Associação Brasileira de Mecânica dos Solos e Engenharia Geotécnica

Aprendendo com o passado, celebrando o presente e inspirando o futuro

21 e 22 de julho de 2025

Centro de Convenções Rebouças

São Paulo, SP

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Collapsible soils in Argentina

Experiences and case histories

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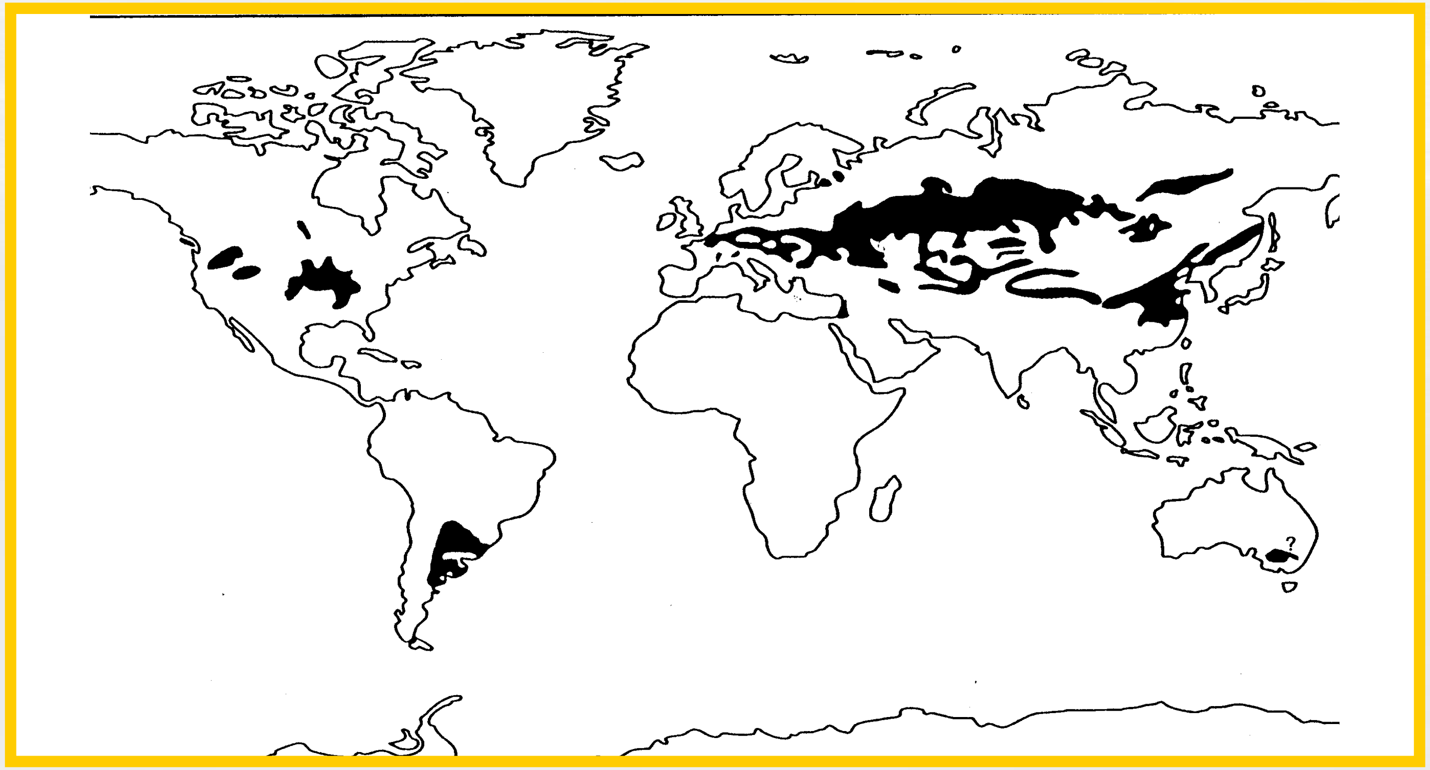
LOESSIAL SOILS

Loess Definition & General Description (after Rinaldi 2009)

- German Term: Loose
- Wind-Blow Formation
- Platy Silt and Sand Particles (oriented in the depositional direction).
- Minor clay fraction (illite and montmorillonite).
- Double Porosity (macro and micropores)
- Water soluble and non-soluble salts
- Unsaturated in natural state

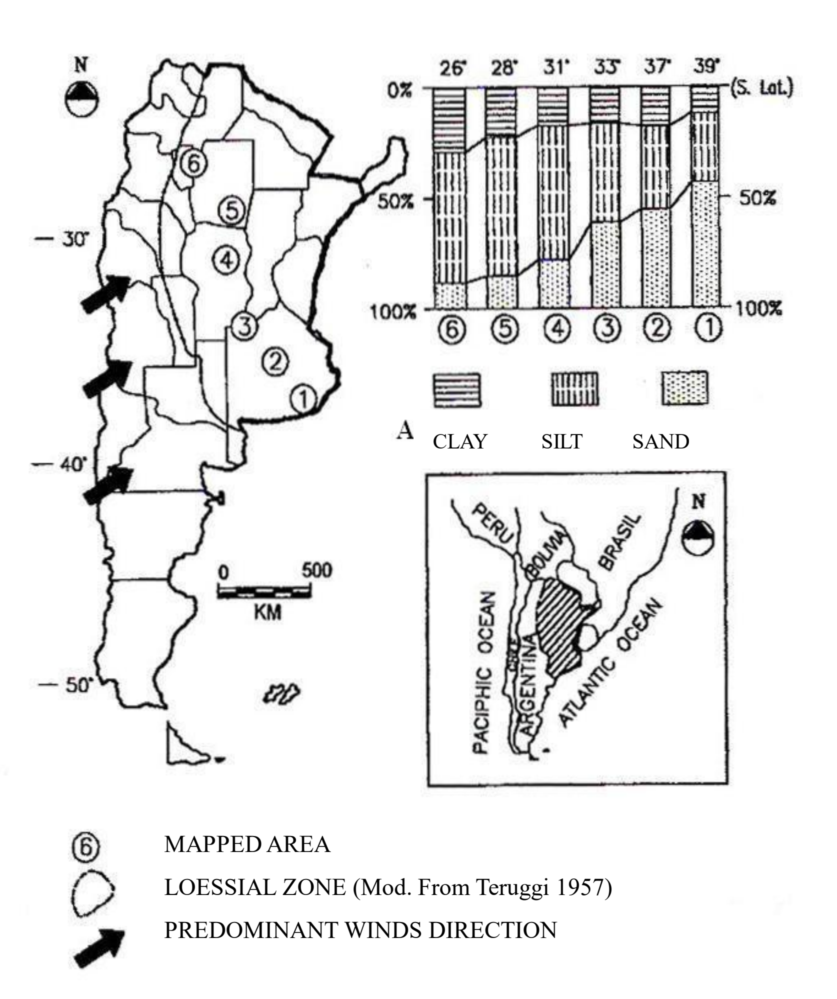
Distribution In The World (after Rinaldi 20009)



- 10 % of the total continental surface: 13.000.000 km^2
- Thickness: Few meters up to 300 m
- West Valley Mississippi River and Eas of Washington
- Largest Deposits:

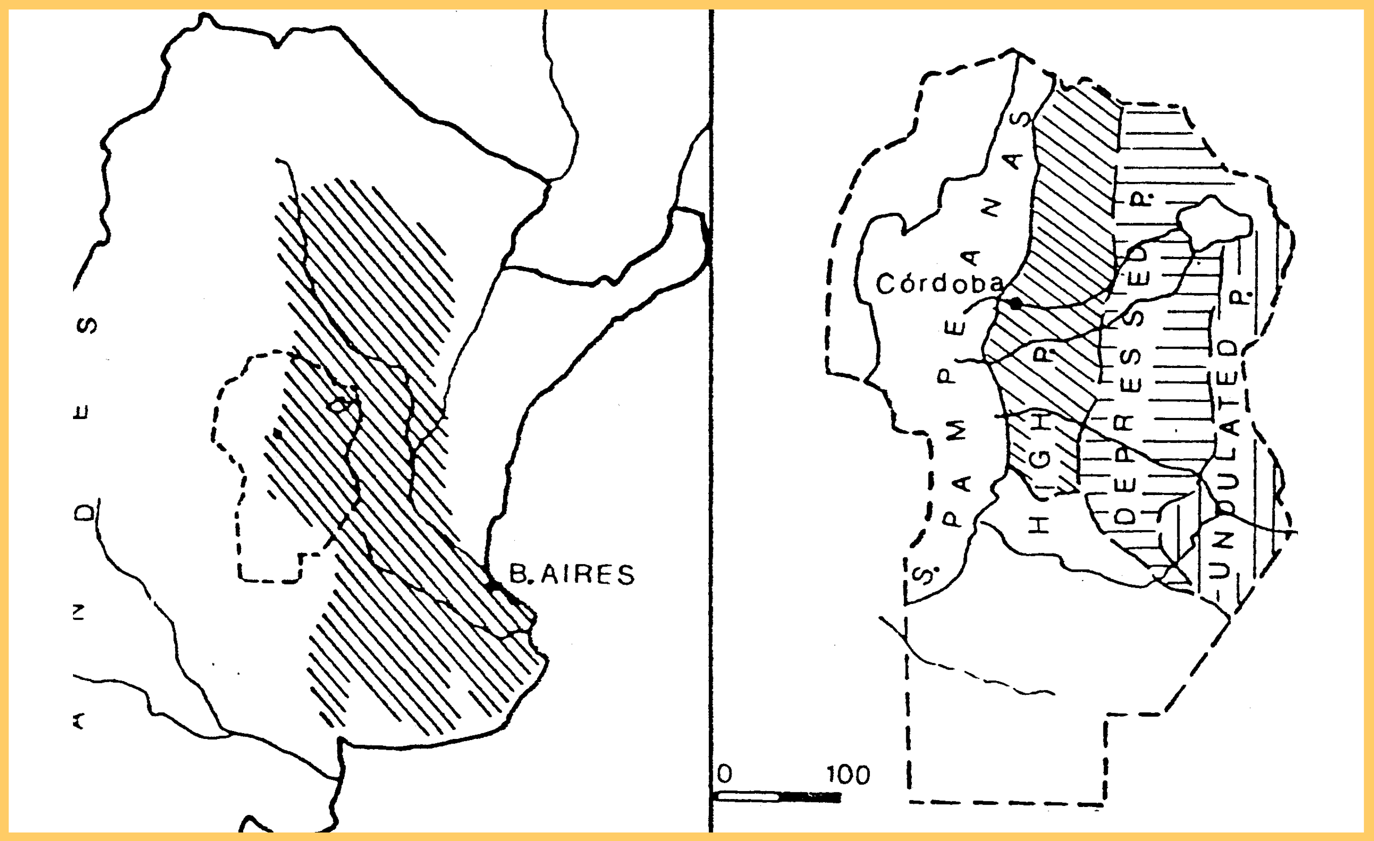
  North Hemisphere: China

Argentinian Loess Origin (after Rocca et al. 2006)



Distribution In Argentina

(After Rocca et al 2006)



Main Properties (after Rinaldi 2009)

- Color: Brownish to yellow
- Very stable at low water content
- High volume change when loading or wetting (collapse)
- Higher vertical permeability
- High susceptibility to surface erosion and piping

Average properties of ancient pampean loess

The elevations refer to the level of the Paraná River.

Zone	Deep (m)	Elev. (m)	e_o	ω (%)	ω_L (%)	ω_P (%)	IP (%)	Cc	CsCr	γ_s (kN/m^3)	γ
Ia)	10.16	15.00	0 848	32.0	67.0	30.0	37.0	0.32	0.024	25.98	18.53
Ia)	12.16	13.00	0.888	33.5	67.0	31.5	35.5	0.33	0.025	25.98	18 33
Ib)	20.00	5.16	0.826	31.4	41.3	27.8	13.5	0.15	0.010	25.78	18.53
Ib)	27.20	-2.04	0.848	32.0	51.0	30.0	21.0	0.18	0.012	25.98	18.53
Ic)	32.70	-7.54	1.180	44.5	69.0	33.5	35.5	0.28	0.020	25.98	17.25

Properties of recent loess

Averages and Standard Deviation (STD) calculated in analysis of 420 profiles.

	ω (%)	ω_L (%)	I P (%)	PT4 (%)	PT10 (%)	PT40 (%)	PT200 (%)	γ_d KN/m^3
CL 2A								
AVERAGE	16.08	24.25	4.58	99.93	99.49	96.98	90.64	12.9
STD	5.15	2.84	1.93	0.50	1.81	4.95	10.53	1.07
CL 2Ax								
AVERAGE	17.37	24.50	4.84	99.62	99.34	95.48	87.82	13.9
STD	4.74	3.32	1.76	3.11	1.58	6.51	15.22	5.00
CL 2B								
AVERAGE	22.07	26.54	6.71	99.79	98.54	93.39	84.17	14.8
STD	7.78	5.34	3.52	1.04	3.13	13.00	15.55	8.33
CL 2C								
AVERAGE	28.66	35.02	10.86	100.00	99.63	96.61	88.55	13.4
STD	11.16	10.40	6.77	0.00	0.86	6.27	9.87	1.17

(After Rocca et al 2006)

Collapsible soils in Argentina
Experiences and case histories

Grain Size Distribution

Grain Size	Content %
Sand (> 0.75 mm)	5 - 15
Silt (0.75 - 0.002 mm)	40 - 60
Clay (< 0.002 mm)	12 - 35
$CaCO_3$	2 - 10

Mineral Composition

Particle Size	Mineral Components	% Content by weight)
Sand	Quartz (2-30)	20 - 30
	Feldspar (20-65)	20 - 65
	Volcanic Glass (1-25)	1 - 25
	Basalt (1-25)	1 - 25
Silt	Quartz (20-30)	20 – 30
	Feldspar (30)	30
	Volcanic Glass (15-60)	15 – 60
	Gypsum (20)	20
Clay	Illite (90)	90
	Montmorillonite (0-5)	0 – 5
	Kaolinite (0-5)	0 – 5
CO_3Ca	Nodules and dispersed	2 - 10

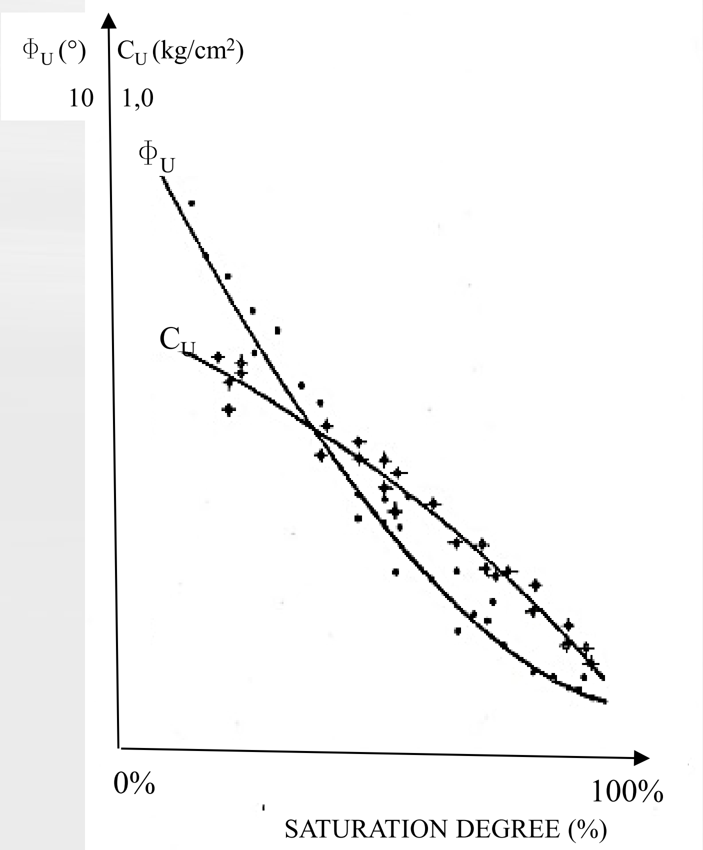
Chemical Composition

Exchangeable Cations (me/100g)					Soluble Cations (me/100g)			
Ca	Mg	Na	K	CEC	Ca	Mg	Na	K
3 –12	2 – 6	1 - 15	1 - 3	14 - 25	0.1 - 0.5	0.06 – 0.2	0.5 - 4	0.03 - 0.1

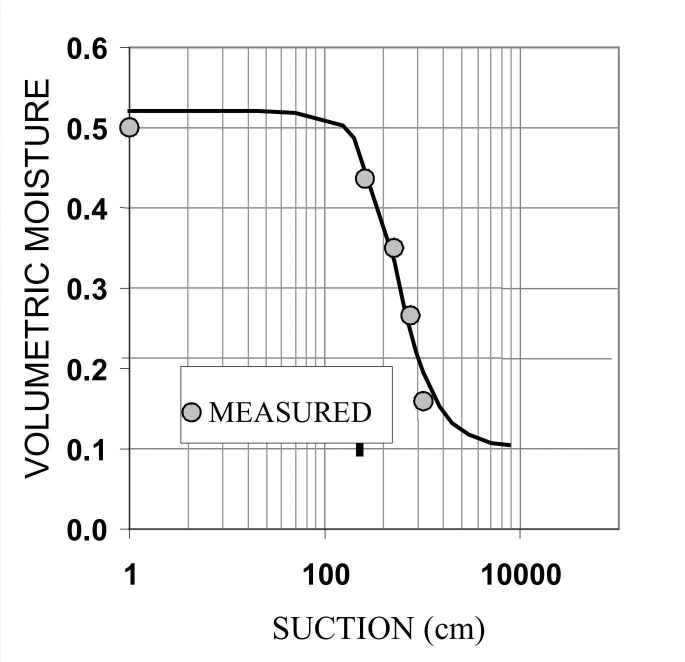
(After Rinaldi 2009)

COLLAPSIBLE LOESSIAN SOILS

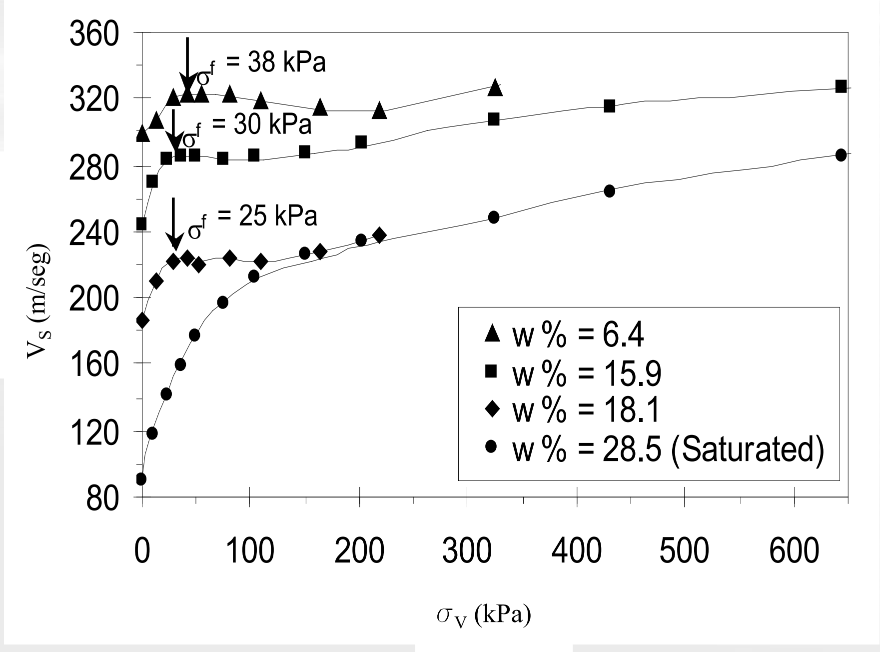
Main Parameters



(After Rocca et al 2006)



(After Terzariol et al 2003)



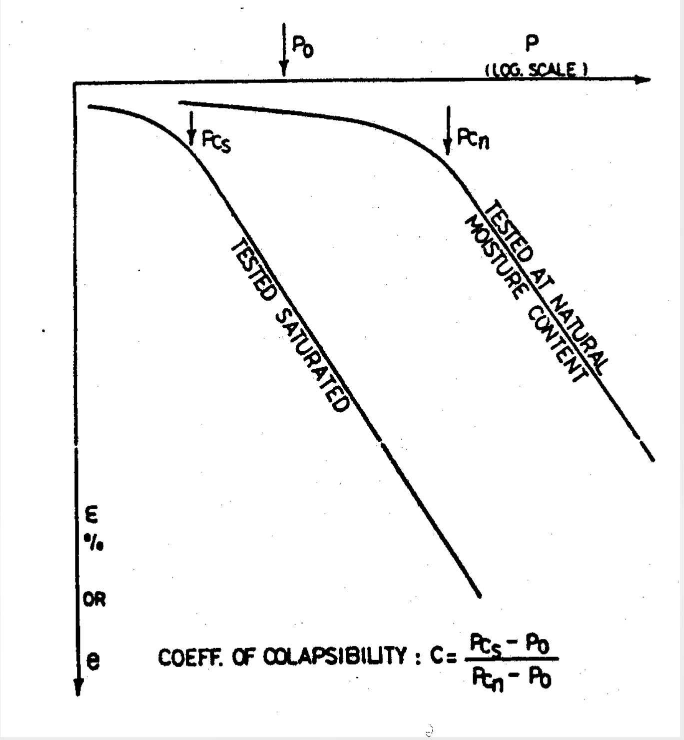
(After Claria 2000)

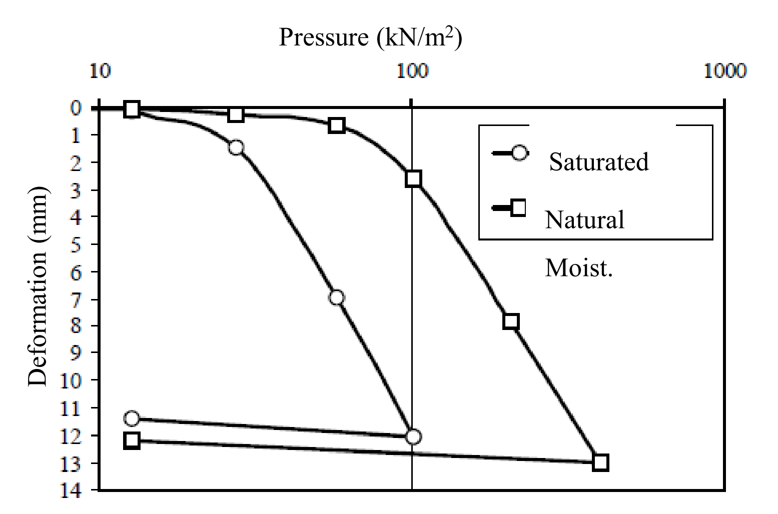
$$F_s = \frac{\sigma_w}{\sigma_s} = a\ n^{(p-m)}\ \theta_v^{-p}$$

(After Francisca et al 2024)

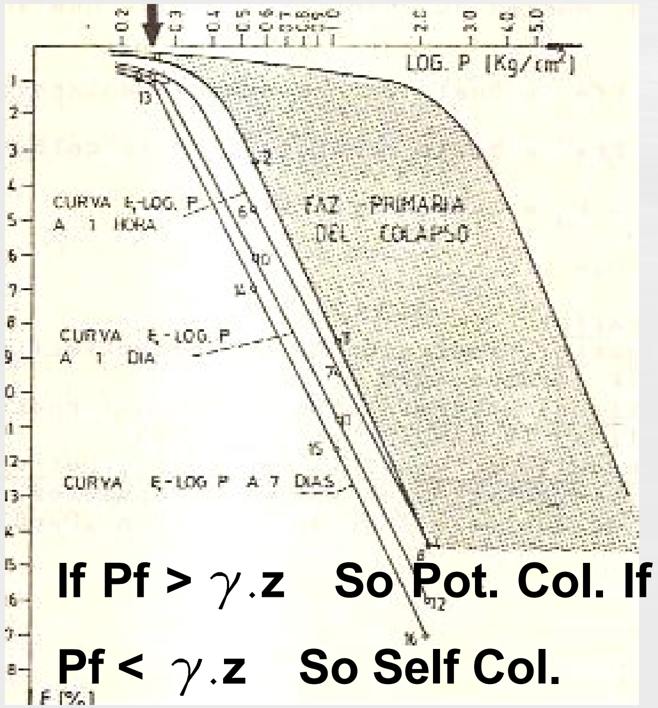
Mechanical Characterization

Laboratory Tests (after Redolfi 1980 – Rocca et al 2006)





Pf

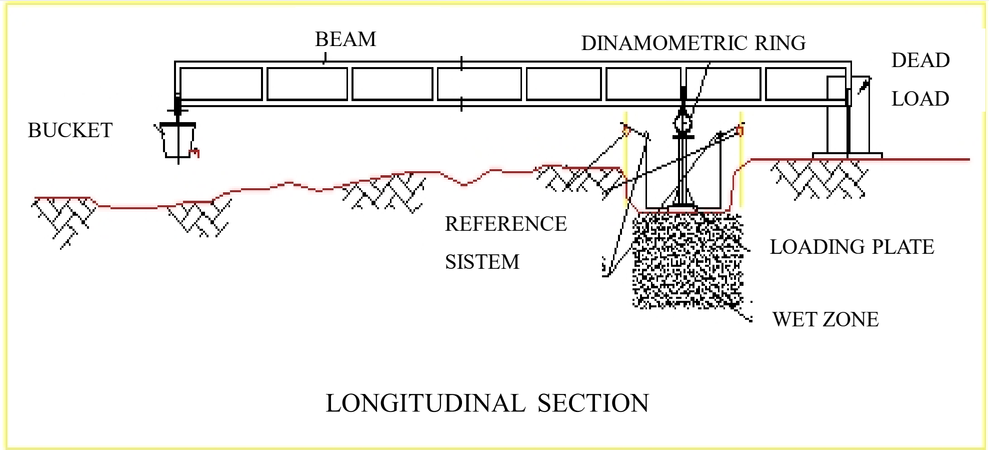


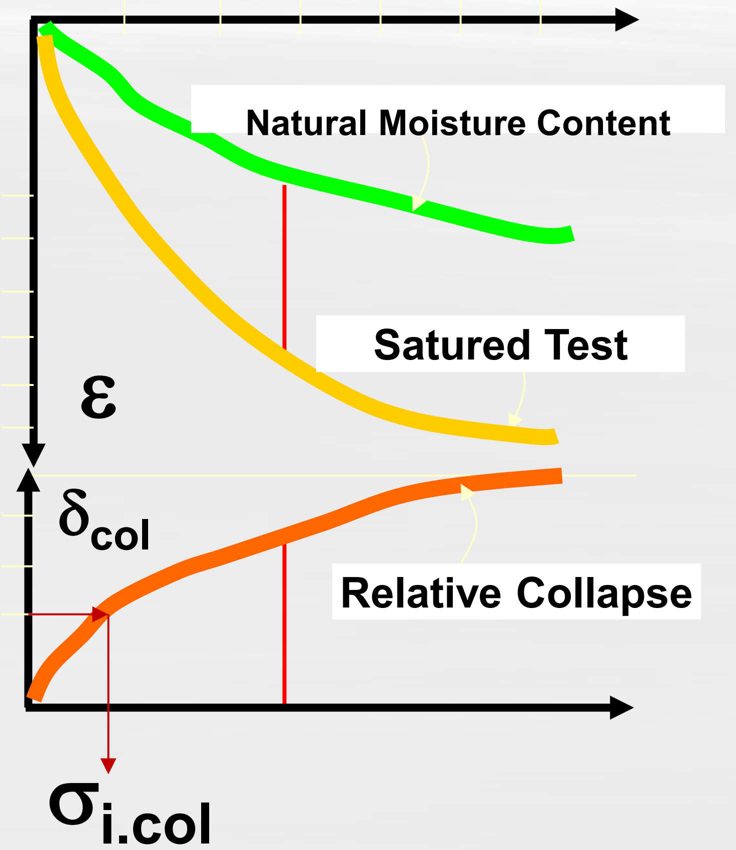
If Pf > γ.z So Pot. Col. If

Pf < γ.z So Self Col.

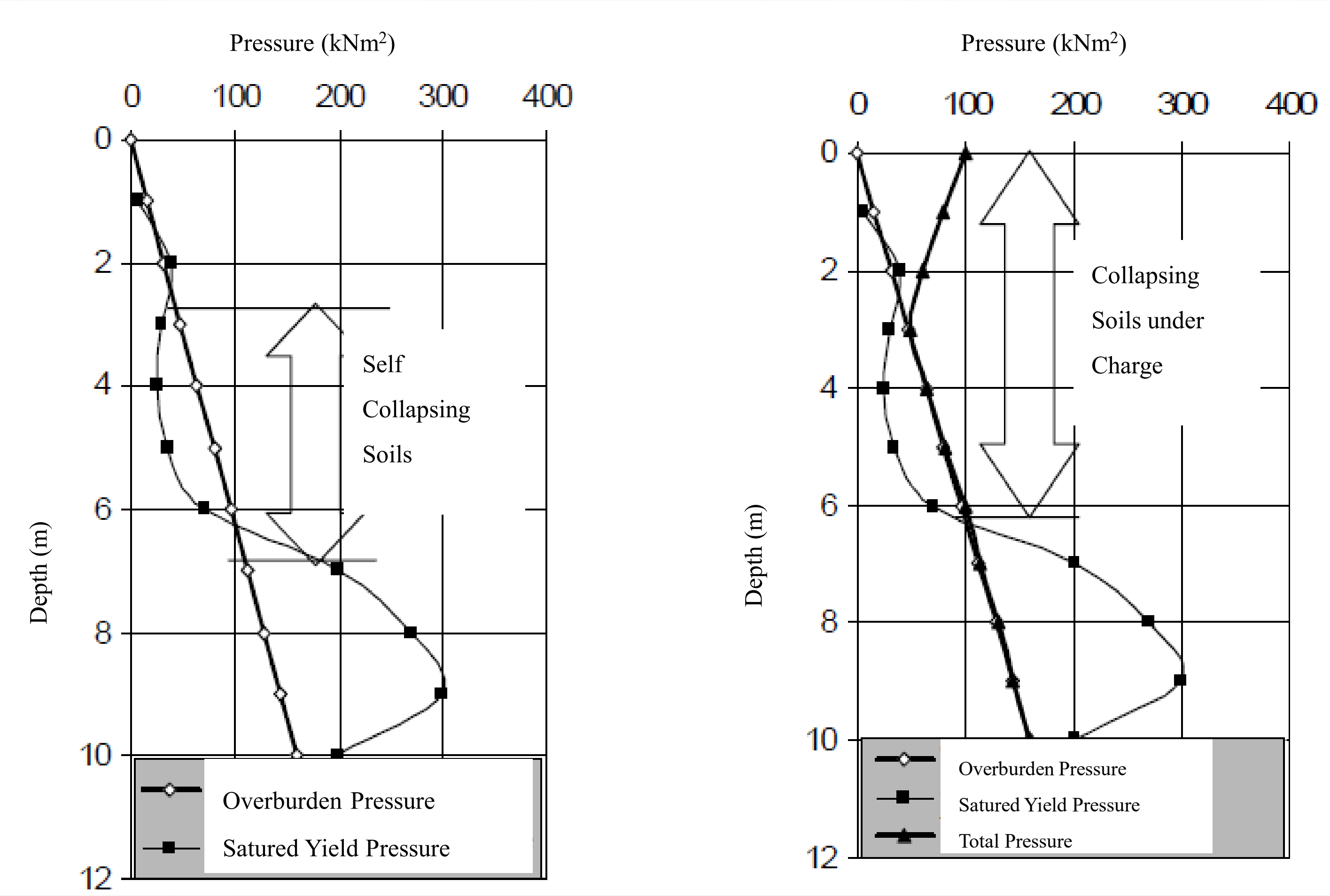
In Situ Tests

(After Terzariol et al 1999)





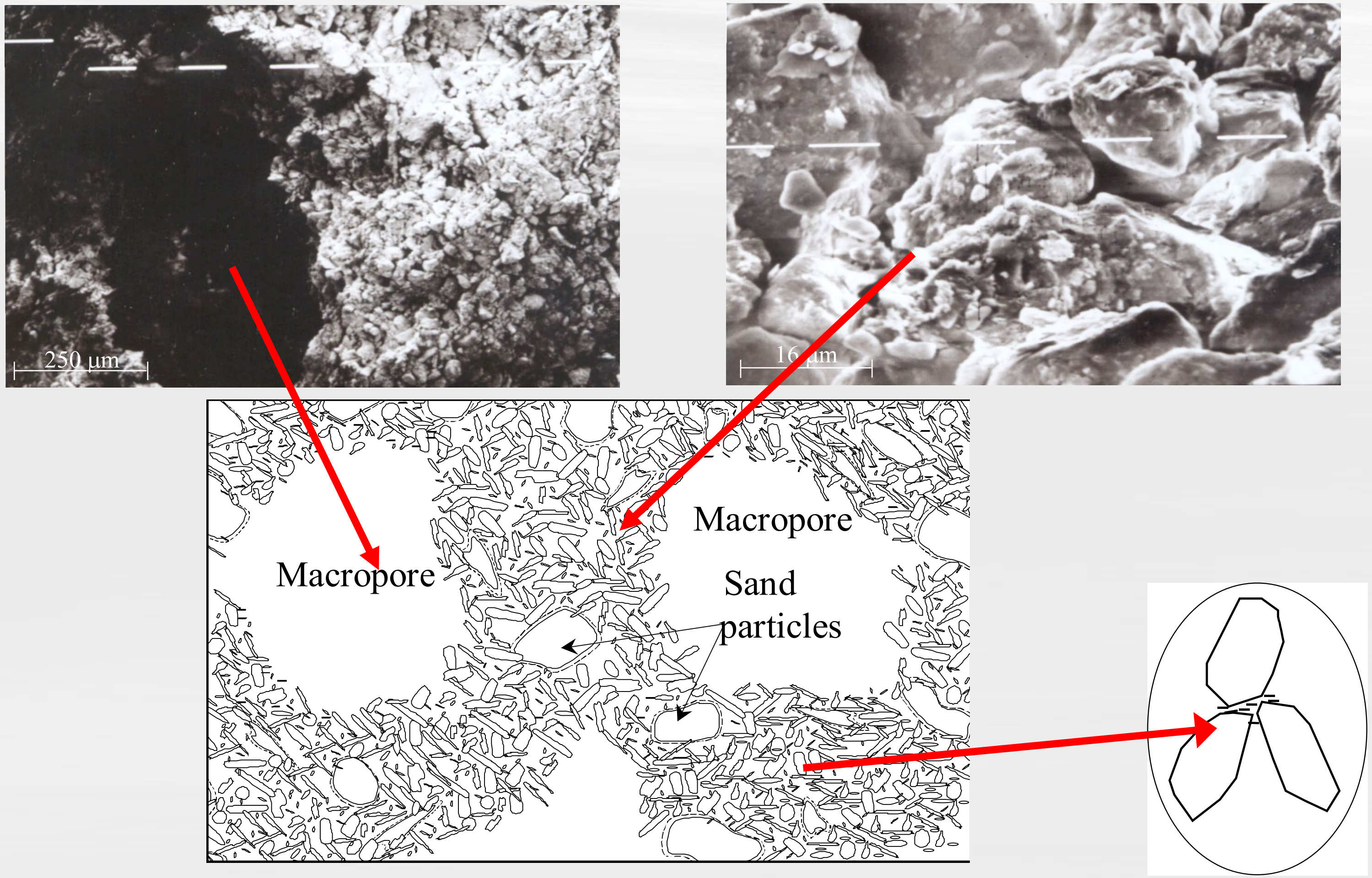
Collapsibility Profiles (after Rocca et al 2006)



Comparison between collapse and consolidation processes

PROPERTY	COLLAPSE	CONSOLIDATION
Initial Saturation Degree	Non Satured	Satured
Void Ratio	High	High
Water Flux during process	Absorption	Expulsion
Pore Pressure	Tend to Disipate	Increase Quickly
Process duration in Lab	10 or 20 minutes	Days/Weeks
Shear Stenght Before	High	Low
Shear Strenght After	Low	High

INTERNAL STRUCTURE OF LOESS

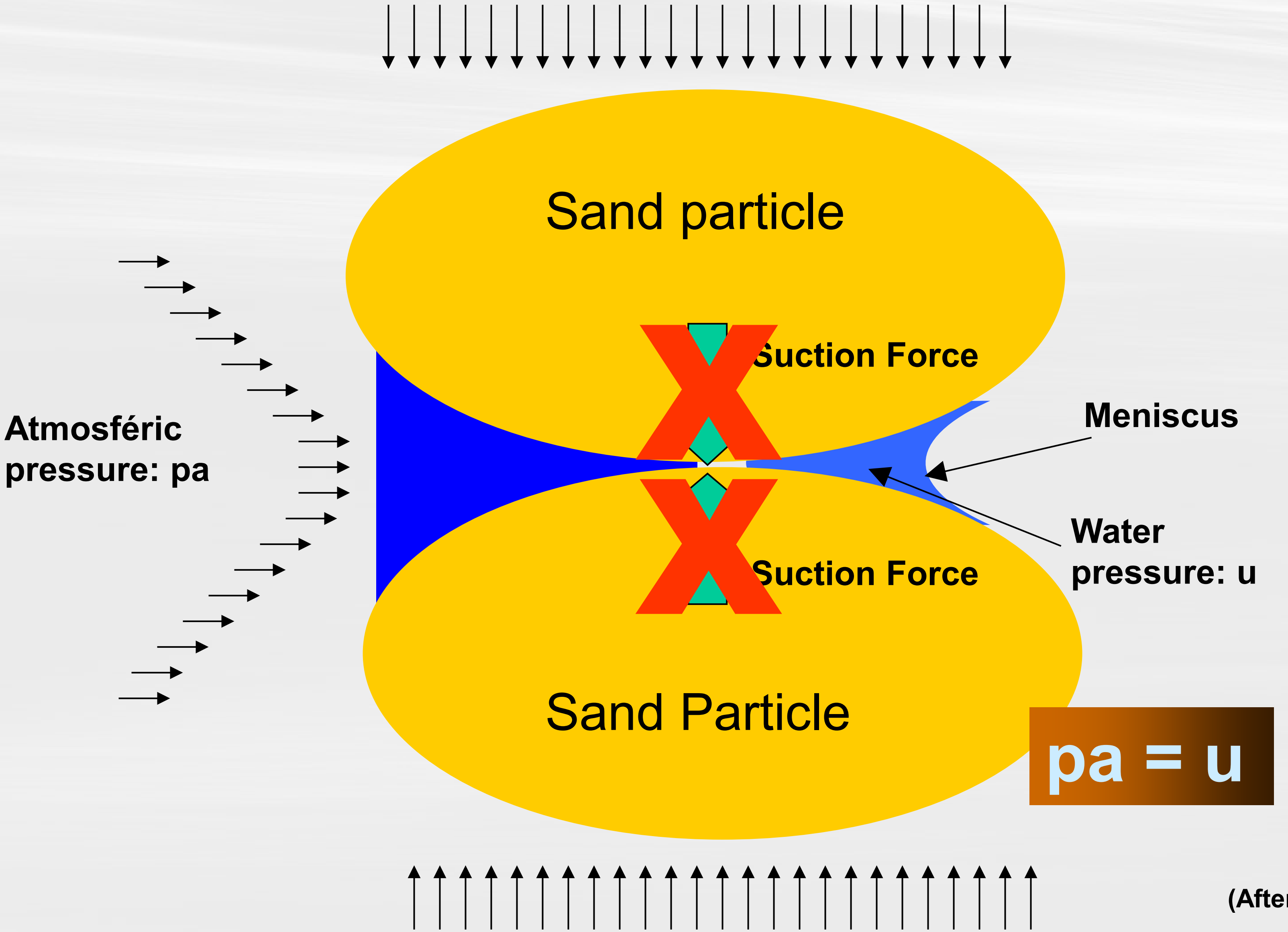


Mechanism of Soil Collapse

- Weakens of Inter-particle Bonds
- Shear Stresses Concentration and Failure
- Particle Sliding and Closure of Pores

Reduction of Suction Forces

Dissolution of Salts



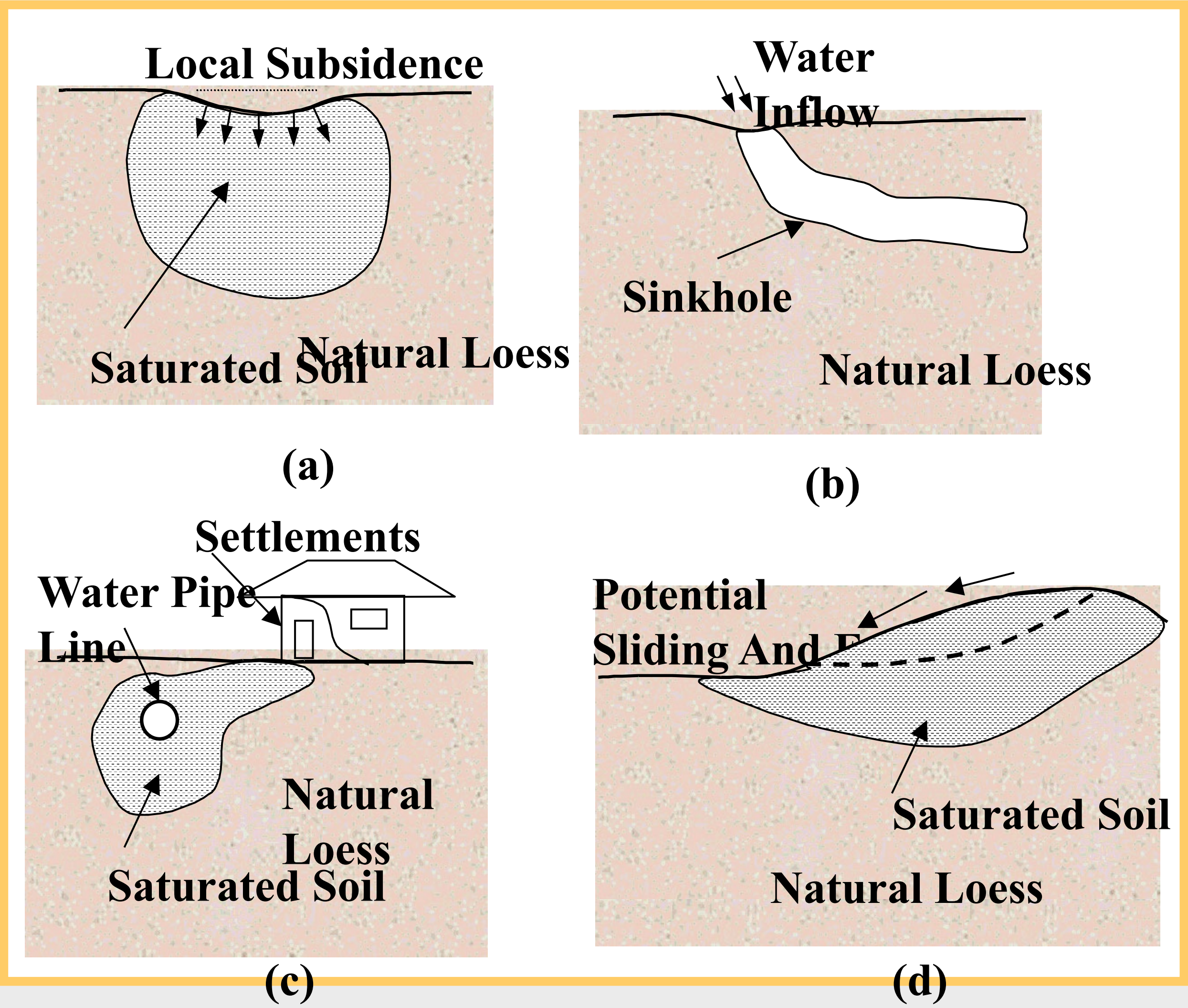
(After Redolfi 2007)

Slaking Test

Before Starting

ENGINEERING PROBLEMS IN COLLAPSIBLE SOILS

Effects of Water



(After Rinaldi 2006)

Effects on Foundtions

(After Terzariol 2012)

Erosion

(After Terzariol 2012)

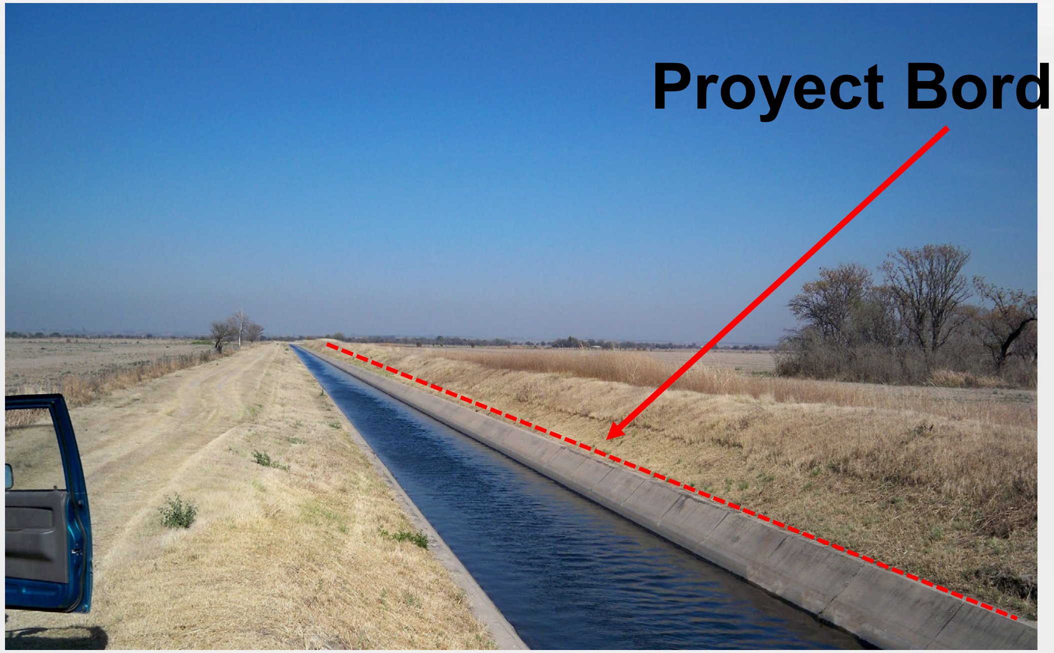
Piping

(After Terzariol 2007)

Buried Pipelines

(After Terzariol 2007)

Local and General Subsidence



(After Terzariol 2012)

Sliding on urban excavations (After Terzariol 2025)

ENGINEERING SOLUTIONS

IMPROVE SOIL

PREVENT SOIL WETTING

MITIGATE EFECTS

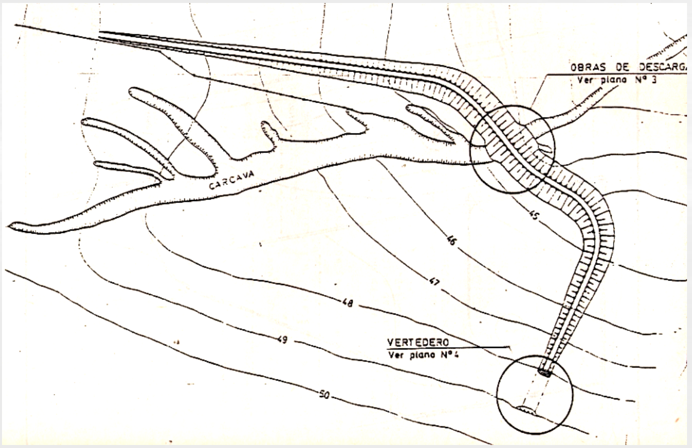
DEEP FOUNDATIONS

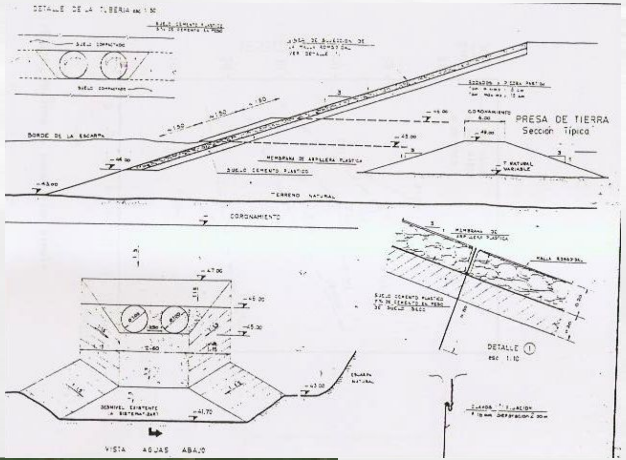
PREVENT SOIL WETTING

(After Terzariol 2006)

EROSION CONTROL

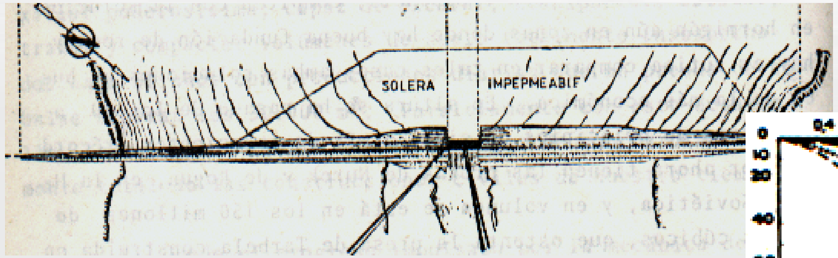
(After Abbona et al 1989)

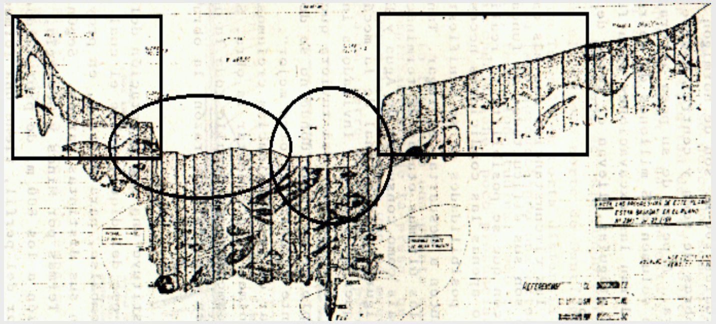


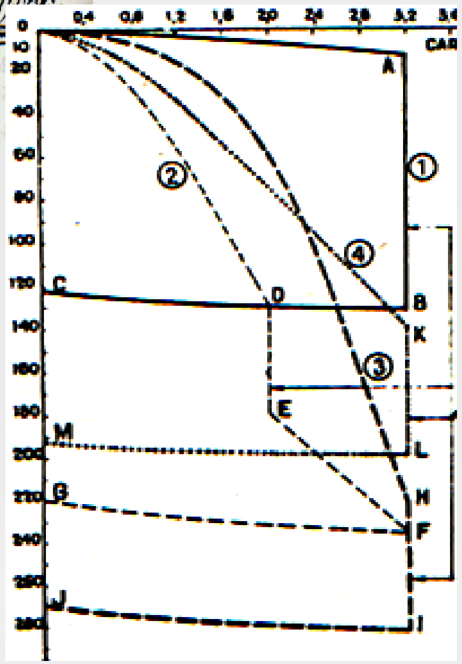


DAMS

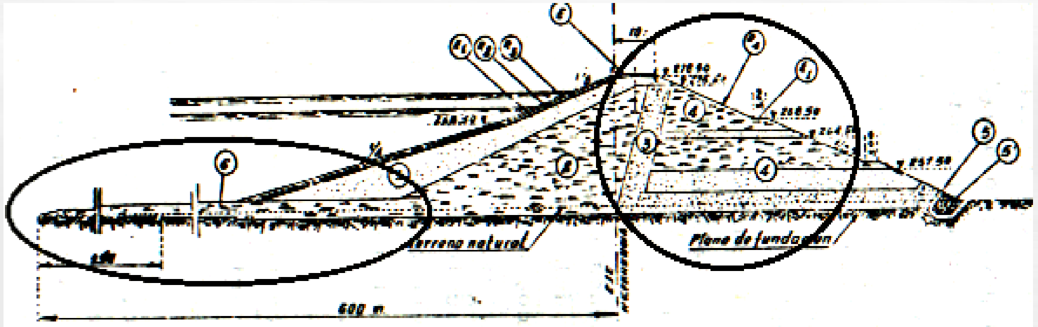
Foundations Pre Wetting

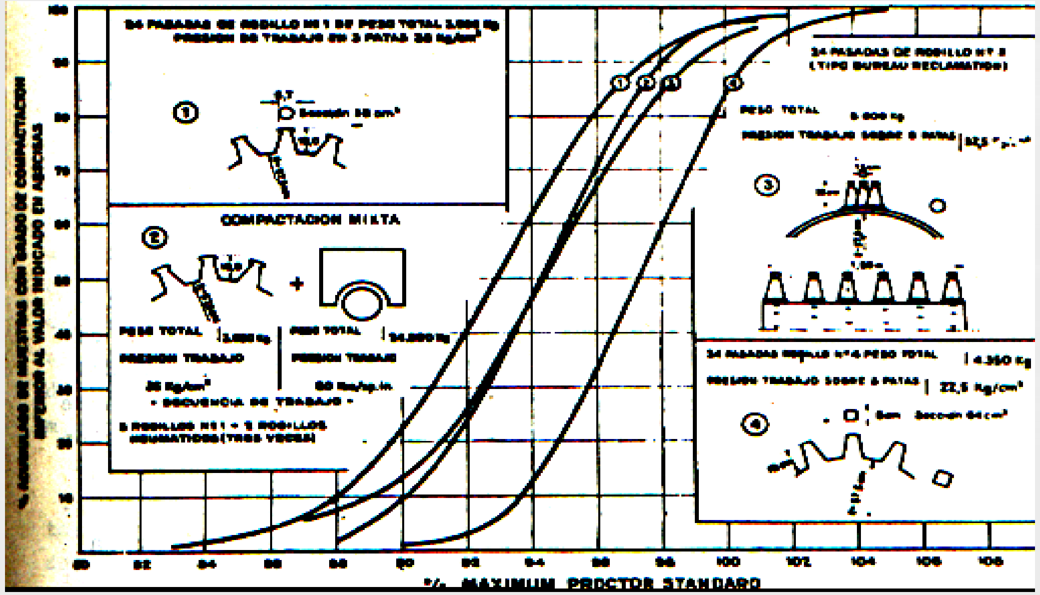




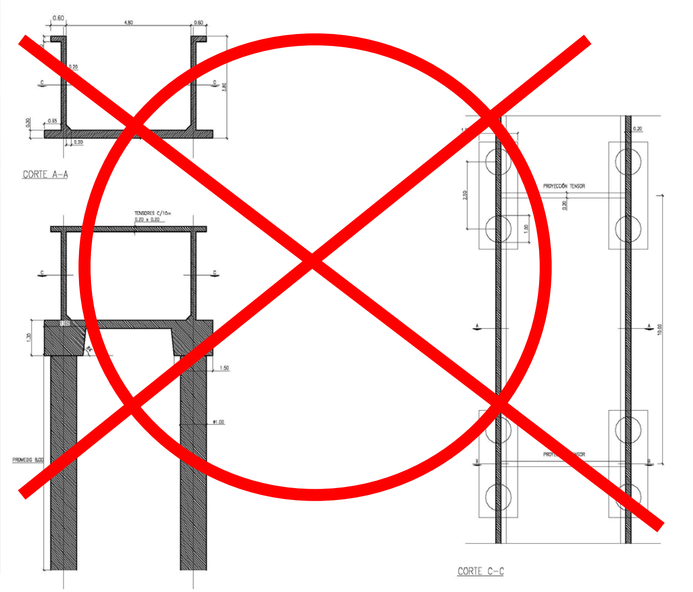


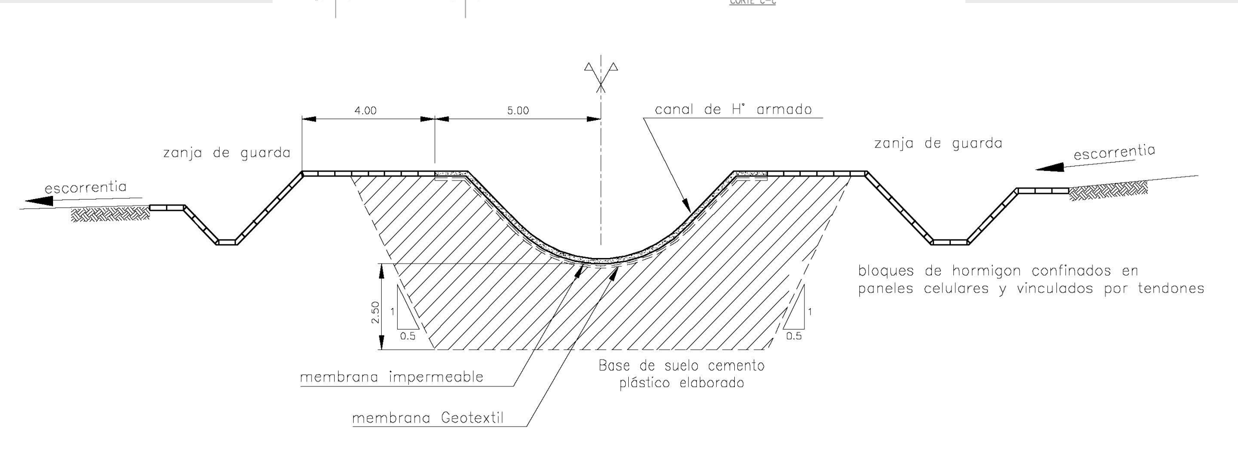
Use Loess Soil as Construction Material





SOIL IMPROVEMENT

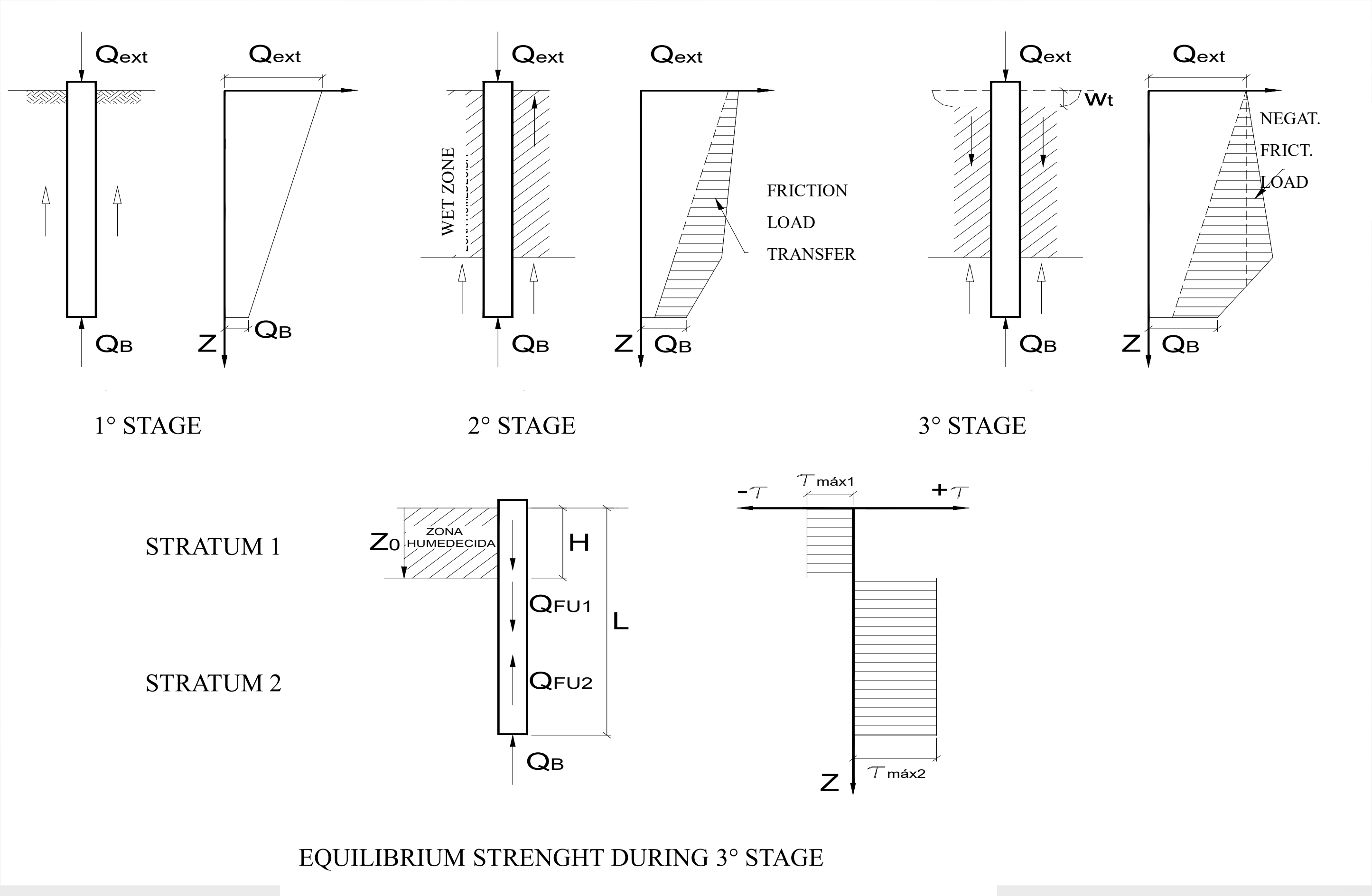




(After Terzariol 2012)

DEEP FOUNDATIONS

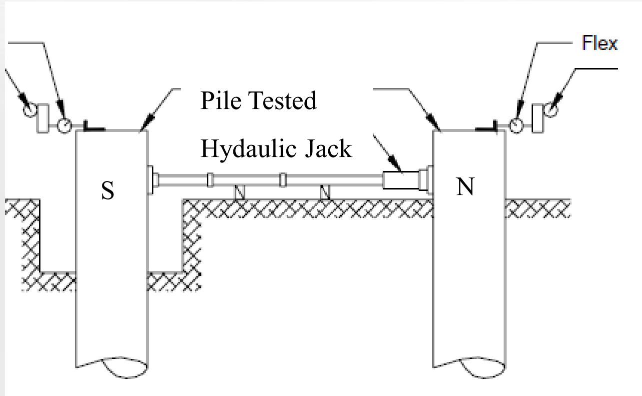
Vertical Loads (After Redolfi et al 1992)

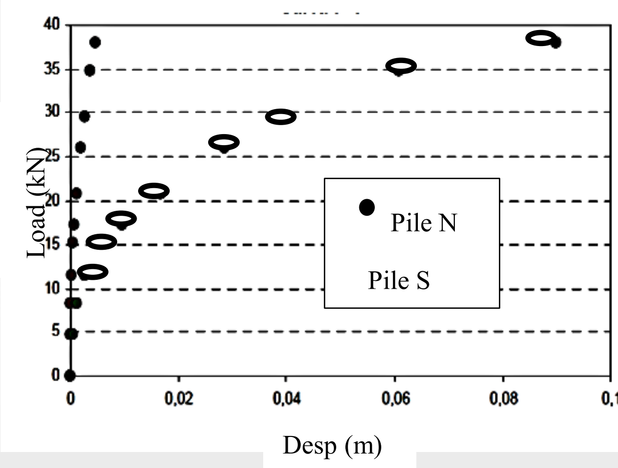


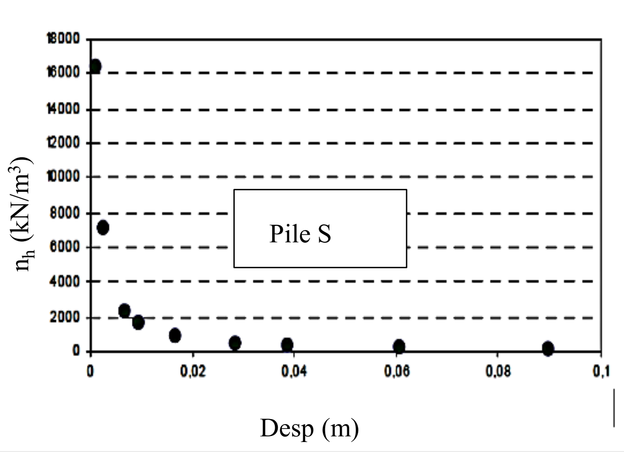
DEEP FOUNDATIONS

Lateral Loads

(After Terzariol 2006)

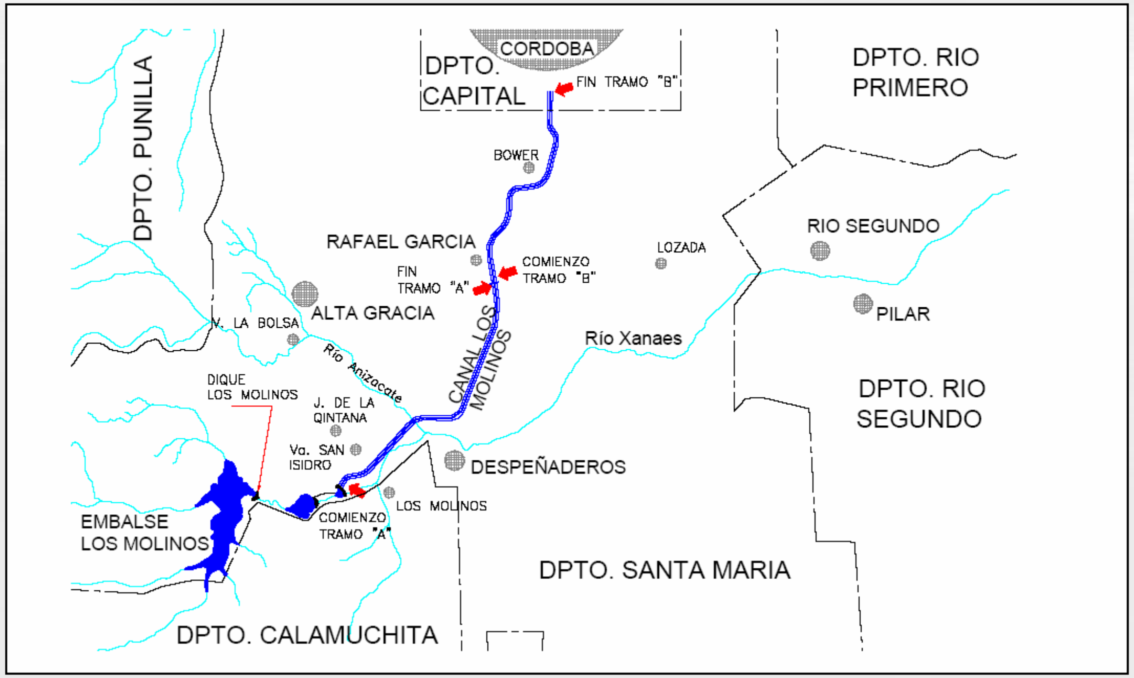




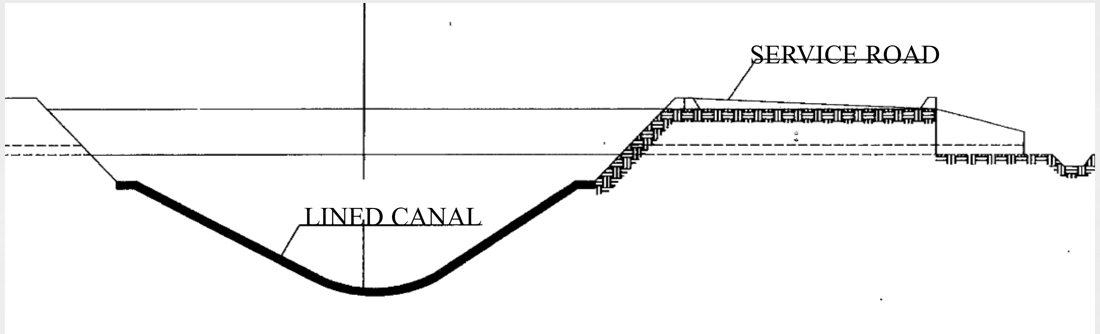


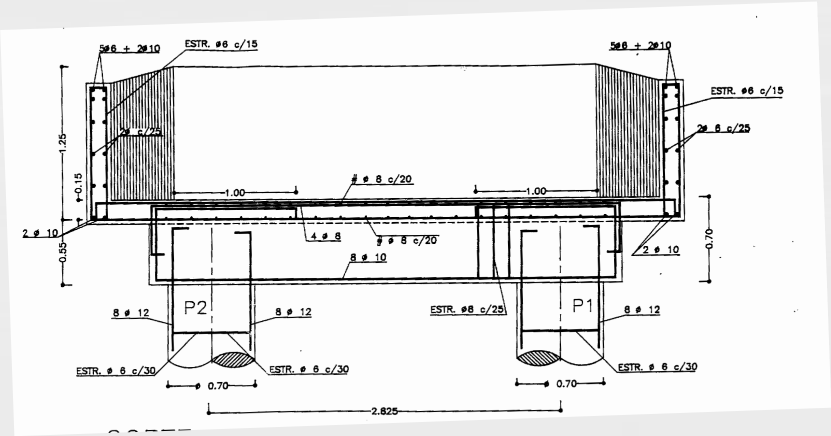
HISTORY CASES

“Los Molinos-Córdoba” Canal



(After Terzariol 2012)





Collapsible soils in Argentina

Experiences and case histories

(After Terzariol 2012)

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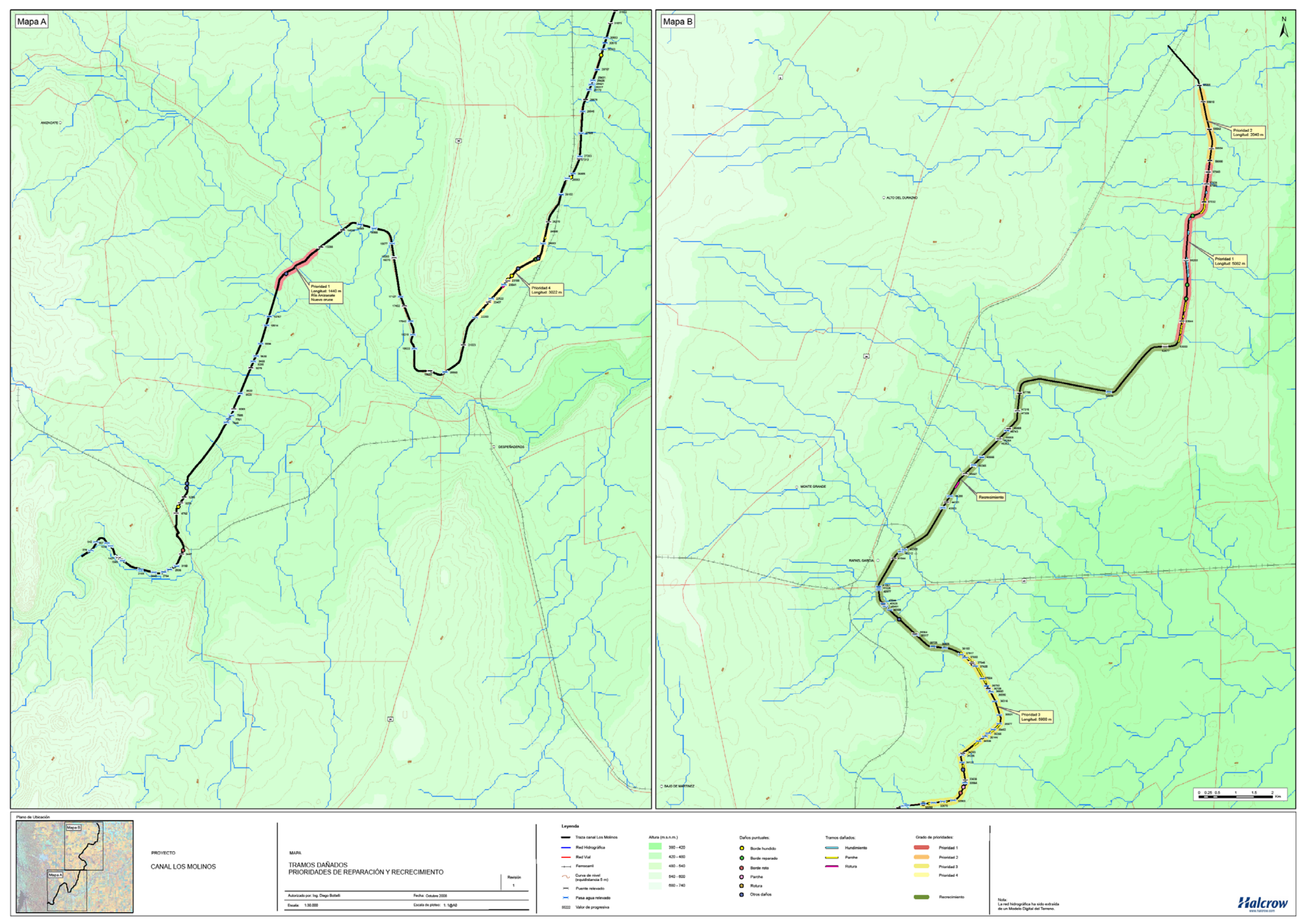
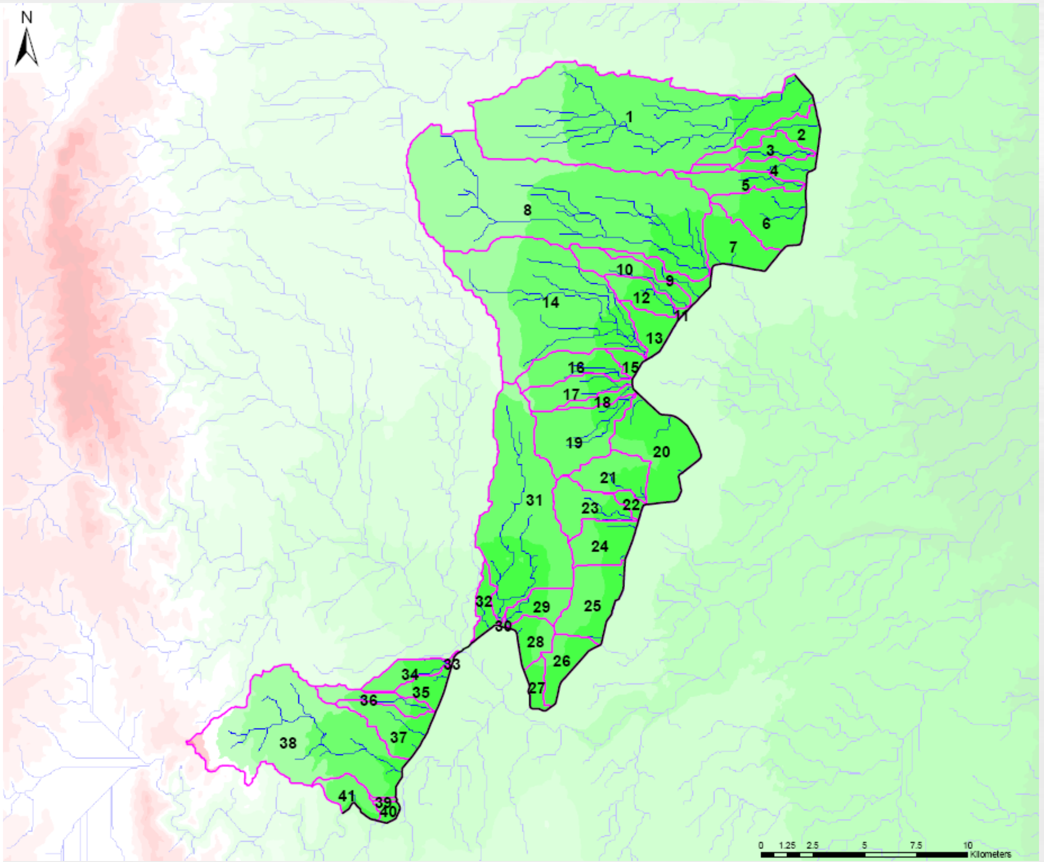
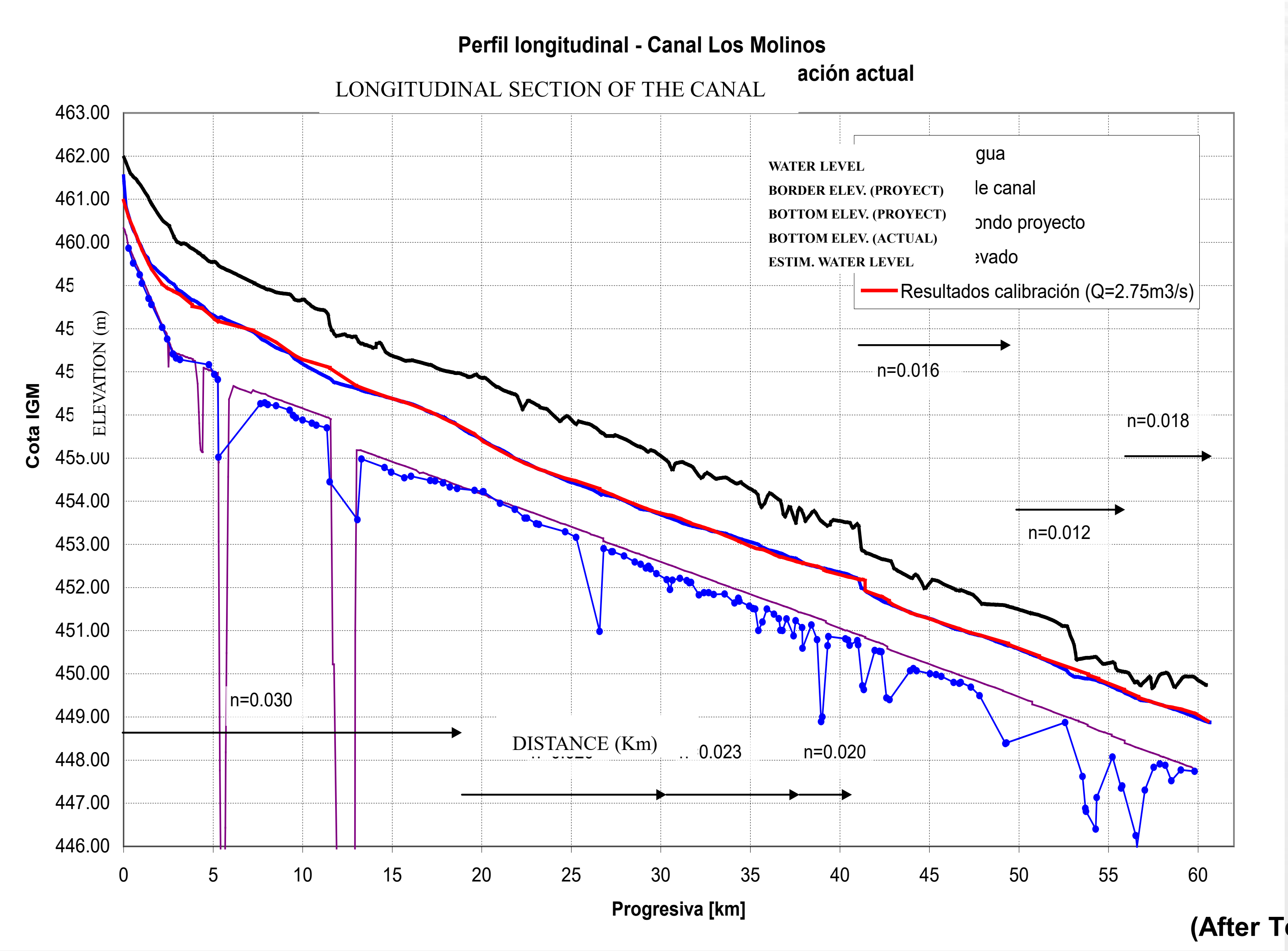




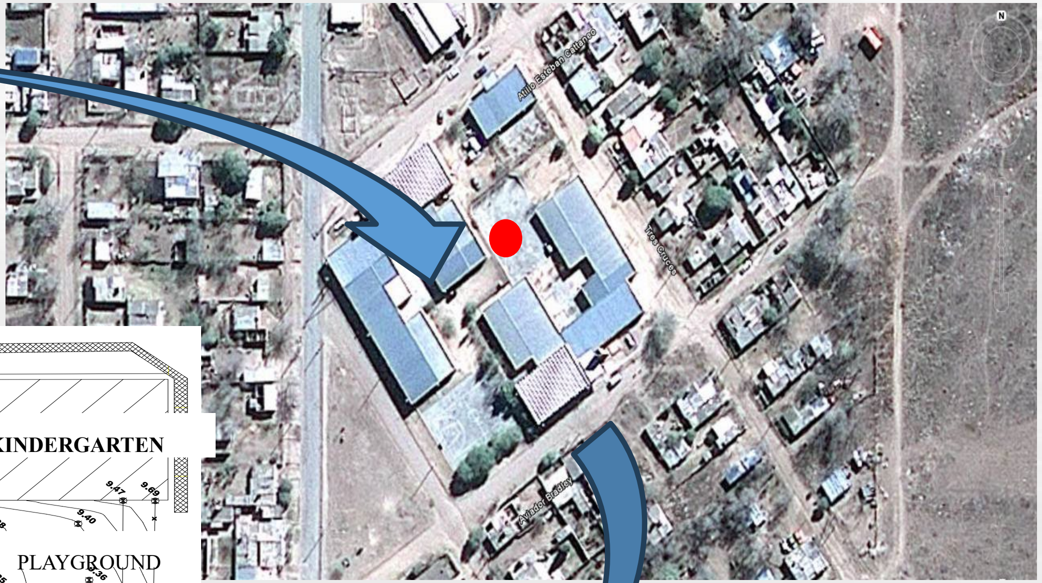
(After Terzariol 2012)

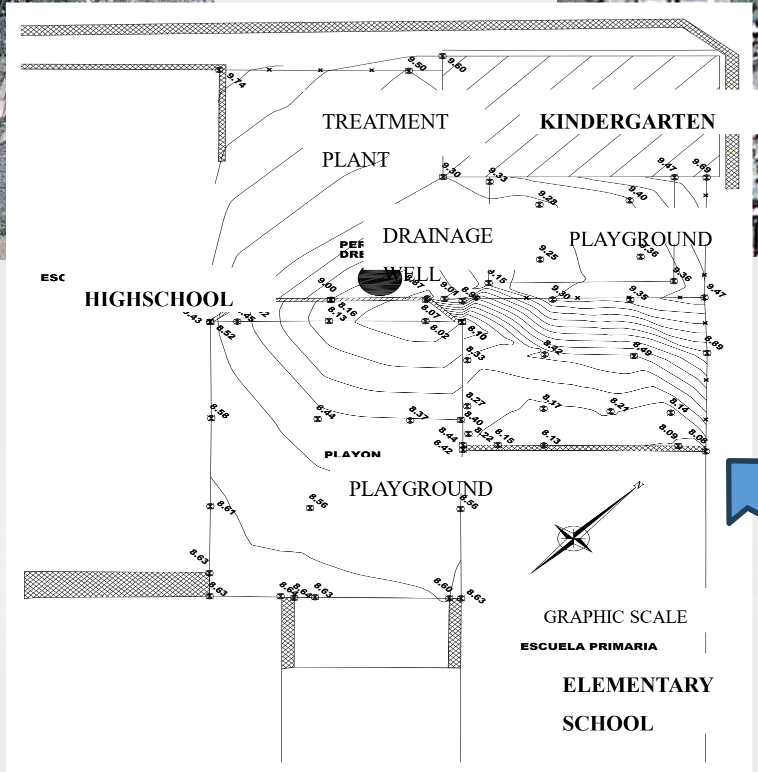
Collapsible soils in Argentina
Experiences and case histories



(After Terzariol 2012)

Damage for self-collapse Education Center

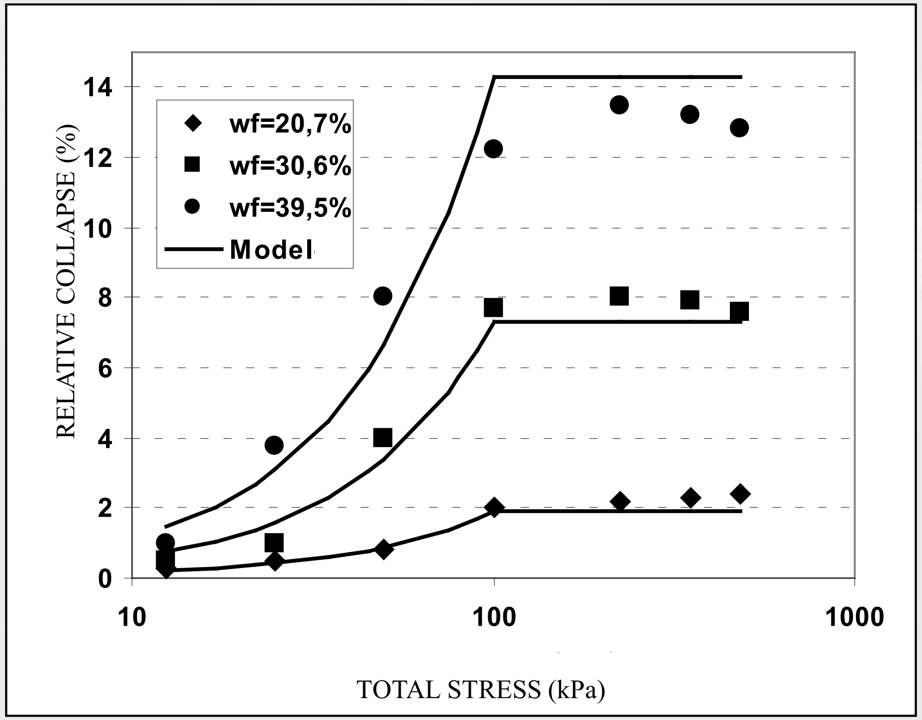


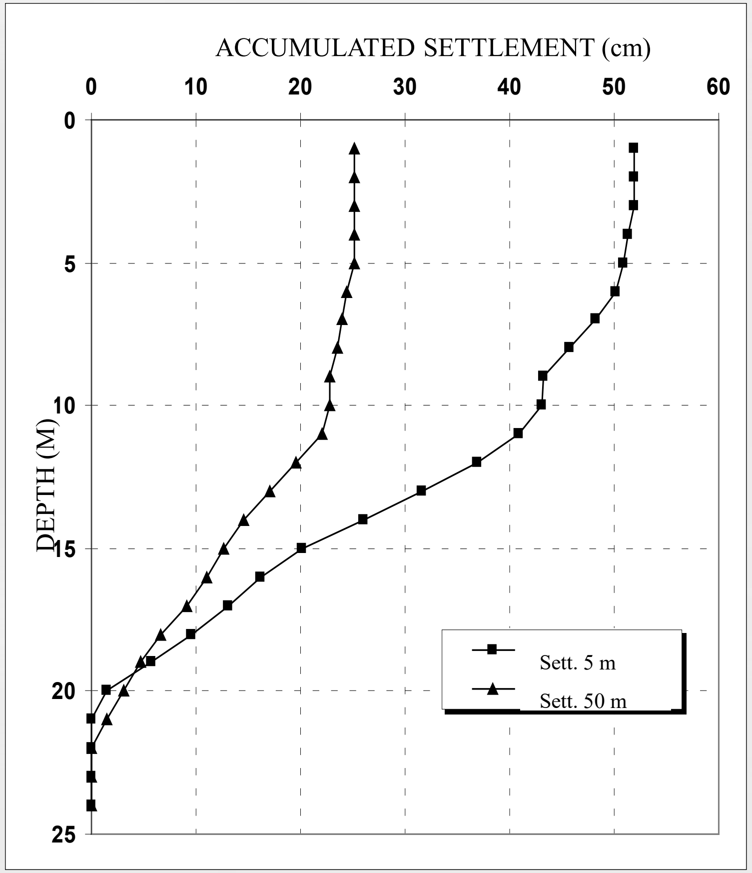


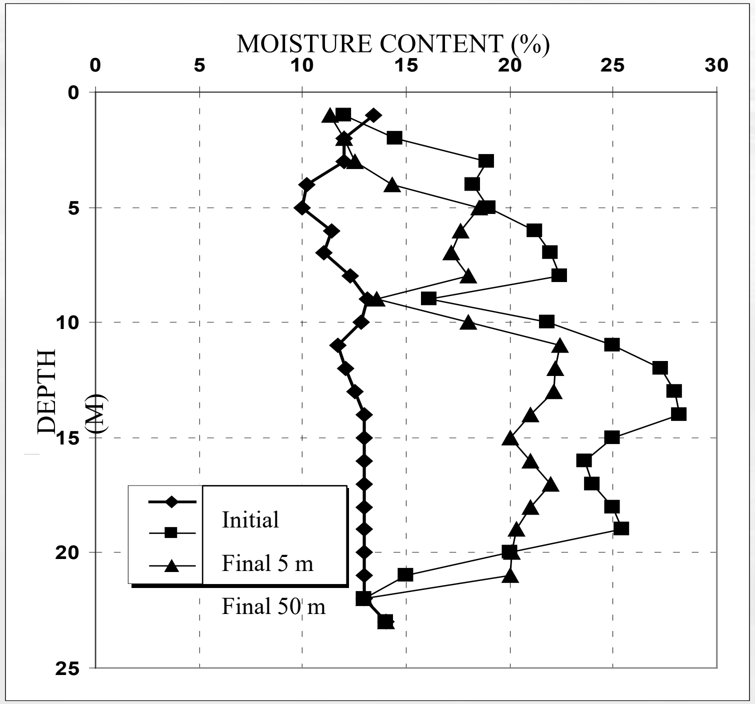
(After Terzariol et al 2009)

Collapsible soils in Argentina

Experiences and case histories







(After Terzariol 2012)

Final Remarks

- A description of both primary and secondary loessic soils is presented.
- Collapsible loessic soils are described, analyzing their regional problems and, in particular, the structures built on them.
- The most relevant geomechanical parameters for these soils are provided.
- Recommendations are made regarding the most commonly used characterization methods in the field and their results.
- An evaluation is carried out of the foundation systems used in Argentina over more than 60 years of experience.
- The design methods for these foundations and the expected behaviors with them are presented.
- Through two analyses of two local case histories related to foundation and construction problems on collapsible soils, evaluating the construction methodologies employed, the prediction methods commonly used.
- Finally, this presentation reflects the experiences of more than 50 years of studies and research carried out to date at the Geotechnical Laboratory of the Faculty of Exact, Physical, and Natural Sciences of the National University of Córdoba, Argentina.

UT PORTET NOMEN MEUM CORAM GENTIBUS

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dos Solos e Engenharia Geotécnica

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21 e 22 de julho de 2025
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