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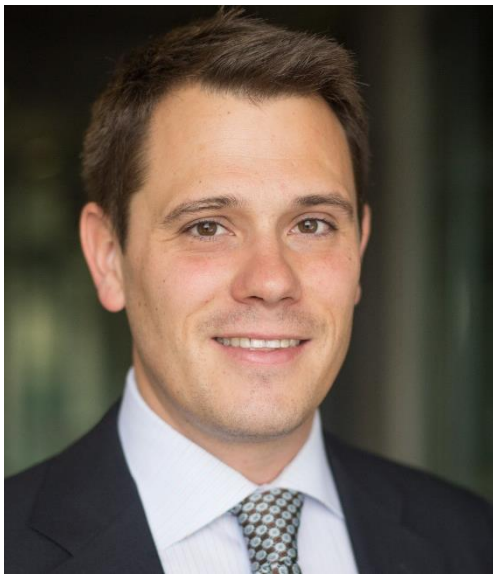
Unsaturated Soil Mechanics instruction: Guiding the non-specialist instructor

A panel discussion with panelists Sandra Houston, John McCartney and Alessandro Tarantino, moderated by Marina Pantazidou (a TC106-TC306 collaboration) and organized during the 8th International Conference on Unsaturated Soils.

Sandra Houston

Sandra Houston is Professor Emerita in the School of Sustainable Engineering and the Built Environment at Arizona State University. Professor Houston's contributions to the field of geotechnical engineering focus on unsaturated soils and arid region problem soils, including in particular collapsible and expansive soils and unsaturated flow. Sandra has served in numerous leadership positions in the American Society of Civil Engineers (ASCE), Geo-Institute (GI), and the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE). She is a recipient of the 2017 ASCE Terzaghi Award, the 2004 William H. Wisely American Society of Civil Engineers Award, the 2018 Distinguished Lecturer for the Pan-American Unsaturated Soils Conference series, and the 9th Pedro de Alba lecturer. Professor Houston has also served as president of the Geo-Institute, and chair of the ASCE Board-level Committee on Diversity and Inclusion. She was the formational Chair of the GI Committee on Unsaturated Soils and served for many years as a USA representative and secretary of the TC106 Committee on Unsaturated Soils.



John McCartney

John S. McCartney is a Professor in the Department of Structural Engineering at the University of California San Diego, specializing in Geotechnical and Geoenvironmental Engineering. His research interests include unsaturated soil mechanics, geosynthetics engineering, and energy geotechnics. His research in unsaturated soil mechanics has focused on the dynamic response of unsaturated soils, compression response of unsaturated soils to high stresses, hydraulic interaction between unsaturated soils and geotextiles, and impacts of temperature on the behavior of unsaturated soils in geo-thermal heat exchange and heat storage applications. His research has been recognized by the Quigley award from CGS in 2020, the Walter L. Huber Research Prize from ASCE in 2016, the Casagrande Award from ASCE in 2013, the J. James R. Croes medal from ASCE

in 2012, the DFI Young Professor Award in 2012, the NSF CAREER Award in 2011, and the IGS and Young IGS Awards from the International Geosynthetics Society in 2018 and 2008, respectively. He is the chair of the ASCE GeoInstitute Committee on Unsaturated Soils. He is an editor of Computers and Geotechnics, an associate editor of Canadian Geotechnical Journal and serves on the editorial boards of Geotechnical Testing Journal, Geomechanics for Energy and the Environment, and Geosynthetics International. He received B.S. and M.S. degrees in Civil Engineering from the University of Colorado Boulder in 2002 and a Ph.D. degree in Civil Engineering from the University of Texas at Austin in 2007.

Alessandro Tarantino

Alessandro Tarantino is Professor of Experimental Geomechanics at the University of Strathclyde in Glasgow, Scotland. His current research interests include the direct measurement of water tension in soils and plants, micromechanical behaviour of saturated and unsaturated clays, soil-plant-atmosphere interaction, and stability of natural and engineered slopes subjected to rainwater and floodwater infiltration. He has led major European consortium research projects including the Marie Curie European Training Network 'TERRE ('Training Engineers and Researchers to Rethink geotechnical Engineering for a low carbon future, 2015-2019). He is co-editor of the books 'Advanced Experimental Unsaturated Soil Mechanics' (2005) and 'Laboratory and Field Testing of Unsaturated Soils' (2009). He has been keynote/theme lecturer at numerous International Conferences (the 16th IACMAG Conference 2022 the most recent one) and will deliver the next ICE Géotechnique Lecture (October 2023).

Marina Pantazidou

Marina Pantazidou is an associate professor at the Civil Engineering School of the National Technical University of Athens, Greece. Apart from university appointments in the US and Greece, her professional experience also includes work in hazardous waste consulting. Her research topics are drawn from environmental geotechnics and engineering education. She is author of 100 publications, 25 of which on geotechnical engineering education topics. She has been a guest editor for two special issues on geotechnical engineering education, one on case studies developed for geotechnical engineering instruction. She has been actively involved with the Hellenic Society for Soil Mechanics and Geotechnical Engineering (secretary general 2012-2015 and board member 2015 -) and the ISSMGE Technical Committee TC306 on Geo-engineering Education (core member 2010-2013, vice chair 2013-2017, chair 2017 -). She chaired the ISSMGE Int. Conf. on Geotechnical Engineering Education GEE2020, (streamed from) Athens, Greece, June 23-25, and has been elected to deliver the ISSMGE-TC306 3rd John Burland Honour Lecture.

▶ GOAL FOR THE UNSAT2023 PANEL ON EDUCATION: Answer potential questions by non-specialists

What follows is the perspective –in the form of questions– phrased by a non-specialist, Marina Pantazidou, after being tutored by a specialist, Michael Bardanis. This collaboration was crucial: without the specialist's involvement, the non-specialist would not have the necessary stamina to translate bewilderment about issues in Unsaturated Soil Mechanics (UNSAT SM) into questions. The goal of the collaboration was to involve panelists in order to produce as a team an UNSAT Soil Mechanics Q & A collection that will be helpful to Soil Mechanics instructors willing to include some elements of UNSAT Soil Mechanics in their courses.

The questions are grouped under topics typically addressed in an introductory course in Soil Mechanics/Geotechnical Engineering. A few more advanced questions are also included in order to give a broader perspective. Panelists providing answers have been asked to keep in mind the different aims of instructors and, if possible, provide answers suitable for each aim. A gradation of three such aims –all modest– is described below:

I. Instructor aims to remove from her notes/lectures something that is "plainly wrong" (unacceptable) from an UNSAT SM perspective. Here we focus on students not having to unlearn something before expanding their own UNSAT SM knowledge in a subsequent course.

II. Instructor aims to clarify that a statement or an equation in her notes is –from an UNSAT SM perspective– a simplification, and state the range of validity of the statement/equation. The focus here is on alerting the students that they are taught about only part of the picture: they learn principles and calculations suitable for only subsets of reality (e.g. only saturated soils). Note: Aim (II) includes aim (I).

III. Instructor aims to create "receptors" for future knowledge about UNSAT SM. This is the most ambitious of the three modest aims: when students see something in a more advanced geotechnical engineering course, they will recognize that it fits with what they have seen in the introductory course.

▶ LIST OF QUESTIONS

GROUP OF QUESTIONS A: Soil profile above the water table

- **1.** What is the distribution of pore water pressure above the water table in the field? In a soil column?
- **2.** May we talk of an "equilibrium" water pressure distribution in the field other than hydrostatic?
- **3.** Is it reasonable to assume that equilibrium conditions are rare in the field for low permeability soils?

GROUP OF QUESTIONS B: "Effective stress" or in general "variables we need to keep track of in order to describe and predict soil behavior"

- **4.** From the perspective of an UNSAT SM specialist, can the existing alternative expressions for effective stress that include both air pressure and water pressure be excusable for explaining concepts in an introductory course? [Example: Bishop's Equation: $\sigma' = \sigma - u_a + \chi (u_a - u_w)$]

• **5.** What is really the "claim to prediction" of effective stress? (Textbooks do not agree: see Appendix on last page.) If we have excused other description/prediction failures of the effective stress for saturated soils, then why are we so strict for the failure of effective stress to describe/predict states in unsaturated soils?

GROUP OF QUESTIONS C: Sandcastles & other demonstrations for effective stress (e.g. Elton, 2001)

• **6.** Is it wrong to tell students that sand castles stand due to higher effective stress? Should we say instead that the castle stands due to higher shear strength?

• **7.** Is it wrong to tell students that vacuum-packed coffee is strong due to higher effective stress?

GROUP OF QUESTIONS D: Shear stress

• **8.** In my course, I teach the Mohr-Coulomb criterion for shear strength ($\tau' = c' + \sigma' \tan\phi'$). I see that in UNSAT SM there are a few alternative expressions, e.g. Jaksa (2020) gives the following two:

$$\tau_f = c' + \left[(\sigma - u_a)_f + \chi_f (u_a - u_w)_f\right] \tan\phi' \quad (1)$$

$$\tau_f = c' + (\sigma - u_a)_f \tan\phi' + (u_a - u_w)_f \tan\phi^b \quad (2)$$

I do not know what to make of this variety, so I prefer say nothing about unsaturated strength to my students. Do I have a simple better alternative than say nothing?

• **9.** Is there any simple demonstration based on principles (not on examples, e.g. sand castles) of suction contributing to shear strength?

ADVANCED GROUP OF QUESTIONS E: Motivation

• **10.** I get the impression that the answer to the question "which shear strength equation to use" is contested within the UNSAT SM community (see also Question No 8). Is this question a main issue for UNSAT SM? If not, perhaps we could withhold judgement and focus on more important/applied issues?

• **11.** Which geotechnical problems require UNSAT SM for the analysis that will produce their solution?

• **12.** Are there any applications of UNSAT SM in the field? Has the UNSAT SM community recorded some case studies?

ADVANCED GROUP OF QUESTIONS F: Evidence

• **13.** After so many years of being taught and teaching about effective stress, it is hard to give it up. Do I understand correctly that its main failure for UNSAT soils is in predicting volume change? Or deformation? Or both?

• **14.** Please give me some carefully selected annotated results, ideally both in the lab and the field, showing the inability of effective stress to predict … (whatever is the answer to Question 13 above) and the successful prediction of a suitable UNSAT SM approach.

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APPENDIX – **what do we read about effective stress in current textbooks** (Atkinson, 2007; Briaud, 2013; Budhu, 2011; Powrie, 2014).

Atkinson (2007: p 70) quotes Terzaghi's (1936) strong definition: "all measurable effects of a change of stress, such as compression, distortion, change of shearing resistance, are due exclusively to change in effective stress". Then on page 71 he comments: "No conclusive evidence has yet been found that invalidates Terzaghi's original postulate, at least for saturated soils at normal levels of engineering stress, and the principle of effective stress is accepted as an axiom in Soil Mechanics".

Briaud (2013: p 252) says only that the effective stress "is one of the most important parameters to know when dealing with soils".

Budhu (2011: p 152) says in bold italics "***Deformations of soils are a function of effective stresses, not total stresses***."

Powrie (2014: p 22) states in his usual succinct style "It is the effective stress which controls the volume and strength of soil."

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