DECEMBER 2004 MEETING

December 15, 2004

TECHNICAL PROGRAM

Case Studies of Residential Foundation Movements in Southern Houston Area

Speakers: Dr. Robert L. Lytton, P.E., Dr. Xiong Zhang, and Dr. Rifat Bulut, all of TAMU Civil Engineering Department in College Station TX, Tel. 979-845-8211.

PRESENTATION SUMMARY

After completing his doctoral work in August 2004, Dr. Xiong Zhang put together a three-dimensional transient simulation of the deformations and stresses and strains in an L-Shaped residence with walls, windows, and doors under the influence of a tree and its root zone responding to the weather patterns in Arlington, Texas. This work was the first of its kind in modeling movement of a residential foundation.

Dr. Zhang developed five models to run the analysis which Dr. Lytton presented to an audience of 70.

1. Coupled hydro-mechanical stress model
2. Evaportranspiration and infiltration model
3. Soil-structure interaction model (including shear, slip, and separation between the soil and slab)
4. Foundation and wall model
5. Superstructure cracking model

The simulation was run on Texas A&M's supercomputer and covered two years of the entire building responding to the movements of the foundation soil as a result of the climate. The software used as ABAQUS, a 3D Finite Element Analysis program that allows water to move through the soil elements and element stiffness that can vary throughout the analysis. Contact (jointed) elements were used to simulate the soil-structure interaction. The foundation and superstructure were modelled using general shell elements.

The software was set up to solve rather complex partial differential equations at each joint for each time step. The time step used was a 24-hour day so that 730 time steps were analyzed, using approximately 24 hours of supercomputer run time for each problem. Two problems were analyzed, with the difference being the tree location relative to the foundation.

The slab was taken from one of the example problems (Appendix A.4) in the soon-to-be-published Post-Tensioning Institute 3rd Edition Design Manual. The 4" slab with 12"x34" deep grade beams was simplified as a 16" uniform slab that gave similar stiffness. The laboratory tests for the Arlington TX site that were input into the analysis included liquid limit, plastic limit, %-200 sieve and %-2 microns hydrometer tests. The exterior walls were simulated as brick veneer and the interior walls were simulated as stud walls with drywall sheeting.

Dr. Zhang's analysis was setup to simulate a residence and the soil conditions that are typical of Houston and other parts of Texas. Four shallow footings in Arlington had been monitored for movement for two years and that data was plotted and used in the analysis. The weather used was actual historical data from Arlington TX in the 99/01 period. The method used to compute evapo-transpiration was the FAO-56 Penman-Monteith method and accounted for solar radiation, relative humidity, wind speed, rainfall, vegetation types, soil permeability, and soil water content.

Dr. Zhang had translated the simulation data into several movies that separately showed the changing patterns of soil and slab movement, the suction in the supporting soil, and the slab directional moment,

shear, stress, strain and liftoff patterns that occur over time. The movies also showed where the stresses concentrate above the doors and windows as well as in the foundation slab.

Some points made by Dr. Lytton during his presentation:

- Diffusion decreases as suction increases.
- Soil with cracks has a diffusion rate of about 100 times that of non-cracked soil.
- When modeling soil in FEA programs, use the long-term soil modulus (on the order of Es = 1000 psi), rather than what is obtained from short-term tests (Es of about 15,000 psi).
- Matric Suction is the tensile pressure of water.
- Water has a tensile strength of 3000 - 3600 psi when confined, but this goes to zero when the suction is low.
- Mechanical stress (weight of foundation and superstructure) has relatively little effect on the other soil properties as compared to that of suction.
- When the tree was modelled near the corner of the foundation, they found the foundation cantilevered up to 4 meters (13 ft) in the vicinity of the tree.

The data presented was about 2 Gigabytes in size and too large to include on the FPA website. However,Dr. Zhang took a snapshot of each movie and included the snapshots as slides in his presentation. To download the slide show presentation, click here

To read summaries of prior FPA presentations by Dr. Lytton and Dr. Bulut:

Dr. Lytton and Dr. Bulut presented to the FPA in August 2001 on the filter paper method and new software being developed to make finite element analyses of foundations on expansive soils using elastic half-space.

Dr. Lytton and Dr. Aubeny presented to the FPA in August 2002 on using suction to determine shallow slope failures.

Dr. Robert L. Lytton , P.E., Dr. Charles P. Aubeny, and Dr. Rifat Bulut in August 2003 on how to run suction tests.

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