Department of Civil & Environmental Engineering

Soils and Their Role in Infrastructure

Presentation at "Soils: The Foundation of Life"
National Academy of Sciences
Washington, D.C.
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Outline of Presentation

- The State of Our Infrastructure
- The Many Ways That Soils Are Used in Infrastructure – Some Examples
- Particular Challenges Posed by Soils
- Engineering Properties and Behavior of Soils
- New and Emerging Opportunities

The State of Our Infrastructure

Current State of our Nation's Infrastructure[1]

- 2013 American Society for Civil Engineering (ASCE) Report Card:

Infrastructure Type	Grade
Dams	D
Levees	D-
Bridges	C+
Roadways	D
Railways	C+
Schools	D
Public Park	C-
Ports	C

- Overall GPA in 2013: D+
- Estimated Cost to Improve: $3.6 trillion

I-35W Mississippi River Bridge Collapse (2007)[2]

Hurricane Katrina Levee Failures (2005)[3]

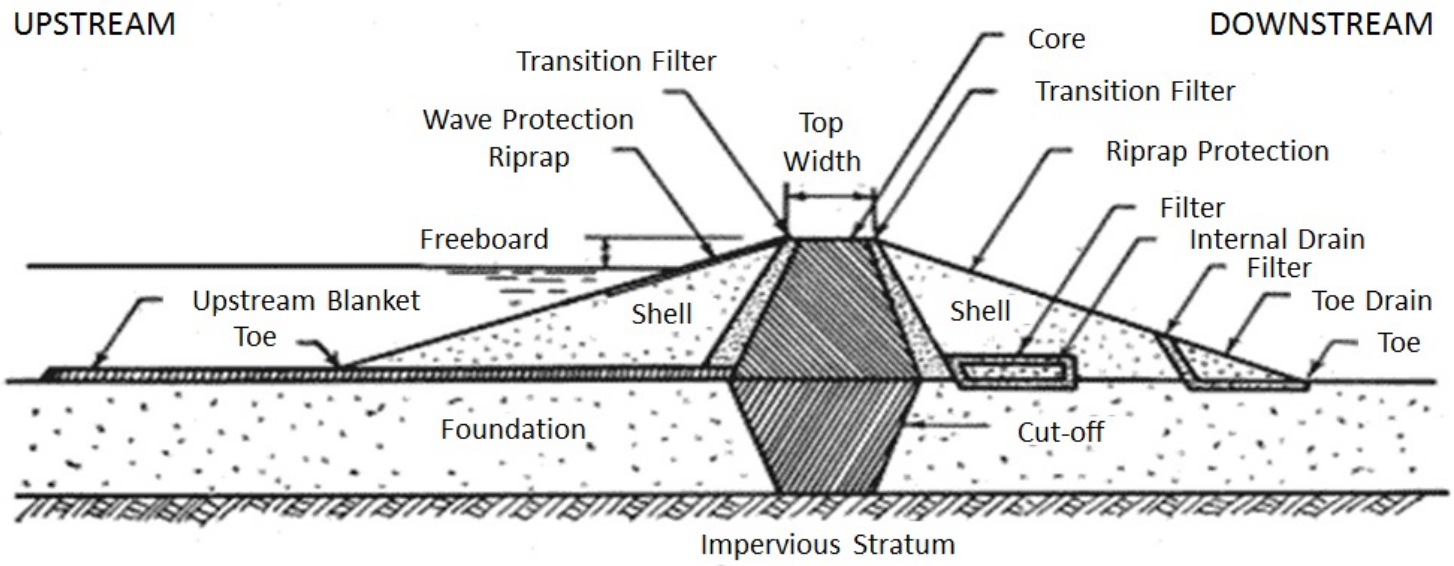
TVA Kingston Fossil Plant Coal Fly Ash Slurry Spill (2008)[4]

A 25-foot wall of ash ≈ 1 mile from the retention pond

Aerial Image of Kingston Ash Slide

The Many Ways That Soils Are Used in Infrastructure: Some Examples

Soil as a Construction Material[5]



Soil & rock are the most abundant construction materials on Earth!

Soil as a Construction Material[6]

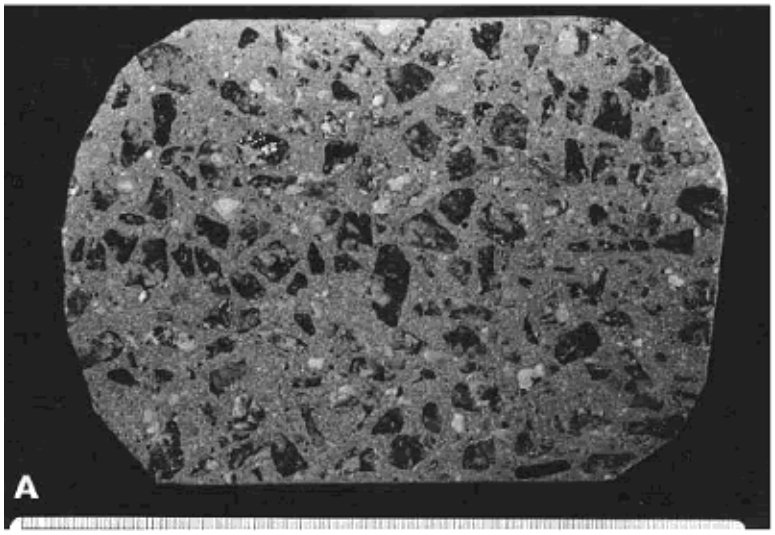
Sacramento-San Joaquin Delta Levees

Ramsden Bellhouse & Kent Hill, Essex

Rail Embankment Construction, Newcastle, NSW

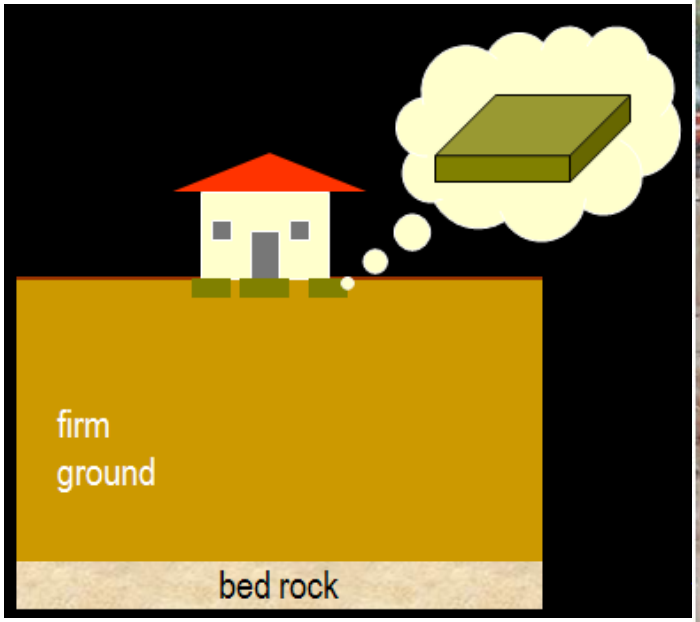
Wet Soil Mixing (Hayward Baker)

Soil as a Dominant Ingredient in Other Construction Materials[7]

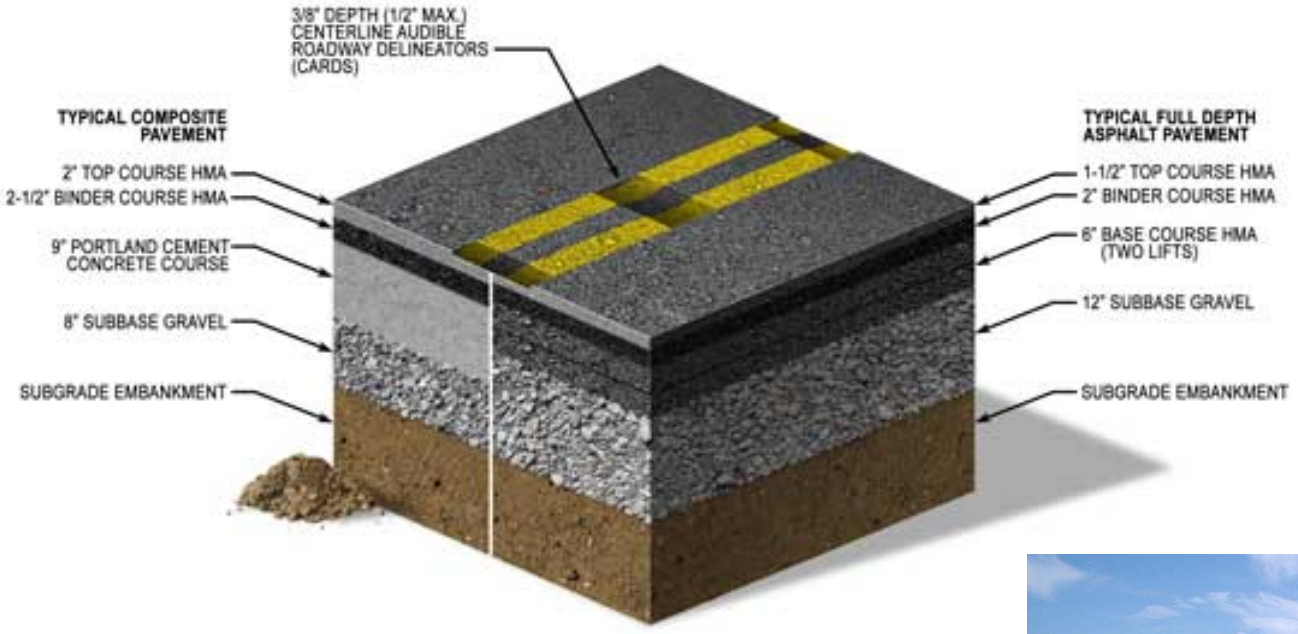


Soil: Its Indirectly Responsible For Our Other Materials as Well... [8]

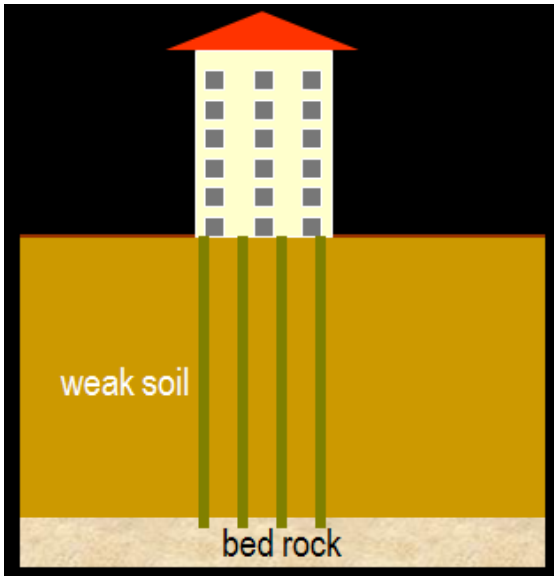
Structural Support: Foundation Bearing Capacity
Shallow Foundation Systems[9]



Bearing Support: Asphalt Pavements, Concrete Pavements, Building Slab Construction[10]

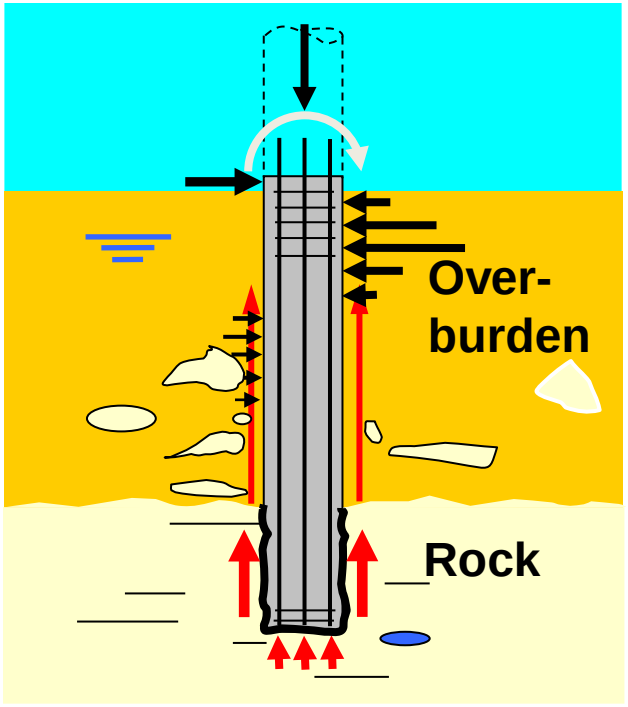


Structural Support: Foundation Bearing Capacity
Deep Foundation Systems[11]



Driven Piles

Drilled Shafts



Separation of Soil at Two Elevations: Engineered Slopes/Embankments[12]

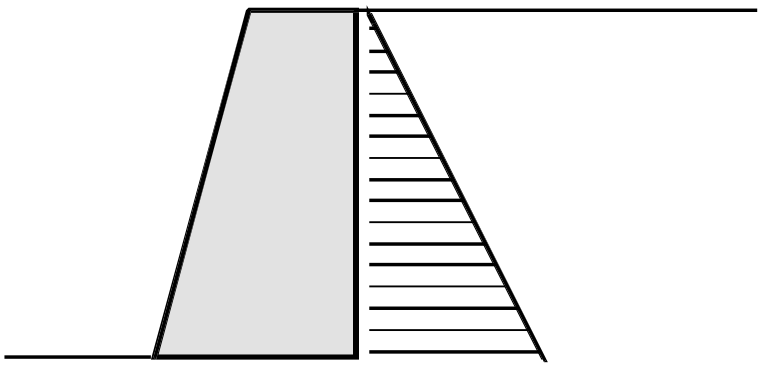
Engineered Embankment Fill

Soil Nailing

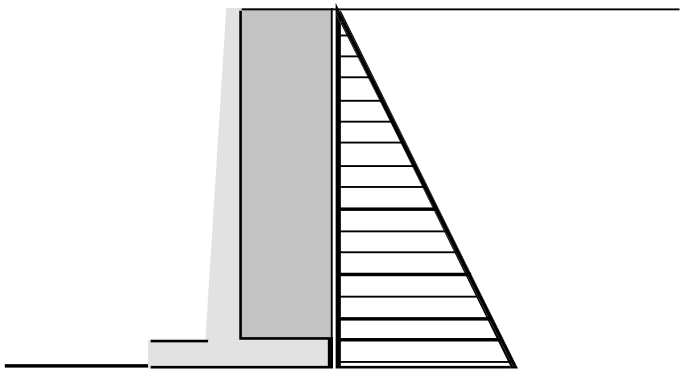
Engineered Cut Slope

Separation of Soil at Two Elevations: Earth Retaining Structures[13]

Gravity Retaining Walls

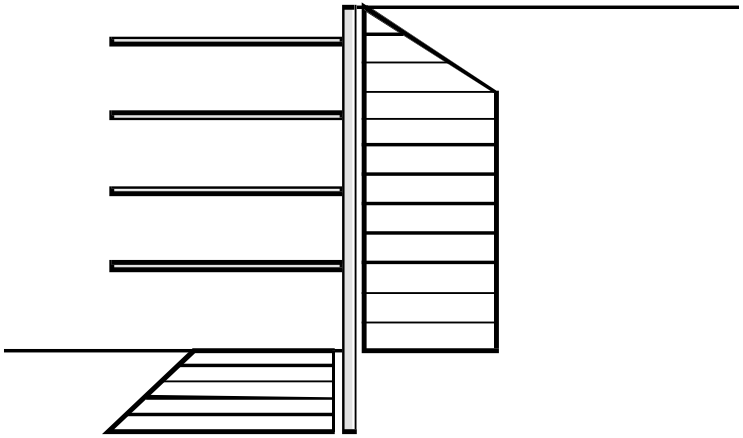


Cantilever Retaining Walls (T-Walls)

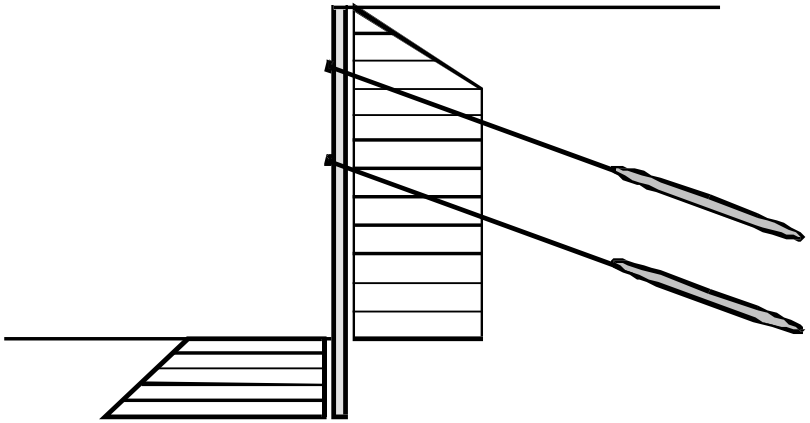


Separation of Soil at Two Elevations: Braced Excavations & Tiebacks[14]

Excavation Support Systems - Braced



Excavation Support Systems – Tie Backs



Tunneling and Underground Space Construction[15]

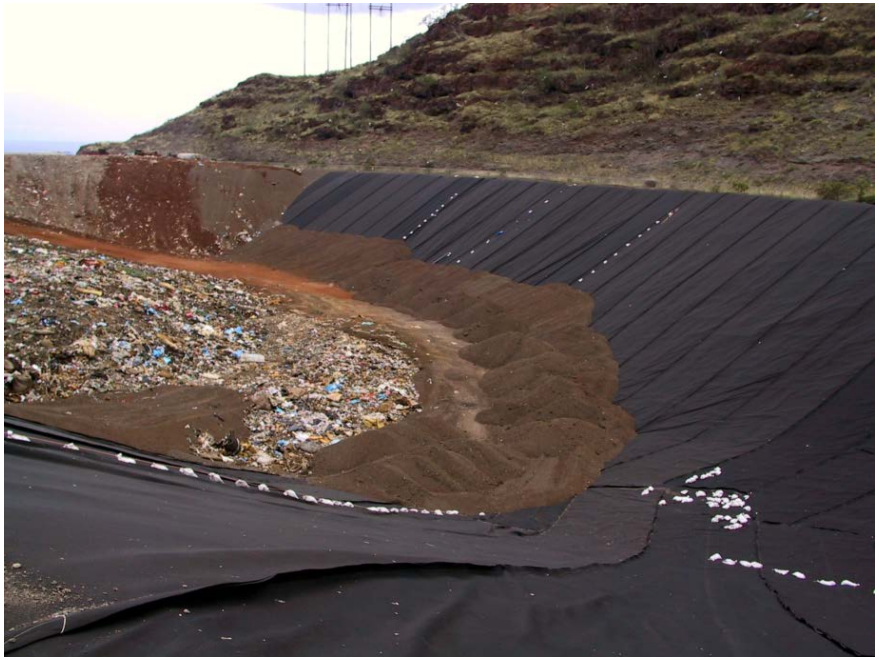
Montague Tunnel One Year after Hurricane Sandy

Access Into Underground Tunnel For Large Hadron Collider

Subway Tunnel – Underground City Infrastructure

Bearing Capacity Supports used in Mining Tunnels

Waste Containment: MSW Landfills, High-Hazard Waste[16]



MSW landfill liner system, Waimanalo Gulch Sanitary Landfill, Oahu, HI

Apex Regional Landfill, Las Vegas, NV

Particular Challenges Posed By Soils

Earthquakes[17]

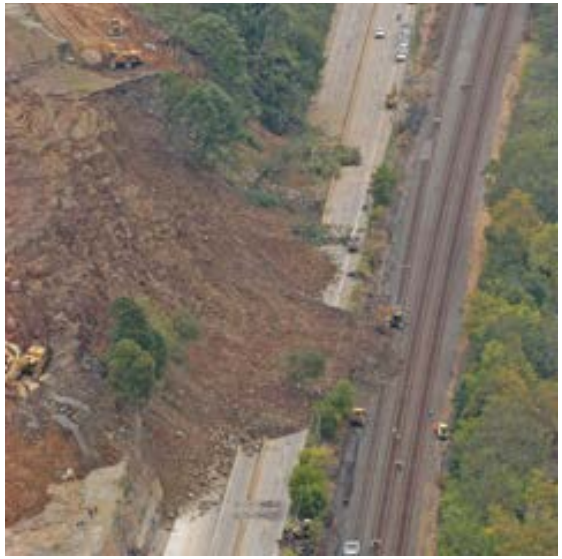
Surface Fault Rupture – 1999 Chi-Chi earthquake in Taiwan

Liquefaction in Christchurch, NZ, 2011

Structural Damage & Tsunamis – Fukushima, Japan

Lateral Spreading in Christchurch, NZ, 2011

Landslides[18]



Construction-Induced Landslide, Pittsburg, PA

Rainfall-induced landslides in WA

Freeway 3 Landslide, Taiwan

Shrink/Swell Behavior[19]

Pavement Damage Due to Expansive Soils

Pavement Damage Due to Frost Heave

Expansive Clay Shrink-Swell

Environmental Issues[20]

U.S. Titanium – Mid-Atlantic Superfund Site

Soil excavation and cleanup at a Superfund site

Engineering Properties
&
Behavior of Soils

Traditional Civil Engineering Properties of Soils

- Shear Strength – How strong is the soil?
- Compressibility – How much does the soil move under load?
- Permeability – How fast does water flow through the soil?

Bearing Capacity Failure: Ultimate Limit State[21]

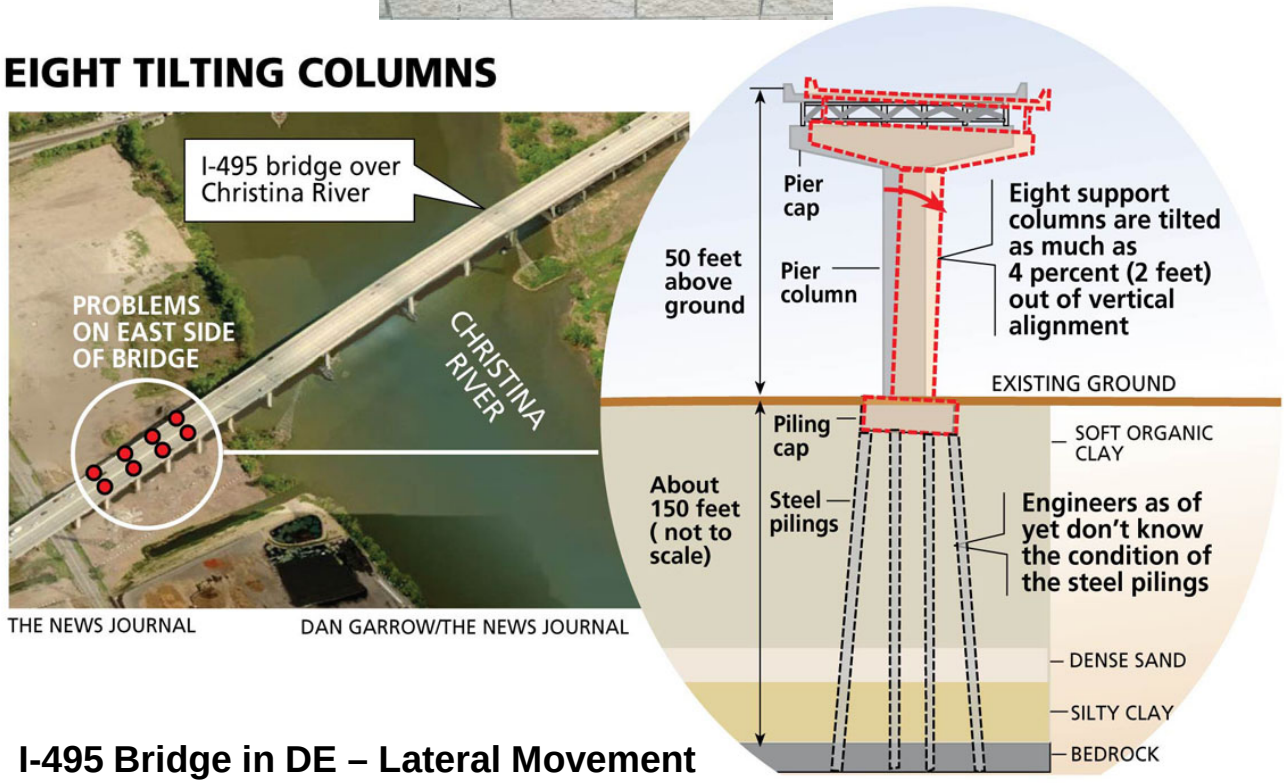
Transcona Grain Elevator, 1913

Niigata 1964 EQ Liquefaction Damage

Movement-Related Failure: Serviceability Limit State[22]

Settlement-Induced Masonry Cracking

Tilt: Leaning Tower of Pisa



I-495 Bridge in DE – Lateral Movement

Teton Dam, Internal Erosion Failure[23]

Engineering Properties of Soils

Traditional Civil Engineering Properties of Soils

- Shear Strength – How strong is the soil?
- Compressibility – How much does the soil move under load?
- Permeability – How fast does water flow through the soil?

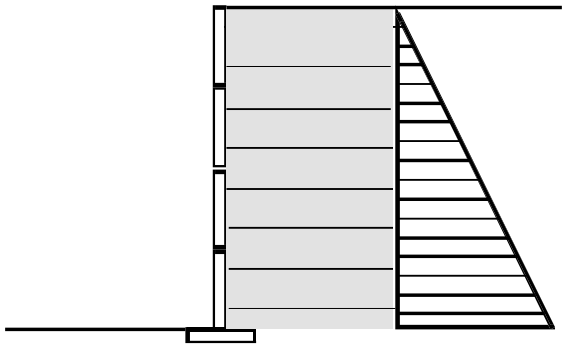
Emerging Areas of Focus

- Innovative techniques for improving the engineering behavior of soils, in a cost-efficient way (“ground improvement”)
- A greater focus on soil behavior at the micro-scale
- Fully coupled thermo-hydro-mechanical behavior
- Biogeochemical soil behavior…

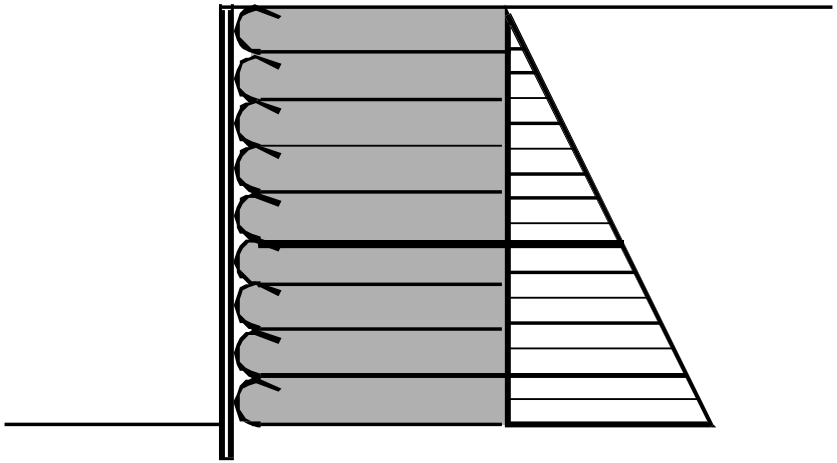
New and Emerging Opportunities

Physical Modification of Soil Properties
Tensile Reinforcement of Soils at the Macro-Scale[24]

Reinforced Earth Walls



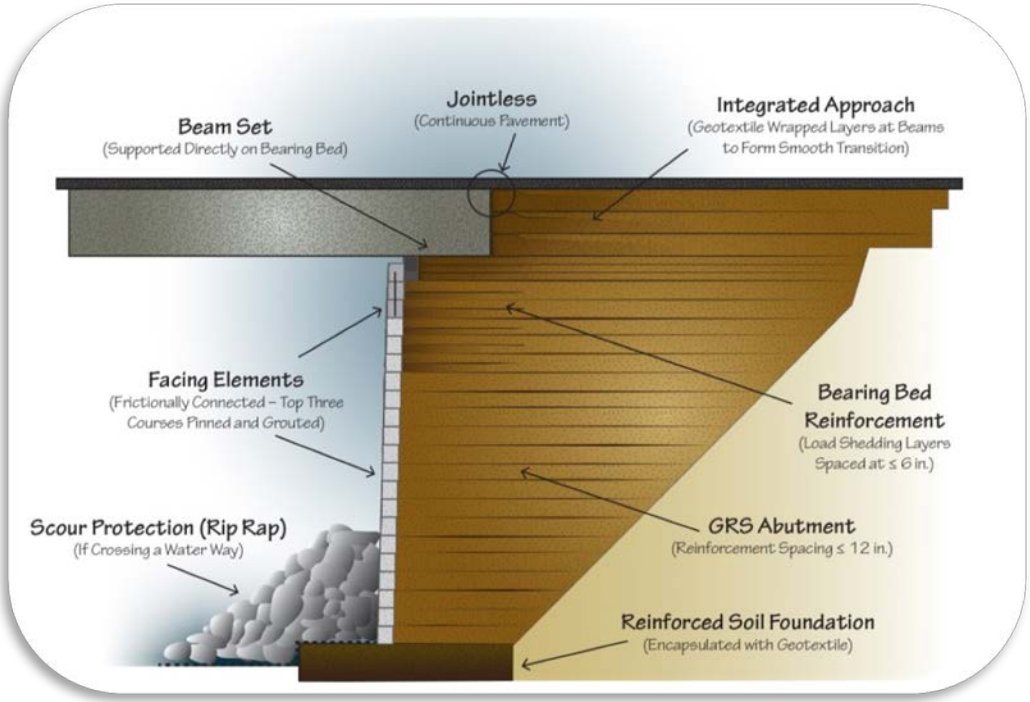
Mechanically Stabilized Earth Walls



Geosynthetic Reinforced Soil – Integrated Bridge System[25]

Chesapeake City Road, DE

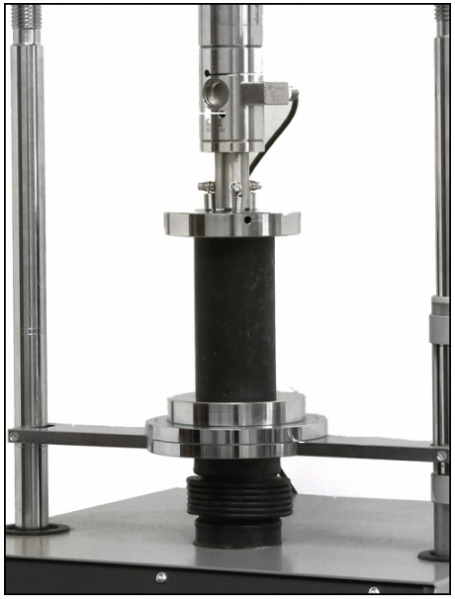
A Closer Look



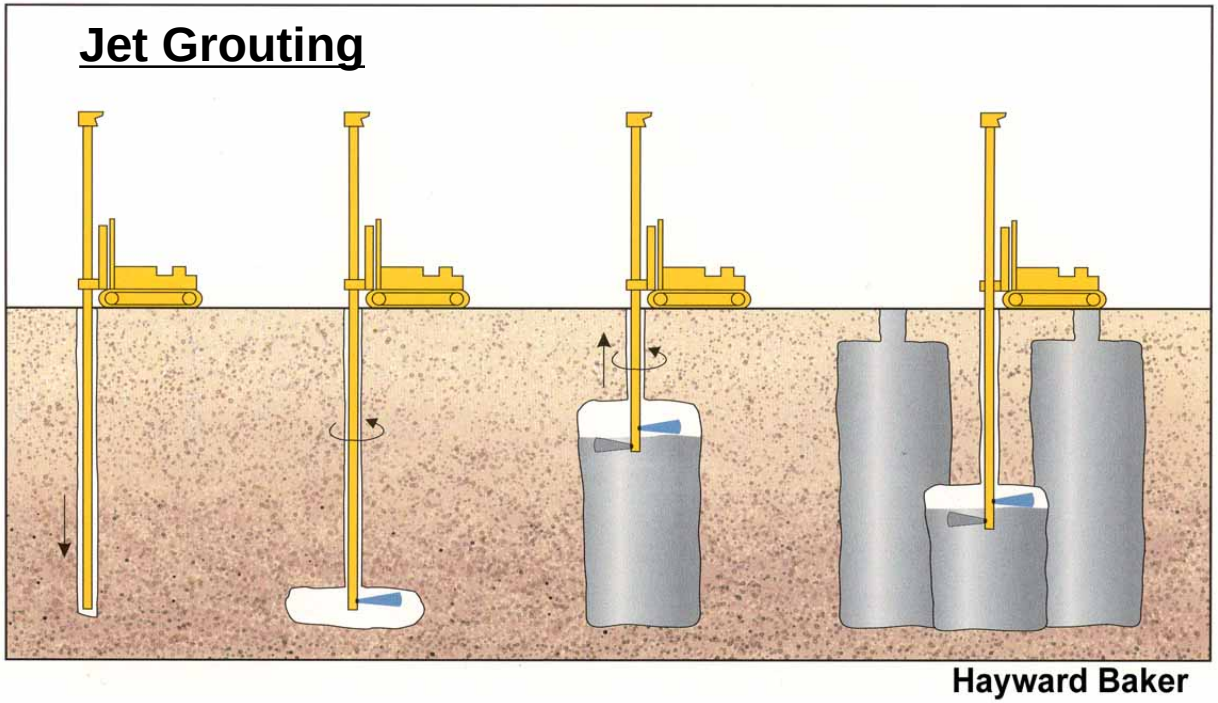
Physical Modification of Soil Properties
Tensile Reinforcement of Soils at the Micro-Scale[26]

Chemical Modification of Soil Properties[27]

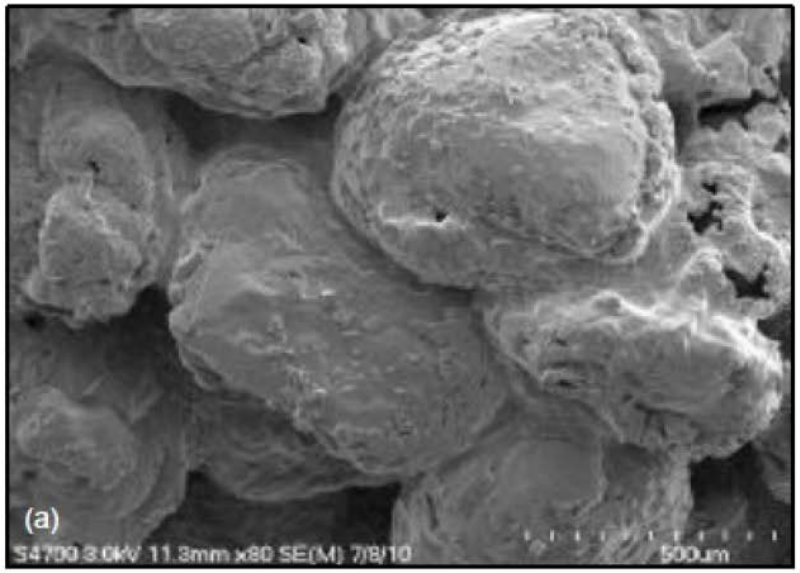
Soil-Cement

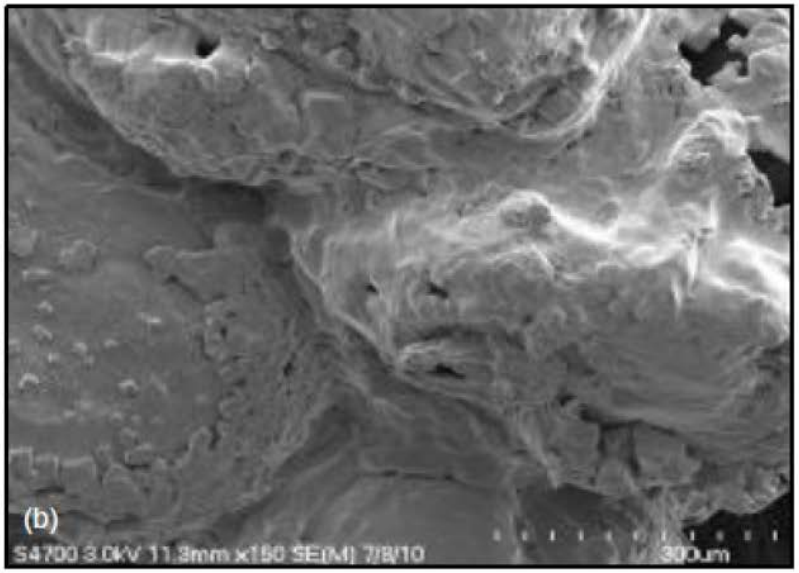


Jet Grouting

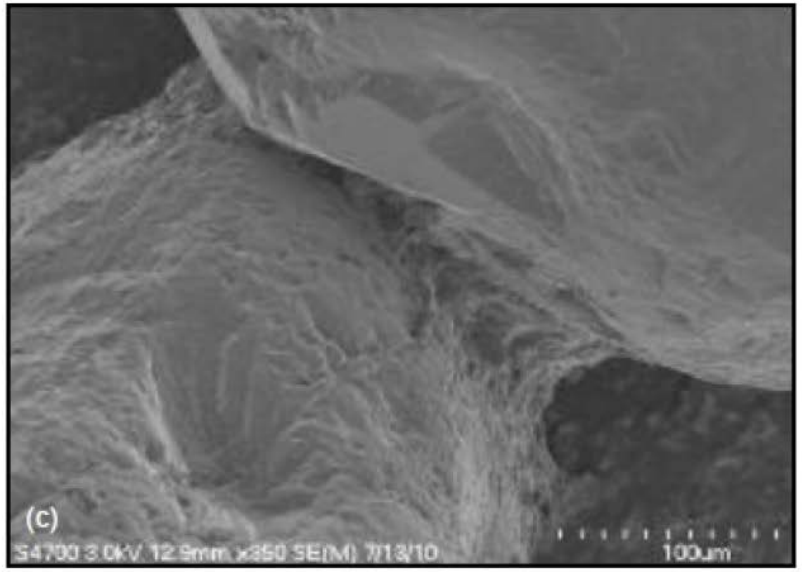


Biological Modification of Soil Properties[28]





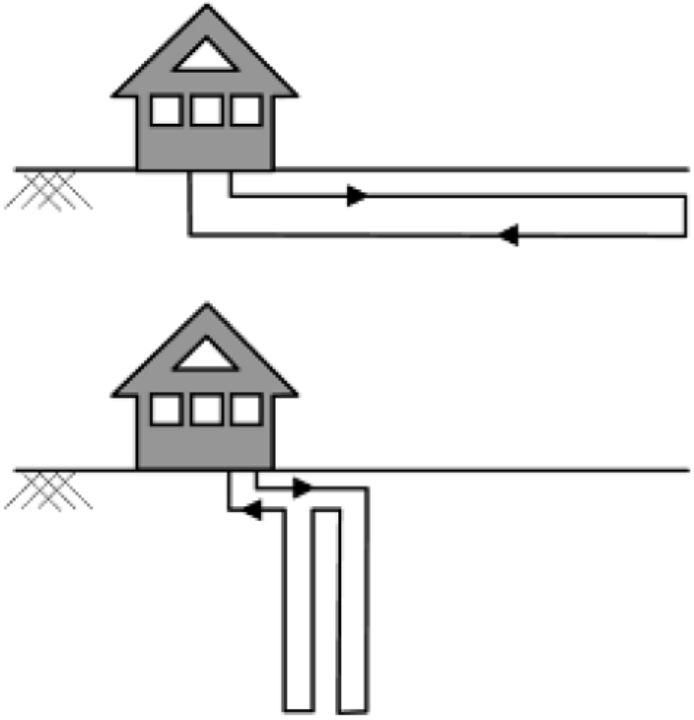
Microbially-Induced Calcite Precipitation



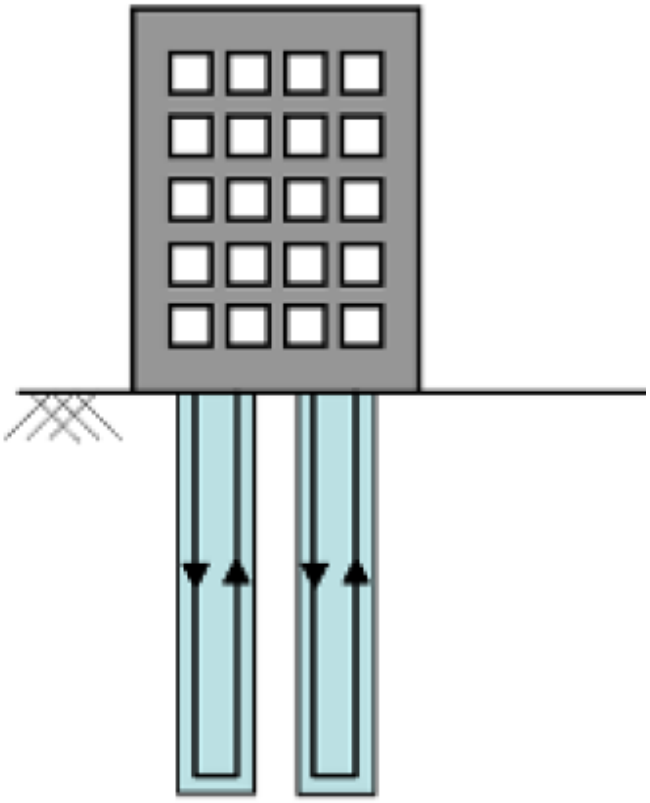
Energy Applications in the Built Environment[29]

Geothermal Storage/Recovery Systems

Ground Source Heat Pumps



Energy Geostructures



Conclusions

- Our current infrastructure in the U.S. is in relatively poor shape, and it will cost a lot to fix things to where they ought to be
- Soil plays an extremely important role in our infrastructure:
  - It is the source of our construction materials
  - It supports everything we build
  - It connects things having different elevations in a variety of ways
  - Underground construction will become even more important in the future
- Soil itself presents numerous challenges, many of which originate from naturally occurring phenomena
- Soils and their role in infrastructure is an area of new, rapid, and exciting innovation with hope for the future

Thank You !

Questions?

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