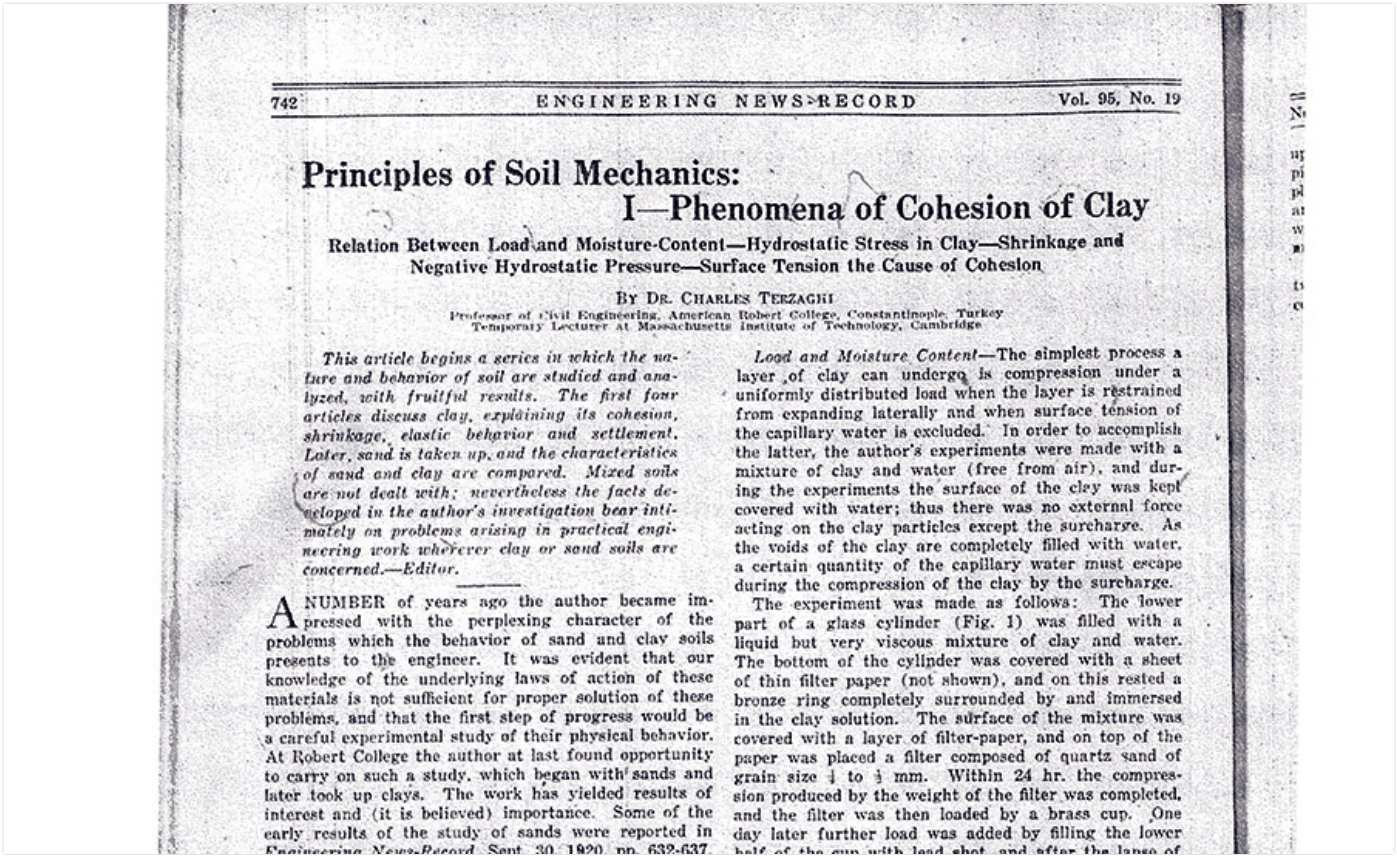
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ENR Brought Ideas of “Father of Soil Mechanics” to the US

By Scott Lewis



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Principles of Soil Mechanics:
I—Phenomena of Cohesion of Clay

Relation Between Load and Moisture-Content—Hydrostatic Stress in Clay—Shrinkage and Negative Hydrostatic Pressure—Surface Tension the Cause of Cohesion

By Dr. Charles Terzaghi
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This article begins a series in which the nature and behavior of soil are studied and analyzed, with fruitful results. The first four articles discuss clay, explaining its cohesion, shrinkage, elastic behavior and settlement. Later, sand is taken up, and the characteristics of sand and clay are compared. Mixed soils are not dealt with; nevertheless the facts developed in the author's investigation bear intimately on problems arising in practical engineering work wherever clay or sand soils are concerned.—Editor.

A NUMBER of years ago the author became impressed with the perplexing character of the problems which the behavior of sand and clay soils presents to the engineer. It was evident that our knowledge of the underlying laws of action of these materials is not sufficient for proper solution of these problems, and that the first step of progress would be a careful experimental study of their physical behavior. At Robert College the author at last found opportunity to carry on such a study, which began with sands and later took up clays. The work has yielded results of interest and (it is believed) importance. Some of the early results of the study of sands were reported in Engineering News-Record, Sept. 30, 1920, pp. 632-637.

Load and Moisture Content—The simplest process a layer of clay can undergo is compression under a uniformly distributed load when the layer is restrained from expanding laterally and when surface tension of the capillary water is excluded. In order to accomplish the latter, the author's experiments were made with a mixture of clay and water (free from air), and during the experiments the surface of the clay was kept covered with water; thus there was no external force acting on the clay particles except the surcharge. As the voids of the clay are completely filled with water, a certain quantity of the capillary water must escape during the compression of the clay by the surcharge.

The experiment was made as follows: The lower part of a glass cylinder (Fig. 1) was filled with a liquid but very viscous mixture of clay and water. The bottom of the cylinder was covered with a sheet of thin filter paper (not shown), and on this rested a bronze ring completely surrounded by and immersed in the clay solution. The surface of the mixture was covered with a layer of filter-paper, and on top of the paper was placed a filter composed of quartz sand of grain size ¼ to ½ mm. Within 24 hr. the compression produced by the weight of the filter was completed, and the filter was then loaded by a brass cup. One day later further load was added by filling the lower half of the cup with lead shot, and after the lapse of

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More art than science, earthwork engineering relied heavily on local custom in 1904 when Karl Terzaghi (1883-1963) earned his engineering degree in Austria. After supervising a dam project in Croatia and studying dam construction projects in the U.S., he concluded that the study of soil mechanics had stagnated. As he later wrote: “The reason for this lack of progress lies mainly in the great difficulty of investigation of soil phenomena.” He devoted the rest of his career to rigorously investigating the physical study of soils and soil behavior.

While teaching at the Royal Ottoman College of Engineering in Istanbul in 1919, he began publishing his findings. His first book, The Mechanics of Earth Construction Based on Soil Physics, was issued in 1924.

ENR first published a paper by Terzaghi in 1920. At that time, ENR Associate Editor Fred Schmitt found Terzaghi's ideas to be so significant that he suggested to Terzaghi that he send in reports of his further studies and findings. They were published as a series of eight articles in 1925 (as Charles instead of Karl).

As Schmitt explained in the series, "The author [Terzaghi] was able to trace the many physical properties of soils to four underlying factors: 1. Friction between the grain surfaces; 2. Viscosity of the capillary water; 3. Surface tension of the capillary water; and 4. The influence of the width of voids on the physical properties of the water itself." The series constituted the first comprehensive treatment of soil mechanics principles read by English-speaking engineers.

Practical application of the theories propounded by Terzaghi soon began in the U.S. Early in the 1930s the Los Angeles Bureau of Waterworks and Supply began applying the factors to the compaction of soils in large earth dams. The outcome was the development of an entirely new procedure for engineering control of such work. Included were simple tests for determining the suitability of materials for earth dams and for checking compaction.

"Terzaghi established not only the technical basis for analyzing soil behavior responses to constructed facilities, but established the gold standard for the role geotechnical engineers perform that endures today," says David P. Sauls, chairman of GeoEngineers Inc. "Terzaghi saw the whole problem, beginning with site geology and ending with the ground's measured behavior during and after construction."

After teaching for several years in the 1920s at M.I.T., Terzaghi returned to Vienna, before settling permanently in the U.S. in 1938 and teaching at Harvard. He published prolifically and consulted widely on projects including the Aswan High Dam, the subsidence of Mexico City, the Chicago subway tunnels and the 10-in. settlement of Charity Hospital in New Orleans. "His consulting engineering reports read as interesting stories that design and explain the solutions to the world's most complex construction projects over the next 30 years," notes Sauls.

Many of the analytic approaches that Terzaghi developed are still valid. "We've refined the numerical analysis techniques and improved the design input data with superior soil sampling and laboratory testing methods," says Sauls. "His work established our understanding of such subjects as: mathematical formulation of soil mechanics to analyze soil performance; settlement of foundation soil under applied load; earth pressures; and tunneling and slopes (landslides, dams, slope stability)," he adds. "Terzaghi is easily the greatest contributor to geotechnical engineering over the past century."