Advances and Research Trends in GeoEnvironmental Engineering and GeoHazards Mitigation

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General Hazards.

• Natural Hazards.
• Man-made Hazards
  – GeoEnvironmental Problems
  – Terrorism.
Motivation
Natural Hazards - Exposure

- Annual exposure of worldwide population

1. Cyclones, Hurricanes and Tornados – 119 m
2. Floods – 196 m
3. Earthquakes – 130 m
4. Drought – 220 m

(source: UNDP- Reducing Disaster Risk – 2004)
Natural Hazards - Losses

For the US – based on best data available

1. Tornados and Hurricanes - $3.5b/yr – Population in hurricane prone coastal areas is increasing

2. Floods - $5b/yr – Development in flood plains and increase in heavy rains

3. Earthquakes - $4-5b/yr – 39 states and 75m people are exposed to earthquake hazard

4. Drought - $6-8 b/yr – 35 % of the country exposed. Population shift to drier regions and land and water use effects.
Advances and Research Trends

• GeoEnvironmental Engineering
  – Multidisciplinary approach to model, simulate and evaluate material response for remediation applications.

• GeoHazards Mitigation
  – Multilevel processes and integrated systems. Large Scale Simulations.
  – New technologies for modification of “natural” and “built” environment. Smart Materials.
Advances and Research Trends

• For both: Realization that you must deal with existing “materials” soils with complex behavior.
  – Rapid developments of non-intrusive techniques for site investigation/characterization and monitoring.
  – Soil can be highly heterogeneous, so the introduction of uncertainty and stochastic simulation of both material properties and behavior.
Advances and Research Trends

• Introduction of Uncertainty at all levels and use stochastic simulations, rather than deterministic approaches.

• Improved Simulation Methods (multiprocesses and multiscale)

• Multi-scale Monitoring Systems to evaluate performance- Need for “smart”- networked sensors.

• Consistent evaluation of risk.
Advances and Research Trends
Example: GeoEnvironmental Engineering

• Conception/construction of “smart” barriers for contaminant migration.
  – Need to incorporate complex mechanisms and interactions: chemical, biological and mechanical response.
  – Iron, zeolites soil mixes for degradation, absorption and reduction of seepage velocity for organic compounds.
  – Monitoring? Embedded or remote sensors
Advances and Research Trends
Example: GeoHazard Drought-Flood

- Use of Multi-scale monitoring (sensors) systems to integrate vastly different data types (precipitation, soil moisture, temperature). Remote sensing for determining health of vegetative cover.
- Use of sophisticated “global” or large scale stochastic models to simulate and predict catastrophic events as drought and floods.
Advances and Research Trends
Example: Earthquake Hazards

• Prevention of poor performance of loose soils during earthquake loading: liquefaction.
  – Use of biological methods to alter material response
  – Chemical/ Mechanical
  – Complex Biochemical mechanical Nanoprocesses
Foundation Failure
Structural - adequate
System Performance - Unacceptable
Example: Enhanced Understanding of Material Response

Multi-disciplinary Approach

Seismic event

Transmission of Seismic waves

Site Response

Soil-Foundation-Structure Interaction

System Response

Performance Modeling

Consequences (Losses/Decisions)

Seismic Hazard

Performance Simulation

Impact Assessment

Earth Sciences

Engineering

Social Sciences
Multidisciplinary Approach
Example: Earthquake Hazards

- Seismology
- Tsunamis
- Geotechnical engineering
- Built environment - Buildings & Lifelines
- Risk assessment – Decision sciences
- Public policy
Advances and Research Trends
Earthquake Hazards

• Use of Large scale testing for both individual components (beams, columns) and multicomponent arrays (structural and non-structural elements).

• Analysis and Simulation of large scale systems.

• Use of smart-networked sensors to monitor health and identified adverse performance.
Network for Earthquake Engineering Simulation (NEES)

Goal

- Improve understanding of effect of earthquakes on building and infrastructural systems through collaborative research

- 16 Universities are funded for enhanced capabilities in earthquake engineering research

- Research

- $9 million annual commitment (FY 2004)
NEES Capabilities

- Integrates resources for research and education to serve the earthquake engineering community
  - Shared use facilities,
  - Data repository,
  - Simulation tools,
  - Collaborative/communication tools,
  - Numerical and model-based simulation,
  - Partnering, training, ...
Illustration

Super-material (UCSD)

• Fiber-reinforced polymeric composite with embedded microchips with on board data processors and copper wires
• Sensors provide information on damage and ambient conditions to assess the condition of the structure
• Copper wire allow wireless communication
• Embedded sensors allow tunable electromagnetic properties to heal the material
Summary.

- Soil as a complex material: non-intrusive site investigation and material parameter determination. Incorporation of uncertainty
- Infrastructure as complex systems requiring multi-scale and networked sensors and the associated processing capability.
- Modification of material response for both natural and constructed systems. Smart materials
- Multidisciplinary approach and incorporation of multiple mechanisms and processes to describe complex material response