4TO CONGRESO PARAGUAYO
Vialidad y Tránsito

ESTABILIZACION DE SUELOS CON CAL

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APC
ASOCIACION PARAGUAYA DE CARRETERAS

Asunción Paraguay 20 y 21 Octubre

PIARC

Premisa

El entendimiento científico sobre el cambio climático ***es hoy suficientemente claro*** para justificar que las ***naciones*** tomen prontas acciones

Academia Nacional de Ciencias EU, 2005

Sustentabilidad

Resiliencia

Chapter 7.0 Design Details And Construction Conditions Requiring Special Design Attention (continued)

7.6 Subgrade Improvement And Strengthening

U.S. Department of Transportation Publication No. FHWA NHI-05-037
Federal Highway Administration
May 2006
NHI Course No. 132040

7.6.1 Objectives of Soil Stabilization

- Secar suelos húmedos y facilitar compactación
- Incrementar capacidad de soporte y restringir el potencial de cambio volumétrico de suelos altamente plásticos o compresibles
- Reducir susceptibilidad a la humedad

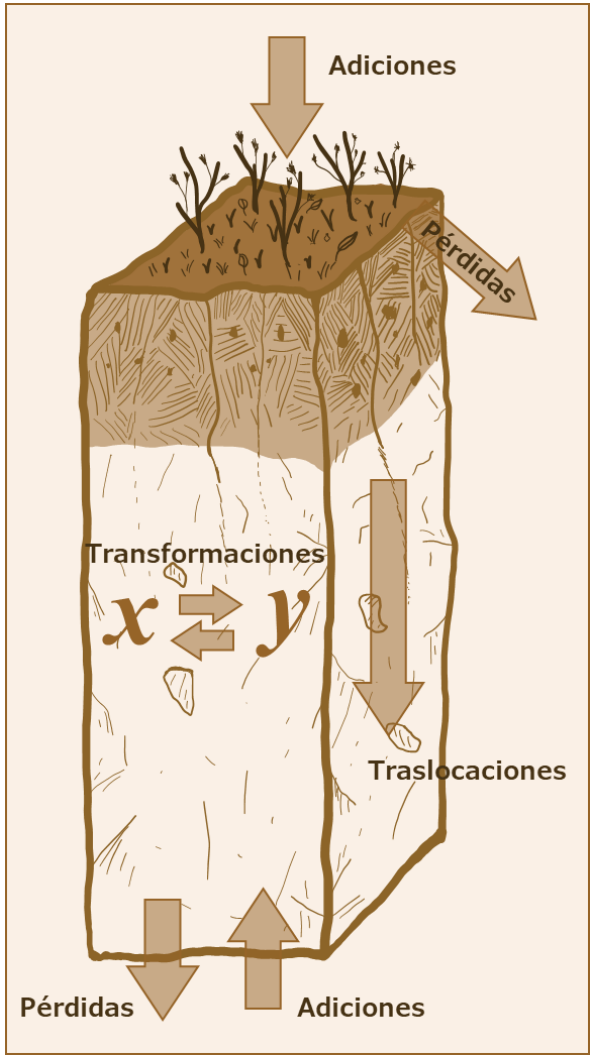
https://www.fhwa.dot.gov/engineering/geotech/pubs/05037/05037.pdf

U.S. Department of Transportation Federal Highway Administration
Bridges & Structures

Formación Suelos

Factores

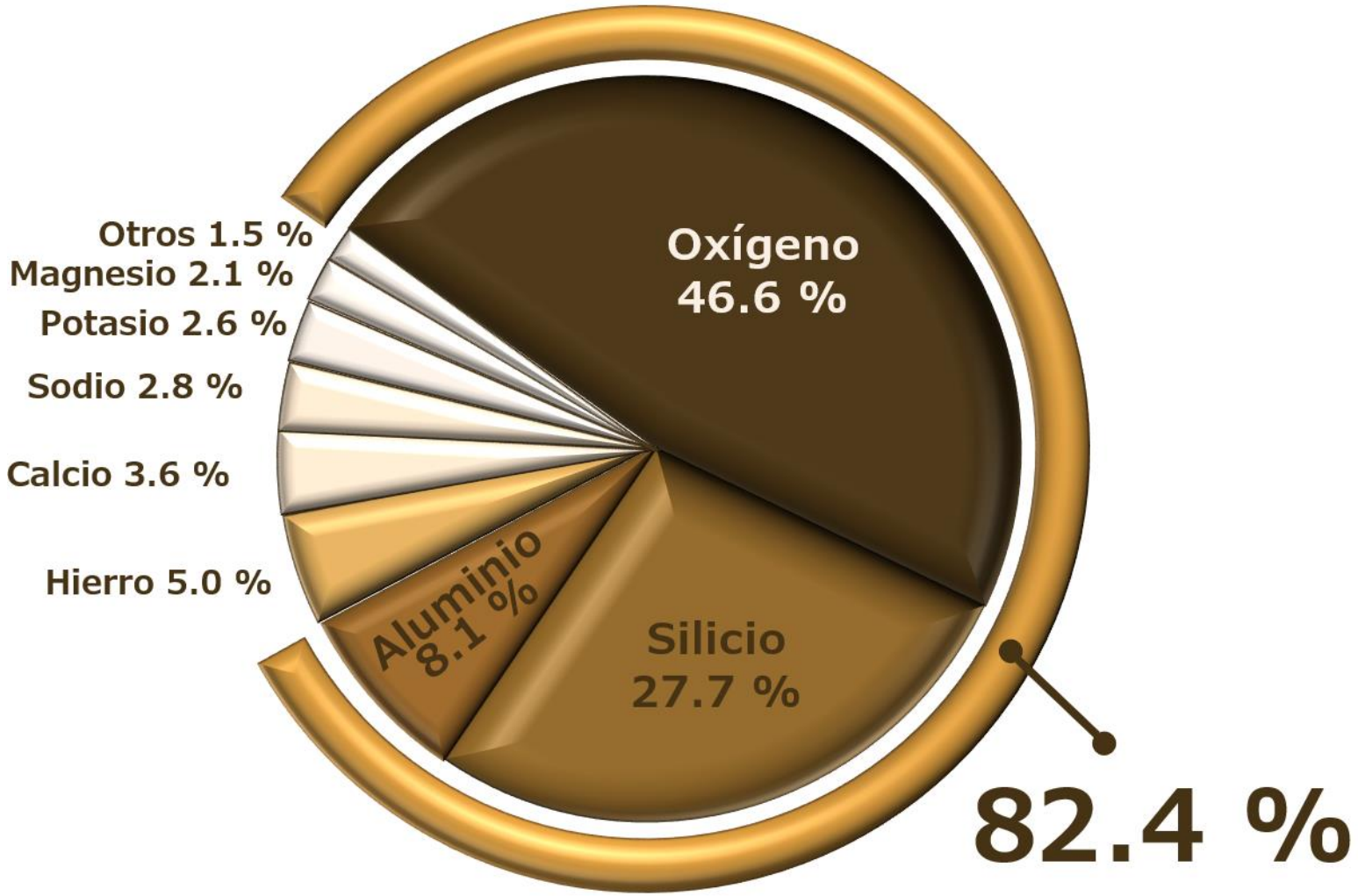
- Material parental
- Clima
- Biota
- Topografía
- Tiempo



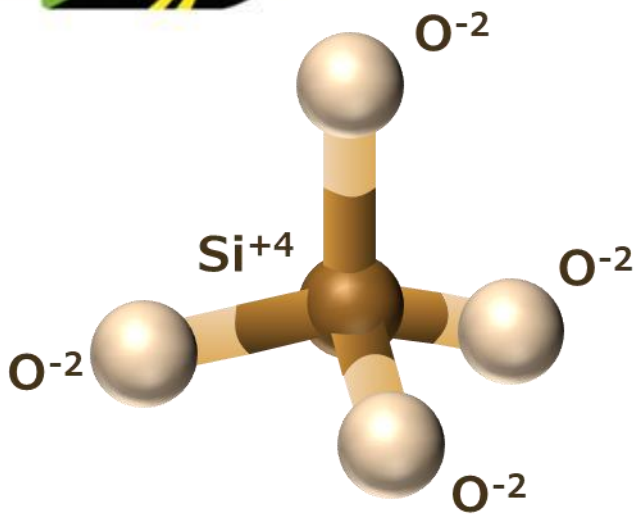
Procesos

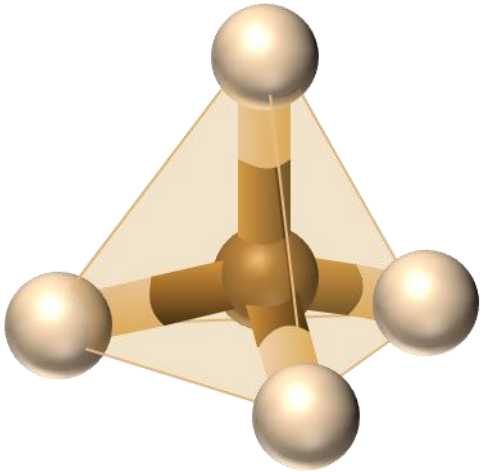
- Adiciones
- Pérdidas
- Translocaciones
- Transformaciones

Composición Corteza



Bloques Sílice





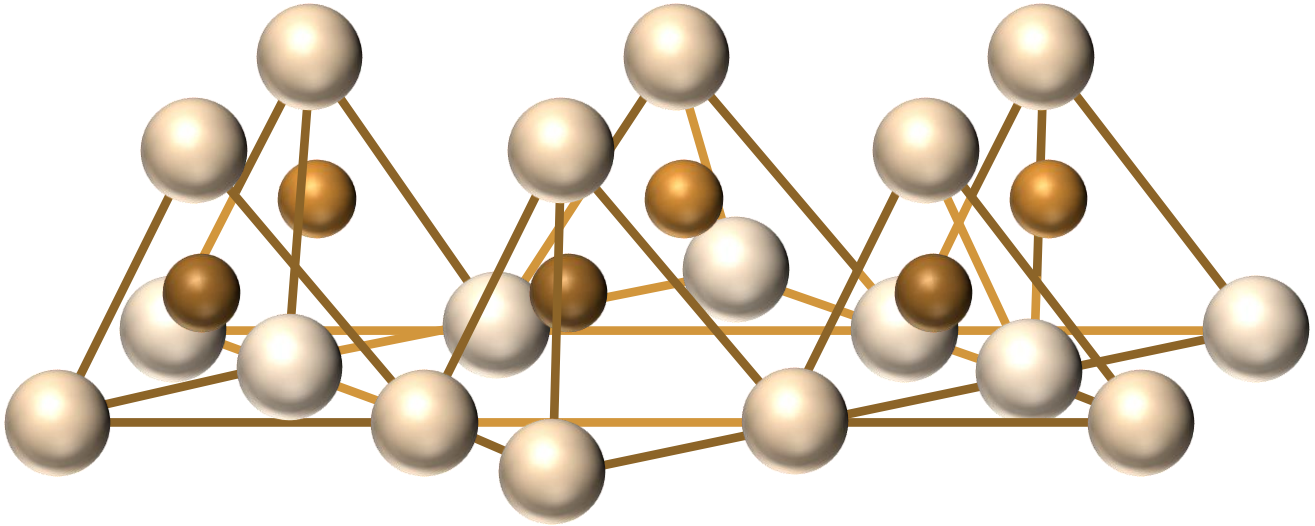
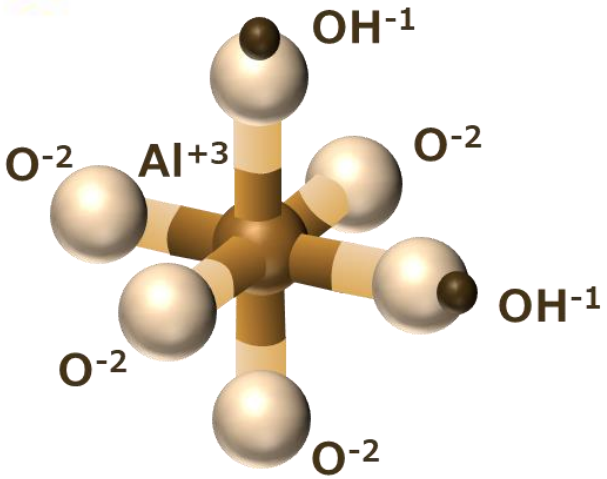
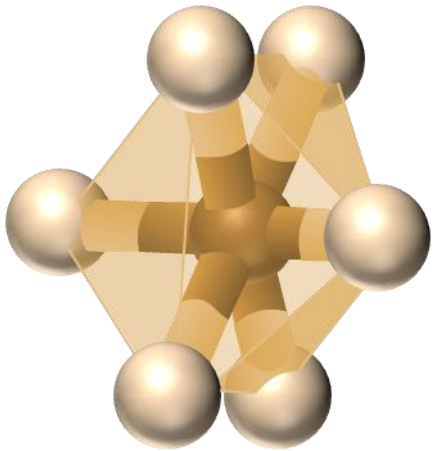


Lámina de sílice

Representación simple

Bloques Alúmina





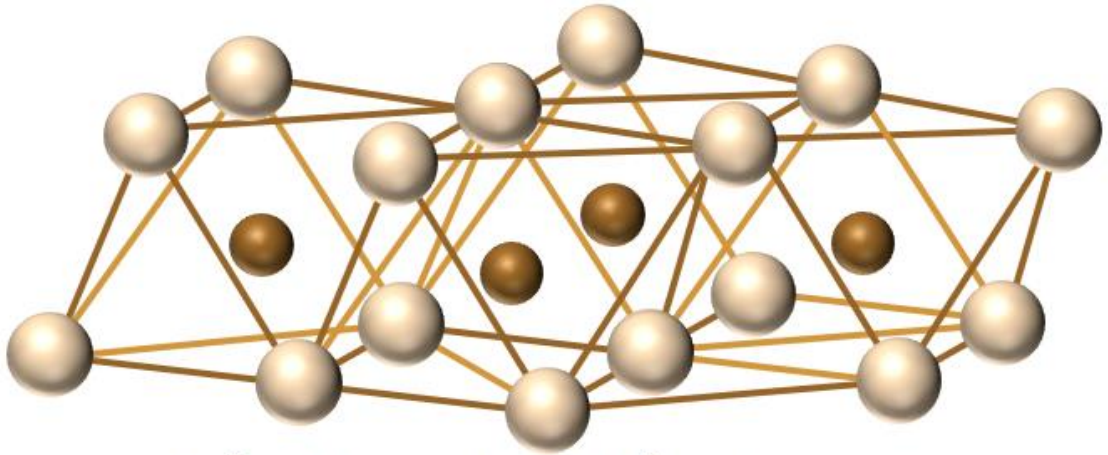
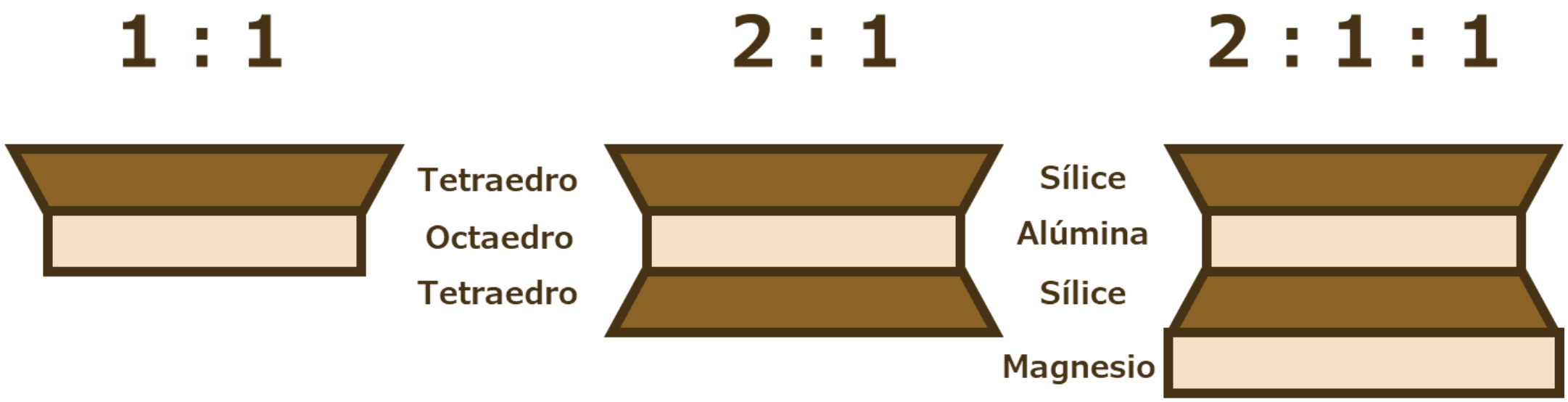


Lámina de Alúmina

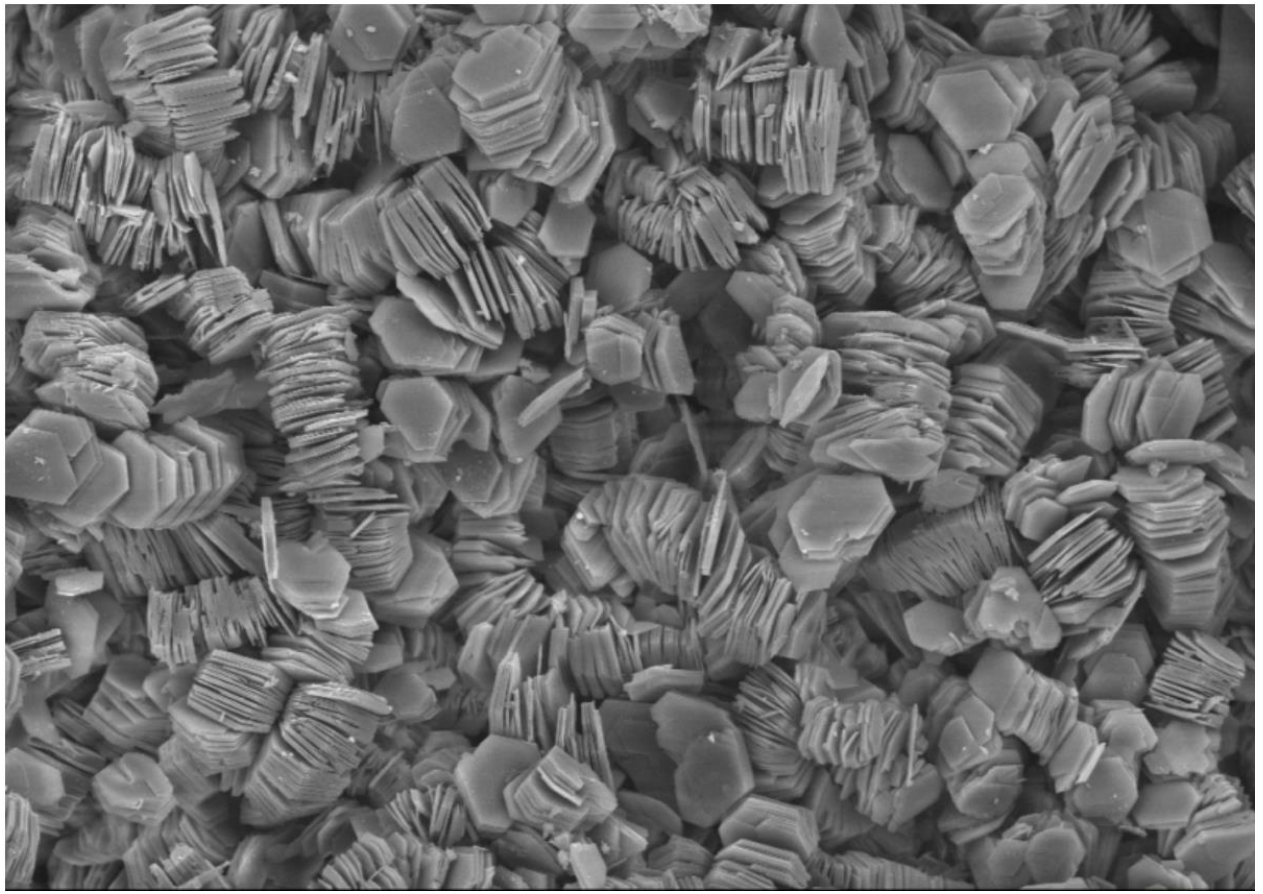
Representación simple

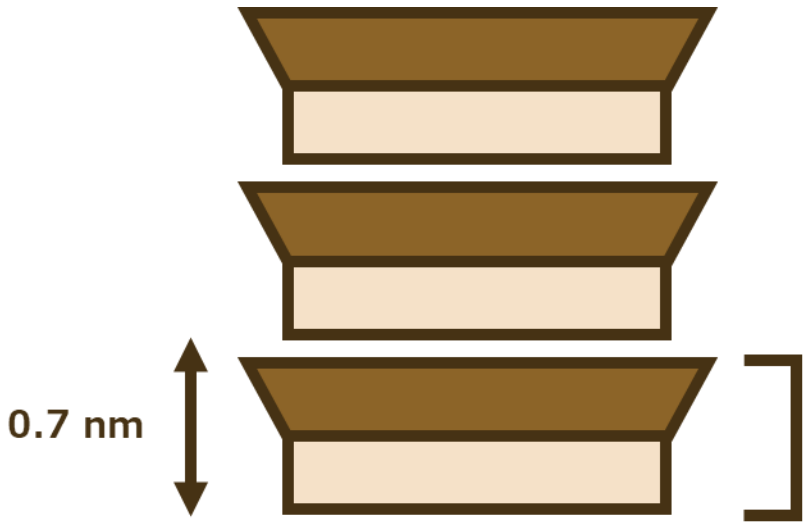
Filosilicatos



Filosilicatos 1:1

Caolinitas





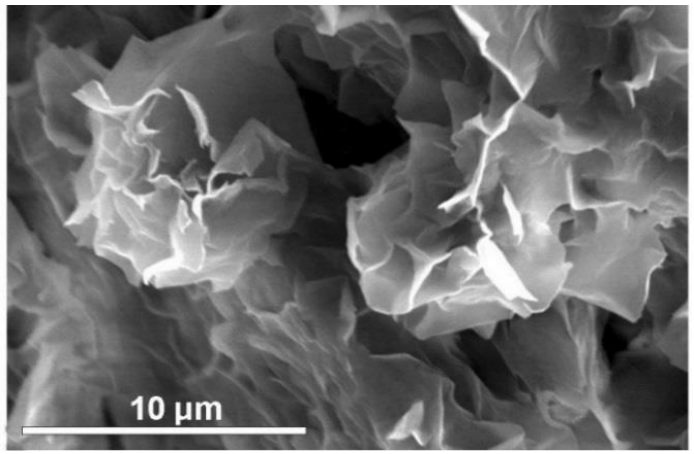
Celda Unitaria

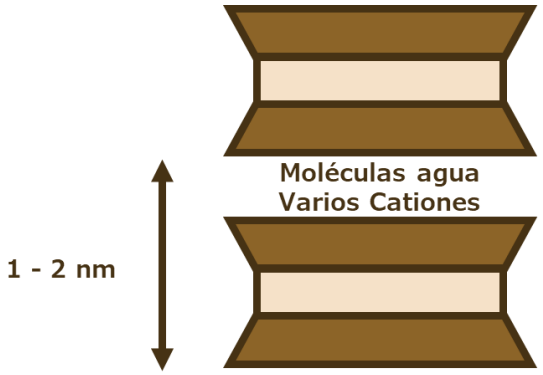
Unidad mínima que se repite para
Formar la estructura cristalina

Requiere 3,000 unidades para formar
Una partícula de arcilla de 0.002 mm

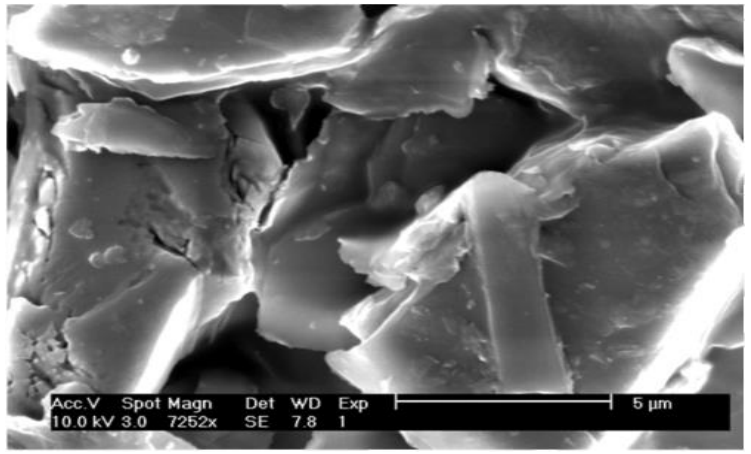
Filosilicatos 2:1

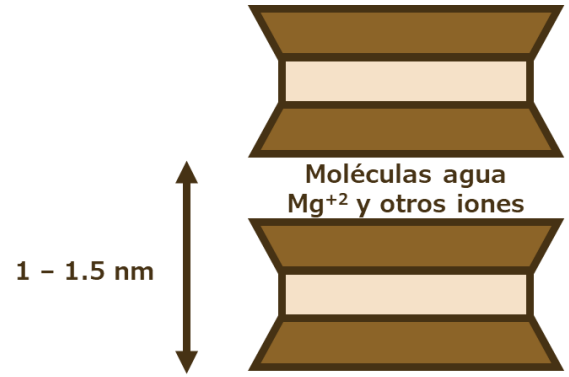
Esmectitas



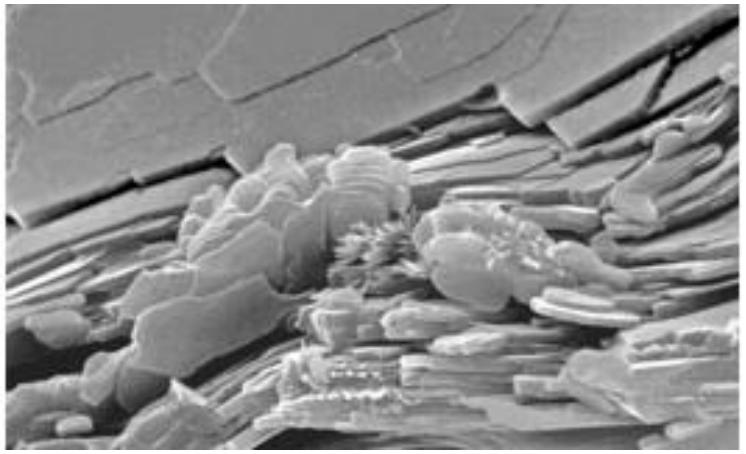


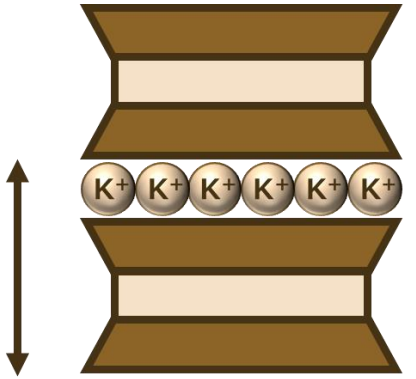
Vermiculitas

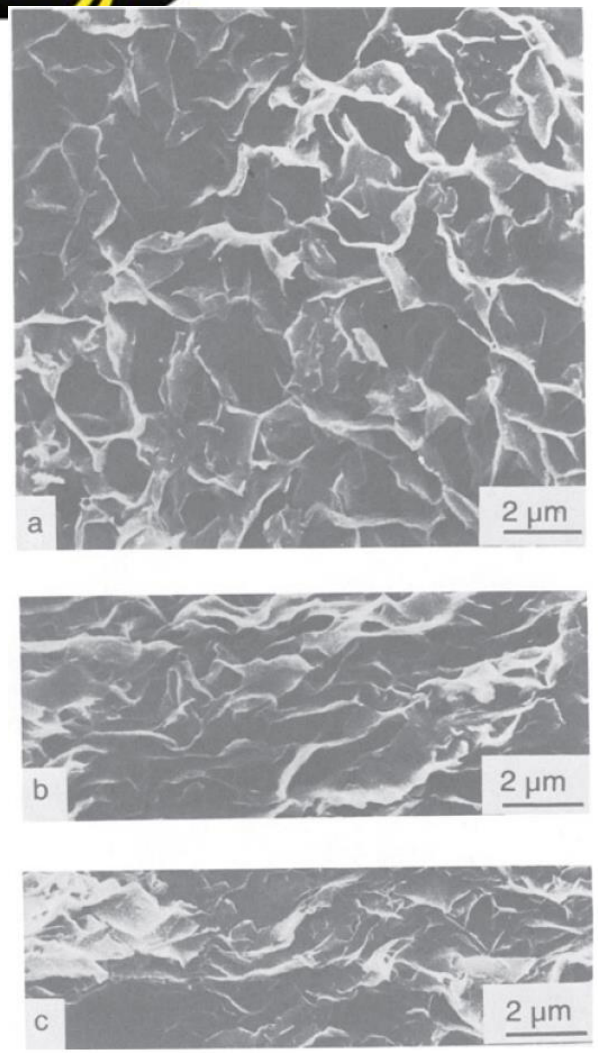




Micas



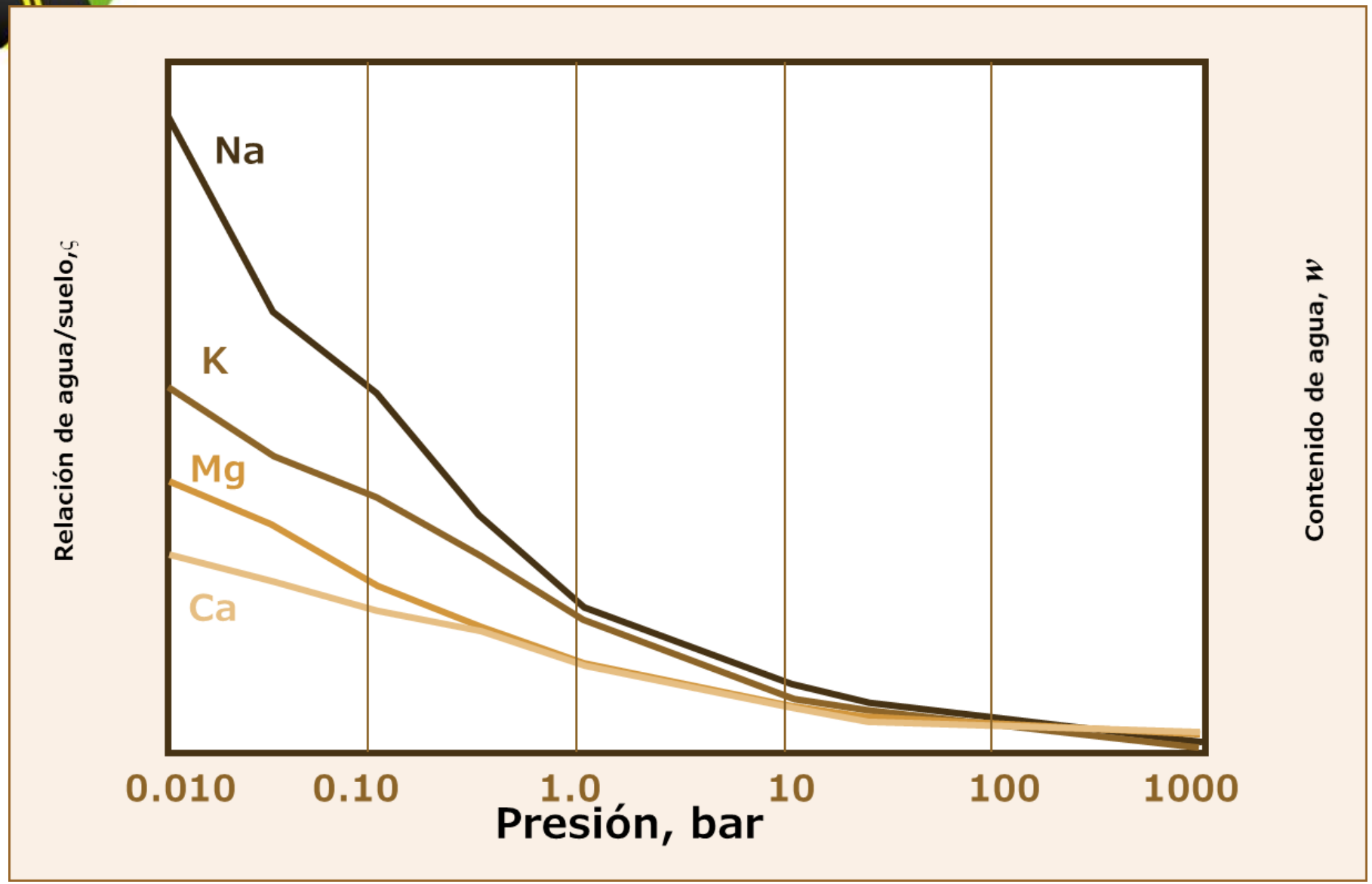




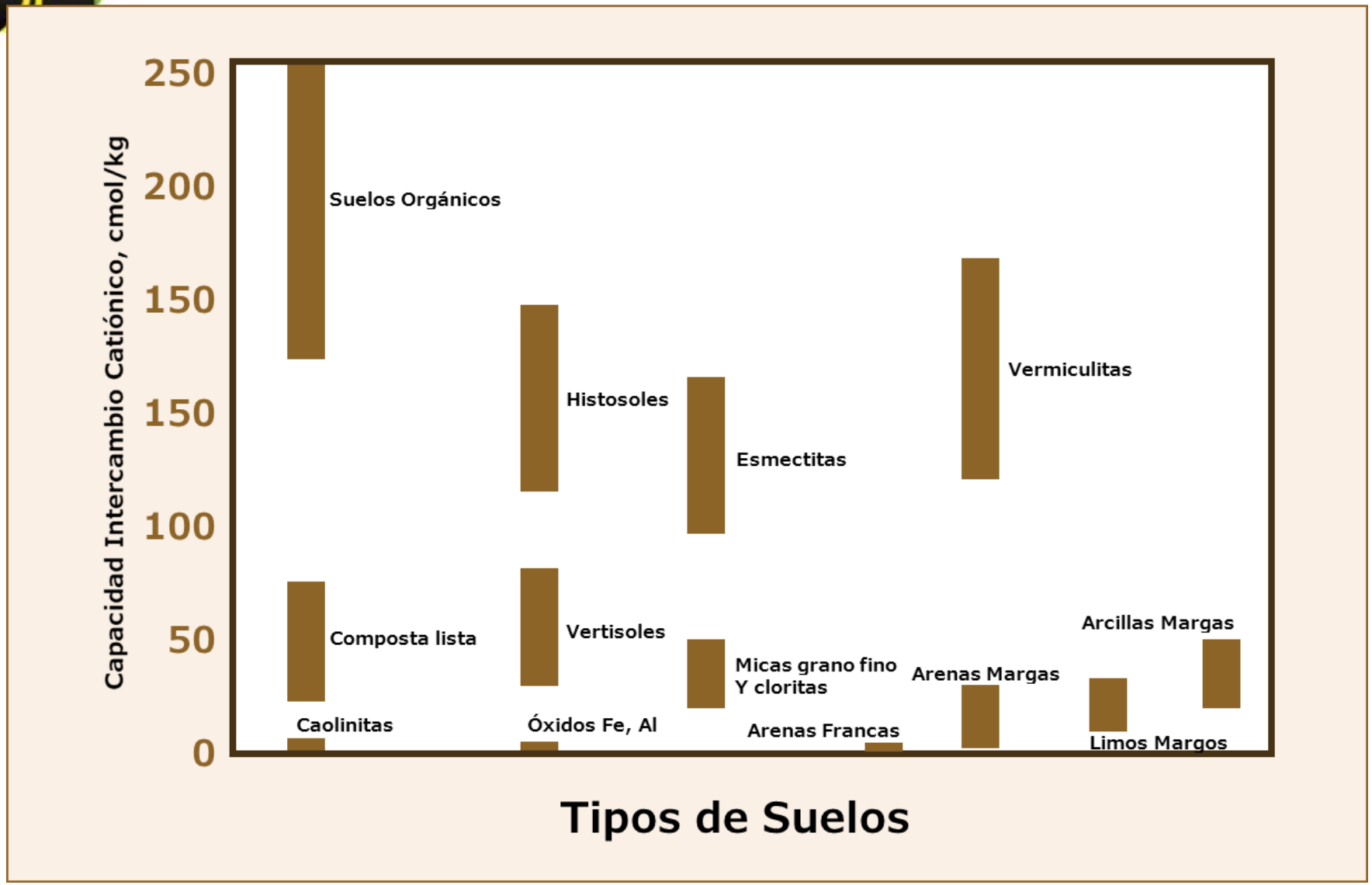
Saturado

Seco

Retención Agua

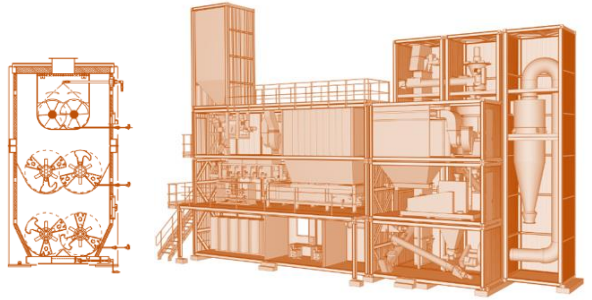


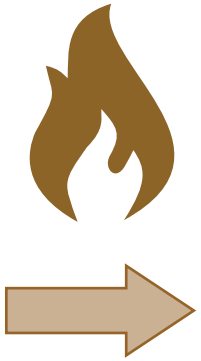
Capacidad Intercambio Catiónico

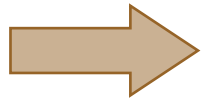


Fabricación Cal

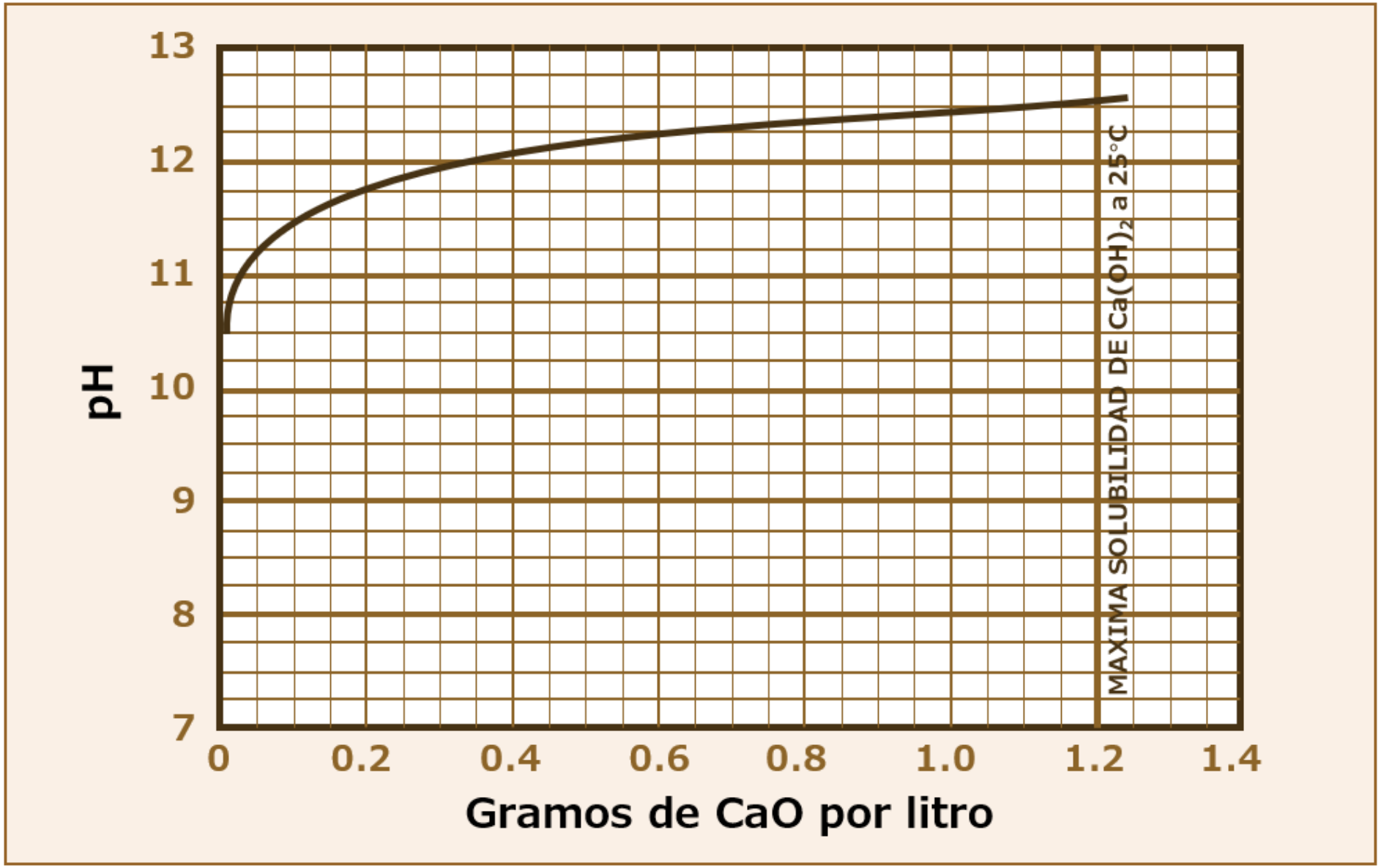
CALIDRA
SIEMPRE AHÍ



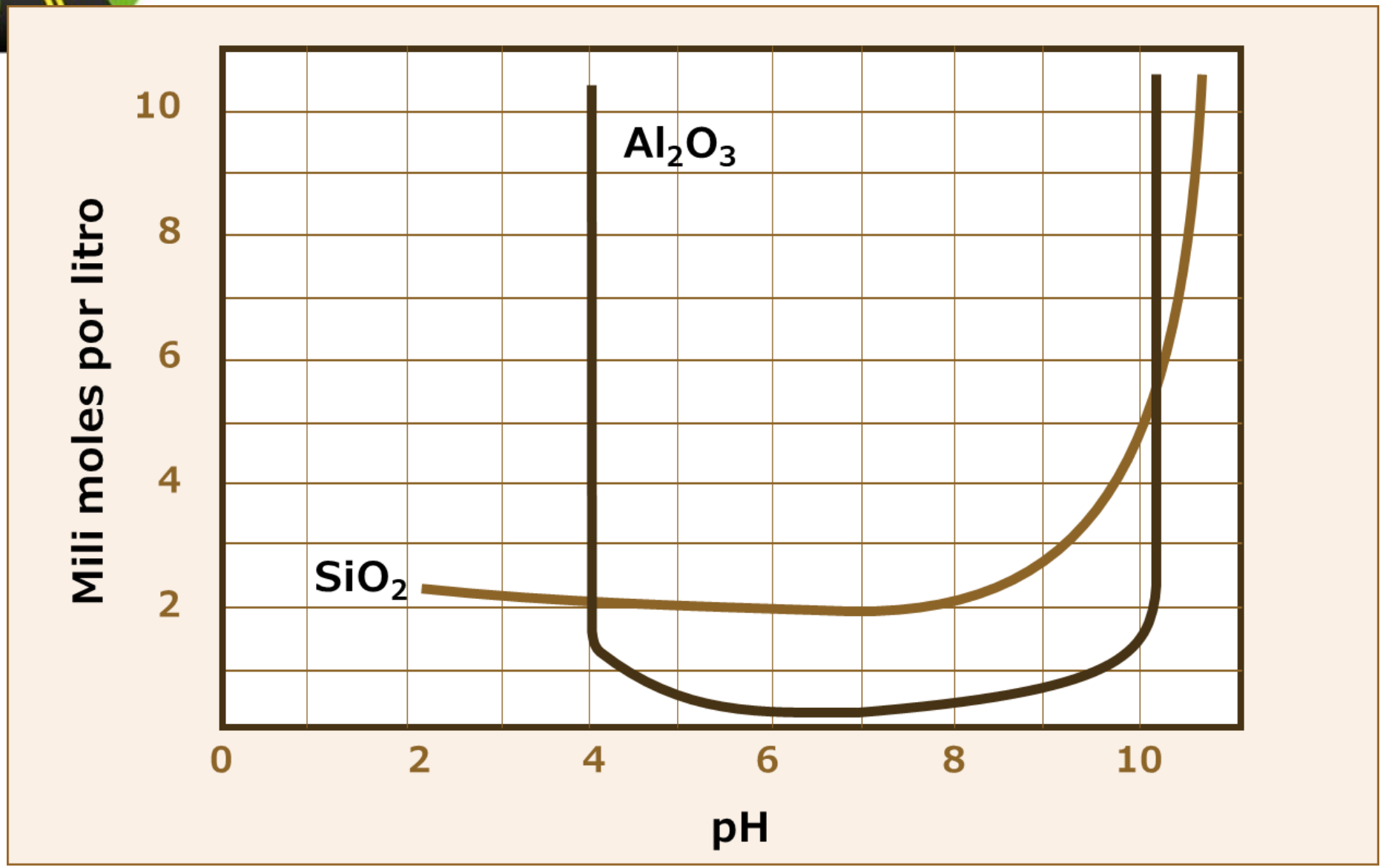




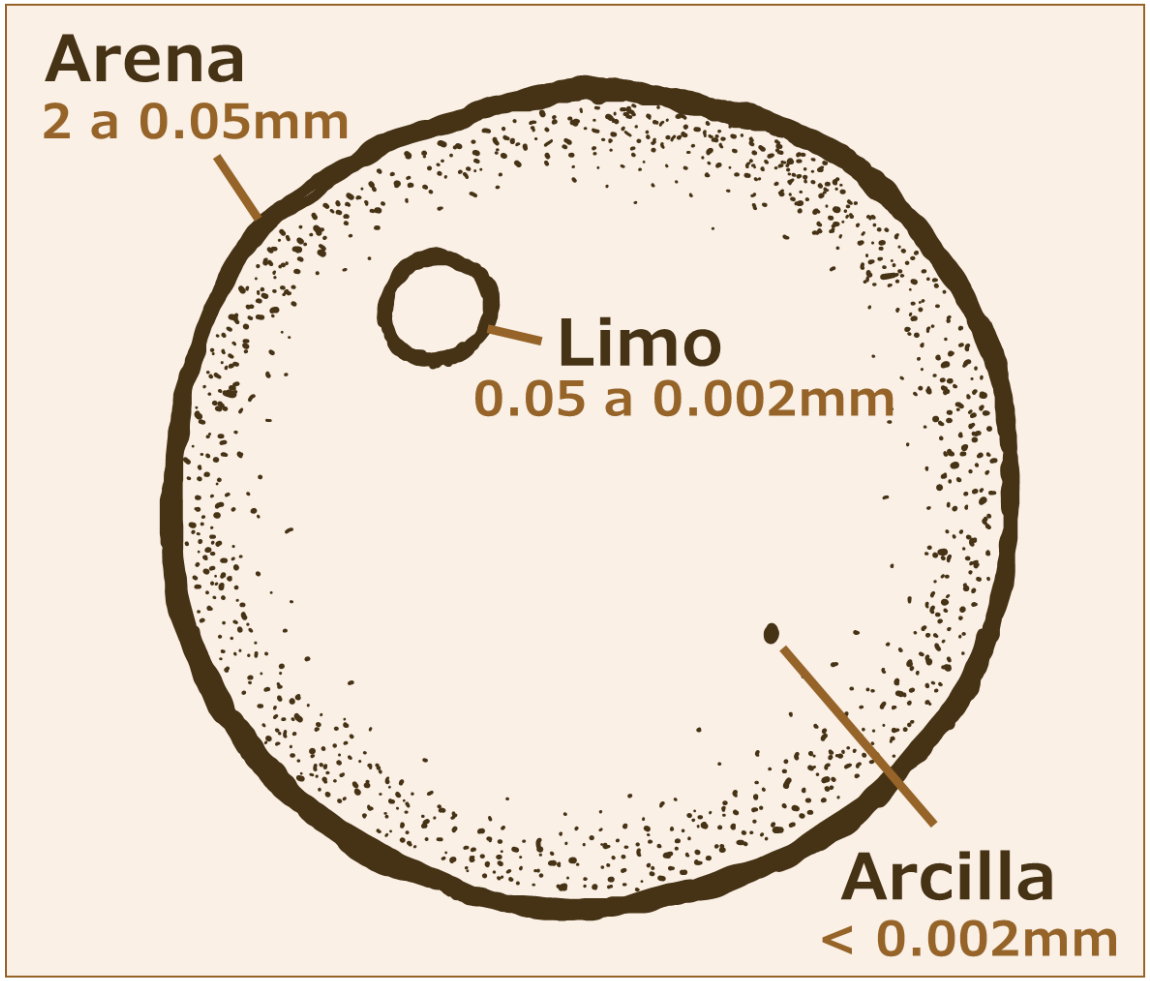
Solubilidad Cal



Solubilidad Si y Al



Efecto Tamaño



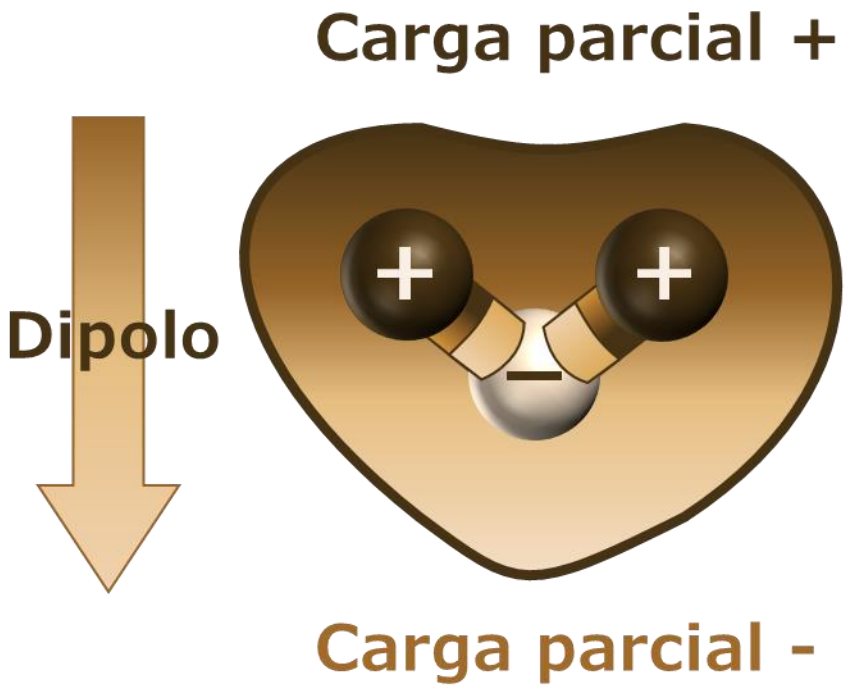
*Los minerales de **arcilla** son los componentes del suelo que **controlan en mayor medida las propiedades físicas** del suelo".*

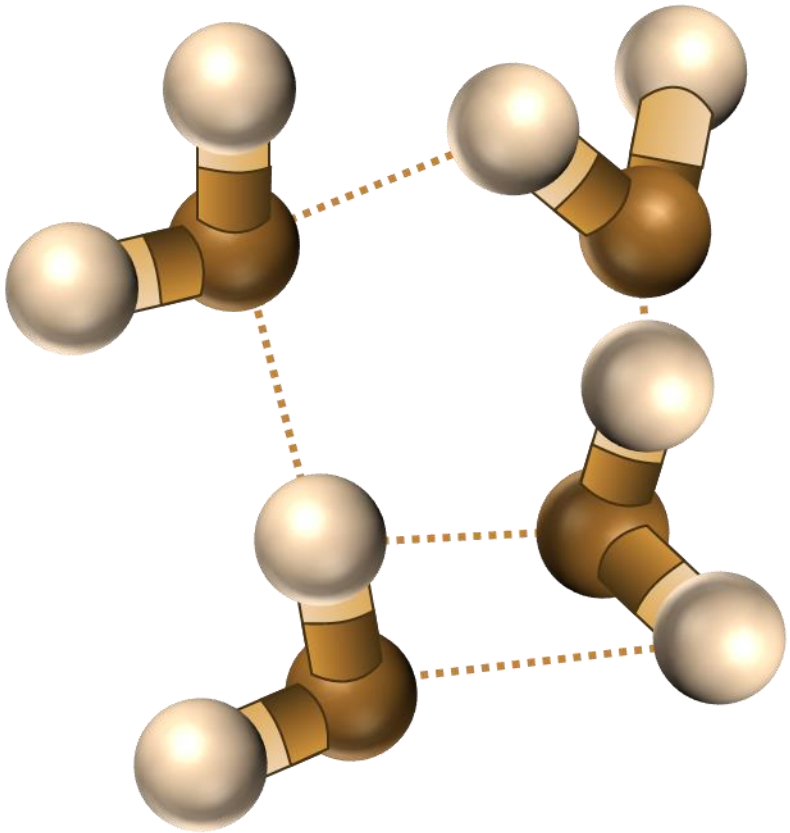
Ralph Early Grim
Father of Clay Mineralogy

"The clay minerals in soils and their significance".

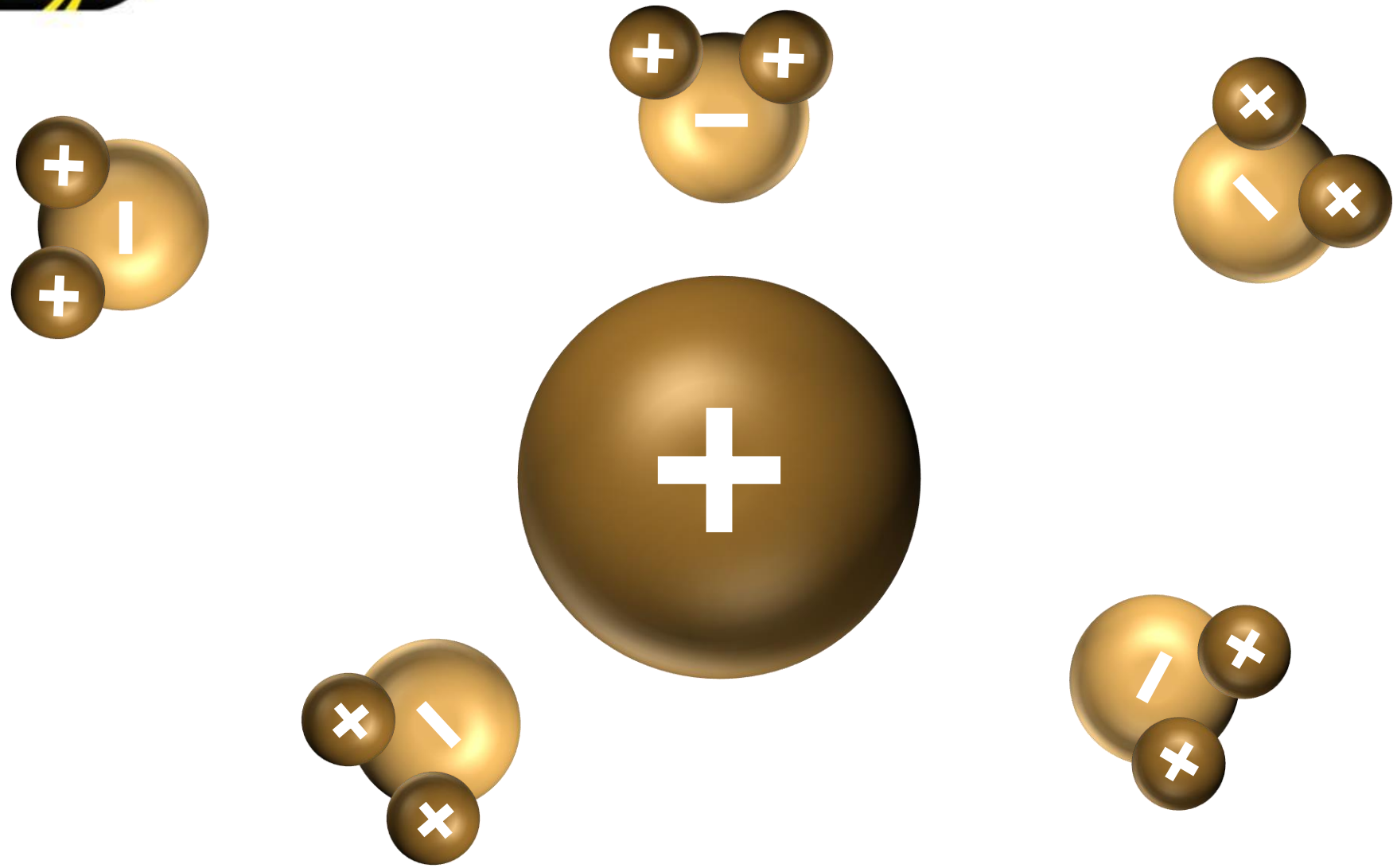
Conference on soil mech. and its application

Carga Eléctrica Agua

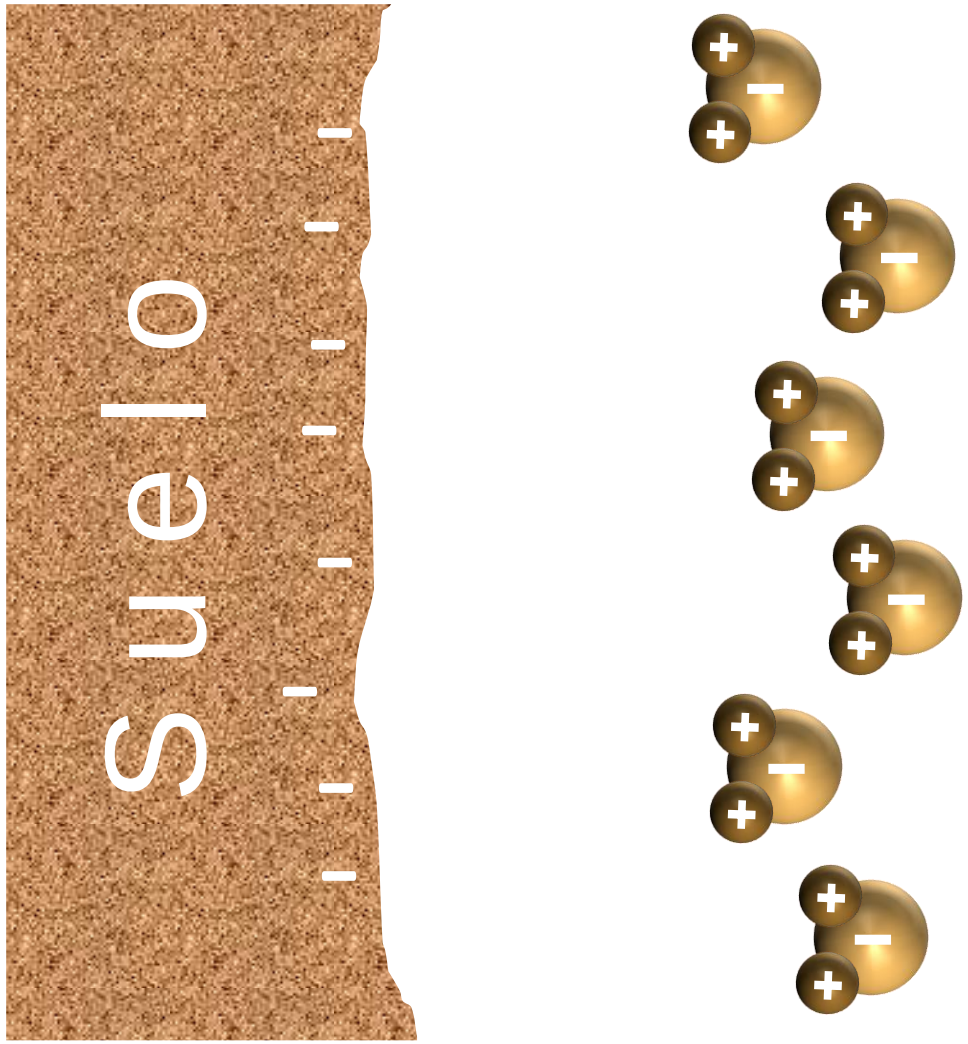




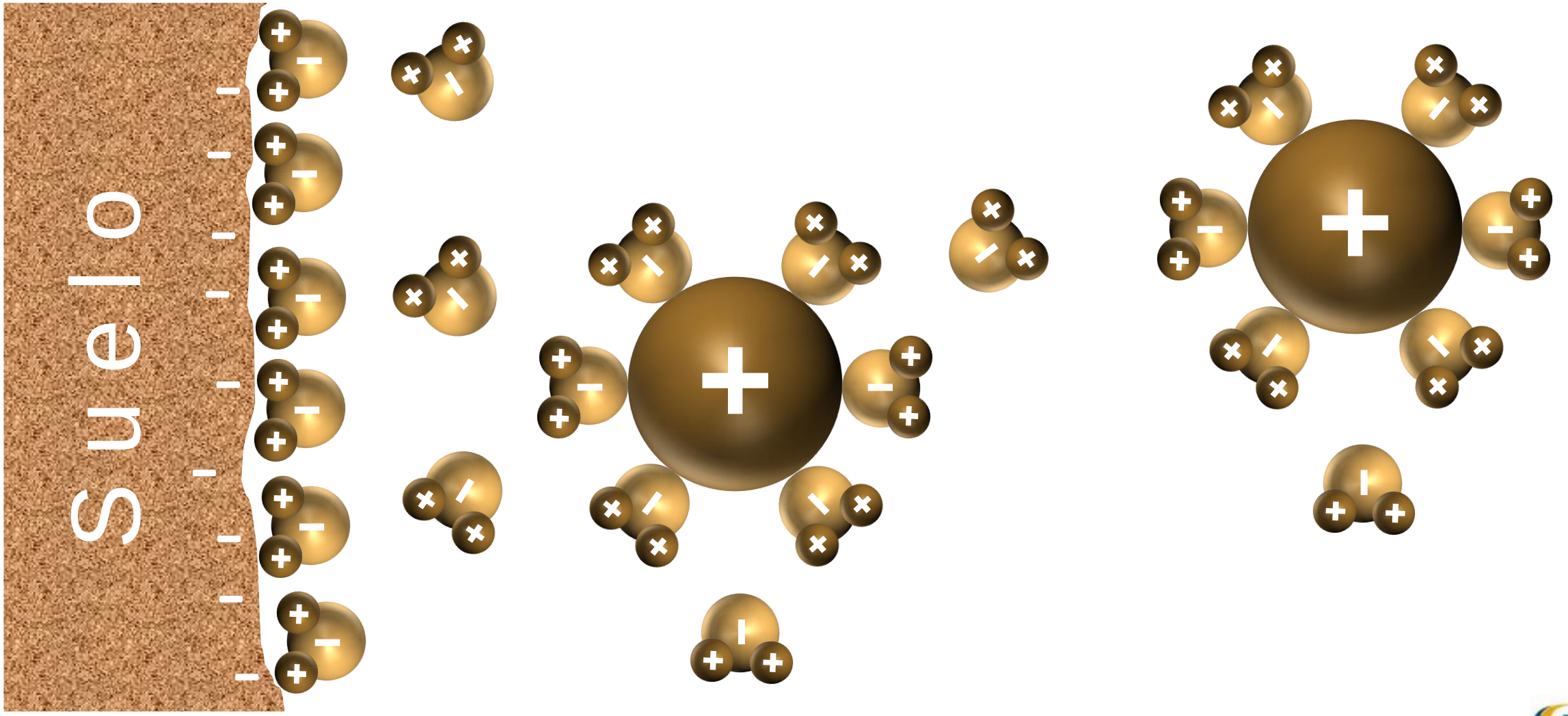
Hidratación Ión



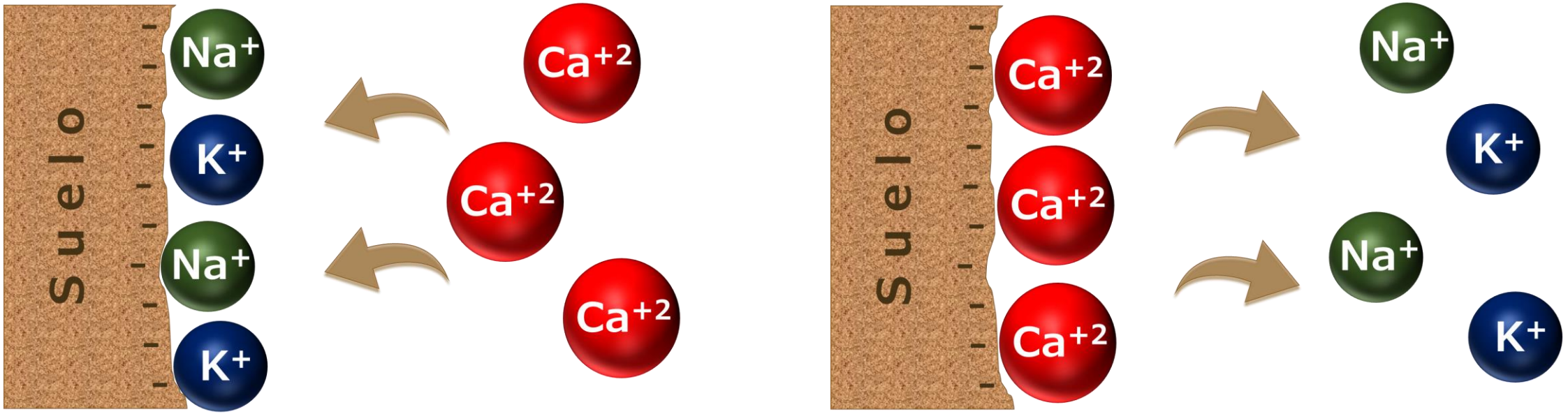
Doble Capa Difusa



Doble Capa Difusa



Intercambio Catiónico

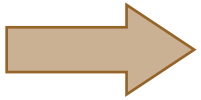


$$Na^{+} < K^{+} << Mg^{++} < Ca^{++}$$

Reacciones Suelo-Cal

OH^-

Ca^{++}



- Reducción fuerzas repulsión
- Disminución capa difusa de agua
- Encapsulamiento partículas suelo
- Fortalecimiento unión entre partículas

Reacciones Puzolánicas

$Ca(OH)_2$

SiO_2

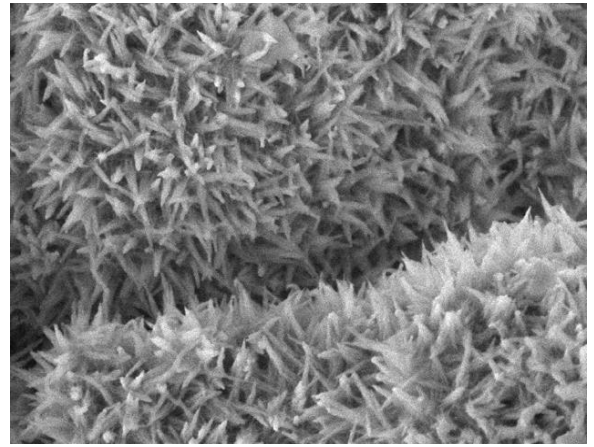
Al_2O_3

Reacción puzolánica

- Silicato Cálcico Hidratado

  $CaO - SiO_2 - H_2O$

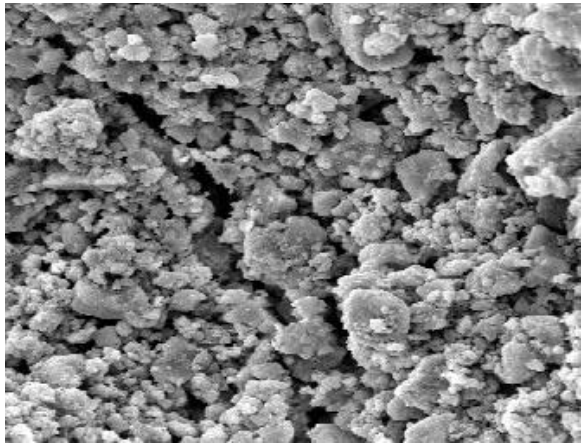
  CSH



- Aluminato Cálcico Hidratado

  $CaO - Al_2O_3 - H_2O$

  CAH



La estabilización de suelos con cal es un cambio químico del suelo que si se realiza correctamente es ***permanente*** *Mallela et al, 2004; Yong y Ouhandi, 2007; Chen y Lin, 2009, Akula, 2020*

Efectos Largo Plazo

Summary

ZACHRY DEPARTMENT OF CIVIL ENGINEERING
TEXAS A&M UNIVERSITY

After ~47 years of lime treatment,

- Engineering characterization showed the treatment to be still effective
  - A decrease in PI, EI, clay, silt and erodibility.
  - An increase in strength and textural modification from clays to silty sands.

ZACHRY DEPARTMENT OF CIVIL ENGINEERING

Evaluating the Long-Term Durability of Lime Treatment in Hydraulic Structures: A Case Study on the Friant-Kern Canal

13-Jan-2020

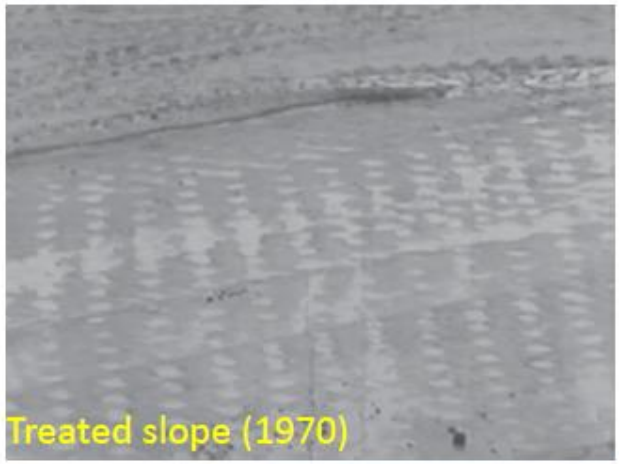
TRB ANNUAL MEETING 2020 — Transportation Research Board
January 12–16, 2020 › Washington, D.C.

Authors:
Pavan Akula[1]
Narain Hariharan[1]
Dallas Little[2]
Didier Lesueur[3]
Gontran Herrier[4]

Efectos Largo Plazo

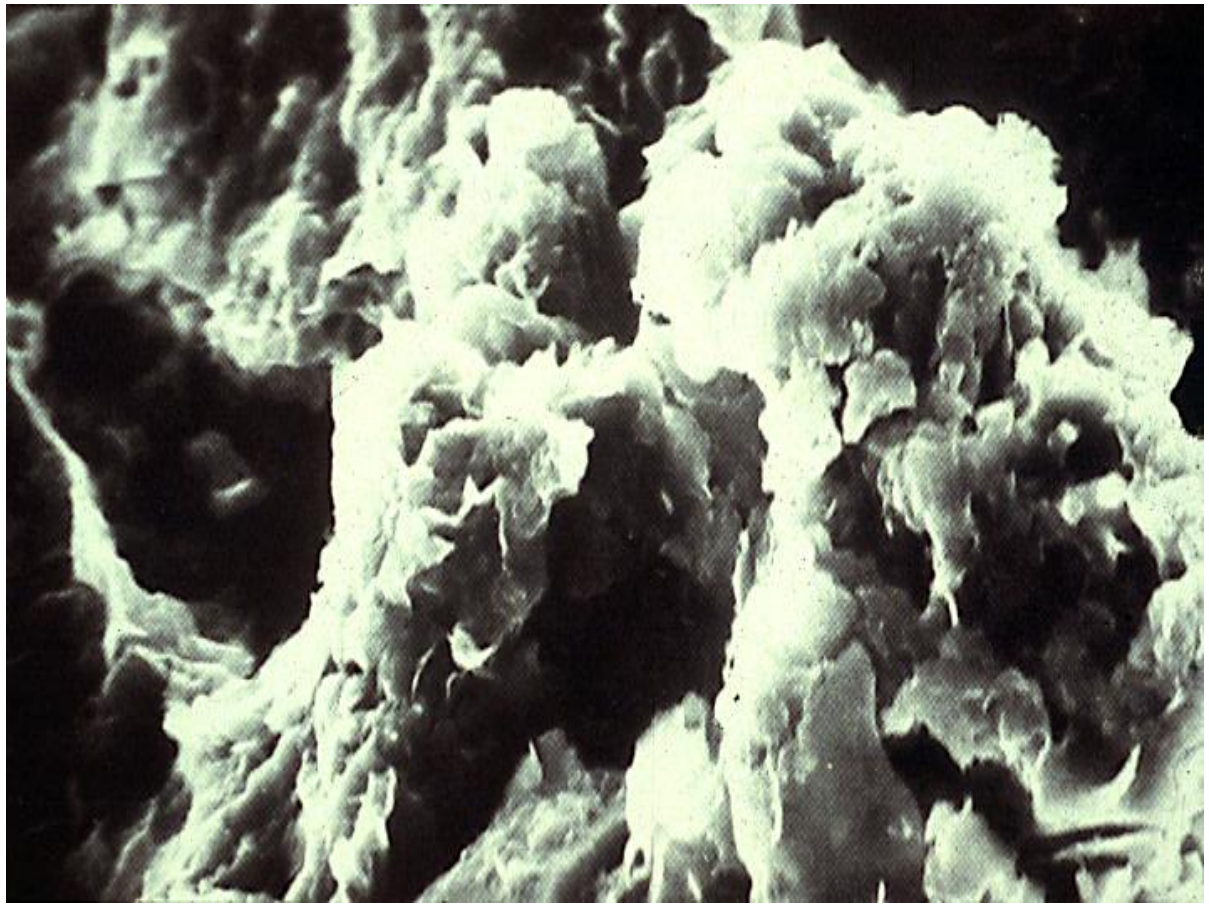
Failed slope

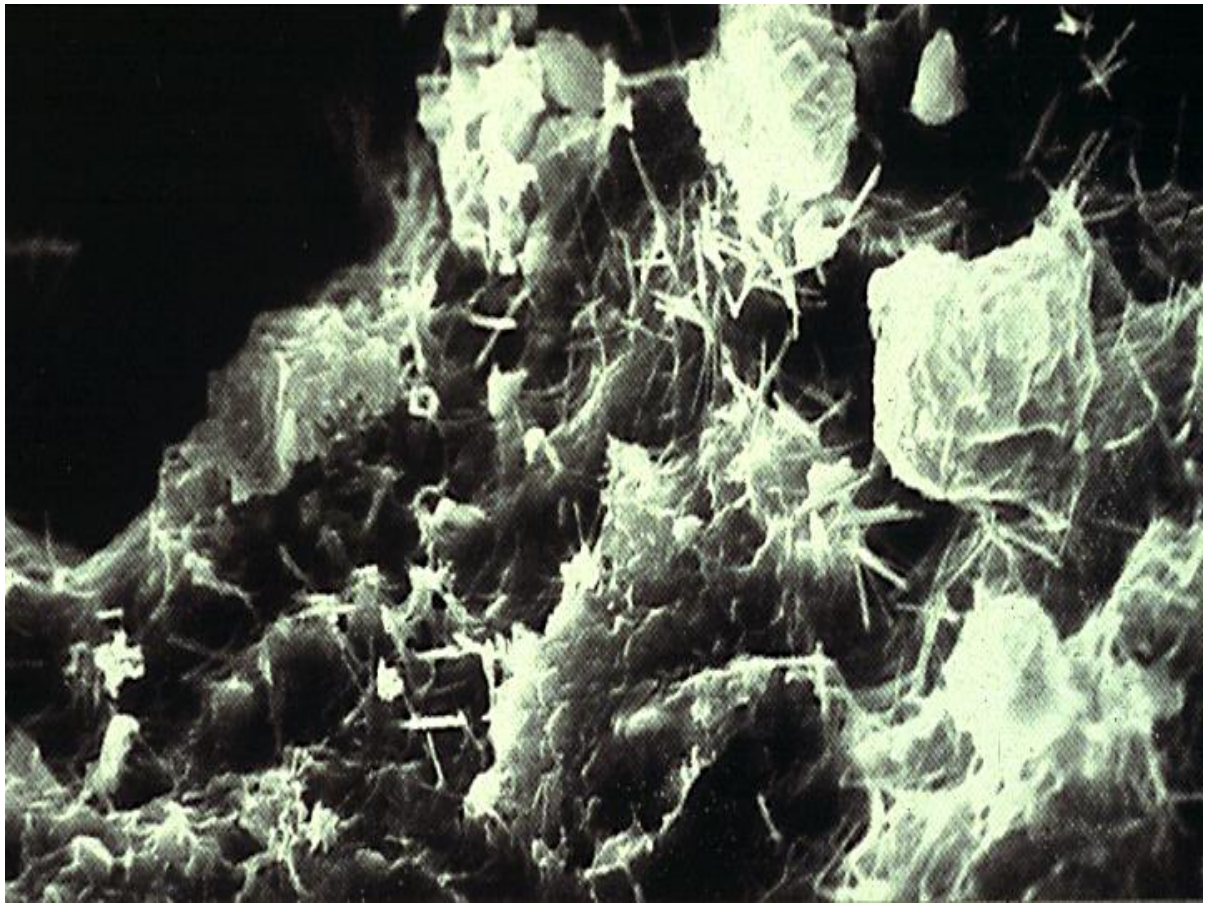
(Source: Herrier et. al. 2012)



(Source: Herrier et. al. 2012)

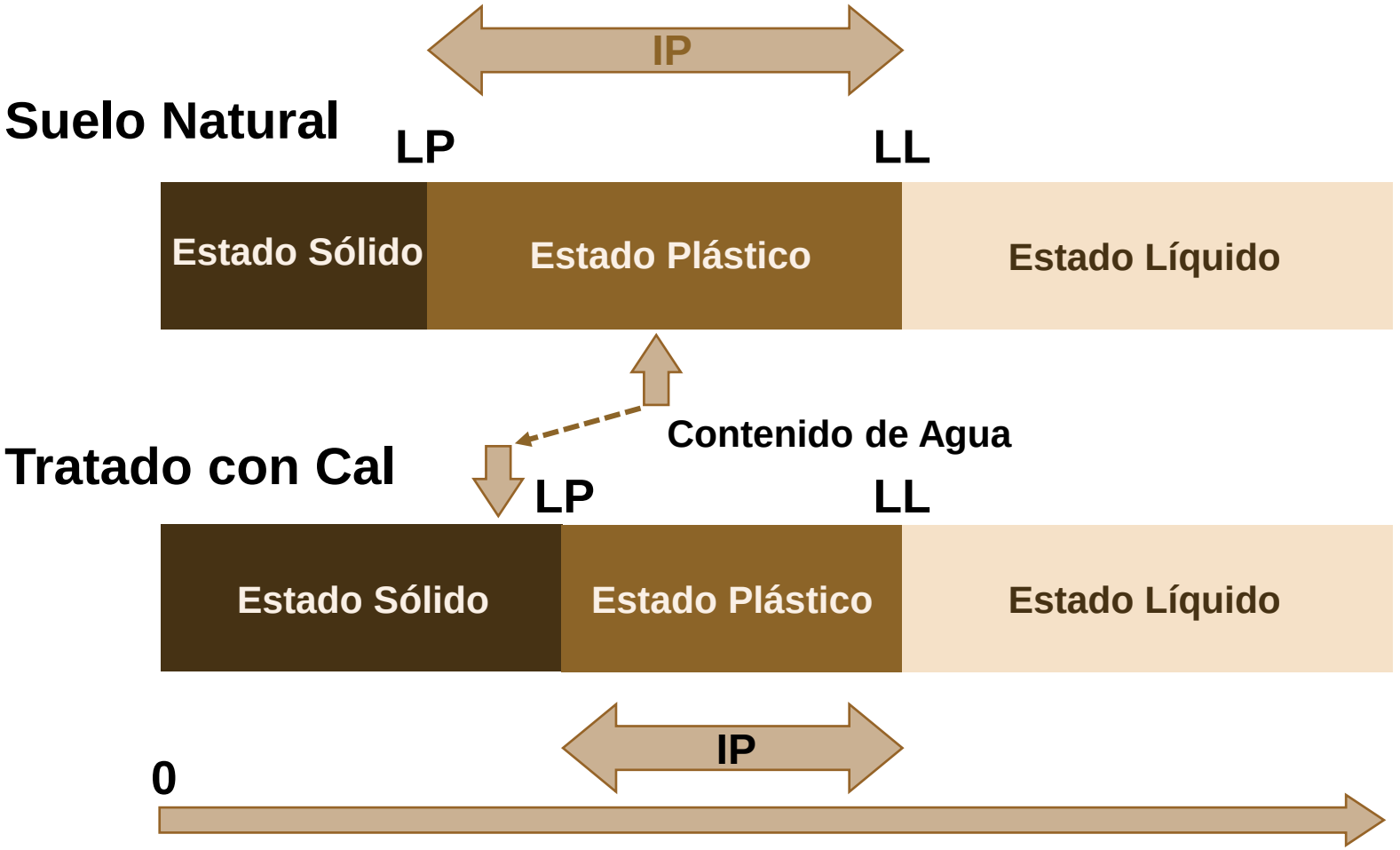
Efectos Largo Plazo

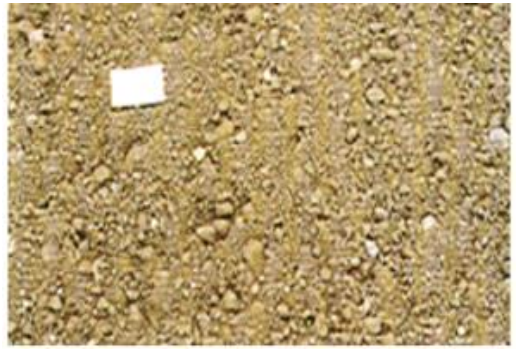




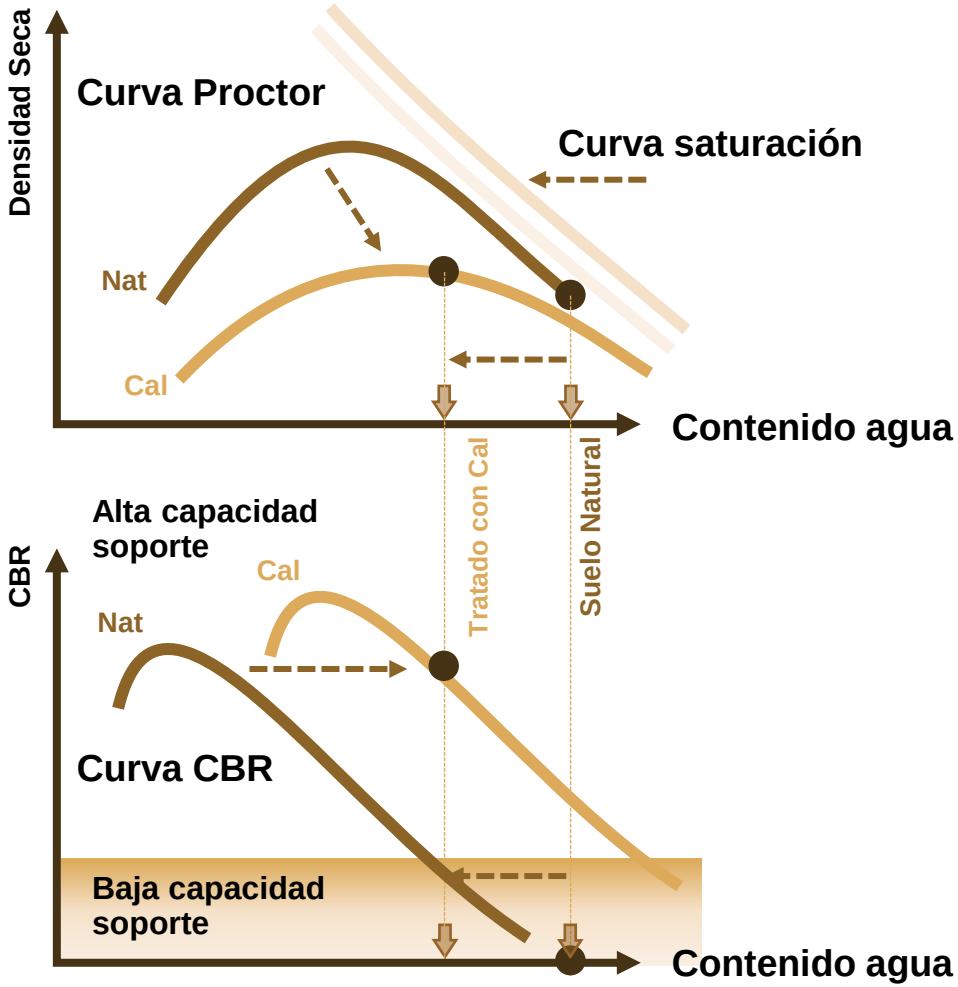
Efectos Largo Plazo

Efectos Corto Plazo





Efectos Corto Plazo



Facilita compactación

Mejora capacidad soporte

Tratamiento Suelo - Cal

Secado

Minimiza demoras por condiciones meteorológicas

Modificado

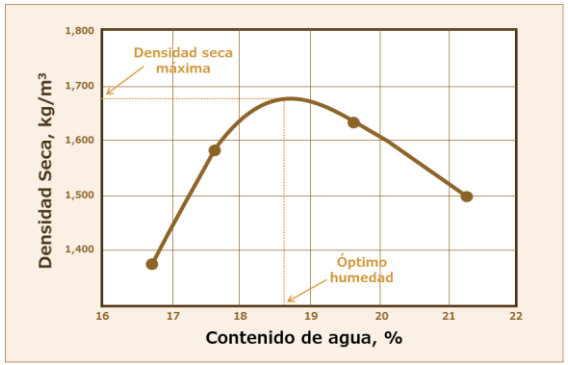
Transforma químicamente suelos arcillosos en material friable, granular, trabajable y compactable

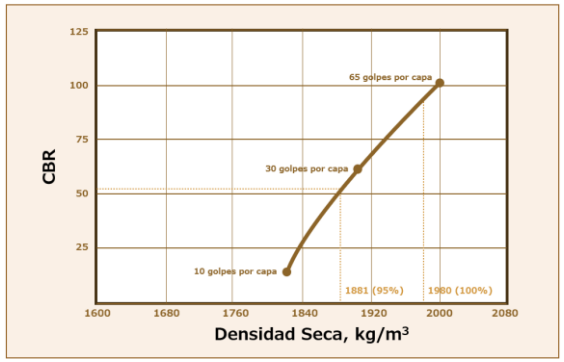
Estabilizado

Cambios químicos de largo plazo en suelos arcillosos inestables creando capas estructurales permanentes flexibles, fuertes e impermeables

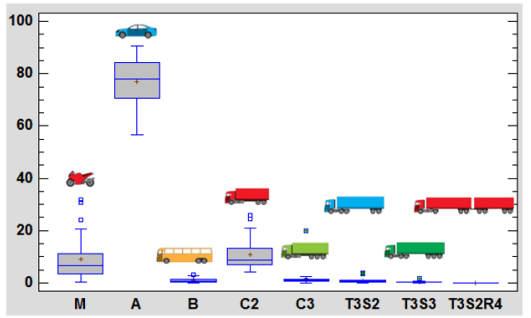
Diseño Mezcla Suelo - Cal

Propiedades Suelo

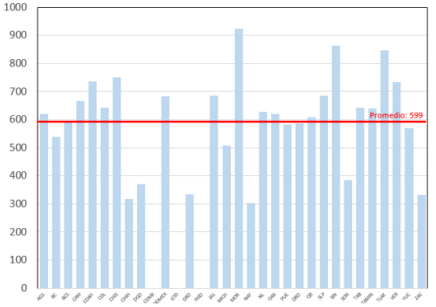


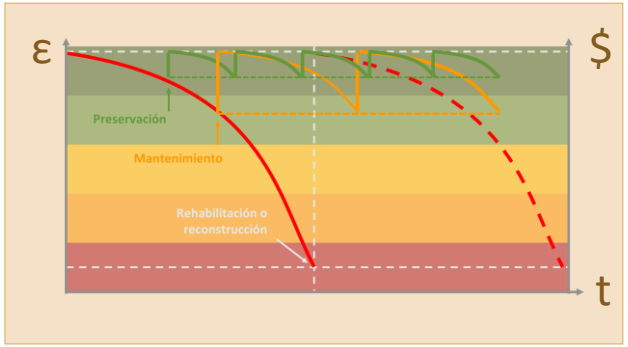


Necesidades Proyecto



TDPA





Diseño Mezcla Suelo - Cal

Necesidad

Propiedades Naturales

Requerimientos Comportamiento

Propiedades Estabilizadas

Diseño

Proyecto

Recursos Económicos

ONNCCE ORGANISMO NACIONAL DE NORMALIZACIÓN Y CERTIFICACIÓN DE LA CONSTRUCCIÓN Y EDIFICACIÓN, S.C.

ASTM INTERNATIONAL

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS AASHTO THE VOICE OF TRANSPORTATION

NIT-SCT NORMATIVA SCT — NORMATIVA PARA LA INFRAESTRUCTURA DEL TRANSPORTE

Normativa

NIT·SCT NORMATIVA SCT — NORMATIVA PARA LA INFRAESTRUCTURA DEL TRANSPORTE

Libros

- Introducción (INT)
- Legislación (LEG)
- Proyecto (PRY)
- Construcción (CTR)
- Conservación (CSV)
- Operación (OPR)
- Control y Aseguramiento de Calidad (CAL)
- Características de los Materiales (CMT)
- Características de los equipos y sistemas de instalación permanente (EIP)
- Métodos de Muestreo y Prueba de Materiales (MMP)

Características de los Materiales (CMT)

Parte
1. Materiales para Terracerías

Título
- 01. Materiales para Terraplén
- 02. Materiales para Subyacente
- 03. Materiales para Subrasante
- 04. Materiales Tratados con Cal para Terracerías

N·CMT·1·04/19 VER DESCARGAR

4. Materiales para Pavimentos

Título
- 01. Materiales para Revestimiento
- 02. Materiales para Subbases y Bases
- 03. Materiales para Estabilizaciones

Capítulo
- 001. Cal para Estabilizaciones

N·CMT·4·03·001/17 VER DESCARGAR

Construcción (CTR)

Parte
1. Conceptos de Obra

Título
- 01. Terracerías
- 02. Estructuras
- 03. Drenaje y Subdrenaje
- 04. Pavimentos

Capítulo
- 001. Revestimientos Estabilizados y no Estabilizados. (Nombre anterior: Revestimientos)
- 002. Subbases y Bases
- 003. Capas Estabilizadas

N·CTR·CAR·1·04·003/14 VER DESCARGAR

Métodos de Muestreo y Prueba de Materiales (MMP)

Parte
1. Suelos y Materiales para Terracerías
2. Materiales para Estructuras
4. Materiales para pavimentos

Título
- 01. Materiales para Revestimiento, Subbase y Base
- 02. Cal para Estabilizaciones

Capítulo
- 001. Muestreo de Cal para Estabilizaciones
- 003. Características Granulométricas de la Cal
- 005. Contenido de Óxido de Calcio (CaO) y Óxido de Magnesio (MgO) en la Cal Viva
- 006. Contenido de Hidróxido de Calcio Ca(OH)2 en la Cal Hidratada
- 011. Determinación del Potencial de Hidrógeno (pH) en Materiales Tratados con Cal
- 012. Muestreo de Materiales Tratados con Cal

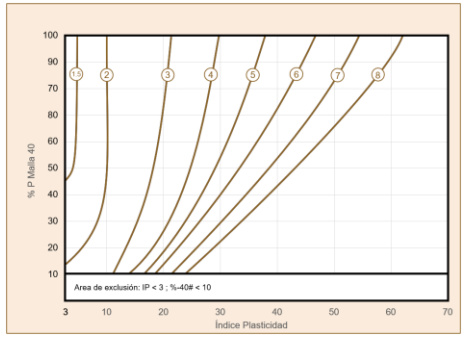
SCT Secretaría de Comunicaciones y Transportes — IMT Instituto Mexicano del Transporte

https://normas.imt.mx/

Diseño Mezcla Suelo - Cal

Contenido de Cal

CONTENIDO DE CAL

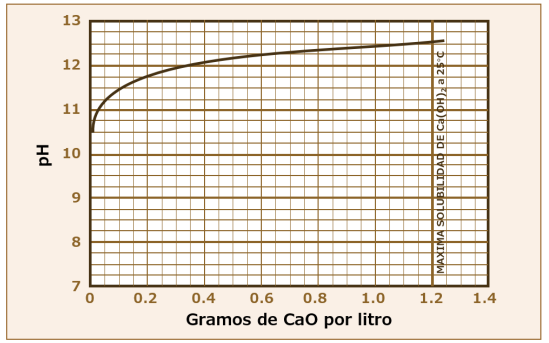


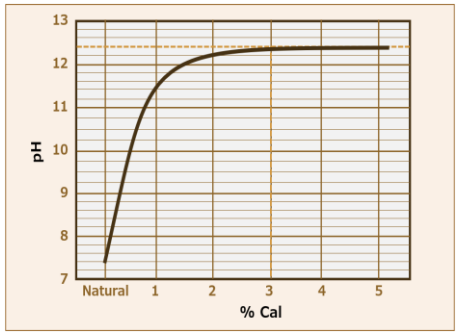
AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO
THE VOICE OF TRANSPORTATION

Standard Method of Test for

Determination of the Strength of Soil-Lime Mixtures

AASHTO Designation: T 220-66 (2013)

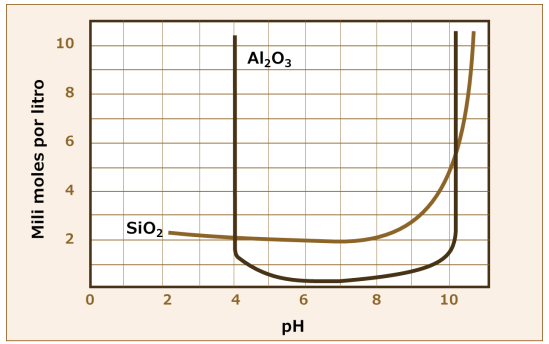




ASTM INTERNATIONAL

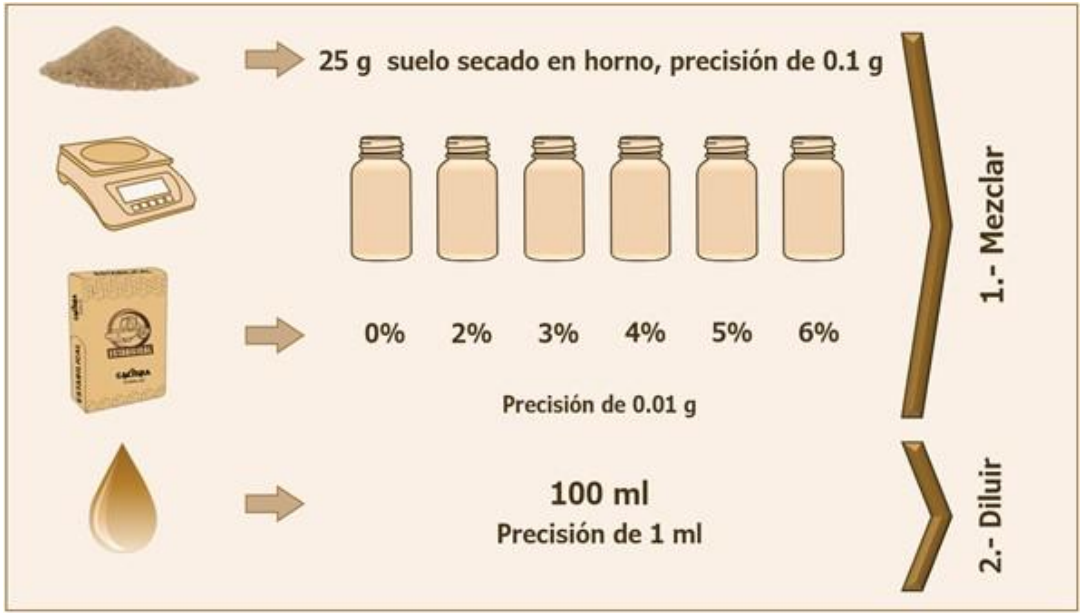
Designation: D6276 – 19

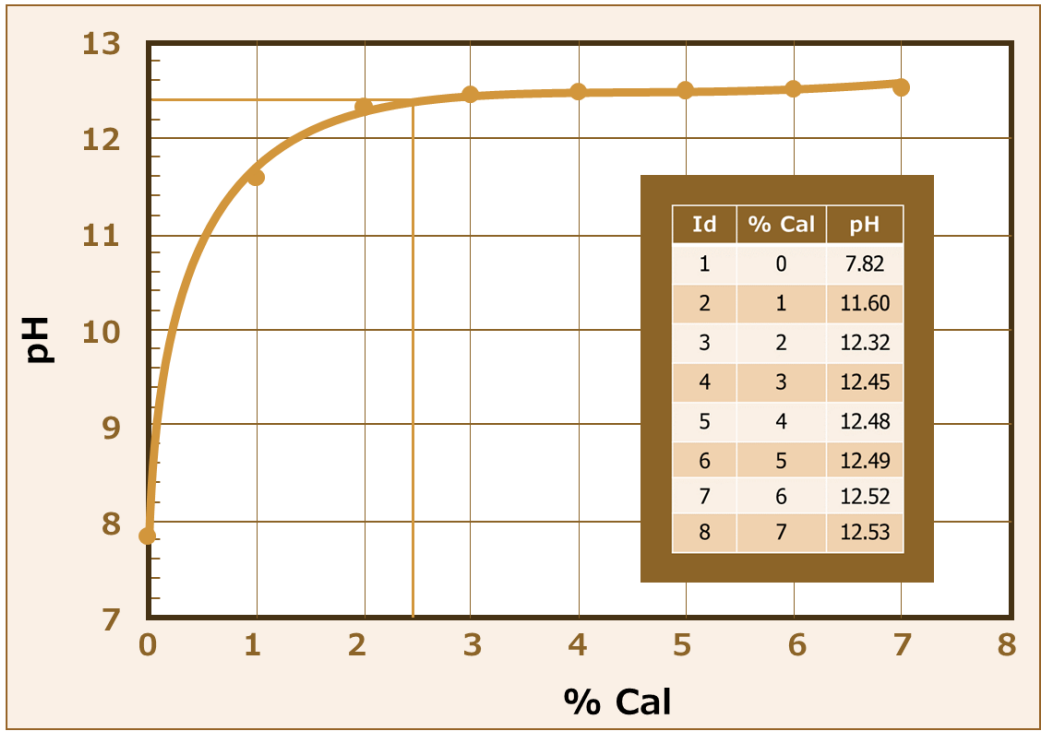
Standard Test Method for Using pH to Estimate the Soil-Lime Proportion Requirement for Soil Stabilization[1]



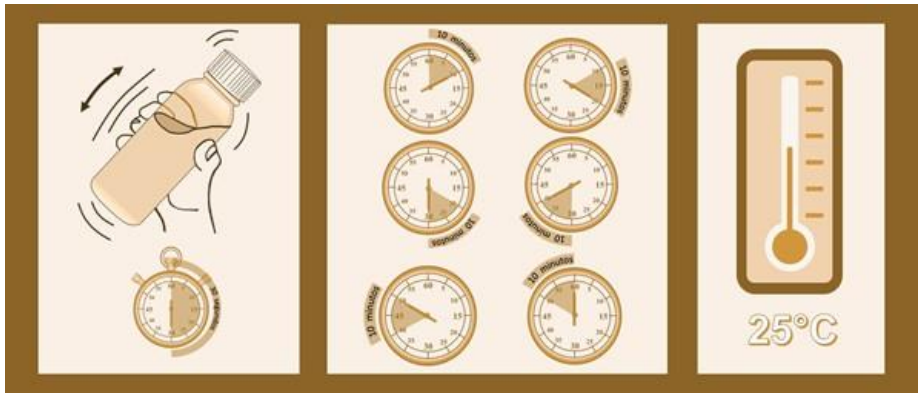
- Condiciones propicias
- Se satisfacen las reacciones

Eades & Grim

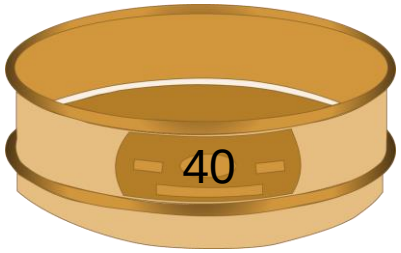


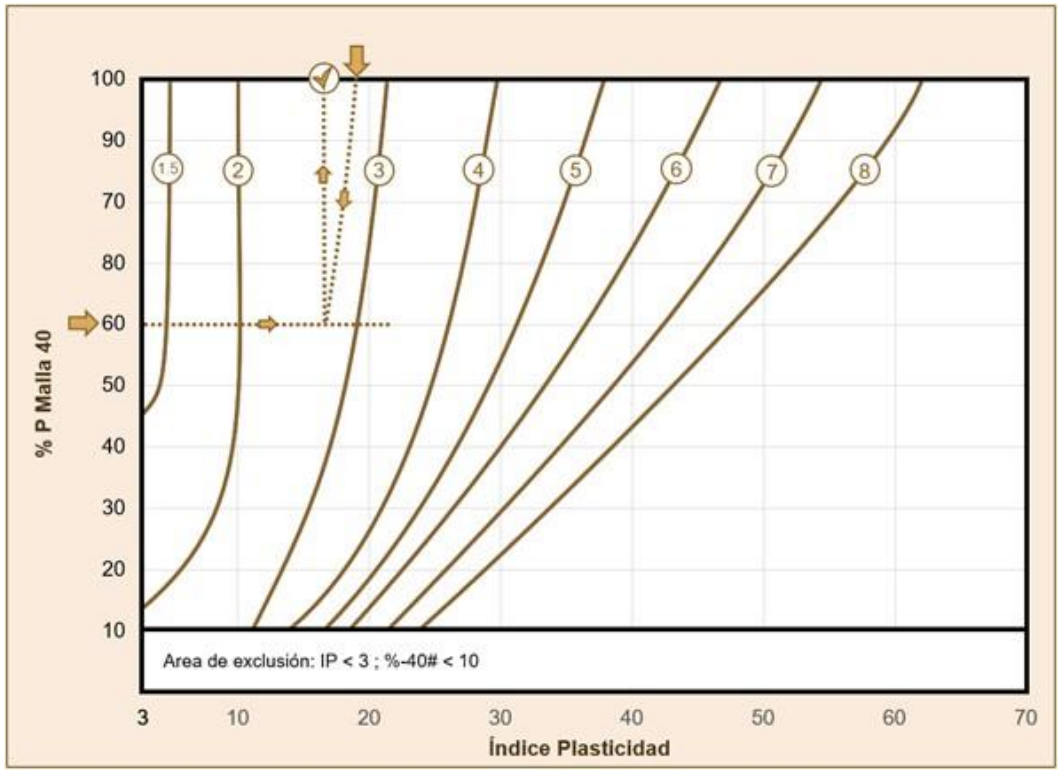


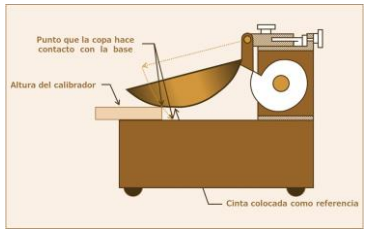
Id	% Cal	pH
1	0	7.82
2	1	11.60
3	2	12.32
4	3	12.45
5	4	12.48
6	5	12.49
7	6	12.52
8	7	12.53

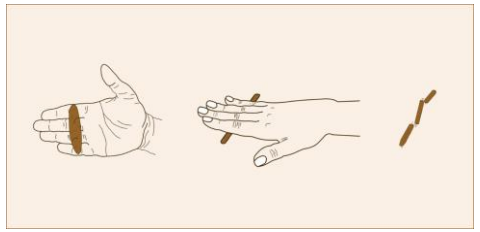


Método Gráfico









CONTENIDO DE CAL → **PRUEBAS LABORATORIO**

→ Asegurar que el suelo tratado, cumple con las ***necesidades de ingeniería***

- **UCS**
- **CBR**
- **Resiliente Mr**
- **Exp, Compr, IP**

→

- Capacidad de soporte
- Susceptibilidad al agua
- Respuesta a cargas repetidas

Curado Acelerado

PRUEBAS LABORATORIO ← CURADO

- Química
- Curado
- Desarrollo reacciones

VDOT Virginia Department of Transportation

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
AASHTO THE VOICE OF TRANSPORTATION

CALIDRA SIEMPRE AHÍ

40°C

DÍAS 7

Condiciones de curado

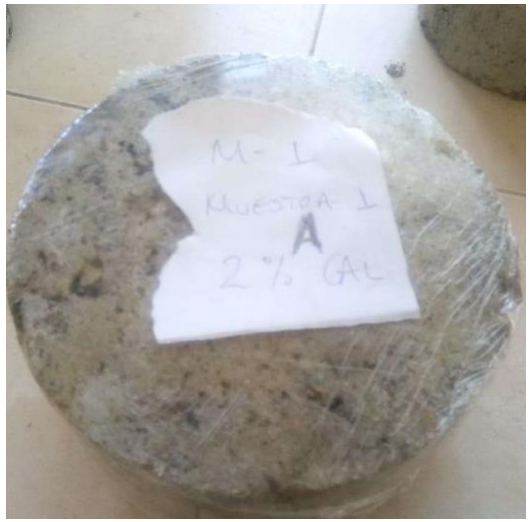
PRUEBAS LABORATORIO ← CURADO

Designation: D5102 – 09

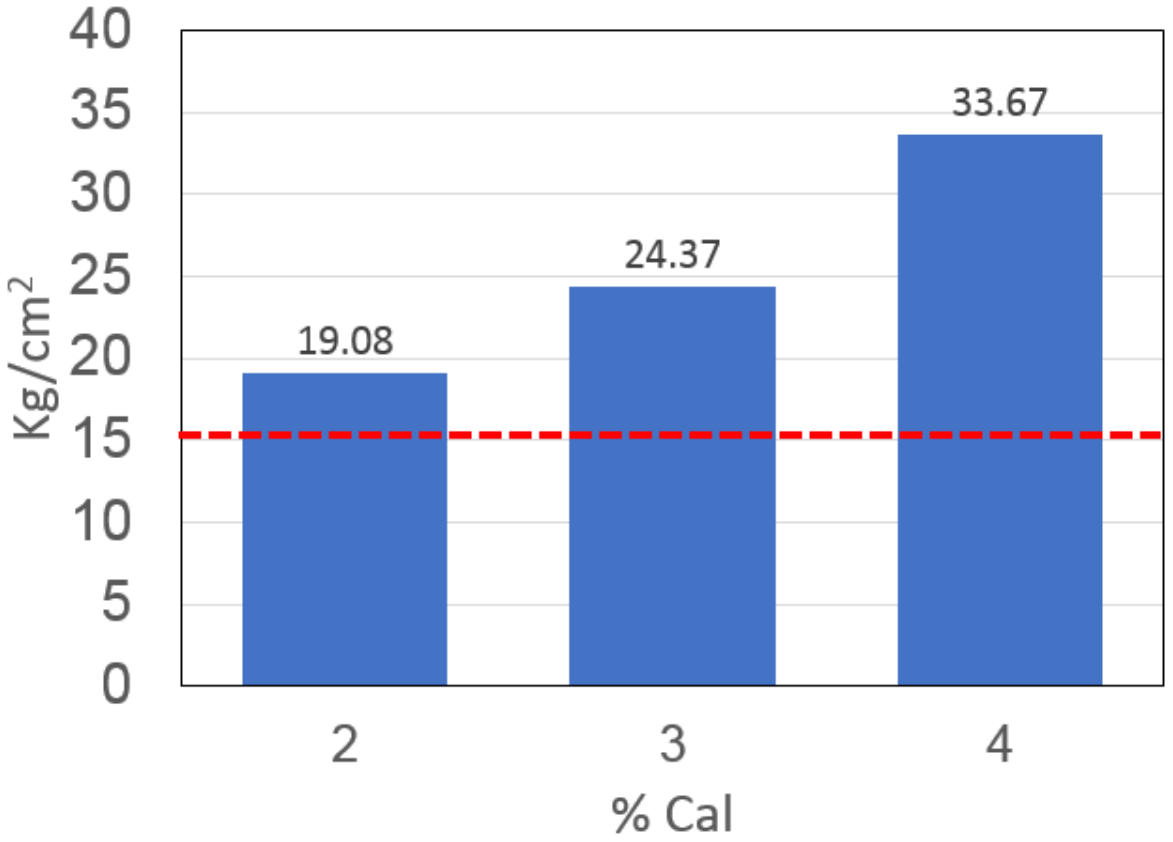
Standard Test Methods for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures[1]

NOTE 7—When accelerated curing conditions are necessary to expedite the curing process for simulating long-term field conditions, curing temperatures in excess of 49°C (120°F) should be avoided. Research indicates that a temperature of 40°C (105°F) at various curing times is appropriate for accelerated curing without introducing pozzolanic reactive products that significantly differ from those expected during field curing.[3]

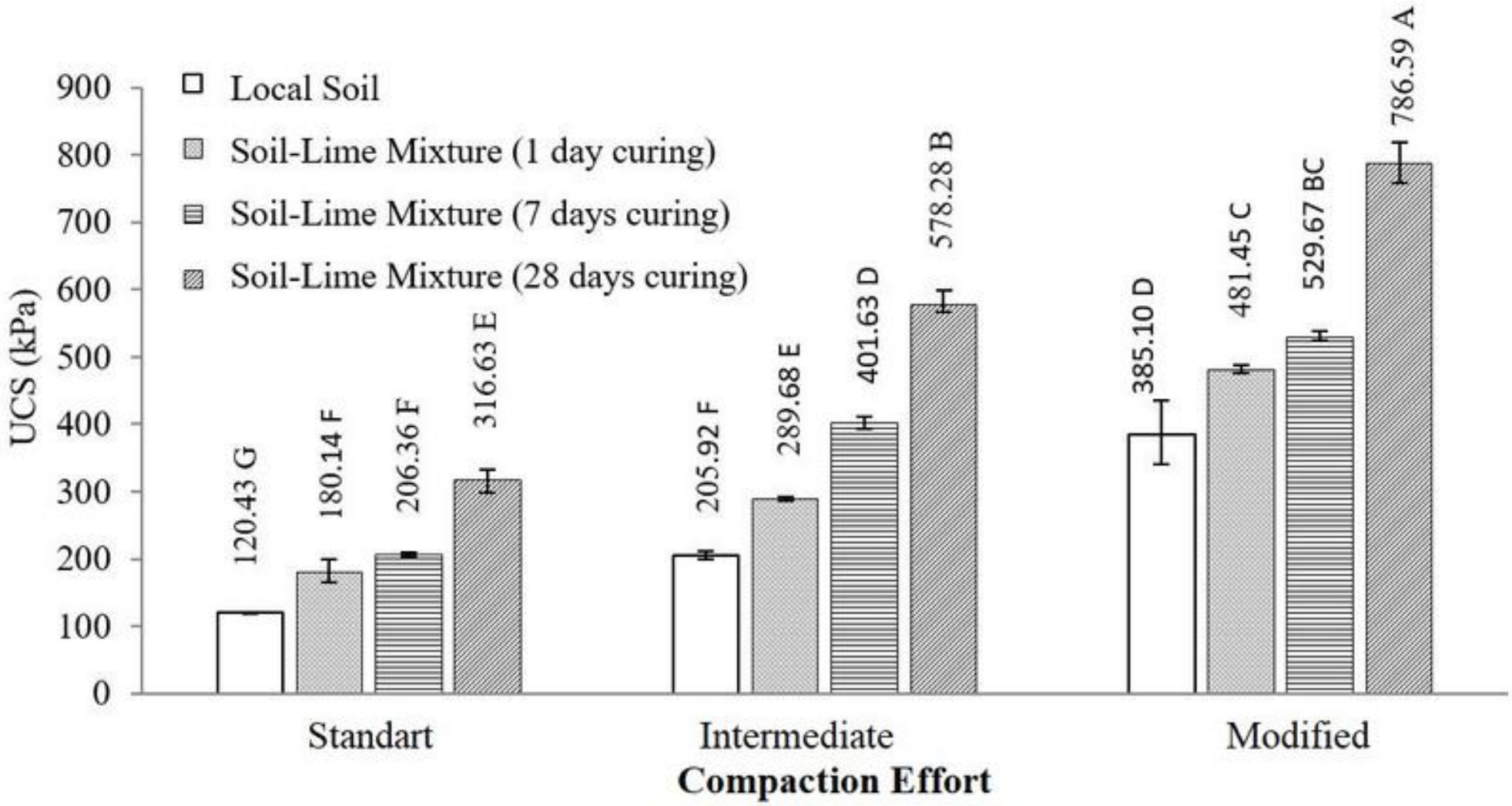
UCS



Concalab.co



UCS


Local Soil
Soil-Lime Mixture (1 day curing)
Soil-Lime Mixture (7 days curing)
Soil-Lime Mixture (28 days curing)
UCS (kPa)
900
800
700
600
500
400
300
200
100
0
120.43 G
180.14 F
206.36 F
316.63 E
205.92 F
289.68 E
401.63 D
578.28 B
385.10 D
481.45 C
529.67 BC
786.59 A
Standart
Intermediate
Modified
Compaction Effort

California Bearing Ratio

STATE OF THE ART REPORT 5

Reactions, Properties, Design, and Construction

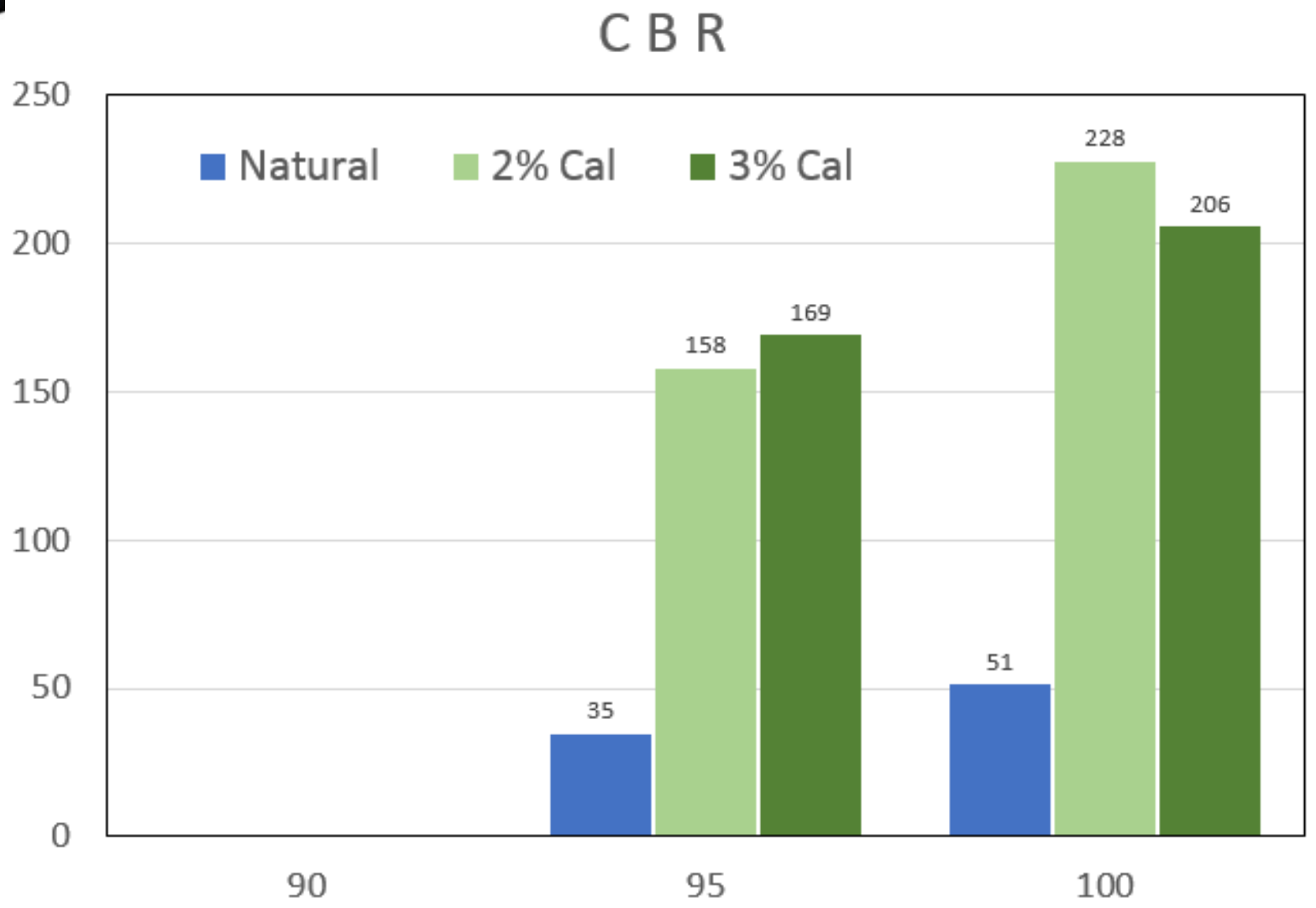
TRANSPORTATION RESEARCH BOARD
National Research Council

STRENGTH

The strength of lime-soil mixtures can be evaluated in many ways. The unconfined compression test is the most popular procedure, and the stabilometer and CBR tests are used to a lesser extent. These methods, however, are definitely not the most applicable or desirable. Only limited data are available concerning the tensile properties of lime-soil mixtures (*27–30*), and additional effort is needed to evaluate the tensile characteristics of lime-treated materials.

It should be emphasized that the strength of a soil-lime mixture is dependent on many variables and that it varies substantially (*18,20*). Soil type, lime type, lime percentage, curing conditions of time and temperature, and the interactions between these variables are the major factors influencing strength (*27,28,30*).

A distinction must be made with respect to curing. An immediate beneficial strength effect occurs with the addition of lime as a result of the immediate reactions (cation exchange, flocculation, and agglomeration). The long-term strength gain is primarily related to the pozzolanic reaction. Therefore, it is necessary to divide the discussion between cured and uncured strength.


C B R
250
200
150
100
50
0
Natural
2% Cal
3% Cal
35
158
169
51
228
206
90
95
100

Designation: D1883 – 16

Standard Test Method for
California Bearing Ratio (CBR) of Laboratory-Compacted Soils[1]

5. Significance and Use

5.4 The criteria for test specimen preparation of self-cementing (and other) materials which gain strength with time must be based on a geotechnical engineering evaluation. As directed by the client, self-cementing materials shall be properly cured until bearing ratios representing long term service conditions can be measured.

Standard Method of Test for

The California Bearing Ratio

AASHTO Designation: T 193-13 (2017)

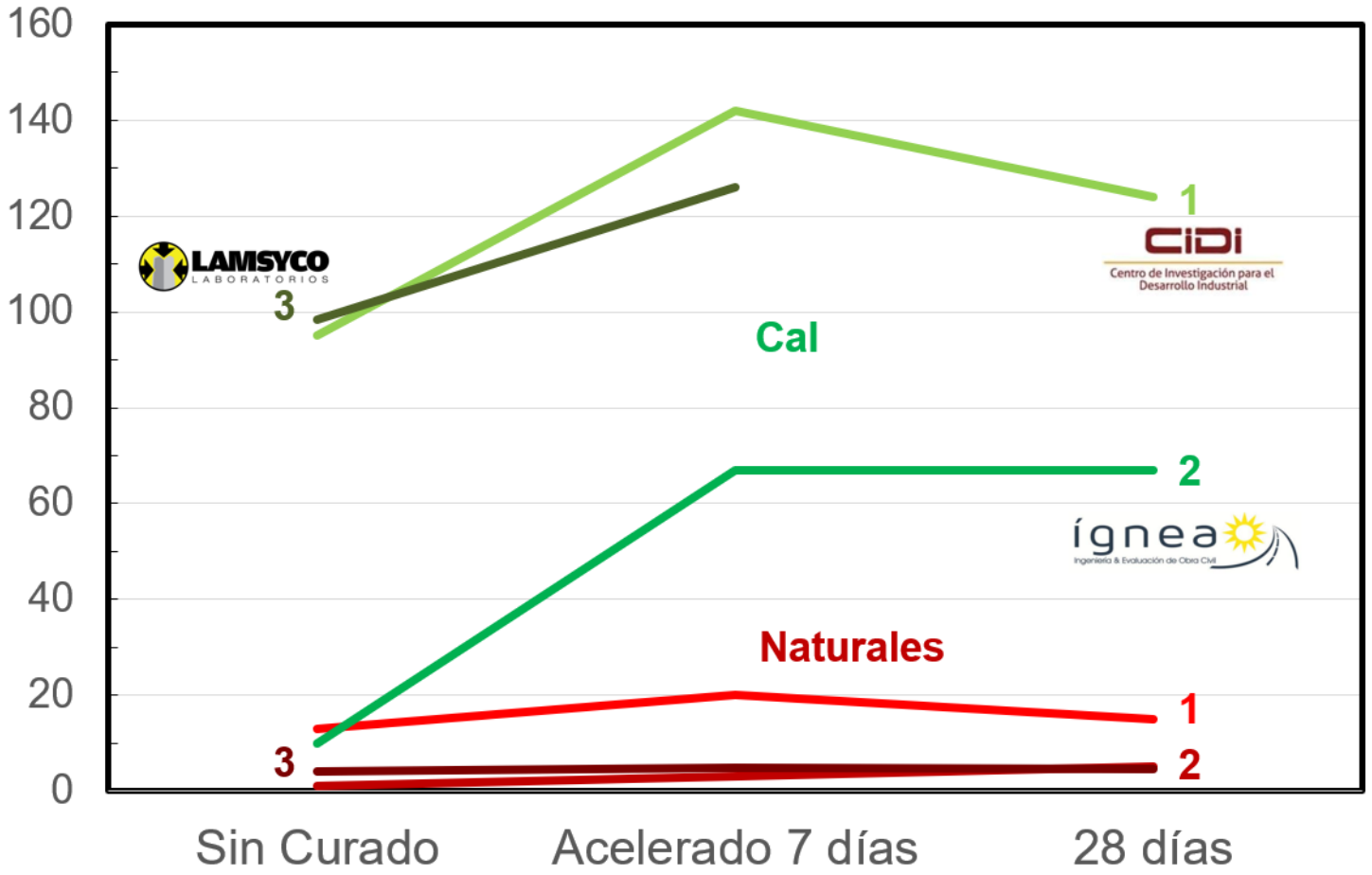
Technical Section: 1a, Soil and Unbound Recycled Materials

Release: Group 3 (August 2017)

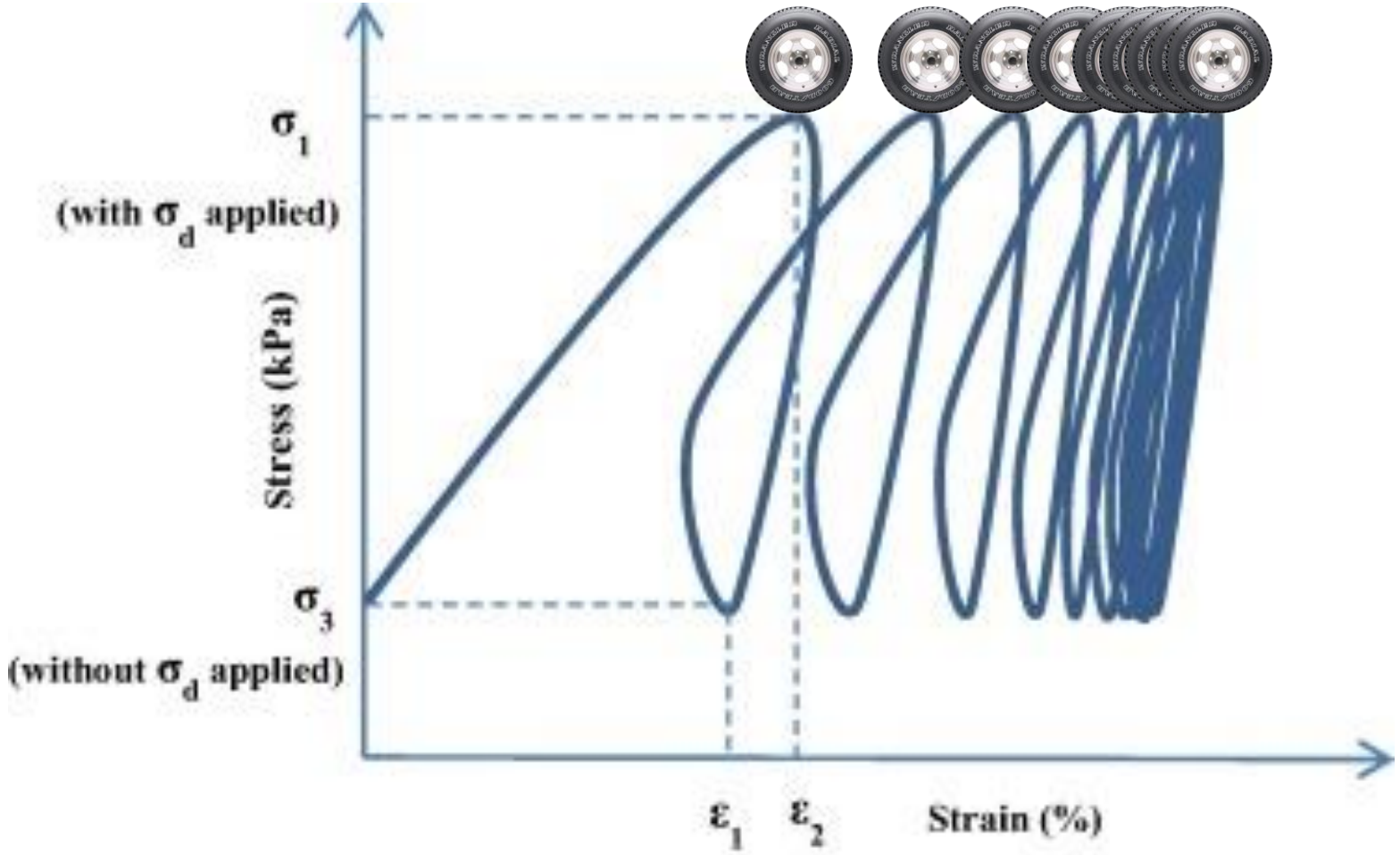
AASHTO
American Association of State Highway and Transportation Officials
444 North Capitol Street N.W., Suite 249
Washington, D.C. 20001

The criteria for test specimen preparation of self-cementing (and other) materials that gain strength with time must be based on a geotechnical engineering evaluation. As directed by the engineer, self-cementing materials shall be properly cured until bearing ratios representing long-term service conditions can be measured.

CBR @Curado


160
140
120
100
80
60
40
20
0
LAMSYCO LABORATORIOS
3
1
CIDI
Centro de Investigación para el Desarrollo Industrial
Cal
2
ígnea
Ingeniería & Evaluación de Obra Civil
Naturales
1
3
2
Sin Curado
Acelerado 7 días
28 días

Módulo Resiliente



	ID	S – S_{opt}, %	M_R, MPa	a_{MSC}[1]
NAT	TLV-1	0	82.7	0.04
	TLV-2	2	55.2	0.00
	TLV-3	Saturado, 12	10.3	0.00
	TLV-4	+2 (sat), 15	6.9	0.00
CAL	MSC (1)	0	207	0.14
	MSC (2)	2	220.6	0.14
	MSC (3)	Saturado, 10	193.1	0.13
	MSC (4)	Saturado, 12	179.3	0.13

$$log_{10}(W_{18}) = Z_R \cdot S_0 + 9.36 \cdot log_{10}(\boldsymbol{SN} + 1) - 0.20 + \frac{log_{10}\left(\frac{\Delta PSI}{4.2 - 1.5}\right)}{0.40 + \frac{1094}{(\boldsymbol{SN} + 1)^{5.19}}} + 2.32 \cdot log_{10}(\boldsymbol{M_R}) - 8.07$$

$$SN = a_1 \cdot D_1 + a_2 \cdot m_2 \cdot D_2 + a_3 \cdot m_3 \cdot D_3$$

[1] $\boldsymbol{a}_{MSC} = 0.249 \log E_{MSC} - 0.977$

Pavement ID	UCCS, MPa	M_r, lab, MPa	M_r, FWD, MPa	CBR
US 61 N	2.0	350	427	200
US 82E	1.9	200	2,400	150
US 82W	1.6	270	1,350	47
US 45N	1.8	371	1,200	133


SUELO NATURAL
SUELO-ESTABILICAL

Resiliencia Eventos Extremos

Resiliencia Eventos Extremos

4th Int. Conf. on Transportation Geotechnics (ICTG), May 24-27, 2021

Improving mechanical properties of two Mexican soils by utilizing calcium oxide'

By:

Natalia Pérez 1(1),Javier Castañeda(2), Paul Garnica(1), Mario Peña(2)

(1) Mexican Transportation Institute, nperez@imt.mx, paulgarnica@ciid.com.mx

(2) Calidra, fcastaneda@calidra.com.mx

INSTITUTO MEXICANO DEL TRANSPORTE

CALIDRA SIEMPRE AHÍ

ICTG 2021 VIRTUAL

INSTITUTO MEXICANO DEL TRANSPORTE

UNIVERSITY OF SASKATCHEWAN

CALIDRA SIEMPRE AHÍ

Effect of Moisture Changes on Mechanical Properties of a Quicklime - Treated Soil containing Organic Matter

Natalia Perez-Garcia, Mexican Transportation Institute

Paul Garnica-Anguas, Mexican Transportation Institute

Delwyn Fredlund, University of Saskatchewan

Francisco Castañeda, Calidra

100 YEARS TRB MOVING IDEAS: ADVANCING SOCIETY

4° ICGT 2021

	Monterrey	Guadalajara
UCS	SW	MH
Liquid limit	34	64
Plasticity index	16	34
Gs	NT	2.4
Passing #200, %	4.31	63.7
Sand, %	61.9	36.3
Clay, %	NT	16

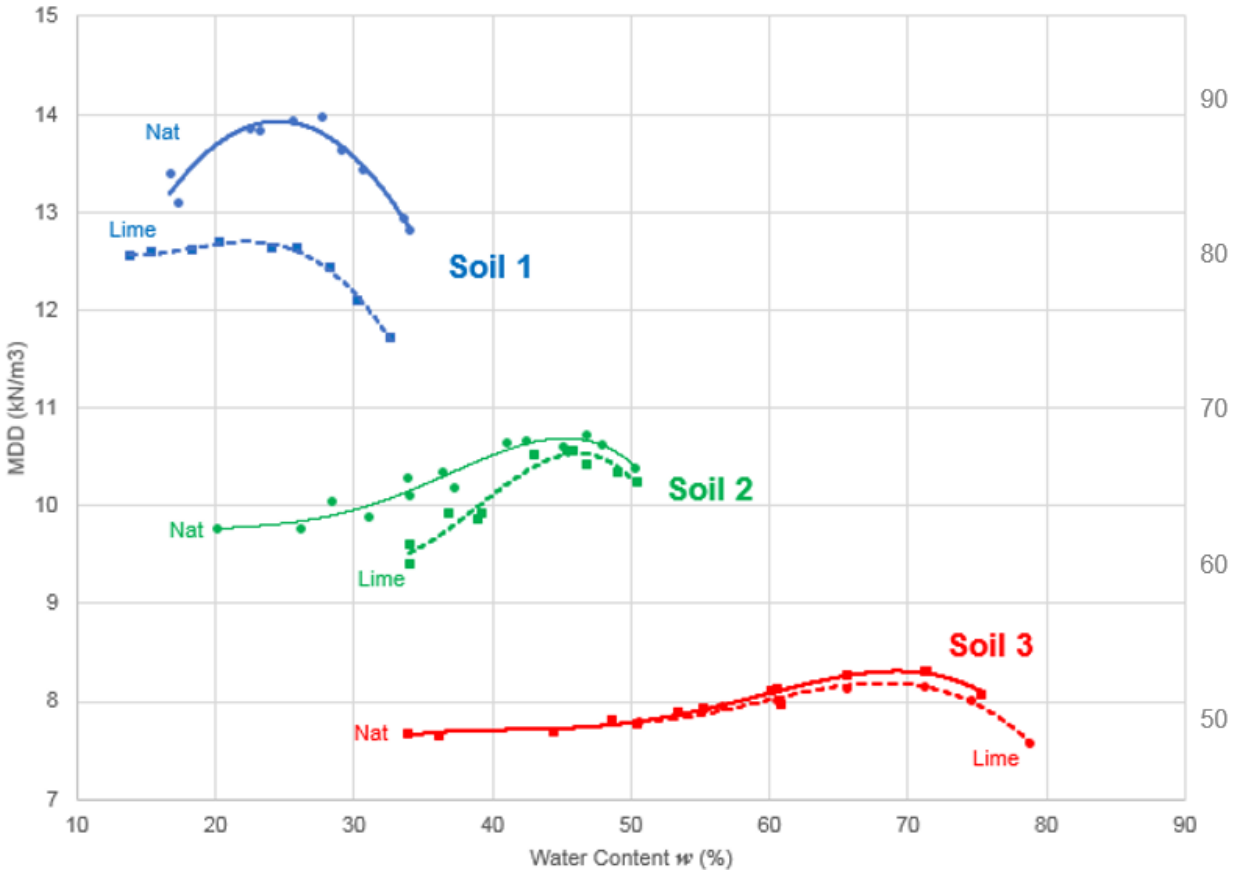
NT: Not Tested

Guadalajara: 4% lime

Monterrey: 5% lime

INSTITUTO MEXICANO DEL TRANSPORTE

TRB



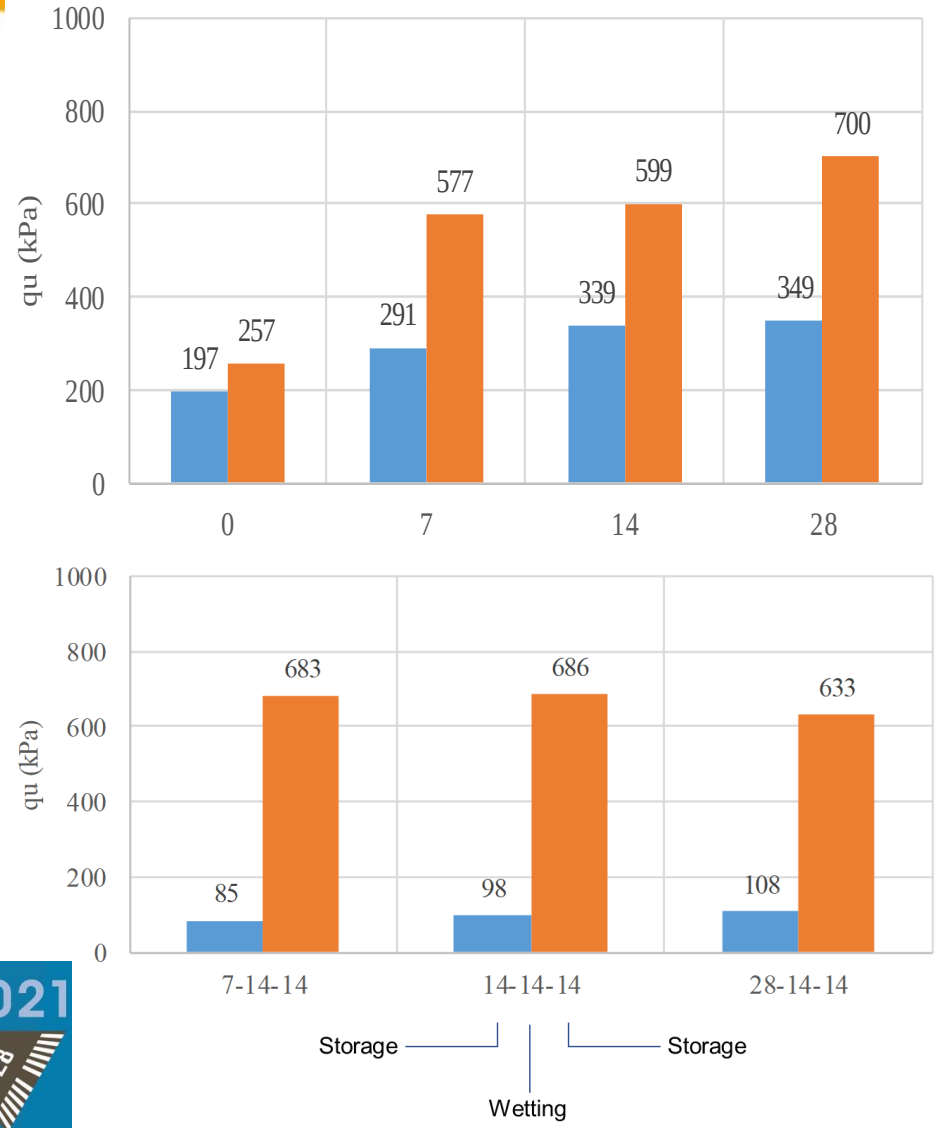
	NAT	LIME
LL	36	46
PL	26	39
PI	10	7
% -200 #	64	
G, ton/m³	2.252	

	NAT	LIME
LL	61	73
PL	38	48
PI	23	25
% -200 #	73	
G, ton/m³	2.509	

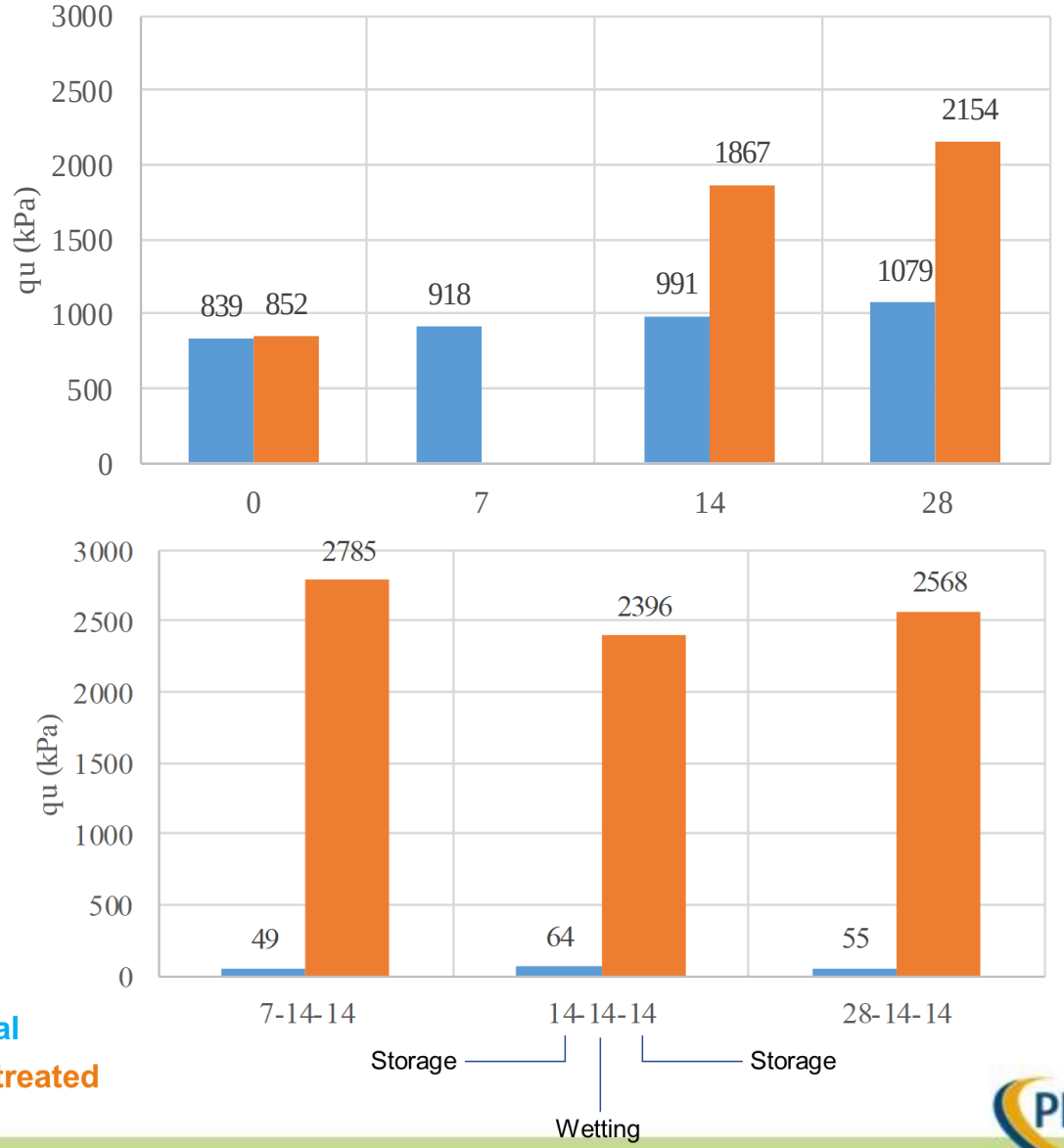
	NAT	LIME
LL	87	85
PL	58	58
PI	29	27
% -200 #	85	
G, ton/m³	2.500	

UCS

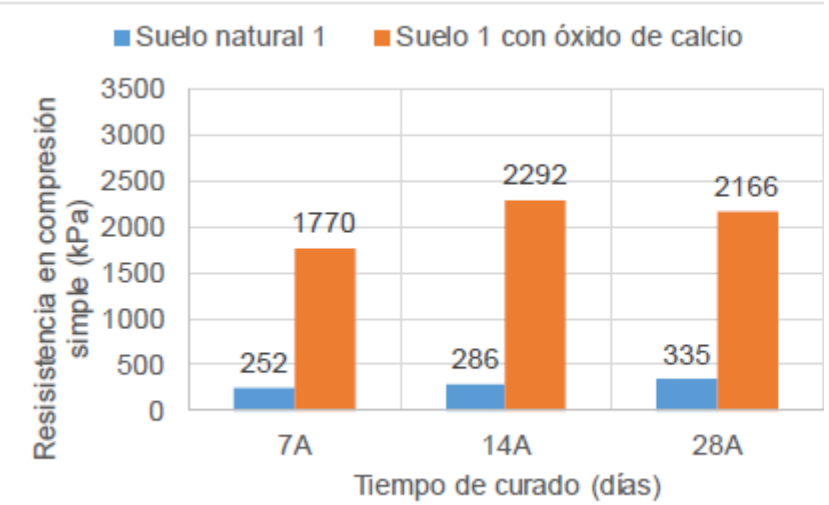
GDL

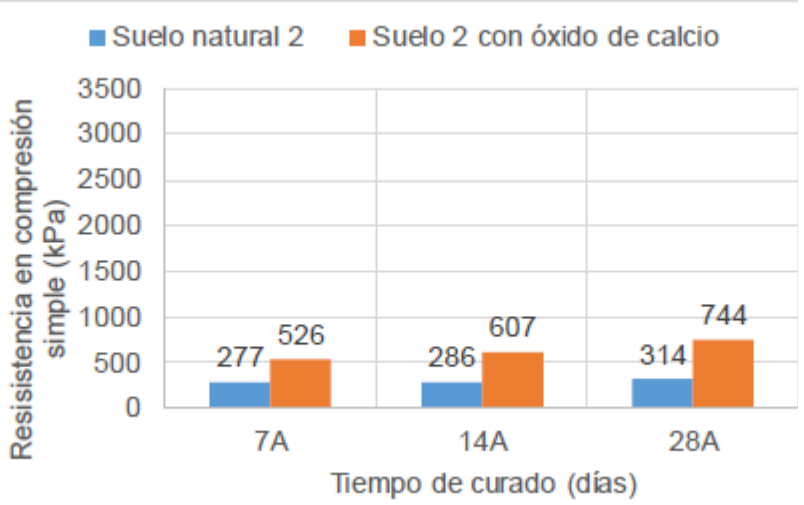

qu (kPa)
1000
800
600
400
200
0
197
257
291
577
339
599
349
700
0
7
14
28
qu (kPa)
1000
800
600
400
200
0
85
683
98
686
108
633
7-14-14
14-14-14
28-14-14
Storage
Storage
Wetting
Natural
Lime treated

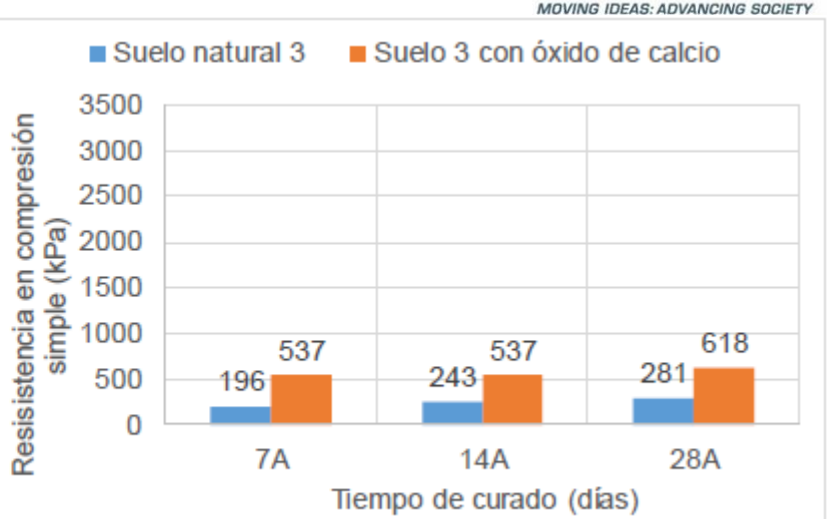
MTY

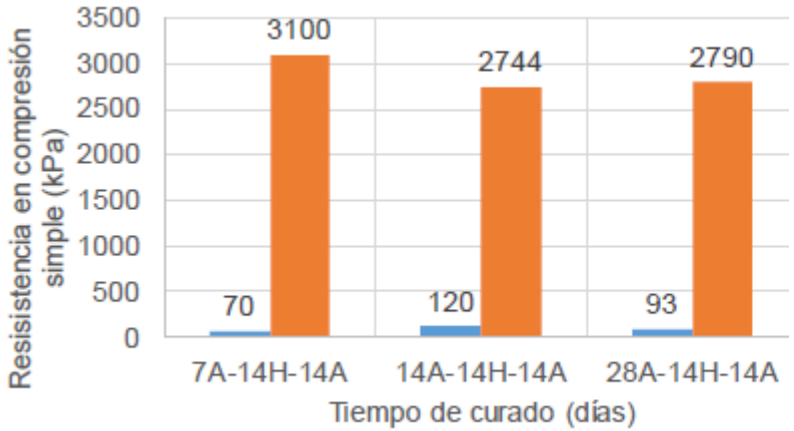

qu (kPa)
3000
2500
2000
1500
1000
500
0
839
852
918
991
1867
1079
2154
0
7
14
28
qu (kPa)
3000
2500
2000
1500
1000
500
0
49
2785
64
2396
55
2568
7-14-14
14-14-14
28-14-14
Storage
Storage
Wetting

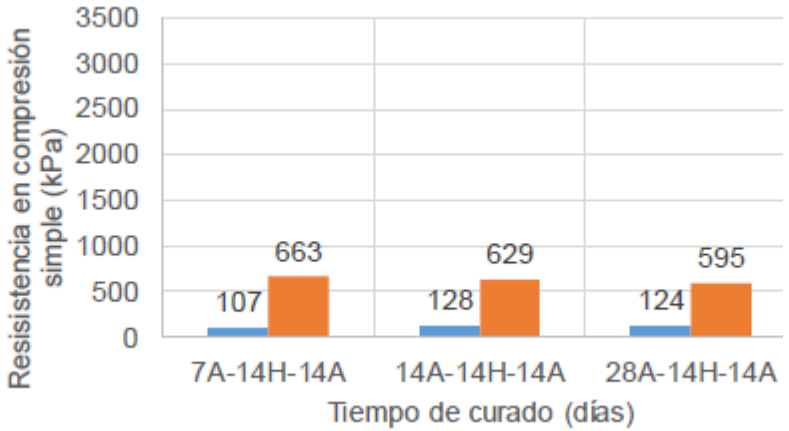
UCS

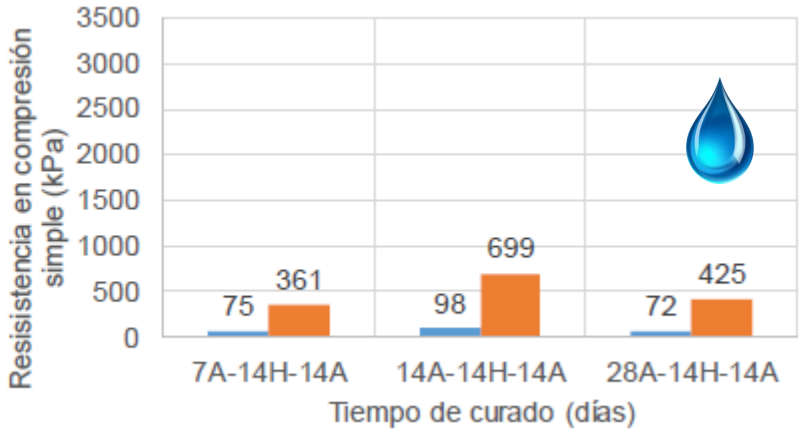

Suelo natural 1
Suelo 1 con óxido de calcio
Resistencia en compresión simple (kPa)
3500
3000
2500
2000
1500
1000
500
0
252
1770
286
2292
335
2166
7A
14A
28A
Tiempo de curado (días)


Suelo natural 2
Suelo 2 con óxido de calcio
Resistencia en compresión simple (kPa)
3500
3000
2500
2000
1500
1000
500
0
277
526
286
607
314
744
7A
14A
28A
Tiempo de curado (días)


Suelo natural 3
Suelo 3 con óxido de calcio
Resistencia en compresión simple (kPa)
3500
3000
2500
2000
1500
1000
500
0
196
537
243
537
281
618
7A
14A
28A
Tiempo de curado (días)

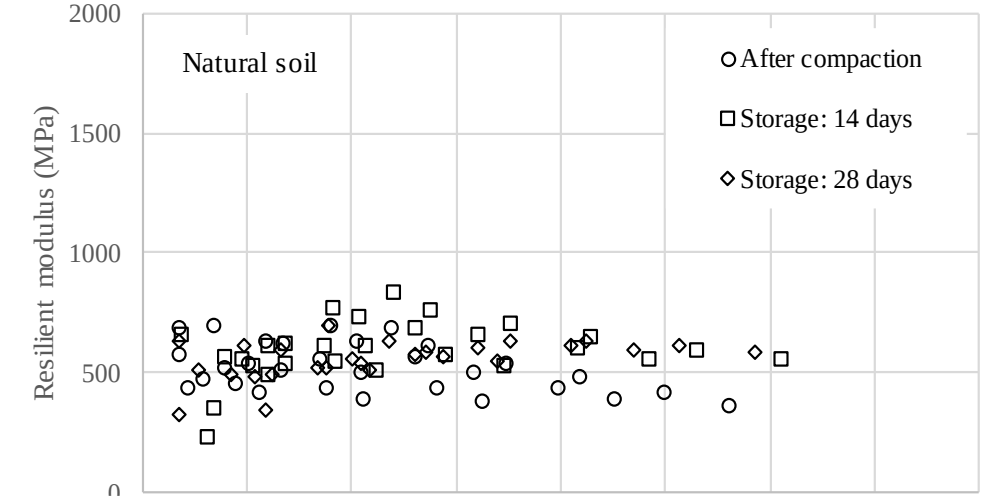

Resistencia en compresión simple (kPa)
3500
3000
2500
2000
1500
1000
500
0
70
3100
120
2744
93
2790
7A-14H-14A
14A-14H-14A
28A-14H-14A
Tiempo de curado (días)

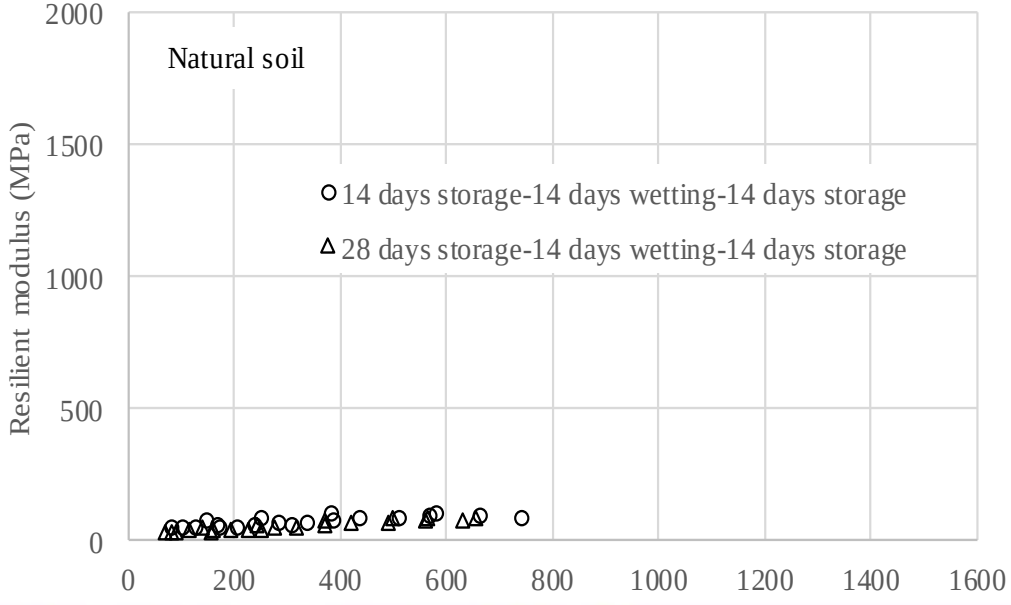

Resistencia en compresión simple (kPa)
3500
3000
2500
2000
1500
1000
500
0
107
663
128
629
124
595
7A-14H-14A
14A-14H-14A
28A-14H-14A
Tiempo de curado (días)


Resistencia en compresión simple (kPa)
3500
3000
2500
2000
1500
1000
500
0
75
361
98
699
72
425
7A-14H-14A
14A-14H-14A
28A-14H-14A
Tiempo de curado (días)

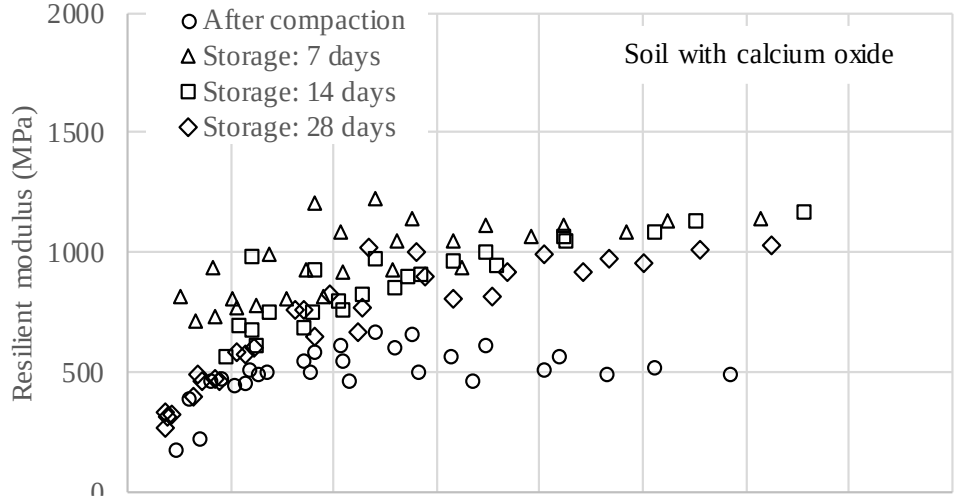
Módulo Resiliente

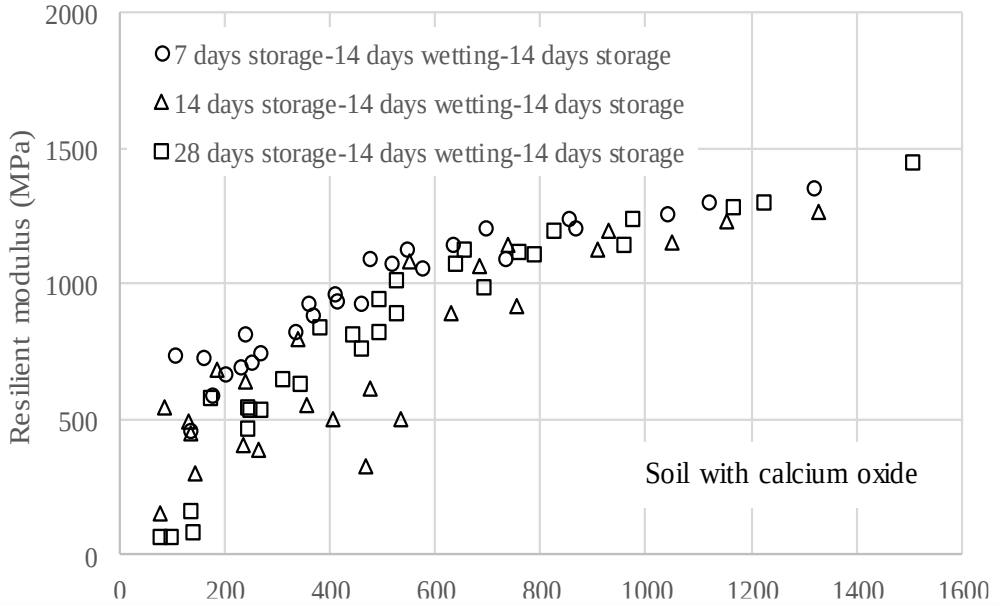
Natural





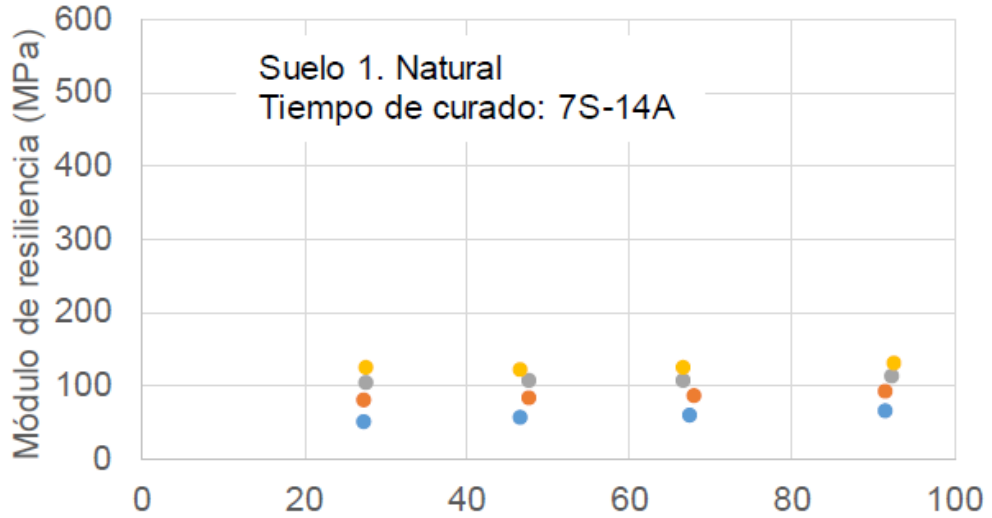
Lime treated

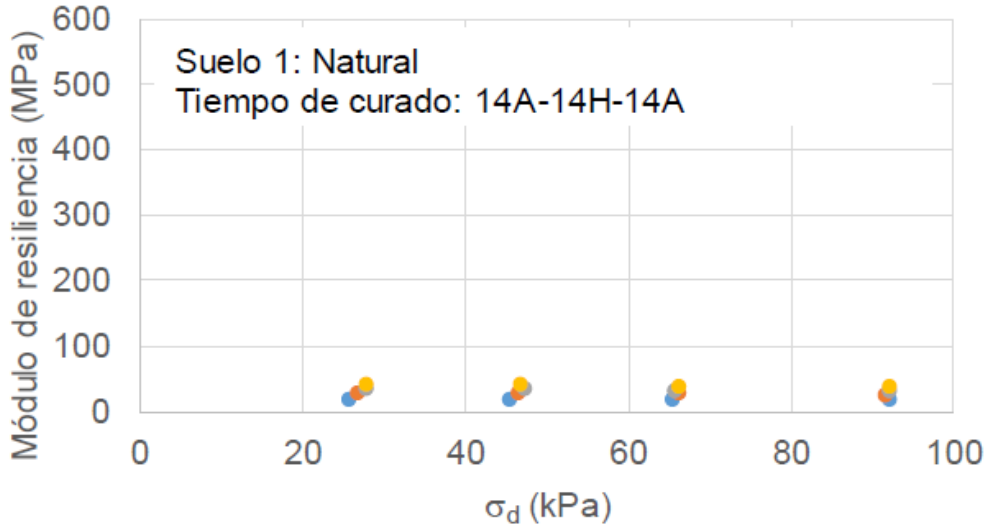




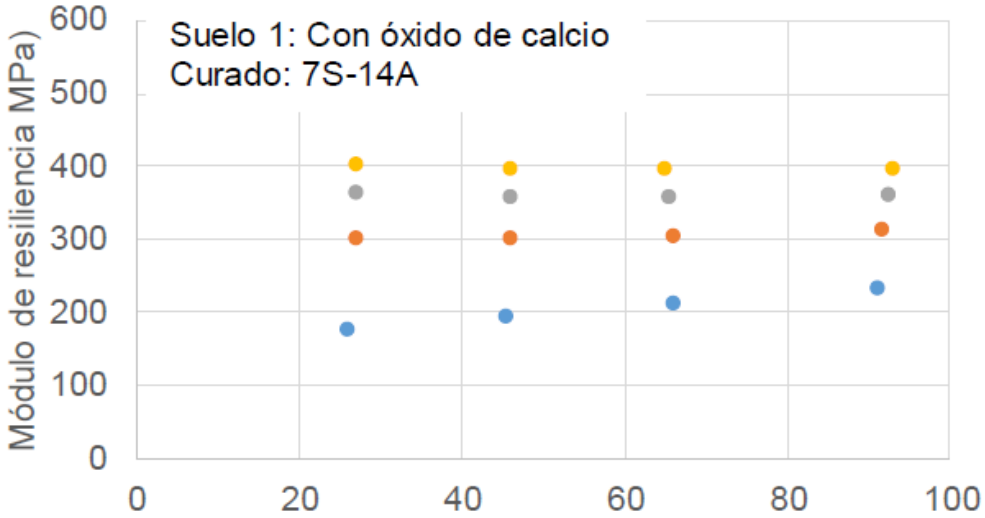
Módulo Resiliente

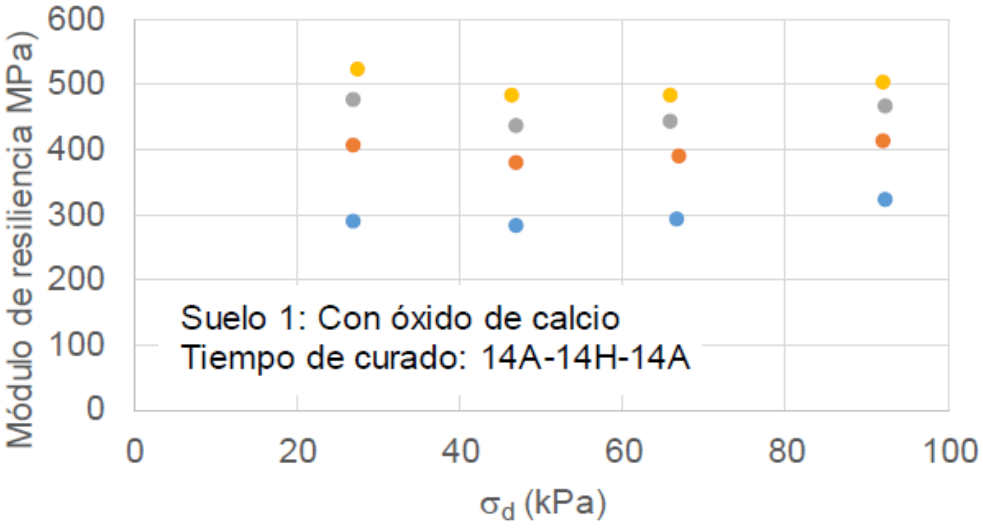
Natural



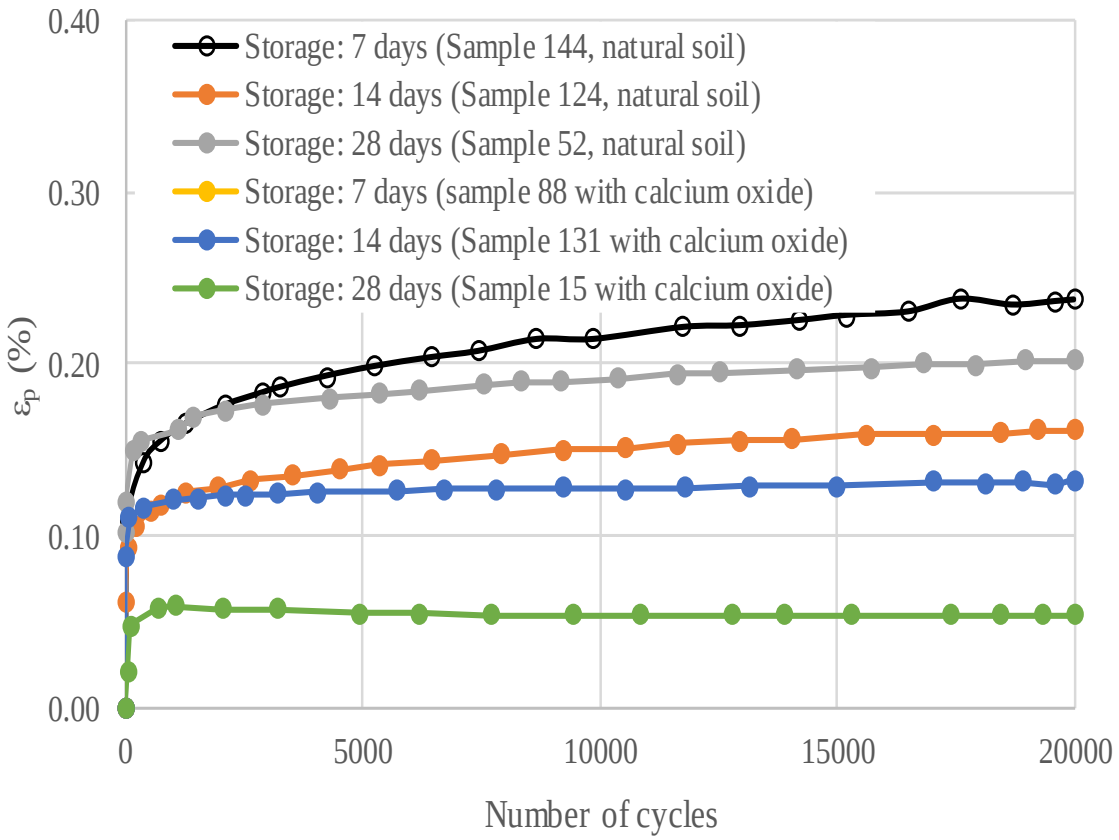


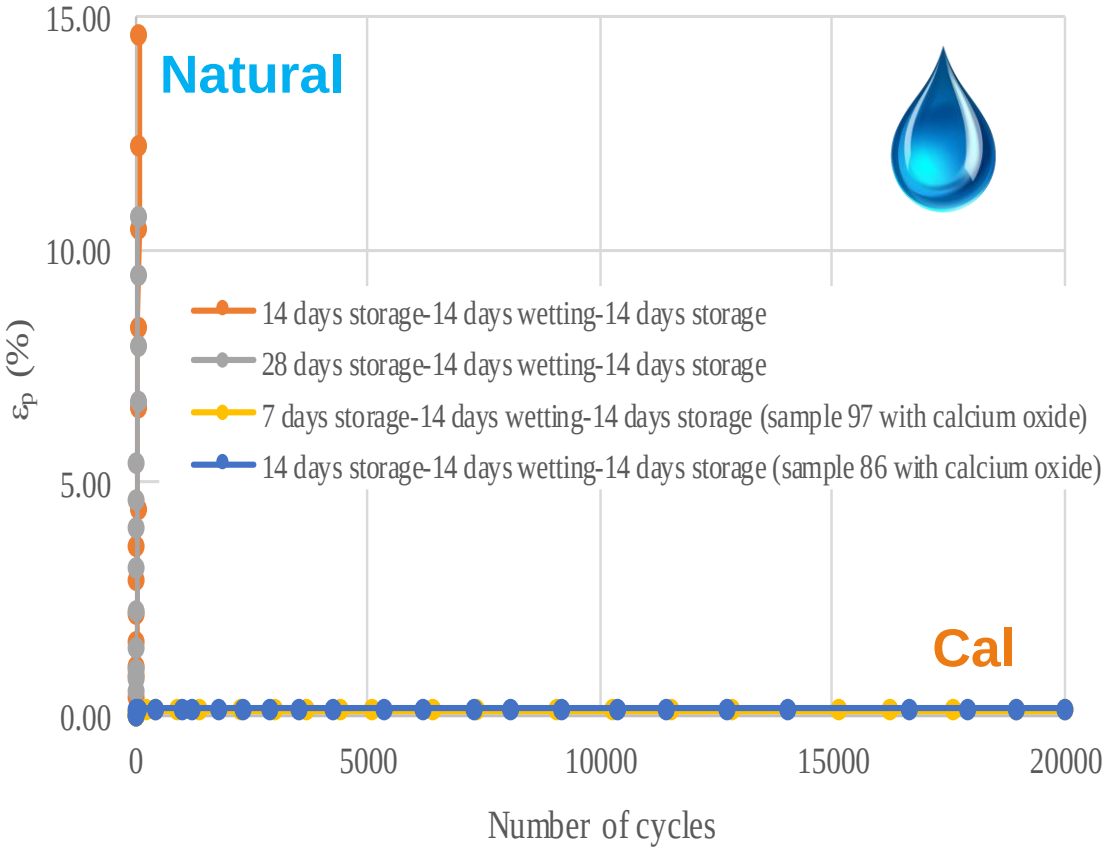
Lime treated



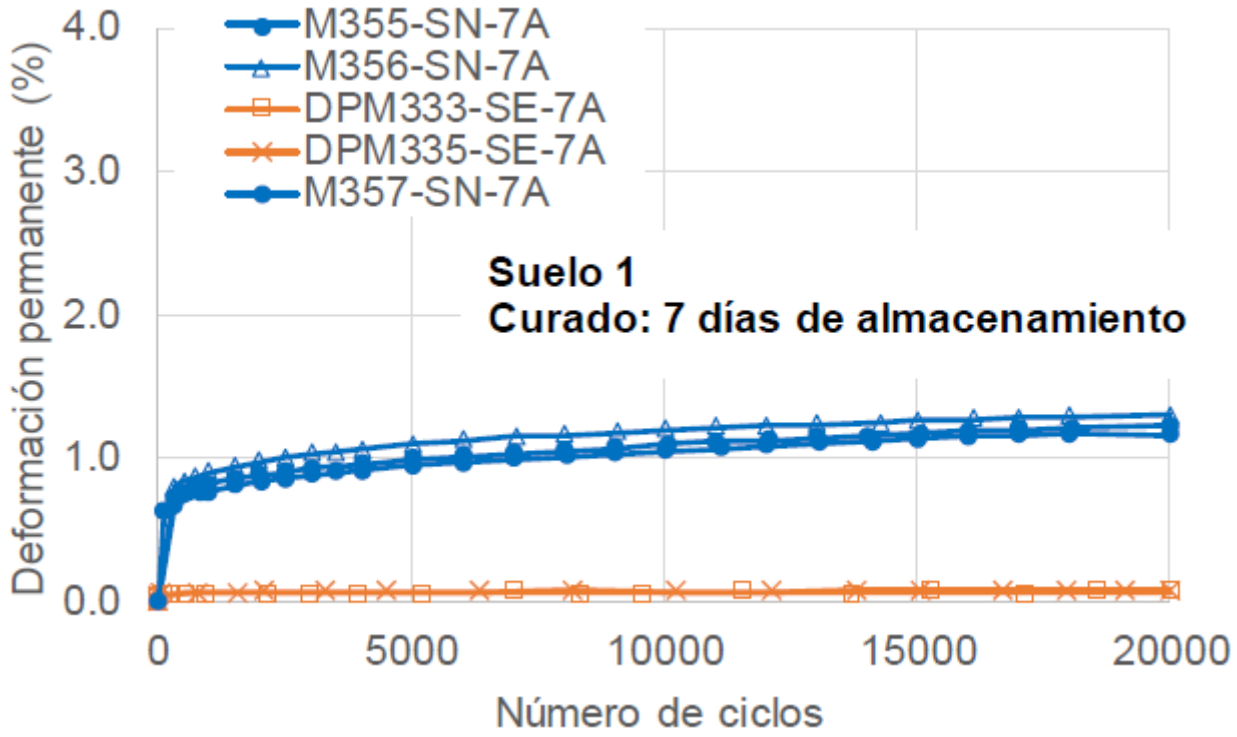


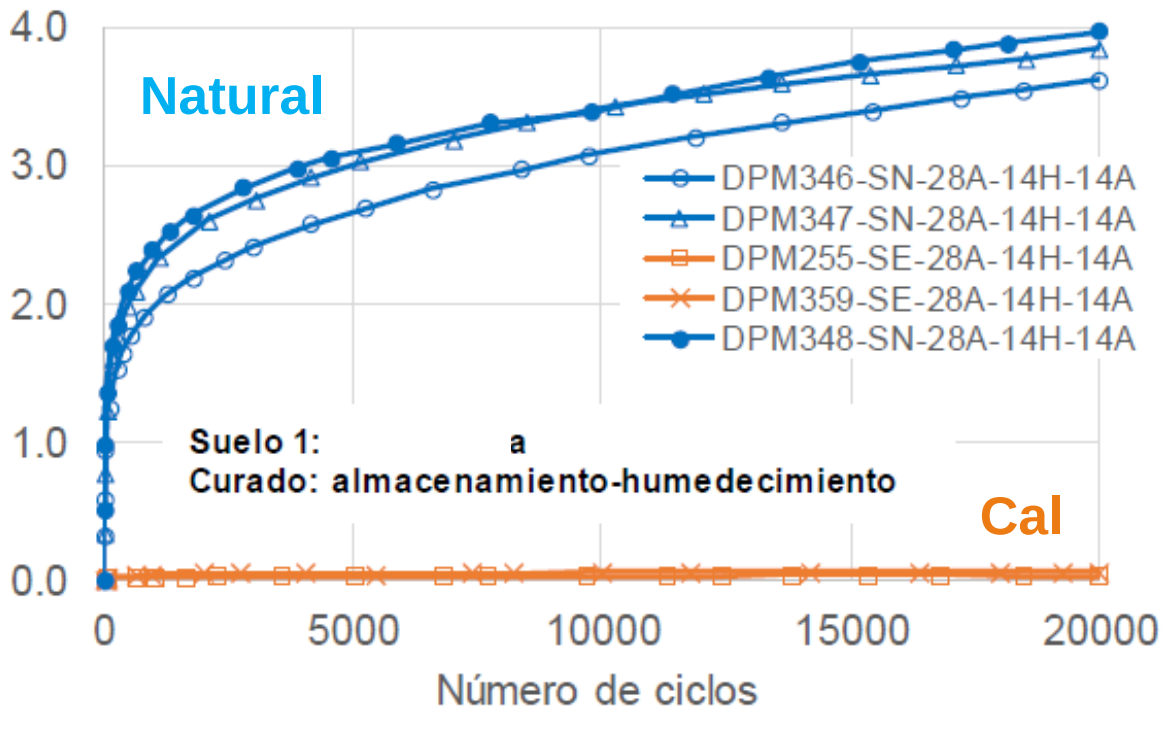
Deformación Carga Cíclica



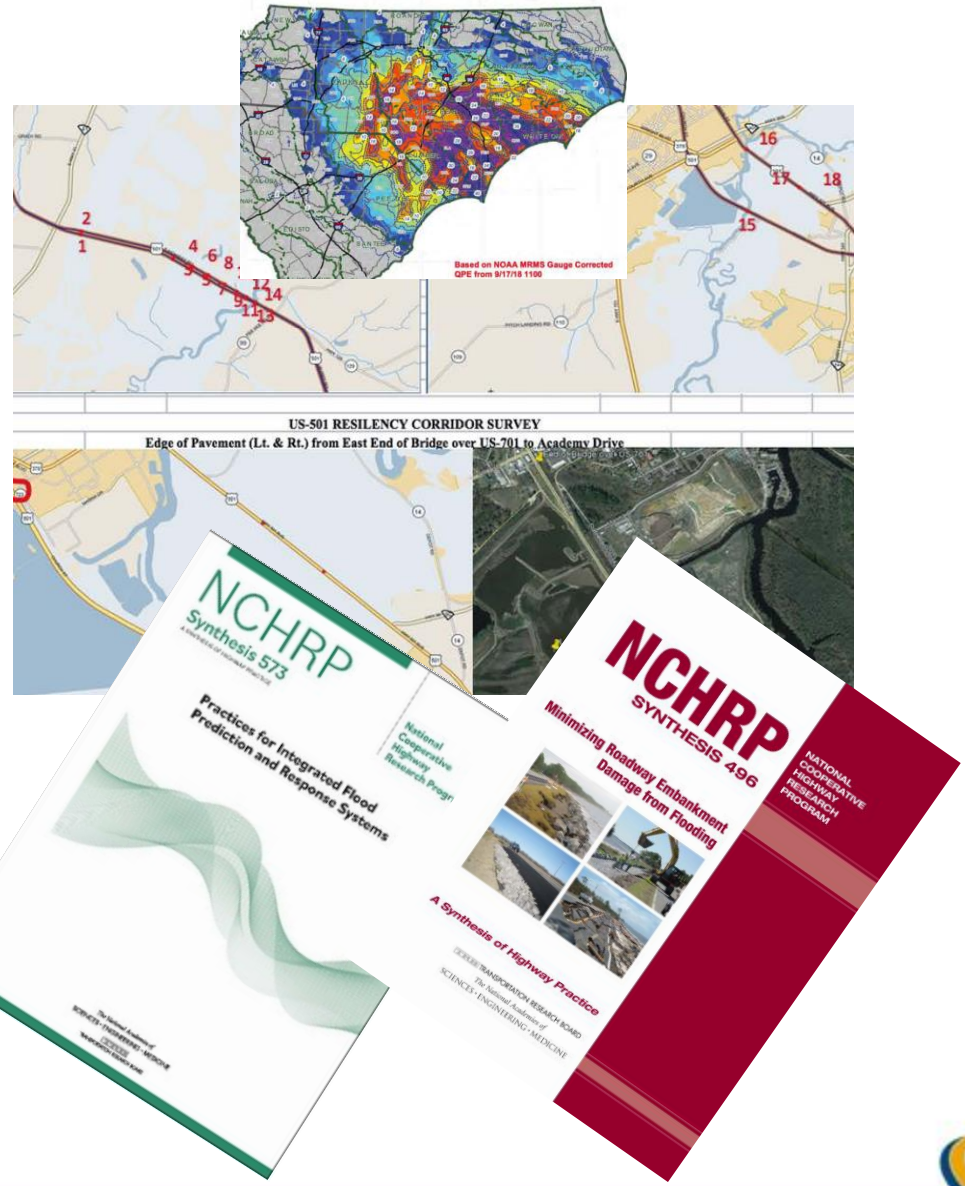


Deformación Carga Cíclica






DANGER
BRIDGE CLOSED
WHEN
FLOODED
WEIGHT
LIMIT
15
TONS
WHEN
FLOODED
TURN AROUND
DON'T
DROWN


Based on NOAA MRMS Gauge Corrected
QPE from 9/17/18 1100
US-501 RESILIENCY CORRIDOR SURVEY
Edge of Pavement (Lt. & Rt.) from East End of Bridge over US-701 to Academy Drive
NCHRP
Synthesis 573
Practices for Integrated Flood
Prediction and Response Systems
National
Cooperative
Highway
Research Progr
NCHRP
SYNTHESIS 496
Minimizing Roadway Embankment
Damage from Flooding
A Synthesis of Highway Practice
NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM

- Temperaturas más altas
- Tormentas más frecuentes y poderosas
- Incremento nivel mar
- Elevación nivel freático
- Incremento de fenómenos de precipitación abundante

Caso Éxito


Satélite IR
21/10/2018 08:55:00 pm
1
7 AM MIÉ
2
7 PM MAR
4
4 AM MAR
5
4 PM LUN
"Willa"

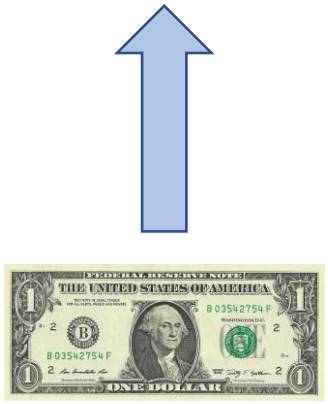
Valle de Urraca Nayarit, Mex



Aplicaciones

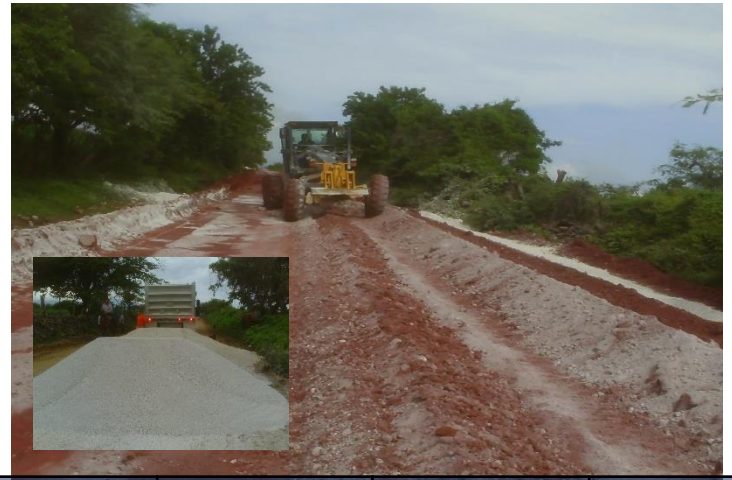
- Autopistas
- Carreteras
- Caminos rurales
- Plataformas industriales
- Parques eólicos
- Unidades habitacionales
- Aeropuertos
- FFCC
- Obras hidráulicas…

Capas Tratadas



Capas Tratadas

- Control finos
- Estabilidad volumétrica
- Capacidad soporte



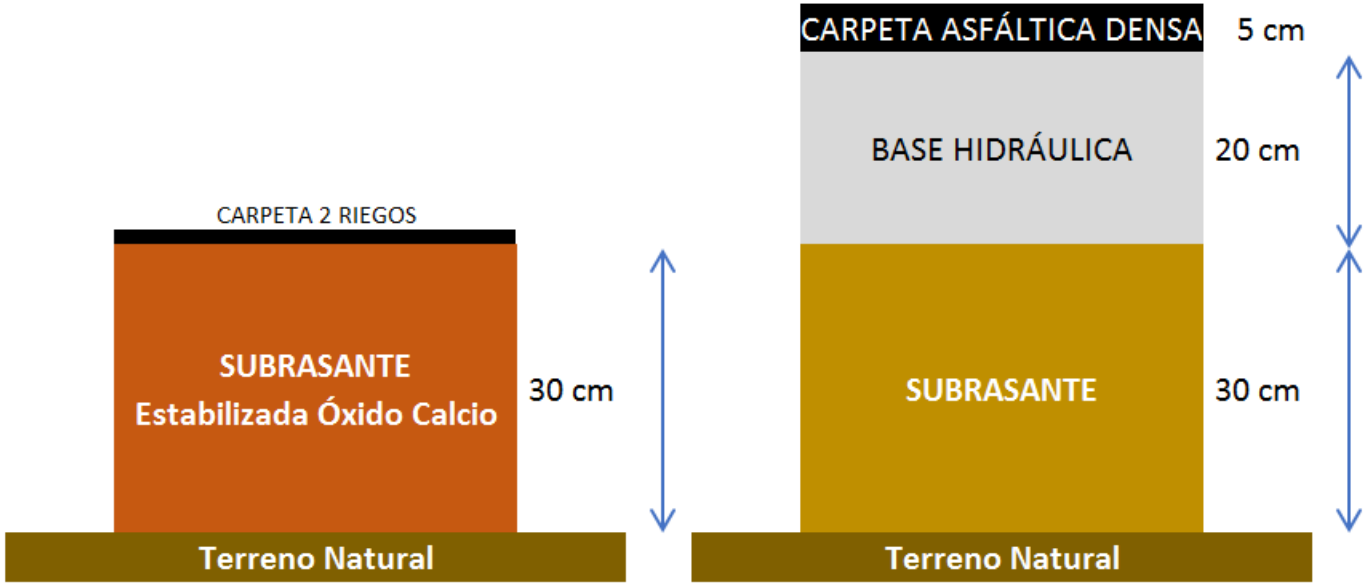
MATERIAL:	CBR	L.L. %	L.P. %	I. Plástico	Expansión
Arcilla natural	34	34	14	20	1.00%
3% Cal	88	35	26	9	0.00%

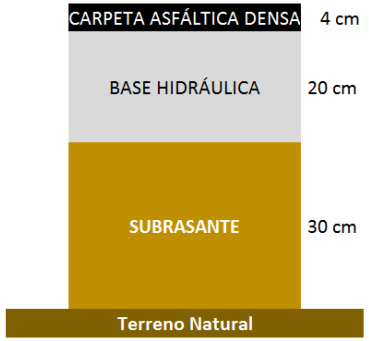
Propuesta CALIDRA

Km 0+000 al 4+000	
D_{max}	867 µm
E_{sg}	111 Mpa
SN	2.17
W_{18}	297,724

Método Tradicional

Km 4+300 al 7+254	
D_{max}	898 µm
E_{sg}	129 Mpa
SN	1.71
W_{18}	140,262





2.11 veces más Km

LONGITUD 5.2 km	VOL.	UNIDAD	P.U.	IMPORTE
Terraplenes para la formación de la capa subrasante compactada al 95% de su P.V.S.M., en un espesor de 30 cm.	11,981	M3.	91.93	$1,101,413.33
Suministro y formación de la capa de base hidráulica, compactada al 100% de su P.V.S.M. y T.M.A. 2" con V.R.S del 100% como mínimo en un espesor de 20 cm.	7,368	M3.	294.04	$2,166,486.72
Riego de impregnación por metro cuadrado aplicado (Inciso J.1. de la Norma N-CTR-CAR-1-04-004)	36,126	M2	10.54	$380,768.04
Riego de arena para cubrir la base impregnada en proporción de 4.0 Lts. por m2.	145	M3.	264.64	$38,372.80
Construcción de carpeta de concreto asfáltico en caliente de 4 cm. de espesor, T.M.A. 1/2" , incluye cemento asfaltico grado PG 64-22 (producido por PEMEX como EKBE) y riego de liga, compactada al 95% de su P.V.S.M., P.U.O.T.	1,493	M2	2471.01	$3,689,217.93
	TOTAL			**$7,376,258.82**
	$ por Km			**$1,418,511.31**

LONGITUD 4.4 km	VOL.	UNIDAD	P.U.	IMPORTE
Cal viva y/o estabilical de Calidra o similar en caracteristicas mecanicas y fisicoquimicas P.U.O.T.	411,100	KG.	2.24	$920,864.00
Suministro, homogenización, formación y compactación de la capa con calidad de sub rasante estabilizada de 30 cm. de espesor, compactada al 100% de su P.V.S.M., P.U.O.T.	8,222	M3.	34.32	$282,179.04
Riego de impregnación por metro cuadrado aplicado (Inciso J.1. de la Norma N-CTR-CAR-1-04-004)	25,546	M2	13.71	$350,235.66
Riego de arena para cubrir la base impregnada en proporción de 4.0 Lts. por m2.	102	M3.	100.29	$10,229.58
Construcción de carpeta de 2 (dos) riegos con materiales pétreos 2 y 3-B.	25,546	M2	54.5	$1,392,257.00
	TOTAL			**$2,955,765.28**
	$ por Km			**$671,764.84**

111% + económico


CONSERVA CAMINO
SAN BLAS - GPE. VICTORIA

Aplicaciones Autopistas

Aeropuertos

Subgrade Soil Support and Stabilization

O'HARE Airport Modernization Research Project

Research Progress Presentation – July 20, 2006

Co-PIs: Erol Tutumluer
Marshall R. Thompson
RA: H.S. Brar

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN
CENTER OF EXCELLENCE FOR AIRPORT TECHNOLOGY

Task 2:

Evaluate currently available data for the subgrade test sections constructed in the Fall of 2003 and the necessity/usefulness of constructing additional subgrade treatment test sections at O'Hare

Plate load tests conducted (8/04) on the test sections:

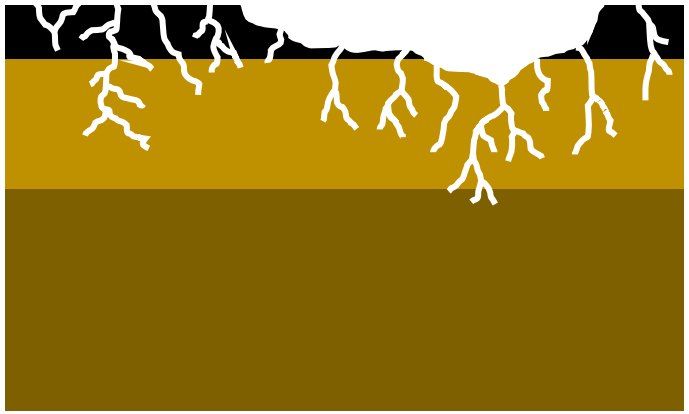
- **Plate 1:** 12-inch stabilization/compaction – no admixture
- **Plate 2:** 12-inch quicklime fine (40 lb/yd²) & fly ash (80 lb/yd²) stabilization
- **Plate 3:** 12-inch quicklime fine stabilization (40 lb/yd²)
- **Plate 4:** 12-inch lime kiln dust stabilization (40 lb/yd²)

DFW DALLAS FORT WORTH INTERNATIONAL AIRPORT

Hartsfield-Jackson Atlanta International Airport

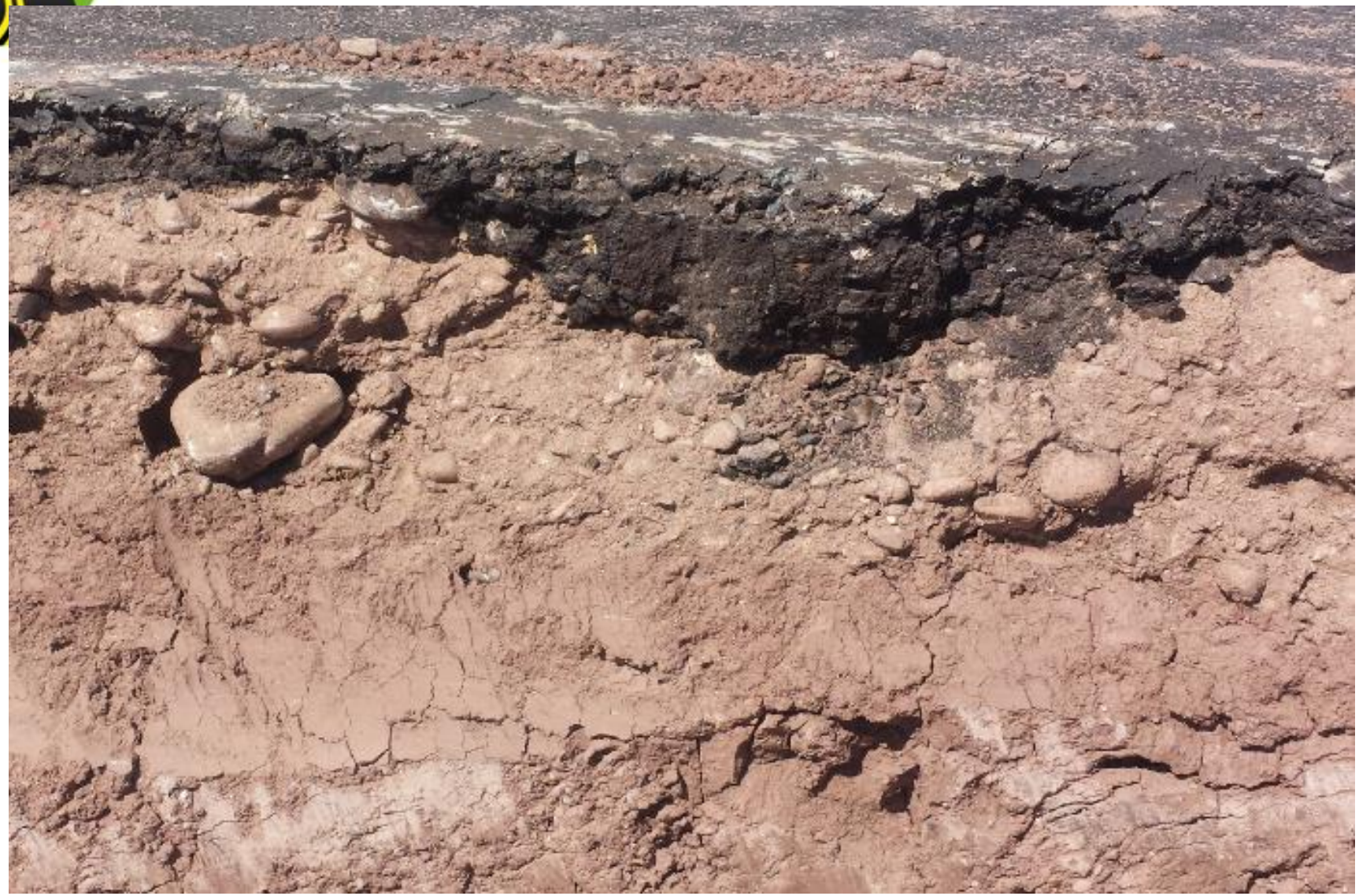
Aeropuertos

Solución Tradicional



- Bacheo
- Micro carpeta
- Recarpeteo

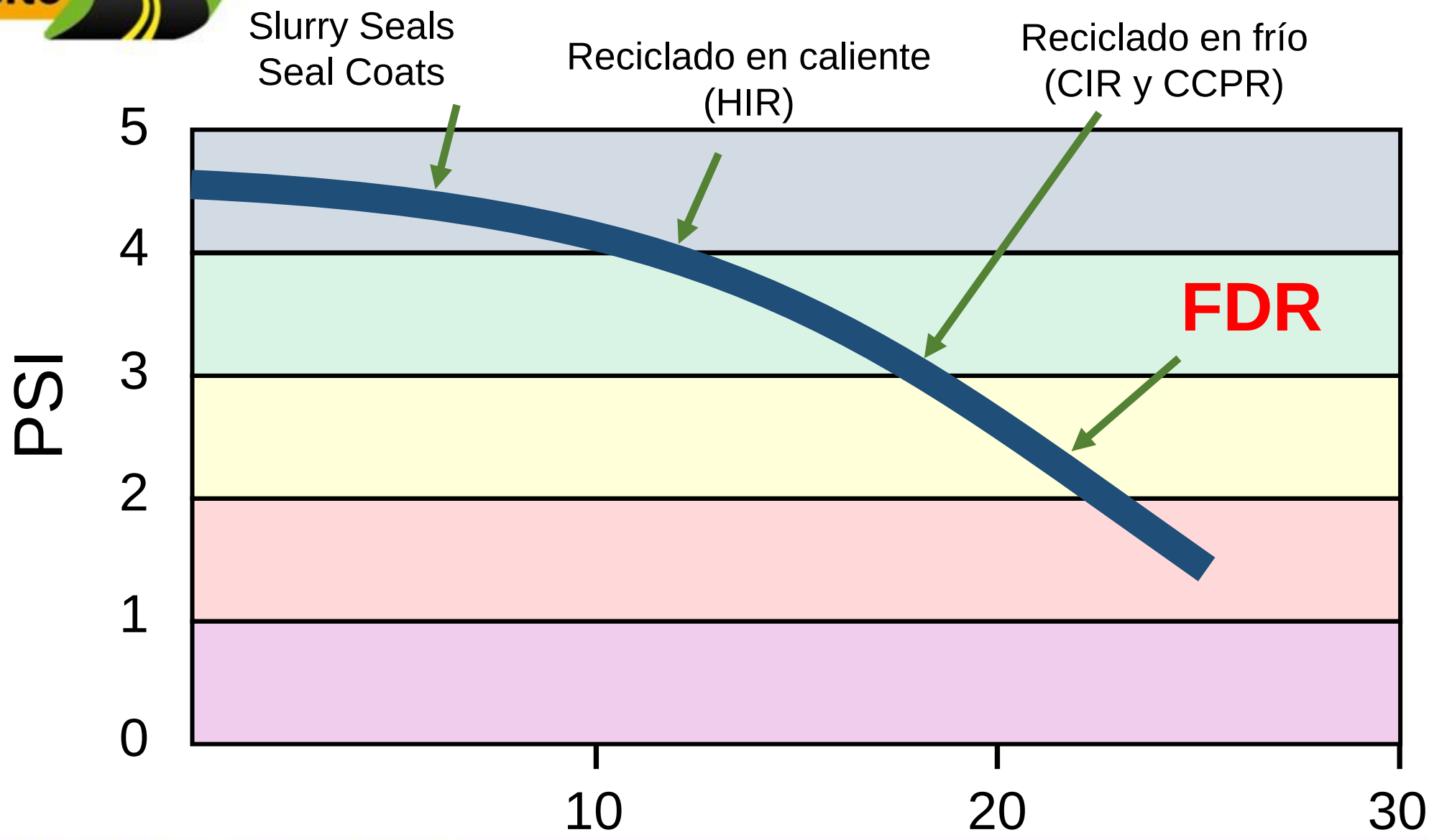
Solución Tradicional



Correcciones FDR

- Acocodrilamiento (cracking)
- Ahuellamiento (rutting)
- Desprendimientos (stripping, raveling)
- Capacidad estructural inadecuada
- Inestabilidad de sub capas
- Baches
- ***Mantenimiento excesivo***

- Conservación de fuentes no renovables de energía
- Eliminación de fallas superficiales
- Corregir deficiencias de sub capas
- Corregir deficiencias granulométricas
- Restauración y reconstrucción de perfiles
- Reducción de bordos excesivos
- Mejoramiento estructura de pavimento
- Ahorro costos


Slurry Seals
Seal Coats
Reciclado en caliente
(HIR)
Reciclado en frío
(CIR y CCPR)
FDR
PSI
5
4
3
2
1
0
10
20
30


More than 10 million tons of RAP stockpiled in Virginia

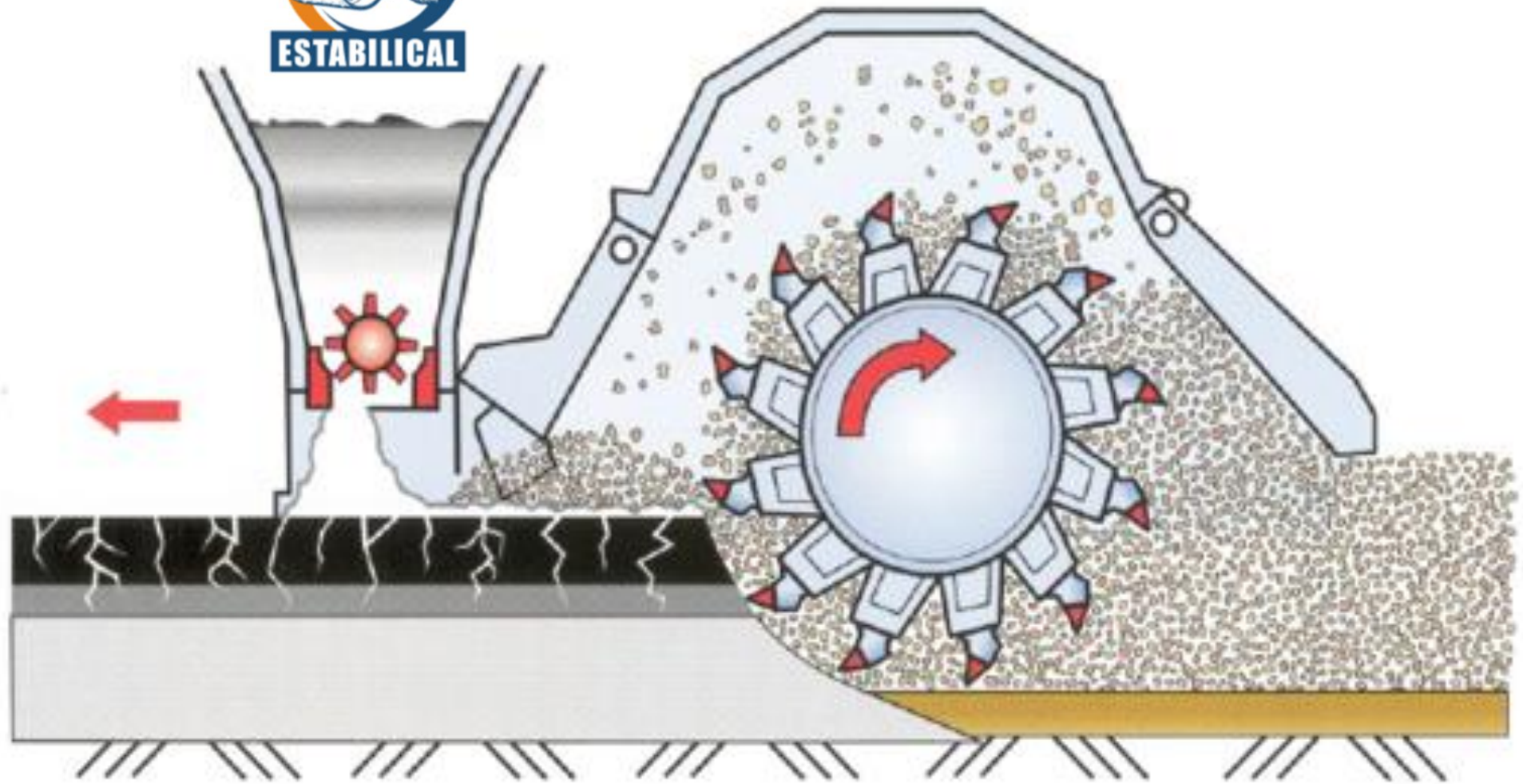
Pulverización

Mecánica

Química

Bituminosa

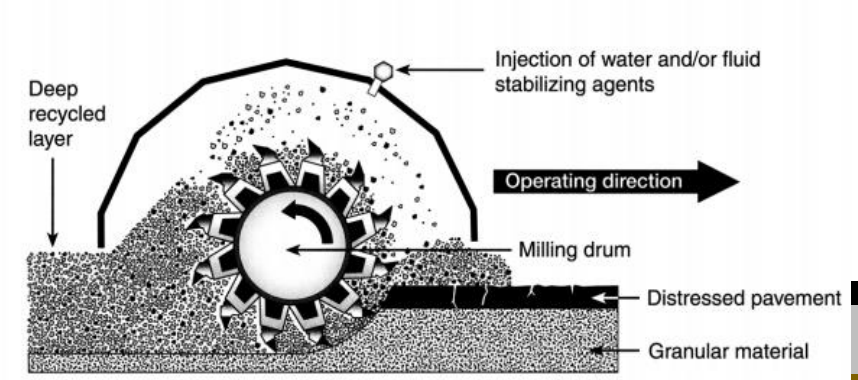
ESTABILICAL

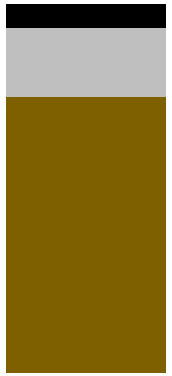


SON 16

Hermosillo - Mazatán

Bacheo profundo FDR + Cal



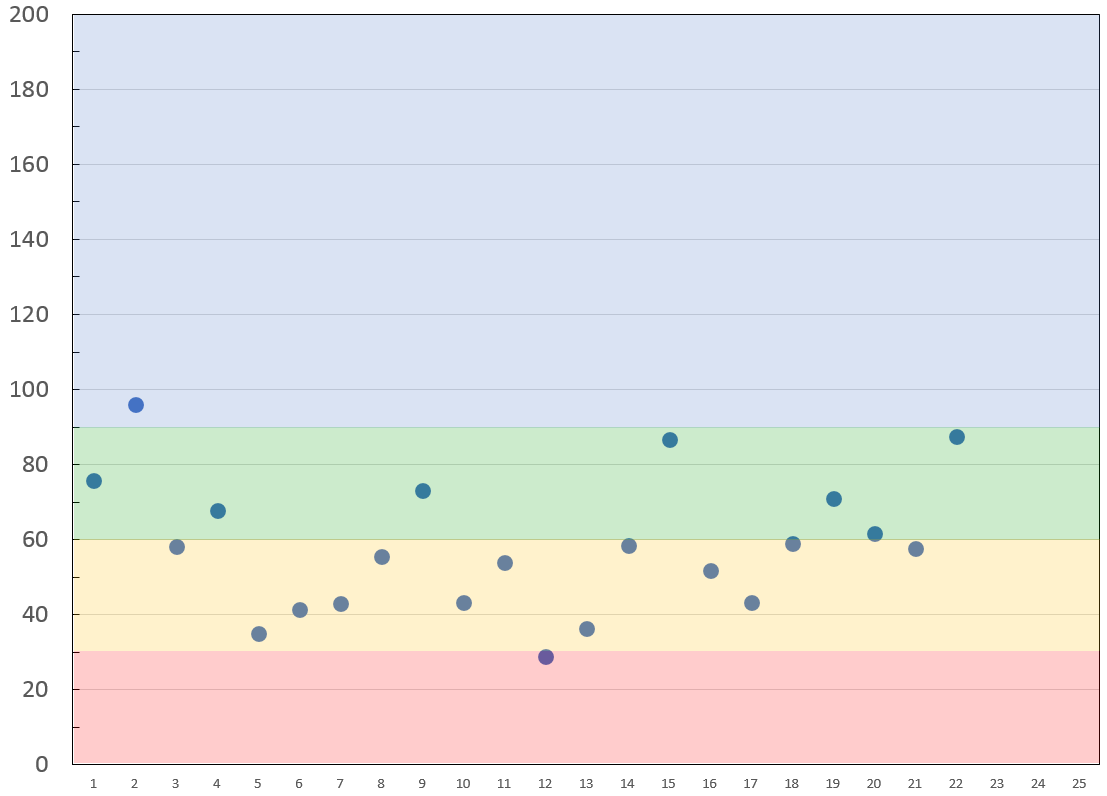


10 cm RAP

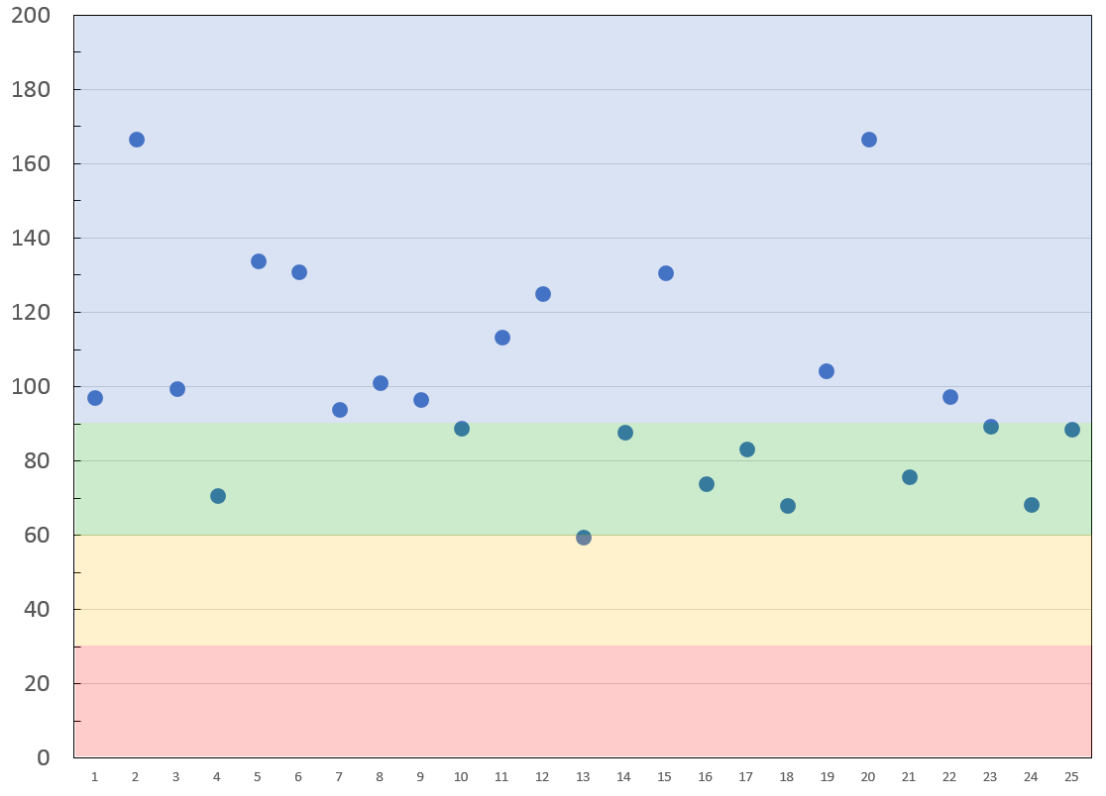
20 cm Base

Gobierno del Estado de Sonora

JUNTA DE CAMINOS

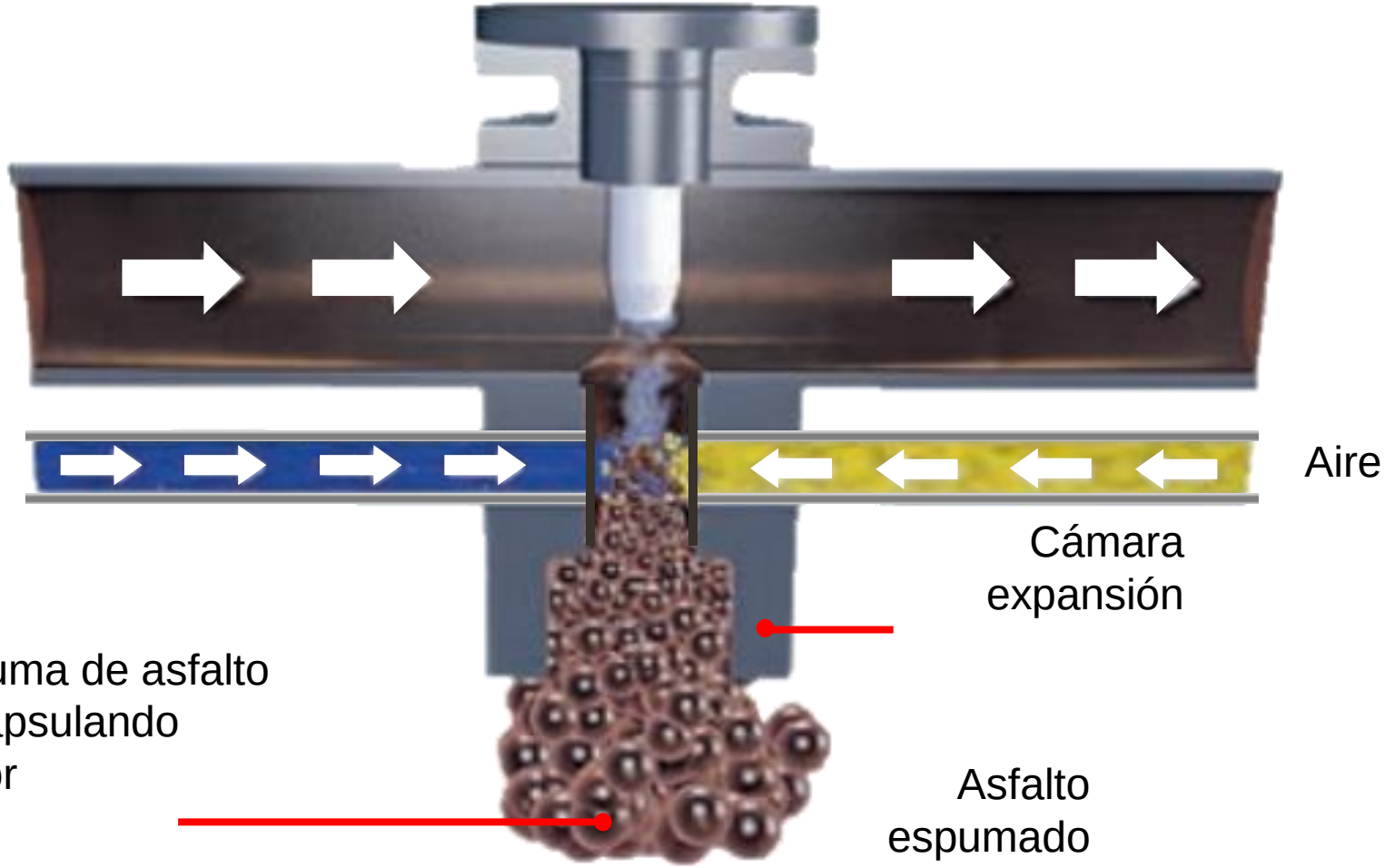


23 octubre 17



01 noviembre 17


A 200 m


Asfalto caliente
Agua
Aire
Cámara expansión
Espuma de asfalto encapsulando vapor
Asfalto espumado

75% RAP + 25 % Arena

Equipo: WR240
→ Orilla del camino

- San Luis Potosí-Zacatecas
- San Luis Potosí-Rioverde
- Libramiento Norte de la Laguna
- Durango-Torreón
- Gómez Palacio-Corralitos
- Tapachula-Arriaga
- Acayucan-Cosoleacaque

caminos y puentes federales

APP ARRIAGA - TAPACHULA

coconal

PRECOVA pavimentos y recubrimientos

GRUPO CONSTRUCTOR PIRÁMIDE

SUPRA GRUPO

Tren Maya

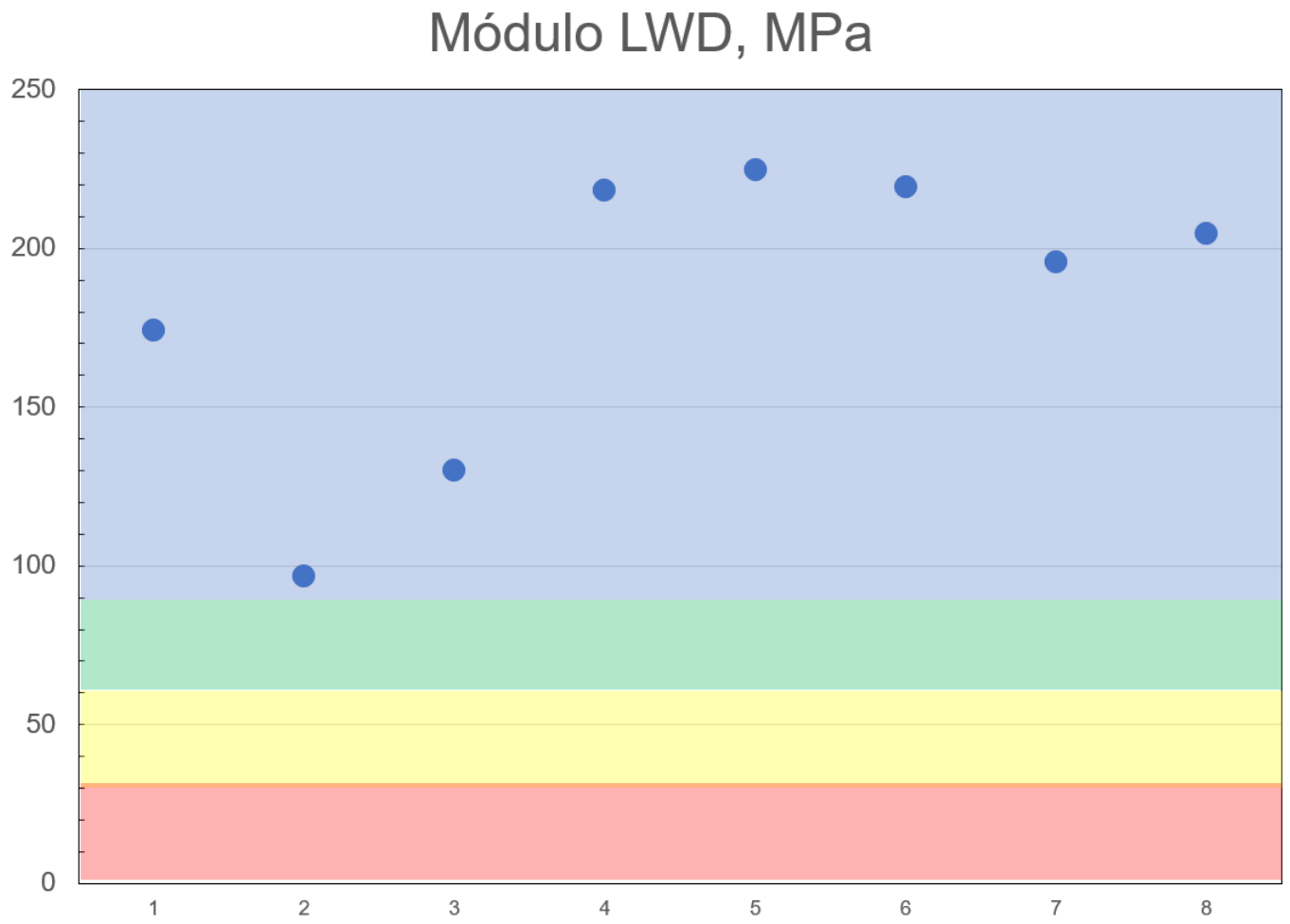

TRAMO SELVA 1 (232 km aprox.)
TRAMO SELVA 2 (264 km aprox.)
TRAMO CARIBE 1 (246 km aprox.)
TRAMO CARIBE 2 (130 km aprox.)
TRAMO GOLFO 1 (262 km aprox.)
TRAMO GOLFO 2 (167 km aprox.)
TRAMO GOLFO 3 (165 km aprox.)
SUBTOTAL (1,460 km aprox.)
GI GRUPO INDI
ICA
carso
INFRAESTRUCTURA Y CONSTRUCCION
MOTA-ENGIL
SEDENA
SECRETARÍA DE LA DEFENSA NACIONAL
GOLFO DE MÉXICO
MAR CARIBE
YUCATÁN
CAMPECHE
QUINTANA ROO
TABASCO
CHIAPAS
Guatemala
Mérida
Izamal
Chichén Itzá
Valladolid
Cancún
Puerto Morelos
Playa del Carmen
Cobá
Tulum
S.F. Campeche
Felipe Carrillo Puerto
Calakmul
Bacalar
Chetumal
Escárcega
Balancán
Palenque
Tenosique
SIMBOLOGÍA
Estación Tren Maya
Alternativa Valladolid - Cancún

Tren Maya

ESTABILICAL

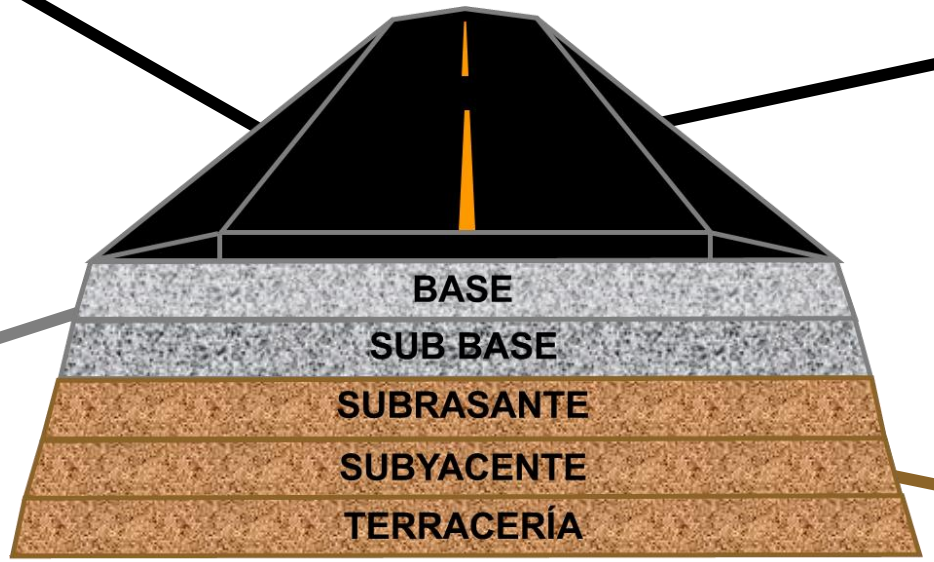

CAT
CAT


V-2
DYNAPAC
DYNAPAC


Módulo LWD, MPa
250
200
150
100
50
0
1
2
3
4
5
6
7
8

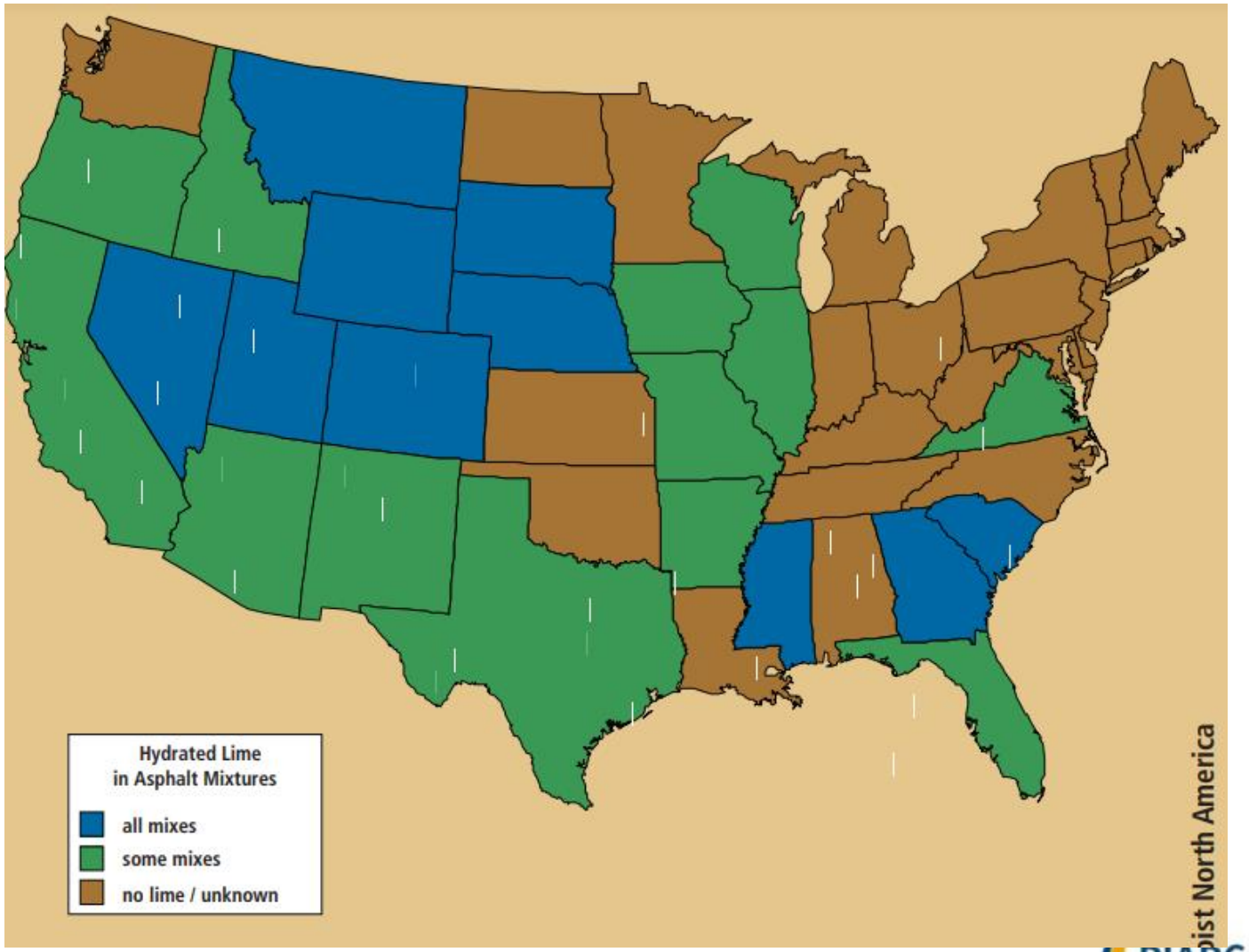

INFRAESTRUCTURA

Estrategia C3C



Observed increase in durability in the USA

The use of hydrated lime in asphalt mixtures has become widespread in the USA.
As already mentioned in the introduction, we estimate that 10% of the asphalt mixtures manufactured in the USA now hold hydrated lime.
However, the situation is not homogeneous and Figure 1 shows the repartition on a State by State basis.
Interestingly, States experiencing tough climates, like those in the Rocky Mountains (severe winter) or those on the Gulf of Mexico (high humidity combined with high temperature), are favouring the use of hydrated lime.



https://www.asphacal.com/sites/asphacal/files/Press%20article%20ERR20%20-%20Hydrated%20lime%20EN.pdf

Filler Activo

Themechanismsofhydratedlimemodificationofasphaltmixtures:a state-of-the-artreview

Didier Lesueur[a]*, Joëlle Petit[b] and Hans-Josef Ritter[c]

[a]LhoistR&D,1400Nivelles–Belgium; [b]Carmeuse,5300Seilles–Belgium; [c]BundesverbandderDeutschen Kalkindustriee.V.,50968Köln–Germany

Although already known for a long time, hydrated lime (HL) attracted a strong interest as an asphalt additive during the 1970s in the USA, when moisture damage and frost became some of the most pressing pavement failure modes of the time. Given its extensive use in the past 40 years, HL is known to be more than a moisture damage additive: it is an "active filler" that also reduces the chemical ageing of the bitumen and stiffens the mastic more than a normal mineral filler above room temperature. These properties impact durability, and HL is now seen as an additive that increases asphalt mixture durability. This article is a literature review on the fundamentals of the effect of HL on asphalt mixtures. The reasons for it being so effective lie in the strong interactions between both the aggregate and the bitumen and a combination of four mechanisms, two on the aggregate and two on the bitumen. HL modifies the surface properties of the aggregate, allowing for the development of surface composition and roughness more favourable to bitumen adhesion. Then, HL can treat the existing clayey particles adhering to the aggregate surface, inhibiting their detrimental effect on the mixture. Also, HL reacts chemically with the acids of the bitumen, which in turn slows down the age hardening kinetics and neutralises the effect of the "bad" adhesion promoters originally present inside the bitumen, enhancing the moisture resistance of the mixture. Finally, the high porosity of HL explains its stiffening effect above room temperature.

- Resistencia a la deformación
- Adherencia agregado-asfalto

- Daño por humedad
- Envejecimiento
- Fatiga

Methods of treatment to reduce moisture damage, particularly stripping, include use of good aggregate, pretreatment of aggregates, and use of additives. The survey results show that pretreatment of aggregate with lime is the most effective. The amount of lime typically used is in the range of 1 to 1.5 percent. Amines are used by many agencies as asphalt additives; however, their reported effectiveness is mixed.

A variety of test methods has been employed to assess the potential for moisture damage in asphalt concrete mixtures. Thus far, no test is "superior" or can correctly distinguish a moisture-susceptible mixture in all cases; however, the American Associa-

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 175

MOISTURE DAMAGE IN ASPHALT CONCRETE

TRANSPORTATION RESEARCH BOARD
National Research Council

R. GARY HICKS
Oregon State University, Corvallis, OR

Topic Panel

JOHN J. CARROLL, *Federal Highway Administration, Washington, D.C.*
ROBERT N. DOTY, *California Department of Transportation, Sacramento, CA*
ROBERT P. LOTTMAN, *University of Idaho, Moscow, ID*
G.W. MAUPIN, *Virginia Transportation Research Council, Charlottesville, VA*
VYTAUTAS P. PUZINAUSKAS, *The Asphalt Institute, College Park, MD*
KEVIN D. STUART, *Federal Highway Administration, McLean, VA*

Aplicaciones Vivienda

Parques Industriales

Aplicaciones Distritos Riego

Aplicaciones Receptores Agua

Conclusiones

UNM

Effects of Suction & Moisture on Resilient Modulus of Lime Treated Clayey Subgrade Soils

Transportation Research Board Conference 2014
Paper ID: 14-5500

Presented by:
Md Tahmidur Rahman
MS, University of New Mexico

Co-Author:
Rafiqul Tarefder
Associate Professor, University of New Mexico

TRB
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

Lime Stabilization of Clayey Soils

- Lime is the oldest and the most effective traditional stabilizer
- Candidate soils: plasticity index >10 and passing No. 200 sieve > 25%

- *Benefits:*
  - ✓ Structural Improvement: strength gain
  - ✓ Volumetric Stability: reduction of plasticity and swelling
  - ✓ Durability: freeze-thaw actions

- *Mechanism* (Little 2012):

Lime + Water + Clayey particles (silicates, aluminates)

↓

Ca-Si-H, Ca-Al-H, Ca-Al-Si-H gels

Coating | Crystallization

↓

Coarse Textured Cemented Structure

UNM

Conclusiones

- Estudios amplios y contundentes
- Diversidad aplicaciones
- La cal: el químico versátil
- Durabilidad
- Reducción costos
- Mejoramiento propiedades
- ***Sustentabilidad***

Impacto Ambiental

- Disponibilidad
- Afectaciones
- Costos

¿ Preguntas ?

ESTABILIZACIÓN DE SUELOS CON CAL

Francisco Javier Castañeda Garay

A través del tiempo, el desempeño de las construcciones ha dependido también de la calidad de los suelos en los que se cimentan; de ahí que con las técnicas y materiales apropiados se puedan evitar problemas en las estructuras.

En esta obra, el autor expone los beneficios que aporta la cal en diversos tipos de suelos, un ejemplo de ello es su excelente funcionamiento como estabilizador en suelos de alta plasticidad con alto potencial expansivo, como las arcillas que se encuentran en las obras carreteras. Asimismo, explica –de manera clara y sencilla– las características del suelo, las pruebas de laboratorio necesarias para lograr las reacciones químicas, la calidad y cantidad de producto que se deberá usar en cada caso, así como las zonas en que se recomienda su uso.

Por dichas razones, este libro es un gran material de consulta y guía –apegado a la normatividad vigente– para los profesionales de la construcción, ingenieros civiles y químicos especialistas en el tema.

Contenido

Suelos
La cal
Fundamentos
Diseño de mezclas suelo-cal
Procedimiento constructivo
Pruebas suelo-cal
Casos prácticos

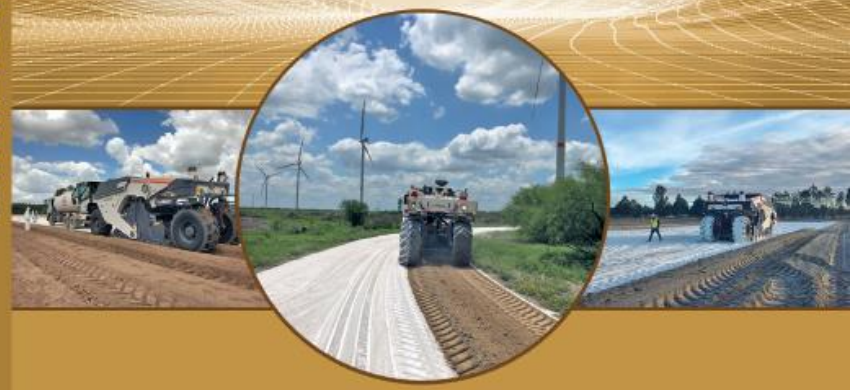
ISBN 978-607-17-0000-0

Castañeda

ESTABILIZACIÓN DE SUELOS CON CAL

ESTABILIZACIÓN DE SUELOS CON CAL

- Características de los suelos
- Pruebas de laboratorio
- Uso de equipo básico y especializado



Francisco Javier Castañeda Garay

trillas

YouTube MX

calidra

Calidra
7650 suscriptores
SUSCRITO

Calidra Infraestructura el aliado en tus proyectos.

Demanda mínima de cal metodo gráfico

Reciclado de Pavimentos con Asfalto Espumado

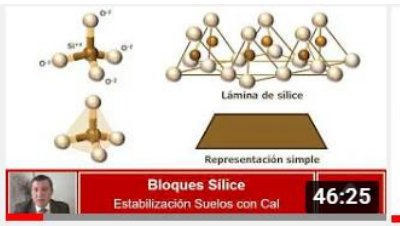
Análisis de PU para Capas Estabilizadas con Cal

Procedimiento Constructivo y Control de Calidad

Conoce Calidra, más de 100 años nos respaldan.

Diseño de Pavimentos Considerando Capas...

Curso Determinación de Porcentaje de Cal



Suelos Susceptibles a la Estabilización con Cal y...

Cápsula Calidra: Estabilización de suelos co...

Reciclado de Pavimento con Asfalto Espumoso

Gracias

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