Non-linear Dynamic problems

Panel Discussion

by

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16th ICSMGE
Computational Geotechnics

- Constitutive models
- Numerical analysis methods
- Calibration, verification and validation by analytical results, experiments and measurements of field data

Computational methods are invaluable tools in geotechnical engineering although more growth is expected
Several issues are encountered in Computational Geotechnics

1) Calibration of Constitutive model
2) Verification; Analytical and Physical
3) Validation of the numerical models; Case study - Application
Several issues are encountered in Computational Geotechnics

For the validation of performance based design
1) Large deformation and Post failure problem
2) To solve numerical instability and regularization
The piles marked with circular symbols Nos. 1, 2, 3 and 4 are the piles that were checked by a soundness investigation after the earthquake.

The first layer of the ground was reclaimed soil with a thickness of 11 m.

The second layer was alluvial clay.

The ground water table was about 2.2 m beneath the ground surface.
Resultant Curvature of Piles

Failure curvatures of $D = 500\text{mm}$ and $D = 600\text{mm}$ of the SC pile and the PHC-A pile are $2.48 \times 10^{-3}$ and $3.48 \times 10^{-3} \text{ (1/m)}$.

- In Fig. (a), the curvature reached a large value at about 6 sec, when a large acceleration took place at point N1 of the building.
- The curvature responses show a longer period after liquefaction and a large residual curvature remaining at point F3, which corresponds to the location of the cracks examined by the investigation at pile No. 3.
- In Fig. (b), the curvature responses express a large value at about 7 sec.

compared to the upper part of the piles, the curvature of the piles at the bottom of the reclaimed layer after liquefaction vibrated for a relatively shorter period, indicating that the kinematic behavior of the interaction between the soil and the piles at the bottom of the Bs layer is different from that at the pile head.
Distribution of saturation

After 118 hours (failure)

<table>
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<tr>
<th></th>
<th>初期飽和度</th>
<th>飽和透水係数</th>
<th>水位上昇速度 (m/ hour)</th>
<th>破壊までの時間 (hour)</th>
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<tbody>
<tr>
<td></td>
<td>基礎</td>
<td>盛土</td>
<td>基礎</td>
<td>盛土</td>
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<tr>
<td>I</td>
<td>1.0</td>
<td>0.6</td>
<td>1</td>
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饱和透水係数は基本ケースIの $1.0 \times 10^{-5}$ (m/sec)からの倍率を表す
Pore water pressure

After 118 hours (failure)

Model 1
Deviatoric strain and deformed mesh: failure = 5% strain

Rapid development of strain

110時間後

114時間後

118hrs (deviatoric strain = 5%)

122時間後

126時間後

Deformation x10
Distribution of local PWP Gradient

15hrs. (the rise of water table is stopped)

50hrs

80hrs

118hrs (failure)

Deviatoric strain

Model I
Characteristics of geomaterials

1. Elasticity and hypo-elasticity
2. Plasticity, hypo-plasticity
3. Rate sensitivity, viscoelasticity and viscoplasticity
4. Dilatancy
5. Density dependency and confining pressure dependency
6. Strain-hardening and strain-softening characteristics
7. Cyclic deformation characteristics
8. Structural and induced anisotropy
9. Non-coaxiality
Characteristics of geomaterials (continued)

10. Deformation localization, bifurcation, and instability
11. Discontinuity
12. Degradation and the growth of microstructures
13. Multi-phase mixture properties
   suction-saturation relation
14. Heterogeneity and non-locality
15. Physicochemical properties
16. Temperature dependency
17. Electromagnetic characteristics, the dielectric constant, and conductivity
There are several methods for the regularization of the ill-posedness of governing equations.

1) Non-local formulation of constitutive models. Micro-structure cannot be disregarded; material length scale is needed.

2) Viscoplastic type formulation.

3) Dynamic formulation.

4) Discrete model and finite element analysis with strong discontinuity etc.

5) Solid-fluid two-phase formulation (weakly).

We can overcome the difficulties in the computation such as strong mesh size dependency and instability in the computation.
Researchers:

(A) What capabilities must the constitutive model have and why?
   In general, characteristics (1)-(17)

(B) How will the parameters be determined?
   Laboratory tests and in situ tests; directly and data adjusting method through element simulation

(C) Will the procedure you propose be more reliable than the simplified procedures that a practitioner might normally use?
   Reliable for soil-structure interaction problem considering liquefaction.

(D) Do you know if your procedure will yield accurate results? If not, what sort of research is needed in the future to confirm this? Should we subject the procedures to benchmarking exercises before using them in practice?
   Comparison with the results of physical model tests

(E) Is your procedure the optimal method of analysis for the problem at hand or is it overkill?
   Yes, the method is appropriate.
(F) Is the approach economically competitive relative to other approaches?
Yes

(G) Given the state of current computer technology, can the analysis be done within a realistic time frame?
Yes

(H) Would you advocate using the results of your analysis as a means of understanding mechanisms of deformation and failure or as firm numbers for use in design (i.e. to come up with actual design parameters like the diameter of a pile)?
Yes
Characteristics of geomaterials

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• Procedure for the determining the parameters
Procedure for the determining the parameters (continued)

- Monotonic shear test
  - Internal friction angle
  - Phase transformation angle
  - Failure stress ratio
  - Phase transformation stress ratio

- Cyclic shear test (Liquefaction test)
  - Liquefaction strength
  - Dilatancy coefficient parameters
    - Quasi-OCR

- Cyclic shear test (Cyclic deformation test)
  - $G-\gamma, h-\gamma$
  - Referential strain parameters
  - Hardening function parameters

- Permeability test
  - Coefficient of permeability

- : Parameters for the E-P model
- : Directly determined
- : Estimated by empirical equations or calibrated by data adjusting method through element simulation