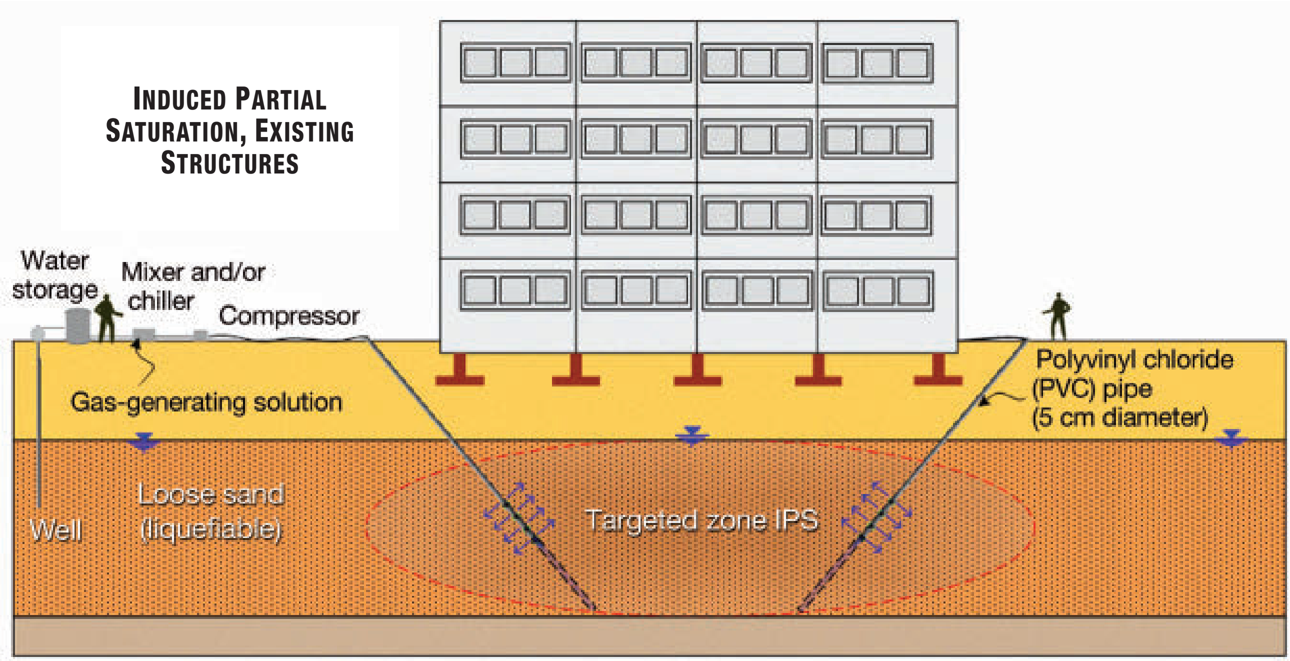

New Method for Alleviating Soil Liquefaction to Undergo Field Tests

IN MANY LOCATIONS around the world, the phenomenon of soil liquefaction has greatly compounded the devastation associated with earthquakes. Although scientists now understand the causes of soil liquefaction, combating the problem has proved complicated, particularly in developed areas. However, a new approach that shows promise as a means of preventing liquefaction in soils beneath existing and new structures is about to undergo field tests, raising hopes that a straightforward, inexpensive defense against liquefaction may soon be available.

Liquefaction occurs when seismic shaking increases the pore water pressure in loose, saturated sandy soils. The higher water pressure causes the soils to lose their shearing strength, resulting in ground and foundation failures that can have devastating effects on engineered structures. Although measures for counteracting liquefaction exist, they are often expensive and at times impracticable, particularly in the case of existing developments. For example, replacing or compacting liquefiable soils beneath existing structures typically is not possible, and installing dewatering systems can sometimes result in settlement and damage to existing structures.

For the past several years, two researchers in Northeastern University's civil and environmental engineering department—Mishac Yegian, Ph.D., P.E., F.ASCE, the College of Engineering Distinguished Professor, and Akram Alshawabkeh, Ph.D., P.E., F.ASCE, the George A. Snell Professor of Engineering—have sought to develop a simpler, more practical, and less expensive way of mitigating the effects of liquefaction. Known as induced partial saturation (IPS), the process generates minute gas bubbles within the pore spaces of sandy soils susceptible to liquefaction. In this way, the soils go from being fully saturated to partially saturated. By decreasing the extent to which pore water pressure increases, IPS is expected to improve the resistance of soils to liquefaction.

The IPS process depends on several environmentally friendly chemicals that dissolve in water and slowly generate bubbles containing oxygen gas. The process involves dissolving a very low (less than 1 percent by weight) concentration of an ecofriendly chemical in water, which can be taken from on-site groundwater supplies. The resulting solution is then injected belowground by means of a pump, and it passes through an injection tube having multiple openings. The mixture percolates and diffuses into the soil, releasing tiny oxygen bubbles that "lock themselves" into the pores between sand particles without disturbing the soil, Yegian says. "It's a simple idea," he notes. However, because liquefaction is a serious concern in many locations around the world, the market for IPS is potentially "in the billions" of dollars, Yegian says. A patent for IPS has been filed by Northeastern University.

Because of the permeable nature of sandy soils that are prone to liquefaction, pumping the solution through such soils is relatively easy. As a result, the effective region for treatment by means of IPS is "quite large," Yegian says. Within a few hours of injection, the solution can travel up to several meters, minimizing the number of injection points required for treatment. Moreover, adding more injection points will decrease the time required to treat a given area. On the basis of their laboratory research, the investigators have concluded that gas bubbles generated in sandy soils remain trapped even under horizontal and vertical water flow gradients, as well as during seismic shaking.

NORTHEASTERN UNIVERSITY (PATENT PENDING), BOTH

Compared with conventional methods for addressing liquefaction, IPS is expected to cost less than and lend itself to treatments that are more targeted than is currently possible, Yegian says. To be effective, conventional measures for counteracting liquefaction typically must be carried out across an entire site or across an entire depth of a soil profile, regardless of where the susceptible sands are actually located. By contrast, the IPS technique could be used "exactly where the liquefaction zone is," he says. For example, if such a zone were present only within a soil layer at a certain depth, the chemical mixture could be injected precisely at that location and to the required depth. Because it offers a "very targeted, very effective treatment," Yegian says, IPS "would be extremely suitable and cost effective for new sites but extremely valuable for existing sites with existing buildings."

Thus far the IPS process has undergone only small-scale laboratory testing, but more advanced testing is about to begin. In August 2011 Yegian and Alshawabkeh, together with their colleagues, received a $1.2-million grant from the National Science Foundation's George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES) to field-test the process for three years. The colleagues are Sabanayagam Thevanayagam, Ph.D., P.E., M.ASCE, a professor in the civil engineering department at the State University of New York at Buffalo; Arvin Farid, Ph.D., P.E., M.ASCE, an assistant professor in the civil engineering department at Boise State University; and Kenneth Stokoe, Ph.D., P.E., D.GE, M.ASCE, who holds the Jennie C. and Milton T. Graves Chair in Engineering at the University of Texas at Austin. In February the researchers completed work on a computer model for simulating the generation, transport, and distribution of gas bubbles in the IPS process. The results from the model have been verified by means of small-scale tests conducted in tanks, Yegian says.

The researchers will use the model to design the field tests. Scheduled to begin in one to two months, the first such experiments are intended to test equipment and gain experience with the IPS process. By the end of this summer, the researchers plan to conduct large-scale laboratory tests on the IPS process using a geotechnical laminar box located at the State University of New York at Buffalo as part of the NEES program. Ultimately, the process will be conducted on a large scale in the field at the NEES's Wildlife Liquefaction Array, in Southern California. Overseen by the University of California at Santa Barbara, this research site contains liquefiable soils and is located in a region prone to earthquakes. After being treated by IPS, the site will be vibrated using the large NEES shaker owned by the University of Texas at Austin. By implementing the IPS process in this location, the researchers hope that an earthquake will eventually enable them to test the performance of the IPS process under actual seismic conditions, Yegian says. Such an event would provide the "ultimate confirmation of the IPS system," he notes. —JAY LANDERS

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