INGENIERÍA CIVIL

Programa de Doctorado en Ingeniería

Línea de Investigación

Geotecnia y Riesgos Geoambientales

50 AÑOS POSGRADOS INGENIERÍA CIVIL

Área Curricular de Ingeniería Civil y Agrícola
Facultad de Ingeniería
Sede Bogotá

UNIVERSIDAD NACIONAL DE COLOMBIA

IMPLICATIONS OF UNSATURATED RESPONSE IN THE BEHAVIOUR OF RETAINING STRUCTURES THROUGH THE USE OF COMPUTATIONAL TOOLS

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Hay un país para volver: Colombia

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COLCIENCIAS

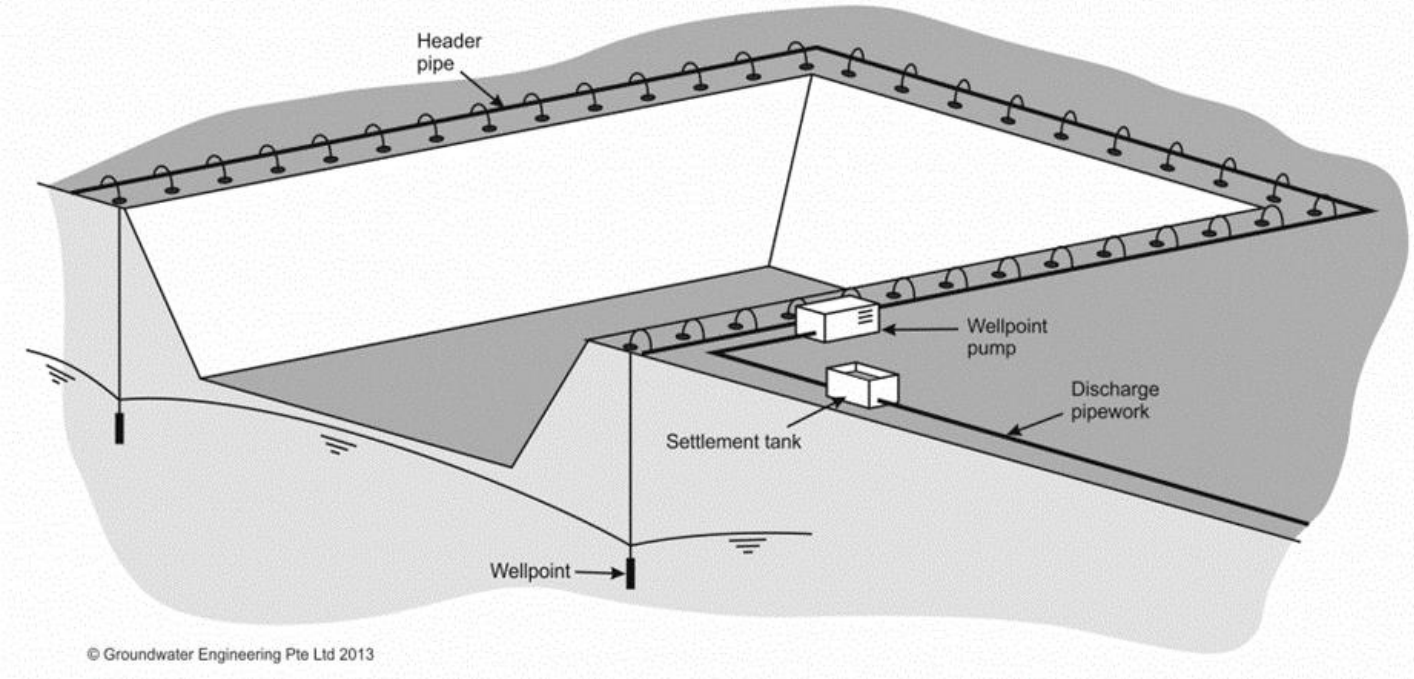
SRS suelos no saturados

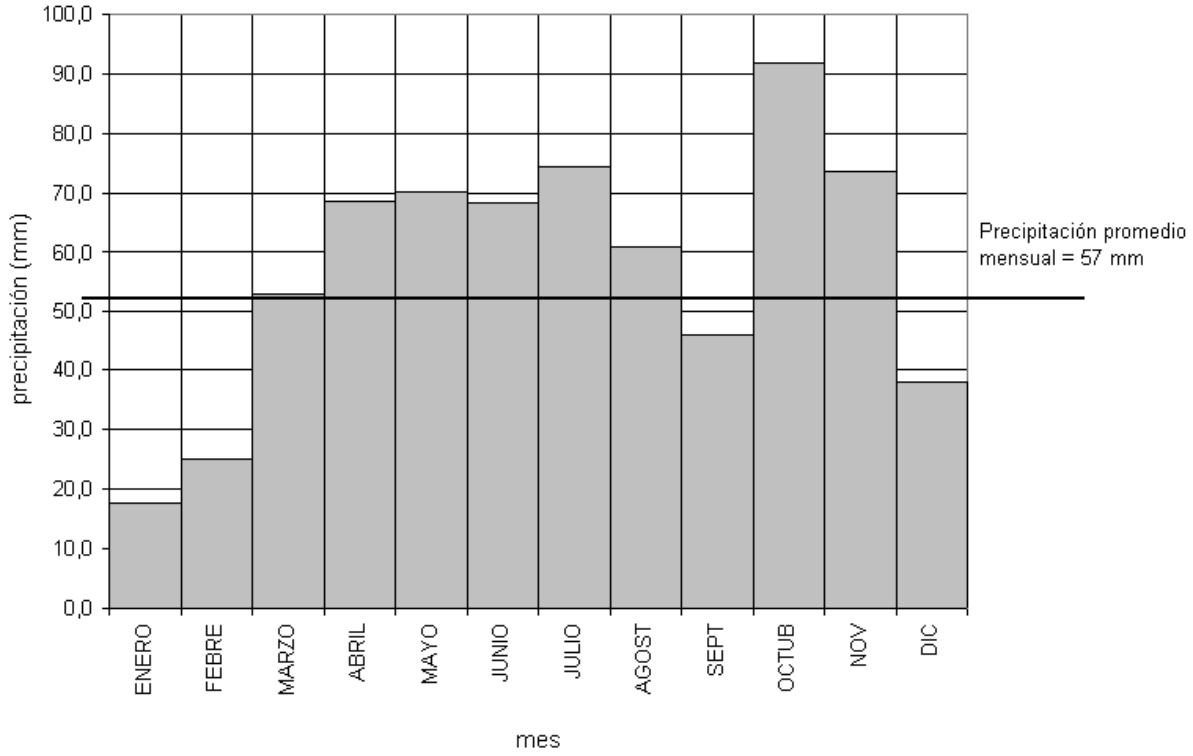
Design highly conservatives
+
Environmental variables

Combinations diafragm-wall, curtain piles + soil nailing + anchors

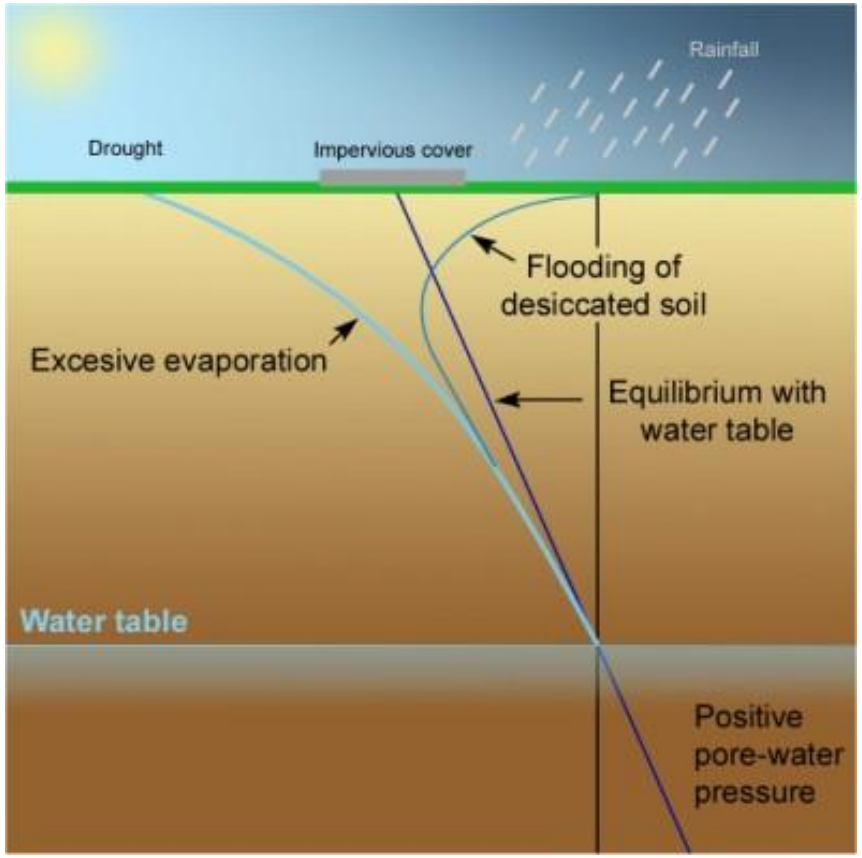
Dry or tropical climate?

Phenomenon present only at profiles with deep GWL?





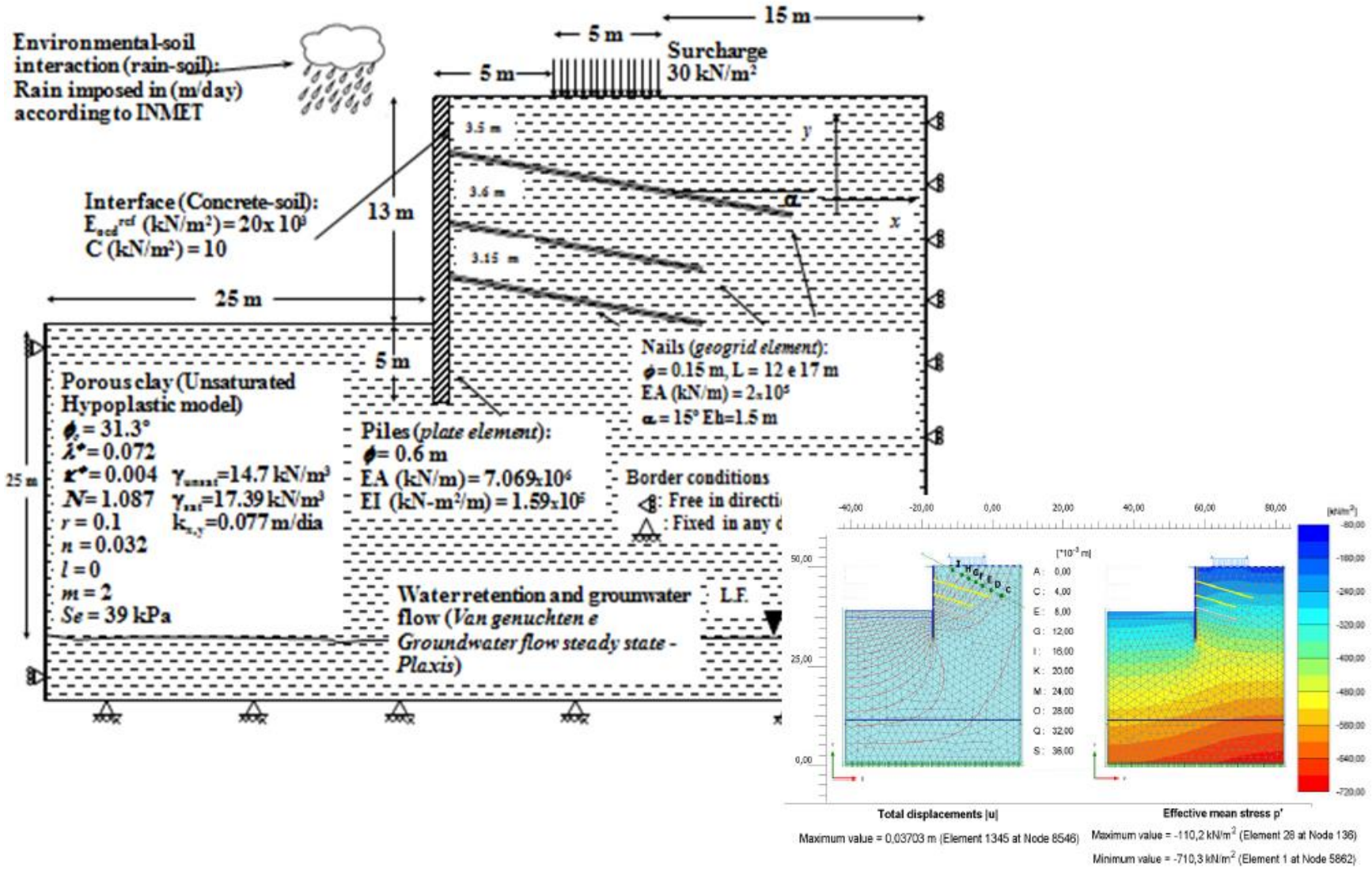
Dry and wet season very pronounced?



Global climate change??

- ✓ Background
- ✓ Objective
- ✓ Methodology
  - ✓ Atmosphere soil-interaction
  - ✓ Reference constitutive model
  - ✓ Numerical simulations
- ✓ Results
- ✓ Concluding remarks

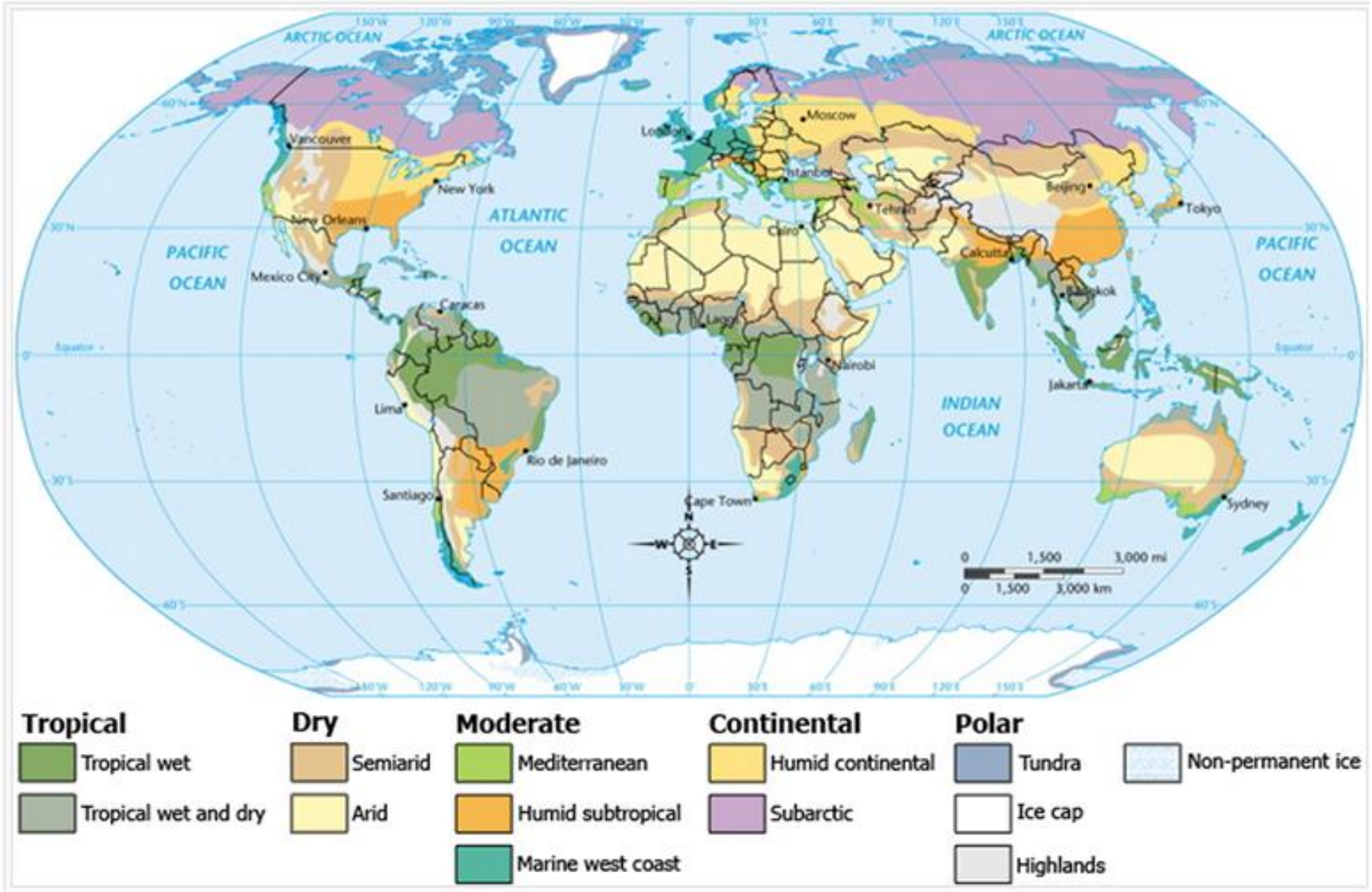
BACKGROUND

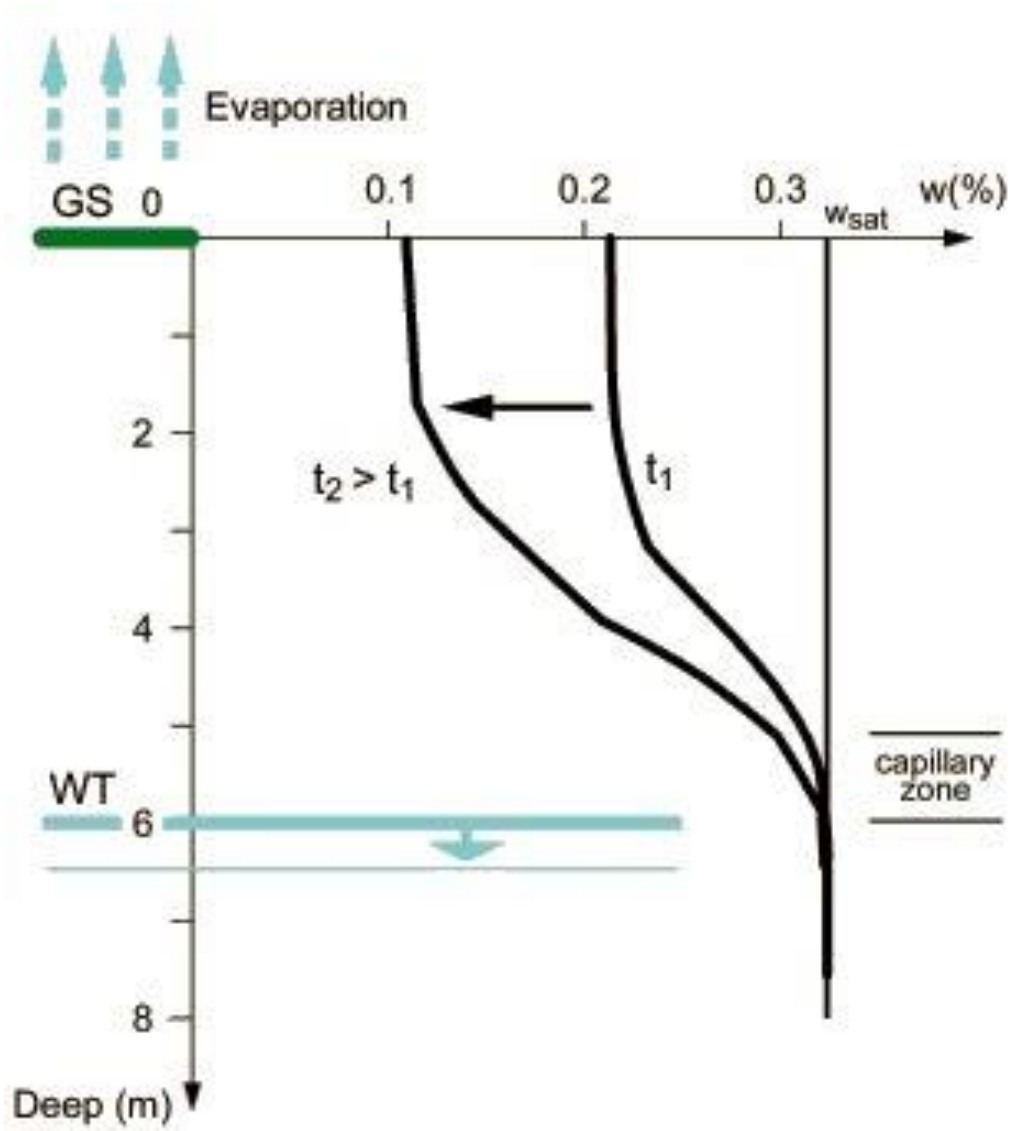

Environmental-soil interaction (rain-soil): Rain imposed in (m/day) according to INMET
15 m
5 m
5 m
Surcharge 30 kN/m²
3.5 m
3.6 m
3.15 m
y
x
α
13 m
Interface (Concrete-soil):
E_oed^ref (kN/m²) = 20x 10³
C (kN/m²) = 10
25 m
5 m
25 m
Porous clay (Unsaturated Hypoplastic model)
φc = 31.3°
λ* = 0.072
κ* = 0.004
N = 1.087
r = 0.1
n = 0.032
l = 0
m = 2
Se = 39 kPa
γunsat=14.7 kN/m³
γsat=17.39 kN/m³
k_x,y=0.077 m/dia
Piles (plate element):
φ = 0.6 m
EA (kN/m) = 7.069x10⁶
EI (kN-m²/m) = 1.59x10⁵
Nails (geogrid element):
φ = 0.15 m, L = 12 e 17 m
EA (kN/m) = 2x10⁵
α = 15° Eh=1.5 m
Border conditions
: Free in directi
: Fixed in any d
Water retention and groundwater flow (Van genuchten e Groundwater flow steady state - Plaxis)
L.F.
Total displacements |u|
Maximum value = 0,03703 m (Element 1345 at Node 8546)
Effective mean stress p'
Maximum value = -110,2 kN/m² (Element 28 at Node 136)
Minimum value = -710,3 kN/m² (Element 1 at Node 5862)

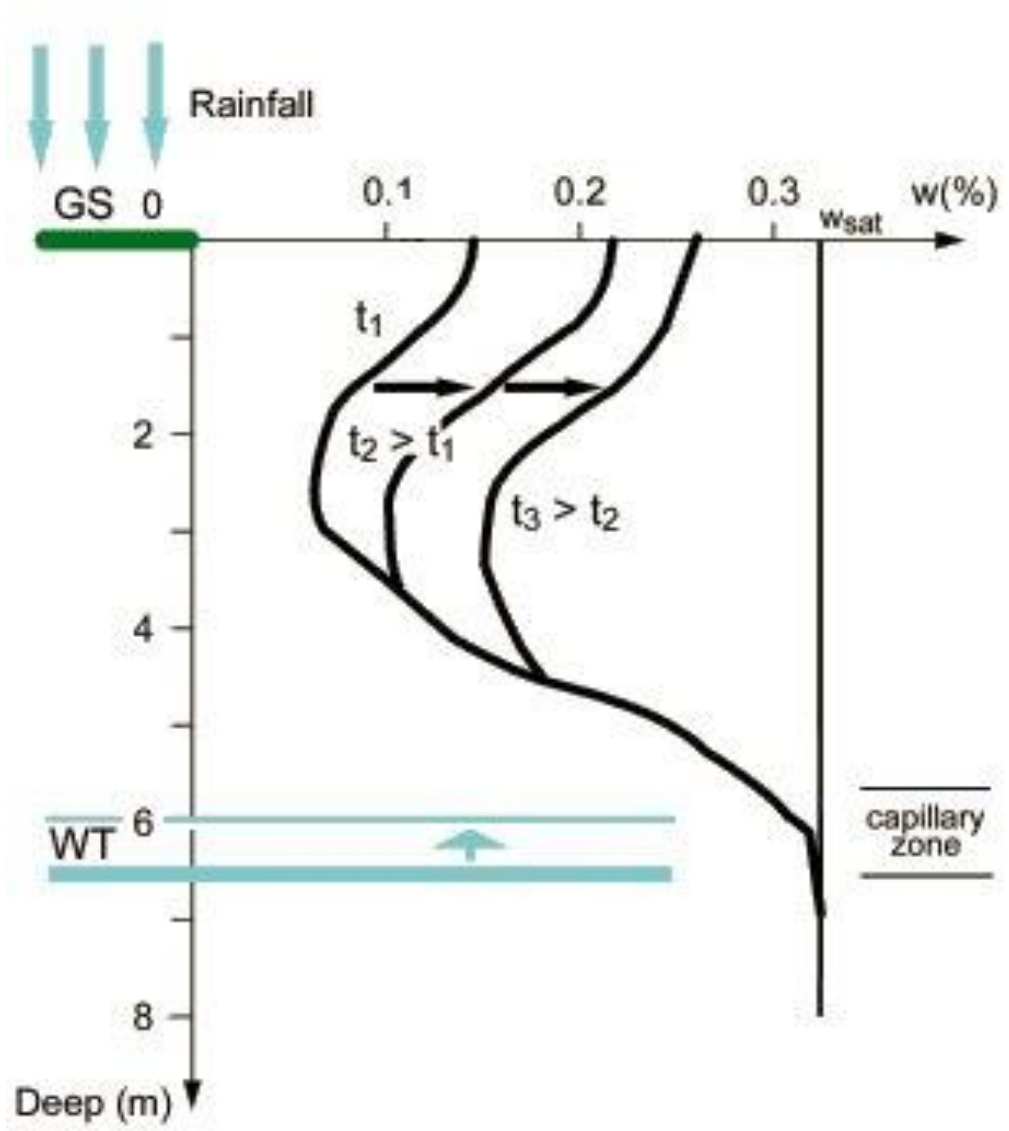
OBJECTIVE

To simulate artificially by means of numerical analysis the unsaturated behaviour of excavations in residual soils, considering atmosphere-soil interaction

METHODOLOGY


ARCTIC OCEAN
ARCTIC OCEAN
PACIFIC OCEAN
ATLANTIC OCEAN
PACIFIC OCEAN
INDIAN OCEAN
Vancouver
New York
New Orleans
Mexico City
Caracas
Lima
Rio de Janeiro
Santiago
Moscow
Istanbul
Cairo
Tehran
Beijing
Tokyo
Calcutta
Nairobi
Jakarta
Cape Town
Sydney
0 1,500 3,000 mi
0 1,500 3,000 km
Tropical
Tropical wet
Tropical wet and dry
Dry
Semiarid
Arid
Moderate
Mediterranean
Humid subtropical
Marine west coast
Continental
Humid continental
Subarctic
Polar
Tundra
Ice cap
Highlands
Non-permanent ice


Evaporation
GS
0
0.1
0.2
0.3
w_{sat}
w(%)
2
4
WT
6
8
$t_2 > t_1$
t_1
capillary zone
Deep (m)


Rainfall
GS
0
0.1
0.2
0.3
w_{sat}
w(%)
t_1
2
$t_2 > t_1$
$t_3 > t_2$
4
WT
6
8
capillary zone
Deep (m)

REFERENCE CONSTITUTIVE MODEL

A hypoplastic model for mechanical response of unsaturated soils (Masín & Khalili, 2008)

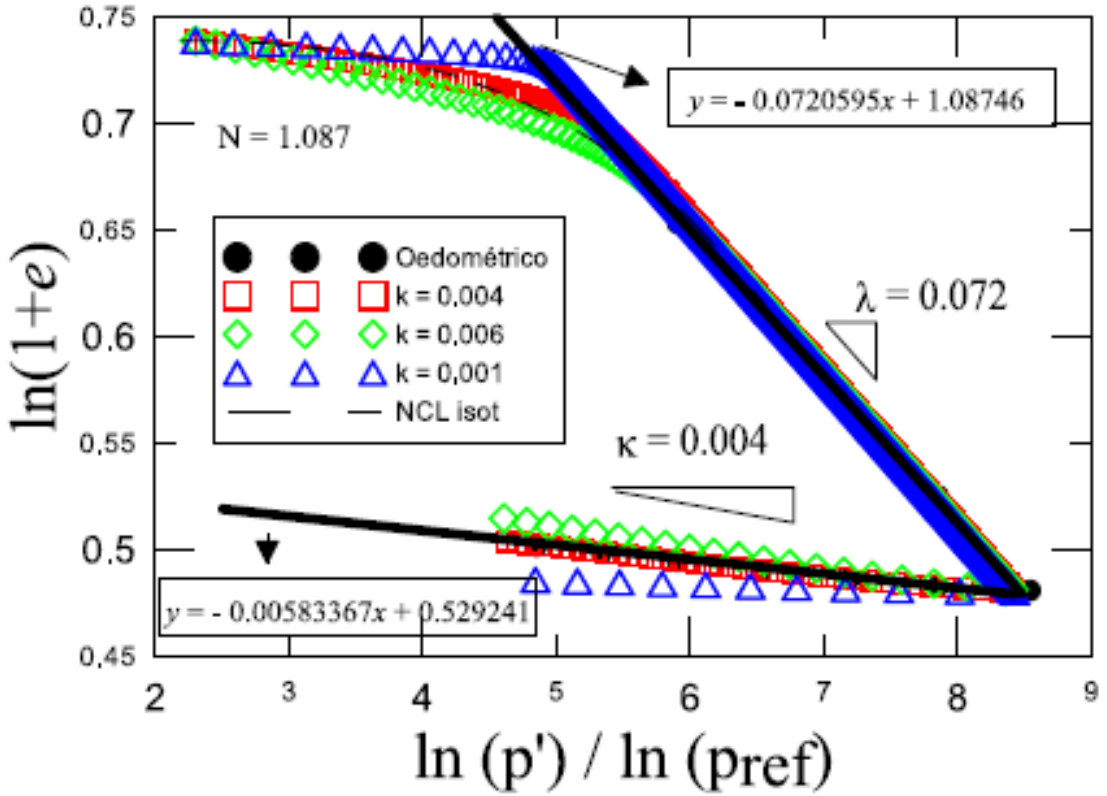
$$\overset{\circ}{\mathbf{T}} = f_s(\mathscr{L} : \mathbf{D} + f_d \mathbf{N}\|\mathbf{D}\|) + \mathbf{H}$$

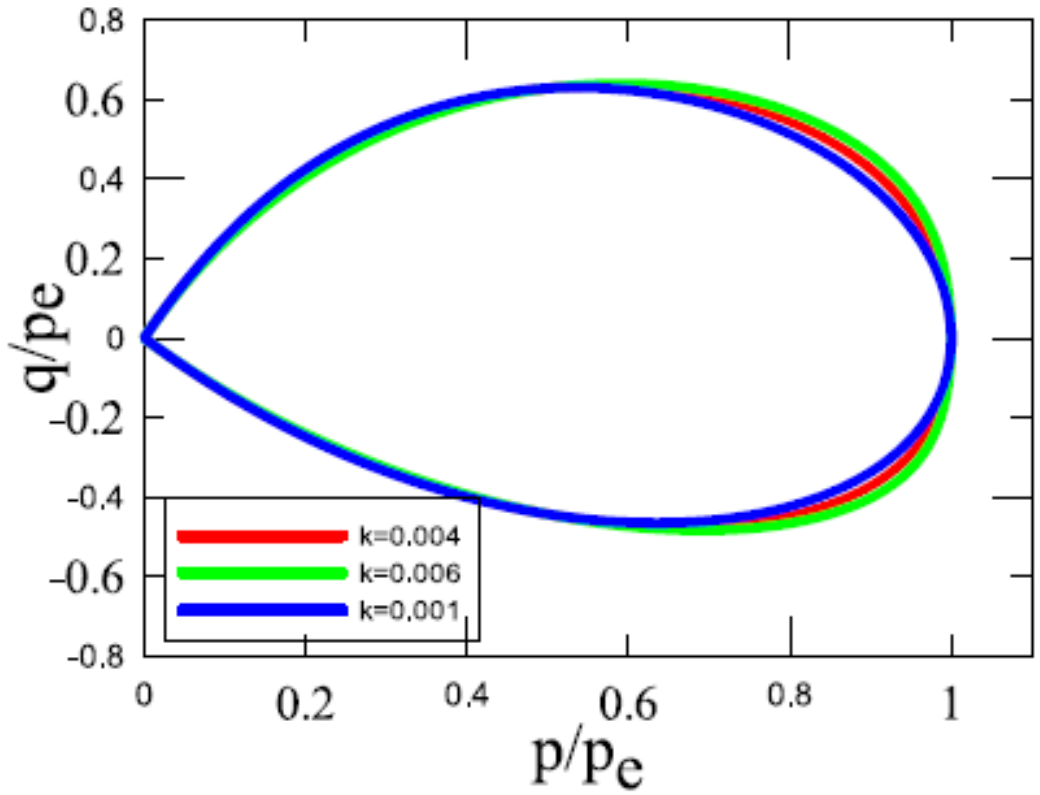
Saturated parameters of the model				
λ^*	κ^*	N	ϕ_c	r

Unsaturated parameters of the model			
m	l	n	S_e

REFERENCE CONSTITUTIVE MODEL

Calibration parameters





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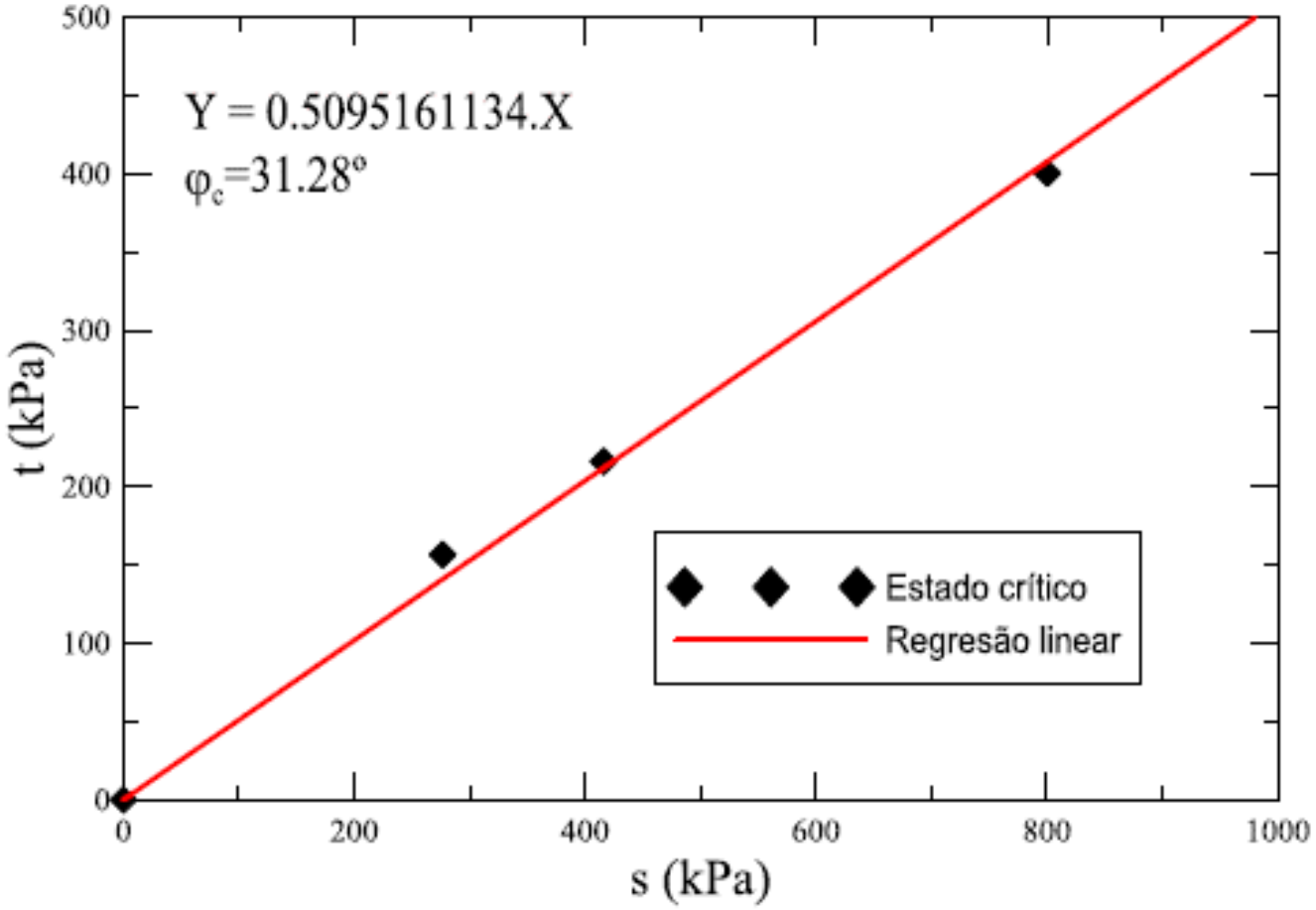
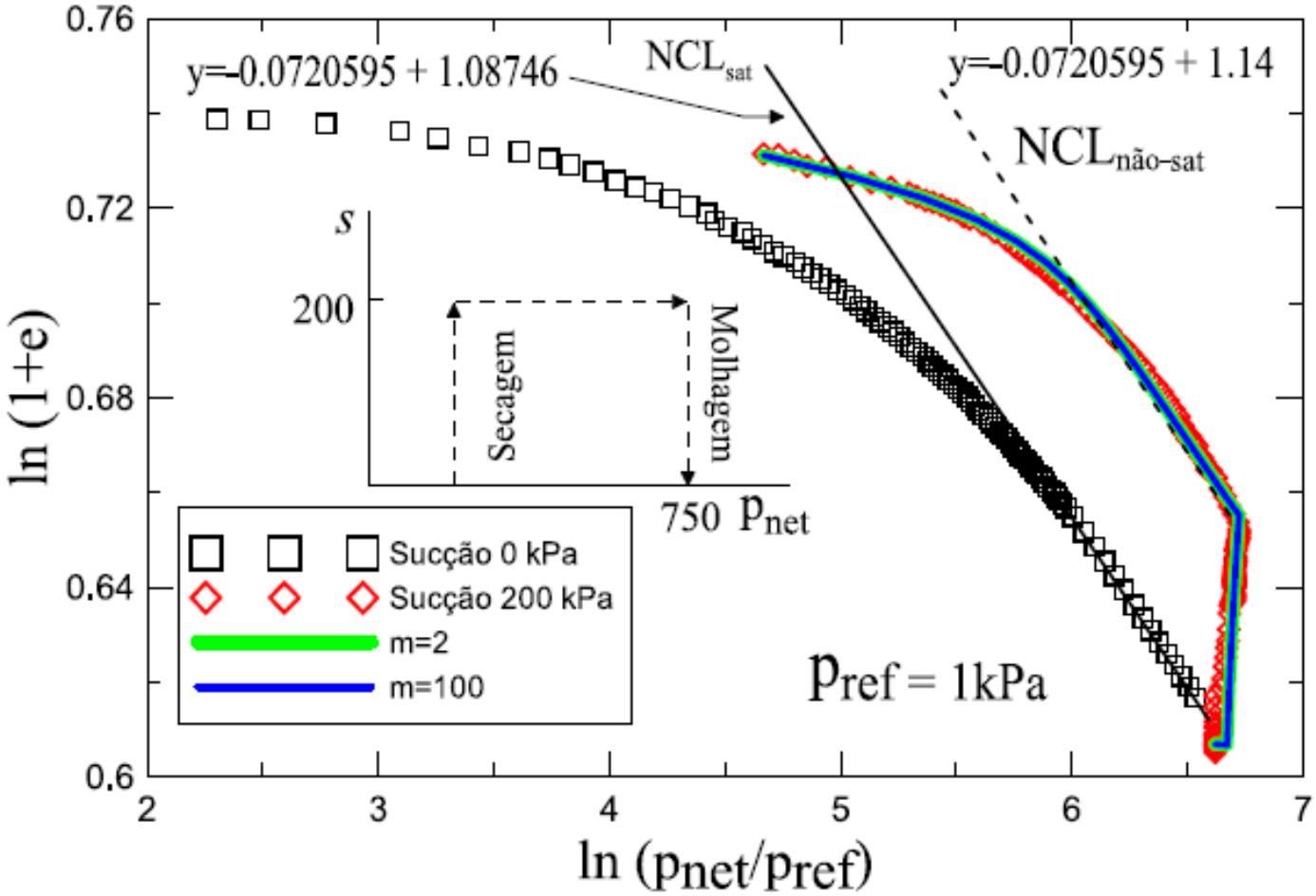
Calibration parameters



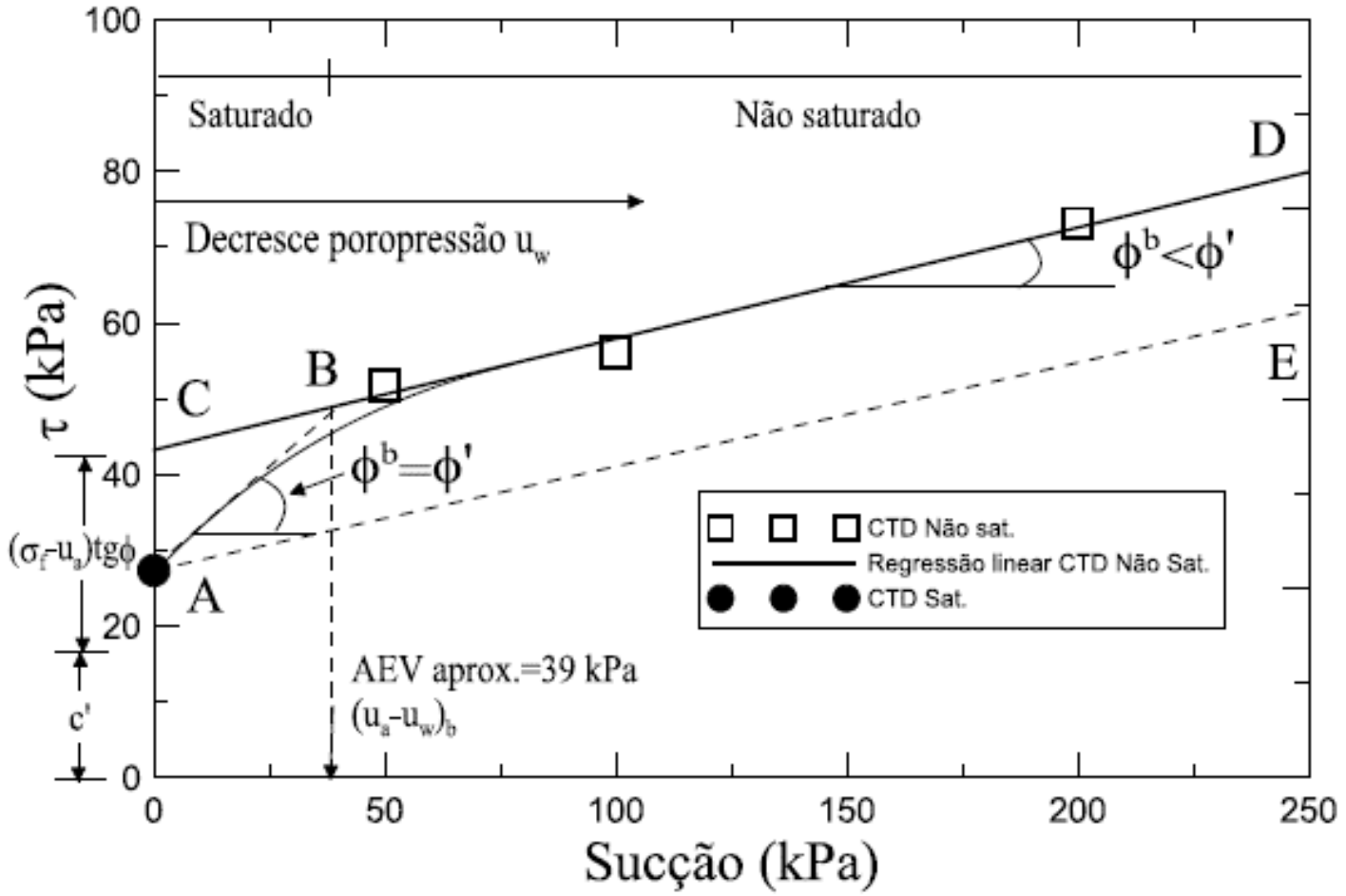
REFERENCE CONSTITUTIVE MODEL

Calibration parameters

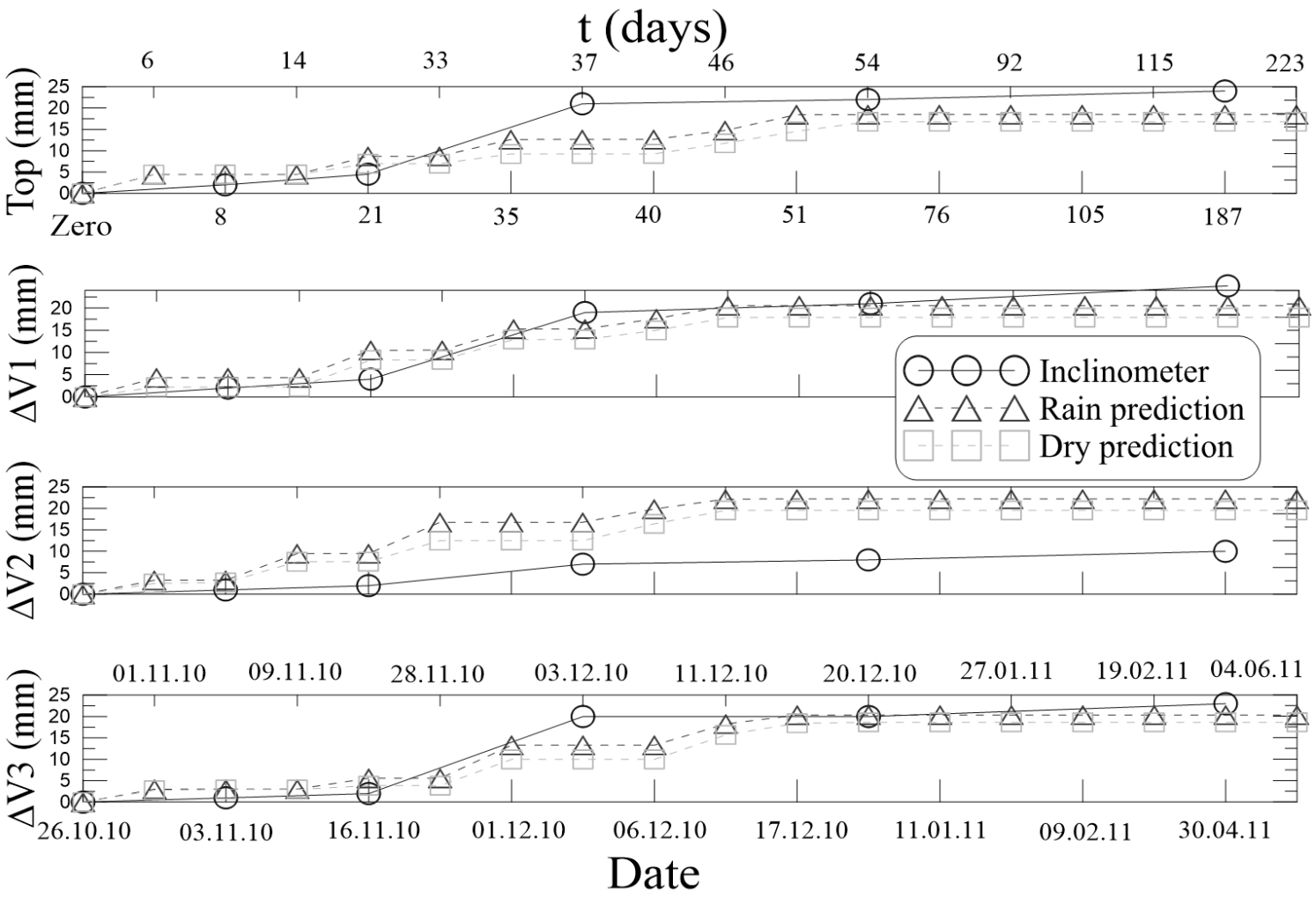


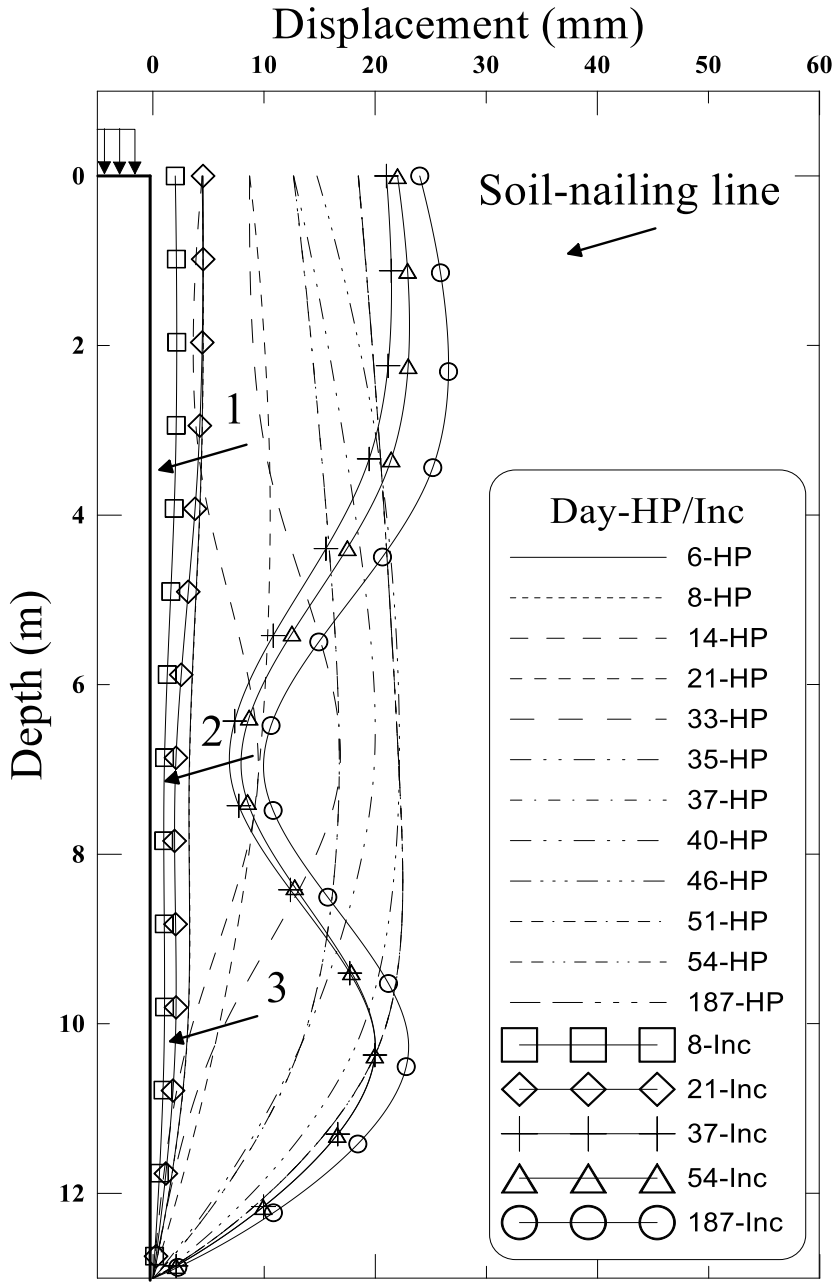
REFERENCE CONSTITUTIVE MODEL

Calibration parameters



NUMERICAL SIMULATIONS





CONCLUDING REMARKS

According to possible implications in design when is involved the suction, it is important to highlight that the contentions depend of the interaction environment-soil, i.e. the seasonality affects in the developing of the project. In the season dry, it is clear that exist an increasing in terms of strength in the soil, due to action of the suction in the profile, even when the excavation sequences enter in the rain season does not reach critical values, among factors, by the porous configuration and the evaporation of the environment.

OUTLOOKS

m Parâmetro	Temporária (época seca)	Temporária (época seca + chuva)	Permanente	Comentários
Coesão efetiva	$15-20\,kN/m^2$	$10-15\,kN/m^2$	$2,5-5\,kN/m^2$	Valores baseados principalmente no FS influenciado pela ficha da contenção
Ângulo de atrito efetivo	$25-27°$	$25-27°$	$25-27°$	——
Resistência não drenada	$50-75\,kN/m^2$	——	——	Resposta na interface solo-tirante tende a ser não drenada, e no solo-grampo, drenada
Cargas nos grampos três primeiras linhas	$75-100\,kN$	$100-150\,kN$	$150-200\,kN$	Projetados com Coesão drenada (grampo)
Cargas nas ancoragens duas ultimas linhas	$150-200\,kN$	$200-250\,kN$	$250-300\,kN$	Projetados com Resistência não drenada (tirante) [a]

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