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The John A. Blume Earthquake Engineering Center

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PEER-SPONSORED WORKSHOP ON TRANSPORTATION SYSTEMS JULY 10-11, 1998

The Blume Center is organizing and hosting an Invitational Workshop on Earthquake Risk to Highway Transportation Systems sponsored by the Pacific Earthquake Engineering Research (PEER) Center. The workshop will be held on July 10-11, 1998 at Stanford University. The purpose of the workshop is to bring together researchers and practicioners from the academic, public, and private sectors to identify critical issues in: (1) earthquake risk analysis of transportation systems, (2) evaluation of methods leading to earthquake preparedness, and (3) development of technologies that will enable efficient and effective post-disaster response, recovery, and reconstruction.

The workshop organizers are **Prof. Anne Kiremidjian** and Prof. Sam Chiu from Stanford University and Prof. James Moore from the University of Southern California. For more information contact **Carol Strovers** at the Blume Center.

BLUME CENTER COSPONSORS PPP 2000 FORUM

On January 21, PPP (Public Private Partnership) 2000 held its third forum on natural disaster reduction, "Cities and Megacities at Risk from Natural Disaster." The event was cosponsored by the Blume Center, the World Seismic Safety Initiative (WSSI), and the World Federation of Engineering Organizations (WFEO). **Prof. Anne Kiremidjian, Prof. Haresh Shah, Dr. Stephanie King, Dr. Rachel Davidson,** and **Dr. Anju Gupta** played instrumental roles in the organization of the forum, which was held in Washington DC. The forum was very successful, with more than 100 representatives from academia, the private sector, non-governmental organizations, and local, State, and Federal government. The forum participants offered diverse perspectives on natural disasters, including earthquakes, hurricanes, and floods, and on the links between natural hazards and other urban issues.

The PPP 2000 Forums on Public Policy Issues in Natural Disaster Reduction is a cooperative endeavor of the nineteen Federal agencies composing the Subcommittee on Natural Disaster Reduction, the Institute for Business and Home Safety, and other private sector organizations. The project consists of a total of 14 forums held in 1997 and 1998 that address various aspects of reducing the effects of natural disasters.

BLUME CENTER NEWS

On January 4-7, **Prof. Helmut Krawinkler** attended a US-Japan Workshop on Near-Field Ground Motion Issues held in Hawaii.

Prof. Anne Kiremidjian was interviewed on the Stanford Channel on January 9. The topic was "Are we prepared for the next earthquake?"

Ph.D. candidates **Erik Straser** and **Hoon Sohn** presented papers at the International Modal Analysis Conference (IMAC) held in Santa Barbara, California on February 2-6.

Prof. Anne Kiremidjian is serving on the National Academy of Engineering Committee on Assessing the Cost of Natural Disasters.

Dr. Renate Fruchter has been invited to be a guest editor of the special issue on "Computing and Information Technology in A/E/C Education" for the ASCE Journal on Computing in Civil Engineering.

Several students and faculty members from the Blume Center participated in the EERI (Earthquake Engineering Research Institute) Annual Meeting held February 4-7 in San Francisco.

On February 26, Ph.D. candidate **Erik Straser** gave a seminar at the USGS in Menlo Park describing his research, the development of WIMMS - A Wireless Modular Monitoring System.

At the February 27 CUREe (California Universities for Research in Earthquake Engineering) Board Meeting at UC Davis, **Prof. Helmut Krawinkler** stepped down as CUREe President. He enjoyed his tenure as president, but is looking forward to devoting more of his time to his research activities.

Prof. Anne Kiremidjian presented an invited paper at the Asia Pacific Workshop on Earthquake Damage Mitigation in Kobe, Japan on March 9-13.

In March, the Blume Center hosted a delegation of faculty members from Kazakstan who were here to explore research collaboration. A group of scientists from Toshiba Research also visited the Blume Center in March to exchange research ideas on health monitoring of structures.

On March 13, **Dr. Stephanie King** and her husband Chris Rojahn welcomed the birth of their second child, a

RESEARCH SPOTLIGHT

Finite Element Analysis of Strain Localization in Geologic Materials Taking a Strong Discontinuity Approach

by Richard A. Regueiro, Ph.D. Candidate
Research Advisor: Professor Ronaldo I. Borja

Sponsored by The National Science Foundation Project:
"Finite Element Analysis of Strain Localization in Excavations" (Grant No. CMS97-00426)

Introduction

Localized deformation (i.e., strain localization) in the form of slip surfaces and shear bands appears naturally in geomaterials such as soil and rock. As a result, in order for the practicing geotechnical engineer to make informed analysis and design decisions for geotechnical structures in which localized deformation may develop, slip surfaces and shear bands should be represented numerically by a finite element model. The usefulness of a finite element model is realized when analyzing geotechnical structures with complex geometry and soil behavior because for such problems an analytical limit equilibrium solution is unwieldy. The standard finite element method, however, does not result in meaningful approximations of geomaterial behavior when localized deformation is present (i.e., finite element solutions are mesh-dependent). Therefore, a more sophisticated approach to modeling the formation of slip surfaces and shear bands in soil and rock in a mesh-independent manner is in order.

Model Development

Many attempts have been made to numerically model localized deformation, however, in the absence or material length scales or other regularization treatments, these attempts typically do not satisfy two necessary criteria for a finite element solution to be meaningful (i.e., mesh-independent): objectivity with respect to mesh refinement and insensitivity to mesh alignment. A previously-developed model [1] which meets these two criteria without any regularization treatments represents localized deformation as a strong discontinuity (jump in displacement field). This model is adopted to formulate a non-associative, strain-softening Drucker-Prager plasticity model in the context of strong discontinuities [2] and to implement this plasticity model within the framework of the assumed enhanced strain finite element method [3].

The assumption that localized deformation in soil and rock may be represented as a jump in displacement field (which leads to a singular strain field) is valid because as a shear band forms between two soil bodies (composed primarily of sand) sliding along one another, the thickness of the band is negligible (the band reduces to a surface), and the strain across the band approaches infinity; see pictures in [4] for sand, [5] for clay, and [6] for rock.

Numerical Example

A plane strain excavation problem is presented to demonstrate objectivity with respect to mesh refinement and insensitivity to mesh alignment of the enhanced finite element solutions. An important result is the greater strut load predicted by the enhanced finite element solution, which demonstrates the unconservative nature of the standard finite element solution

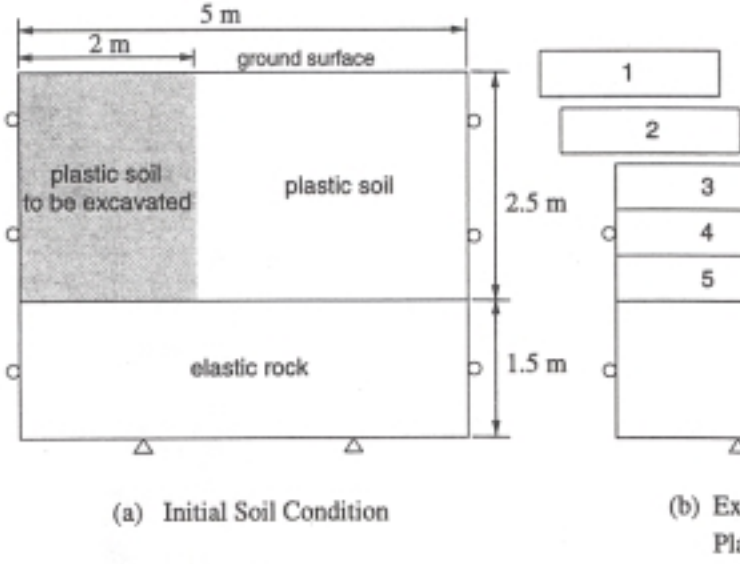

Figure 1. Plane strain excavation problem: (a) Initial soil condition showing portion of soil to be excavated. (b) Excavation sequence and placement of rigid wall showing wall reaction, R.

for strain localization problems.

Boundary conditions and excavation sequence are described in Figure 1; symmetry is accounted for in the analysis. The finite element analysis proceeds as follows: the gravity load is applied, and displacements are zeroed; the five soil layers are removed sequentially as numbered in Figure 1(b), with a rigid wall placed simultaneously as the second soil layer is excavated; and after the fifth soil layer is excavated, the rigid wall is moved leftward to simulate bracing system collapse, which is motivated by the observance of elements at the excavation base localizing during the fifth excavation step. The material parameters are arbitrarily chosen in order to be able to demonstrate the abilities of the model and not to attempt a strain localization finite element analysis of an actual excavation field case study; in addition, the plane strain condition renders the analysis limited regardless of the choice of material parameters.

Three levels of mesh refinement are used to analyze the problem: 320 element mesh, 1280 element mesh, and 5120 element mesh. Linear quadrilaterals were employed. Deformed meshes are shown in Figure 2, and load-displacement curves are shown in Figure 3. The enhanced finite element solution is insensitive to mesh alignment because the slip line propagates sharply through the unstructured meshes in Figure 2 (i.e., element sides are not aligned with the slip line) and because the slip lines of each mesh refinement have similar orientation and location; the localized elements which are traced by the slip line are shaded gray. Objectivity with respect to mesh refinement is demonstrated by the similar initial slopes of the enhanced solution curves shown in Figure 3. The enhanced solution curves do not lie one on top of the other as is seen in Figure 3 because the standard solution curves are different for each mesh (which is already a well-known feature of the standard finite element solution) and because the slip lines fully propagate through each mesh at different load steps. The enhanced solution curve for a 5280-element mesh ramps up dramatically, most likely as a result of an S-shaped slip line forming across the mesh (refer to Figure 2).

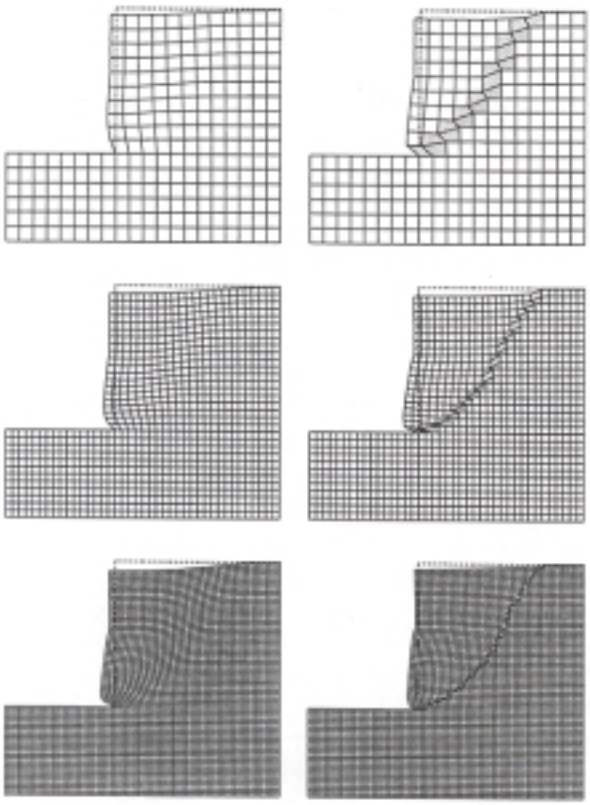

Figure 2. Deformed meshes for standard and enhanced solutions with non-associative, dilative plastic flow.

Conclusions and Future Work

With a soil constitutive model like Drucker-Prager formulated in the context of strong discontinuities, along with the eventual consideration of the fluid phase, nonlinear geometric effects, and three dimensions, the model has the potential to aid the practicing geotechnical engineers in analyzing geotechnical structures which are susceptible to developing localized deformation.

References

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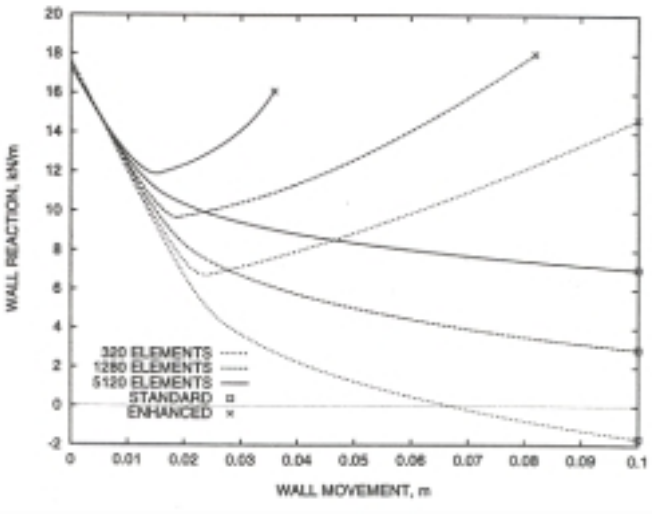

Figure 3. Load-displacement curves for non-associative, dilative plastic flow.

NEWLY SPONSORED RESEARCH PROJECTS

Several of our faculty members in the Department of Civil and Environmental Engineering at Stanford have received funding for one-year research projects through the Pacific Earthquake Engineering Research (PEER) Center.

Prof. Anne Kiremidjian is the task leader for the PEER Demonstration Project on Seismic Risk of Highway Transportation Systems. This urban area demonstration project will implement the findings from various research components of the overall research program. The goal is to evaluate the impact of transportation system disruption on an urban area in California. The project will emphasize modern computational tools, including geographic information systems (GIS), database management systems, and distributed computing. The project will be guided by the recommendations from the invitational workshop held in July (see article on page 1).

Prof. Helmut Krawinkler is the task leader for research on the Development of Framework for Performance-Based Engineering Models and Codes. This topic involves the development of a framework, including the technical basis, for performance-based earthquake engineering. The work will support other completed or planned topics as part of a national effort to promulgate performance-based earthquake engineering. The scope includes hazard definition, analysis and design, target performance levels, and social systems for performance-based earthquake engineering. **Prof. Allin Cornell** will be addressing the Technical Basis for Performance-Based Seismic Design, and Prof. Krawinkler will focus on the Seismic Demands for Performance-Based Design.

Prof. Kincho Law will be developing a Distributed Software Paradigm for Nonlinear Dynamic Analysis as part of the effort on the topic of Next Generation Analytical Platform for Nonlinear Dynamic Analysis. This topic involves the development of modern simulation software for performance-based earthquake engineering. The platform should enable an engineer to employ a hierarchy of models and methods of analysis likely to be part of new frameworks for performance-based design.

FIFTH ANNUAL CALIFORNIA GIS CONFERENCE

The Fifth Annual California GIS (Geographic Information Systems) Conference will be held February 17-19, 1999 at the Marriott City Center in Oakland, California. The theme of the conference, which is sponsored by the California chapters of the Urban and Regional Information Systems Association (URISA), is "GIS: Your Bridge to the Future." Abstracts for presentations on any topic relating to GIS technology are being solicited. For more information, please contact the program chair, **Dr. Stephanie King**, at the Blume Center or see the web site: http://www.calgis.org.

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