

# Curva de Retenção

Capacidade de Retenção  
de  
Líquidos em Meios Porosos

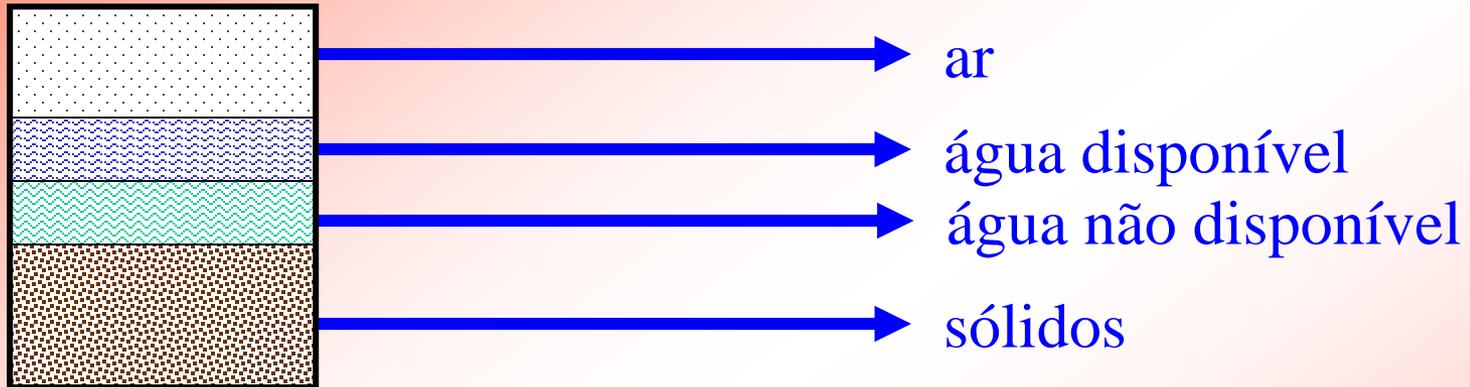
2017

# Curva de retenção de água

(Curva característica da relação solo-água)

- A curva de retenção é uma relação constitutiva fundamental na mecânica dos solos não saturados
- A curva de retenção descreve a relação entre a sucção do solo e a quantidade de água presente nele.
- A relação pode ser definida em termos de sucção total ou matricial

## Relações Importantes de volume - massa - peso



Índice de vazios

$$e = \frac{V_a + V_w}{V_s}$$

Porosidade

$$n = \frac{V_a + V_w}{V_t}$$

Densidade seca

$$\rho_d = \frac{V_s \rho_s}{V_t} = \frac{M_s}{V_t}$$

# Teor de Umidade

- Gravimétrico
  - Geotécnico
  - Minério
- Volumétrico

Teor de umidade gravimétrico (geotécnico)

$$w_g = \frac{V_w \rho_w}{V_s \rho_s} = \frac{M_w}{M_s}$$

Teor de umidade gravimétrico (minério)

$$w_m = \frac{M_w}{M_t}$$

Teor de umidade volumétrico

$$\theta = \frac{V_w}{V_t} = \frac{w_g \rho_d}{\rho_w}$$

## Teor de umidade volumétrico

$$\theta = \frac{V_w}{V_t} = nS = w \frac{\rho_d}{\rho_w} = \gamma_s (1 - n)w$$

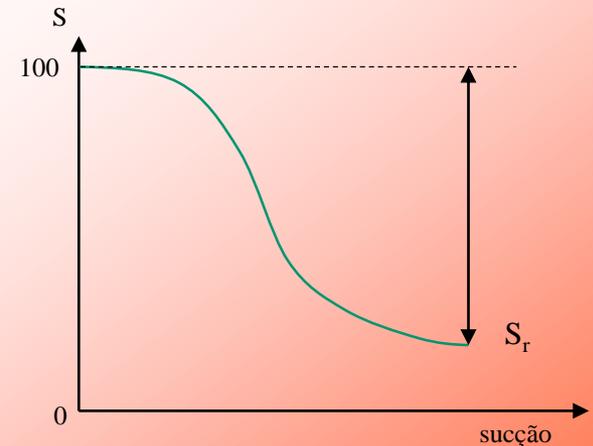
## Grau de saturação

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

$$S = \frac{\theta}{n} = \frac{\theta}{\theta_s}$$

## Grau de saturação efetivo

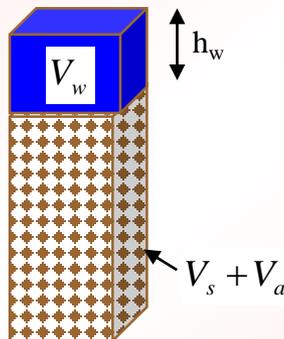
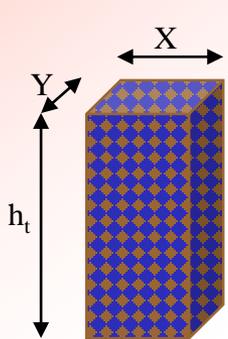
$$S_e = \frac{S - S_r}{100 - S_r}$$



# Porosidade Efetiva

$$n_e = (1 - S_r)n$$

Altura equivalente de água ( $h_w$ )



$$V_w = XYh_w$$

$$h_w = \frac{V_w}{XY}$$

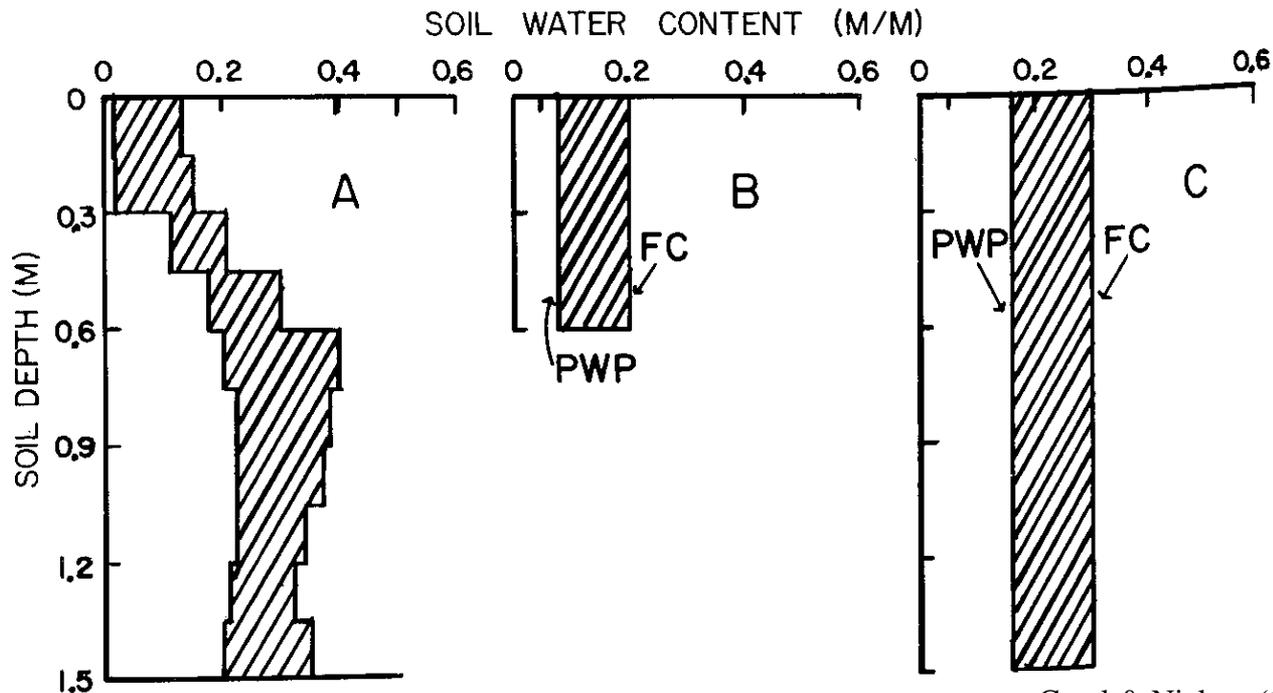
$$h_w = \frac{V_w h_t}{XY h_t} = \frac{V_w h_t}{V} = \theta h_t$$

$$h_w = \theta h_t$$

$h_t$  = altura total do solo

# Capacidade de Campo

- É o teor de umidade de um perfil de solo após a drenagem praticamente completa.
  - Afetado por: nível de água, estrutura, heterogeneidades.
- Em laboratório é obtida por meio da drenagem de uma amostra até a vazão de drenagem seja desprezível.



Casel & Nielsen (1986)



$\theta = 42\%$

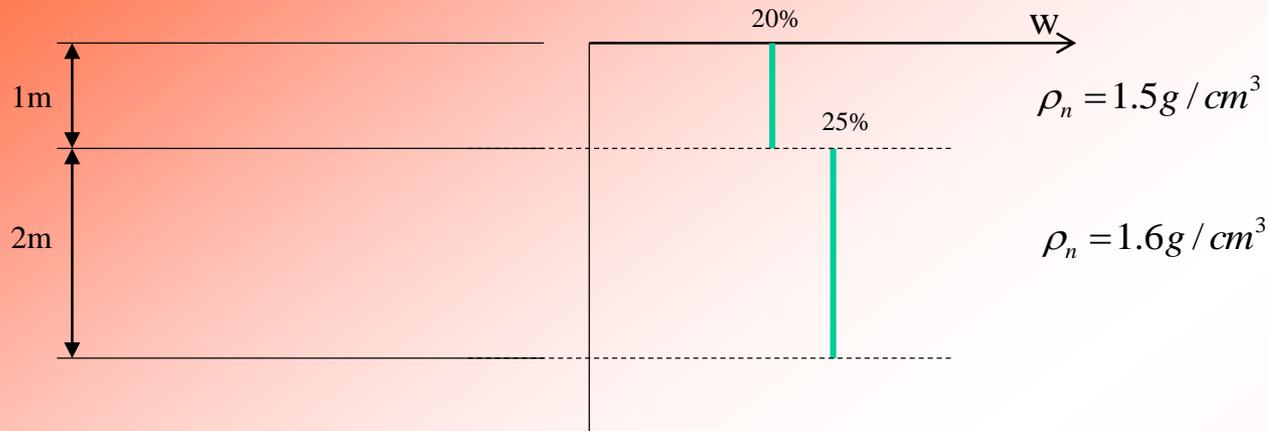


$\theta = 18\%$



$\theta = 13\%$

# Exercício



Qual a altura de água contida neste perfil?

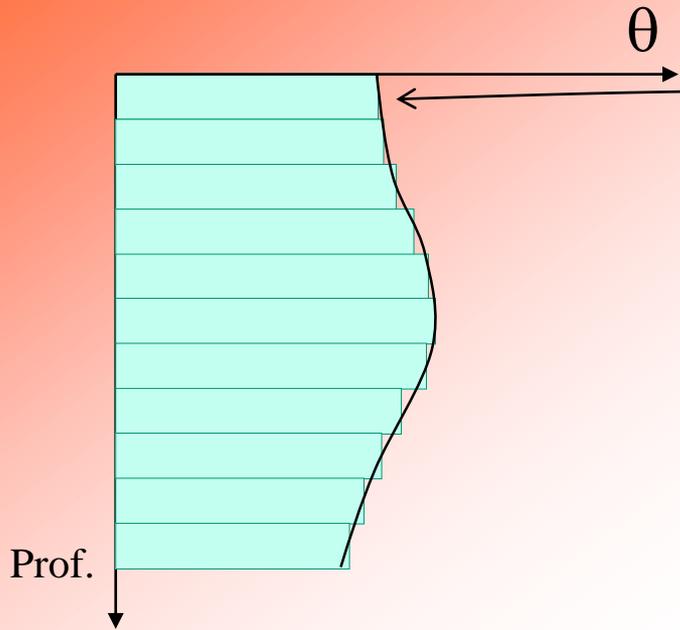
$$h_w = \theta h_t$$

$$h_{w-0-1m} = \frac{\rho_n}{\rho_w} w h_t = \frac{1.5}{1} * 0.2 * 100 = 30 \text{ cm} = 300 \text{ mm}$$

$$h_{w-1-3m} = \frac{\rho_n}{\rho_w} w h_t = \frac{1.6}{1} * 0.25 * 200 = 80 \text{ cm} = 800 \text{ mm}$$

$$\text{Total} = 1100 \text{ mm}$$

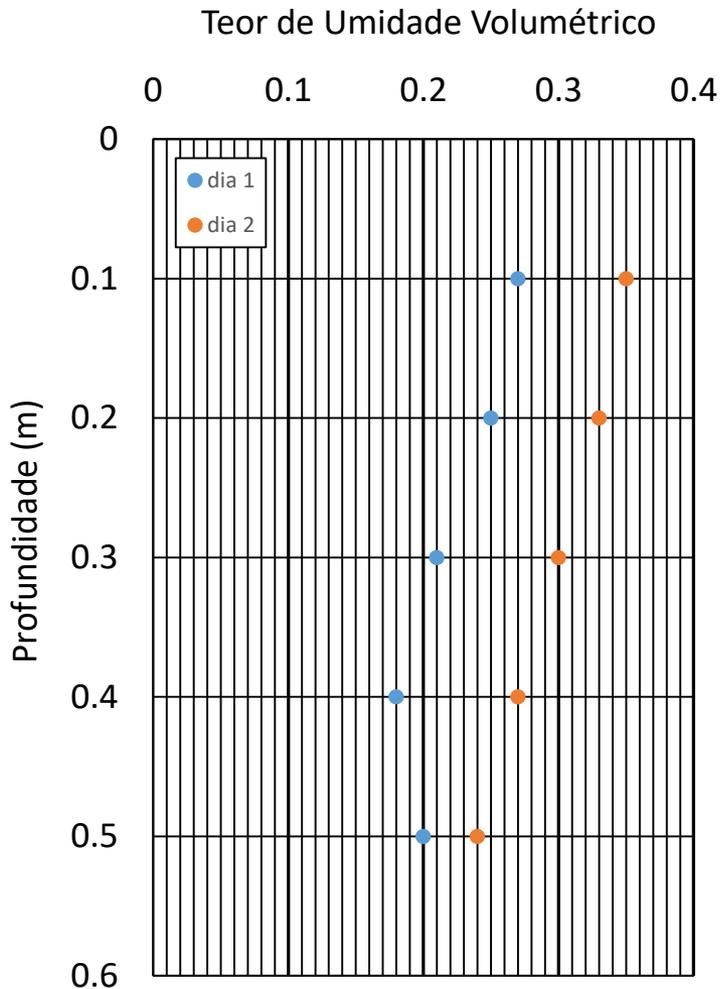
# Perfil de umidade



$$h_w \cong \theta_1 \Delta h_1 + \theta_2 \Delta h_2 + \theta_3 \Delta h_3 + \theta_4 \Delta h_4 \dots + \theta_n \Delta h_n$$

$$h_w \cong \sum_1^n \theta_n \Delta h_n$$

# Exercício



Dados de Libardi (2005)

Determinar a quantidade de água armazenada nos dois dias?

Qual a variação da quantidade de água nos dois dias?

Dia 1

$$h_{w-0-0.5m} = 114.5mm$$

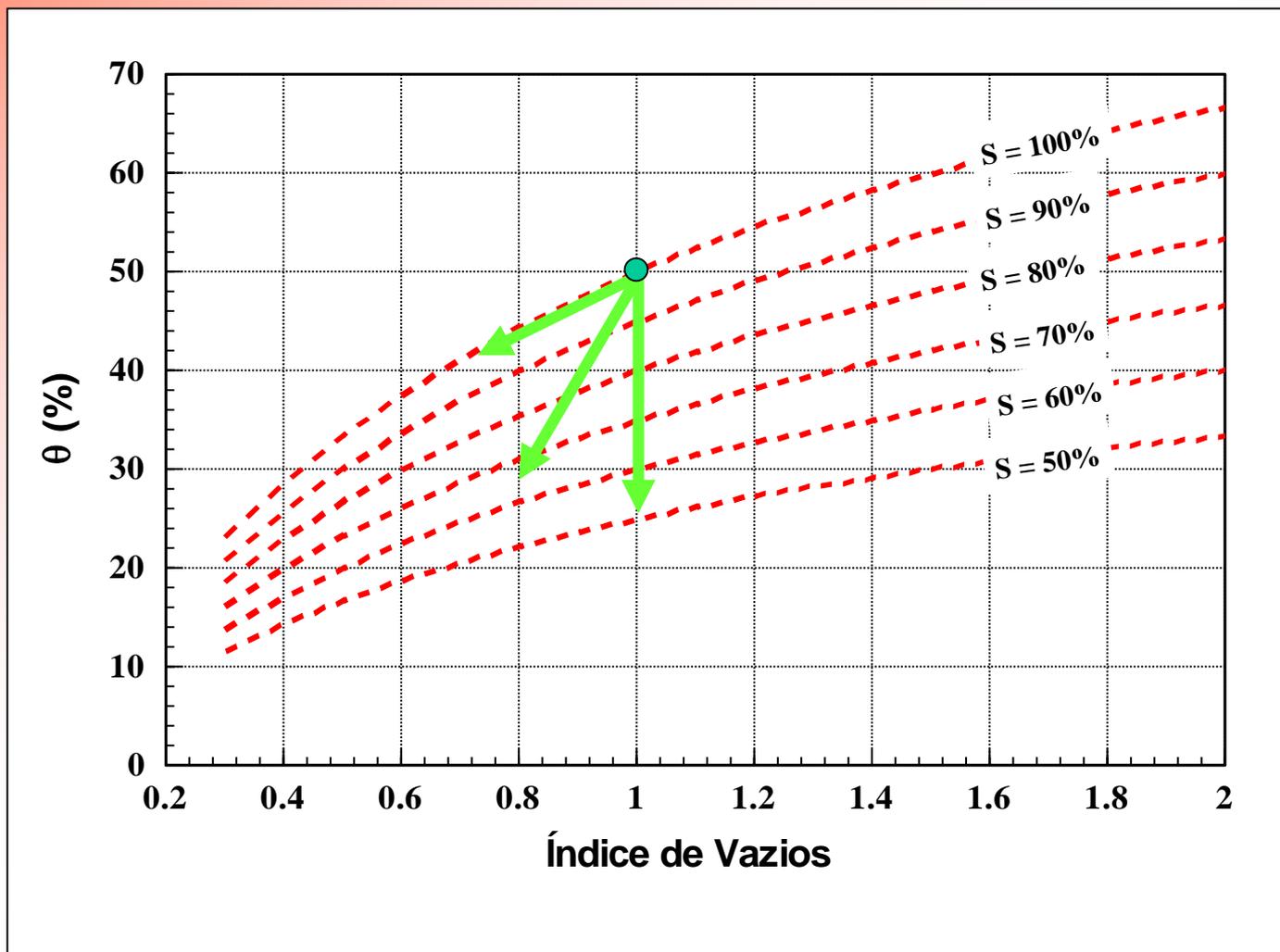
Dia 2

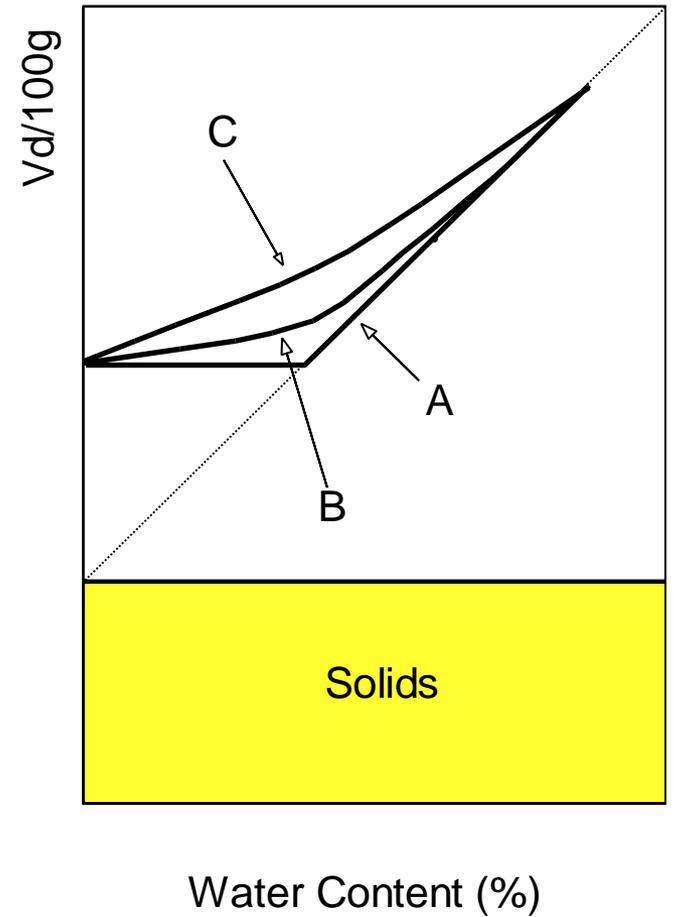
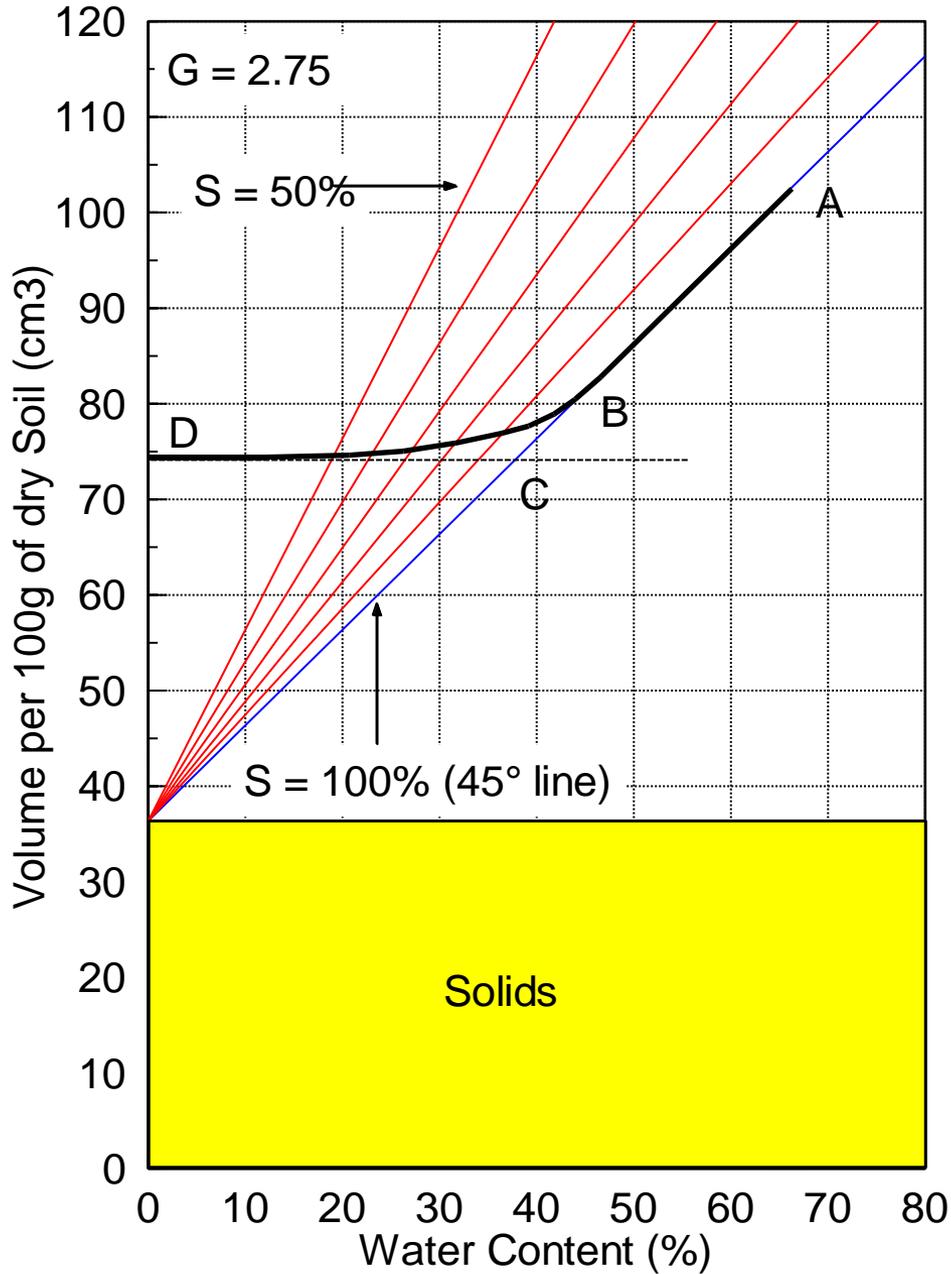
$$h_{w-0-0.5m} = 154.5mm$$

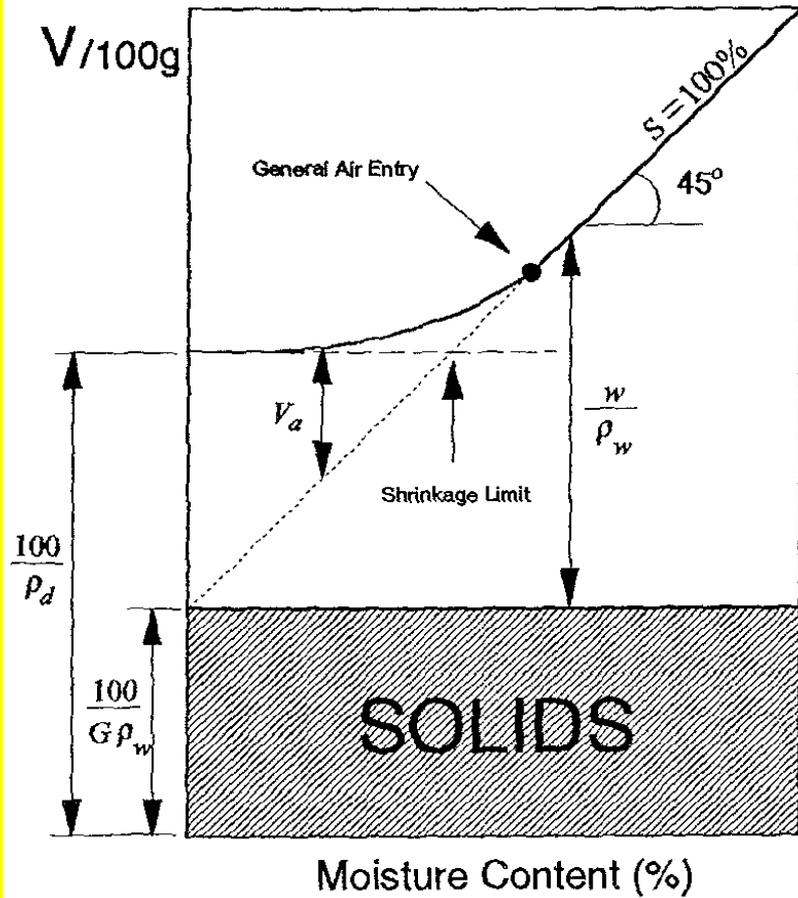
Variação

$$\Delta h_{w-0-0.5m} = 40mm$$

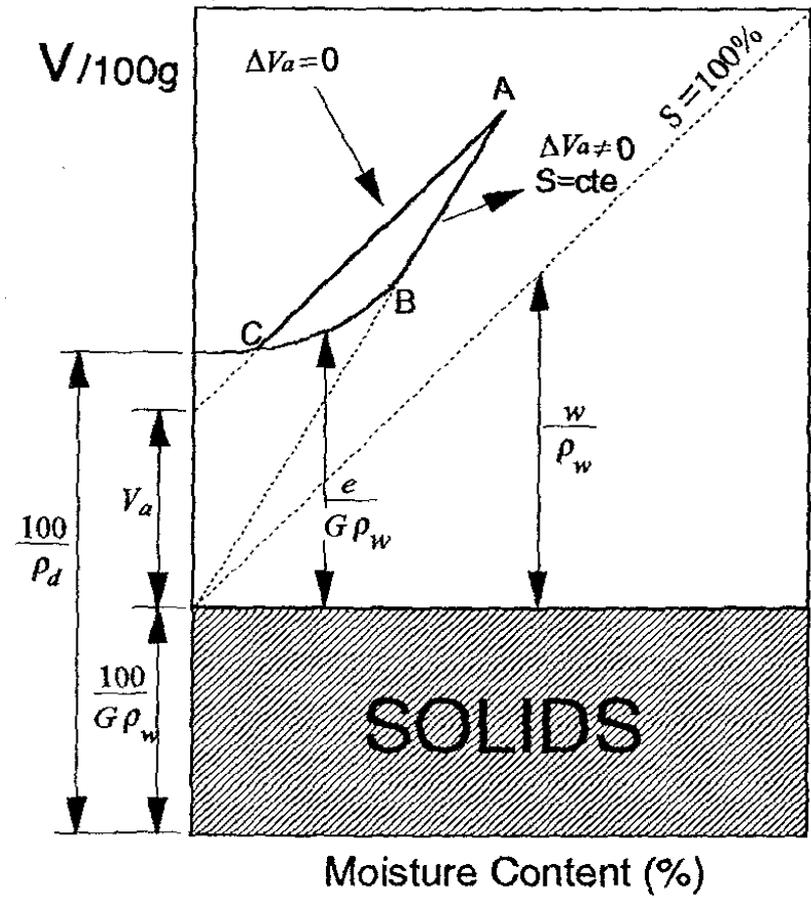
# Variação de volume



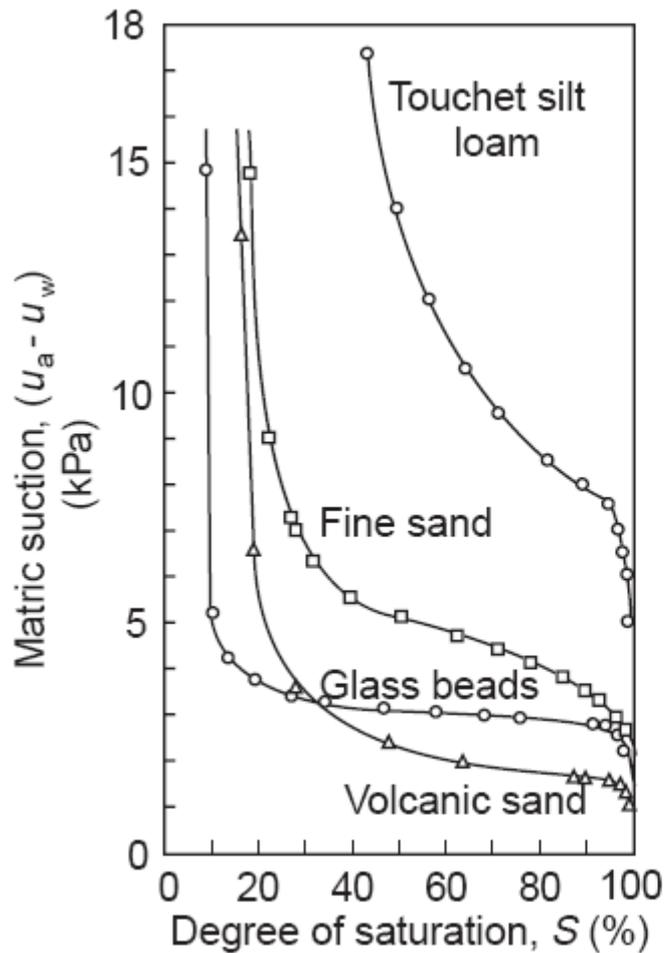




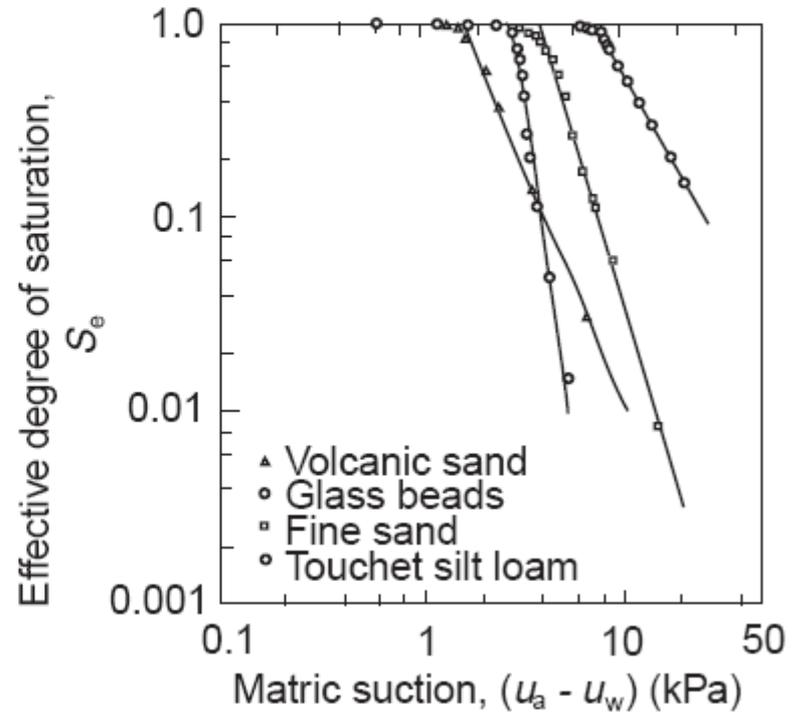
(a)



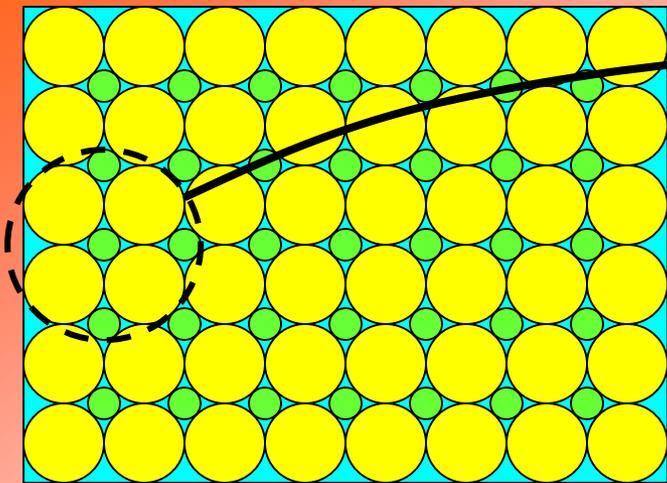
(b)



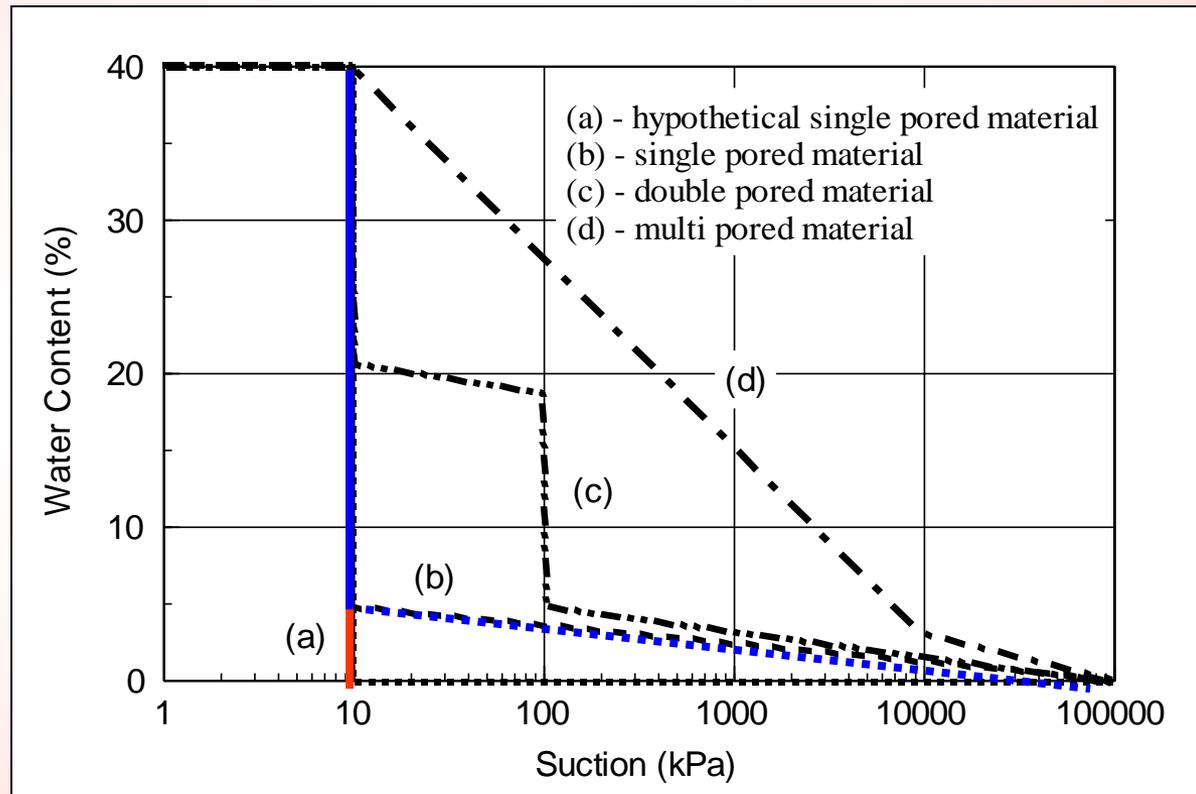
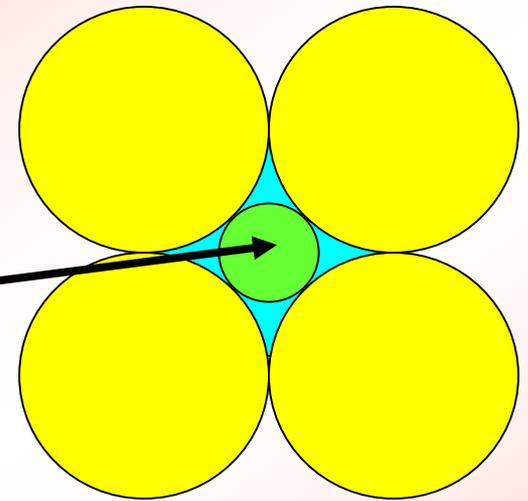
(a)

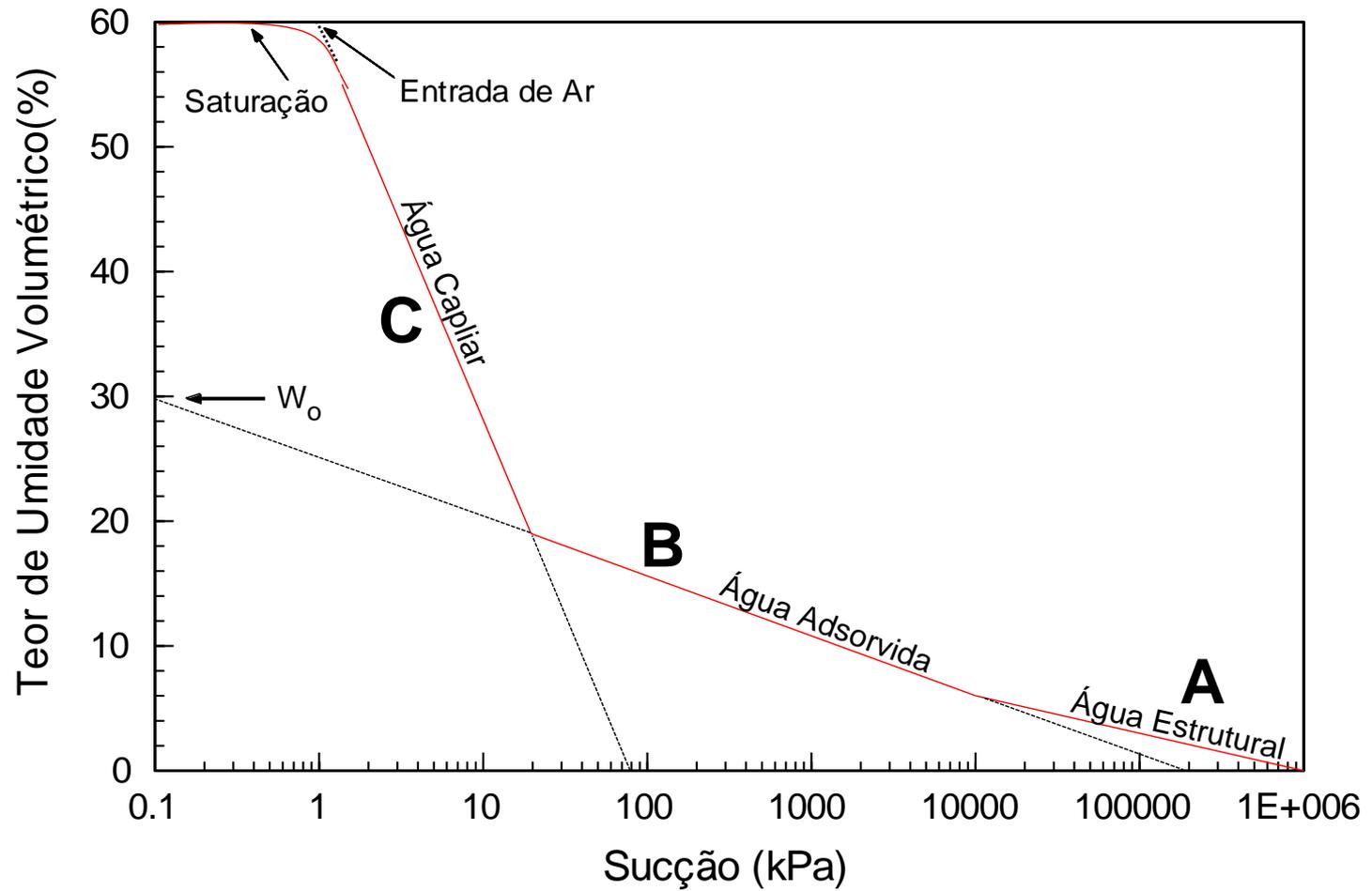


(b)



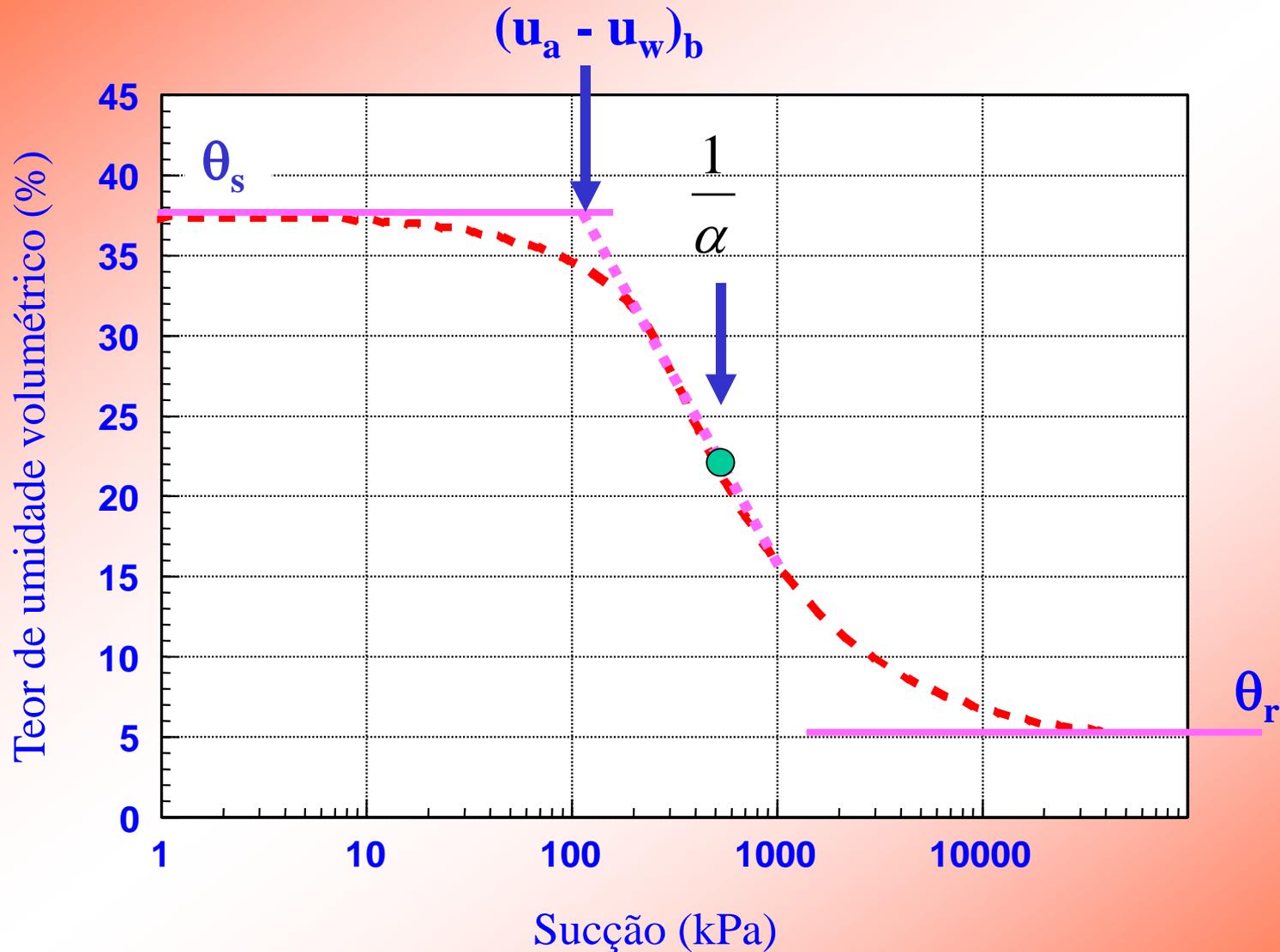
Região onde a água é removida primeiro

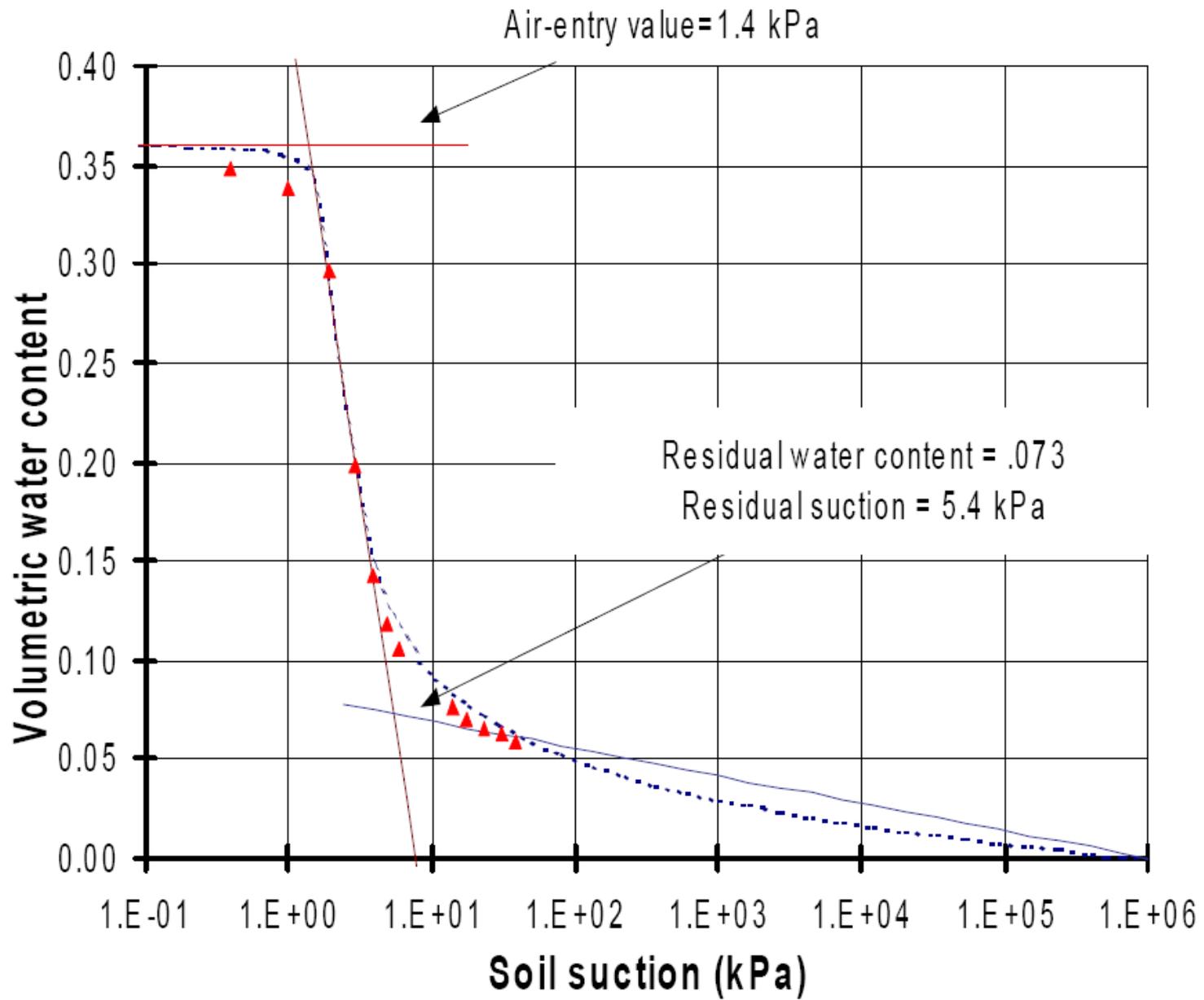




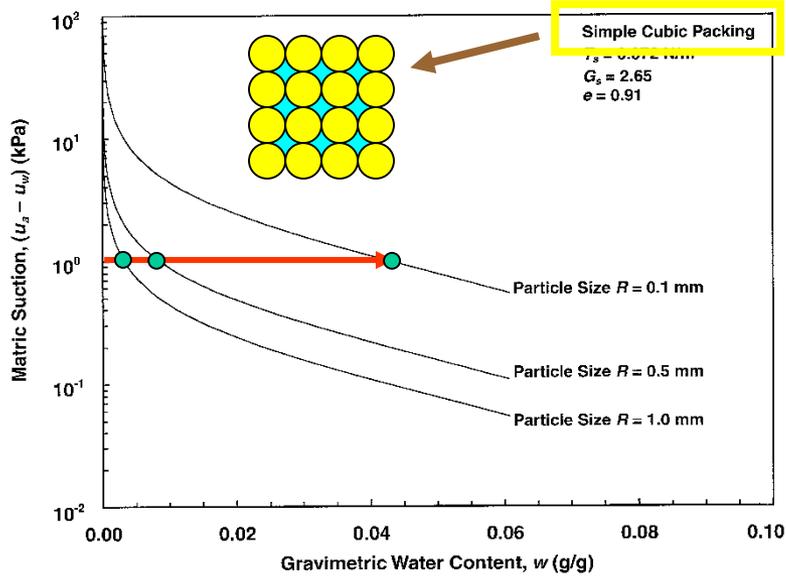
Modificado de McQueen & Miller (1974)

*Parâmetros usados nas equações de ajuste a dados experimentais  
(significado físico)*

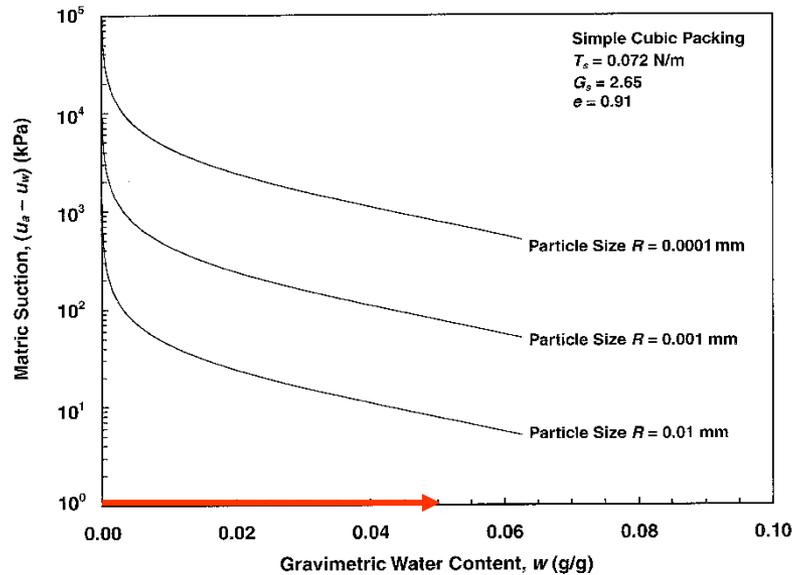




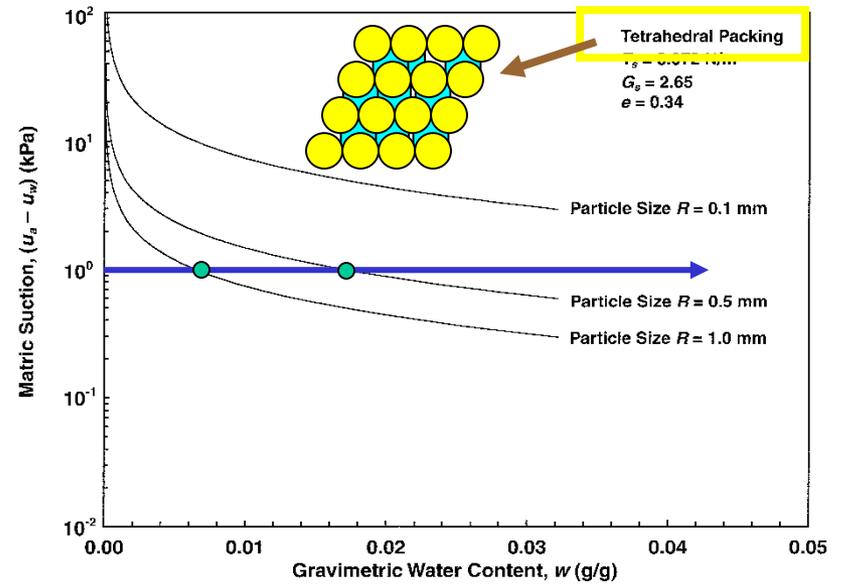
# Curvas teóricas com esferas



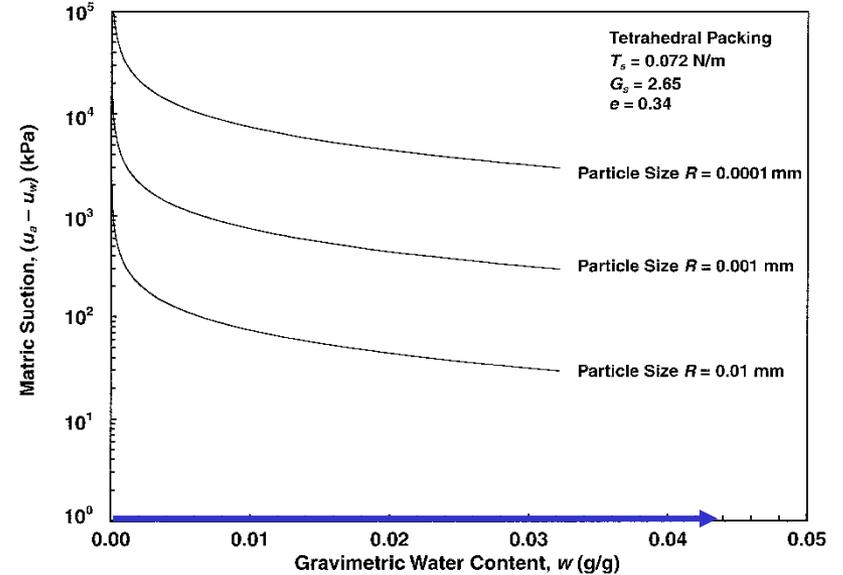
(a)



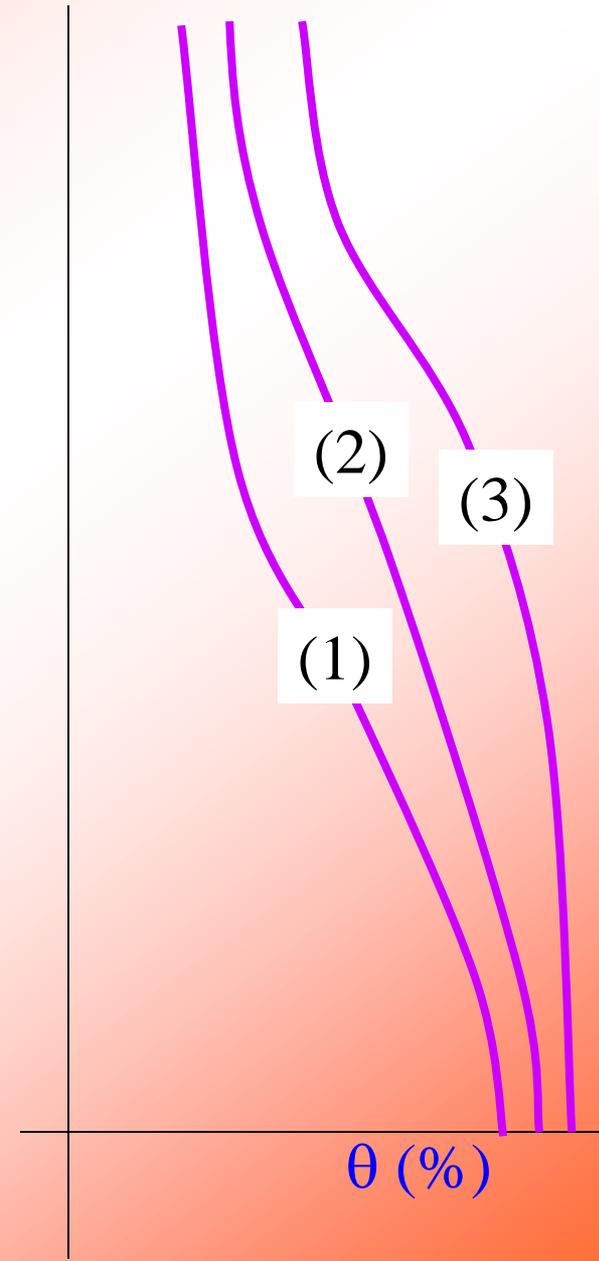
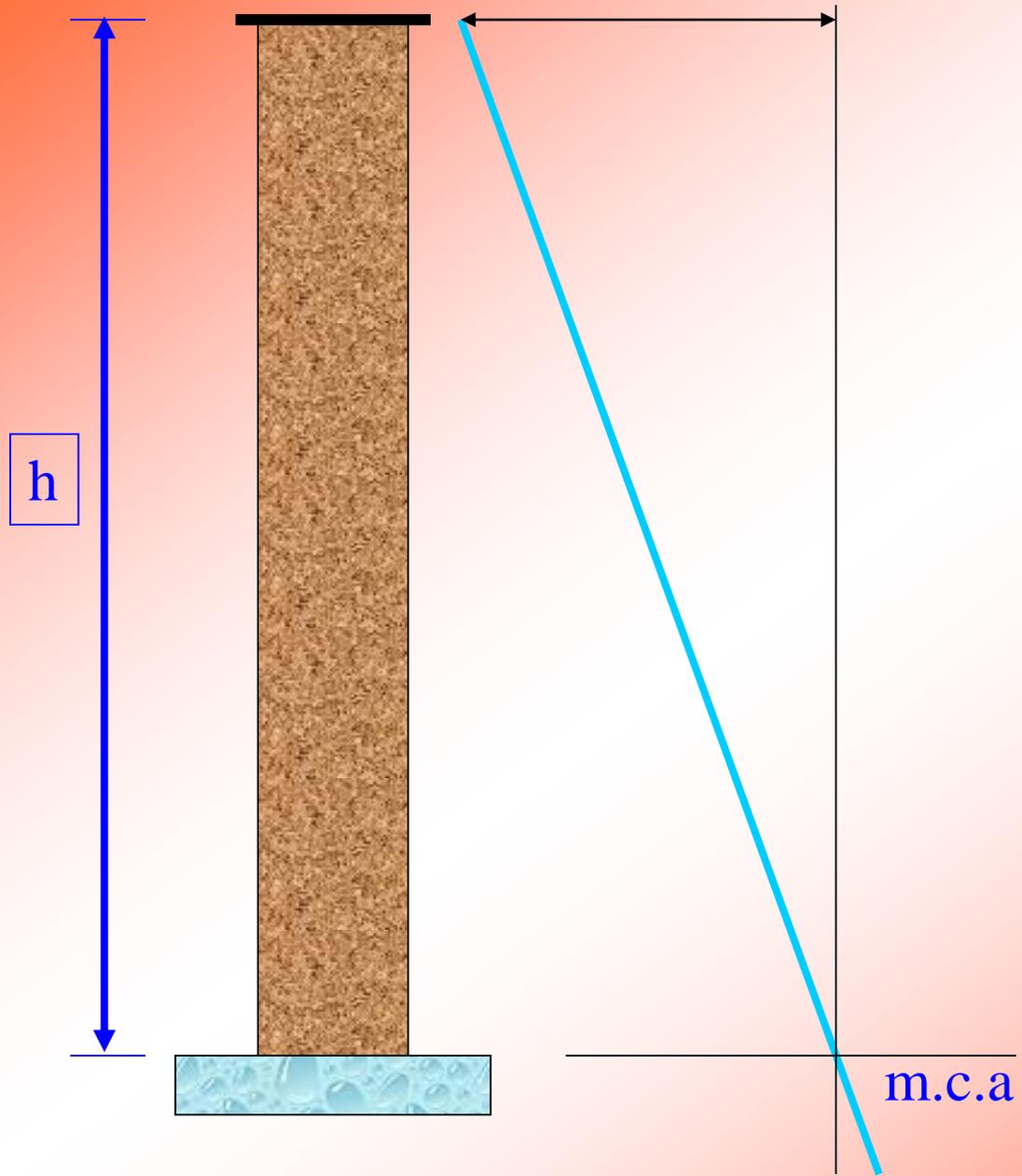
(b)



(a)



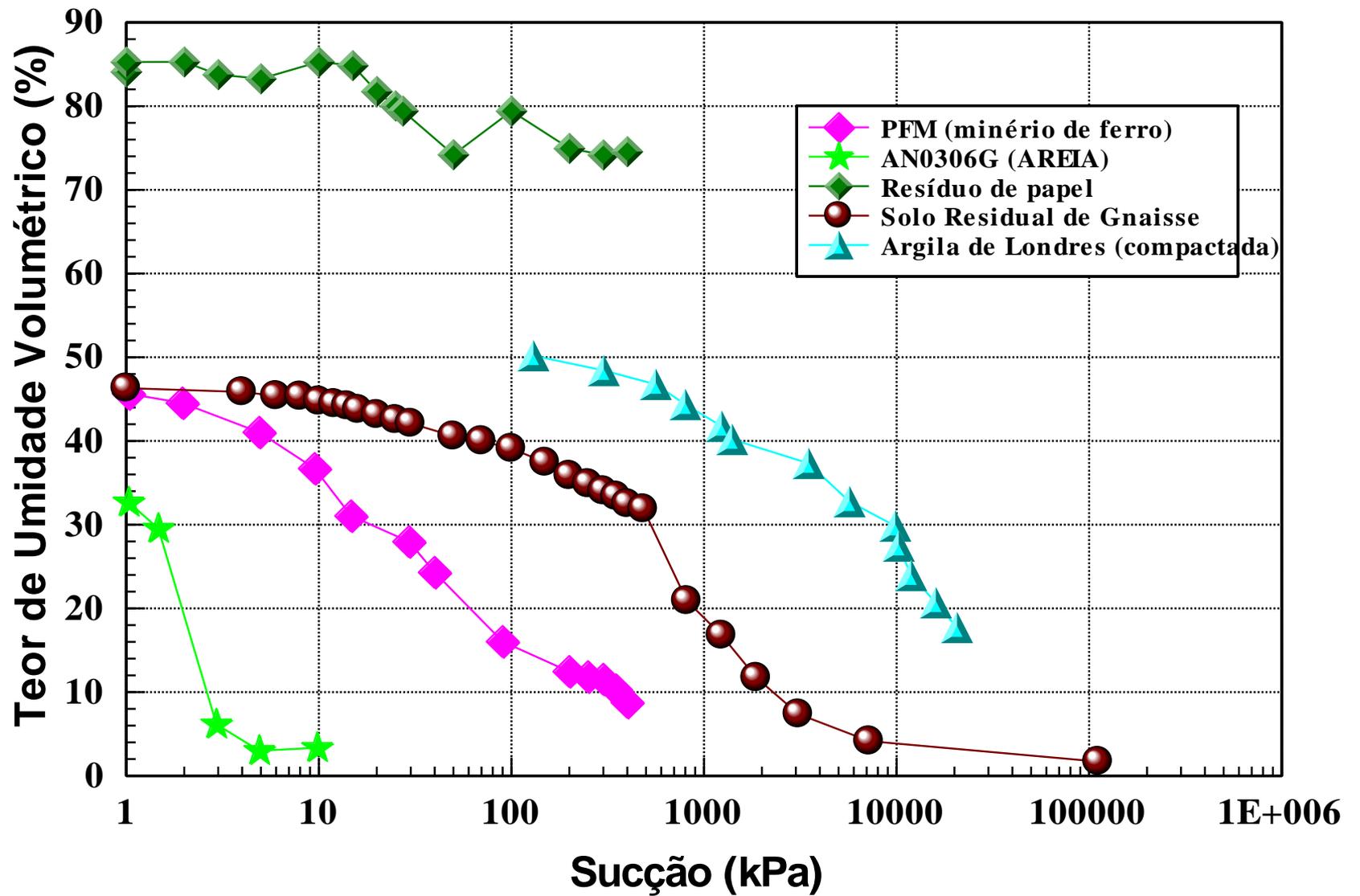
(b)

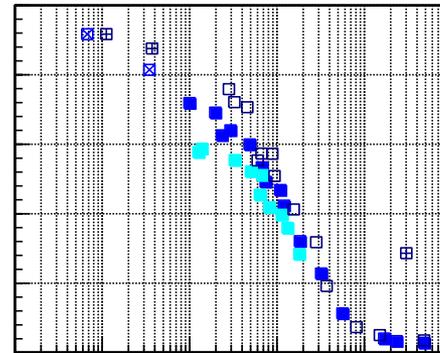
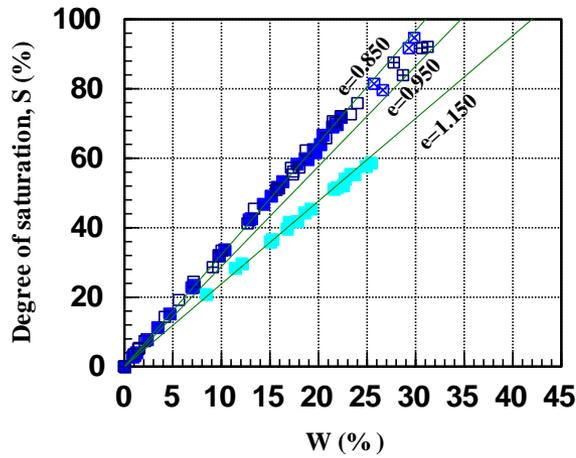
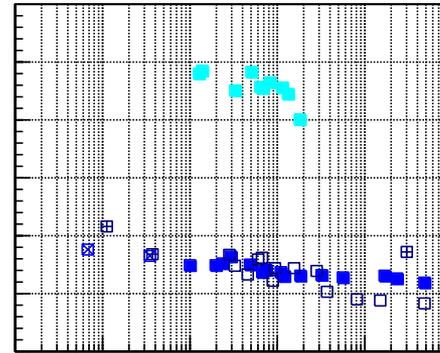
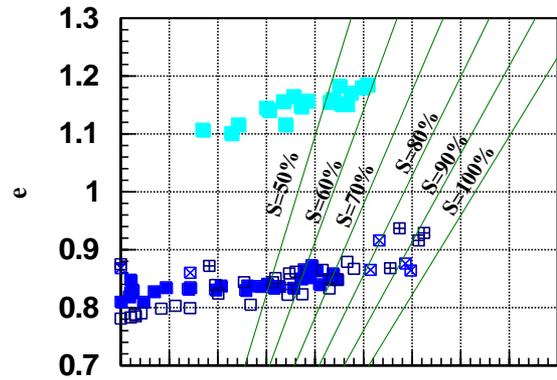




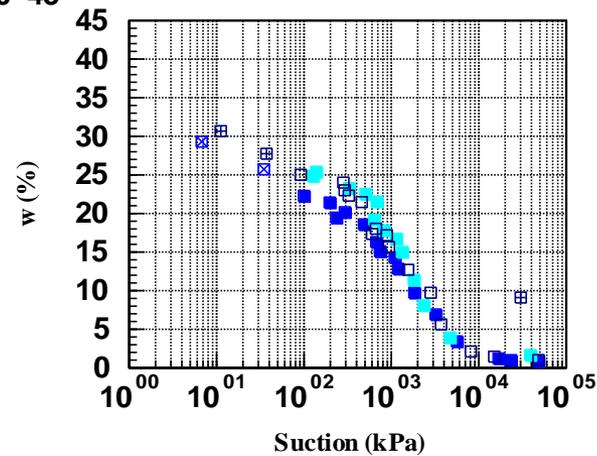
# Capacidade de retenção de líquidos



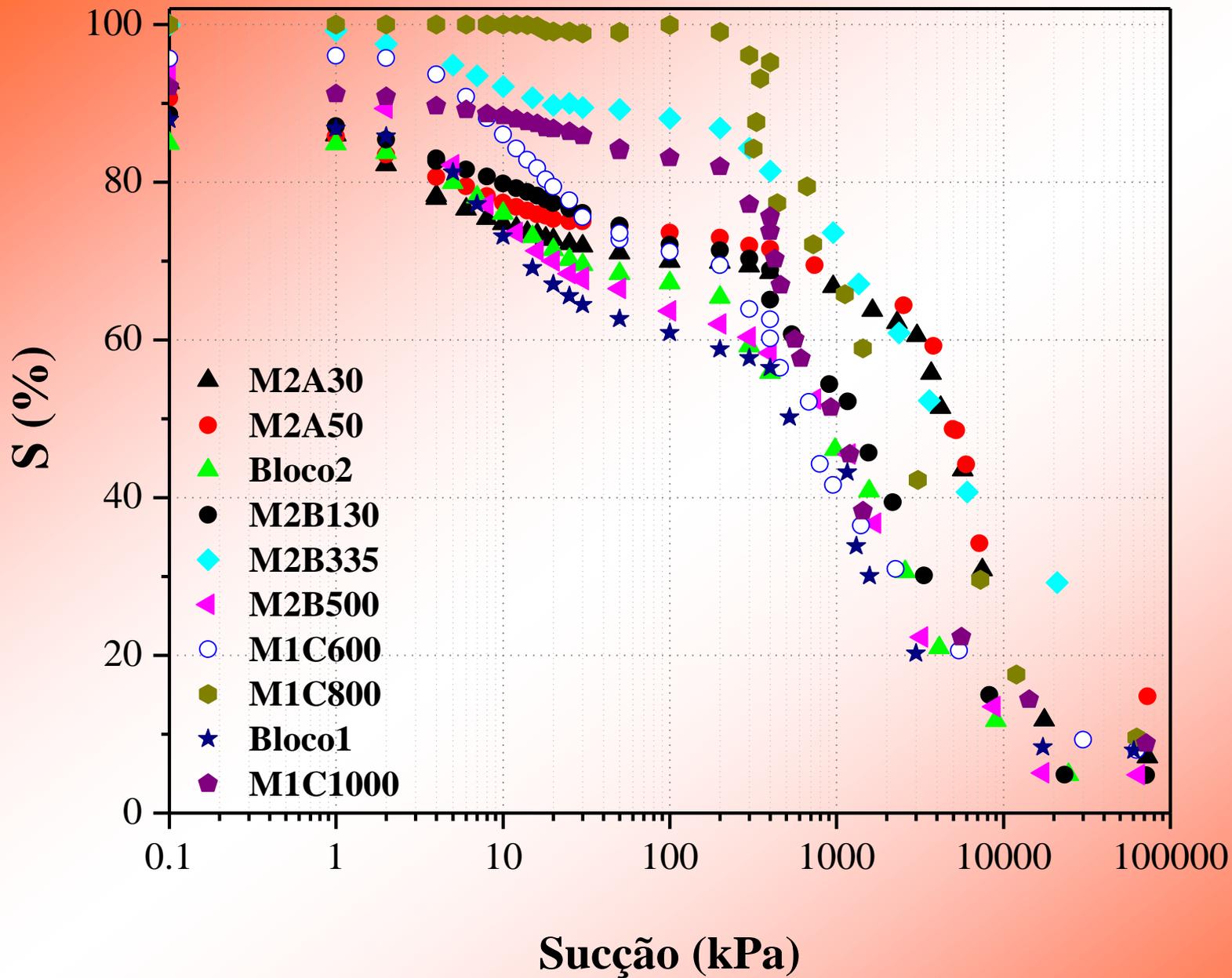


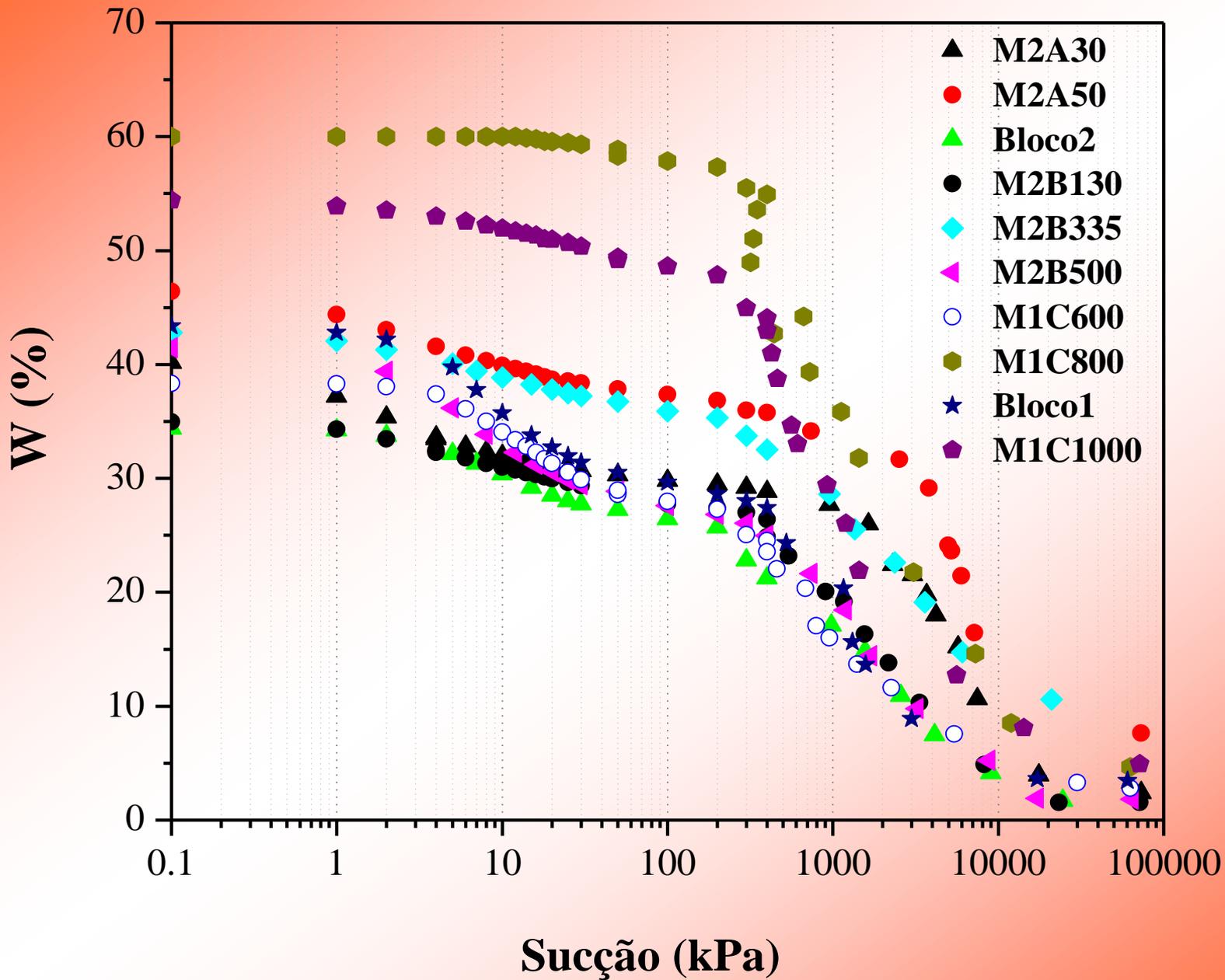


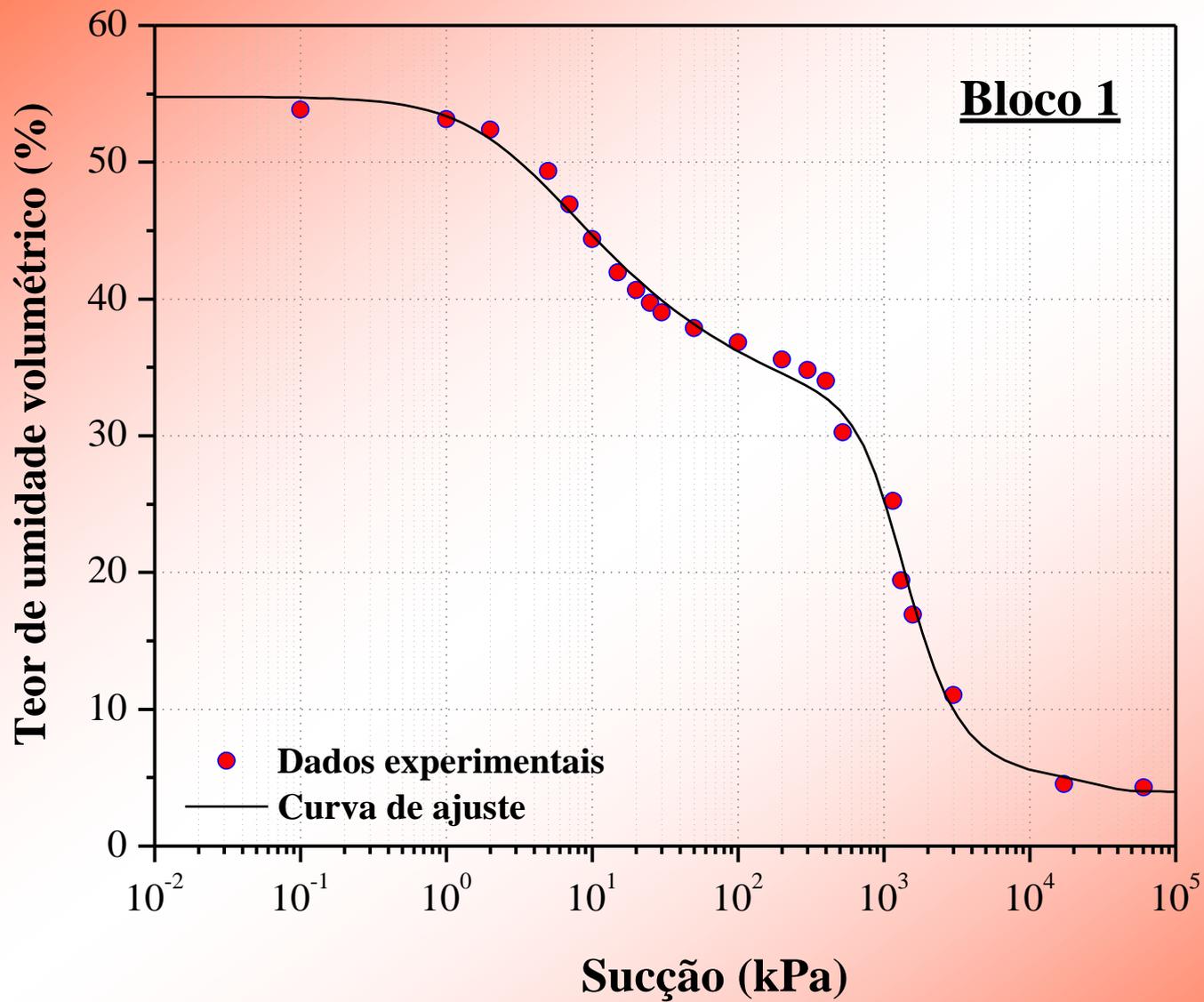
- Depth 3.0 m
- P2B
  - ⊗ P2BS
  - P1B
  - P3B
  - ⊞ P3BS



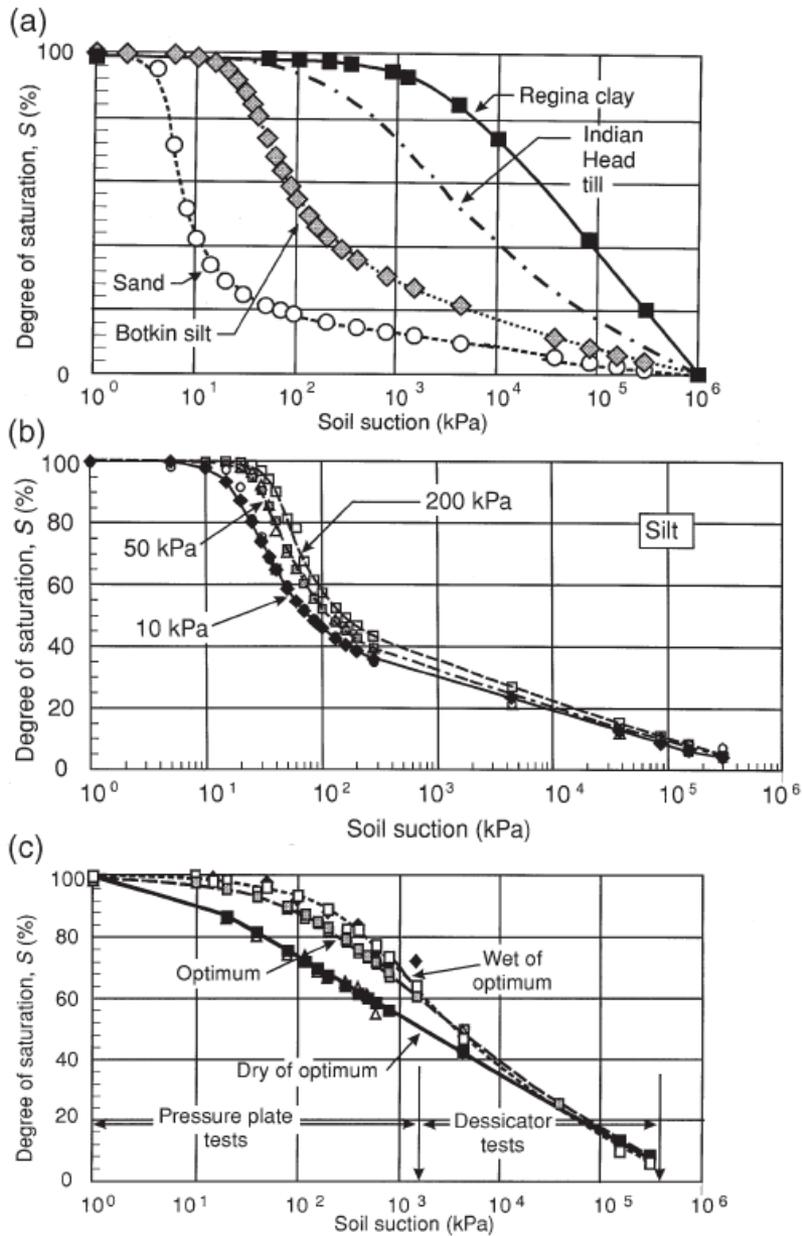
Solo Residual de Gnaisse







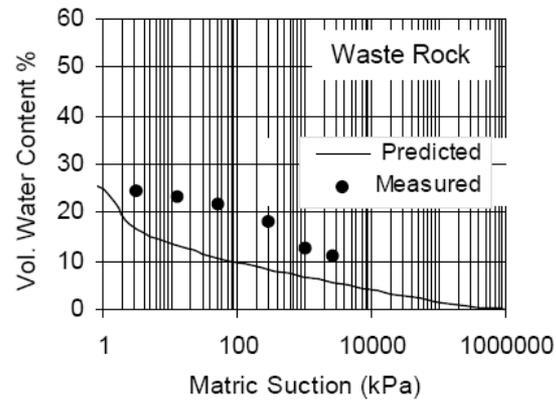
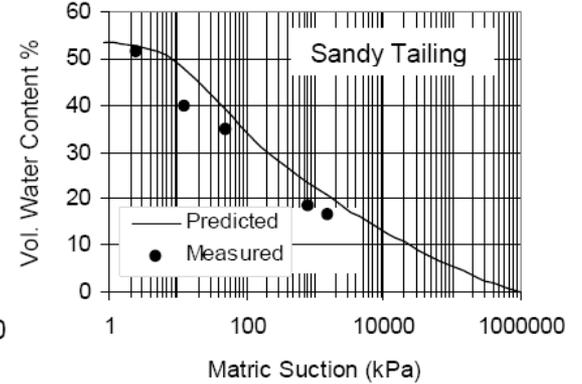
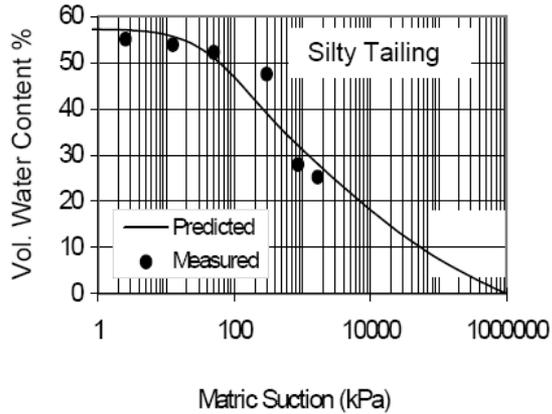
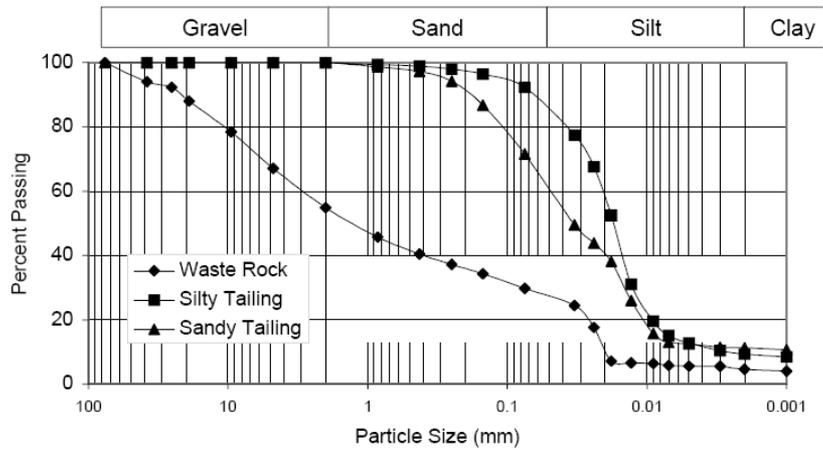
# Curva de Retenção de Água



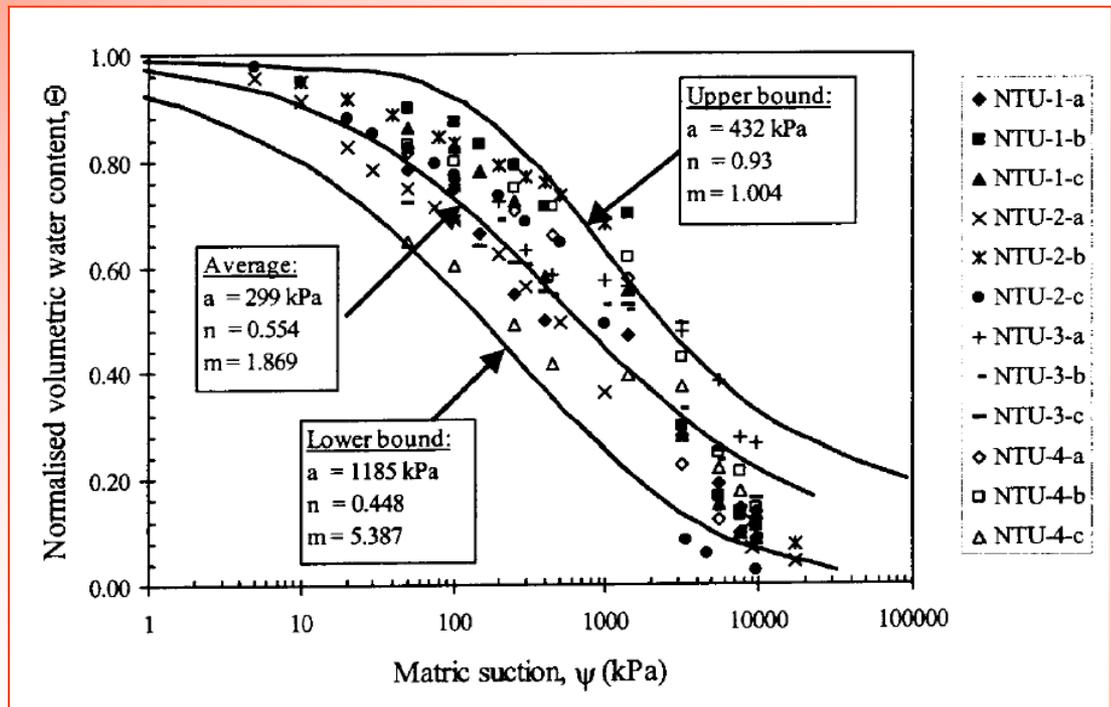
(a) - Influência da textura do solo (Vanapalli 1994)

(b) - Consolidação (Huang 1994)

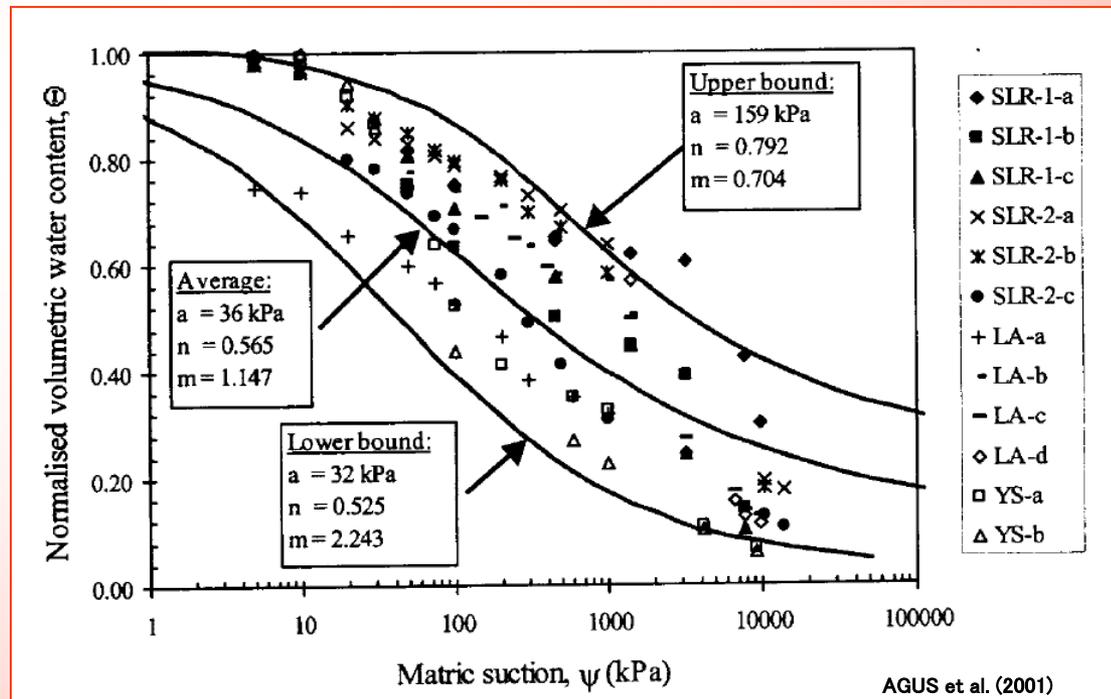
(c) compactação (Vanapalli 1994)

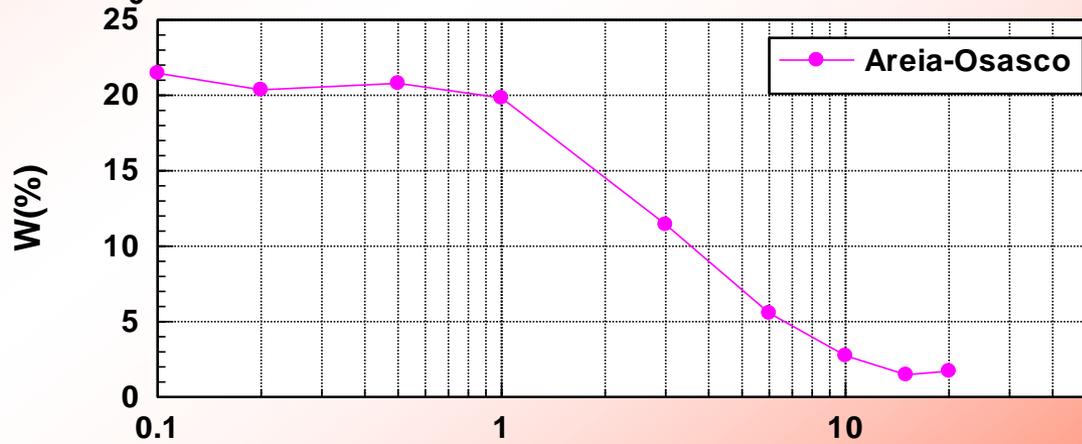


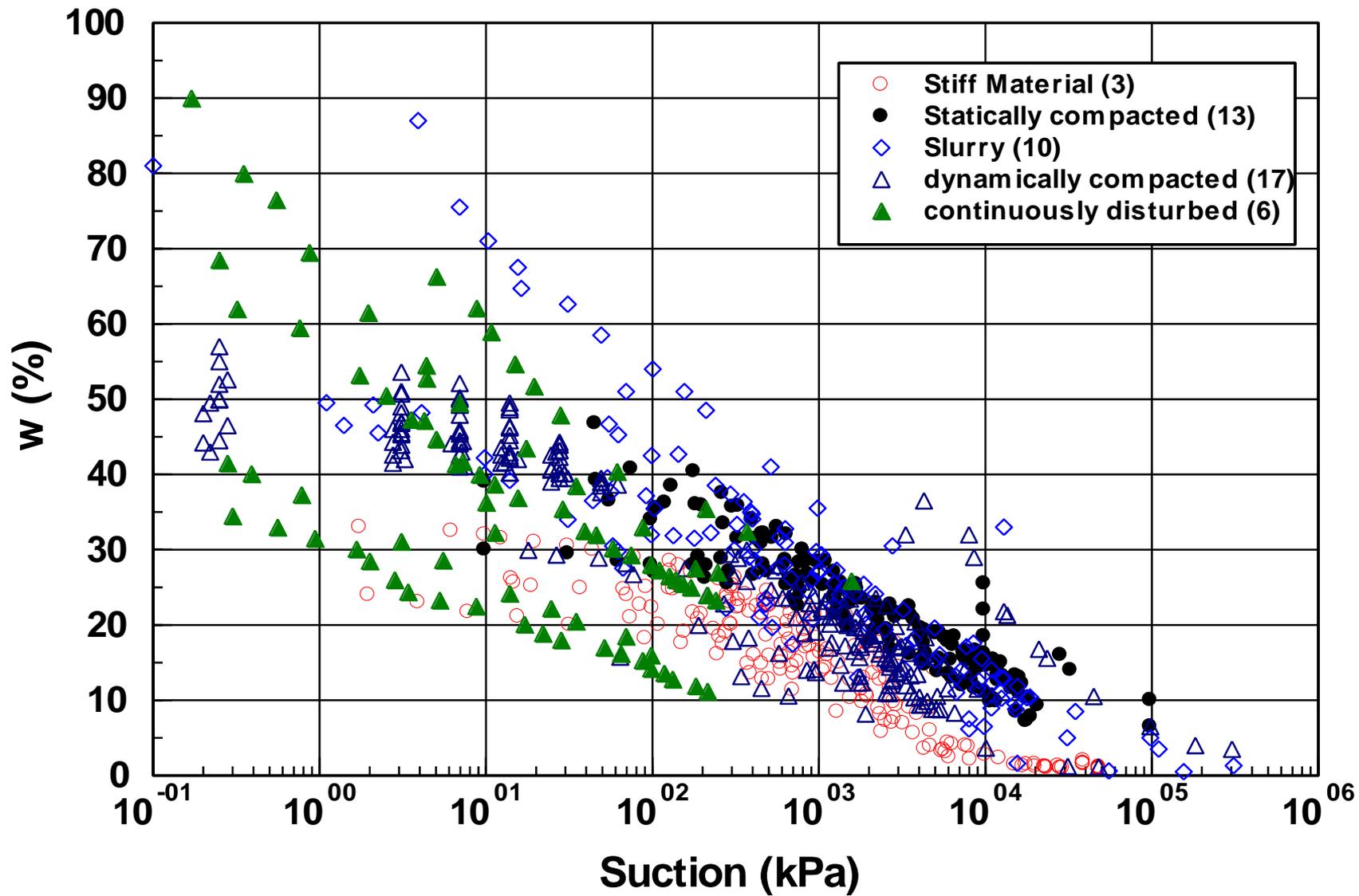
Curva de retenção do solo sedimentar da formação Jurong – Singapura



Curva de retenção do solo residual de granito (Bukit Timah)







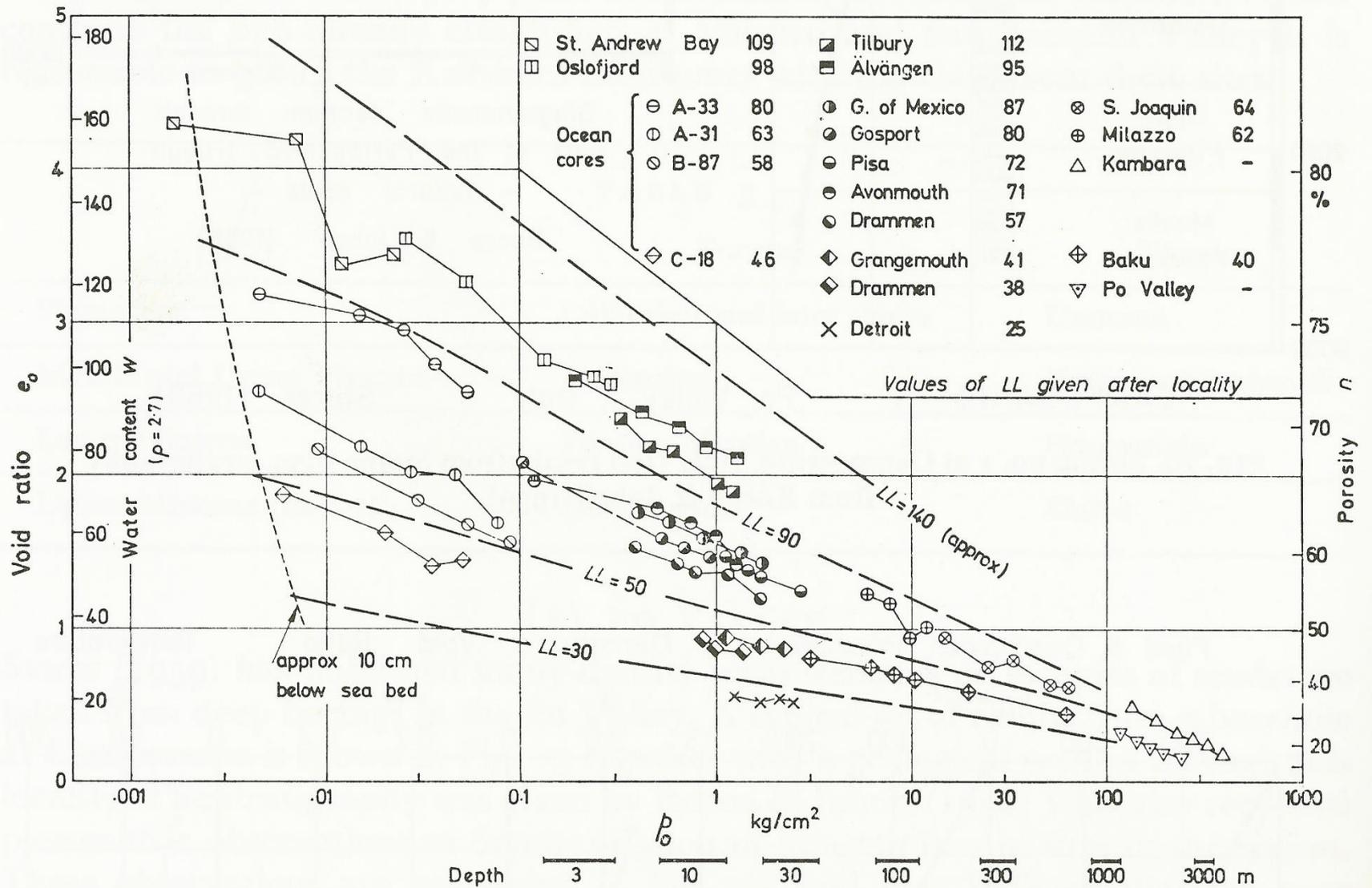


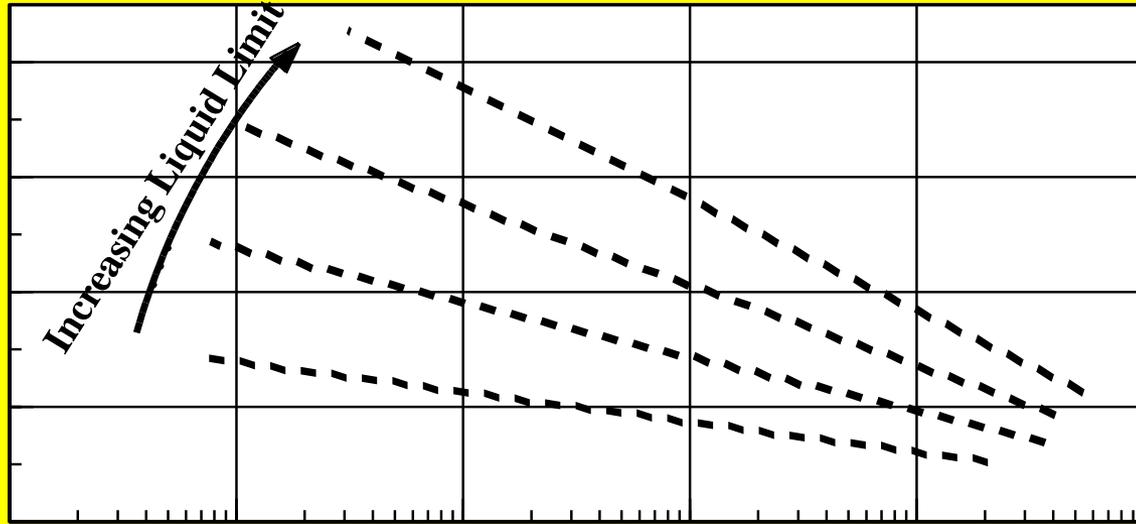
FIG. 21. Sedimentation compression curves for normally consolidated argillaceous sediments.

$$Se = wG$$

$$Se \cdot S = 1$$

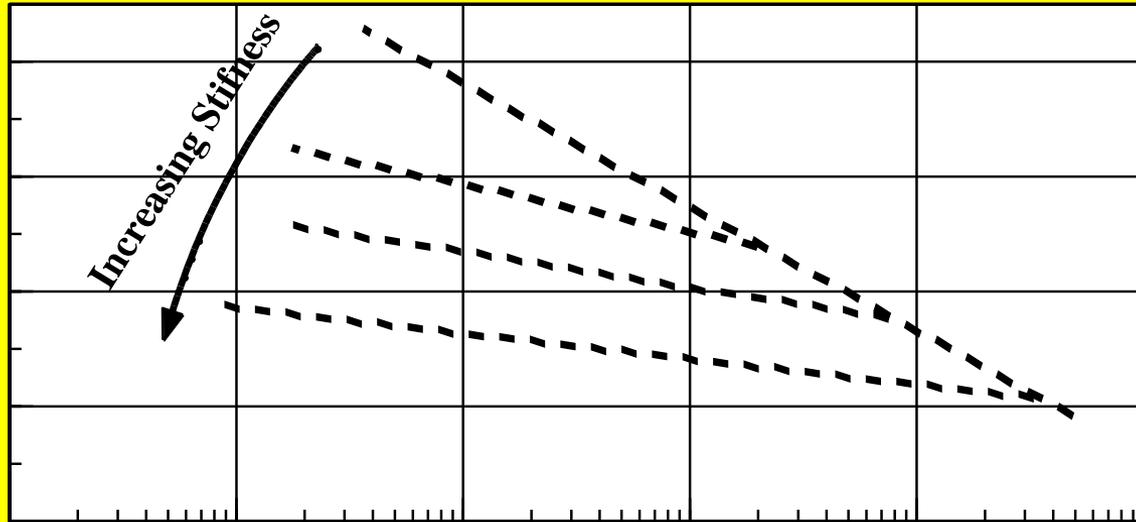
$$e = wG$$

Water Content (%)



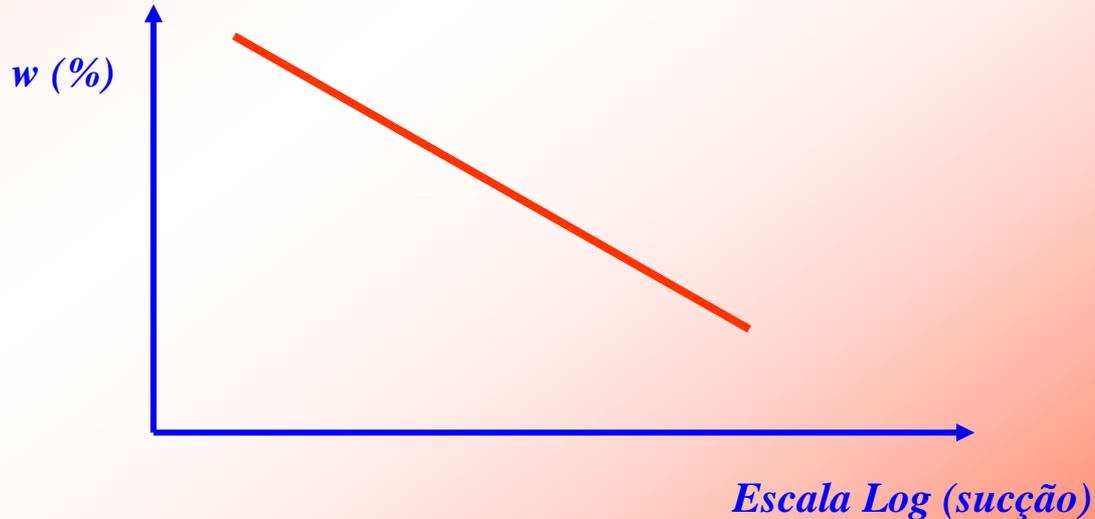
Suction (kPa)

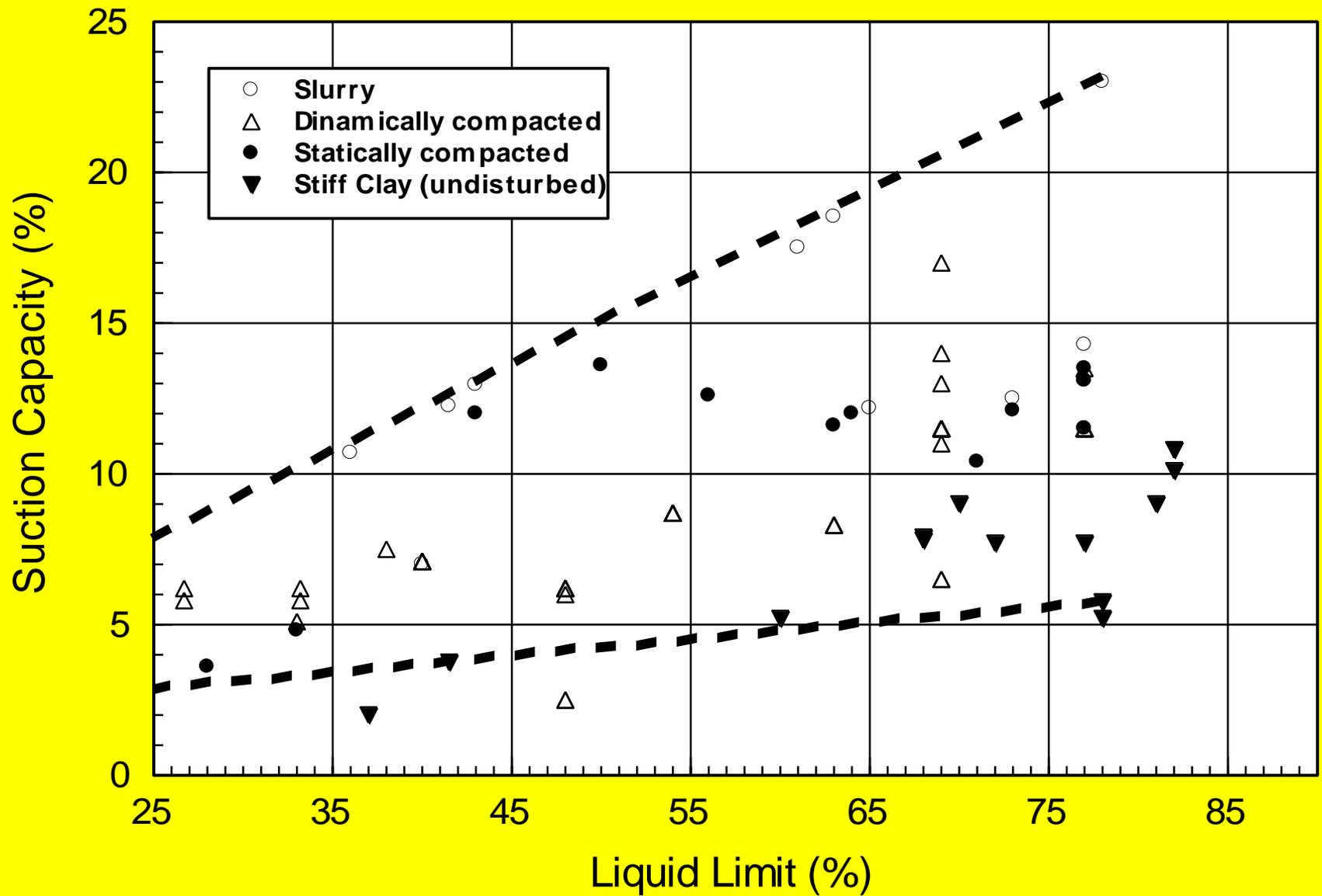
Water Content (%)

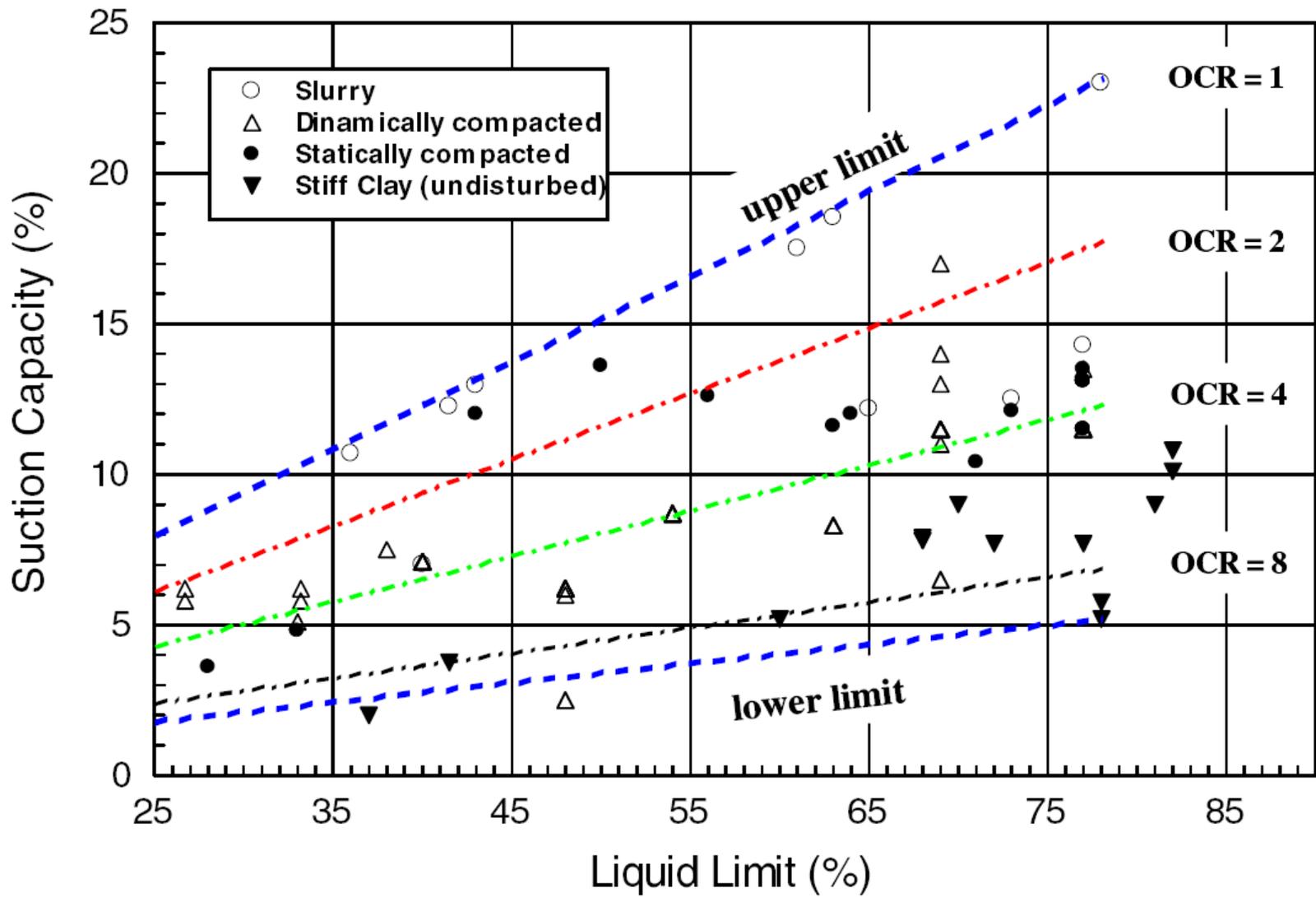


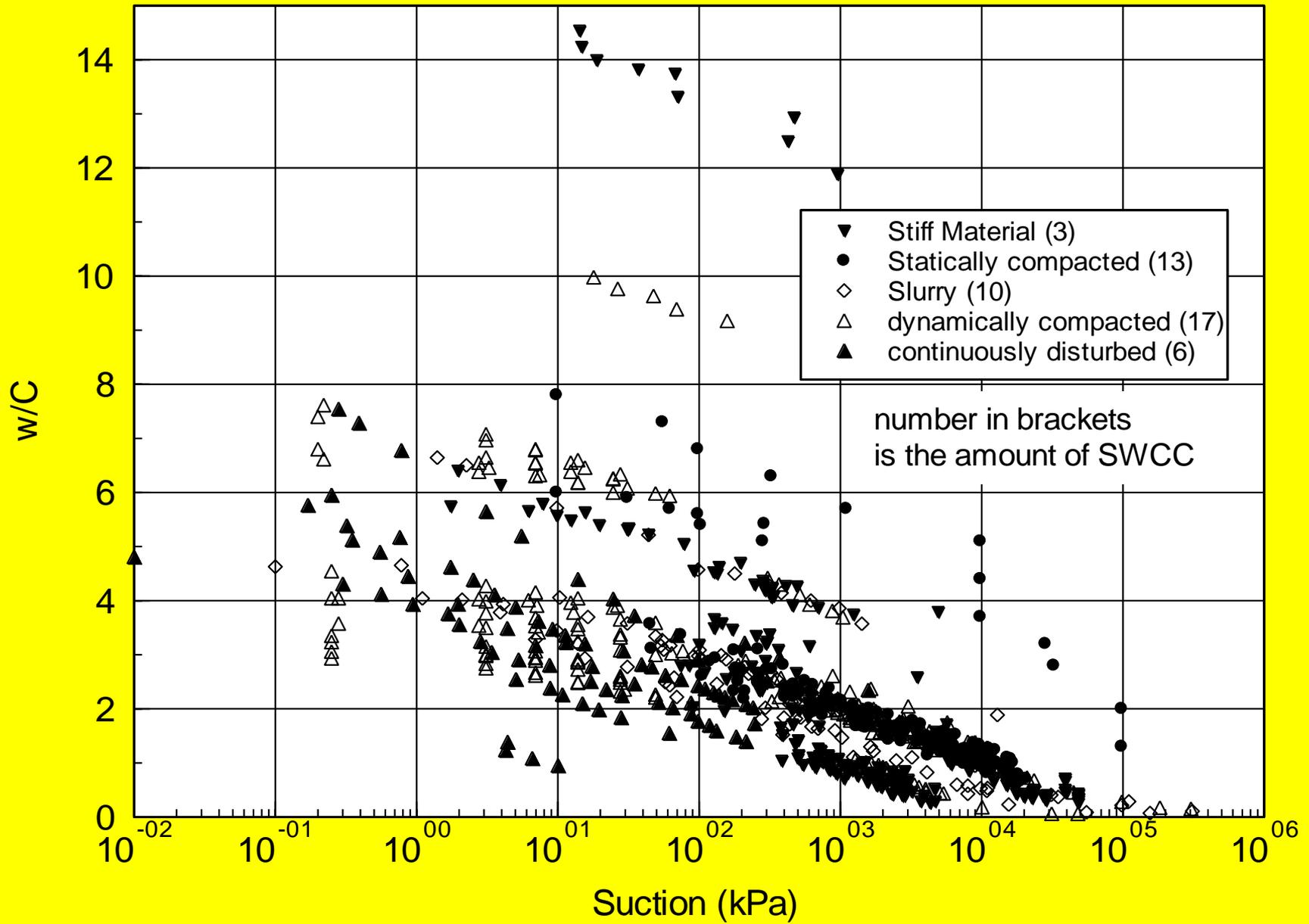
Suction (kPa)

$$C = \frac{\Delta w}{\Delta \log(\textit{sucção})}$$

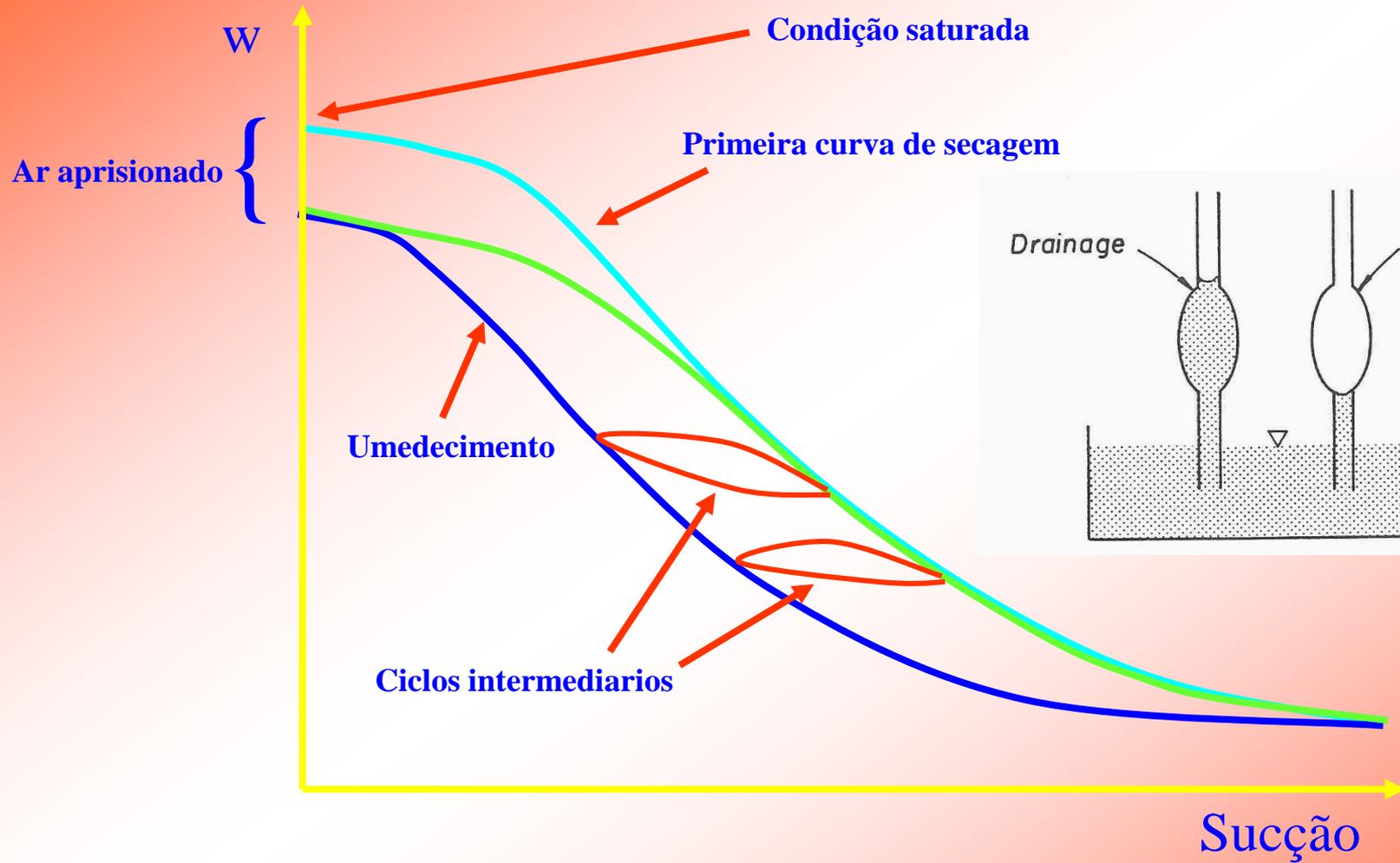




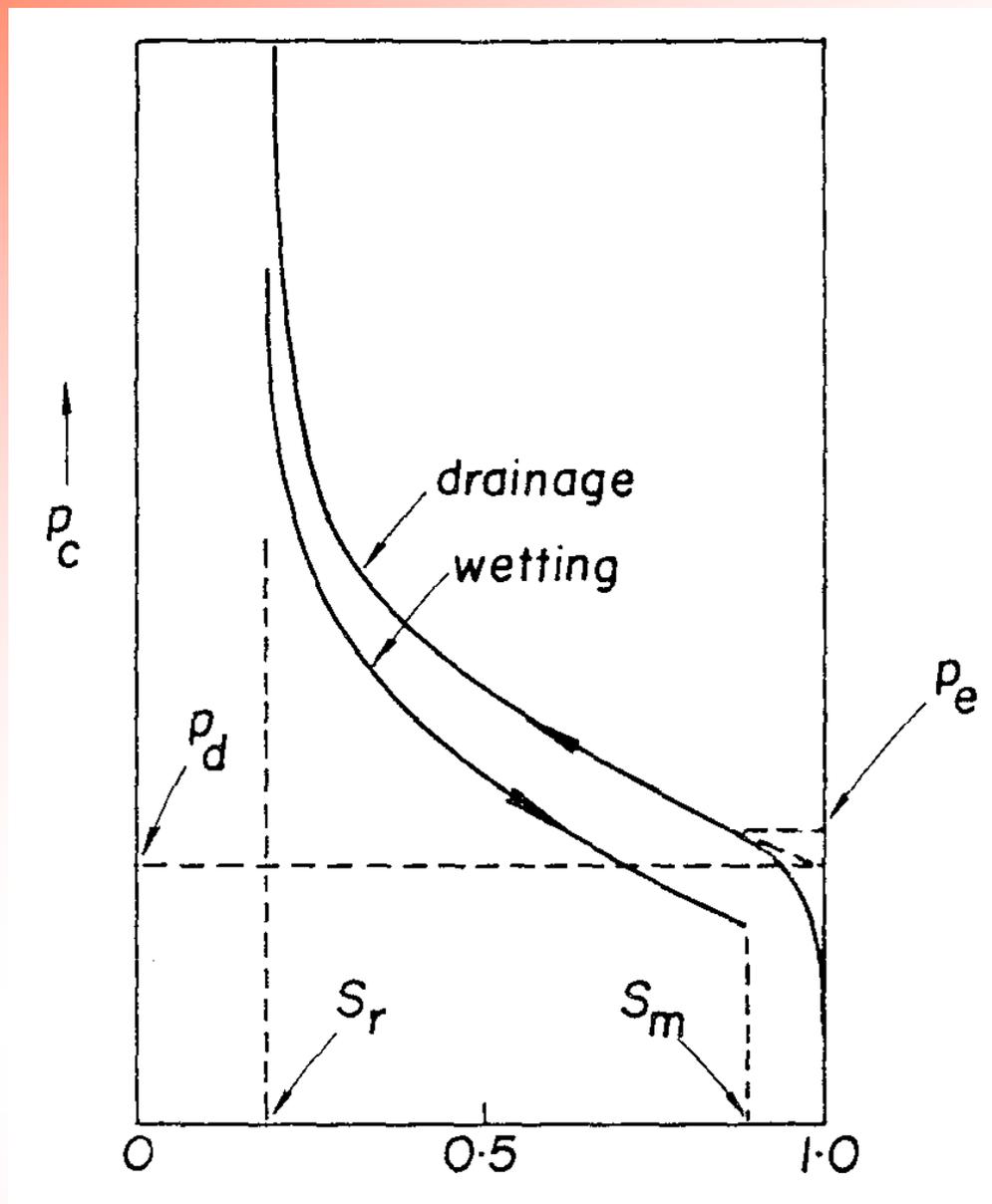




# Histerese na Curva de Retenção

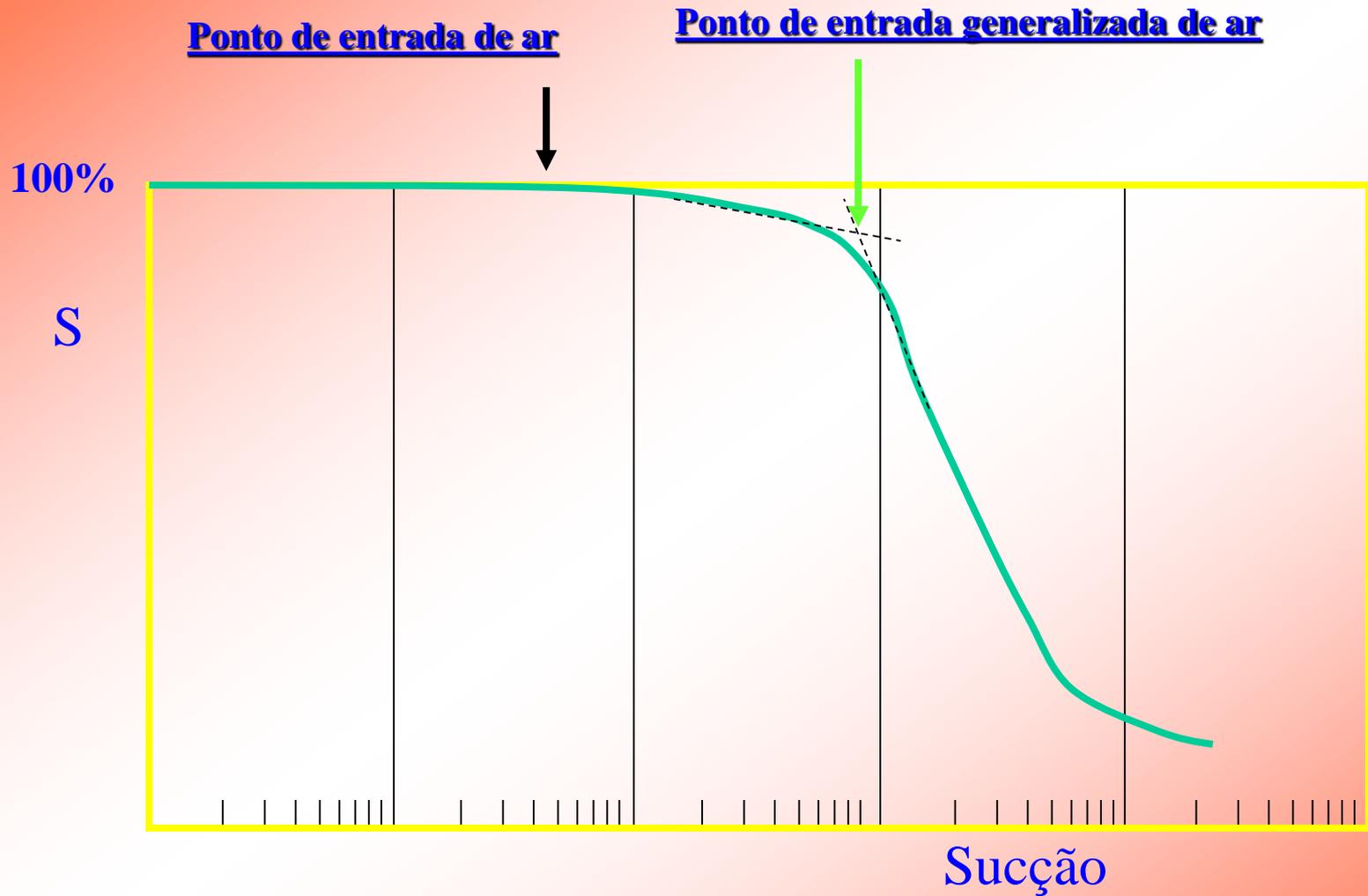


# Sucção em função do grau de saturação



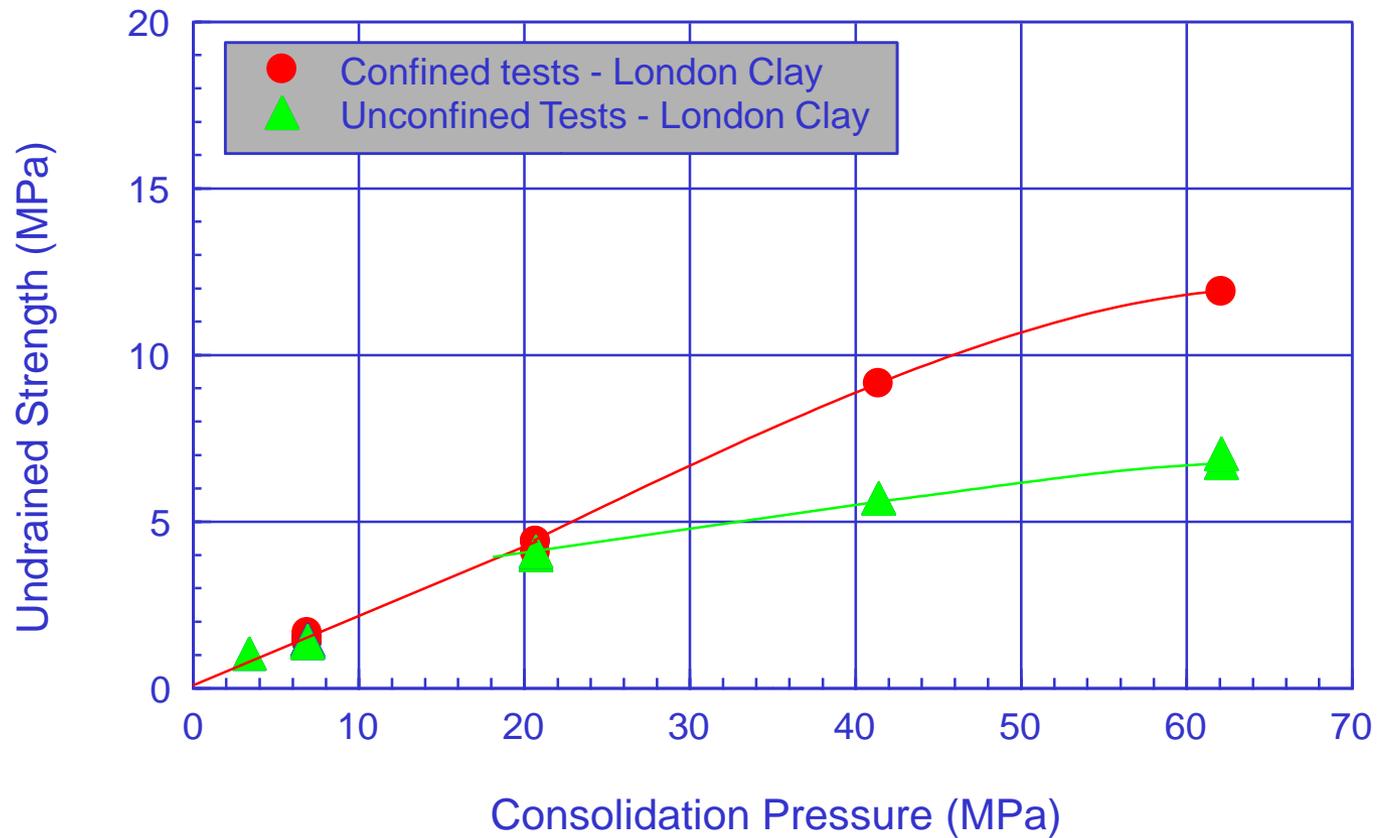
(Corey, 1994)

# Entrada de ar

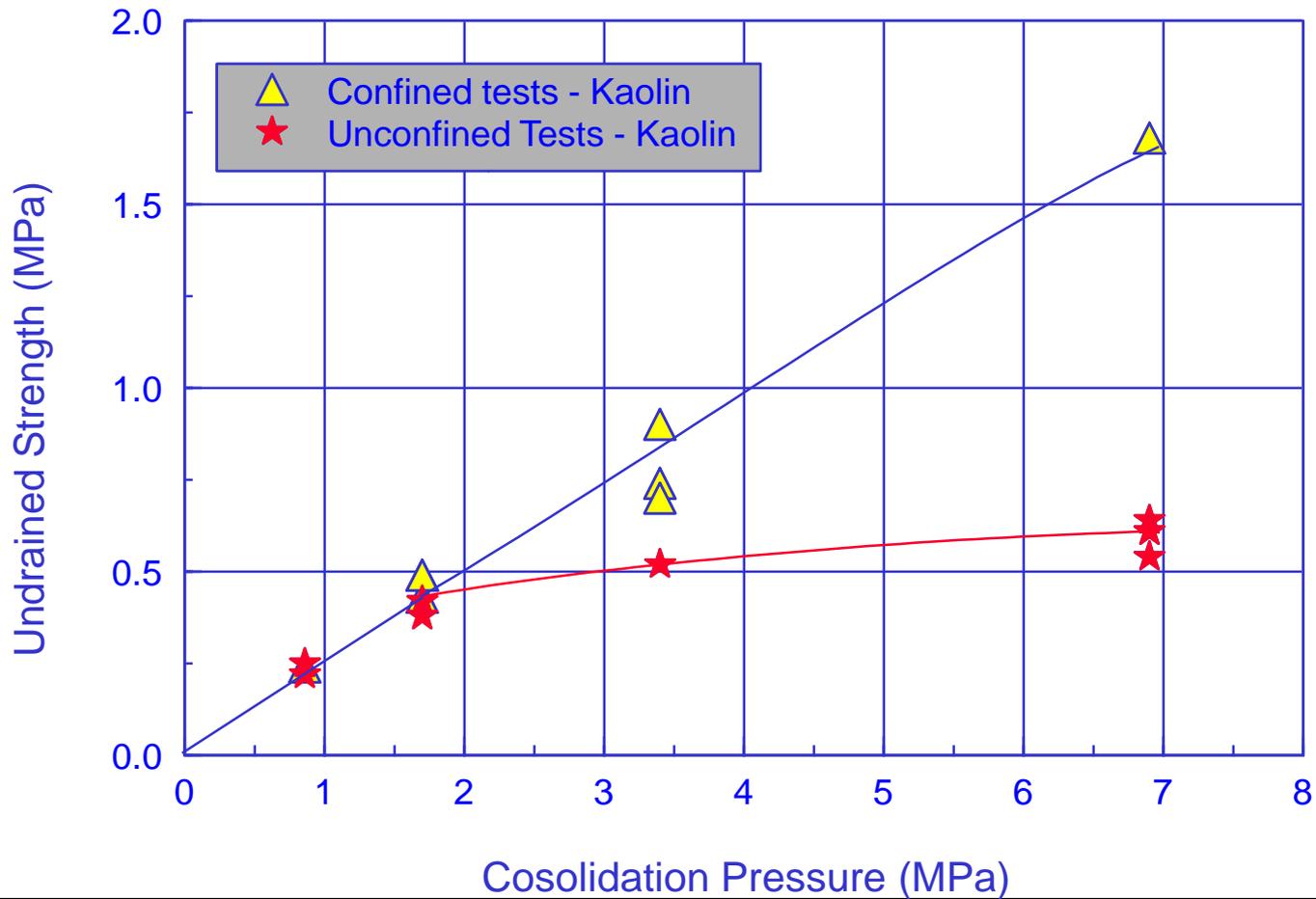


*Parâmetros com implicações de comportamento*

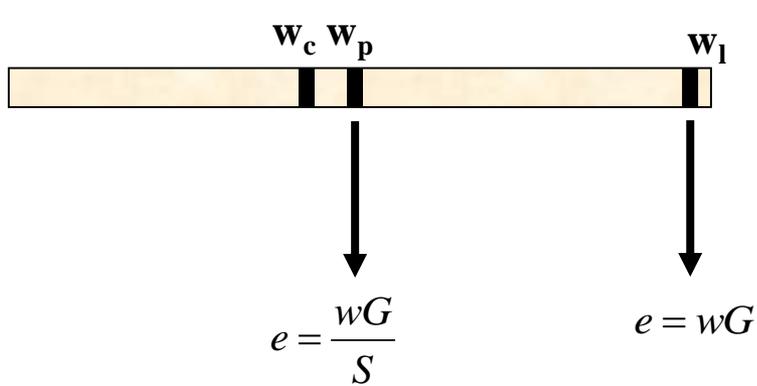
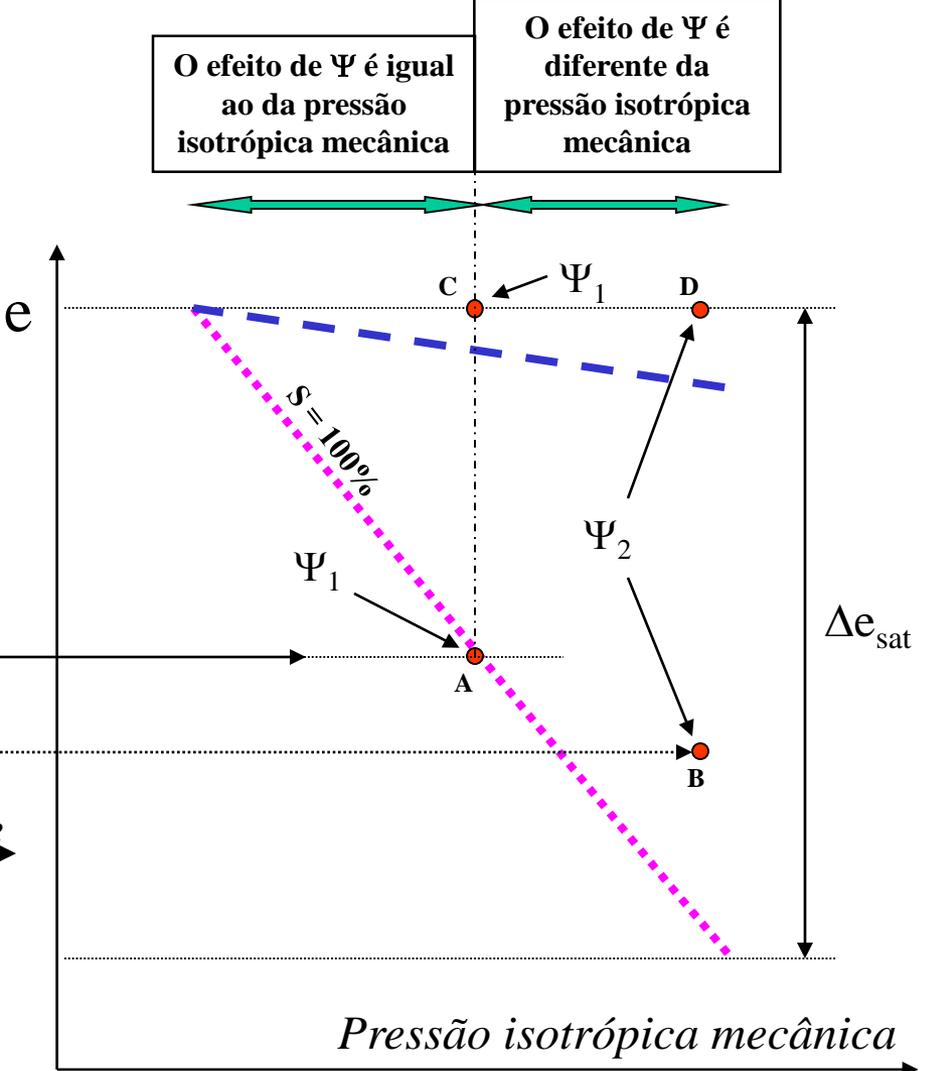
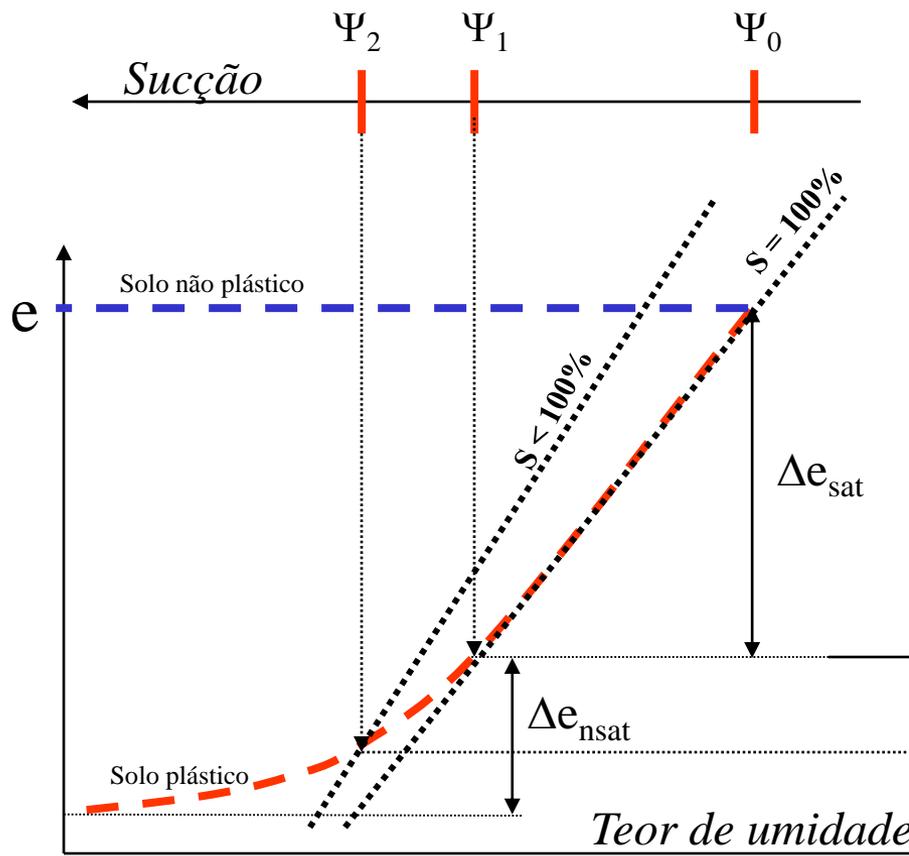
# Efeito da Entrada de ar

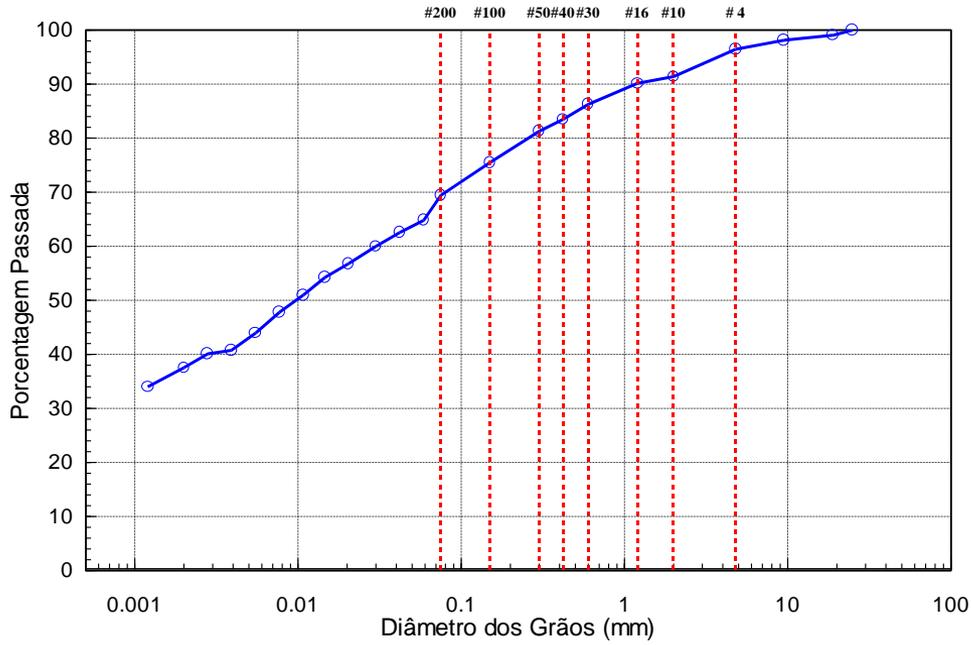


# Efeito da Entrada de ar

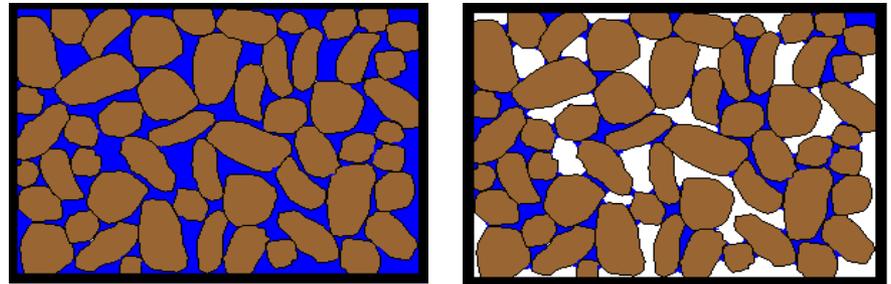
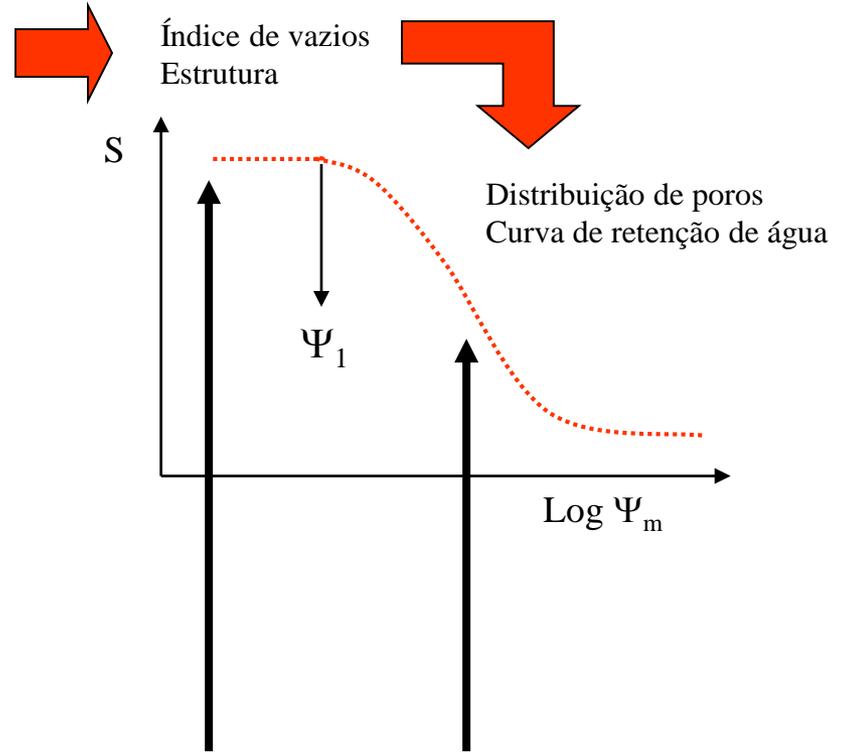


**A Ligação entre a  
Caracterização do Material e  
o Estado Não Saturado**





argila	silte	areia fina	areia média	a. grossa	pedregulho
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# Curva de Contração

