Introductory Slides

CVEN 5768 Rock Engineering Spring 2019





Production-Consumption Model

Cradle to Grave (Take – Make – Waste)



Adapted from D. Roberts and W. Wallace

Hydrologic Cycle



From Laboratory Manual in Physical Geology by Busch et al., 1997.



Geologic Cycle from *Physical Geology*, C. Plummer et al., 1996.

Systems Approach



Infrastructure

Infrastructure is that part of the anthrosphere composed of the utilities, facilities, and systems used in common by members of a society and upon which the society depends for its normal function.

Water – Waste – Sanitation -Energy – Shelter - Transportation – Land Use



NON-NATURAL SYSTEMS (Built Environment - Anthrosphere)

NATURAL SYSTEMS

(Biosphere- Hydrosphere-Geosphere – Atmosphere)



Geology, Engineering Geology, Rock Mechanics

Geology

study of the earths materials and processes through geologic time (Petrology, Mineralogy, Structural Geology, Geomorphology, etc.)

• Engineering Geology

"exists solely to serve the art and science of engineering" – geologic descriptions of rocks connected with engineering works

Rock Mechanics

Branch of *geotechnical engineering* concerned with the engineering mechanics and the properties of rocks



"Every work of man(kind) is built on, in, or with the Earth, except those things that fly, float or fall down, and these last three must start or end with some Earth contact."

Geotechnical Board (1989)

Geotechnology

- Waste Management
- Infrastructure Development and Rehabilitation
- Construction Efficiency and Innovation
- National Security
- Resource Discovery and Recovery
- Mitigation of Natural (and non-natural) Hazards
- Frontier Exploration and Development
- Sustainability and Sustainable Technologies

From Rocks to Soils

Fresh Rocks (I) Weak Rocks - Stiff Soils (II-V) Soils (VI)

Weathering



Figure 9-1 Climatic influences on types of weathering processes. (From Peltier, 1950; reproduced by permission from the *Annals of the Association of American Geographers*, 40:219, Fig. 3.)



Figure 12.1. Typical range of seismic velocities for rock and surficial deposits (after *Ground Water Hydrology* by D.K. Todd, 1980. Reprinted by permission of John Wiley & Sons, Inc.). A. Unsaturated material. B. Saturated material.



bedrock

bedrock

Objectives of Rock Mechanics

- Determine the properties of rocks and rock masses
- Model and predict the behavior of rock masses
- Observe, monitor, and evaluate the response of rock masses and engineering structures built in or on rock masses

Rock Mass Properties

- Physical Properties (Age, Geological Name, Weatherability, Durability, Hardness, etc.)
- Mechanical Properties (Deformability and Strength)
- Hydraulic Properties (Permeability, Storativity)
- Thermal Properties (Thermal expansion, conductivity)
- In Situ Stresses

Rock as an Engineering Material

DIANES

Discontinuous In-homogenous Anisotropic Non-linear Elastic Scale-dependent



large right lateral ottset to drainage pattern

SAN ANOR

small-scale drainage pattern also shows right lateral offset

GROUP	TYPICAL DISCONTINUITIES	TYPICAL SCALE
Rock Type Defects	Microfissures	0.2'
	Bedding Plane Partings Foliation Partings	2'
Detailed Discontinuity Pattern	Joints Minor Shears Minor Seams	20'
	Shears Seams	200'
Gross Discontinuity Pattern	Major Shears or Crushing Zones	2000'
	Regional Fault Zones	20,000
Induced Fractures	Buckling or Spalling Fractures	0.2'- 20'

Rock Anisotropy

- Foliated metamorphic rocks (schists, slates, phyllites, gneisses)
- Stratified sedimentary rocks (shales, sandstones, limestones)
- Rocks cut by one or several joint sets

Scale Effects



Rock Masses as Complex Systems

- Self-organization
- Open dissipative structures
- Interconnectedness
- Small changes affect the whole

"Minor geological details' refer to features that can be predicted neither from the results of careful investigations of a dam site nor by means of reasonable amount of test borings..."

(Karl Terzaghi in "Effect of Minor Geological Details on the Safety of Dams", 1929)

Uncertainty

- Uncertainty in the material itself
- Uncertainty in data collection and testing
- Uncertainty in model prediction
- Uncertainty in rock mass behavior

Law of incompatibility: As complexity arises, precise statements lose meaning and meaningful statements lose precision.

Coupled Hydro-Thermo-Mechanical Processes



History

- First US Rock Mechanics Symposium held at CSM in 1956.
- 44th US Rock Mechanics Symposium in SLC in 2010
- First book on rock mechanics (La Mecanique des Roches) by Talobre in 1957 (1967)
- ISRM formed at Salzburg, Austria in 1962 under the leadership of Leopold Müller
- ISRM web site <u>http://www.isrm.net</u>
- Am. Rock Mechanics Association: http://www.armarocks.org
- Int. J. of Rock Mech. and Mining Science founded in the UK by Albert Roberts in 1964. <u>http://bit.ly/8gF6e0</u>
- First ISRM Congress held in Lisbon in 1966.
- 14th ISRM Conference in Brazil in 2019.





Vaoint Dam (Italy)









http://www.youtube.com/watch?v =uqkFXm2HtMA

Malpasset Dam (France)

Before

After



http://www.youtube.com/watch?v=9 61-wGFlcc&feature=related







Libby Dam (MT)

http://en.wikipedia.org/wiki/Lib by_Dam

Earth Dams



Teton Dam (Idaho)



Second hole in face of dam. A few minutes after 11:30 a.m. June 5, 1976.

June 5, 1976

http://www.youtube.com/watch?v=KEdM6Ys6spA http://www.history.com/shows/modernmarvels/videos/engineering-disasters-tetondam#engineering-disasters-teton-dam







Underground Excavations































BEWARE OF FALLING ROCK



















- Ground freezing and TBM <u>http://www.bing.com/videos/search?q=ground+freezi</u> <u>ng+video&FORM=VIRE1#view=detail&mid=4381F3479</u> <u>90BF3EAEC784381F347990BF3EAEC78</u>
- Tunnel Boring Machine <u>http://www.youtube.com/watch?v=qx_EjMlLgqY</u>
- Micro-tunneling <u>http://www.youtube.com/watch?v=_tOx0KTmzbw</u>
- Tunneling Through the Alps <u>https://www.youtube.com/watch?v=QaTN_R1b001</u>