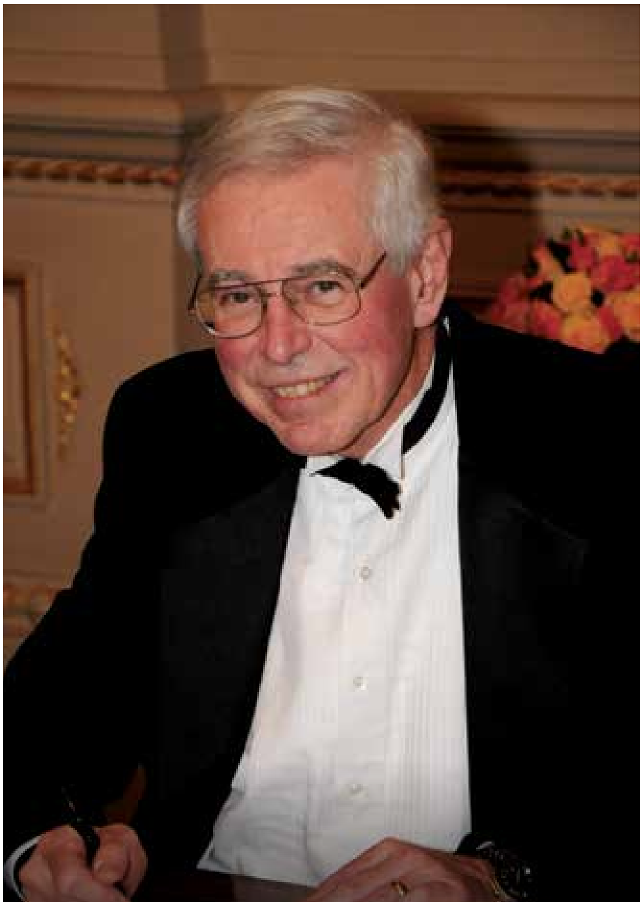
Thomas D. O'Rourke, PhD, Dist.M.ASCE, NAE

By Suguang (Sean) Xiao, EIT, S.M.ASCE, Hai (Thomas) Lin, EIT, S.M.ASCE, and Hanna Moussa Jabbour, S.M.ASCE



O'Rourke signs the membership book during his induction ceremony for the Royal Academy of Engineering. (Photo courtesy of the Royal Academy of Engineering.)

Professor Thomas D. O'Rourke has worked in geotechnical engineering for more than 40 years. He earned his BS in civil engineering at Cornell University in 1970 and his PhD in civil engineering at the University of Illinois at Urbana-Champaign in 1975. He currently holds the Thomas R. Briggs Professorship in Engineering at Cornell University. Some of his most extraordinary work involves geotechnical and earthquake engineering for large, geographically distributed systems, such as water supplies, energy delivery networks, and transportation facilities.

O'Rourke has taught approximately 10 courses at both the undergraduate and graduate levels, including planning and engineering for critical infrastructure, retaining structures and slopes, foundation engineering, introduction to geotechnical engineering, rock engineering, geoenvironmental engineering, and geotechnical engineering design project. He received the Daniel Lazar '29 Excellence in Teaching Award (1998) and the Kenneth A. Goldman '71 Excellence in Teaching Award (2003) from Cornell University.

O'Rourke was a geotechnical and/or lifeline expert in many post-earthquake reconnaissance missions, such as the Ecuador (1987), Armenia (1988), Loma Prieta, CA (1989), Kobe, Japan (1995), and Kocaeli, Turkey (1999) earthquakes. He has assisted with the recovery of Christchurch, New Zealand, after the Canterbury Earthquake Sequence (2010-2011), and chaired the international peer reviews of the Ministry of Business, Innovation, and Employment guidelines for foundations and foundation improvements

Examining the damaged Granada Trunk Line after the 1994 Northridge earthquake in the San Fernando Valley in California.

for residential buildings, Earthquake Commission (EQC) evaluation of liquefaction land damage and shallow ground improvement fields trials, and increased liquefaction vulnerability assessment for review by the New Zealand High Court. He was a member of the National Academies Committee on New Orleans Regional Hurricane Protection Projects to evaluate the performance of the hurricane protection system (HPS) of New Orleans following Hurricane Katrina. Professor O'Rourke led a team to determine the effects of the World Trade Center Disaster (9/11) on the New York City water supply, electric power, telecommunication, and underground transportation networks.

O'Rourke authored or co-authored more than 370 publications on geotechnical engineering, underground construction technology, geographically distributed systems, earthquake engineering, impact of extreme events on civil infrastructure, and infrastructure rehabilitation. Since 1995, he has delivered 155 invited lectures, keynotes, and conference presentations worldwide.

O'Rourke's outstanding contributions have been well recognized through numerous awards and honors. Select awards include the ASCE Charles Martin Duke Lifeline Earthquake Engineering, Stephen D. Bechtel Pipeline Engineering, and Ralph B. Peck awards, as well as the LeVal Lund Award for Practicing Lifeline Risk Reduction. He received the 2016 Earthquake Engineering Research Institute (EERI) George W. Housner Medal. He was the 2008 Rankine Lecturer and 2016 Karl Terzaghi Lecturer. He is a member of the National Academy of Engineering (1993), an International Fellow of the Royal Academy of Engineering (2014), a Distinguished Member of ASCE (2014), a Fellow of the American Association for the Advancement of Science (2001), and an Honorary Member of EERI (2013).

Q: When did you discover the research need of soil-pipeline interaction?

I started working on soil-pipe interaction during my PhD work on the Washington DC Metro. I was working on instrumenting the excavation for the Gallery Place Station. Some ground movements occurred during the excavation phase of the construction. We were concerned primarily about the effects of the ground movement on the National Portrait Gallery, which was located about 5 ft from the edge of the excavation. However, there were also many pipelines in the road north of the excavation that were not receiving attention. I was interested in how they might be deforming. So, when we set up our settlement survey, we put settlement points on the Gallery buildings north of the excavation, and on the street surface over underlying pipelines. Many times, when you have a deep excavation or a tunnel, it affects the pipelines before it affects the buildings. At that time, people were principally concerned about the effects of differential settlement on buildings. I was concerned about the effects of differential settlement *and* lateral displacement on buildings, both of which were caused by the excavation. I also questioned what the ground movement was doing to the pipelines. So I started looking at the behavior of different types of pipeline in response to ground deformation. Eventually I began studying how pipeline systems responded to ground deformations and to earthquake effects, and started to numerically simulate these effects on entire systems.

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Q: What's the difference between the effects of earthquakes on tunnels and pipelines?

A circular tunnel is a large cylinder, and the most meaningful deformation caused by interaction with seismic waves is cross-sectional distortion. Tunnel liners are thin relative to their diameter, and their primary response in an earthquake is racking into an oval shape from shear wave propagation. This type of deformation results in circumferential bending stresses. A pipeline has a much smaller diameter, and its main response is in the longitudinal direction with respect to seismic waves. Therefore, pipelines tend to deform as beams or beam columns that experience primarily tension and compression due to interaction with seismic waves. Some pipelines have the diameters of little tunnels. For example, transmission and trunk lines supplying water to Los Angeles may have relatively large diameters on the order of 10 ft.

From l to r: Suguang (Sean) Xiao, Hanna Moussa Jabbour, Prof. O'Rourke, and Hai (Thomas) Lin at Cornell.

Q: What did you learn as a student that most directly influenced your success?

Combining geology with structural and solid mechanics is the essence of geotechnical engineering. Too often, people aren't as well prepared in geology as they should be. Understanding the geologic origins of soil and rock, stratigraphy and structure, and stress history provides an invaluable framework for evaluating engineering properties and characterizing site conditions. Understanding the basics of geohydrology is likewise important and essential for underground flow characterization, effective stress assessment, control of water during construction, and stabilization of slopes and excavations.

O’Rourke stands on ground deformed by liquefaction near the Nishinomiya-ko Bridge after the 1995 Kobe earthquake in Japan.

Q: Based on the Hurricane Katrina investigations, what did geotechnical engineers do well, and where do they need to improve?

Expanding on the lessons from Hurricane Katrina, geotechnical engineers have made major contributions to the recently constructed Hurricane and Storm Risk Reduction System in New Orleans that has substantially improved protection against storm surge and flooding with state-of-the-art facilities, such as the Inner Harbor Navigational Canal-Lake Bourne Surge Barrier. Hurricane Katrina, however, raises many important questions at many different levels, some of which are still unresolved. In addition to geotechnical problems of subsidence, erosion, site characterization, and HPS loading and failure mechanisms, Hurricane Katrina reveals issues on a larger scale. The sustainability of New Orleans is part of broader problem associated with the sustainability of the 25000 km^2 Mississippi Deltaic Plain.

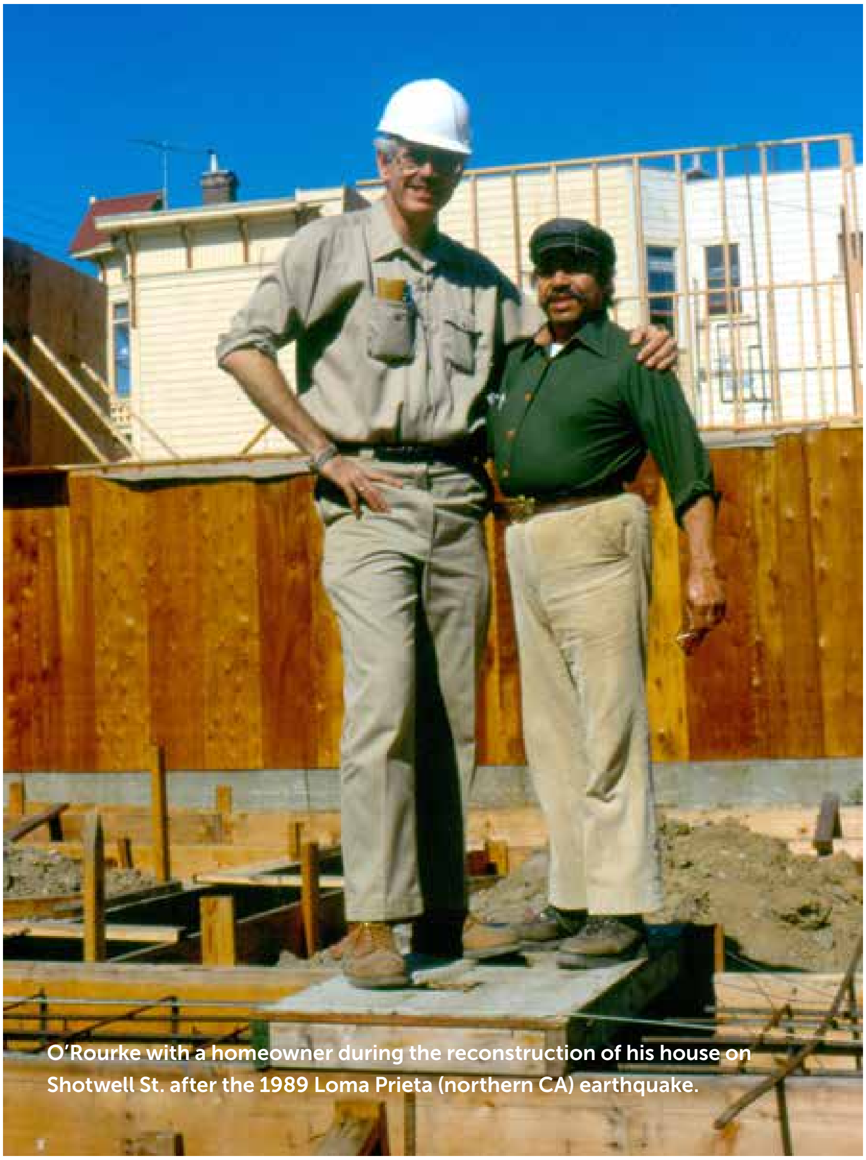
Q: Please talk briefly about the concept of “new normal” for natural disasters?

I took the phrase “new normal” from language used after the 2008-2009 financial crisis. A well-known financial advisor, Mohamed El-Erian, coined the phrase to illustrate that the world of finance has been normalized by elevated levels of risk that we never knew existed until the banks almost collapsed. The financial crisis and its normalizing effects was perhaps the most effective lesson ever learned in public risk perception, and I thought that a similar concept could be applied to natural disasters. Within recent years, we have witnessed the 2004 Sumatra-Andaman and 2011 Tohoku earthquakes and tsunamis, 2010 Maule earthquake, 2010-11 Canterbury Earthquake Sequence, Hurricanes Katrina and Sandy, and Typhoon Haiyan. Three of these earthquakes are among the largest six ever recorded. The severity and far-ranging consequences of these extreme events have established in effect a new normal for natural disasters. It’s imperative that we develop sound planning policies and design concepts to better prepare for mega disasters. Instead of being rare events, mega disasters are likely to be experienced several times in the coming decade.

Another feature of the “new normal” concept is that some infrastructure is too big to fail, just like some banks are too big to fail. Examples include the hurricane protection system (HPS) in New Orleans and nuclear power facilities in Japan. Clearly, the 565-km-long HPS and 54 nuclear reactors in Japan are infrastructure that are too big to fail. Perhaps we had to experience such failure to learn that we cannot afford to repeat the lessons. The failure of the Fukushima Daiichi Power Plant from the tsunami after the Tohoku earthquake not only toppled nuclear power in Japan, but had worldwide consequences in the disavowal of nuclear power in Germany and

Switzerland. Had the Tokyo Electric Power Company realized that a tsunami would overtop its flood protection system and inundate the diesel generators in its turbine buildings, the company would surely have moved the diesel generators to an elevated location above the flood waters. Recognizing that some infrastructure is too big to fail, work is now being done to evaluate the consequences of a San Andreas Fault rupture cutting off the water supply to southern California as part of the resilience plan adopted by Los Angeles.

The application of probabilistic concepts in modern engineering has been enormously successful in protecting critical infrastructure. Nevertheless, when one gets into the tail of a probability curve, one is not sure how rare a very low probability event really is. In addition to designing for low probability events in terms of long recurrence intervals, it would be advantageous also to perform a sanity check on the critical infrastructure by asking, "What would happen if the rare event is exceeded?" If such queries were professionally sanctioned and required, such an audit would have led to moving the diesel generators at Fukushima to a higher elevation as a low-cost action against losing infrastructure that's too big to fail. We need protocols for such audits on our most sensitive and critical infrastructure.



O'Rourke with a homeowner during the reconstruction of his house on Shotwell St. after the 1989 Loma Prieta (northern CA) earthquake.

Q: Could you talk about some lifeline systems you have worked on?

Examples of lifeline systems include water supplies, electrical power, telecommunication, gas and liquid fuel, waste water conveyance and treatment, and transportation. The importance of geotechnical engineering on lifeline performance is illustrated by the 1906 San Francisco earthquake. When firemen turned on the hydrants after the earthquake, there was no water because soil liquefaction had caused water supply pipelines to break up. Approximately 490 city blocks burned to the ground, an additional 32 blocks were severely damaged, and 28,000 buildings destroyed, making this event the greatest single fire loss in U.S. history. Pipelines damaged by ground failure deprived firefighters of water, leading to massive building losses from fire.

After that earthquake, the Auxiliary Water Supply System (AWSS), a water distribution network exclusively for fire protection, was constructed. Cornell University researchers modeling the AWSS collaborated with engineers at EQC led by Dr. Charles Scawthorn, who modeled fire initiation and spreading. The results of the coupled water supply and fire simulations were presented to the San Francisco mayor and other city officials, and a bond measure was passed in 1987 for $46 million with 89 percent voter approval to provide funding for rehabilitation of the AWSS and other fire-related infrastructure. A Portable Water Supply System (PWSS) was developed, consisting of special vehicles, called hose tenders, carrying about 1.5 km of 125-mm-diameter hoses and above-ground hydrants. The fire that erupted in the Marina district of San Francisco after the 1989 Loma

Prieta earthquake was suppressed by the PWSS. The water supply modeling performed at Cornell correctly predicted liquefaction and loss of water in the existing underground pipelines, and was a key factor in developing the successful alternate fire protection measures in San Francisco.

Q: If you had to pick just a couple of your published papers, which do you consider the most notable?

The 2009 Rankine Lecture on the geotechnics of large geographically distributed systems and the paper I coauthored with Wayne Clough on ground movements caused by deep excavations and their influence on adjacent buildings:

- "Geohazards and large, geographically distributed systems. Rankine Lecture." *Géotechnique* (2010).
- "Construction-induced movements of in-situ walls." *GSP No. 25* (1990).

Q: Who has been the most influential person in your career?

Two people: David Henkel and Ralph Peck. David Henkel was a well-known geotechnical engineer and a professor at Cornell for many years. He co-authored with Alan Bishop a classic book on triaxial testing. He developed one of the first models to show how ocean storm waves generate submarine landslides, which is fundamental for the design and construction of offshore oil infrastructure. Ralph Peck was an inspirational teacher and mentor, and a member of my PhD thesis committee, chaired by my advisor and friend, Ed Cording. I learned a lot from Ralph Peck's classes, but mostly I learned a lot from the way he conducted himself and the way he worked with people. He helped me understand the interaction among construction, geology, and mechanics.

Q: What advice would you like to share with young geotechnical engineers?

Choose your career because you fundamentally enjoy what you are doing. Work because you are inspired by what you do. Find a mentor who is experienced, and who you can work with and learn from. Learning through the experience of another person is a great way to expand your capabilities and enhance your contributions to engineering.

At the Transportation Test Center in Pueblo, CO, O'Rourke discusses auger boring and jacking an instrumented pipeline under the railroad tracks to evaluate its response to repetitive train loading.

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