2nd International FLAC/DEM Symposium

Lateral Earth Pressures with Layered Backfill

Jim S. Shiau, PhD (Newcastle)

Senior Lecturer in Geotechnical Engineering

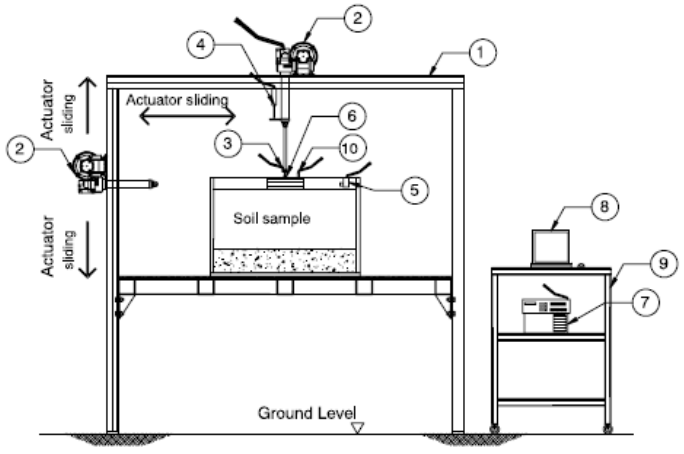
Faculty of Engineering and Surveying
University of Southern Queensland
Toowoomba, QLD, Australia

USQ, Toowoomba, Queensland, Australia

Background to research

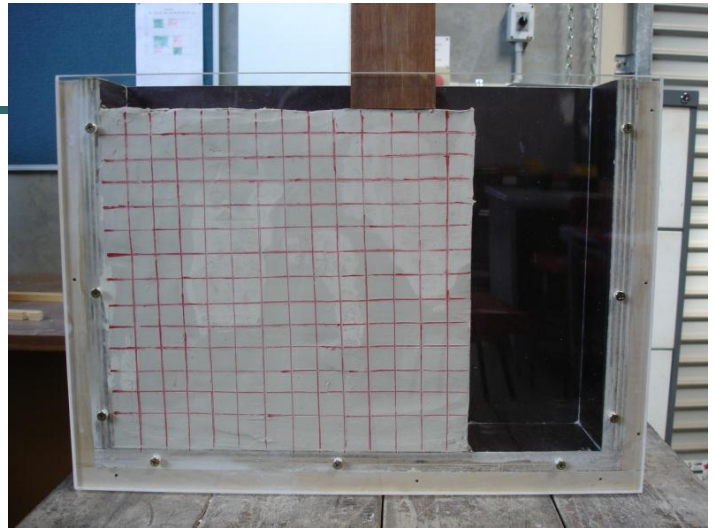
- **To make use of the existing resources at USQ (both 2D and 3D FLAC licences), we aim to develop numerical models for various geotechnical applications.**

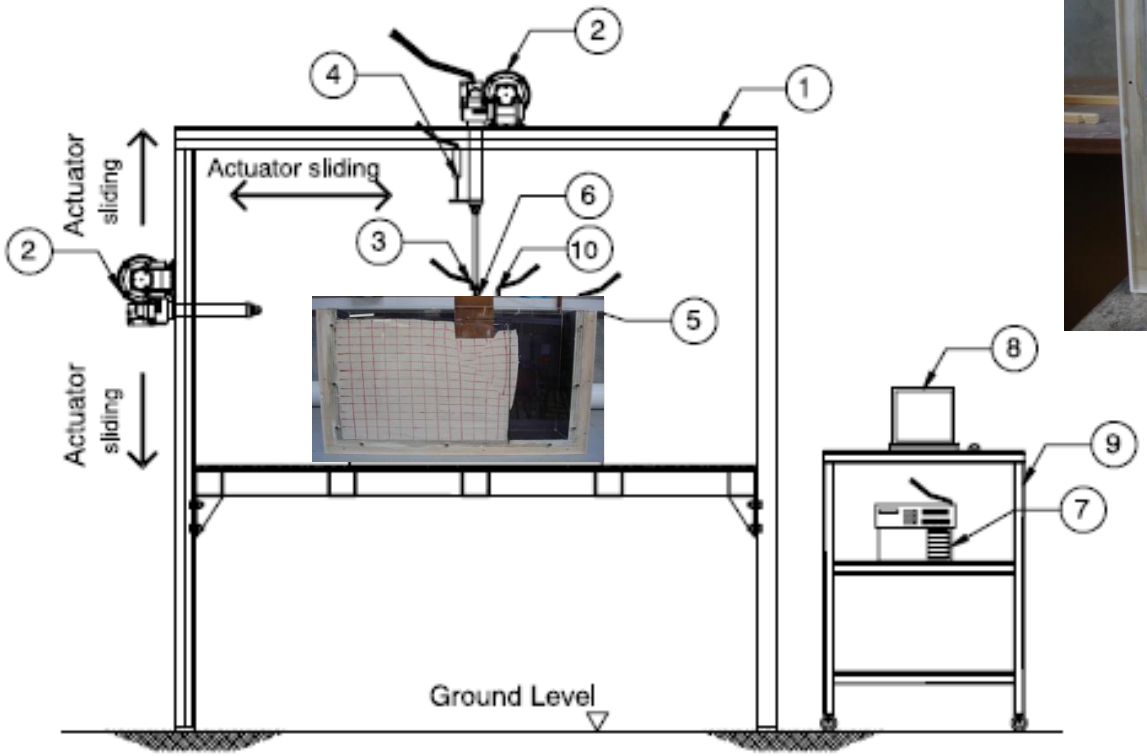
- **Research at USQ also involves developing various physical models for teaching purposes, so as to complement the numerical approach using computer modeling.**

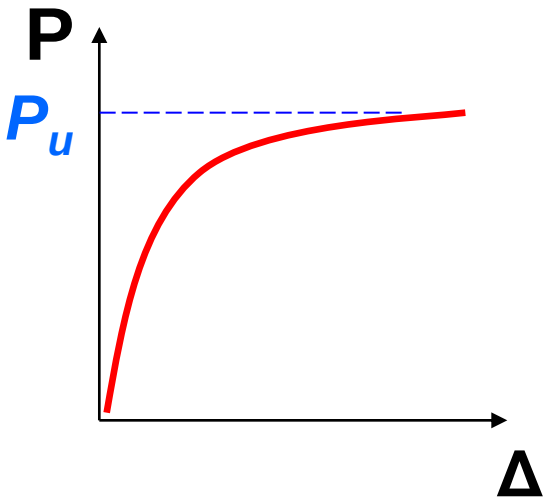


Background to research

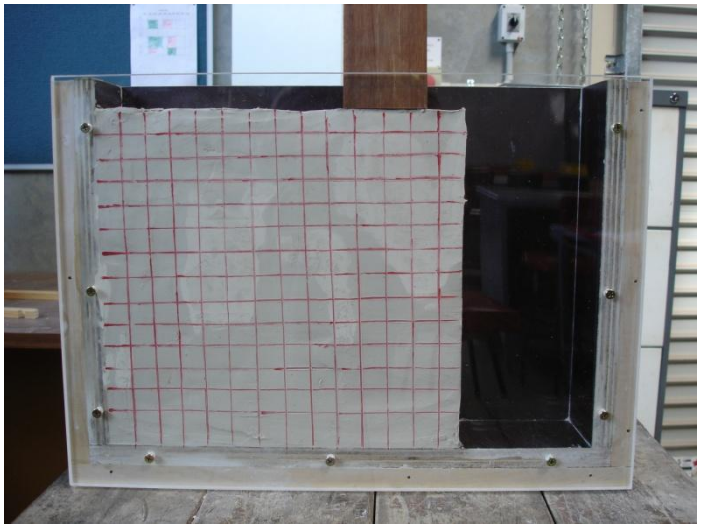
USQ Geotechnical Stability Testing Rigs





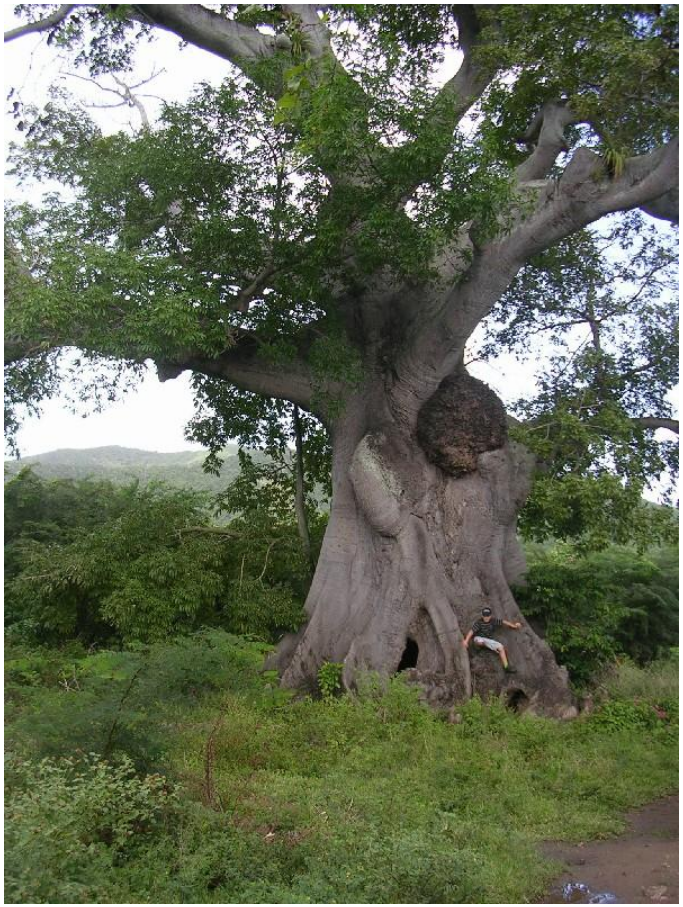


What is physical model?



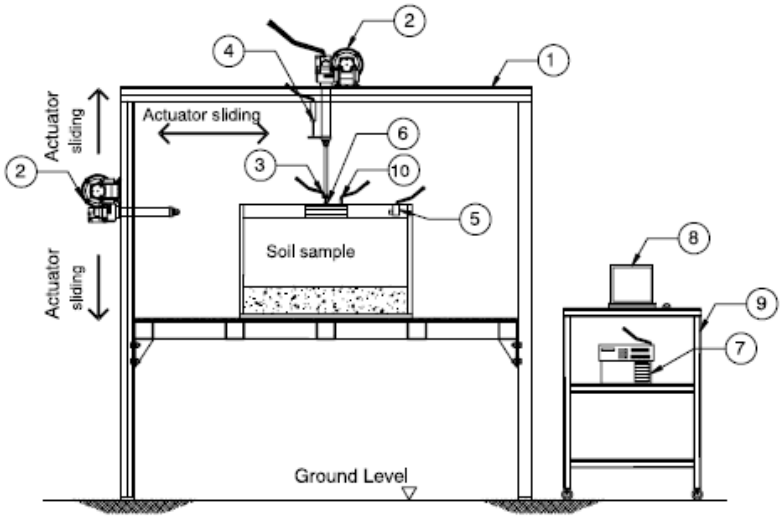
A landslide model to simulate the failure pattern of a slope.

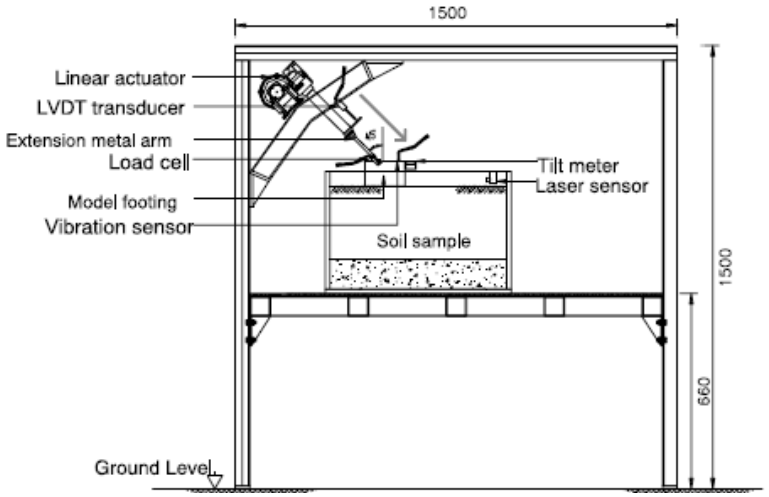
Bonsai vs. Physical Model

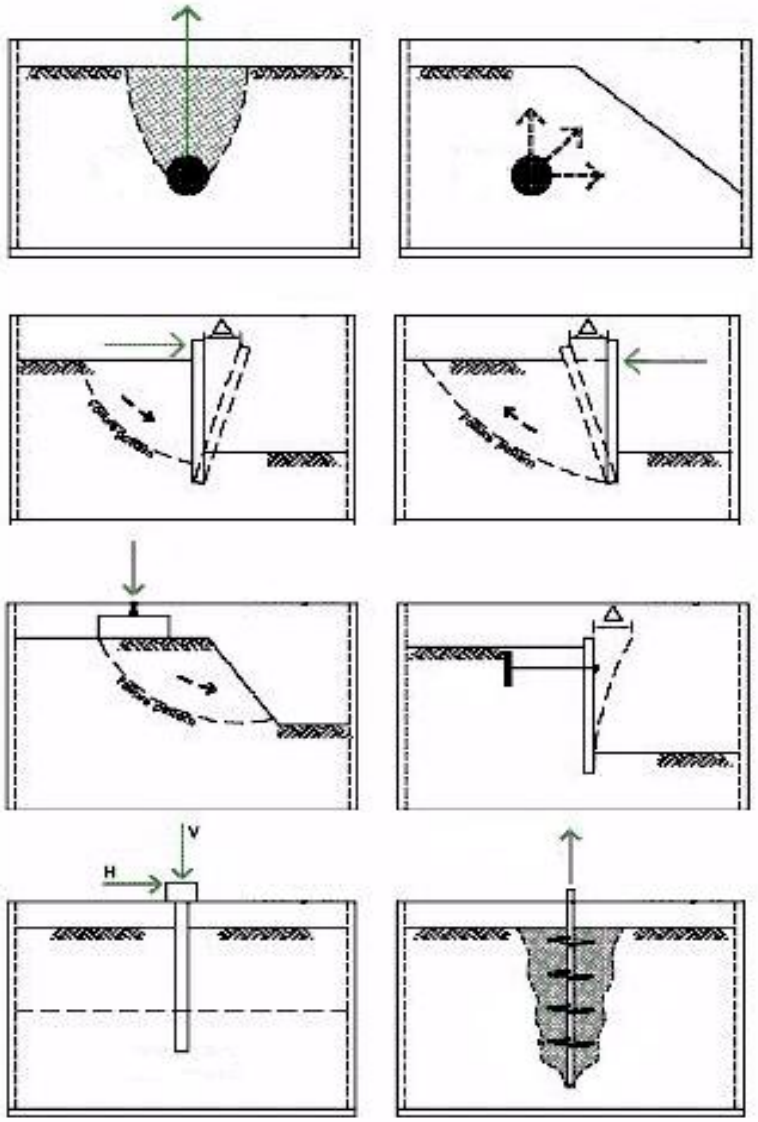


Bonsai

The knowledge gained in the process of Bonsai making would help to understand the behaviour of a real tree.

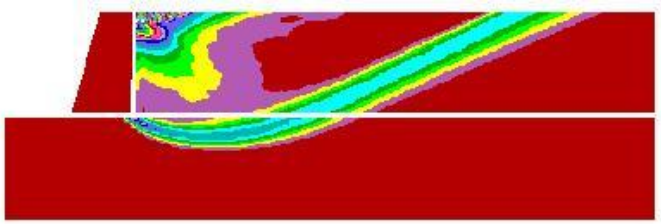

Actuator sliding
Actuator sliding
Actuator sliding
Soil sample
Ground Level
1
2
3
4
5
6
7
8
9
10

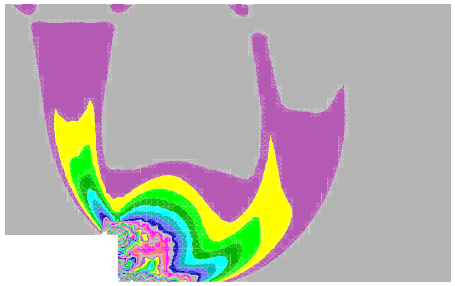

1500
Linear actuator
LVDT transducer
Extension metal arm
Load cell
Model footing
Vibration sensor
Tilt meter
Laser sensor
Soil sample
1500
660
Ground Level

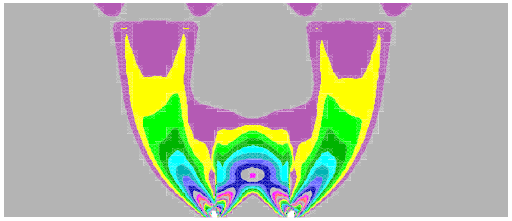

V
H

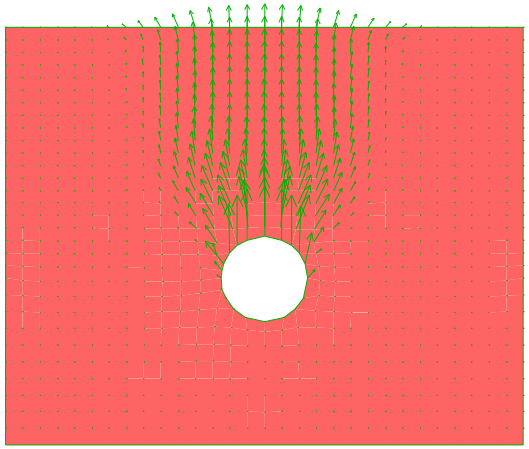
Various Stability Models using FLAC

- Classical earth pressure problems
- Slotted wall
- Trapdoor
- Tunnel heading
- Uplift of buried pipe
- Uplift of ground anchor









Background to research

- **Had some experience in Upper and Lower Bound Limit Analyses during my stay in Newcastle Geotechnical Group during 1998-2003.**

- **Overall, my research interests at USQ**
  - To develop stability models using FLAC.
  - To develop stability models using Upper and Lower limit analyses.
  - Physical modeling using simple stability testing rigs at USQ.

- **Two papers in this symposium:**
  - Modeling Uplift of Plate Anchor
  - Earth Pressures with Layered Backfill

Goal and Objective

Lateral Earth Pressures with Layered Backfill

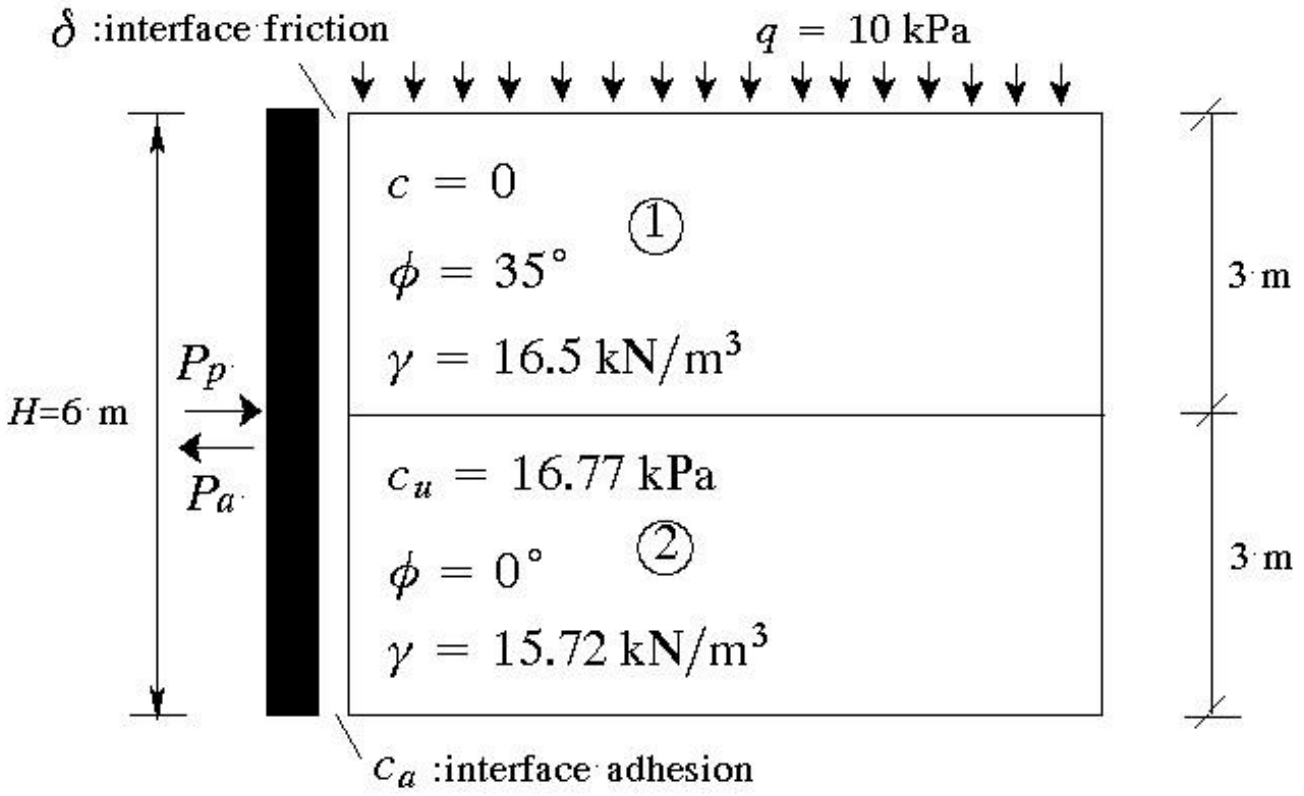
- **To investigate the situation of active and passive earth pressures on the back of a retaining wall with layered backfill.**

- **To compare FLAC results with those using classical earth pressure theory and *FE Limit Analyses - Upper and Lower* Limt Analyses.**

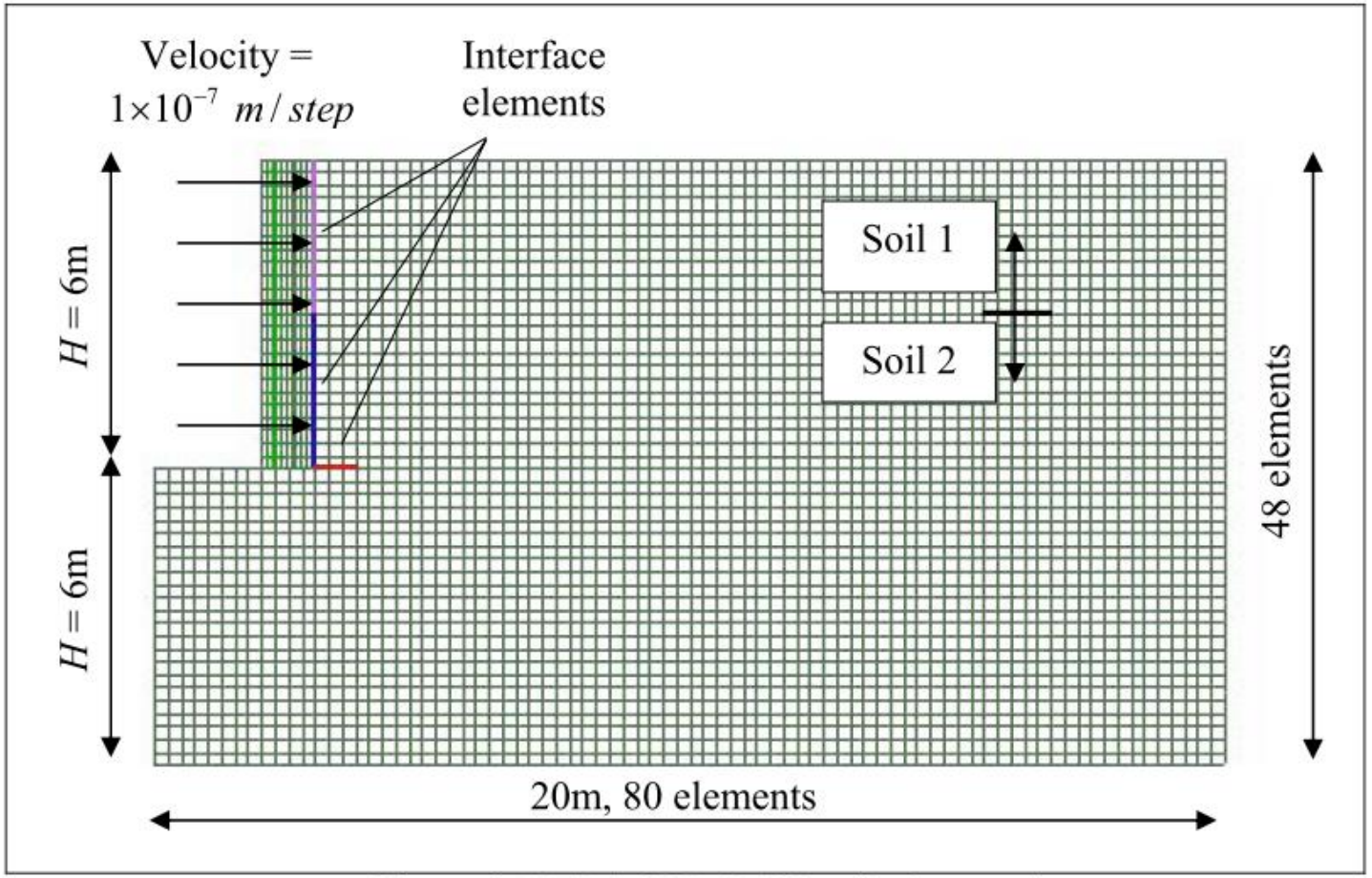
  - *FLAC*
  - *Rankine/Coulomb/Log Spiral*
  - *Upper and Lower bounds*

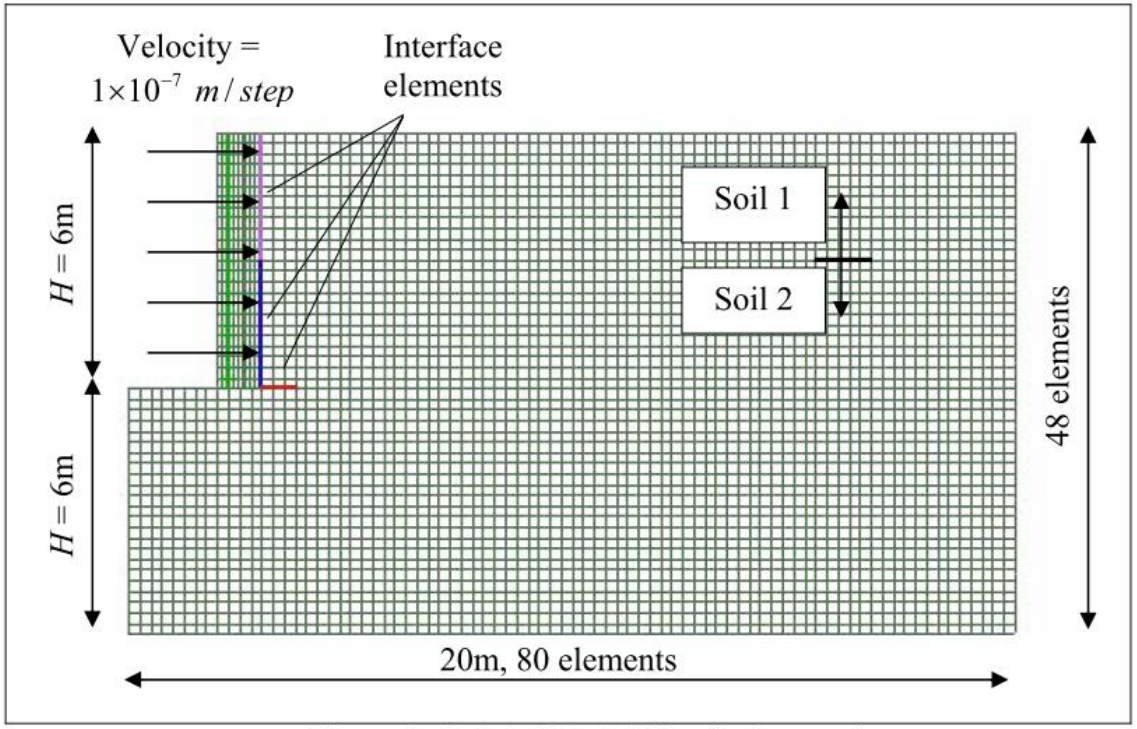
  For smooth and rough wall cases!

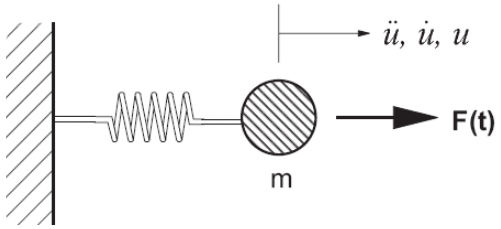
The problem definition



The problem definition





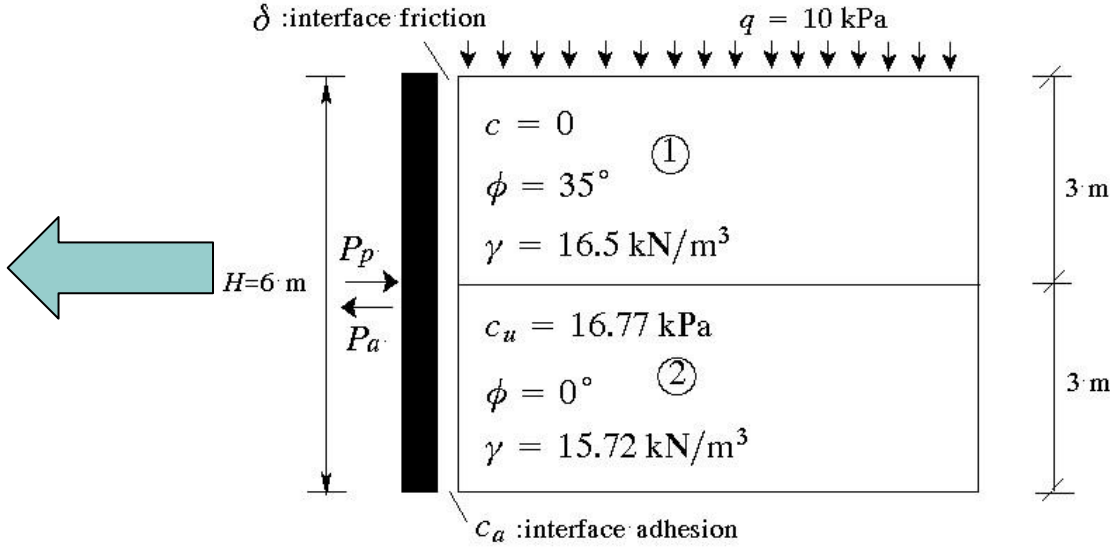


$$m\frac{d\dot{u}}{dt} = F$$

To solve a static system using the dynamic equation of motion, an artificial nodal damping is needed so that kinetic energy can be gradually removed.

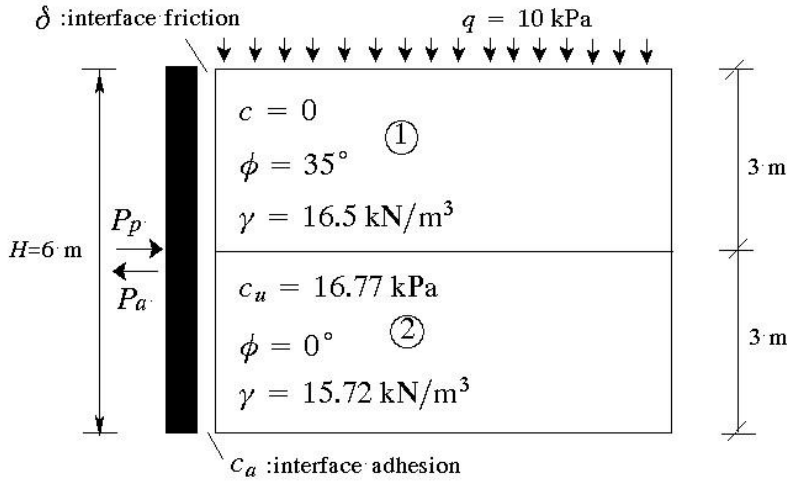
Smooth case - Active wall

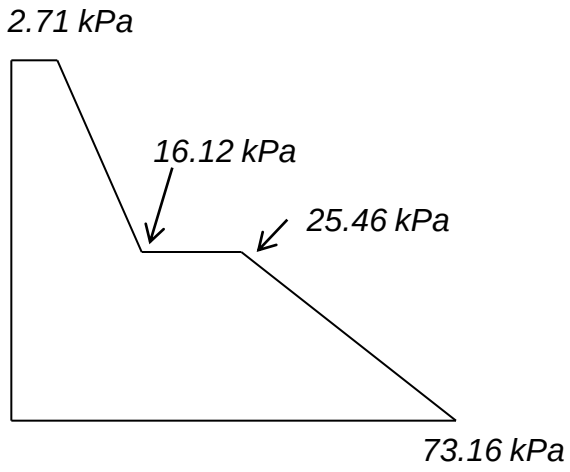
- **FLAC solution**
- **Textbook solution – Rankine**
- **Upper and Lower bound solutions**



Textbook solution of the problem

Active wall – smooth wall case – Rankine's solution





Active Pressure Diagram

Rankine: Total horizontal active thrust = 176.18 kN/m

FLAC solution = 167.20 kN/m

Upper and lower bound solutions of the problem

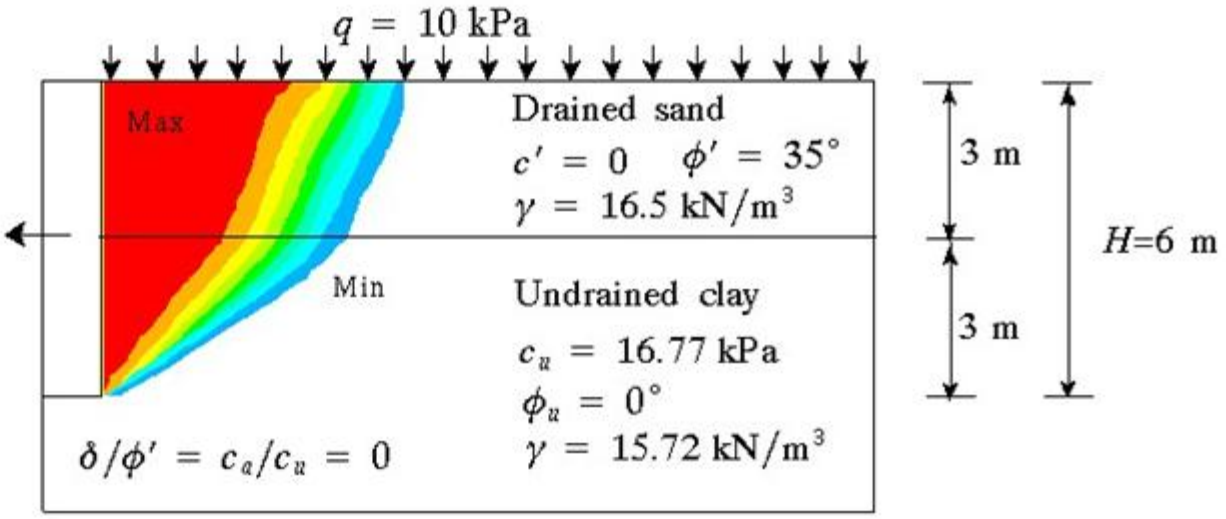
Active wall – smooth wall case

Smooth wall

$(P_a)^{UB} = 166.35$ kN/m

$(P_a)^{LB} = 173.21$ kN/m

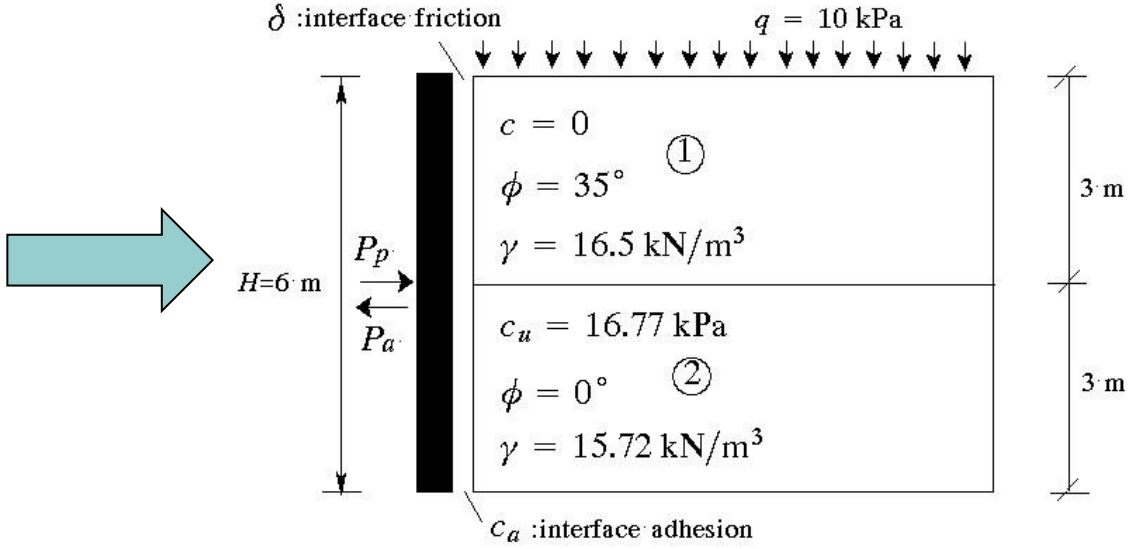
$(P_a)^{Rankine} = 176.18$ kN/m



FLAC solution = 167.20 kN/m

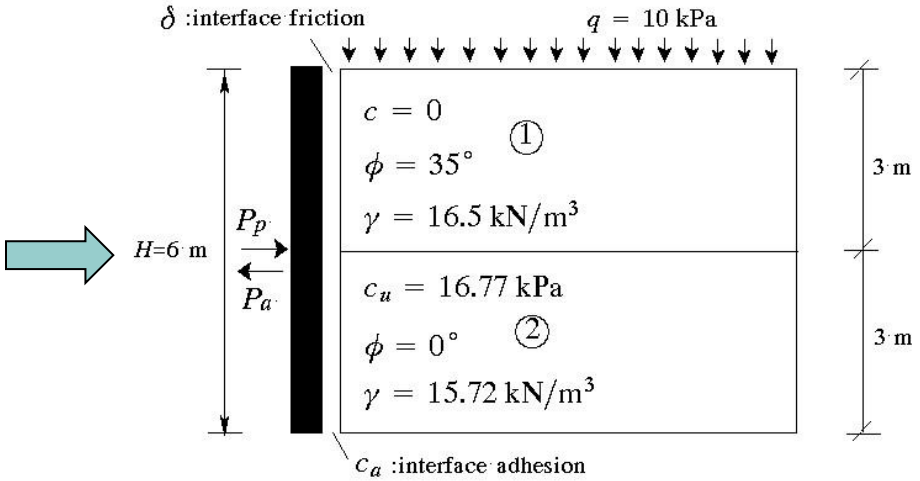
Smooth case - Passive wall

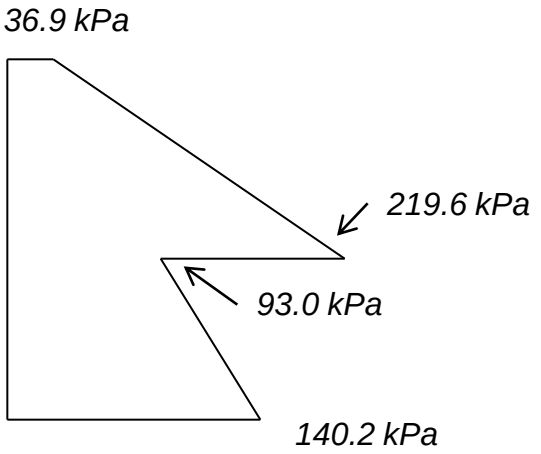
- **FLAC solution**
- **Textbook solution – Rankine**
- **Upper and Lower bound solutions**



Textbook solution of the problem

Passive wall – Smooth wall case – Rankine's solution





Active Pressure Diagram

Rankine: Total horizontal passive thrust = 734.55 kN/m

FLAC solution = 744.50 kN/m

Upper and lower bound solutions of the problem

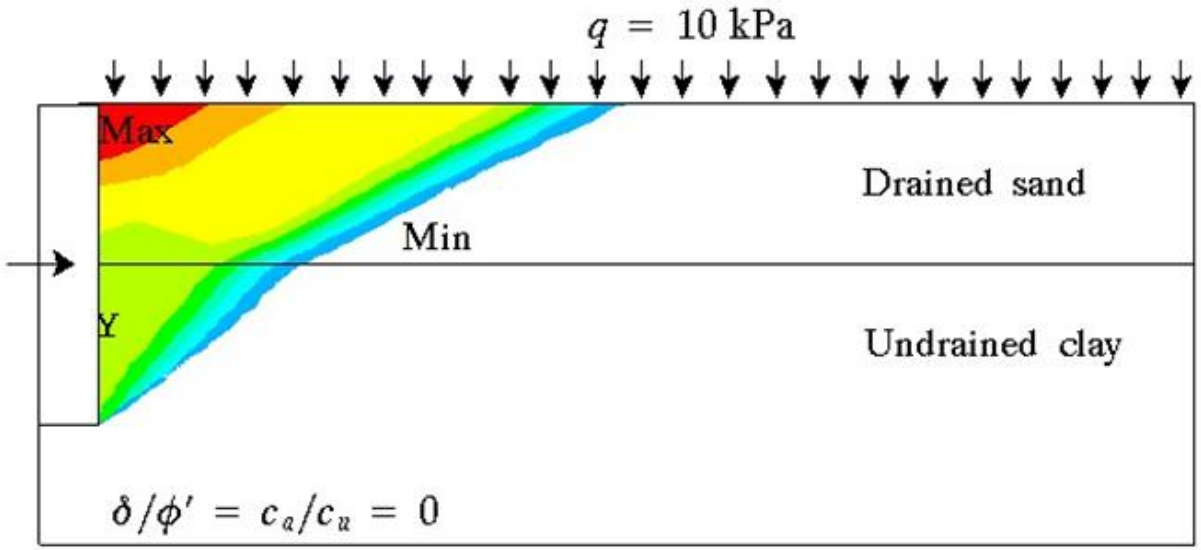
Passive wall – smooth wall case

Smooth wall

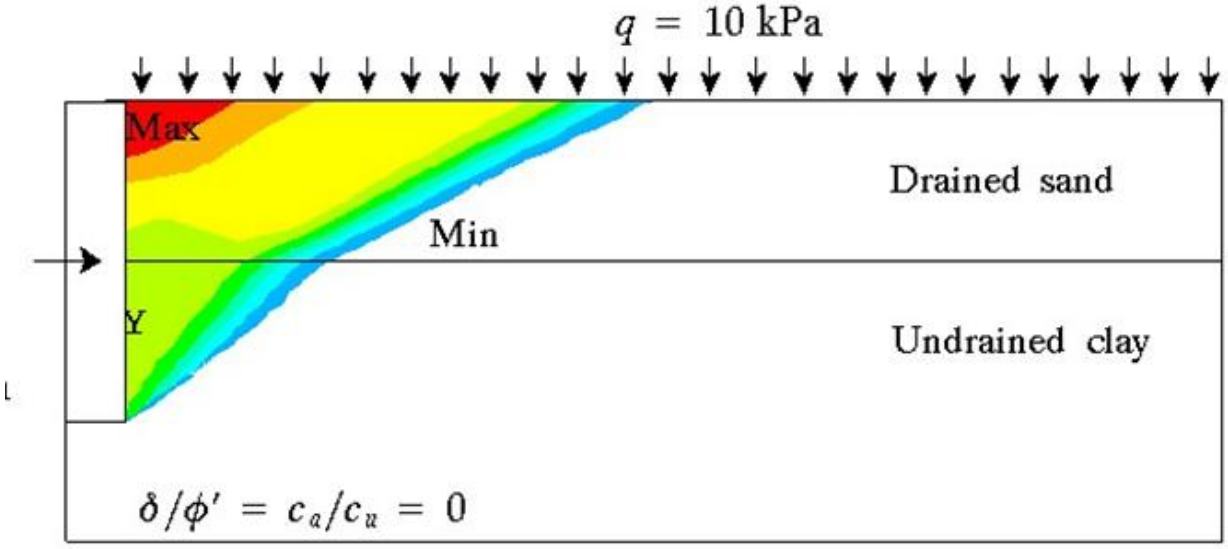
$(P_p)^{UB} = 740.87\ \text{kN/m}$

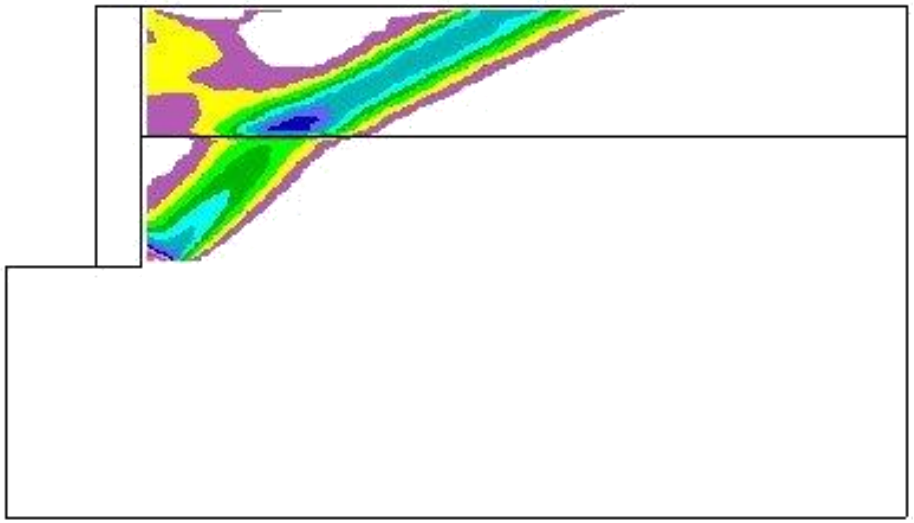
$(P_p)^{LB} = 734.53\ \text{kN/m}$

$(P_p)^{Rankine} = 734.55\ \text{kN/m}$



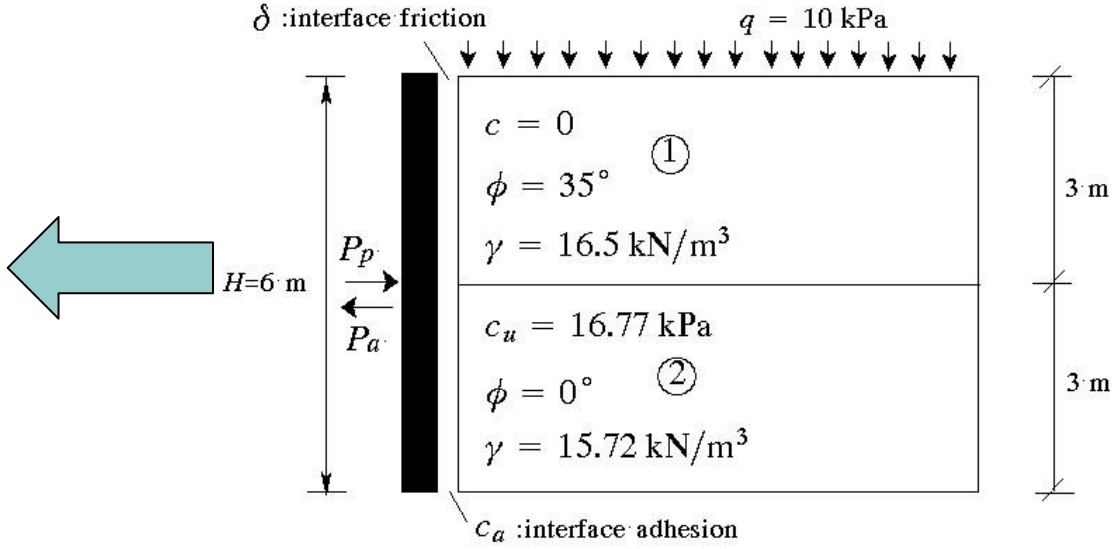
FLAC solution = 744.50 kN/m


q = 10 kPa
Max
Min
Y
Drained sand
Undrained clay
δ/φ′ = c_a/c_u = 0



Rough case - Active wall

- FLAC solution
- Textbook solution – Coulomb
- Upper and Lower bound solutions



Upper and lower bound solutions of the problem

Active wall – rough wall case

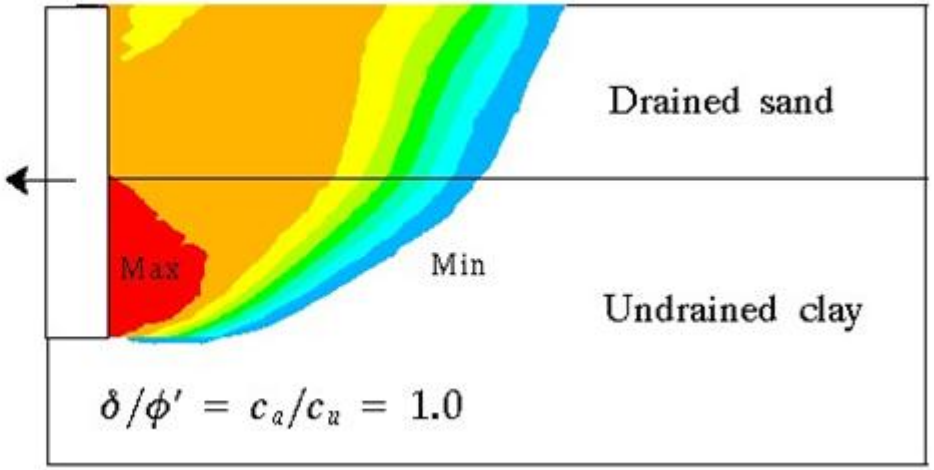
Rough wall

$(P_a)^{UB} = 124.58$ kN/m

$(P_a)^{LB} = 133.07$ kN/m

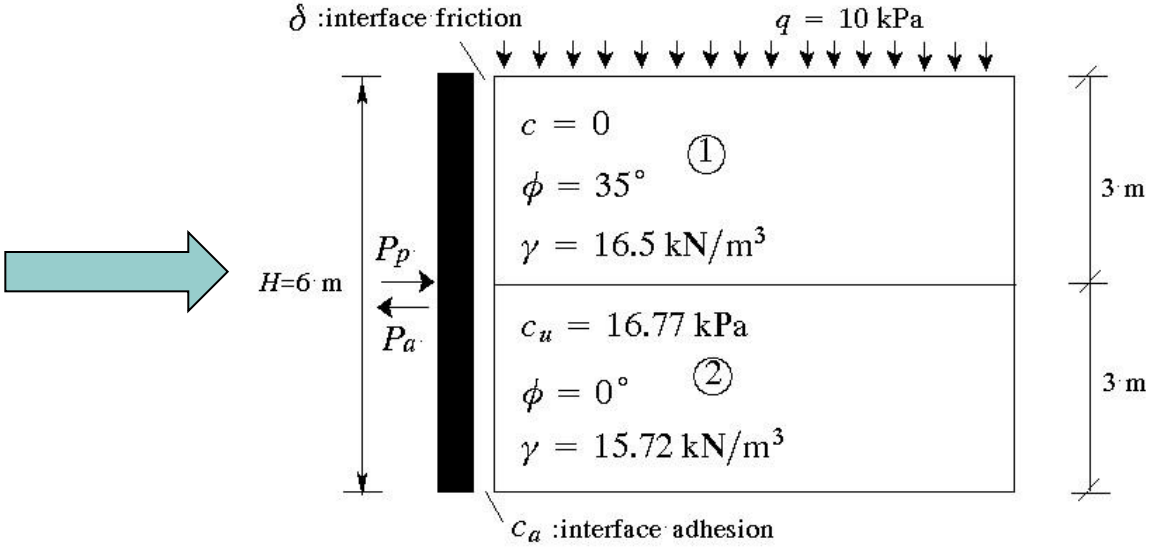
Coulomb = 128.80 kN/m

FLAC solution = 127.60 kN/m



Rough case - Passive wall

- FLAC solution
- Textbook solution – Coulomb
- Upper and Lower bound solutions



Upper and lower bound solutions of the problem

Passive wall – rough wall case

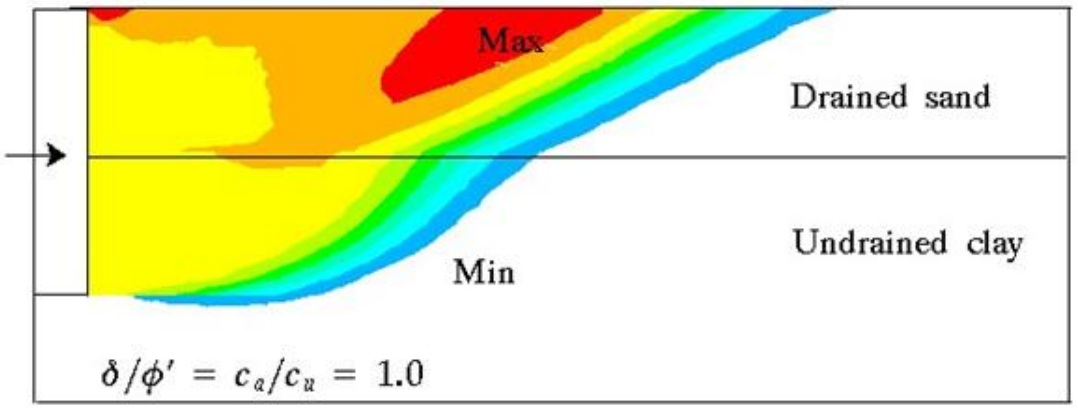
Rough wall

$(P_p)^{UB}$ = 844.24 kN/m

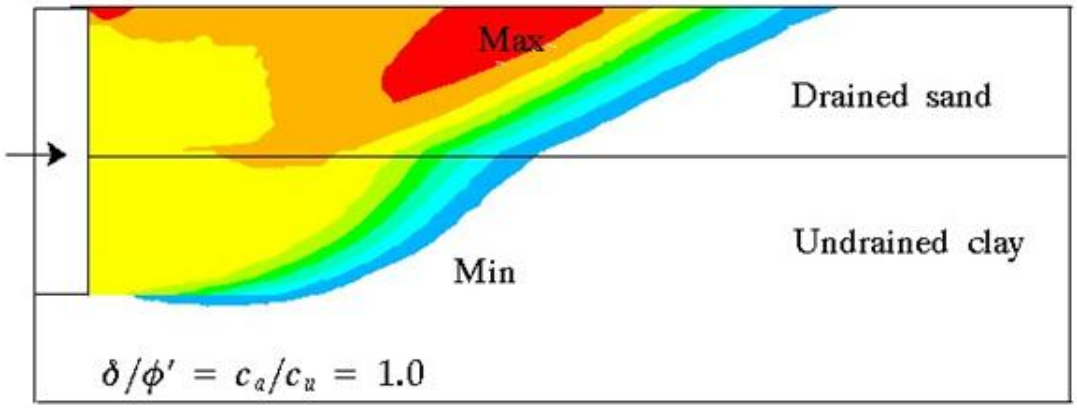
$(P_p)^{LB}$ = 826.95 kN/m

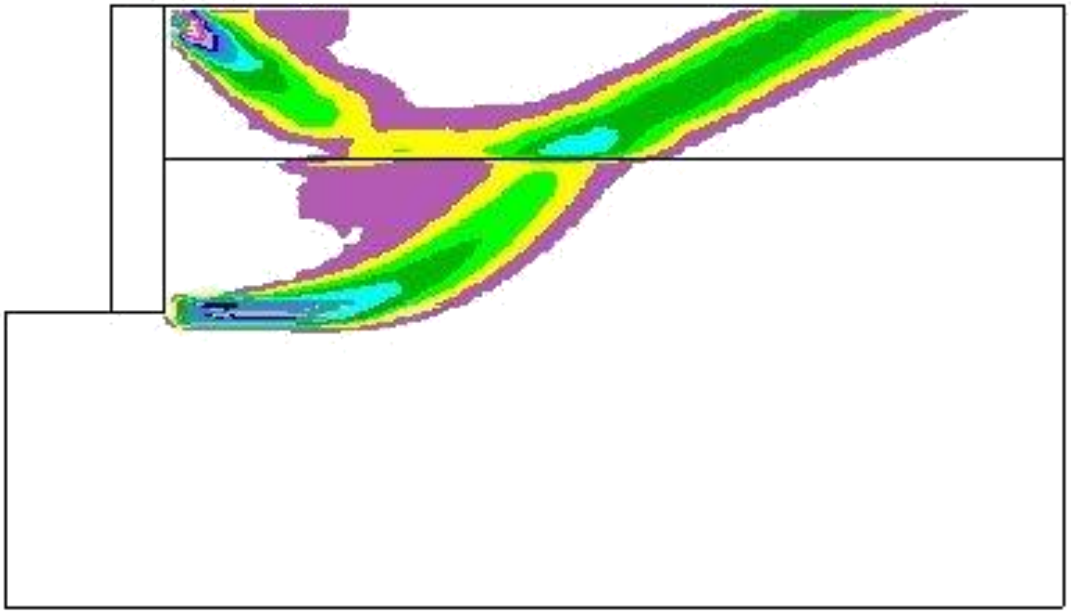
Log-Spiral = 1010.70 kN/m

Coulomb = ???



FLAC solution
= 837.20 kN/m


Max
Drained sand
Undrained clay
Min
$\delta/\phi' = c_a/c_u = 1.0$



Results Summary

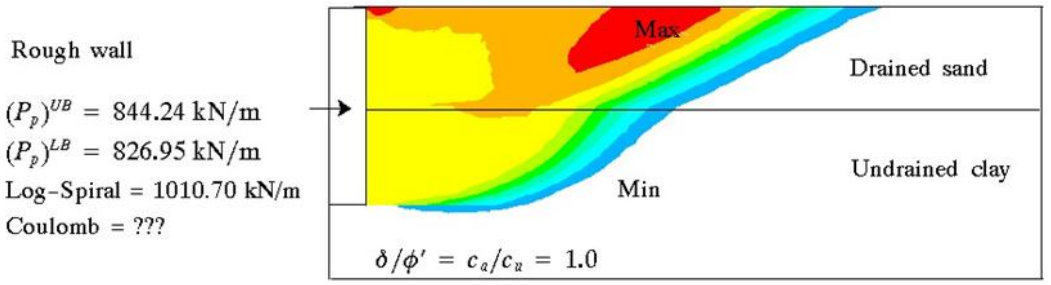
Table 3. Comparison of results for active force (kN/m).

Active walls	Rankine / Coulomb	LB	UB	*FLAC*
Smooth wall	176.18	173.21	166.35	167.20
Rough wall	128.80	133.07	124.58	127.60

Table 4. Comparison of results for passive resistance (kN/m).

Passive walls	Rankine / Log-Spiral	LB	UB	*FLAC*
Smooth wall	734.55	734.53	740.87	744.50
Rough wall	1010.7	826.95	844.24	837.20

Summary



- **FLAC results favorably compared with upper and lower bound solutions in all cases.**
- **Classical earth pressure theories favorably compared with FLAC and upper and lower bound solutions only in smooth wall cases (active and passive) and rough active wall case.**
- **For the rough passive wall case, the log-spiral failure surface Shields & Tolunay's (1973) theory is not particularly accurate for the layered problem. It's on the unsafe side with some 20% overestimation ~ needless to mention Coulomb's solution with linear slip assumtion.**

Future Work

- Pressure distribution behind the wall.
- Velocity jump and change of velocity direction across layered media.
- Shear stresses across the layered media for the passive + rough wall case