EGEL

Geo-Education

J. Carlos Santamarina

KAUST

Basic Observations

Past 100 years of Geotechnical Engineering
- Explosion in knowledge ... very broad
- Computer tools & readily available information

Future:
- Challenges: climate change, sea level rise, energy, sustainability

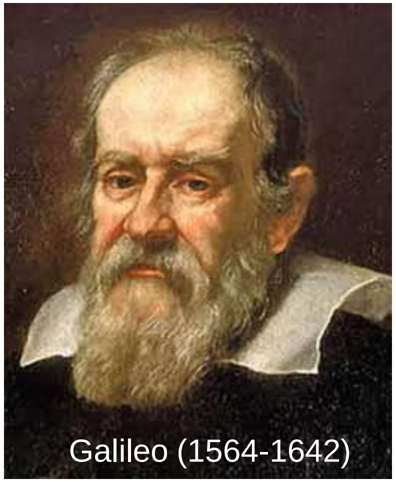
Lab	On a bench Multi-physics HTCBM Material database
In Situ	Multi-physics *(innovations needed)* Mathematically inverted field tests
Numerical	Robust, task-specific, visual Multi-physics Self-consistent parameter input (data-based) Built-in stochastics (including spatial variability)

My Personal Choices

Assumption: ***Young engineers readily get pragmatic knowledge once in Industry***

Basic needs

mechanics	e.g., equilibrium & compatibility
physics	e.g., conservation
chemistry	e.g., water and minerals
biology	e.g., limiting factors to life
geology	e.g., formation & time
materials	e.g., particulate matter
mathematics	e.g., algebra


Galileo (1564-1642)

Fundamentals + logical thinking

Physics-inspired ... data-driven

Simple ... but not simpler

Fun

Not to Teach (Pruning)

Multiple semantics (clay) & misnomers (cohesive soil)

Incorrect concepts:

- “Lubrication” to explain compaction curve
- Sequential primary and secondary consolidation
- Invoke tensile strength to explain desiccation crack formation

Superseded:

- Graphical approaches $c_{v,}$ preconsolidation pressure
- Plastic limit

Unsound “tricks”:

- buoyant unit weight
- UU tests and total stress analyses

Fragile correlations and equations:

- Check dimensionally inhomogeneous expressions
- Equations that violate asymptotic trends

To Tweak and Refocus

Curriculum around extremes

- dry or water saturated soils
- drained and undrained analyses

Old-sounding but elegant

- *feeling flow* with flownets (boundary conditions)
- *feeling equilibrium* with Mohr circle
- elegance of elastic solutions
- combining equilibrium and failure: Mohr-Coulomb
- the “essentially engineering” upper and lower bounds

To Teach (Evolving Emphasis)

Particulate nature of soils and fractured rocks

Critical relevance of effective stress!

Extend scientific foundations

Update formation history and diagenesis

bonding and structured soils

stratigraphy and spatial variability

Increase emphasis: well-designed field tests to infer properties

Increase awareness of the pervasive tendency to localizations

Long-term performance (including repetitive loads of all kinds)

soils are particulate materials ... therefore

Inherently <u>non-linear</u>, <u>non-elastic</u>, <u>porous</u> and <u>pervious</u>

Particle-level characteristics and processes ➔ macroscale response

- Shape (formation history): packing, anisotropy, stiffness, ϕ_{cv}
- Size: particle-level forces (10μm-to-50μm)
- Fabric: *fines* electrical forces (fluid pH & c_{ion})
  coarse shape and C_u
- Porosity: fines wide range & f(σ')
  coarse narrow range & mostly defined at packing

The particulate skeleton (frictional) coexists with the pore fluids (viscous)

- Skeleton and fluid interact ➔ coupling ... Skempton's A & B
- Mixed fluids: add capillary effects

Mechanical behavior of the granular skeleton: f(σ')

- Stiffness (Hertz), frictional strength (Coulomb), dilation in shear (Taylor)
- Frictional strength ➔ limited stress anisotropy

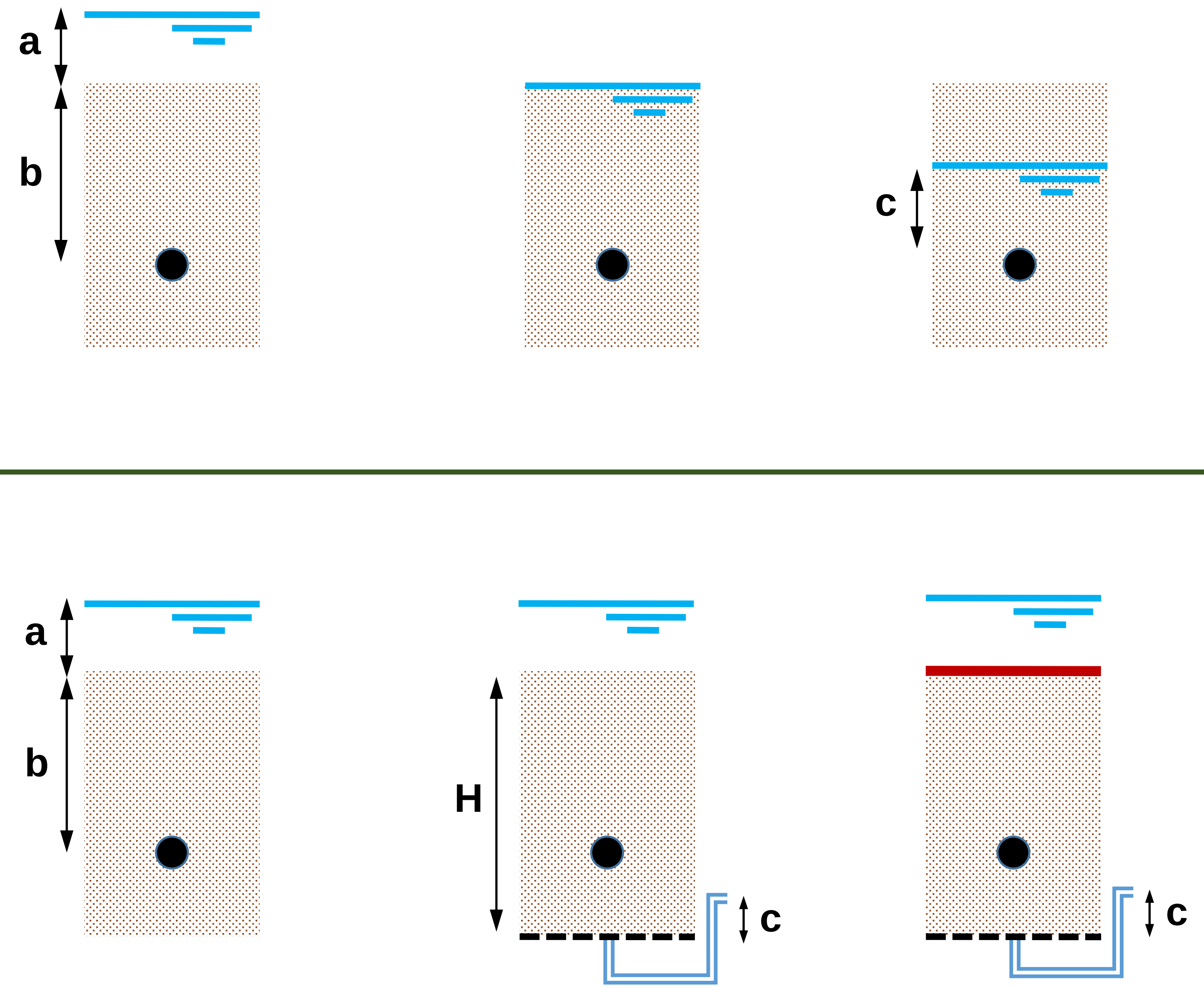
Particle-level deformation mechanisms = f(strain level)

- Small-strain: grain deformation at constant-fabric
- Large-strain: fabric changes

γ_{th}= f(d,σ')

Soils are not inert

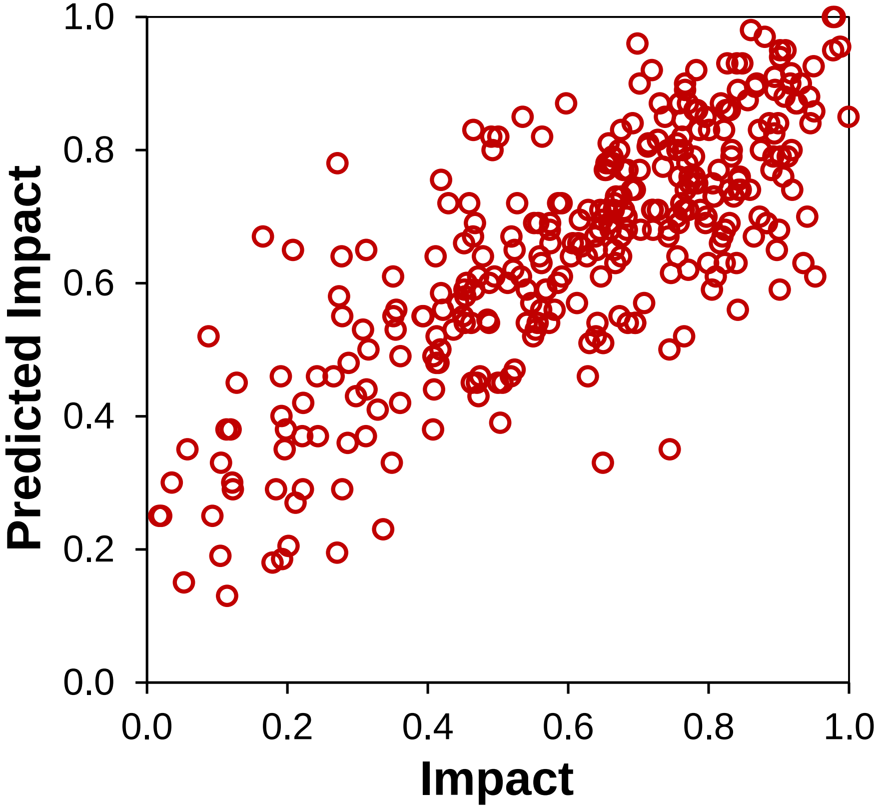
what is the vertical effective stress at the point?

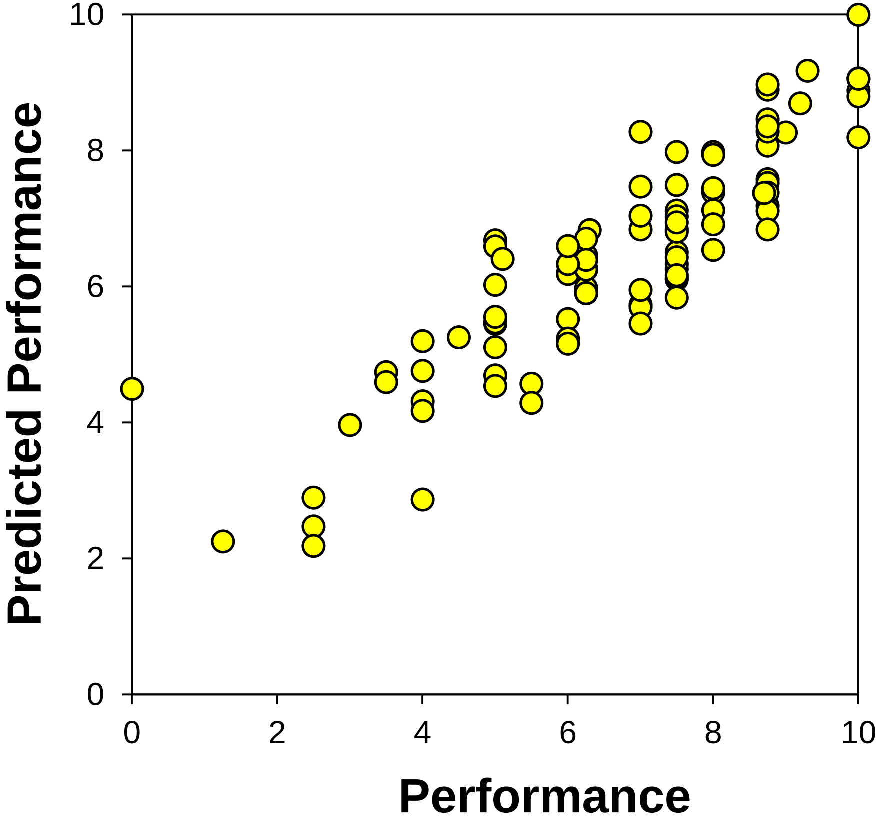


To Teach: The Importance of Dedication

Details in TED talk https://www.youtube.com/watch?v=8JH-Xh55iEg

Impact* = α *Intellectual potential* + β *Social skills* + χ *Dedication





Im= 0.1 IP + 0.2 S + 0.7D

Per= 0.3 IP + 0.2 S + 0.5D

University = Neuro-Gym

Most universities: Geo-Labs are dirty/abandoned facilities

Invitation: let's clean up our labs !

We must make choices

Institutions: different missions & different curricula

Students: different backgrounds/abilities

In any case: no time to waste

Students: meaningful existence

Let's commit not to underestimate students intellect

There is no shortcut to geoengineering [Euclid]

A changing world: Engineering as the driver for innovation