LIQUEFACTION SIMULATION IN GRANULAR MATERIALS USING DISCRETE ELEMENT METHOD.

Earthquake induces loading which causes reversal of principal stresses with each cycling and the loose sand deposits under undrained conditions loose their strength due to build up of pore water pressure eventually leading to zero effective stresses i.e., Seed's definition of liquefaction. Intensive investigations have been carried out by several researchers to determine the mechanism of loss of strength. Analytical treatments on the liquefaction behavior of granular materials generally assume continuum behavior and several models have been proposed by various researchers and these models cannot capture the evolution of macro liquefaction features from the micro level response. Therefore there is a need to model these materials in a more fundamental way taking the particulate nature in to account. Discrete Element Method (DEM) pioneered by Cundall and strack (1979) models the assemblies as discrete particles interacting through contact forces with the macro behavior obtained by keeping track of micro behavior is useful for an in-depth understanding of the fundamentals of liquefaction behavior.

DEM models the granular materials as individual elements which can make and break contacts with their neighbors and is capable of analyzing interacting bodies undergoing large absolute or relative motions. It's important feature is that it incorporates the Coulombs frictional law at contacts between elements. The equilibrium contact forces are obtained from a series of calculations by solving Newton's law of motion followed by force displacement law at each contact. When all forces for each contact in the assembly are updated, forces and moment sums are determined on each element, and the above process is repeated in cycles. A 2-D model called DISC was developed at Indian Institute of Science (IISc) and cyclic behavior of sands has been simulated (Sitharam, 2002). Further based on TRUBAL, (developed by Cundall and Strack, 1979) a three-dimensional discrete element model was developed at IISc for simulating undrained cyclic tests on three-dimensional granular media.

Three-dimensional assembly consisting of 1000 polydisperse spheres having particle diameters ranging from 20 to 100 mm consisting of 21 different sizes corresponding to log normal distribution is used in the numerical simulations.

Figure 1 shows the 3-D view of the assembly. The polydisperse assembly generated is compressed isotropically to the required level of compression. The undrained (constant volume) cyclic triaxial test is carried out on isotropically compressed assembly using strain-controlled boundary conditions. Constant strain amplitude (1%) cyclic test under undrained conditions is carried out by applying the deviatoric strains repetitively on both compression and extension side on a sample at a confining pressure of 15 kPa.

Figure 2 shows the experimental results of cyclic triaxial tests with 1% strain amplitude under undrained conditions at a confining pressure of 105 kPa.

Figures 3 shows the numerical results of a cyclic triaxial test on an assembly of spheres (as shown in fig.1) corresponding to a confining pressure of 15 kPa. It is observed that with repetative strain cycles on compression and extension sides there is a continuous reduction in deviator stress and mean p and the assembly undergoes complete liquefaction at about 8 cycles similar to the experimental results described in fig 2 . There is continuous degradation in the value of the modullus of the assembly with cycles.

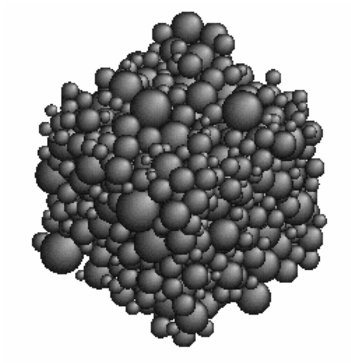


Figure 1 3-D view of polydisperse assembly

Discrete element provides information of the physical process at the micro level, which is difficult to monitor in actual physical systems

Figure 4a shows the plot of average coordination number versus mean p. When the average coordination number is less than 3 the assembly becomes unstable and the system collapses. Figure 4b shows the plot of contact normals distribution on compression and extension side during cyclic traixial test for a single cycle. It is clearly seen that there is a greater concentration of contact normals in the major principal stress direction (compression side) and upon reversal in principal stress the contact normals (fabric) reorient at right angles in tune with applied stress. This confirms the reversal of fabric during cyclic loading.

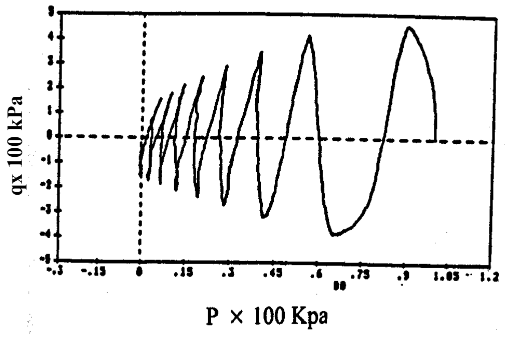
Numerical simulations using DEM offers a unique opportunity to understand the physical process from the grain scale level.

References

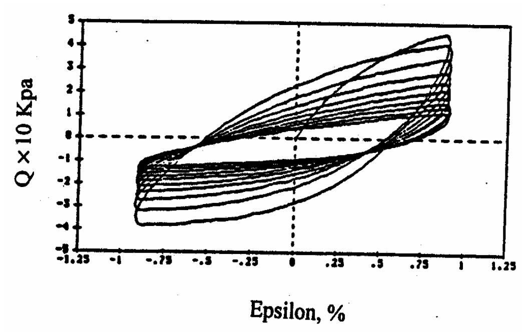
Cundall, P.A. and Strack, O.D.L., (1979), A discrete numerical model for granular assemblies, Geotechnique, 29, 1, 47-65.

Li, X.S., Chan, K. and Shen, C.K. (1988), An automated triaxial testing of soil and rock, ASTM STP 977, Robert T. Donaghe, Ronald C. Chaney and Marshall L. Silver, Eds., American Society of testing materials, Phildelphia, pp. 95-106.

Sitharam (2002), Discrete element modeling of cyclic behavior of granular materials, International journal of Geotechnical and Geological Engineering, Kluwer publishers, Netherlands, (in print).

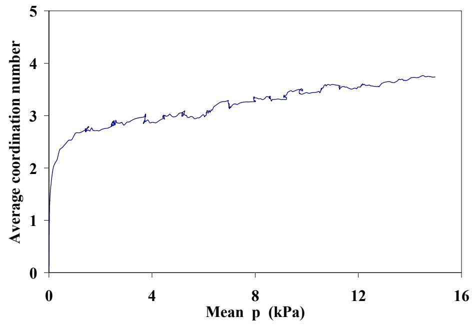


a)



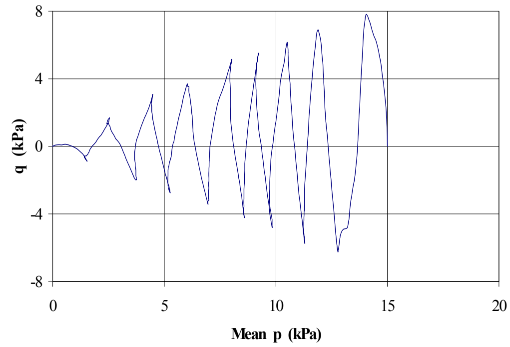
b)

Figure2. Cyclic triaxial experimental results (after Li et al., 1988)

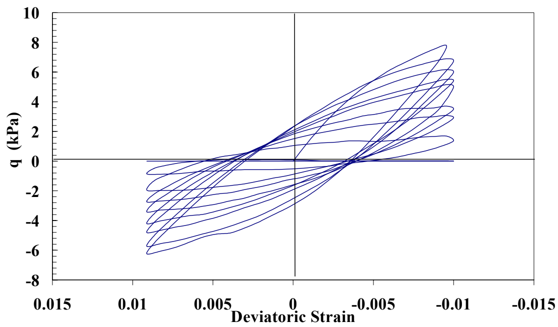


a)

Figure 4. Micromechanical results on sphere assembly using DEM

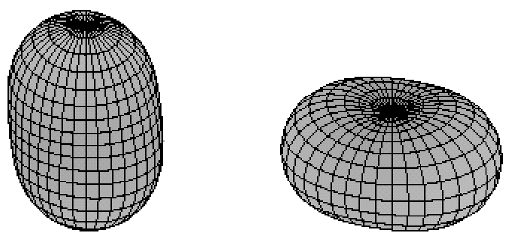


a)



b)

Figure 3. Numerical results on a sphere assembly using DEM.



Compression side **Extension side**

b)