FACULTY OF CONSTRUCTION AND LAND USE
建設及地政學院

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

DYNAMIC RESPONSE OF A COLLAPSED REINFORCED CONCRETE CHIMNEY

By

Professor Phillip L. Gould
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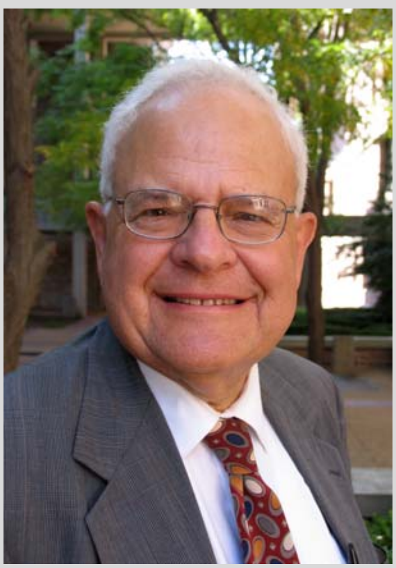
Date: **24 October 2008 (Friday)**

Time: **6:30 to 7:30pm**

(Refreshments will be served at 6pm)

Venue: **M1603, Li Ka Shing Tower, The Hong Kong Polytechnic University**



SUMMARY

During the Ismit (Kocaeli) Earthquake of August 17, 1999, a 115 m. high reinforced concrete chimney or heater stack, located at the Tüpras Refinery, collapsed. The falling debris cut 63 pipes, which contributed to interrupted production for more than 14 months. This stack was designed and constructed according to international standards and is representative of similar structures at refineries throughout the world, including those in earthquake-prone regions. It was distinguished from similar stacks at the site by a much larger rectangular opening for the flue duct, circumscribing a horizontal arc of about 50°. The opening was located about 1/3 of the height above the base and appeared to be the region of initiation of the collapse.

The investigation is focused on the dynamic response of the stack due to an earthquake motion recorded at a nearby site. In this paper, the results of a response spectrum analysis of the Tüpras stack and a generic U.S. stack are summarized. Then, a nonlinear static analysis of the collapsed stack is presented using a demand-collapse comparison. The demand is represented by an acceleration-displacement response spectrum based on the recorded motion as well as some smoothed adaptations typical of design spectra based on a statistically simulated time history data set, while the capacities are calculated from pushover curves using a nonlinear reinforced concrete finite element analysis. Finally nonlinear dynamic analysis results of the Tüpras stack are introduced to verify the pushover analysis and show the failure mechanism of the stack more clearly.

Results are presented that show the effects of the hole and the orientation of the motion with respect to the hole. Also higher-mode contributions to the pushover pattern are considered. A new 3-D pushover procedure is introduced and the analysis results are shown to compare favorably with those obtained by a nonlinear dynamic analysis. The study confirms that the stack could readily fail under the considered earthquake and the failure mechanism predicted is consistent with the debris pattern.

KEY WORDS: stack; chimney; stress concentration; response spectrum; earthquake analysis

THE SPEAKER

Phillip L. Gould is the Harold D. Jolley Professor of Civil Engineering at Washington University in St. Louis, Missouri. He is a Registered Structural and Professional Engineer, and a member of several professional societies. His B.S. and M.S. degrees were earned at the University of Illinois at Urbana and he has worked as a structural engineer, engaging in the design of institutional and multistory buildings and highway bridges. He received the Ph.D. degree from Northwestern University.

Dr. Gould's research activities have centered on shell analysis with applications to finite element modeling, biomedical engineering, earthquake engineering, and the structural design of thin-shell structures. Numerous technical papers have accrued from these studies and Dr. Gould became an internationally recognized authority on the design of hyperbolic cooling towers. The development of accurate methods for the dynamic analysis of these enormous structures remains an enduring achievement of Dr. Gould and his students. He has also served as a consultant to various industries and governmental agencies, and has evaluated the earthquake resistance of the countries tallest cooling towers, a failed concrete chimney and a large airport terminal. Dr. Gould headed the technical investigations of two large cooling towers that were damaged during construction.

A Senior U.S. Scientist Award enabled Dr. Gould to spend a year as a guest professor at the Ruhr-University in Bochum, Germany. He has also served as a guest professor at the University of Sydney, Australia, the Shanghai University of Technology, China, the University of Bologna, Italy and has lectured at many universities in the U.S. and worldwide.

Dr. Gould is the author of books in the fields of thin shell analysis; earthquake and wind engineering; introductory elasticity; and finite element analysis. Also, he is the founding editor of the prestigious journal, ENGINEERING STRUCTURES and continues as Editor-in-Chief.

Dr. Gould has been active in promoting the profession of structural engineering. He was instrumental in the formation of the Structural Engineers Association of Missouri and Kansas. He was elected as a national director of the Earthquake Engineering Research Institute. In the American Society of Civil Engineers, Dr. Gould has served on several national and regional committees and was the chair of the Committee on Thin Shell Design. He was recognized by the St. Louis Section with the Professional Recognition Award for lifetime service.

Dr. Gould has been at the forefront of increasing earthquake awareness and promoting mitigation in mid-America. He led the effort to enforce the earthquake provisions of the BOCA in the St.Louis region that resulted in acceptance by the local governmental agencies. The department of Civil Engineering under his leadership established the first degree and certificate programs in earthquake engineering in the U.S. He served as the chair of the Missouri Seismic Safety Commission, and as the Program Coordinator for Education and the St. Louis Regional Director of the Mid-America Earthquake Center. The education program of the MAE Center received very positive reviews from NSF during the annual site visits and the Consequence-Based Engineering Institute developed by Dr. Gould and his colleagues was a new and exciting vehicle for cross-disciplinary earthquake engineering education.