Classificação dos solos
e
Caracterização das areias e argilas

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Introdução

Os sistemas de classificação foram desenvolvidos para fornecerem a engenheiros e técnicos informações gerais sobre a natureza do solo de um local específico.

De modo geral, ambientes que possuam características semelhantes produzem tipos de solos similares. É isto que permite o sucesso de sistemas de classificação.

Por que existem tantos sistemas de classificação?

Aplicações

Linguagens

Cultura

Etc .....

Por que Classificar?

- "O propósito da classificação é organizar o nosso conhecimento de forma que as propriedades dos 'objetos' possam ser lembradas e suas relações entendidas visando um determinado objetivo."
- "O processo envolve a formação de classes por meio do agrupamento dos 'objetos' com base nas suas propriedades comuns."
- "Em qualquer sistema de classificação os grupos são formados tomando-se os aspectos dos quais se tem o maior número, as mais precisas e mais importantes informações."

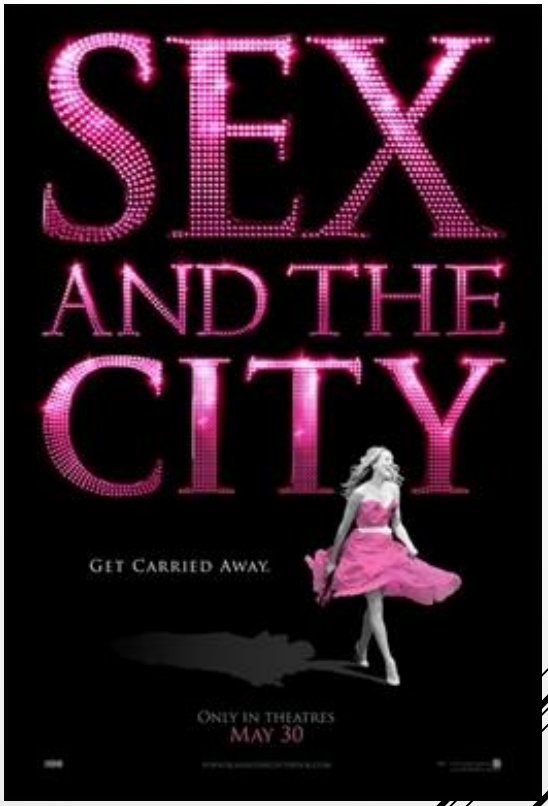
Marlin G. Cline, "Basic Principles of Soil Classification", Soil Science 67, 1949:81-91.





Walt Disney
A FAMÍLIA DO FUTURO
Disney DVD


NICOLAS CAGE JULIANNE MOORE JESSICA BIEL
NEXT
IF YOU CAN SEE THE FUTURE, YOU CAN SAVE IT.
COMING SOON


SEX AND THE CITY
GET CARRIED AWAY.
ONLY IN THEATRES
MAY 30

Modos de Classificar os Solos

Procedimento:

Natural

Técnico

- **Natural:** Agrupa os solos por meio de alguma propriedade intrínseca, comportamento ou gênese do solo, sem fazer referência ao uso.
- **Técnico:** Agrupa os solos com base em alguma propriedade ou função que se relaciona diretamente ao uso do solo.

Como é possível "traduzir" uma classificação em outra?

- Um relação direta entre classificações é rara.
- No entanto, muitos conceitos dos diferentes sistemas são semelhantes, e algumas idéias de um sistema podem ser correlacionadas com outro.

Traduzir uma parte
na outra parte
— que é uma questão
de vida ou morte —
será arte?

Traduzir-se de Ferreira Gullar

O Relativo e o Absoluto

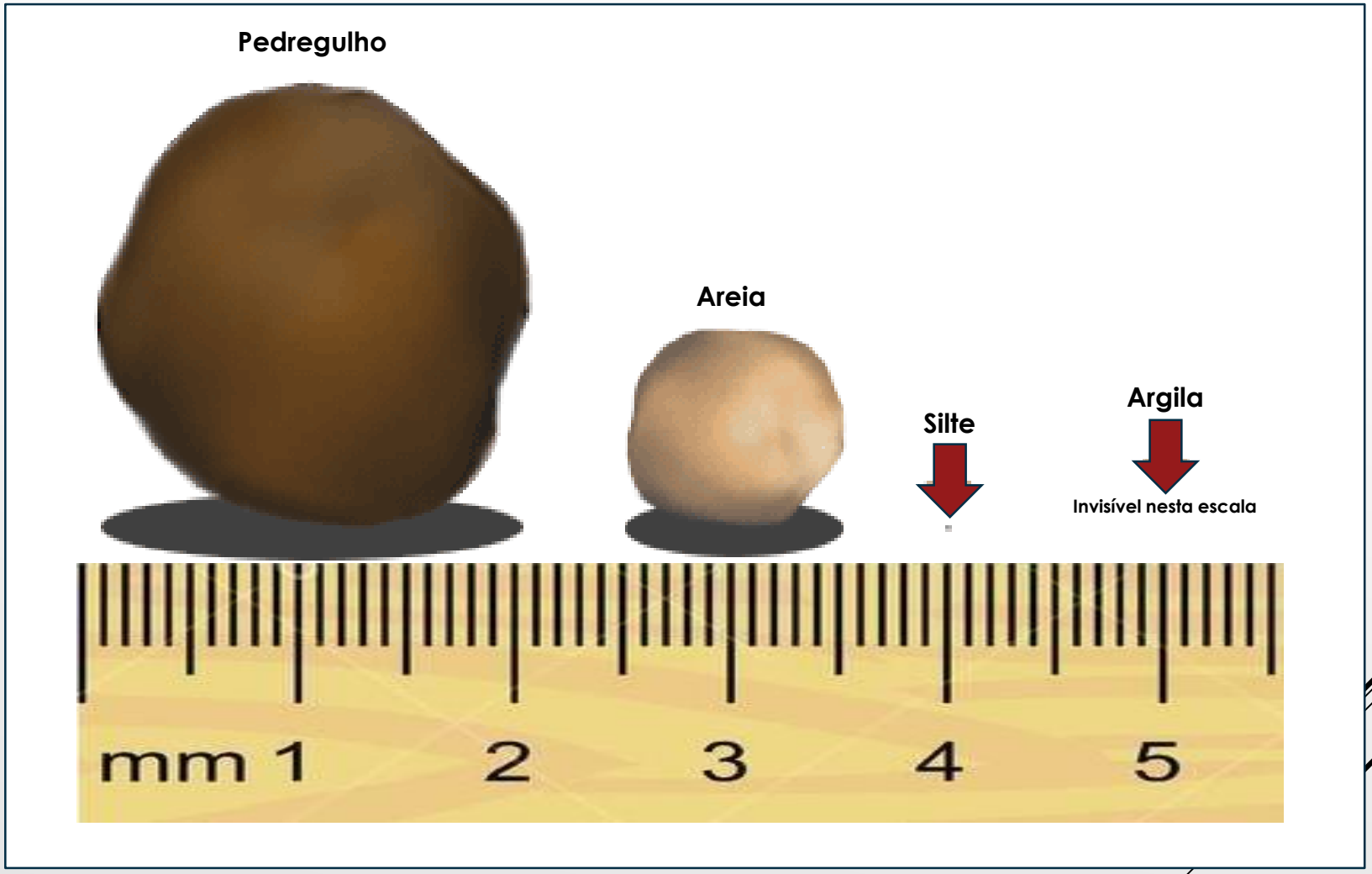
Quase absoluto

Relativo

Tamanho relativo das partículas de solo

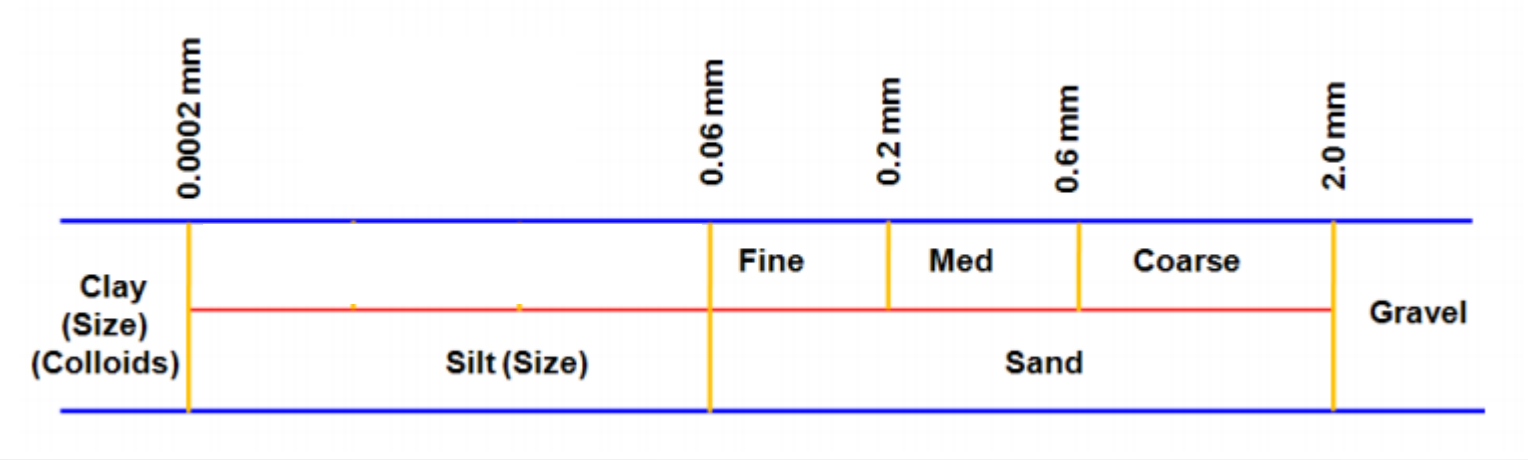
Barril	Prato	Moeda
		
Areia	**Silte**	**Argila**

Tamanho relativo das partículas de solo

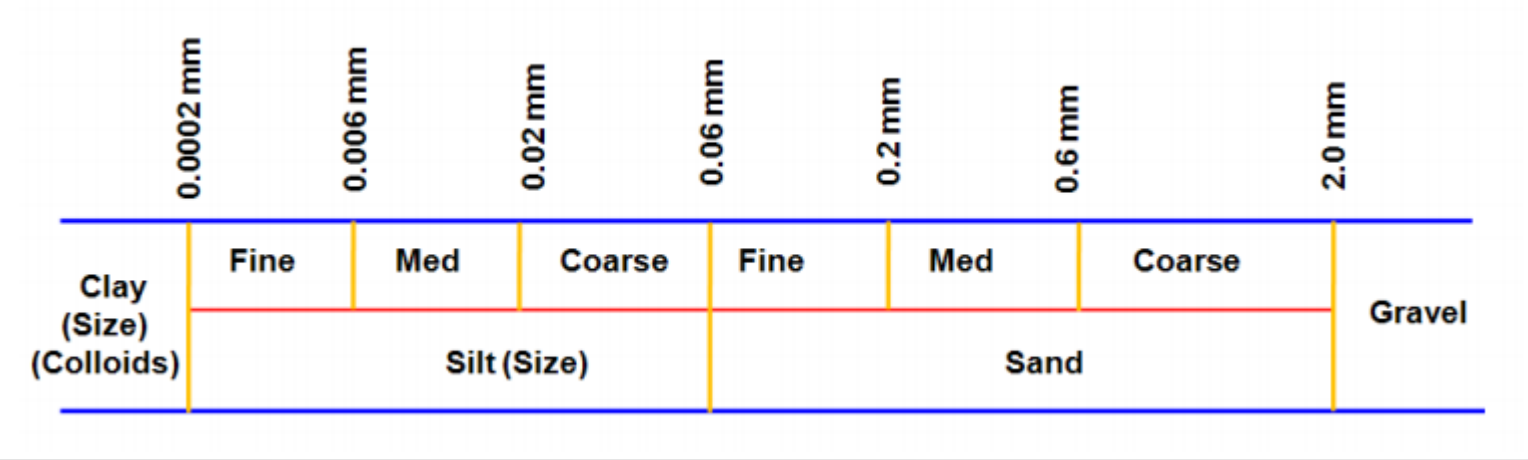


Classificação por tamanho das partículas

ABNT,DIN



MIT, BSI



Termos e Qualificações

Main terms		Qualifying terms	
GRAVEL	G	Well graded	W
SAND	S	Poorly graded	P
		Uniform	Pu
		Gap-graded	Pg
FINE SOIL, FINES	F	Of low plasticity ($w_L < 35$)	L
SILT (M-SOIL)	M	Of intermediate plasticity (w_L 35–50)	I
CLAY	C	Of high plasticity (w_L 50–70)	H
		Of very high plasticity (w_L 70–90)	V
		Of extremely high plasticity ($w_L > 90$)	E
		Of upper plasticity range ($w_L > 35$)	U
PEAT	Pt	Organic (may be a suffix to any group)	O

Craig (1997)

O solo como um material de engenharia

O solo significa coisas diferentes dependendo de quem defina:

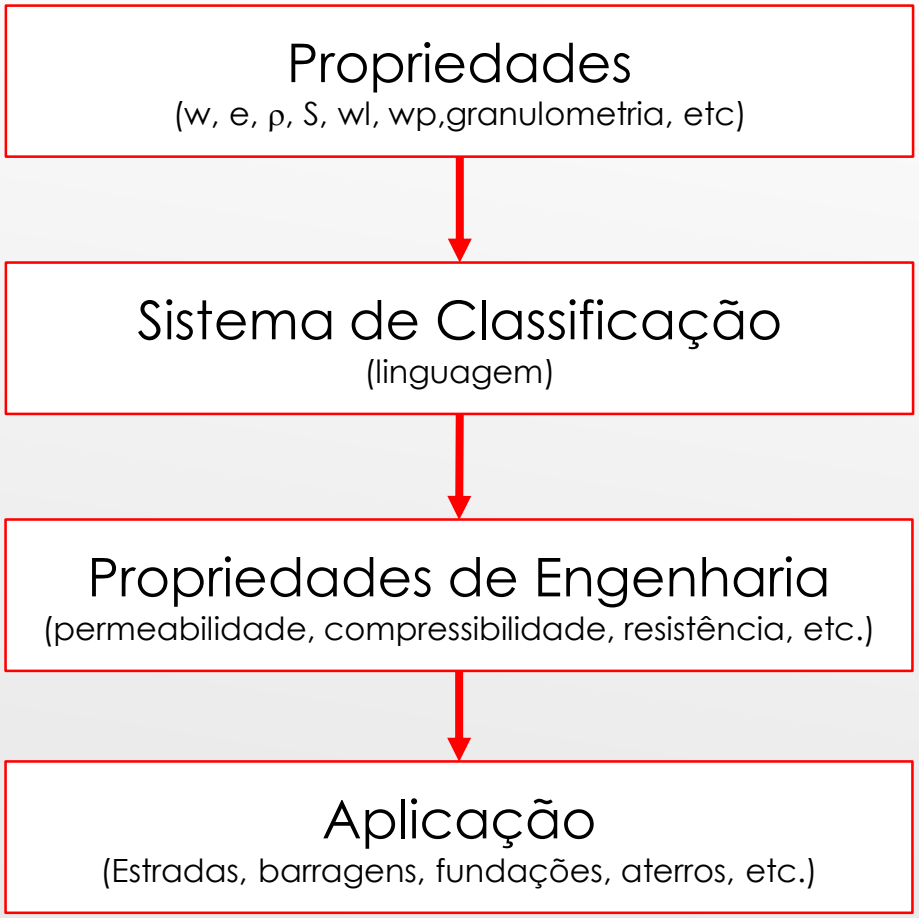
Para um geólogo – Solo é o produto de um processo pregresso ocorrido na superfície.

Para o pedólogo – Solo representa a conseqüência de processos físico-químicos que estão acontecendo.

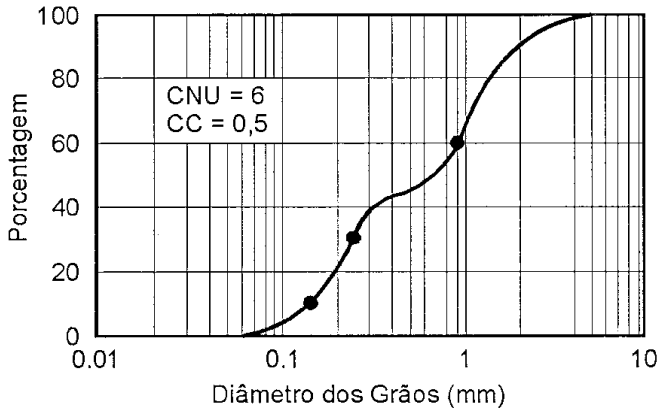
Para o engenheiro – é uma material onde se pode:

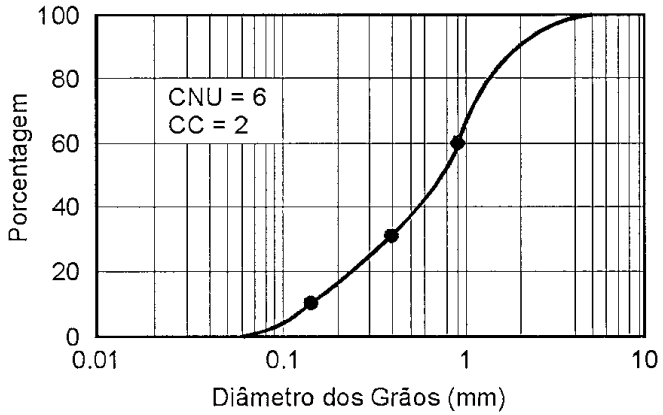
- Construir sobre e dentro dele
- Construir com ele

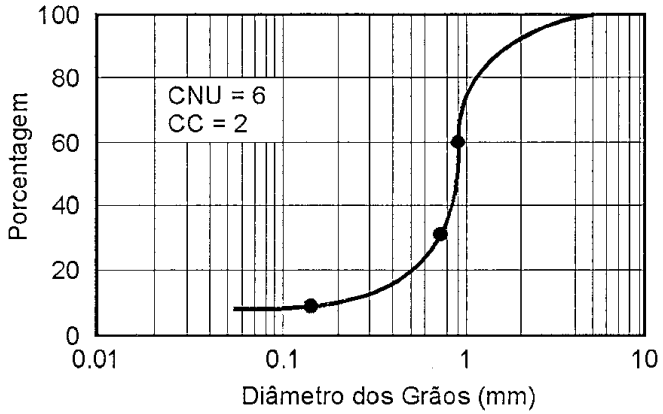
Papel do sistema de classificação na engenharia



Modificado de Holtz & Kovacs (1981)







$$C_U = \frac{D_{60}}{D_{10}} = CNU$$

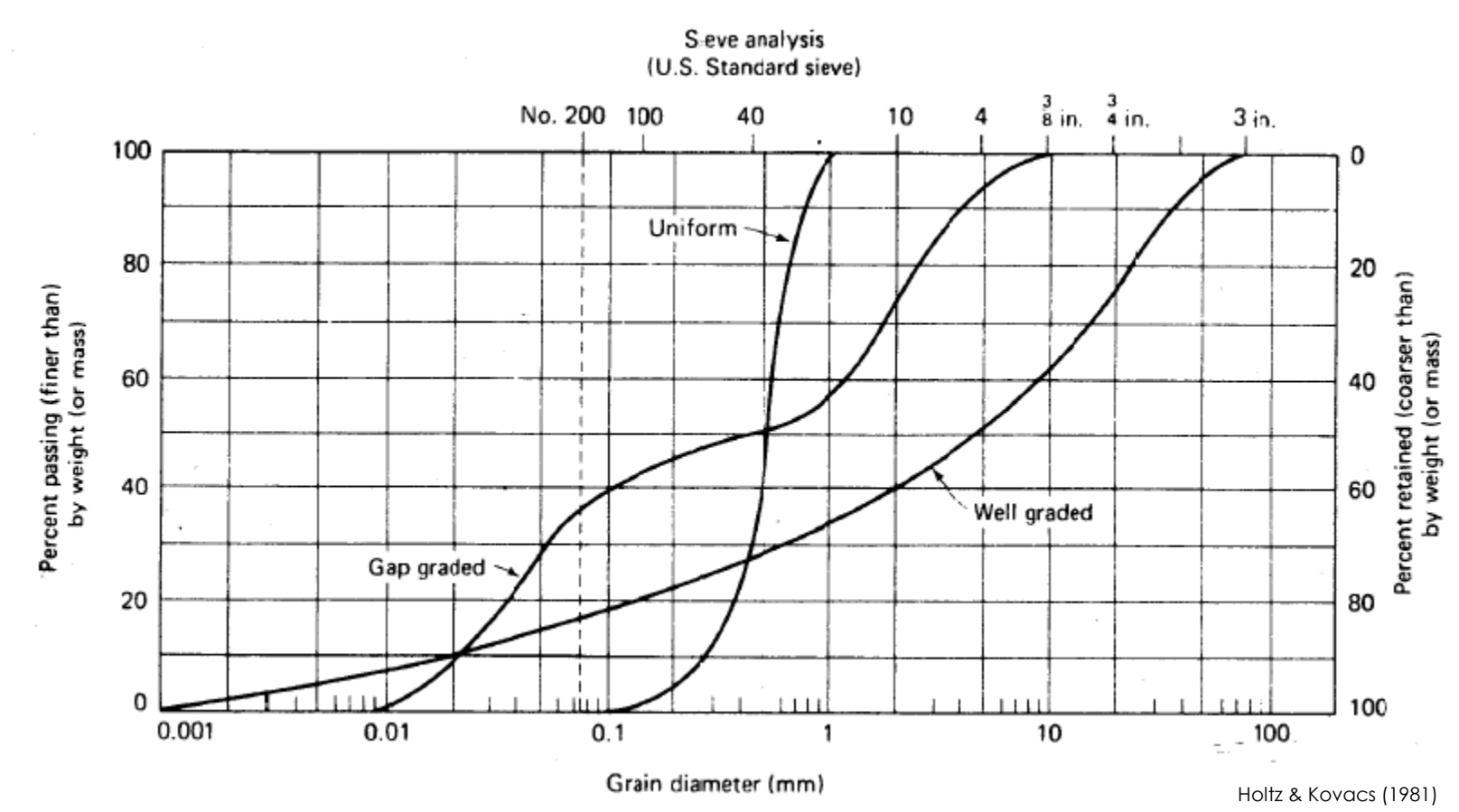
- **Quanto maior o CNU mais bem graduada e a areia.**
- **Areias com CNU menor que 2 são chamadas uniformes.**

$$C_Z = \frac{(D_{30})^2}{D_{10} D_{60}} = CC$$

- **O material é bem graduado quando CC está entre 1 e 3.**
- **Quando CC é menor do que 1 a curva é descontínua.**
- **Quando CC é maior do que 3 a curva tende a ser muito uniforme na parte central.**

Pinto (2000)

Distribuição granulométrica



Holtz & Kovacs (1981)

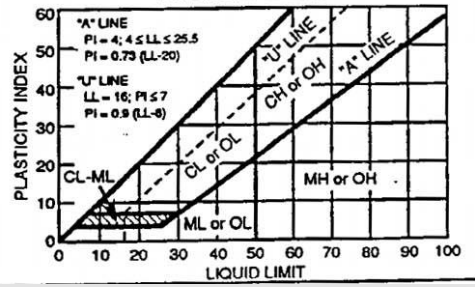
UNIFIED SOIL CLASSIFICATION SYSTEM

Soils are visually classified for engineering purposes by the Unified Soil Classification System. Grain-size analyses and Atterberg Limits tests often are performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. Graphic symbols are used on boring logs presented in this report. For a more detailed description of the system, see "Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)" ASTM Designation: 2488-84 and "Standard Test Method for Classification of Soils for Engineering Purposes" ASTM Designation: 2487-85.

MAJOR DIVISIONS				GRAPHIC SYMBOL	GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS Less than 50% passes No. 200 sieve)	GRAVELS (50% or less of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures
					GP	Poorly graded gravels, gravel-sand mixtures, or sand-gravel-cobble mixtures
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixtures
			Limits plot above "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixtures
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)			SW	Well graded sands, gravelly sands
					SP	Poorly graded sands, gravelly sands
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures
			Limits plot above "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS Limits plot below "A" line & hatched zone on plasticity chart	SILTS OF LOW PLASTICITY (Liquid Limit less than 50)			ML	Inorganic silts, clayey silts of low to medium plasticity
		SILTS OF HIGH PLASTICITY (Liquid Limit 50 or more)			MH	Inorganic silts, micaceous or diatomaceous silty soils, elastic silts
	CLAYS Limits plot above "A" line & hatched zone on plasticity chart	CLAYS OF LOW PLASTICITY (Liquid Limit less than 50)			CL	Inorganic clays of low to medium plasticity, gravelly, sandy, and silty clays
		CLAYS OF HIGH PLASTICITY (Liquid Limit 50 or more)			CH	Inorganic clays of high plasticity, fat clays, sandy clays of high plasticity
	ORGANIC SILTS AND CLAYS	ORGANIC SILTS AND CLAYS OF LOW PLASTICITY (Liquid Limit less than 50)			OL	Organic silts and clays of low to medium plasticity, sandy organic silts and clays
		ORGANIC SILTS AND CLAYS OF HIGH PLASTICITY (Liquid Limit 50 or more)			OH	Organic silts and clays of high plasticity, sandy organic silts and clays
ORGANIC SOILS		PRIMARILY ORGANIC MATTER (dark in color and organic odor)			PT	Peat

NOTE: Coarse-grained soils with between 5% and 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone on the plasticity chart have dual classifications.

PLASTICITY CHART



DEFINITION OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Boulders	Above 12 in.
Cobbles	12 in. to 3 in.
Gravel	3 in. to No. 4 sieve
Coarse gravel	3 in. to 3/4 in.
Fine gravel	3/4 in. to No. 4 sieve
Sand	No. 4 to No. 200 sieve
Coarse sand	No. 4 to No. 10 sieve
Medium sand	No. 10 to No. 40 sieve
Fine sand	No. 40 to No. 200 sieve
Fines (silt and clay)	Less than No. 200 sieve

Classificação Unificada para Solos

Name			Group Symbols	Laboratory criteria			
				Fines (%)	Grading	Plasticity	Notes
Coarse grained (more than 50% larger than 63 μm BS or No. 200 US sieve size)	Gravels (more than 50% of coarse fraction of gravel size)	Well graded gravels, sandy gravels, with little or no fines	GW	0–5	$C_U > 4$ $1 < C_Z < 3$		Dual symbols if 5–12% fines. Dual symbols if above A-line and $4 < I_P < 7$
		Poorly graded gravels, sandy gravels, with little or no fines	GP	0–5	Not satisfying GW requirements		
		Silty gravels, silty sandy gravels	GM	>12		Below A-line or $I_P < 4$	
		Clayey gravels, clayey sandy gravels	GC	>12		Above A-line and $I_P > 7$	
	Sands (more than 50% of coarse fraction of sand size)	Well graded sands, gravelly sands, with little or no fines	SW	0–5	$C_U > 6$ $1 < C_Z < 3$		
		Poorly graded sands, gravelly sands, with little or no fines	SP	0–5	Not satisfying SW requirements		
		Silty sands	SM	>12		Below A-line or $I_P < 4$	
		Clayey sands	SC	>12		Above A-line and $I_P > 7$	

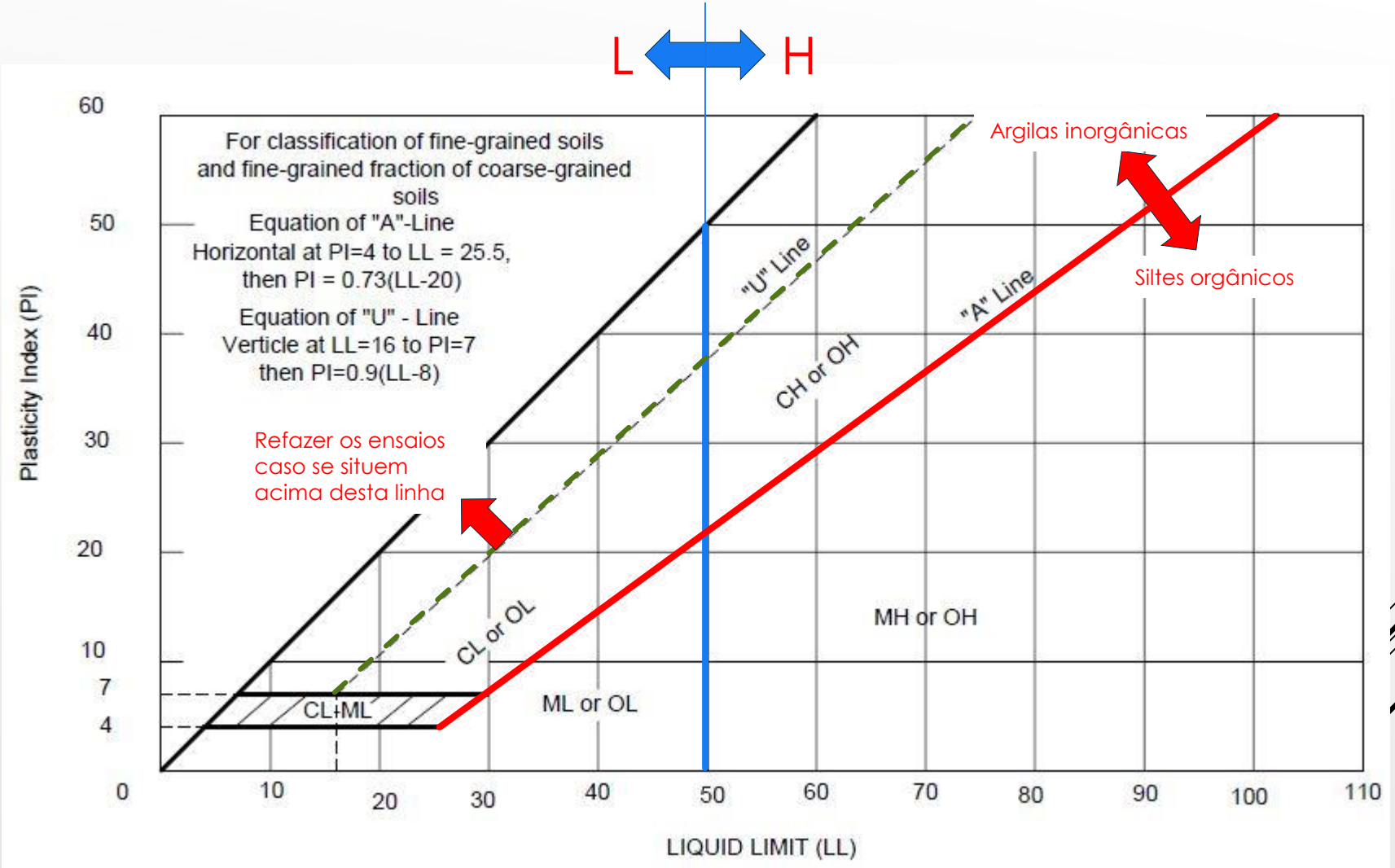
Craig (1997)

Classificação Unificada para Solos

Name			Group Symbols	Laboratory criteria
Fine grained (more than 50% smaller than 63 μm BS or No. 200 US sieve size)	Silts and clays (liquid limit less than 50)	Inorganic silts, silty or clayey fine sands, with slight plasticity	ML	Use plasticity chart
		Inorganic clays, silty clays, sandy clays of low plasticity	CL	Use plasticity chart
		Organic silts and organic silty clays of low plasticity	OL	Use plasticity chart
	Silts and clays (liquid limit greater than 50)	Inorganic silts of high plasticity	MH	Use plasticity chart
		Inorganic clays of high plasticity	CH	Use plasticity chart
		Organic clays of high plasticity	OH	Use plasticity chart
Highly organic soils		Peat and other highly organic soils	Pt	

Craig (1997)

Carta de Plasticidade



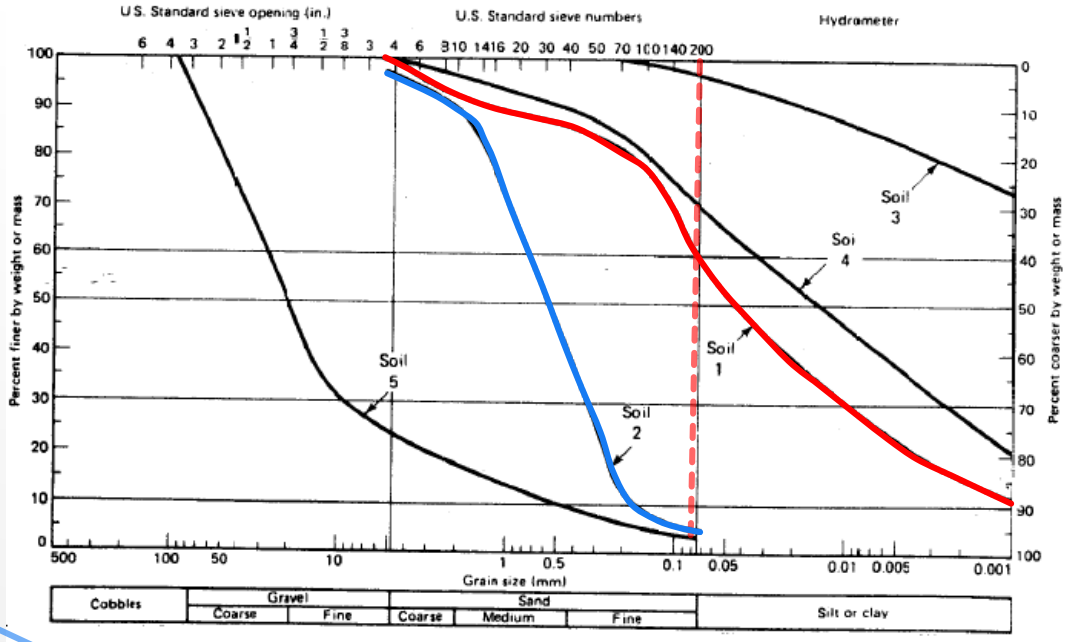
http://epg.modot.org/index.php?title=Image:321.2.11.2_Plasticity_Chart.jpg

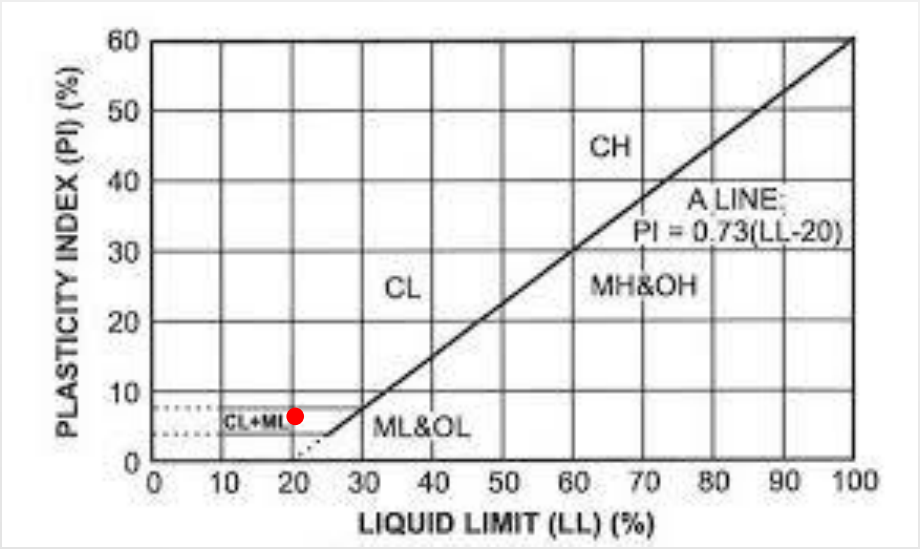
Exemplo

Sieve Size	Soil 1, % Finer	Soil 2, % Finer	Soil 3, % Finer
No. 4	99	97	100
No. 10	92	90	100
No. 40	86	40	100
No. 100	78	8	99
No. 200	60	5	97
LL	20	—	124
PL	15	—	47
PI	5	NP*	77

*Nonplastic.

+50% passa na #200
Necessita dos limites para classificar





Name			Group Symbols	Laboratory criteria			
				Fines (%)	Grading	Plasticity	Notes
Coarse grained (more than 50% larger than 63 µm BS or No. 200 US sieve size)	Gravels (more than 50% of coarse fraction of gravel size)	Well graded gravels, sandy gravels, with little or no fines	GW	0–5	$C_U > 4$ $1 < C_Z < 3$		Dual symbols if 5–12% fines. Dual symbols if above *A*-line and $4 < I_P < 7$
		Poorly graded gravels, sandy gravels, with little or no fines	GP	0–5	Not satisfying GW requirements		
		Silty gravels, silty sandy gravels	GM	>12		Below *A*-line or $I_P < 4$	
		Clayey gravels, clayey sandy gravels	GC	>12		Above *A*-line and $I_P > 7$	
	Sands (more than 50% of coarse fraction of sand size)	Well graded sands, gravelly sands, with little or no fines	SW	0–5	$C_U > 6$ $1 < C_Z < 3$		
		Poorly graded sands, gravelly sands, with little or no fines	SP	0–5	Not satisfying SW requirements		
		Silty sands	SM	>12		Below *A*-line or $I_P < 4$	
		Clayey sands	SC	>12		Above *A*-line and $I_P > 7$	

Cu = 3.9
Cz = 0.91

Table B-3. Characteristics of soil groups pertaining to roads and airfields

Major Divisions (1)	(2)	Letter (3)	Symbols: Hatching (4)	Symbols: Color (5)	Name (6)	Value As Subgrade When not Subject to Frost Action (7)	Value As Subbase When not Subject to Frost Action (8)
Coarse-Grained Soils	Gravel and Gravelly Soils	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Excellent
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Good
		GM d		Yellow	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Good
		GM u				Good	Fair
		GC			Clayey gravels, gravel-sand-clay mixtures	Good	Fair
	Sand and Sandy Soils	SW		Red	Well-graded sands or gravelly sands, little or no fines	Good	Fair to good
		SP			Poorly graded sands or gravelly sands, little or no fines	Fair to good	Fair
		SM d		Yellow	Silty sands, sand-silt mixtures	Fair to good	Fair to good
		SM u				Fair	Poor to fair
		SC			Clayey sands, sand-silt mixtures	Poor to fair	Poor
Fine-Grained Soils	Silts and Clays LL < 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor to fair	Not suitable
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Poor to fair	Not suitable
		OL			Organic silts and organic silt-clays of low plasticity	Poor	Not suitable
	Silts and Clays LL ≥ 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable
		CH			Inorganic clays of high plasticity, fat clays	Poor to fair	Not suitable
		OH			Organic clays of medium to high plasticity, organic silts	Poor to very poor	Not suitable
Highly Organic Soils		Pt		Orange	Peat and other highly-organic soils	Not suitable	Not suitable

NOTES: 1. Divisions of the GM and SM groups (column 3) into subdivisions of d and u are applicable to roads and airfields only. Subdivision is based on the LL and PI; suffix d (for example, GMd) will be used when the LL is 25 or less and the PI is 5 or less; the suffix u will be used otherwise.

http://www.areforum.org/guest/General%20Structures/USCS.pdf

Table B-4. Terzaghi classification

Unconfined Compressive Strength (Tons/Sq Ft)	Consistency
< 0.25	Very soft
0.25 to 0.50	Soft
0.50 to 1.00	Medium
1.00 to 2.00	Stiff
2.00 to 4.00	Very stiff
> 4.00	Hard

http://www.areforum.org/guest/General%20Structures/USCS.pdf

Table B-2. Characteristics of soil groups pertaining to embankments and foundations

Major Divisions (1)	(2)	Letter (3)	Symbols Hatching (4)	Symbols Color (5)	Name (6)	Value for Embankments (7)	Permeability cm per sec (8)
Coarse-Grained Soils	Gravel and Gravelly Soils	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Very stable, pervious shells of dikes and dams	$k > 10^{-2}$
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Reasonably stable, pervious shells of dikes and dams	$k > 10^{-2}$
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets	$k = 10^{-3}$ to 10^{-6}
		GC			Clayey gravels, gravel-sand-clay mixtures	Fairly stable, may be used for impervious core	$k = 10^{-6}$ to 10^{-8}
	Sand and Sandy Soils	SW		Red	Well-graded sands or gravelly sands, little or no fines	Very stable, pervious sections, slope protection required	$k > 10^{-3}$
		SP			Poorly graded sands or gravelly sands, little or no fines	Reasonably stable, may be used in dike section with flat slopes	$k > 10^{-3}$
		SM		Yellow	Silty sands, sand-silt mixtures	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes	$k = 10^{-3}$ to 10^{-6}
		SC			Clayey sands, sand-silt mixtures	Fairly stable, use for impervious core or flood-control structures	$k = 10^{-6}$ to 10^{-8}
Fine-Grained Soils	Silts and Clays LL < 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor stability, may be used for embankments with proper control	$k = 10^{-3}$ to 10^{-6}
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Stable, impervious cores and blankets	$k = 10^{-6}$ to 10^{-8}
		OL			Organic silts and organic silt-clays of low plasticity	Not suitable for embankments	$k = 10^{-4}$ to 10^{-6}
	Silts and Clays LL ≥ 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor stability, core of hydraulic-fill dam, not desirable in rolled-fill construction	$k = 10^{-4}$ to 10^{-6}
		CH			Inorganic clays of high plasticity, fat clays	Fair stability with flat slopes, thin cores, blankets and dike sections	$k = 10^{-6}$ to 10^{-8}
		OH			Organic clays of medium to high plasticity, organic silts	Not suitable for embankments	$k = 10^{-6}$ to 10^{-8}
Highly Organic Soils		Pt		Orange	Peat and other highly organic soils	Not used for construction	

NOTES: 1. Values in columns 7 and 11 are for guidance only. Design should be based on actual test results.
2. The equipment listed in column 9 will usually produce the desired densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.
3. The range of dry unit weights listed in column 10 are for compacted soil at OMC when using the Standard Proctor Test (ASTM 1557-91).

http://www.areforum.org/guest/General%20Structures/USCS.pdf

Table B-2. Characteristics of soil groups pertaining to embankments and foundations (continued)

Compaction Characteristics (9)	Max Dry Unit Weight Std Proctor (pcf) (10)	Value for Foundations (11)	Requirements for Seepage Control (12)
Good; tractor, rubber-tired, or steel-wheeled roller	125 -135	Good bearing value	Positive cutoff
Good; tractor, rubber-tired, or steel-wheeled roller	115 -125	Good bearing value	Positive cutoff
Good; with close control; rubber-tired or sheepsfoot roller	120 -135	Good bearing value	Toe trench to none
Fair; rubber-tired or sheepsfoot roller	115 -130	Good bearing value	None
Good; tractor	110 -130	Good bearing value	Upstream blanket and toe drainage or wells
Good; tractor	100 -120	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
Good with close control; rubber-tired or sheepsfoot roller	110 -125	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
Fair; sheepsfoot or rubber-tired roller	105 -125	Good to poor bearing value	None
Good to poor; close control essential; rubber-tired or sheepsfoot roller	95 -120	Very poor, susceptible to liquefaction	Toe trench to none
Fair to poor; sheepsfoot or rubber-tired roller	95 -120	Good to poor bearing value	None
Fair to poor; sheepsfoot roller	80 -100	Fair to poor bearing value, may have excessive settlements	None
Poor to very poor; sheepsfoot roller	70 - 95	Poor bearing value	None
Fair to poor; sheepsfoot roller	75 -105	Fair to poor bearing value	None
Poor to very poor; sheepsfoot roller	65 - 100	Very poor bearing value	None
Compaction not practical		Remove from foundations	

http://www.areforum.org/guest/General%20Structures/USCS.pdf

Caracterização das Argilas e Areias

Comportamento das Argilas

- Estrutura
- Índice de vazios

Sensibilidade das argilas (Índice de estrutura)

Ensaio de compressão simples (não confinada)

- Indeformado → R_I
- Remoldado → R_R

$$Sensibilidade(S) = \frac{R_I}{R_R}$$

S	Classificação
1	Insensível
1 a 2	Baixa sensibilidade
2 a 4	Média sensibilidade
4 a 8	Sensível
>8	Ultra-sensível

Consistência

Índice de consistência

$$IC = \frac{LL - w}{LL - LP}$$

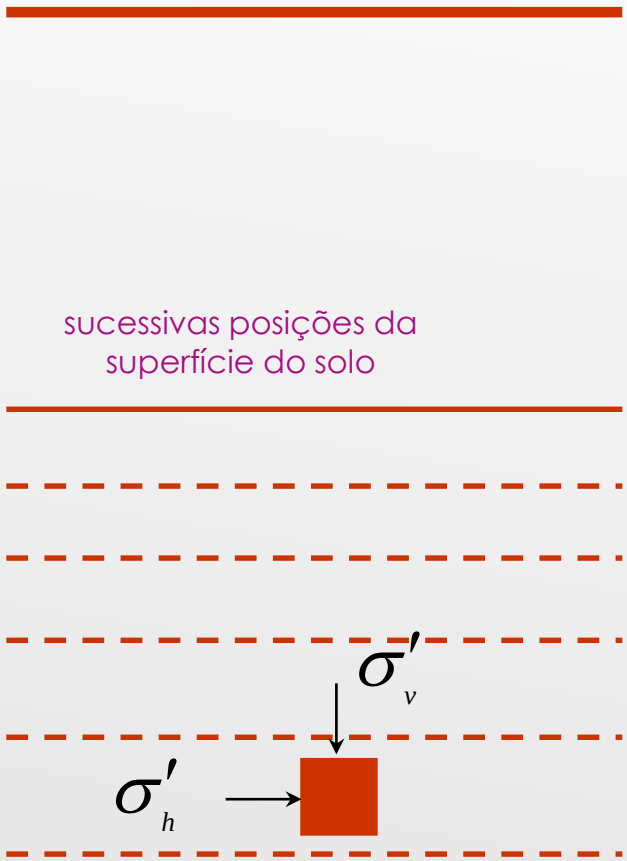
Índice de liquidez

$$IL = \frac{w - LP}{LL - LP}$$

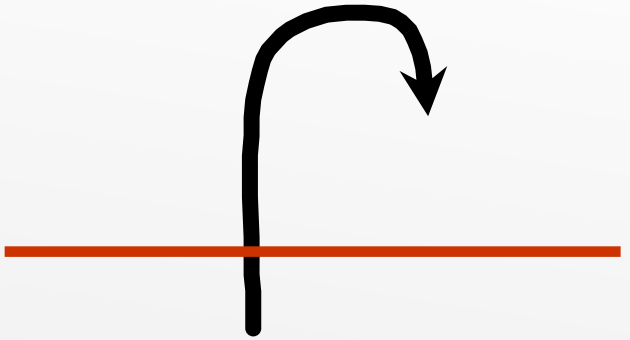
Ensaio de compressão simples (não confinada)

Consistência	Resistência (kPa)	IC
Muito mole	< 25	
Mole	25 a 50	< 0,5
Média	50 a 100	0,5 a 0,75
Rija	100 a 200	0,75 a 1,0
Muito rija	200 a 400	> 1,0
Dura	> 400	

Formação das Argilas



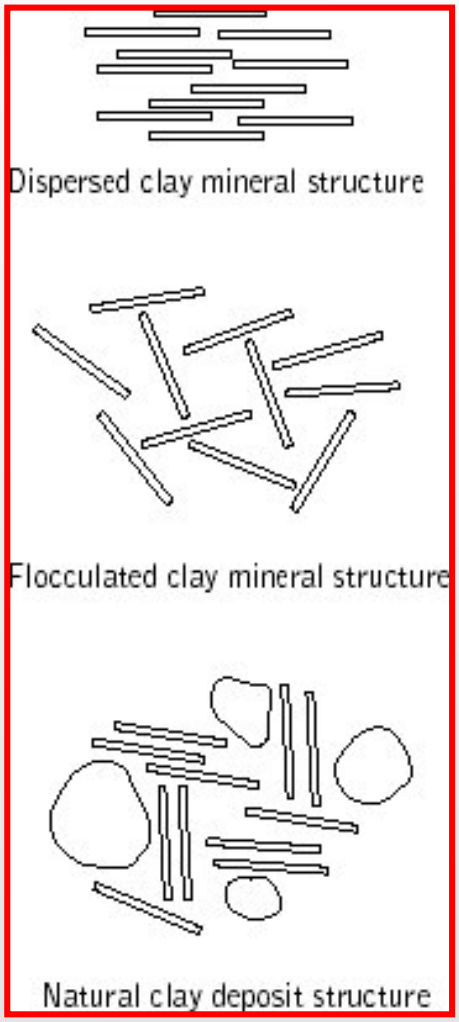
deposição
(normalmente adensado)

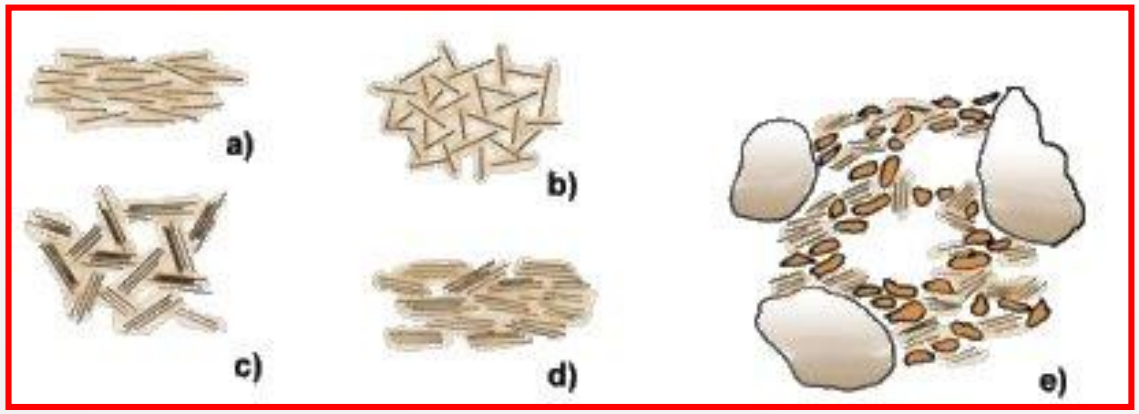


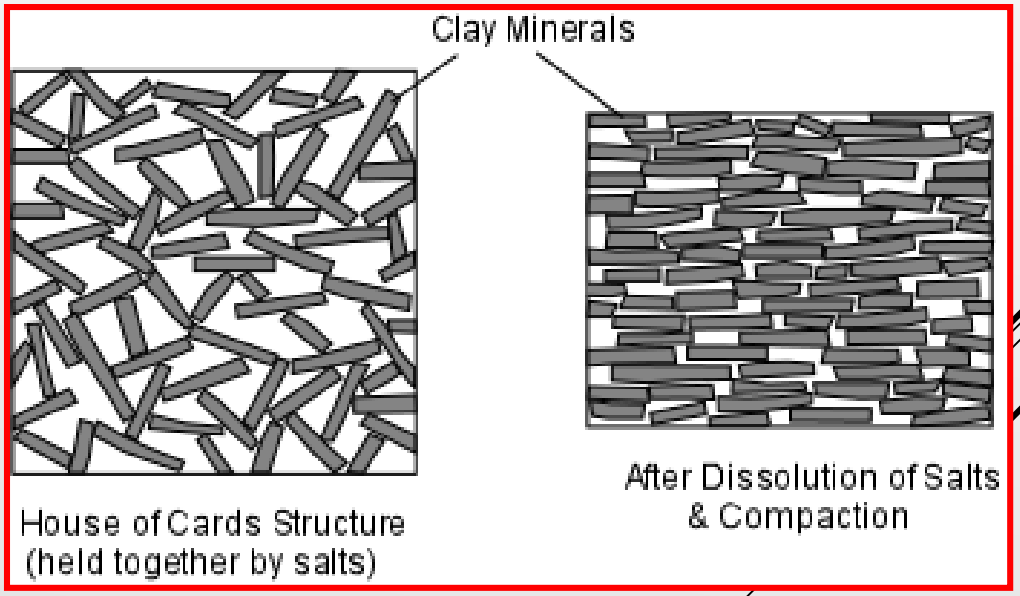
erosão
(sobre-adensado)

- **Variabilidade natural dos solos**
- **Variabilidades nos procedimentos (detalhes) dos ensaios**

Sensibilidade das Argilas





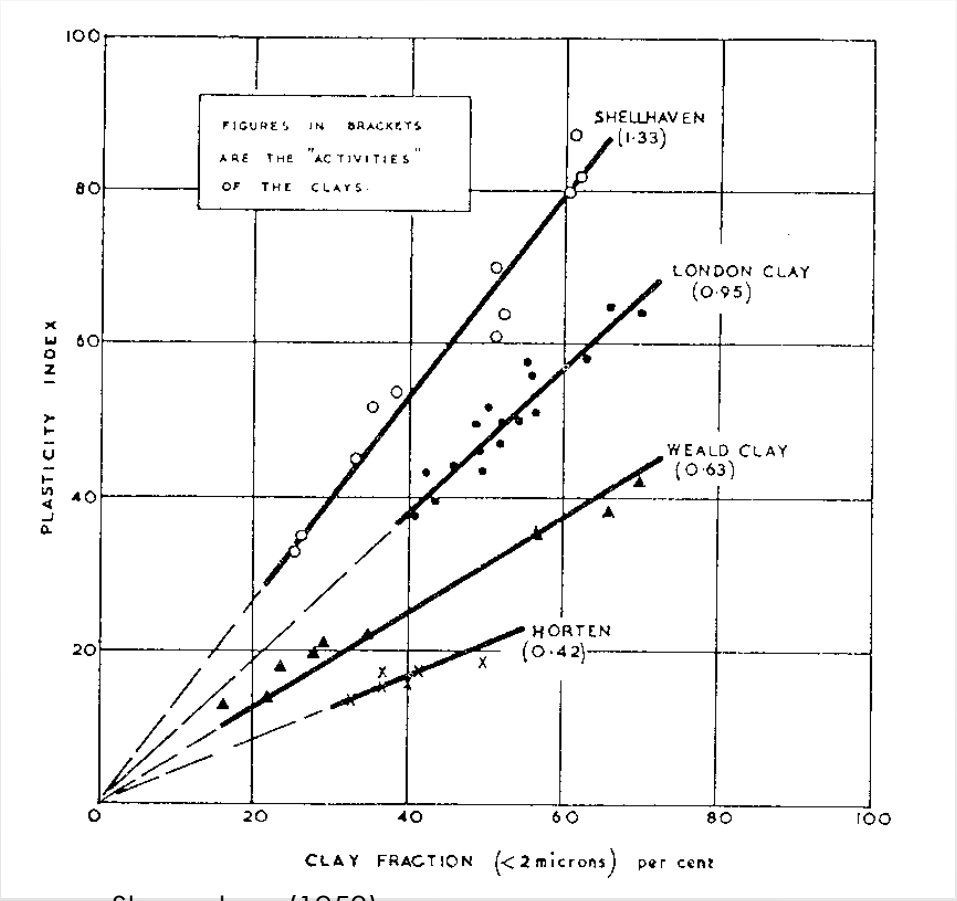


http://www.tulane.edu/~sanelson/geol204/slopestability.htm

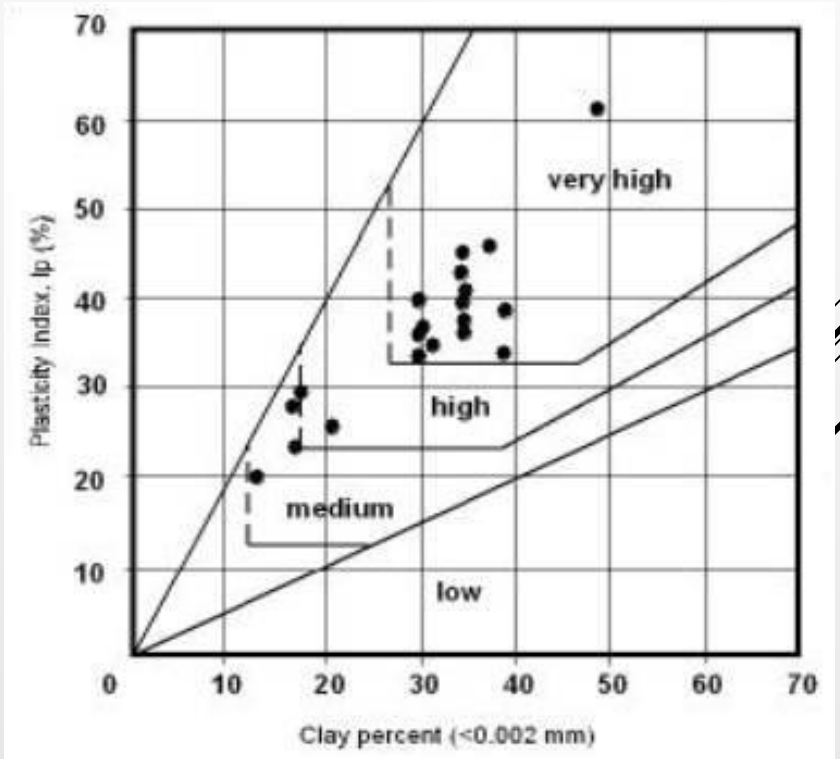
http://www.ngi.no/en/Areas-of-research-and-development/Soil-and-rock-slides/The-Quick-Clay-Landslide-at-Rissa---1978/

Atividade de uma Argila

$$\text{Índice de Atividade} = \frac{\text{Índice de plasticidade } (I_p)}{\text{Fração Argila } (< 0.002mm)}$$

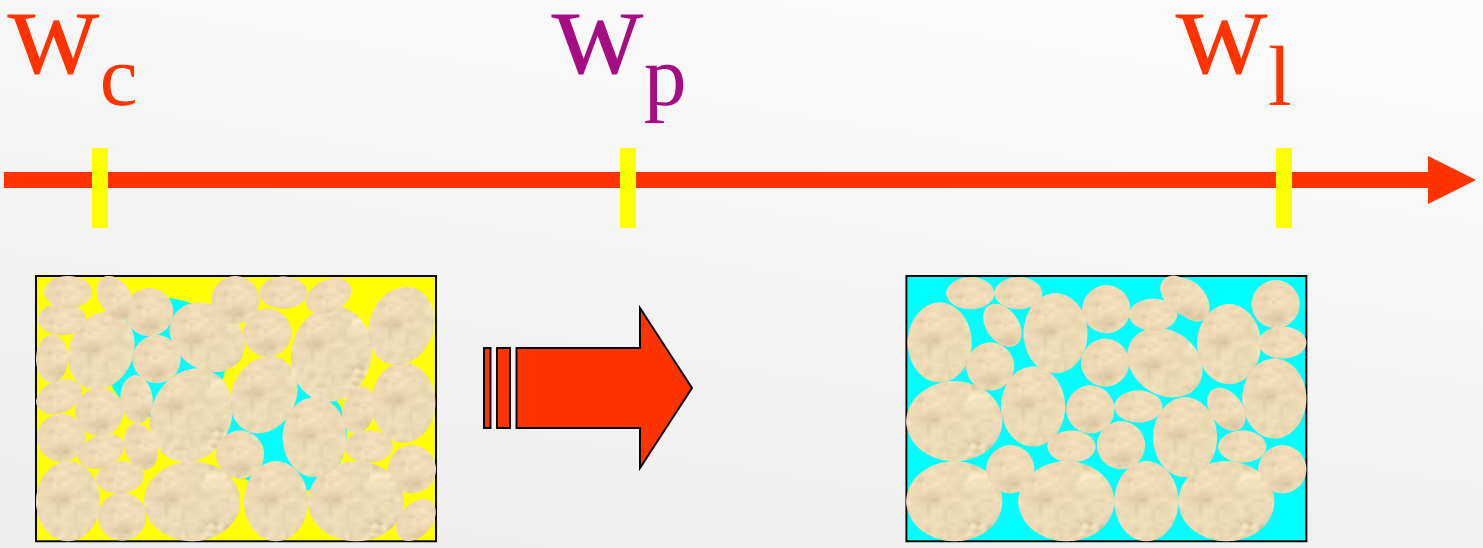


Skempton (1953)



Ylmaz & Erzin (2004)

Limites de Aterberg



$$e = \frac{V_v}{V_s}$$

$$Se = wG$$

$$S = \frac{V_w}{V_v}$$

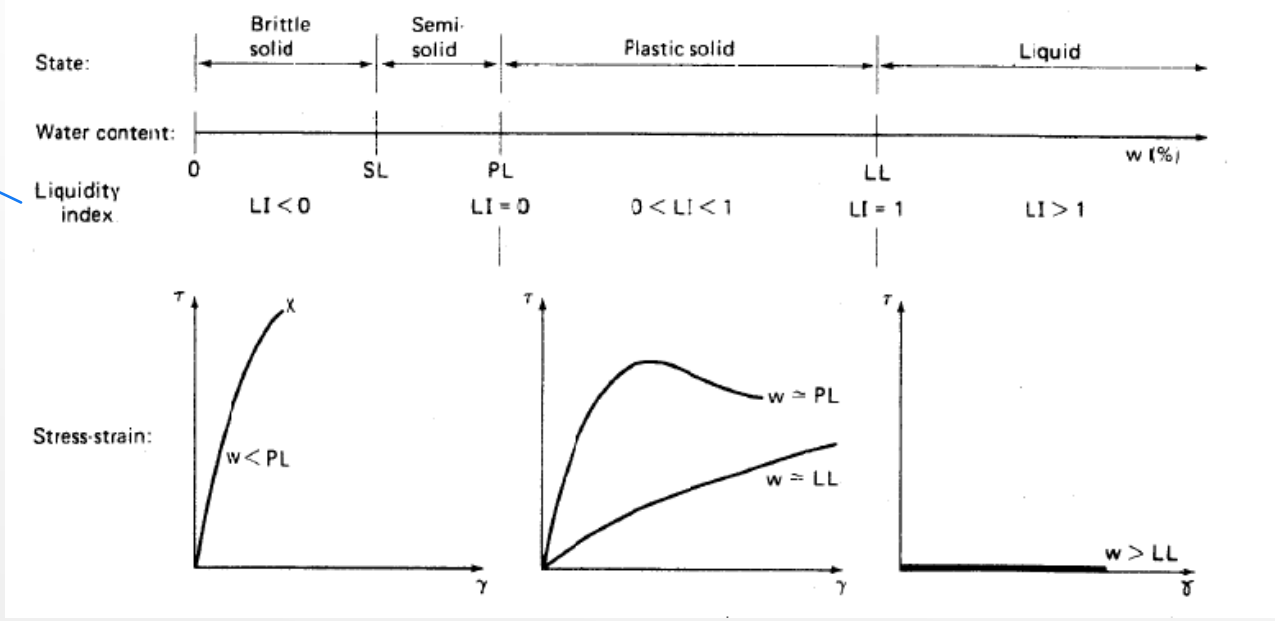
Índice de Consistência

$$IC = \frac{LL - w}{LL - LP}$$

Índice de Liquidez

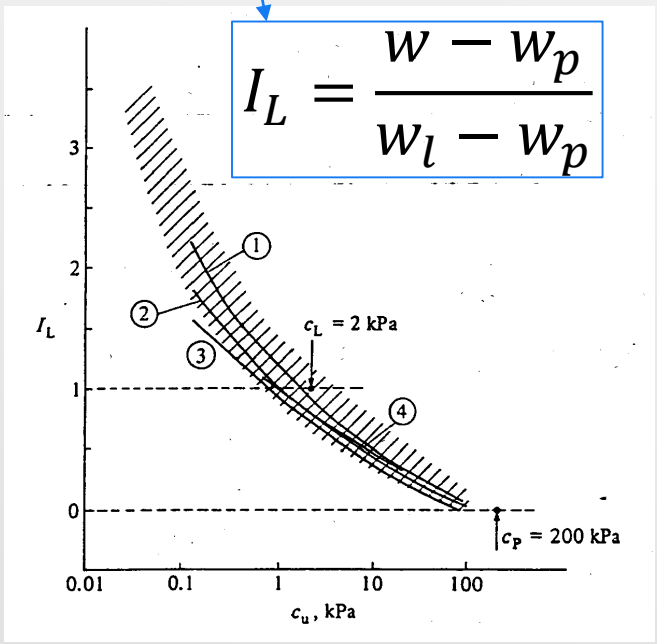
$$IL = \frac{w - LP}{LL - LP}$$

Estados do solo e sua relação tensão deformação



Holtz & Kovacs (1981)

$$I_L = \frac{w - w_p}{w_l - w_p}$$



Muir Wood (1990)

Comportamento das Areias

- Forma dos Grãos
- Compacidade
- Distribuição granulométrica

Compacidade → Índice de vazios → Máximo, Mínimo

	Máximo	Mínimo
Areia uniforme de grãos angulares	1,1	0,70
Areia bem graduada de grãos angulares	0,75	0,45
Areia uniforme de grãos arredondados	0,75	0,45
Areia bem graduada de graõs arredondados	0,65	0,35

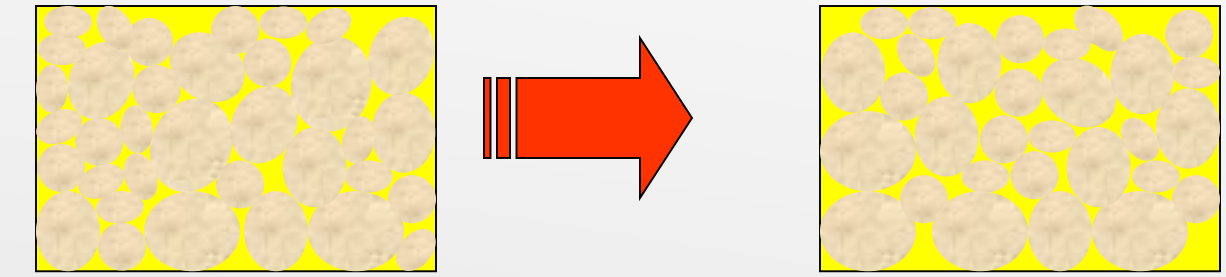
Índice de Compacidade Relativa

$$CR = \frac{e_{max} - e_{nat}}{e_{max} - e_{min}}$$

	CR
Areia fofa	< 0,33
Areia de compacidade média	0,33 a 0,66
Areia compacta	> 0,66

Índice de Vazios Máximo e Mínimo de Areias

e_{min} e_{nat} e_{max}



$$e = \frac{V_v}{V_s}$$

Compacidade Relativa

$$CR = \frac{e_{max} - e_{nat}}{e_{max} - e_{min}}$$