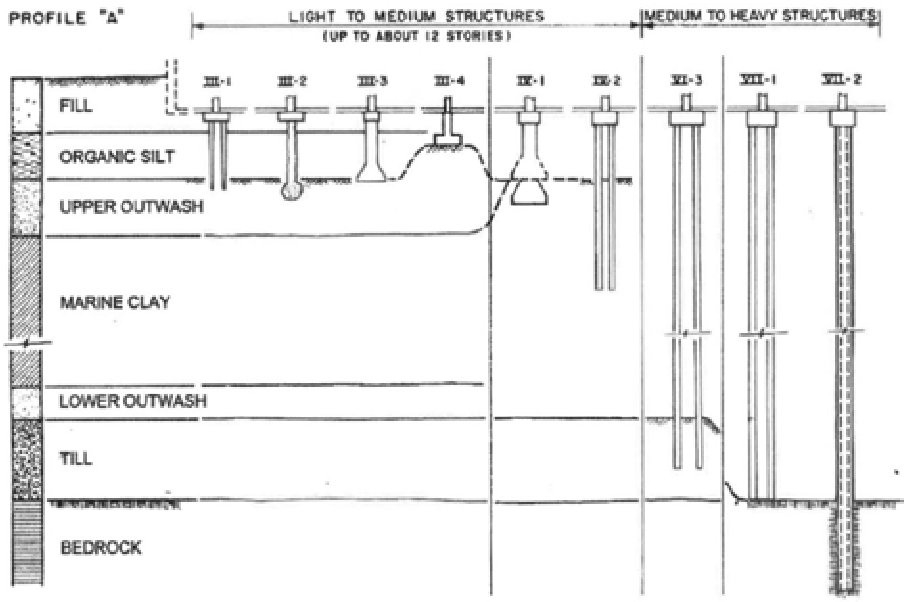


Figure 4. **Deep foundations used throughout the decades. (Courtesy of Woodhouse and Barosh, Civil Engineering Practice, *Journal of the Boston Society of Civil Engineers*, 2011-12.)**

A number of buildings were developed in the late 1960s to early 1970s at the nearby Christian Science Center (CSC), with most having PIFs to the upper outwash sand, which were the foundation of choice for buildings of intermediate height at that time. Geotechnical engineers usually try to provide the client with the most economical solution that will give the desired performance, while contractors sometimes offer cheaper alternatives. Such was the case of the parking garage and overlying reflecting pool at CSC, where deep end-bearing piles were supplanted with short PIFs, at substantial cost savings. But the architects' desire for water to spill uniformly over all sides of the nearly 700-ft-long reflecting pool were not realized due to very slight, uneven settlement, or perhaps heave of the underlying the blue clay — part of the geotechnical intrigue of Boston's Back Bay.

The John Hancock Tower's construction in the 1960s is another part of the geotechnical lore of Back Bay. To achieve the deep, two-level basement, steel-sheet piling supported by wales and rakers to a central concrete base slab on end-bearing steel H-piles needed intermediate temporary lateral support from a berm of fill and organic silt. But although the organic silt can exhibit a drained friction angle of about 30°, it behaves as very weak clay when undrained. The sheet piling deflected inward 2 to 4 ft, which led the surrounding ground to follow and settle. The adjacent streets and buildings suffered, including Trinity Church, more than 50 ft away and across St. James Avenue.

Imagine the angst at Trinity Church when, just 15 years later, another development with a 32-ft-deep excavation was proposed just across its other abutting street. But this time, a stiff concrete slurry wall with several levels of tiebacks was used, and extensive monitoring confirmed tolerable lateral movements (just 1-3 in.). The deep excavation also allowed this 30-story building to "float," although some auger-cast concrete piles with steel cores were needed for hydrostatic uplift and wind load overturning resistance.

There's Always Geotechnical Intrigue in Back Bay

What type of foundation is needed for a project in Back Bay does not elicit a simple answer. Many factors enter into the solution. A significant factor in the past three decades has been the possible presence of environmental contamination in the fill. What local industries might have been present over the past 160 years? A tannery? A glass manufacturer? A manufactured gas plant, with coal-tar residue still present? Wood and coal ashes were just dumped out back, but these often contain heavy metal residue. It may be more economical to forego the basement excavation and just drive deep end-bearing piles for a rather short building (4-6 stories), rather than remove the contaminated fill. But three blocks away, a 22-story building over even-deeper blue clay happily "floats" on a thick, concrete mat placed 20+ ft below ground, contamination removal costs being less than deep foundation installation. What new problems will the next decades bring? Such is the fascinating geotechnical intrigue of what lurks below Boston's Back Bay.

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Eurasia Tunnel connecting Asia on the left with Europe on the right.

CONNECTI CONTINEN

Challenges of the Eurasia Tunnel in Istanbul

By Ray Castelli, PE, M.ASCE, and David Smith, PE, PMP

The Eurasia Tunnel, the first bored tunnel crossing of the Istanbul Strait (Bosphorus) in Istanbul, Turkey, is a site that presents many unique challenges, including very poor ground conditions, unusually high water pressures, and severe seismic demands. Although this historic waterway separating Europe from Asia has been spanned by three bridges and crossed by an immersed tube railway tunnel, the Eurasia Tunnel is the first bored tunnel across the strait, and the first roadway tunnel crossing.

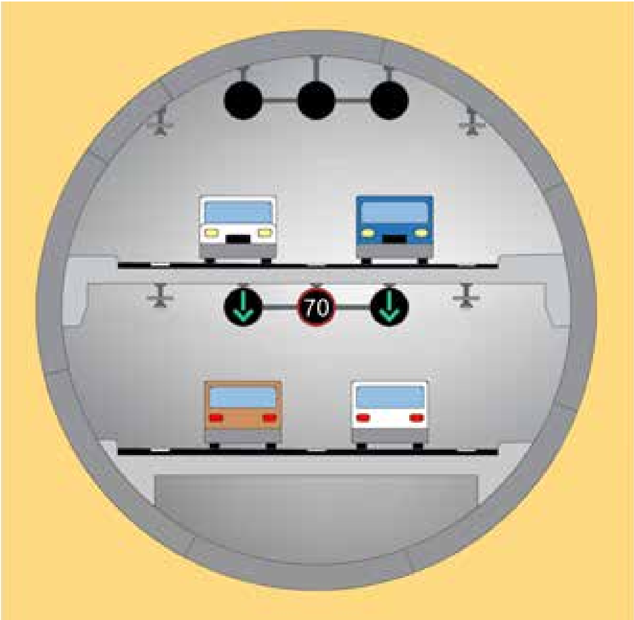

Figure 1. Tunnel cross-section. (Courtesy of Yapı Merkezi, SK E&C JV.)

The Eurasia Tunnel is one element of a new 14.6-km road link opened in December 2016 that helps relieve Istanbul's increasing traffic congestion and greatly reduces the travel time necessary to cross the Istanbul Strait. Prior to the tunnel, vehicles typically experienced long waiting times at the bridges and ferry crossings. The tunnel's centralized location near the heart of the historic area at the southern end of the strait provides a more convenient link to the city (see cover photo).

The 3.4-km-long bored tunnel has a 12-m inside diameter single tube that accommodates a stacked roadway configuration with two lanes on each level (Figure 1). For this arrangement, the roadways were designed with a limited vertical clearance of 3.0 m to accommodate passenger vehicles and small trucks.

The Republic of Turkey's Ministry of Transportation and Infrastructure awarded the design-build-operate-transfer contract to Avrasya Tüneli Íşletme Ínșaat ve Yatirim A.Ş. (Eurasia Tunnel Operation Construction and Investment Inc., or ATAS), the joint venture composed of Yapı Merkezi from Turkey and SK E&C from Korea. Parsons Brinckerhoff (now WSP) was lead designer for the project under a subcontract with ATAS.

The total investment cost for the project was U.S. $1.3 billion, and it was delivered in a period of 55 months, opening in 2016.

Geologic Setting

The basement rock beneath the Istanbul Strait channel has been highly deformed by tectonic activity. This seismic activity caused a series of relatively closely spaced grabens (downward displaced blocks of rock bounded by parallel to sub-parallel faults), and intense fracturing of the basement rock. The Trakya Formation, a sedimentary rock composed of interlayered siltstones/mudstones and sandstones, underlies the entire tunnel alignment. The Trakya Formation outcrops on both sides of the Istanbul Strait, but within a portion of the alignment the rock surface drops below the deepest section of the Eurasia Tunnel.

The Trakya Formation has been intruded by igneous dikes of diabase, andesite, and dacite that are encountered at a frequency of approximately 70 to 200 m. The thickness of the dikes may be as much as 15 to 20 m, but are more commonly in the range of 1 to 5 m.

Faults in the region generally strike approximately N to N30E, thus producing an intercept angle with the Eurasia Tunnel alignment of about 60 to 90 degrees. These faults are likely related to the prehistoric fault system that formed the Istanbul Strait.

Site Conditions

Offshore explorations were performed at 15 locations. Each location included a cone penetration test (CPT) sounding to estimate in-situ alluvial material properties and to define soil stratigraphy, and a boring to obtain soil and rock-core samples for visual classification and laboratory testing. Except at areas of deep alluvial deposits in the center portion of the crossing, all borings were extended into bedrock. Several offshore borings included sonic logging to determine the dynamic properties of the soil and rock. Offshore investigations also included a 3D, high-resolution, shallow seismic geophysical survey, extending from approximately 50 to 100 m to either side of the tunnel alignment to better define soil stratification and the top of rock surface.

As shown in Figure 2, the tunnel is fully within the Trakya Formation from the Asian portal to approximately 130 m west of the Asian shoreline and fully back into rock from approximately 1,400 m east of the European shoreline to the European portal. Within the Istanbul Strait channel, the tunnel encounters mixed-face transition zones and then alluvial deposits for a length of about 2,500 m. The channel has a maximum water depth of 62 m, and, at its lowest point, the tunnel reaches 106 m below sea level. The soil overburden ranges from approximately 32 m where first encountered on the Asian side of the crossing, to a maximum thickness of approximately 57 m at the transition back to rock near the center of the crossing.

Seismicity

The Eurasia Tunnel is located near the North Anatolian Fault Line, one of the most seismically active areas in the world. To address the high seismic risk, the design criteria adopted a performance-based, two-level design earthquake approach: 1) functional evaluation earthquake (FEE), and 2) safety evaluation earthquake (SEE) with a 20 percent and 4 percent probability of exceedance, respectively, during the 100-year

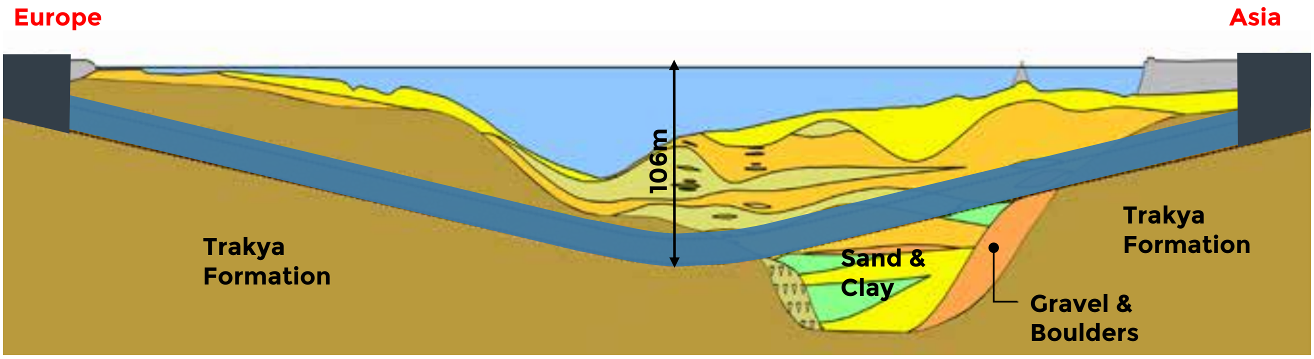

Figure 2. **Subsurface profile along the tunnel alignment.**

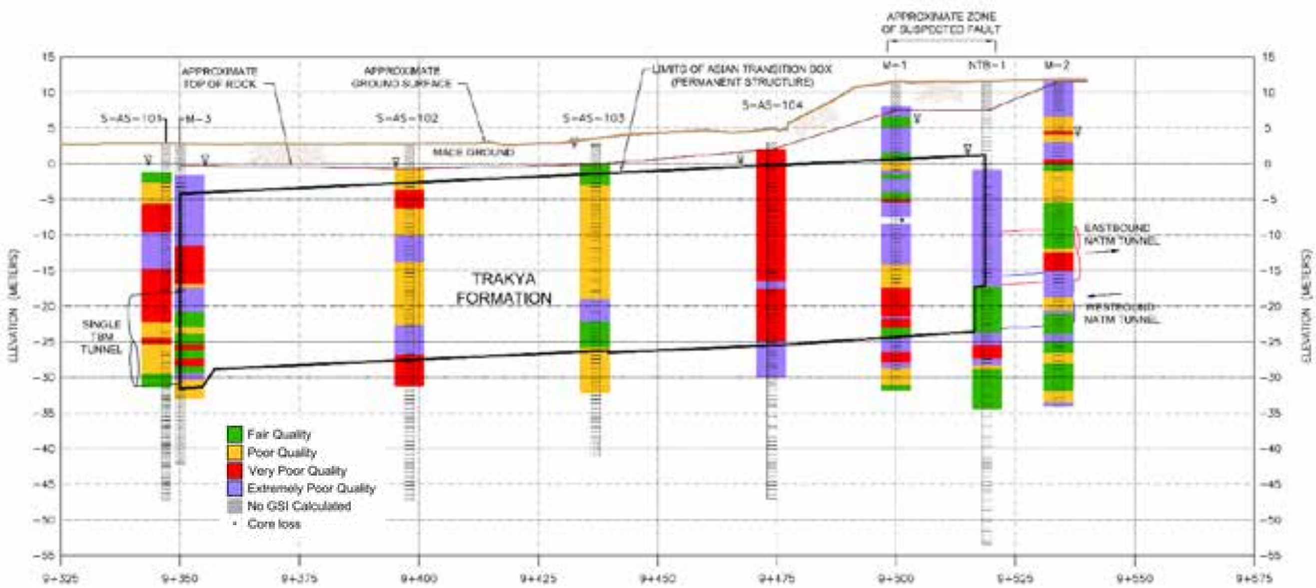

Figure 3. **Subsurface profile at launch shaft based on GSI classification of rock.**

design life of the facility. The FEE and SEE roughly correspond to design seismic events with return periods of 500 and 2,500 years, respectively. The project-specific seismic hazard assessment defines the design earthquake magnitude as 7.25 (moment magnitude) and source-to-site distance as 17 km for both SEE and FEE.

TBM Launch Shaft

The tunnel boring machine (TBM) was launched from a shaft on the Asian side of the crossing, approximately 80 m from the shoreline. An elongated cut-and-cover structure constructed within this shaft provides a transition from the TBM tunnel at the west end to two NATM tunnels extending from the east end of the shaft to provide separate, smaller tunnels for the eastbound and westbound roadways. The shaft excavation was approximately 174 m long, 26 to 38 m deep, and 25 to 36 m wide.

Except for a surficial 1- to 4-m-thick layer of fill, the shaft excavation was within poor to very poor rock of the Trakya Formation. The groundwater level varied from a depth of about 4 m at the west end of the excavation to about 8 m at the higher, eastern end.

The rock conditions at the shaft were very complex, with frequent vertical and lateral variation in rock type along the length of the shaft, and dramatic differences in rock mass quality. Rock mass quality was evaluated using two different methods: Rock Mass Rating (RMR) and Geological Strength Index (GSI). The RMR data indicated that the rock mass quality at the east end was generally poor to very poor, with a representative friction angle of 15° to 25°. At the west end, the rock mass quality was generally fair to poor, with a representative friction angle of approximately 20° to 30°. Using representative GSI values, the friction angles were estimated to range from 20° to 35°. The selection of design rock parameters also considered previous excavation experience in Istanbul. Using this approach, design parameters were assigned to each rock condition mapped at the site. An example of a rock quality profile is presented in Figure 3.

The initial ground support system for the shaft consisted of 0.8-m-diameter bored secant piles in the upper 12- to

Figure 4. **Launch shaft, looking west toward headwall. (Courtesy of Yapı Merkezi, SK E&C JV.)**

18-m height of the excavation and 0.8-m-diameter bored piles spaced 1 m on center in the lower 16- to 22-m section of the excavation. Secant piles were used to prevent seepage from the existing fill and the highly fractured and weathered uppermost rock zone. Both wall systems relied on grouted rock anchors up to 36 m in length and cast-in-place concrete wales to provide the necessary lateral support (Figure 4). The design used a working bond stress of 250 kPa for the anchors, except for zones of decomposed rock, where the bond stress was reduced to 125 kPa.

Shaft excavation began in April 2013. On May 29, 2013, unexpected lateral displacements up to 37 mm were measured at the inclinometers along the western reach of the south support wall when the excavation level was at a depth of approximately 12 to 13 m. On June 6, 2013, lateral displacement at the west wall (TBM headwall) unexpectedly increased from 13 to 26 mm, with corresponding increases in measured anchor loads. These events led to a temporary suspension of excavation operations and partial backfilling of the excavation to stabilize the support walls and to allow time to assess the observed conditions.

A back-analysis was performed using modified geotechnical parameters to replicate the instrumentation data. These analyses indicated that the existing ground conditions were poorer than suggested by the available subsurface investigation data. A 2D finite-element analysis showed that the probable cause of the movement was a circular failure zone forming behind the wall within the free length of the anchors. The lateral extent of this zone was found to be 6 to 8 m behind the wall. The bottom of the shear surface was inferred to be at about elevation -19 m, corresponding to a depth of about 2 m below the deepest secant piles at the western end of the excavation. These findings were supported by the instrumentation data.

Load cell data showed no signs of a loss of load indicative of anchor creep or yielding in the bonded zone. Horizontal extensometer data indicated elongation of the free length of the anchor, consistent with the conclusion that the bond, or fixed, length of the anchors was resisting the anchor loads. Using the modified parameters, the support system design was revised to include several additional levels of ground anchors. These remedial measures were implemented, and the shaft excavation was successfully completed in December 2013.

Tunnel Lining Design

The tunnel lining was constructed using a ring of nine, 2-m-wide, precast reinforced-concrete segments, and a relatively small key segment. Segments were bolted on all sides. To resist water pressures of up to 10.4 bar, the joints between precast segments were protected by two rows of synthetic rubber gaskets. Guide rods were aligned with recesses in adjoining segments to ensure correct positioning of segments and gaskets. The significant depth and large diameter caused high hoop stresses in the lining. This resulted in a required segment thickness of 600 mm, using a concrete compressive strength of 50 MPa.

Loads on the tunnel lining arise from static loads (soil and hydrostatic), the supported road decks, and seismic actions. To determine the maximum stresses in the tunnel lining, soil-structure interaction analyses were performed at multiple locations along the tunnel.

The lining was designed to withstand seismic events with return periods of 500 years (with minimal damage) and 2,500 years (without failure). During a seismic event, the bored tunnel within the marine deposits could be exposed to transient displacements in the transverse or longitudinal directions. Therefore, free-field ground deformation profiles were developed at various locations along the bored tunnel, along with strain-compatible ground parameters.

Deformations acting perpendicular to the tunnel tended to cause ovaling of the tunnel, so the resulting moments, shear, and axial forces were determined, and appropriate reinforcement was designed. Ground deformations acting along the line of the tunnel were initially shown to cause excessive stress in the tunnel lining at the interface between the marine deposits and the stronger Trakya Formation. Increasing the strength of the segments was impractical, so the high stresses were avoided by accommodating displacements at two special "seismic joint" rings, one at each geologic interface. The flexible seismic joint rings (Figure 5) comprised a pair of steel grillages, separated by a rubber membrane and articulated steel bars. Each joint can accommodate 75 mm of elongation, 75 mm of contraction, and 50 mm of lateral offset.

In addition to accommodating seismic deformations, the flexible joint also reduced longitudinal restraint of the adjacent rings. Without sufficient restraint, the waterproofing gaskets could decompress, potentially resulting in leakage due to the high external water pressure. To avoid this, three concrete segmental rings on each side of the seismic joints were designed with additional bolts to ensure that compression is maintained in the gasket.

Figure 5. One of the two seismic joints in the tunnel. (Courtesy of Yapı Merkezi, SK E&C JV.)

Tunnel Construction

The bored tunnel was constructed using a 13.7-m-diameter slurry TBM, which was designed to accommodate the variable geology, abrasive ground, and high groundwater pressures. To avoid extensive work in compressed air, cutting tools were designed to be changed from the rear of the cutterhead, with workers staying in atmospheric pressure. Abrasive rock and blocky ground resulted in significant wear on the cutterhead. Tools incorporated wear-detection devices to alert the operator when cutters and picks needed to be replaced. Repairs to the TBM cutterhead required working in air pressure of up to 11 bar, using saturation diving techniques.

Tunneling from the Asian launch shaft to the European reception box took 476 calendar days (including stoppages). The average advance rate was 7 m/day, with a maximum advance of 18 m in one day.

During installation, the flexible elements of the seismic joints were held rigidly in place by temporary steel blocks that allowed the TBM to thrust against the ring to mine forward. Behind the TBM, supporting elements for the road decks were constructed by drilling rebar into the tunnel segments and casting concrete corbels. Approximately 700 m behind the back of the TBM, the upper road deck was installed using cast-in-place concrete. The lower part of the tunnel was kept free so that rubber-tired service vehicles could deliver precast segments and other materials to the TBM. After TBM breakthrough, the lower deck was installed using precast concrete slabs and cast-in-place in-fill concrete.

A Historic Achievement

The opening of the Eurasia Tunnel to traffic in December 2016 added another notable event to the long and fascinating history of this timeless city. The Eurasia Tunnel was the first underground roadway link between continents, and faced numerous technical challenges due to its depth, highly variable ground conditions, and severe seismic demands. The launch shaft excavation demonstrated the uncertainties of our practice and the importance of geotechnical instrumentation and monitoring during construction to avoid failures and verification of site conditions. By applying recent advances in tunneling technology, and with the skill, knowledge, and dedication of countless engineers, equipment manufacturers, contractors, and workers, the project was completed successfully. The positive reception of the Eurasia Tunnel has prompted the Turkish government to start planning an even bigger triple-deck tunnel under the Bosphorus.

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// What's New in Geo?

ADVANCES IN GEOSYNTHETIC SOLUTIONS FOR SUSTAINABLE LANDFILL DESIGN

Geosynthetics Really *Do* Last!

By Ming Zhu, PhD, PE, M.ASCE,
Marco Isola, PhD, PE, M.ASCE, and
Jorge Zornberg, PhD, PE, F.ASCE

Even though geosynthetics are now a well-established discipline within geotechnical engineering, ingenuity continues to play a significant role in projects involving their use. This is because it's possible to tailor the mechanical and hydraulic properties of geosynthetics to address design needs in almost all aspects of geotechnical engineering. Although the ability to achieve consistent geosynthetic properties has been a key consideration since their early use, concerns about their lifespan have subjected geosynthetics to careful scrutiny.

Engineered turf cover installed at Baldwin County Landfill, GA.

Figure 1. View of stacked geotextile tubes for containment of dredged sediments showing detail of multiple tube operation stages. (Photo courtesy of TenCate Geosynthetics.)

In recent years, however, there's been increasing confidence within the geotechnical profession regarding geosynthetics' performance and long-term durability. Why? It's because polymer formulations have continued to advance, phenomenal research has been (and continues to be) conducted to quantify the longevity of geosynthetics, and field evidence of good performance has been documented for geosynthetic structures that are more than a half-century old.

This article is not intended to document the important results of recent research on durability or add to an already healthy record of field performance of early geosynthetic structures. Instead, its objective is to illustrate how overcoming early concerns about durability has enabled innovative geosynthetic solutions in landfill design. Geosynthetics have been used in modern landfills in the U.S. for over four decades since the passage of the Resource Conservation and Recovery Act in 1976. Beyond the well-established use of geosynthetics in base liner systems, three relatively new applications are featured in this article that involve the use of geosynthetics as part of the waste disposal, slope stabilization, and final closure of landfills. These applications illustrate recent advances in geosynthetic solutions to overcome enduring challenges previously managed using traditional approaches.

Stacked Geotextile Tubes for Waste Disposal

The use of geotextile tubes combines dewatering and disposal of industrial wastes, such as sludges, dredged sediments, and sluiced coal combustion residuals (CCR), into one operation, significantly reducing the handling of saturated wastes. Geotextile tubes involve high-strength, permeable woven geotextiles sewn into a tube. When used for dewatering, the geotextile acts as a filter that allows water flow while retaining the solids in the tube. The dewatering process includes three main stages: hydraulic filling, free water drainage, and consolidation (Figure 1). Flocculants are usually added to fine-grained slurries to facilitate agglutination of solid particles. After dewatering is complete, geotextile tubes can be either transported for off-site disposal or capped in place for permanent disposal. Unlike traditional dewatering techniques, such as settling basins, geotextile tubes offer high dewatering efficiency and provide effective odor control by limiting exposure of waste to air.

A recent trend in geotextile tube applications involves stacking them in multiple layers to reduce the disposal area footprint in large environmental remediation projects. For example, as part of the Onondaga Lake Cleanup Project near Syracuse, NY, about 1.6 million m^3 of contaminated sediments dredged from the lake were dewatered and contained using approximately 1,000 geotextile tubes that were up to 91 m in length and 24-27 m in circumference. The geotextile tubes were stacked in six layers approximately 11 m high within the 22-hectare landfill footprint and permanently capped in place with a soil-geosynthetic final cover in 2017. Figure 1 shows an aerial photo of the stacked geotextile tubes during construction. The key design considerations when stacking geotextile tubes include internal stability of individual tubes, slope stability of stacked tubes, and settlement and bearing capacity of the foundation that supports stacked tubes.

Another trend is to utilize the waste encapsulated in the geotextile tubes as fill material to reduce the quantity of imported construction materials. A geotextile tube wall was constructed in 2016 during closure of an ash pond at a large Mid-Atlantic utility site. The wall separated the ash pond into a pool section that continued to serve as an operations area to receive sluiced CCR, and a construction section where preparation work for final closure grading was to be started. The geotextile tubes were stacked in two layers and formed an approximately 18- to 24-m-wide, 3.4-m-high, and 730-m-long wall. Approximately 61,000 m^3 of in-situ fly ash were dredged and pumped into the geotextile tubes and used as the fill material to construct the wall. Figure 2 shows a section of the installed geotextile tube wall.

Durable Geosynthetic Reinforcements for Waste Containment Stabilization

While many design solutions have been adopted to maximize the available waste capacity within the defined footprint of landfills (e.g., dynamic compaction, bioreactor technology, and landfill mining), the use of geosynthetic-reinforced structures, such as mechanically stabilized earth berms, has been incorporated into landfill designs over approximately the last two decades. While the design of reinforced-soil structures generally requires granular backfill material, landfill owners have started using actual landfill waste as backfill material to optimize the site geometry and reduce construction costs.

The use of waste as backfill material introduces several challenges into the design of the reinforced-soil structures. Geotechnical properties of municipal solid waste are inhomogeneous and highly depend on the composition of the waste itself — in particular, the percentage of organic components that decompose over time. Furthermore, waste degradation involves complex fermentation phenomena, chemical alteration, creep, oxidation, and cementation that results in mineralization of the waste. The resulting waste often has an average temperature of 40° C, with peaks over 60° C

Figure 2. View of geotextile tube wall filled with re-used fly ash in an ash pond at a Mid-Atlantic utility site. (Photo courtesy of TenCate Geosynthetics.)

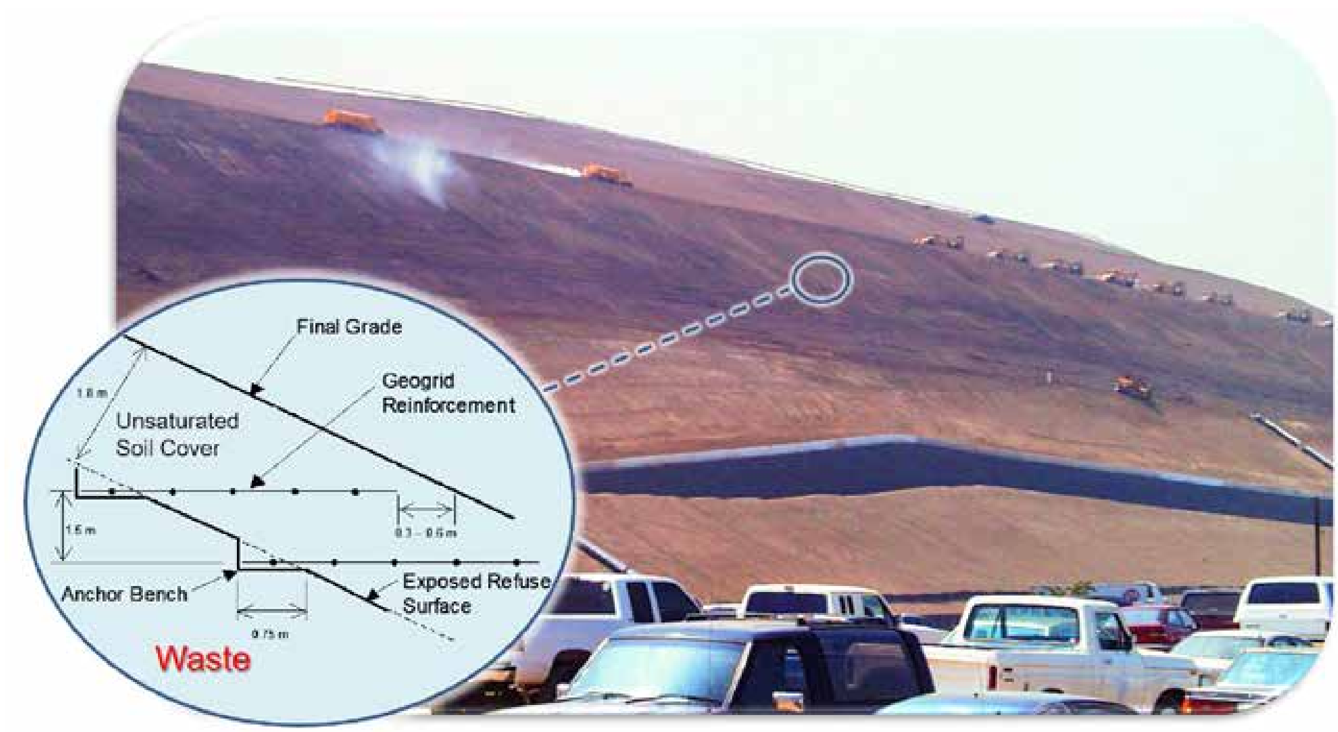


Figure 3. View of a geogrid-reinforced soil cover system on the North Slope of the OII Superfund Landfill. Note the detail of the geogrid reinforcements anchored into solid waste.

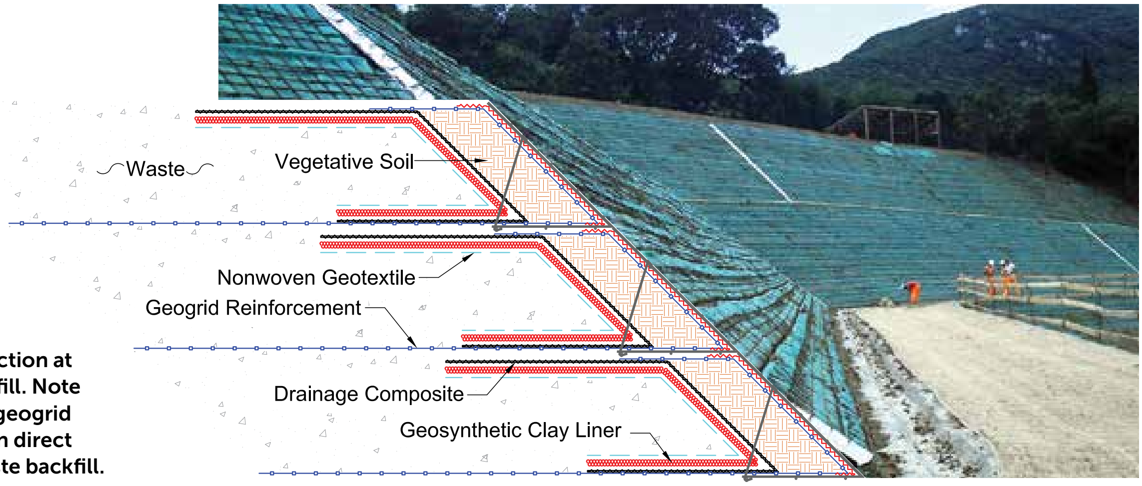


Figure 4. **View of capping cross section at Niccioletta Landfill. Note the detail of the geogrid reinforcements in direct contact with waste backfill.**

due to anaerobic digestion, and is often chemically aggressive. Key aspects to be considered when selecting geosynthetic reinforcements, such as geogrids, include their resistance to chemical degradation under a wide range of pH, creep performance, performance at high temperatures, and resistance to mechanical damage during waste compaction.

The final closure of the Operating Industries, Inc. (OII) Superfund Landfill located near Los Angeles, CA, is an early design example involving geosynthetic reinforcements in direct contact with solid waste. One of the most challenging design and construction features of that project is related to the stability of the landfill's North Slope. The North Slope is located immediately adjacent to the busy Pomona Freeway. It rises up to 65 m above the freeway and consists of slope segments separated by narrow benches that are as steep as 1.5H:1V and up to 30 m high. As illustrated in Figure 3, horizontally placed uniaxial geogrids anchored in the actual solid waste were selected as the most appropriate and cost-effective method for stabilizing the engineered soil cover constructed over the North Slope. The cover has performed well since its construction over 20 years ago, which demonstrates that the geosynthetic reinforcement solution has been both durable and successful.

In 2011, a landfill cell was constructed in Niccioleta, Tuscany, Italy, using waste as fill material for the reinforced side slope (Figure 4). A geogrid material was used to reinforce each layer of waste material, providing the tensile strength required to achieve internal stability. Additionally, two layers of drainage geocomposites and one layer of geosynthetic clay liner were wrapped around each layer of waste to form the landfill's final capping system. A layer of vegetative soil, retained by a turf-reinforcement mat, was subsequently placed in the slope face to provide a vegetated facia and an extra layer of protection for the capping system. As designed, the system allowed the construction of landfill cells having side slopes at angles much steeper than the typical 3H:1V slope, significantly increasing the overall landfill cell capacity.

Engineered Turf Cover for Final Closure

Closure of a landfill is required after reaching final grades to isolate the underlying waste and manage long-term environmental risks. Traditionally, landfills have been closed using soil covers with geosynthetic components. A traditional landfill cover, for example, consists of (from bottom to top) a geomembrane barrier layer, a geocomposite drainage layer, and a protective/vegetative soil layer that is at least 0.6 m thick. Two persistent, long-standing challenges associated with many traditional soil covers are soil erosion and cover slope failures.

The engineered turf cover is a relatively new landfill closure solution that uses engineered turf and a specified infill to replace the protective/vegetative soil layers used in traditional soil covers. The elimination of these soil layers removes soil erosion as a driving force behind cover slope failures. Because engineering turf is not susceptible to erosion, it's less affected by factors such as changing weather conditions and varying soil properties compared to traditional soil covers. Moreover, engineered turf covers require less post-closure maintenance because soil-erosion repairs, re-vegetation, fertilization, mowing, and stormwater pond cleaning are not needed.

The engineered turf component is made of high-density polyethylene (HDPE) synthetic grass blades tufted into a double-layer polypropylene, woven geotextile backing, which is placed directly on top of a HDPE or linear low-density polyethylene-structured geomembrane (Figure 5). The specified infill, either bonded or unbonded clean sand with a minimum layer thickness of 13 mm, is placed inside the synthetic grass blades. The engineered turf and infill function primarily to protect the geomembrane from ultraviolet (UV) exposure, wind uplift, and puncture by external forces, such as vehicular traffic, hail, and animals.

The first engineered turf cover was installed in 2009 at a four-hectare MSW landfill in Louisiana to solve recurrent soil-erosion problems. In 2013, installation of a 28-hectare engineered turf cover was completed at the Crazy Horse MSW Landfill in California; it was selected to meet the design requirements of final cover stability for both static and seismic conditions for steep side slopes up to approximately 2H:1V. To date, engineered turf covers have been or are being installed at more than 40 sites in over 20 states in the U.S., covering a total area of more than 600 hectares. These sites include MSW landfills, industrial waste landfills, and CCR landfills and surface impoundments. Figure 5 shows the aerial photo of a 14-hectare engineered turf cover installed in 2014 at the Hartford Landfill in Connecticut.

Sustainability for landfill closures entails long-term performance and minimal environmental and social impacts. The design life of the engineered turf cover is projected to be over 100 years as a result of the enhanced UV stabilization of the synthetic turf fibers. The carbon footprint of engineered turf cover is smaller than that of traditional soil covers due to faster installation, fewer construction materials, fewer construction equipment operations, and less post-closure maintenance. In addition, land disturbance is avoided because borrow soils are not needed, which results in less impact on local communities as a result of less truck traffic on local roads.

Engineered turf covers also facilitate reuse of the large space at the top of landfills after closure, such as converting them into a solar farm because maintenance of grass within the array isn't needed. Figure 5 shows the 1-megawatt solar-electricity-generating facility installed atop the Hartford Landfill, which powers approximately 1,000 homes per day at peak capacity. The solar array is supported by a racking system ballasted with concrete blocks that sits directly on the engineered turf cover. This approach reduces maintenance, because the solar panels are not subject to potential damage from mowing equipment and the runoff from the drip edge of the solar panels does not induce soil erosion that would undermine the panel foundations. Additionally, the engineered turf cover provides a relatively dust-free environment that promotes efficient solar collection.

Looking Ahead

Advances in geosynthetics have made these materials a well-established technology within the portfolio of solutions available to geotechnical engineers. The old question, "How long will they last?" is being addressed through extensive research, sound engineering design, and innovative applications. This contributes to sustainable landfills by incorporating geosynthetics in the design of landfill components related to disposal operations, stabilization approaches, and final closure systems, as illustrated in the three applications presented in this article.

Innovative geosynthetic materials, products, and designs are expected to continue to emerge with the pursuit of sustainable designs. For example, according to data provided by the U.S. Environmental Protection Agency, there are more than 1,000 active CCR landfills and surface impoundments in the U.S. that require closures, creating opportunities for implementing new geosynthetic solutions. Overall, geosynthetics play an important role in geotechnical projects in general and landfill design in particular because of their versatility, cost-effectiveness, ease of installation, and good characterization of their mechanical and hydraulic properties. The creative use of geosynthetics in geotechnical practice will continue to expand as manufacturers continue to develop new and improved materials, and engineers come up with new design approaches and field applications. GS

▸ **MING ZHU, PhD, PE, M.ASCE**, is the director of engineering with Watershed Geosynthetics, located in Alpharetta, GA. He has more than 10 years of professional experience in geotechnical and geoenvironmental engineering. He can be contacted at *mzhu@watershedgeo.com*.

▸ **MARCO ISOLA, PhD, PE, M.ASCE**, is a senior engineer with Maccaferri, located in Tampa, FL. He provides geotechnical, geoenvironmental, and project management expertise in the transportation and mining sectors. He can be contacted at *m.isola@maccaferri.com*.

▸ **JORGE ZORNBERG, PhD, PE, F.ASCE**, is a professor of geotechnical engineering at The University of Texas at Austin in Austin, TX. He was president of the International Geosynthetics Society (IGS) and currently chairs the G-I Technical Committee on Geosynthetics. He can be contacted at *zornberg@mail.utexas.edu*.

Figure 5. View of engineered turf cover installed at Hartford Landfill showing detail of the different components of the cover.

Look Who's a D.GE

Conrad W. Felice, PhD, PE, P.Eng., D.GE, F.ASCE

CONRAD W. FELICE

Conrad W. Felice, PhD, PE, P.Eng., D.GE, F.ASCE, is serving as the Washington State Department of Transportation owner's representative and geotechnical design manager for the over $2.5 billion I-405 Corridor Program. He is also the managing principal at C. W. Felice, LLC, and adjunct professor in the Department of Civil & Coastal Engineering at the University of Florida. He is a Professional Engineer registered in 15 states and four provinces in Canada.

Felice received an Air Force Reserve Officer Training Corps Scholarship and entered the Air Force as a second lieutenant in 1979. His first assignment was to attend graduate school at the Air Force Institute of Technology, where he received a master's degree in management. Assigned to Hill Air Force Base in Utah, he oversaw the military construction program for the logistics center and commanded a Prime BEEF (Base Engineer Emergency Force) construction team that provided rapidly deployable civil-engineering support anywhere in the world on short notice.

After being selected for an advanced degree program, he was assigned to the Air Force Civil Engineering Research facility, where he led a geologic response unit and was the program manager for the design and testing of strategic and tactical structures to be built around the world to protect U.S. forces and assets. As an Air Force captain, he was then assigned as commander of the civil-engineering squadron at Florennes Air Base, Belgium, where he directed the removal of the ground-launched cruise missiles and facility drawdown as required by the Intermediate Range Nuclear Forces treaty protocols negotiated between the U.S. and the Soviet Union. Felice was then assigned to the Defense Nuclear Agency in Washington, DC, where he developed and led the underground technology development program for the Department of Defense.

Leaving active duty after 11 years of service, he continued his Air Force career as a reserve officer assigned to the Air Force Office of Scientific Research in Washington, DC, where he directed and managed basic science civil-engineering research programs with universities and institutions around the world. Felice completed his career at the Air Force Research Laboratory Munitions Directorate, where he served as deputy chief scientist and provided technical oversight and guidance in support of a mission to develop, integrate, and transition science and technology into defense systems.

During his career, Felice was awarded the Air Force Achievement medal, the Air Force commendation medal, the Department of Defense joint service commendation medal, and the Air Force meritorious service medal. In 2006, he retired from the Air Force after 27 years of service at the rank of lieutenant colonel.

In the private sector, Felice has led the geostructural design and construction of deep foundations for signature long-span bridge projects, including the Rajiv Gandhi Sea Link in Mumbai. His projects have also included hard rock and soft ground tunnels, marine facilities, pipelines projects, and hydro-power facilities. Felice is a current trustee for the Deep Foundation Institute, the current chair of the Tunnel and Underground Structures Committee of the Transportation Research Board, and the Animateur for the International Tunneling Association working group on the seismic design of tunnels. He is a Fellow of the ASCE, a board-certified geotechnical engineer within ASCE's Geo-Institute, and a past member of the Committee on Geological and Geotechnical Engineering for the National Research Council, U.S. National Academy of Sciences. Academically, he earned BS and PhD degrees in civil engineering from Ohio University and the University of Utah, respectively, and a master's degree in facilities management from the Air Force Institute of Technology.

What class did you enjoy most while in school?
I particularly enjoyed my courses in mathematics — especially those related to numerical modeling. Coupled with actual construction experience, these tools provide valuable insight on design alternatives, and how construction staging influences performance.

What was your favorite project?
Without question, the Rajiv Gandhi Sea Link in Mumbai, India. The project consisted of a number of approach structures and the signature cable stay bridge structure for the country across Mahim Bay, adjacent to the Arabian Sea.

What is your favorite song and artist?
I have a soft spot for the old crooners, Frank Sinatra, Andy Williams, and Dean Martin. To those who know me, it will come as no surprise that a favorite song is Frank Sinatra's rendition of "My Way."

What is your favorite movie or television show?
Schindler's List and *Argo*. Movies about people doing extraordinary things for others in the face of adversity.

Where did you spend most of your childhood, and what was it like for you to grow up there?
I grew up in Smithtown, a community located approximately in the middle of Long Island, NY. At that time, the area was mostly rural, with easy access to the beaches on the north and south shores of Long Island.

When did you realize that you wanted to study civil engineering? What were the key factors in your decision to become a civil engineer?
After high school, a cousin of my future wife introduced me to the profession while he was pursuing his civil-engineering degree. Additional encouragement was provided by my future father-in-law, who said it might be an excellent way to take care of his daughter.

How do you feel about the state of civil engineering and the profession as it is today?
Cautiously optimistic. Attracting and retaining people for careers in the civil-engineering profession will continue to be a significant challenge. The state of our nation's infrastructure will continue to need engineering professionals to deal with not only the deterioration and rebuilding of our current systems, but also innovative ways to add new capacity.

What do you feel are the biggest challenges on the horizon for the profession?
A significant challenge that I see — not only on the horizon, but today — is participating on projects using alternative delivery systems. More and more projects both in the public and private sectors are turning to design-build or other contract alternatives in the hopes of not only incorporating innovative ideas on their projects, but also improving schedule and cost performance.

Do you have a message about specialty certification that you'd like to share with other professional engineers?
Certification adds value to the profession, and I encourage all of our young engineers to plan their professional development and careers that will lead to this recognition.

Was the effort to get the D.GE worth it?
Obtaining the certification and maintaining your proficiency to retain it is definitely worth the effort. It is a clear demonstration to those who engage our services about the level of practice they can expect both technically and ethically.

What are some of your personal hobbies and interests?
Golf, when I can get away, but reading is of particular interest. I especially enjoy biographies. There have truly been some remarkable people within our profession, and I enjoy learning about their paths in life, what choices they made and how they made them, and how they faced and overcame adversity. GS

For the complete article, please visit: *geoprofessionals.org*.

The state of our nation's infrastructure will continue to need engineering professionals to deal with not only the deterioration and rebuilding of our current systems, but also innovative ways to add new capacity.

Board Certification for All Civil Engineers

By the time you read this, I will be past president of the Academy of Geo-Professionals (AGP), and Gordon Matheson, PhD, PG, PE, D.GE, M.ASCE, will be our new president. But for now, let me share some insights about ASCE's Civil Engineering Certification program, both now and in the future.

The Diplomate program, now known as Board Certification, is governed by ASCE's Civil Engineering Certification, Inc. (CEC) and includes: The Academy of Geo-Professionals (AGP), the American Academy of Water Resources Engineers (AAWRE), and the Academy of Coastal Ocean Ports and Navigation Engineers (ACOPNE). Two new academies are proposed: the American Academy of Transportation and Development Professionals (AATDP), and the Academy of Sustainable Infrastructure. This remains a small subset of the total civil-engineering profession, and ASCE wants that to change.

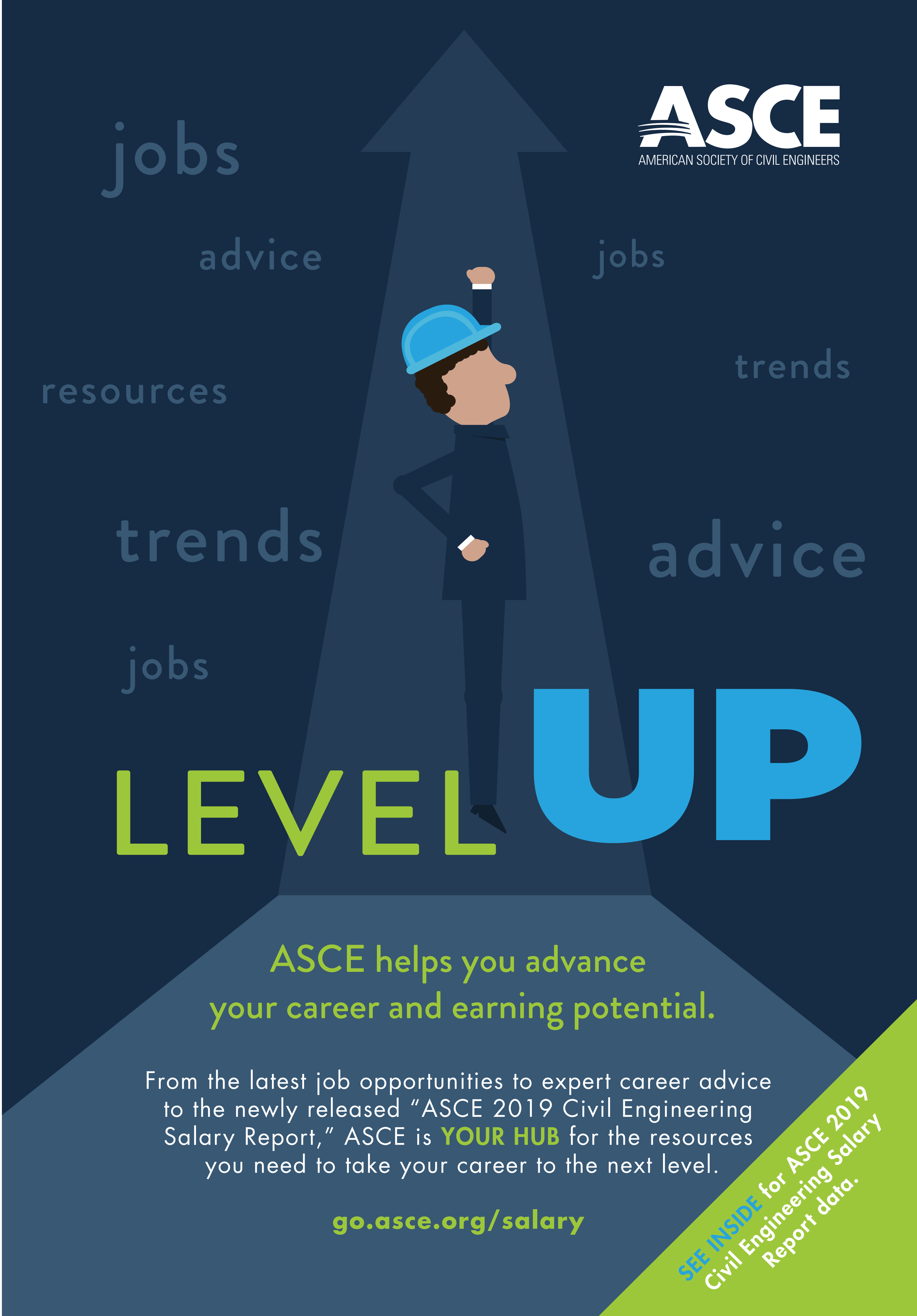
The existing Board Certification program provides recognition of attaining advanced knowledge and skills in a specialty area of civil engineering. In simple terms, it requires a PE license or foreign equivalent, a master's degree, and 8 years post-licensure progressive engineering experience. AGP Past President Allan Marr worked to change the name of the designation from simply Diplomate in Geotechnical Engineering (D.GE), or one of the other Academies, to Board Certification in Geotechnical Engineering. This is much easier for the public to understand because other professions, such as medicine, use this terminology. All the Academies now use the term Board Certification.

ASCE is in the process of evaluating how to expand the certification program for all civil engineers. For about 20 years, ASCE has had various committees working on advancing the requirements for civil-engineering practice, in line with ASCE Policy 465, Academic Prerequisites for Licensure and Professional Practice. For about a decade, that committee focused on trying to convince state licensing boards that an MS degree in civil engineering should be part of the PE licensure process. While a laudable goal, it was not successful, so the ASCE Board of Direction directed the Committee on Preparing the Future Civil Engineer (CPFCE) to explore if and how this goal could be achieved via credentialing. A task committee of the CPFCE, the Task Committee on Credentialing (TCC), has been working for more than a year to explore how ASCE may develop a credentialing system that is aligned with the Civil Engineering Body of Knowledge (CEBOK) and relevant to the entire civil engineering profession. The TCC developed an interim report that laid out the case for a system of Board Certifications offered in the primary specialty areas of civil engineering. These report recommendations were accepted by the ASCE Board of Direction in July, and the Board directed the TCC to continue with market research of the proposed framework, including development of business and implementation plans and marketing strategies. Consideration has been given to requiring that an applicant have a master's degree in civil engineering or equivalent, pass the PE exam, demonstrate expertise in a specialty area of civil engineering through four years of practice, and pass an exam, much like Board Certification works in the medical profession — although this has not been finalized.

It was also discussed that CEC be expanded into a National Academy of Civil Engineering, or some similar name, with each primary specialty area of civil engineering having Certification Boards to replace the existing Academies and administer the credentials. Professional civil engineers who fulfill the requirements for Board Certification will positively impact our profession and raise the bar of the profession.

Much more work must be accomplished to bring this program to fruition. The TCC will work through next summer to develop a final proposal for the program and, at that time, the ASCE Board of Direction will again have an opportunity to make a decision on whether this new certification approach will be the best way for ASCE to advance the profession in the 21st century.

Ray E. Martin, PhD, PE, D.GE, F.ASCE
President, AGP
rayemartineng@aol.com


ASCE
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jobs
advice
jobs
trends
resources
trends
advice
jobs
LEVEL UP
ASCE helps you advance your career and earning potential.
From the latest job opportunities to expert career advice to the newly released "ASCE 2019 Civil Engineering Salary Report," ASCE is YOUR HUB for the resources you need to take your career to the next level.
go.asce.org/salary
SEE INSIDE for ASCE 2019 Civil Engineering Salary Report data.

2019

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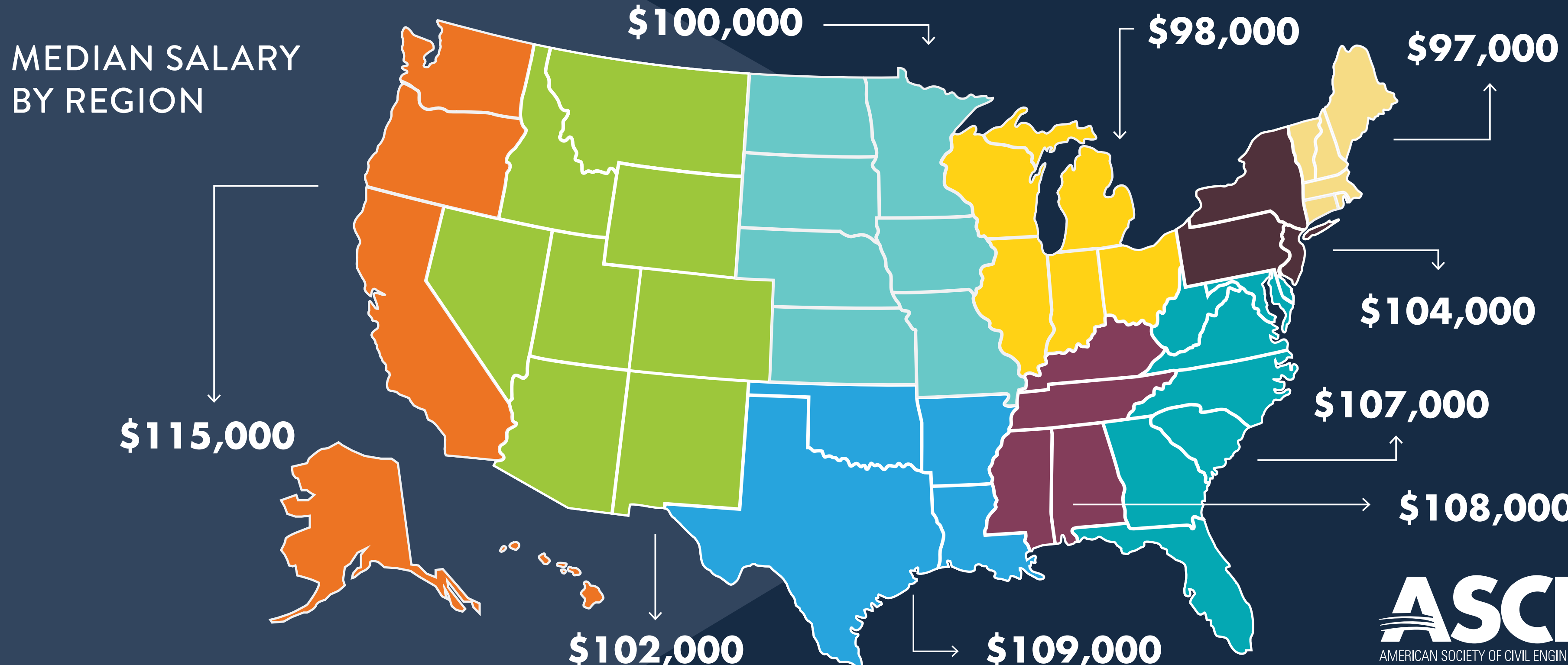
ASCE CIVIL ENGINEERING SALARY REPORT

ASCE members get five free data uses of the salary calculator.

All new data to help you pinpoint exactly what your engineering skills are worth.



ASCE
AMERICAN SOCIETY OF CIVIL ENGINEERS

MEDIAN SALARY BY DISCIPLINE

Construction	$119,000
Utilities	$118,000
Environmental	$109,000
Transportation	$106,000
Architectural	$101,000
Civil	$100,000
Water	$100,000
Geotechnical	$100,000
Structural	$100,000

TYPICAL MEDIAN ENTRY-LEVEL SALARY

$62,000

$109,000

TOTAL MEDIAN PRE-TAX INCOME
(from all sources)

STEADILY CLIMBING

Median Base Salaries by Year

2019 → $108,000

$104,000

$100,000

$96,000

2015 → $92,000

TYPICAL BENEFITS

93% basic health insurance
86% paid attendance at professional conferences
79% ASCE membership dues
76% 401K plan
61% education assistance program

ADDITIONAL PERKS

53% telework
55% paid parental leave
20 PTO days plus **8** holidays per year

EDUCATION PAYS

Median Salaries for Those With:

B.A./B.S. degree **$97,000**

M.A./M.S. degree **$110,000**

Ph.D. **$117,000**

P.E. license **$115,000**

The typical respondent is male, in his early 40s, has a bachelor's or advanced degree and about 18 years of professional experience.

jobs resources training

ASCE CAREER RESOURCES

ASCE CAREER by DESIGN

Plug in to ASCE's online portal Career by Design for young civil engineers, including an essential Welcome to the Profession Toolkit.

ASCE CAREER CONNECTIONS

Craft the perfect resume, develop your personal brand, or search through hundreds of job openings—make your next career move with ASCE Career Connections.

ASCE MENTOR MATCH
POWERED BY ASCE COLLABORATE

Find a mentor, be a mentor. ASCE Mentor Match connects you with civil engineers from around the world based on mutual interests and experience levels.

ASCE COLLABORATE

Join the ASCE Collaborate conversation for a daily idea exchange about the civil engineering technical and career topics that matter to you.

iLead

Develop your leadership skills with a new set of training opportunities, including the Power Skills Series, Younger Member Leadership Symposia, and the Career Booster Webinar Series.

// New Faces in G-I

Guillermo Diaz-Fañas, PE, M.ASCE

Our interviewee earned his bachelor's degree in civil engineering (2010) from the Pontificia Universidad Católica Madre y Maestra (PUCMM) in the Dominican Republic. As a Fulbright Fellow at the University of Illinois Urbana-Champaign (UIUC), he earned a master's degree (2014) in structural engineering. Following his passion for engineering, Diaz-Fañas attended summer graduate programs at the South Korean Advanced Institute of Science and Technology and the Chinese Institute of Engineering Mechanics while he was at UIUC. He is currently a senior technical principal in earthquake engineering, geotechnical engineering, and multi-hazard resilience with the Geotechnical and Tunneling Technical Excellence Center at WSP USA in New York City.

As a practicing engineer, Diaz-Fañas specializes in performance- and risk-based design, seismic hazard analysis, multi-hazard engineering, disaster risk management, and community resilience. He has worked on various projects for about 10 years in Latin America, Canada, and the U.S. His geotechnical and structural engineering background provided him the opportunity to work on projects addressing resilience and multi-hazards. He tells us that an important outcome of his work is to deliver "future-ready solutions."

Growing up in the Dominican Republic, Diaz-Fañas was deeply affected by natural disasters that got him interested in civil engineering. He's witnessed the destruction from a Category 3 hurricane, and the magnitude 6.4 Puerto Plata earthquake in 2003 that devastated his hometown. He found support and guidance to pursue a civil engineering career from engineers and construction professionals in his family, including his father, who operated a construction company.

Diaz-Fañas said: "It wasn't easy for someone like me to get into civil engineering. I faced opposition by those that felt I was not 'male' enough to be a civil engineer and thus lacked support." He continued: "There are younger people out there who feel that they cannot be engineers because they do not see themselves represented in our field." Fortunately for the geoprofession, he continued in engineering and now serves as an inspiration to others and a vocal advocate for underrepresented groups, particularly the LGBTQ+ community.

Diaz-Fañas says he strengthened his technical background with the help of various people and professional relationships that have been an important part of his success. He credits much of his professional growth to his mentor and colleague, Dr. Sissy Nikolaou. His advice to aspiring and younger engineers is to have a good network and start building it early by attending conferences and other professional events. He stresses that it's critically important to get involved in the engineering community by "creating relationships at every level."

Outside of work, Diaz-Fañas enjoys travelling with his husband and spending time with friends and family. He's a member of the United Nations' choir and enjoys playing guitar. He tells us that living in New York City offers access to a culinary mecca and, fittingly, one of his favorite things is discovering new restaurants and cuisines. Learn more about this early-career engineer below.

How does your work today address your childhood hopes of helping schools affected by disasters?

I've participated in reconnaissance and recovery missions after extreme events and have gained experience in urban recovery and resilience planning. For the past two years, as part of a partnership of consultants, firms, and cities, including my WSP USA team and the city of Cali, Columbia, I've worked with *100 Resilient Cities*. That's a movement pioneered by the Rockefeller Foundation to identify design and operational recommendations for school infrastructure resilience that would inform the city's school improvement program and identify related efforts the city could pursue to enhance the resilience of its school system. I was a part of the team that developed a resilient conceptual framework for the catalog of resilient schools, including design concepts, visual representation, and guidance for the Cristóbal Colón School.

How do you view diversity and inclusion in our industry today, and what are your hopes for the future?

As an openly gay Latino engineer, I know a little about the hardships that members of the LGBTQ+ community face when entering engineering. It quickly became apparent to me that the LGBTQ+ demographic is underrepresented in the civil engineering world. Instead of being frustrated about this, I co-founded the Queer Advocacy & Knowledge Exchange, or "Qu-AKE," in 2016. This nonprofit, national inclusive network exists to ensure visibility and protection of LGBTQ+ professionals in engineering, by facilitating networking opportunities, providing a forum for mentorship, and fighting discrimination against members of our community in the workplace.

How have your multilingual skills helped you professionally?

In addition to Spanish and English, I've been very lucky to learn French, Portuguese, Italian, Arabic, and Greek. I often use these skills at work to communicate with coworkers of different backgrounds, as well as on international projects where translation is often required.

By Anna M. Kotas, PE, M.ASCE, Nasser Hamdan, PhD, M.ASCE, Kofi B. Acheampong, PhD, PE, ENV SP, D.GE, M.ASCE, and Menzer Pehlivan, PhD, PE, M.ASCE
G-I Outreach and Engagement Committee

G-I ORGANIZATIONAL **MEMBER NEWS**

Gannett Fleming Helps Memorialize Military Veterans

When the Department of Veterans Affairs' (VA) National Cemetery Administration wanted to ensure accuracies and data for veteran cemetery records, they turned to **Gannett Fleming** and its geospatial technology division, GeoDecisions. GeoDecisions is providing global positioning systems (GPS) and geographic information systems (GIS) services for this project that will deliver centimeter positional accuracy, photo documentation, and veteran data-records validation to identify discrepancies. In time, this information should enable family, friends, and visitors to obtain locational data when paying respects at a veterans' cemetery. Services include surveying the land by GPS and photographing each headstone, flat marker, niche cover, monument, and cemetery infrastructure hard point (for example, flagpoles.) GeoDecisions and its partner, OnPointe 3D Technologies LLC, are performing these services for 22 different cemeteries in the initial year and 49 in total for the project. The largest cemetery in the project is in Calverton, NY, with more than 210,000 features to capture and document. The result will be a highly accurate geodatabase that can be compared to the existing VA Burial Operations Support System database.

News from GeoEngineers

Company Celebrates 30 Years in Oregon

Three decades ago, a group of dedicated employees opened **GeoEngineers**' Portland office with the goal of bringing a unique, people-first brand of geotechnical services to the state. The office was GeoEngineers' second location. In the years since, GeoEngineers has completed more than 7,000 geotechnical, environmental, and water resource projects in Oregon. The firm's Oregon staff members are thankful for the opportunities they've had to impact their local community, and they're looking forward to the next 30 years.

GeoEngineers Participates in Award-Winning Project

The Caminada Headlands project restored nearly six miles of beach and dune, creating a natural barrier between the Gulf of Mexico and sensitive coastal habitats and infrastructure.

GeoEngineers is proud to have been part of the design team for the Coastal Protection Restoration Authority's (CPRA) Caminada Headlands Beach and Dune Restoration project, which recently won the 2019 Best Restored Beaches award from the American Shore and Beach Preservation Association (ASBPA). The Caminada Headlands project, located southwest of Grand Isle, LA, restored more than 13 miles of beach and dune along the coastline. The project had its challenges; in 2010, GeoEngineers was already mobilized and drilling soil borings on the project site when the Deepwater Horizon oil spill occurred. There were days when the company was not allowed on the beach because of clean-up efforts. Despite the many obstacles, GeoEngineers effectively communicated with the state, adapting the project scope to meet budget constraints resulting from the spill. Coastal Engineering Consultants (CEC) eventually led the Caminada engineering project team, and the relationship that started with Caminada eight years ago has grown since. CEC and GeoEngineers continue to work on restoration projects along Louisiana's coastline. Today, the newly restored Caminada Headlands support coastal wildlife, protect interior marshes from inclement weather, and guard Port Fourchon, where 18 percent of the country's entire oil supply is produced.

Geotechnology Adds New Services

Geotechnology is now offering mining and underground development consultation and inspection services to its clients. These new "ground down" services identify, rectify and/or mitigate issues involving mines, tunnels, caves, and karst, to assist with new development opportunities within and above these areas.

"There are vast opportunities that can be pursued underground," said Joel Weinhold, PE, regional manager for Geotechnology's Central Region. "With proper design and construction, we can help repurpose obsolete mines, karst, and other underground areas for private or public use. We are very pleased that we can contribute to sustainable projects that could include surface and subsurface development, new resource exploration, renewable energy, farming, or other commercial and recreational activities."

Maccaferri Celebrates 140 Years

A Roots for the Future event at Maccaferri's plant in Williamsport, MD.

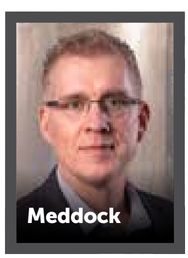
This year, **Maccaferri** celebrated the 140th anniversary of its founding in Bologna, Italy. To mark this milestone, it introduced five initiatives with the theme of "Nurturing the World of Tomorrow." The company supported an artist who raises awareness of marine plastic pollution, planted trees at each of its locations, organized an executive round table discussion about the importance of preserving the environment, hosted a heritage photography exhibition, and sponsored a participant in a sailing regatta. Each of these initiatives built on Maccaferri's long commitment to document sustainable engineering solutions.

Rembco Names New Leadership Team

Rembco Geotechnical Contractors has appointed R. Mike Bivens, PE, to the position of president and CEO for the company. He is part of the new ownership team that is transitioning into leadership as Rembco's past president, Clay Griffin, and vice president, Denise Griffin, prepare for retirement. Bivens joined Rembco in 2004 and has served the company as chief engineer since 2012. He is a graduate of the University of Tennessee with a bachelor's and a master's degree in geotechnical engineering. He is currently pursuing an executive MBA in strategic leadership.

Partners Tim Adkins, James Grubbs, and Bill King are assuming vice presidential roles that involve managing operations, projects, and equipment. With Bivens, this team has over 70 years of experience at Rembco and 20 years of ownership in the company. Rembco, founded in 1982, is a specialty contractor with design/build expertise in foundation support, soil stabilization, and specialty grouting.

SME Names Regional Vice President



Meddock

SME has named Michael S. Meddock, PE, M.ASCE, as regional vice president for Ohio and Indiana. Meddock had previously opened SME offices in Indianapolis, IN, and Columbus, OH, and was supervising SME's team in Cleveland, OH, before assuming this new role. He will be responsible for overseeing and coordinating services, including project management, technical report review, project planning, and business development. Meddock has served as secretary, vice president, and president of the board of ASCE's Michigan Section, Southwestern Branch. He is the president-elect of the Society of Marketing Professional Services, Columbus Chapter.

ZETAŞ Zemin Teknolojisi A. Ş. Celebrates 30 Years

In July, **ZETAŞ Zemin Teknolojisi A.Ş.** celebrated its 30th anniversary with a gala dinner. The evening began with speeches by the two founders of the firm: Turan Durgunoğlu, PhD, who discussed the challenges the company has faced over the years, and H. Fatih Kulaç, who looked to the future with a discussion of the company's strategies for sustainable development. Chief Executive Officer Ogan Sevim discussed the company's vision for quality and safety. Employees with 5, 10, and 15 years of service were recognized with plaques.

ZETAŞ Zemin Teknolojisi A.Ş. provides its clients with fully integrated foundation engineering services, from soil investigation to turnkey design-build geotechnical applications. ZETAŞ has been active in 11 countries across North Africa, the Middle East, and Central Asia. GS

ORGANIZATIONAL MEMBERS: Please submit your news to *geostrata@asce.org*.

News from DFI

Richards Receives DFI Distinguished Service Award

Thomas D. Richards, Jr., PE, D.GE, M.ASCE, former chief engineer for **Nicholson Construction Company**, is the recipient of the Deep Foundation Institute's highest award to an individual, the Distinguished Service Award (DSA). This award recognizes individuals who have made exceptionally valuable contributions to the advancement of the deep foundations industry.

"Tom is a consummate volunteer," said Theresa Engler, executive director of DFI. "He has generously lent his expertise to advance the deep foundations industry, and dedicated his time and efforts to the education of future generations of civil engineers and the improvement of guidelines and standards for quality in deep foundation construction."

Richards worked in the geotechnical construction industry for over 30 years and is widely acknowledged as an expert in the field of micropiles and in the use of anchors for dam and earth support. He participated in the design and construction of hundreds of technically challenging and innovative geotechnical projects throughout the U.S. Richards has dedicated himself to the advancement of the state of practice in the geotechnical construction industry through the generation of publications and involvement with professional organizations, including the Geo-Institute Grouting Technical Committee.

A licensed Professional Engineer in the states of PA, NY, NJ, and the District of Columbia, Richards earned his BS in civil engineering from the University of Pittsburgh.

Huff Named to Board of Trustees

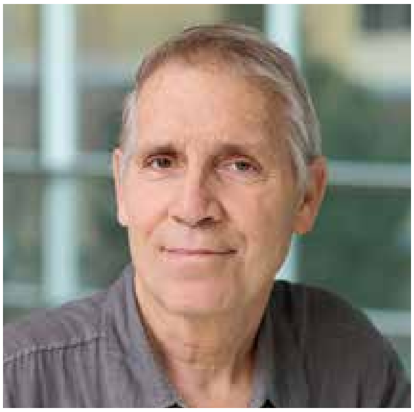
The Deep Foundations Institute Educational Trust, the charitable arm of DFI, recently appointed **Jonathan Huff, PE, A.M.ASCE**, to the Board of Trustees. He's serving as an at-large trustee from August 1, 2019, to December 31, 2020.

Huff is a design engineer/project manager and estimator for Goettle, where his responsibilities include engineering design, estimating, project management, and relationship building. His areas of expertise include augered cast-in-place piles, drilled displacement piles, micropiles, caissons, and tied-back earth retention systems.

Huff obtained his bachelor's and master's degrees in civil engineering from the University of Kentucky, while pitching for the university's D1 baseball team. A member of DFI, ADSC, and PDCA, Huff is chair of the DFI Augered Cast-in-Place Pile Committee and a former chair of the Cincinnati Section of the ASCE Geotechnical Group.

In Memoriam

Joseph A. Caliendo



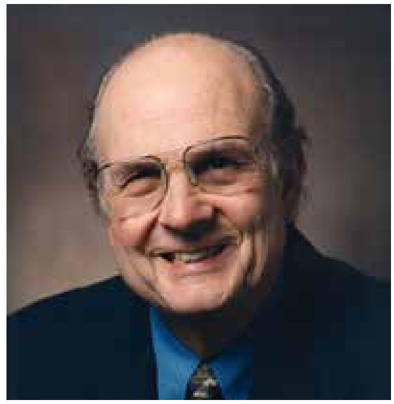
Joseph A. Caliendo, PhD, PE, F.ASCE, associate professor of civil and environmental engineering at Utah State University (USU), Logan, UT, died on August 15, 2019. "Dr. Joe," as he was affectionately called, loved to exercise on Old Main Hill on the USU campus. After walking up and down the Old Main steps several times, he suffered a severe heart attack the day before he died at age 74 years.

Caliendo was born in St. Louis, MO, and raised near Detroit, MI, where he met his future wife, Joyce Dorsey. Joe was a veteran who served in the U.S. Navy as a diver with the Seabees (1970-1972) doing underwater construction. He went on to earn degrees in oceanography and civil engineering, including a PhD in civil engineering from Utah State University. After working as the state geotechnical engineer for the Florida DOT (1986-1992), where he oversaw the design and construction of large bridges with complex foundation systems, Caliendo returned to USU and served as a professor of civil engineering from 1992 until the time of his passing. He was beloved by his students and took a genuine interest in their development.

Caliendo was a gifted educator in the classroom as an instructor, and a mentor on how to live life. For the geotechnical community, he was nationally known in the deep foundations arena, bridging academia and practice via numerous short courses. Nearly 20 years ago, he began teaching deep foundation short courses to state DOTs for the National Highway Institute and to engineers across the U.S., Puerto Rico, and Trinidad in ASCE's short course on deep foundations. Caliendo was possibly best known by geotechnical faculty as the organizer and director of the biennial Professors' Driven Pile Institute. The week-long course was designed to "educate the educators" with deep foundation professionals as teachers, and beginning professors as their students.

While Caliendo had many professional accomplishments, his most important personal success was his family. Caliendo and his wife raised five children and have 13 grandchildren. Joe once remarked, "I've found there are very few things in life worth collecting, but grandkids are an exception." Living life to the fullest to the end, he loved nature and being active outside, especially with his family. His USU colleague and friend professor Paul Barr said, "To those of us that were fortunate to work with Dr. Joe, he was in a class above them all. His personality was infectious, his generosity was unbounded, and his loyalty to family and friends was absolute. His passing has left a void that cannot be replaced."

Richard Campanella



Surrounded by his family, Richard Campanella passed away peacefully on July 10, 2019, in Vancouver. Affectionately known to everyone as "Campy," his name was synonymous with in-situ testing in the geotechnical engineering community. He was highly regarded as a professor, teacher, and researcher.

Campanella was born in New York, but studied at the University of California at Berkeley (UCB) from 1957 to 1965. He was the first PhD student of Professor James K. Mitchell at UC Berkeley studying strain-rate effects on soil. He was a professor in civil engineering at the University of British Columbia (UBC) for over 30 years, starting in 1965. He taught and mentored many graduate students. In the early stages of his time at UBC, he built

STATEMENT OF OWNERSHIP

GEOSTRATA

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I certify that the above statements made by me are correct and complete.

Charles V. Dinges, Aff.M.ASCE

Senior Managing Director of Strategic Communications, Government Relations, Marketing, and Membership at ASCE

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Total number of copies printed (net press run)	10,775	10,200
Sales through dealers and carriers, street vendors, and counter sales and other paid distribution outside USPS®	1,154	654
Mail Subscriptions:	8,897	8,635
Total paid and/or requested circulation	10,051	9,289
Free distribution outside county	1	1
Free distribution by mail carrier or other means— sample, complimentary, and other free copies	0	0
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a world-class laboratory. He was an early adopter of the personal computer and was one of the leaders in computer-controlled laboratory testing. In the mid-1980s, he moved his laboratory experience and knowledge into the field and constructed a unique, custom truck for in-situ testing. He rapidly became recognized as one of the leading experts in the new area of in-situ testing of soils. After testing all the main soil types within driving distance from UBC, he managed to take his truck to the Canadian arctic, as well as to several mine-tailings dams in western Canada, where he obtained valuable research data. During his early years in California, he spent a short time designing airplane parts. He put this skill to good use designing innovative, complex laboratory and in-situ testing equipment.

He leaves behind a legacy of outstanding research work that continues to inspire and aid geotechnical engineers worldwide.

// COREBITS **CHAPTERS**

Utah Chapter

In June 2019, the Utah Geo-Institute Chapter met with the Structural Engineers Association of Utah (SEAU), the Utah Section of ASCE, the Utah Chapter of the Earthquake Engineering Research Institute (EERI), the Utah Chapter of the Structural Engineering Institute (SEI), the Utah Geological Survey, and the Utah Division of Facilities Construction Management. The organizations presented a panel discussion of the Site-Specific Revision, from geotechnical and structural engineering perspectives, to *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7), as well as a revision of the USGS' Earthquake Tools and Applications to the International Building Code (IBC) 2018. The purpose of this workshop was to facilitate discussion on recent revisions to seismic ground motion provisions in IBC 2018 and ASCE 7. The panel discussed the basics of what should be included, and identified potential industry challenges associated with site-specific seismic studies. The ASCE 7 chapter highlights the recent changes in the USGS tools, and guides how these changes relate to the 2018 IBC generalized approach in the industry. Over 150 civil, structural, and geotechnical engineers from across the state of Utah attended the event.

▸ **PLEASE SUBMIT** G-I chapter and company news and career achievements to *GEOSTRATA* via *geostrata@asce.org*.

ASCE **EDUCATION and CAREERS**

ASCE/G-I Co-Sponsored Online Live Webinars

All posted webinars offer professional development hours (PDHs) as indicated.

- **ASCE Canon 8: Ethics Guiding the Profession to an Inclusive Future** (1 PDH)
  December 4, 2019
  12:00 PM - 1:00 PM ET
- **In-Situ Stabilization of Soil Slopes Using Nailed (or Anchored) Geosynthetics** (1.5 PDHs)
  December 5, 2019
  11:30 AM - 1:00 PM ET
- **Foundations for Metal Building Systems** (1.5 PDHs)
  December 12, 2019
  11:30 AM - 1:00 PM ET
- **Observation Method for Scour: A New Tool for the Bridge Engineer** (1.5 PDHs)
  December 13, 2019
  12:00 PM- 1:30 PM ET
- **Compaction of Soils and Properties of Compacted Soils** (1.5 PDHs)
  December 17, 2019
  11:30 AM - 1:00 PM ET
- **Installation, Design, and Performance of Prefabricated Drains, aka PVDs** (1.5 PDHs)
  January 17, 2020
  11:30 AM - 1:00 PM ET
- **(LRFD) for Geotechnical Engineering Features: Micropile Foundations** (1.5 PDHs)
  January 23, 2020
  11:30 AM - 1:00 PM ET
- **Complex Mechanically Stabilized Earth (MSE) Wall Structures** (1.5 PDHs)
  January 31, 2020
  12:00 PM- 1:30 PM ET

ASCE/G-I Seminars

All posted seminars offer continuing education units (CEUs).

- **Earth-Retaining Structures: Selection, Design, Construction, and Inspection** (1.4 CEU/14 PDHs)
  December 5-6, 2019
  Seattle, WA
- **Site-Specific Seismic Hazard Analysis and Design Ground Motions** (1.6 CEU/16 PDHs)
  December 5-6, 2019
  Charleston, SC
- **Application of Soil-Structure Interaction to Buildings and Bridges** (1.4 CEU/14 PDHs)
  January 23-24, 2020
  San Diego, CA

Guided Online Courses

Guided Online Courses are asynchronous, online, instructor-led programs in which you move through a 6- or 12-week learning experience with your peers. The Guided Online Course content includes video lectures, interactive exercises, case studies, live webinars, and weekly discussion topics to help you master the course material. Unlimited, 24/7 accessibility to weekly modules. Complete coursework at the time and pace that is most convenient for you, using your own devices. Courses offer continuing education units (CEUs).

- **Principles of Construction Contracting** (1.0 CEU/10 PDHs)
  January 27 – March 6, 2020
- **Quantity Take-Off: Structures** (1.0 CEU/10 PDHs)
  January 27 – March 6, 2020
- **Development of GIS Models for Asset Management** (2.3 CEU/ 23 PDHs)
  January 27 – April 17, 2020
- **Fundamentals of Crane Lift Plan Preparation** (2.3 CEU/ 23 PDHs)
  January 27 – April 17, 2020
- **Fundamentals of Water Treatment Processes: Physical, Chemical, and Biological** (2.3 CEU/ 23 PDHs)
  January 27 – April 17, 2020
- **Seismic Loads** (2.3 CEU/ 23PDHs)
  January 27 – April 17, 2020
- **Wind Engineering for Buildings** (2.3 CEU/ 23 PDHs)
  January 27 – April 17, 2020

On-Demand Learning

On-demand learning opportunities offer continuing education units (CEUs). Recorded from ASCE's most popular live webinars or in-person seminars, these courses allow you to hear the instructor's lecture, see the presentation, and listen in on questions from the audience.

For more information about webinars, seminars, guided online courses and on-demand learning, visit the ASCE Continuing Education website: *asce.org/continuing_education.*

Internships Available

Are you looking for an internship? Explore the positions listed on the ASCE website to help you obtain the experience you need to further your career path. New opportunities are added all the time, so start your search today: *careers.asce.org/jobs?keywords=internship.*

GEOSTRATA

COMING IN JANUARY/FEBRUARY 2020

Risk in Geotechnical Practice

INDUSTRY **CALENDAR**

2019

Geo-Structural Aspects of Pavements, Airfields, and Railways
November 4-7, 2019
Colorado Springs, CO
gap2019.com

Geo-Structures Confluence
November 8, 2019
St Louis, MO
sections.asce.org/st-louis/structural-and-geo-confluence-0

GeoMEast 2019
November 10-14, 2019
Cairo, Egypt
geomeast.org

Ohio River Valley Soil Symposium (ORVSS)
November 13, 2019
Louisville, KY
kgeg.org/orvss

3rd Annual G-I Web Conferences
December 2-6, 2019
geoinstitute.org/events/web-conferences-2019

2020

2020 Geo-Congress
February 25-28, 2020
Minneapolis, MN
2020.geocongress.org

Structures Congress 2020
April 5-8, 2020
St Louis, MO
structurescongress.org

Central Pennsylvania Geotechnical Conference
April 22-24, 2020
Hershey, PA
central-pa-asce-geotech.org

EWRI Congress 2020
May 17-21, 2020
Las Vegas, NV
ewricongress.org

UESI Pipelines Conference
August 8-12, 2020
San Antonio, TX
pipelinesconference.org

International Symposium on Frontiers in Offshore Geotechnics
August 16-19, 2020
Austin, TX
isfog2020.org

10th International Conference on Scour and Erosion
November 15-18, 2020
Arlington, VA
2020icse.org

2021

IFCEE 2021
May 10-14, 2021
Dallas, TX
adsc-iafd.com/ifcee-2021

For more ASCE conference information:
asce.org/conferences

// GeoPoem

By Katherine E. Zadrozny, PE, M.ASCE

Big Reputation

The structure's existence is beholden to its foundation.
Geotechnical engineers are charmed by the supporting groundwork
and humbled by the soil's secrets.
We cannot truly understand the ages seen
or forces felt by these minerals.
We attempt to break free from our time and space constraints,
to replicate materials and test soils
never fully knowing
the stresses, strains and transformations
that have brought this bit of Earth to our site.
We apply factors of safety
to build into and become a part of this ingenious planet,
so our fellow public can have clean water,
safe schools and work places,
parks and museums.
The structure becomes a beacon
between the Earth's internal light and that of the Heavens above.
Through the soil's support,
We realize our finite presence in the Earth's story,
and we become a piece of the fame. GS

KATHERINE E. ZADROZNY, PE, M.ASCE, a Hokie from Virginia, is a geotechnical engineer at American Engineering Testing, Inc., in St. Paul, MN. She can be reached at *kzadrozny@amengtest.com.*


Hilton Garden Inn – Boston, MA
The Edge Mixed Use – Cleveland, OH
Rolling Hills Wind Farm – Iowa
THE LOGOS
Union University Library – Jackson, TN
Engineered Aggregate Pier
Solutions for All Types of Structures
Grain Bins – Milmine, IL
St. Elizabeth's Hospital – O'Fallon, IL
Marble Alley Lofts – Knoxville, TN
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