In Memoriam: Ray W. Clough

Ray W. Clough, Nishkian Professor of Civil Engineering, Emeritus, University of California, Berkeley, died on October 8, 2016.

Born July 23, 1920, he grew up in Seattle, Washington. He received his B.S. degree from the University of Washington, Seattle, in 1942, and the Sc.D. degree at M.I.T. in 1949. He chose Civil Engineering as his undergraduate major because of his love of the outdoors. During those years he had trekked extensively and climbed several of the major volcanic peaks—Rainier, Baker, Glacier, and St. Helens—in the states of Washington and Oregon.

Immediately after completion of his doctoral studies, Ray came to Berkeley as an Assistant Professor. Despite receiving numerous offers from other universities, his entire academic career was at Berkeley until he retired from teaching in 1987. Ray's contributions in teaching, research and consulting during 1950–1995 in the fields of finite element analysis, structural dynamics and earthquake engineering have been monumental.

Perhaps his most important research contribution in structural engineering was as a co-developer in the "Finite Element Method" beginning with a classic paper in 1956. With the advent of digital computers the finite element method forever revolutionized the field of structural analysis and design. The method has been extended to many fields of engineering and makes it possible to analyze complex systems of many different kinds, including those encountered in design and safety evaluation of structures, and in aircraft, automobile, nuclear and oil industries. Because of the fundamental nature of the finite element concept, researchers in diverse fields of applied science and engineering recognized its potential in solving problems in their respective fields.

On his arrival at Berkeley, Ray was assigned to develop a graduate course on Dynamics of Structures. He, Joseph Penzien, and Vitelmo Bertero developed the teaching program in structural dynamics and earthquake engineering at Berkeley that many considered to be the best in the world. It led to the book *Dynamics of Structures* (co-authored with Joseph Penzien) published in 1975 and again in 1993. It was a landmark book in terms of its broad scope, comprehensive coverage, and philosophy. Several generations of students and engineers, in the United States and abroad learned the subject from this very book. It has been translated into Bahasa Indonesian, Chinese, Greek, French, Japanese, and Russian. The book was a major influence on subsequent textbooks on the subject, including my own.

Although Ray was a leader in the development of analytical methods for predicting the effects of earthquakes on structures, he had been cognizant of the limitations of these methods. Recognizing that analytical capabilities have advanced beyond the experimental results on which they should be based, during the 1970s and 1980s he directed his research activities toward the experimental side of this dual development. His experiments on concrete, steel, and masonry buildings and liquid-storage tanks using the Berkeley shaking table received world-wide attention and the findings of these experiments have influenced design practice.

A series of his papers that appeared in the 1960's contained new and reliable methods for computer earthquake analysis of tall buildings. These contributions influenced substantially the direction of research and the structural earthquake engineering practice. This research provided the basis for many of the popular commercial computer programs, such as ETABS and SAP 2000.

Similarly, a series of papers that appeared in the 1960s and 1970s presented new and accurate methods utilizing the finite element concept for earthquake analysis of concrete dams. He served as a consultant for many of these projects for the U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, the World Bank, and many private companies.

Ray Clough received numerous honors. He was elected to both the National Academy of Engineering (in 1968, only four years after its inception) and the National Academy of Sciences, a rare distinction. He was elected to the Royal Norwegian Scientists Society, received Honorary Doctoral degrees from Chalmers University of Technology, Gothenburg, Sweden, and the Norwegian Institute of Technology, Trondheim, Norway. From the American Society of Civil Engineers, he received the Huber Research Prize, the Howard Award, the Newmark Medal, the Moisseiff Award, and the Norman Medal. The Earthquake Engineering Research Institute honored him with their highest award: the Housner Medal. The University of California, Berkeley, honored him by appointing him to the first endowed chair in engineering as Nishkian Professor of Structural Engineering (1983), and awarded him the Berkeley citation at his retirement in 1987. He received the National Medal of Science, the nation's highest award in science and engineering, at the White House in 1994.

Let me take the liberty of closing on a personal note. Ray was my Ph.D. thesis supervisor and a mentor, who helped me in too many ways to enumerate here. He had a profound influence on my professional growth, for which I remain grateful. My professional and personal relationship with Ray goes back to April 1961, when I, a 20-year old kid in India, received a letter from him offering me a teaching assistantship at $225/month. This letter changed my life. But for Ray's letter, I would, probably, have spent my career in India, teaching, perhaps happy, but in no way having had the exhilarating and personally satisfying career I had at Berkeley. I made this exact statement at the occasion of Ray's retirement. I was truly shocked when Ray casually mentioned that he had offered me that teaching assistantship contrary to University policy, which at that time excluded new foreign students from such positions. Ray, thanks for taking a chance on me.

Anil K. Chopra (November 4, 2016)