

## **SIMULATION OF EARTHQUAKE LIQUEFACTION RESPONSE ON PARALLEL COMPUTERS**

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Simulations of earthquake responses and liquefaction effects generally involve coupling solid and fluid phases, and often require the incorporation of soil plasticity models. Large-scale earthquake simulations are not feasible on most current single processor computers. Utilization of parallel computers, which combine the resources of multiple processing and memory units, allows analysis of large and complex models that may not fit into a single processing unit. Furthermore, parallel computing can potentially reduce the solution time significantly. Application software, such as finite element programs, must be re-designed in order to take full advantage of parallel computing.

This NSF-sponsored joint research effort between Stanford University and University of California at San Diego (Prof. Ahmed Elgamal, Dr. Zhaohui Yang, and Mr. Jinchu Lu) explores the implementation of a geomechanics nonlinear finite element program on distributed memory parallel computers. The research focuses on the development of ParCYCLIC, a parallel nonlinear finite element program developed based on an existing serial code CYCLIC for the analysis of cyclic seismically-induced liquefaction problem. The objective is to extend the computational capabilities of the finite element program to simulate large-scale systems, and to broaden the scope of its applications to seismic ground-foundation interaction problems.

In ParCYCLIC, finite elements are employed within an incremental plasticity, coupled solid-fluid formulation. A constitutive model developed for simulating liquefaction-induced deformations is a main component of this analysis framework. The elements of the computational strategy, designed for distributed-memory message-passing parallel computer systems, include: (a) an automatic domain decomposer to partition the finite element mesh; (b) nodal ordering strategies to minimize storage space for the matrix coefficients; (c) an efficient scheme for the allocation of sparse matrix coefficients among the processors; and (d) a parallel sparse direct solver. ParCYCLIC is used to simulate three dimensional geotechnical experimental models. Simulation results demonstrated that ParCYCLIC is suitable for large-scale geotechnical simulations, and good agreement has been achieved between the computed and the recorded acceleration, displacement, and pore pressure responses. Remarkable parallel speedup has been obtained from the simulation results. It is also shown that ParCYCLIC program, which employs direct solution scheme, remains scalable to a large number of processors.