Delwyn G. Fredlund, Ph.D., P.Eng, D.GE, O.C., F.E.I.C., F.CAE, M.ASCE

By Beshoy Riad, S.M.ASCE, and Robert Abbott, P.E., M.ASCE

For more than 50 years, Delwyn G. Fredlund has dedicated his career to research, teaching, and consulting in the area of unsaturated soil mechanics. He has pioneered the development of the underlying theory governing unsaturated soil behavior and its application to areas of slope stability, the design of laboratory test equipment, and development of software and numerical methods.

After obtaining his Ph.D. from the University of Alberta in 1973, Fredlund spent 34 years teaching and conducting research at the University of Saskatchewan in Saskatoon. His research studies have focused on unsaturated soil mechanics and numerical modeling. After retiring from the U of S, Fredlund joined Golder Associates as a senior geotechnical engineering specialist and principal, and he now assists with solving unsaturated soil mechanics problems worldwide. Fredlund is also a designer of unsaturated soil testing equipment for GCTS in Tempe, Ariz. He's the founder of Unsaturated Soil Technologies Ltd, Saskatoon, Canada, and a consultant to SoilVision Systems, Ltd., a software company dedicated to the modeling of saturated-unsaturated soil systems.

Throughout his career, Fredlund has shared his knowledge with the international community and has helped people in underdeveloped nations and regions around the world. He's implemented collaboration programs between Canada and China, Kenya, Uganda, and Vietnam.

Delwyn G. Fredlund

Fredlund has coauthored two textbooks: *Soil Mechanics for Unsaturated Soils* with Harianto Rahardjo in 1993, and *Unsaturated Soil Mechanics in Engineering Practice* with Rahardjo and Murray D. Fredlund in 2012. Fredlund has worked with numerous professional societies and committees around the world, including chairing the ISSMGE committee TC6 on Unsaturated Soils for 12 years. He's received numerous prestigious awards for engineering and community service. These include the 1999 R.F. Legett Medal from the Canadian Geotechnical Society for his significant lifelong contributions to the geotechnical field in Canada, the 2005 ASCE Terzaghi Award, and the 2009 R.M. Quigley Award for the best paper published in the *Canadian Geotechnical Journal* in 2008. He's also a recipient of the Order of Canada and is a member of the Canadian Academy of Engineering.

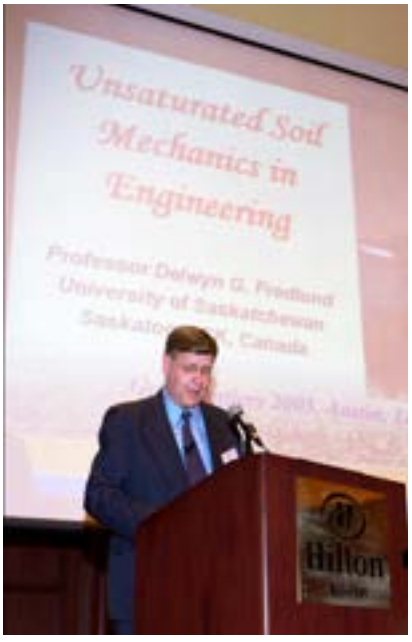
Q: How did you discover your interest in soil mechanics, and particularly unsaturated soil mechanics?

During my third year at the U of S, I was challenged by my class in soil mechanics and found that simple classification tests intrigued me. This interest may have been fueled by growing up on a small farm that grew grain crops, or possibly by my childhood interest in building small dams across a stream that ran through our farm. After my fourth year, I worked with the National Research Council of Canada to study the distress of light structures supported on shallow foundations bearing on highly plastic expansive soils. I learned much and benefited greatly from my early training at the NRC under the supervision of Jim Hamilton and Dr. Robert Legget, then NRC president, who encouraged me in my studies of expansive soil behavior.

Q: Early in your career, why did your interests change from industry to academia?

After two years working on consulting projects with R.M. Hardy and Associates in Edmonton, Alberta, I found that

Receiving the Order of Canada Award from Adrienne Clarkson, governor general of Canada, on behalf of the Queen of England in 2005 for excellence in engineering and involvement in charitable activities.



Delivering the 2005 Terzaghi Lecture, "Unsaturated Soil Mechanics in Engineering Practice," during Geo-Frontiers 2005 in Austin, Texas.

many key assumptions were needed to apply the analytical contributions made by the early fathers of soil mechanics, like Karl Terzaghi, Arthur Casagrande, and Donald Taylor. Those assumptions were an admission that we did not have a perfect science, but rather a "workable applied science." While I yearned to learn something new on every site I investigated, I had to resist the deep desire to turn each consulting project into a research study. Looking back to my early years after receiving my master's degree, the "pull" to undertake research-type studies tugged on my mind to find a better way.

Q: What can researchers do to get unsaturated soil behavior recognized by practitioners?

The principles and concepts fundamental to unsaturated soil mechanics must be taught as part of soil mechanics education. There's no way around teaching the theoretical and applied aspects of unsaturated soil mechanics and the assessment of the water balance at ground surface. Another value-added applications area is related to the assessment of instability of natural slopes subjected to varying weather conditions. Essentially, all geotechnical engineering projects involve interaction with varying weather conditions, and, consequently, varying net moisture flux at ground surface. It's not enough to simply write procedures and guidelines. Rather, geotechnical engineers should be "taken by the hand" on first-time projects to get started applying unsaturated soil mechanics.

Q: How can graduate students apply their training to the greatest benefit of the profession?

Of all disciplines in civil engineering, geotechnical engineering has the greatest need for engineers with a graduate degree because the standard four-year bachelor's degree doesn't provide sufficient training for geotechnical engineering practice. When I first graduated from civil engineering, the general thinking was that postgraduate M.Sc and Ph.D. degrees were requirements for people interested in academic positions. But today, consulting firms commonly boast that more than 50 percent of their geotechnical engineers have graduate degrees. I think that it's fair to say that geotechnical engineers should never feel they have too much training when it comes to understanding the complexities of soil mechanics.

Q: How does your career compare with your thinking from 50 years ago?

I now realize that I had little understanding of what the practice of soil mechanics involved when I started. I had no idea where it would lead — but that's the way life should be lived. I never laid out a career plan for what I'd do next year, let alone during the next decade. Rather, my career simply unfolded day-by-day and melded into year-by-year. Looking back, I could never have imagined how much engineering technology would change in 50 years and where it would lead me. I've been fortunate to work with many brilliant mentors and graduate students along my geotechnical journey. I'm grateful for all their contributions and guidance over the years.

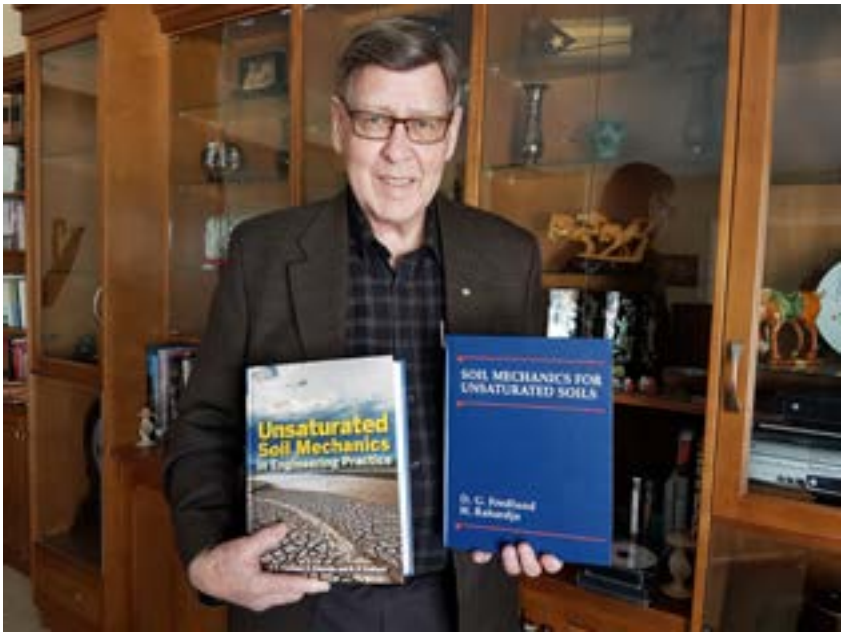
Q: Should we rethink the principles related to saturated soil behavior, and what, if any, are they?

I strongly believe there are fundamental principles that should guide the development of any applied science. These principles should form the basis for studying any material, including saturated and unsaturated soils. They're clearly laid out within the general context of continuum mechanics, which form the basis for a "unified soil mechanics" for engineering practice.

Continuum mechanics teaches us that, to assemble an applied science for any material behavior, it's essential to identify a set of state variables that are independent of the material properties. The starting point related to acceptable state variables applies for all materials. The next fundamental principle of continuum mechanics is related to the role of constitutive relations, which are needed to provide functional relationships between state variables. These are not complex truths, but they can be taught to our undergraduate students while dealing with materials such as concrete and steel. I believe that saturated and unsaturated soil behavior should be presented in a similar context.

Q: What sparked your interest in writing *Unsaturated Soil Mechanics*, and what was the most memorable experience or challenge during its writing?

In 1983, Harianto Rahardjo, a graduate student from Indonesia, came to me after completing my graduate class in unsaturated soil mechanics and suggested I write a book on the topic. Then, about a week later, he told me that he wanted to help me write the book. It took us a decade, but one reason it took so long was the fact that no other texts had been written on the subject. As a guide, we used recent textbooks written on saturated soil mechanics, and then attempted to essentially parallel the applied science that had emerged for saturated soils.



Fredlund with his two textbooks, *Unsaturated Soil Mechanics in Engineering Practice*, coauthored with Harianto Rahardjo and son Murray D. Fredlund in 2012, and *Soil Mechanics for Unsaturated Soils*, coauthored with Rahardjo in 1993.

Q: What's your view of how today's geotechnical engineers use technology?

Technological advances have played a significant role in how geotechnical engineering is practiced. This is particularly true when using numerical modeling for unsaturated soil mechanics applications. Numerical modeling has proven to be particularly valuable in assessing likely soil behavior for all possible boundary conditions and soil properties. Numerical models allow engineers to respond to a wide range of "What if?" questions that could be asked.

Using numerical models this way means that the assumption is made that if the physical (unsaturated soil) behavior is verified by laboratory research and testing, then the soil will likely behave similarly under in-situ conditions (i.e., field verification is not required). There are, however, areas in unsaturated soil mechanics where technological advances have not been as rapid as desired. For example, it's been a challenge to measure soil suctions in situ.

Q: What's the best experience/anecdote you've had as a professor at the University of Saskatchewan?

A graduate student from a middle eastern country arrived at the university in mid-July to start on a graduate program, but by late October I noticed that he wasn't in class. I telephoned him to ask if he was sick. He said no, he was OK, but he felt that it was too cold to go outdoors, so he was staying home!

Graduate students were an integral part of our family life as our four children grew up. Each Saturday evening our home was open for playing Ping-Pong. Many students were exceptional Ping-Pong players, but somehow, they seemed to always allow me to periodically win a game!

Q: What's the "internationalization" project, and what lessons have you learned and shared with others?

An inherent aspect of "internationalization" is sharing. I grew up in a family that believed in sharing with others, so it was only natural that I should develop a belief that there should be a charitable component to my life.

Signing ceremony upon completion of translating *Soil Mechanics for Unsaturated Soils* into the Chinese language. Translation was headed by Professor Chen Zhong-Yi, Tsinghua University, Beijing, China.

Po Shan landslide on Hong Kong Island in 1972.

During my university career, I traveled to developing countries and saw the extreme needs there, and wondered if I could be helpful in some way.

In 1993, when I was living in Singapore, I traveled to Vietnam for one week. My contact from the Ministry of Construction arranged for impromptu talks at several universities in Hanoi. After each talk, I'd ask, "What do you need most?" I'd tell them, "I have nothing to offer, but I'd be interested in knowing what you perceive to be your greatest need." Surprisingly, they needed technical books for their empty libraries. After returning to Canada, I embarked on a venture that I'd never before considered. I asked for and received several thousand used civil engineering technical books. Eventually, I shipped two, 20-ft shipping containers of books and soil-testing equipment to Hanoi. The Canadian government later responded through one of its aid programs with several hundred thousand dollars of financial support. This opened the way for a variety of further ventures, such as funding graduate students to study at the U of S. Some students stayed in Canada, but others returned to Vietnam to take on leadership roles in their universities and the government of Vietnam.

Looking back to those days almost 30 years ago brings me satisfaction in realizing that I could become involved in sharing, even within the bounds of my professional career. And there were so many other side benefits along the way. There was the ability to obtain cataract surgery for blind children, raising funds for the building of schools, and assisting those overcome by addictions. So what began as an adventure has produced many pleasant and lasting memories.

Q: What project are you most proud of, and why?

In 1972, a landslide in the Po Shan district of Hong Kong collapsed a high-rise residential building that killed 78 people. I was retained to visit Hong Kong and take part in research to study slope-stability problems experienced there. Surprisingly, we found matric suctions were largely static over a 25-m soil profile throughout the rainy season, with the exception of a modest decrease in suction in near-ground surface soils and near the water table where its level rose in response to heavy rainfall. Because of this and numerous other studies, it became common practice to cover the soil surface with a material called "chunam" to reduce infiltration by about 90 percent, which greatly improved the overall stability of steep slopes.

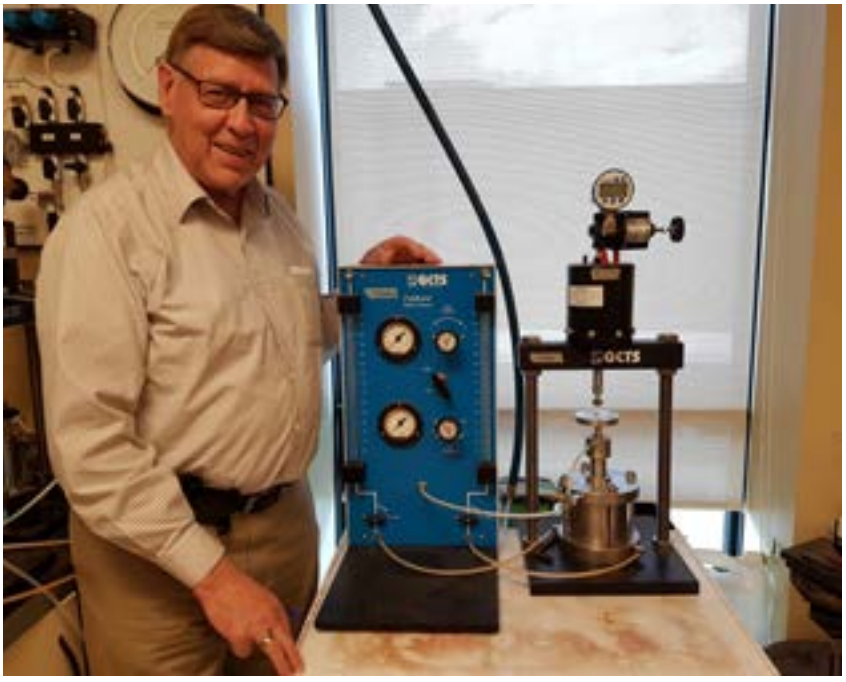
Q: Have you ever had a moment of failure in your professional life? How did you manage it, and what did you learn that helped you in the future?

I'm reminded of writing my first research paper based on the importance of independent stress state variables for the application of unsaturated soil mechanics from my Ph.D. thesis. I submitted the paper and waited and waited for the reviews. Not only was this subject matter important to me, it constituted the heart of my lifetime research. After almost two years of waiting, three reviewers recommended publication, and three reviewers recommended its rejection. The editor decided *not* to publish the manuscript. Needless to say, I felt dejected!

On the verge of tears, I visited my Ph.D. adviser, Dr. Nobert Morgenstern, who suggested trying to publish in another journal. Three months later, the manuscript was published with no revisions, and one year later I received notice that the Canadian Geotechnical Society was presenting me with the Colloquium Award, given annually to a young engineer it deems able to make the most significant future research contribution in geotechnical engineering. That was a good learning experience for me in handling times of failure and not taking such experiences as personal rejection. It also taught me that some of my best papers, at least to me, have been the hardest to get published!

Q. What's the greatest challenge(s) geotechnical engineers face today?

The greatest challenge involves our willingness to find and agree upon paths of compromise as it relates to finding the best pathways for improving the application of soil mechanics as an applied science. Many factors must be balanced. There needs to be value-added benefits that are forthcoming as a result of changes in protocols. We need to get the right balance between cost and benefits accrued. There's a way forward for improved methodologies for both saturated and unsaturated soil mechanics. At the same time, we must take responsibility for selling our technology protocols.



Fredlund designed a new pressure-plate testing device for GCTS that can apply soil suctions up to 1,500 kPa and Ko total stress loading, and continuously monitor overall volume changes and water volume changes.

Q: Did you ever have an "aha" moment about one of your proposed testing and/or design methods, and what was that like?

Morgenstern planted into my mind the seeds of his thinking about independent state variables and the phenomenological continuum mechanics approach to unsaturated soils. My "aha" moment came when I awoke from a dream one night realizing that the state variables needed to form a science-based framework for unsaturated soil mechanics, and that required application of the conservation of energy and mass — the two most fundamental precepts of physics. After having the same dream for three consecutive nights and writing down the mathematical formulation, the fundamentals were clear to me and have remained unchanged ever since. I feel we often get so busy doing things that we don't take time to think.

Q: After such a long and successful career, what keeps you going?

The love of learning. The world around us is filled with unknowns, but we've been given one powerful "tool" that drives us toward getting a better understanding of our world — the Scientific Method. It doesn't matter whether we're looking at a flower or at the soil in which the plant's roots are embedded. There are hundreds of questions that come to our mind. Each question that gets answered simply reveals more questions still waiting to be answered.

Solomon said in Ecclesiastes 12:12, "Of making of many books there is no end and much study wearies the body." My desire to learn gives me a desire to keep going. I've never viewed myself as being a brilliant researcher, but I enjoy attempting to visualize where the future should lead us.

Musicians Del and JoAnne at home during the COVID-19 pandemic.

Q: What's your advice for time management?

During my graduate program, a wise professor told me, "Don't sell your soul to a company or a university, because these entities don't have a soul." It seems like a cruel statement, but there's a lot of truth in it. We must balance family commitments and work, and we should honor one day in seven for complete diversion from the activities of the rest of the week. I also suggest getting plenty of sleep each night.

Q: What was your source for formulating so many innovative ideas to study and test unsaturated soils, and putting them into action?

Earlier, I mentioned Norbert Morgenstern. I could never spend long hours in discussion with him, but when we did meet, I felt I had received seeds of truths and ideas that were pivotal to my understanding of multiphase systems. He inspired me, planting ideas in my mind. His ability to balance his understanding of mathematics and the physics of material behavior proved to be just what I needed to hear. Innovative thinking is also important, and that comes mainly through thought experiments.

Q: A little birdie has told us about the Fredlund family's musical talents. How has music kept you and your family going during the pandemic?

Music has been an important part of my life. While growing up, my parents shared their love of music and encouraged each of their children to play musical instruments. I started playing the mandolin, but graduated to the E-flat alto saxophone. I never took a lesson, but taught myself. When I left home to attend the university, my mandolin and saxophone came with me, to the dislike of my landladies, who felt I made too much noise. This all changed when I met the person who I felt was the best piano player in Canada! She had two degrees in piano performance, so she needed to have patience with me. I married her, and that solved my music (noise) problems!

Throughout my life, playing the saxophone has served well as a distraction from my engineering responsibilities. During the past year, music has truly served as a welcomed diversion during the COVID pandemic. I try to have a portion of each day devoted to music on the saxophone.

Q: If you did it (career or life) all over again, what would you change (or keep the same)?

That's hard to say because wishing for more than I've experienced would simply be selfishness on my part. I say, "thank you" to the people from many countries who have welcomed me into their homes and their hearts. I recall the wife of a government official in Vietnam asking me, "Why did you come to Vietnam, and why do you keep coming back?" My answer is summed up in my life's desire: "If I live my life for myself, I will feed my ego, and when life is over, I will have nothing; but if I live my life for others, I will feed the soul, and my life will have increased meaning." I've tried to live by what I've told our four children: Find needs and try to meet them! GS

Authors Beshoy Riad (l) and Robert Abbott (r).

BESHOY RIAD, S.M.ASCE, is a Ph.D. candidate at the Missouri University of Science and Technology in Rolla, Mo., where he conducts research on constitutive modeling of the hydromechanical behavior of unsaturated soils with consideration of the hysteresis behavior. He can be contacted at *beshoy.riad@mst.edu*.

ROBERT ABBOTT, P.E., M.ASCE, is a Ph.D. candidate in the Department of Civil, Architectural, and Environmental Engineering at the Missouri University of Science and Technology in Rolla, Mo., and an associate with Burns & McDonnell in Kansas City, Mo. He can be contacted at *raazxc@mst.edu*.