Effect of the clay-water interaction in the hydration process of compacted bentonite

Abel Jacinto[a], Alberto Ledesma[b]

[a]National University of Tucumán (UNT)

[b]Technical University of Catalonia (UPC)

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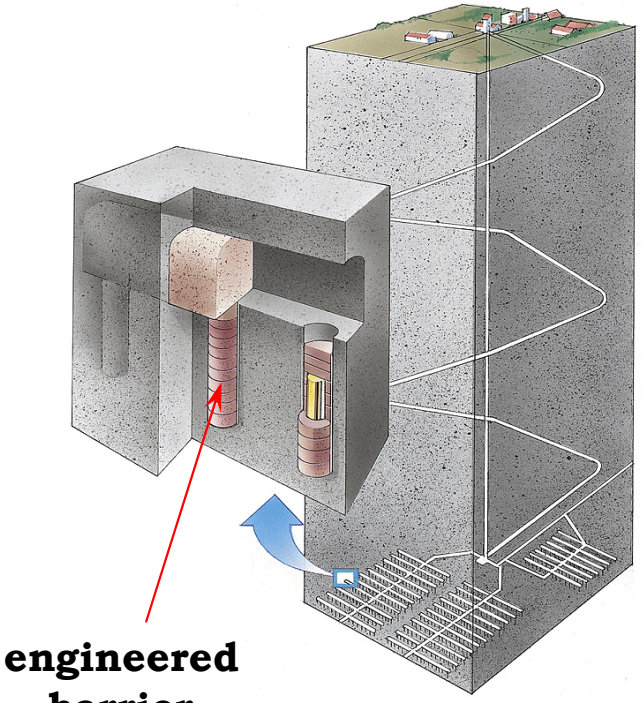
INTRODUCTION

Motivation

- **Compacted bentonite** is used as engineered barrier in the design of high level radioactive waste repositories.

- In general, **hydration tests** on compacted bentonite samples need **more time** and **water** for saturation than predicted by simulations.

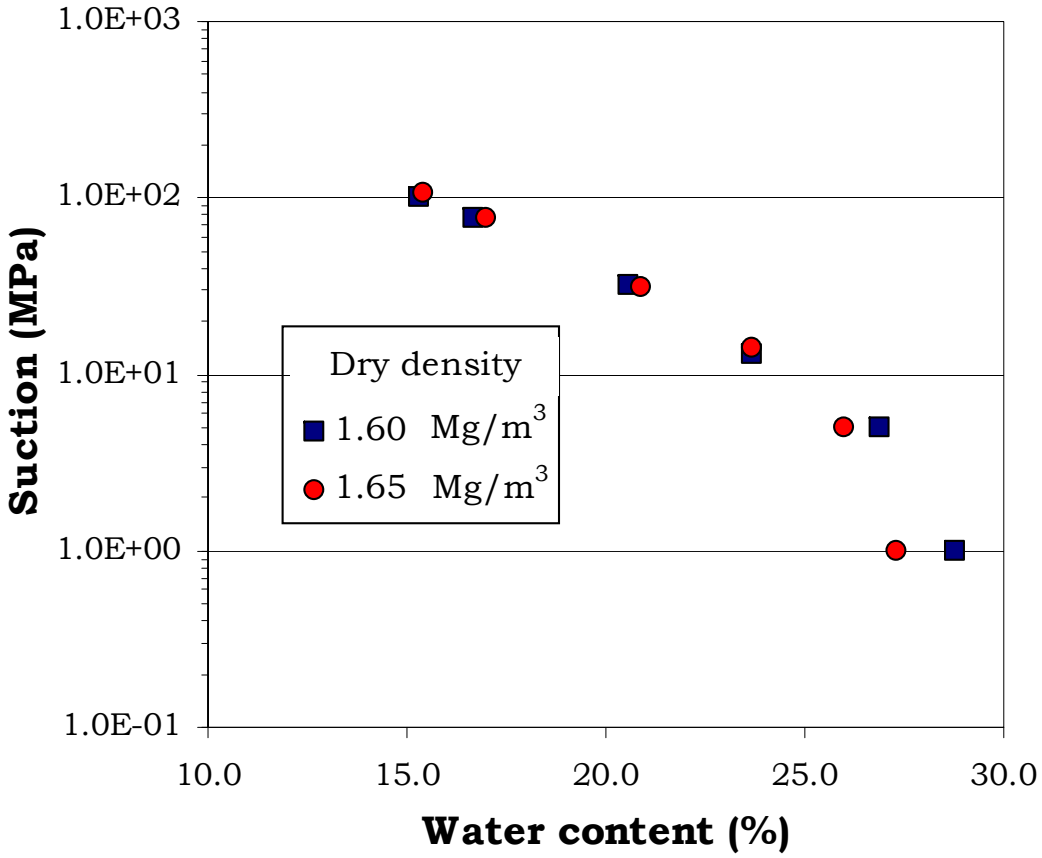
- This effect can be partially attributed to the **interaction** between the **clay minerals** and the **water**.



http://www.skb.se

INTRODUCTION

Retention curve of compacted bentonite (constant volume)

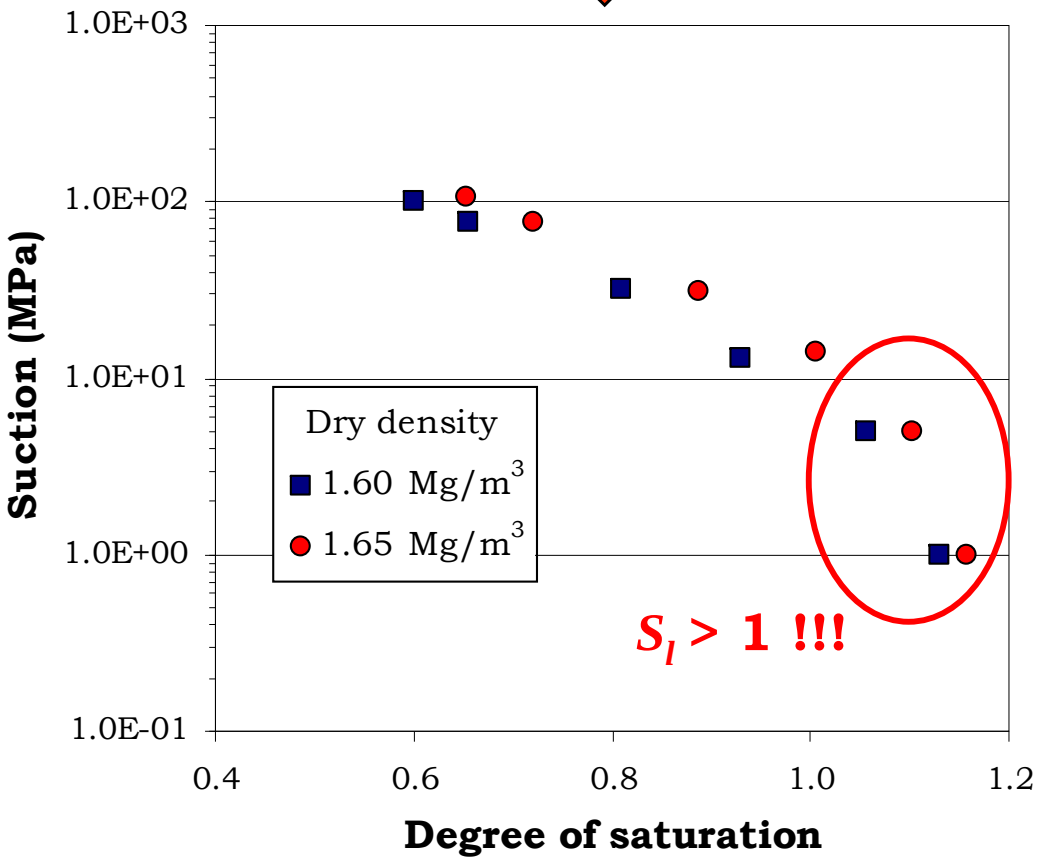


FEBEX bentonite

Lloret et al. (2004)

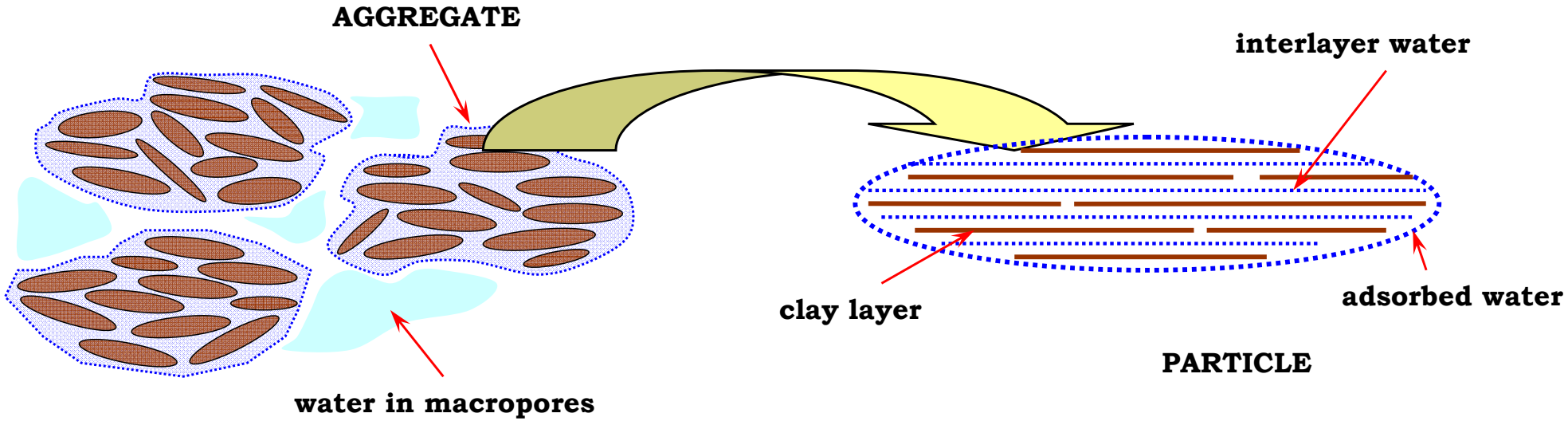
$$S_l = \frac{\rho_s \cdot w}{\rho_w \cdot e}$$

ρ_w = 1.0 Mg/m³



INTRODUCTION

Water in compacted bentonite



Low (1979)
Hawkins & Egelstaff (1980)
Cariati et al. (1981)
Derjaguin et al. (1986)
Push et al. (1990)
Skipper et al. (1991)

→ **clay-water interaction**

↓

water properties are different from those of bulk water

WATER DENSITY IN COMPACTED SAMPLES

Weighted water density

$$w = w_i + w_e + w_f$$

w : total water content

w_e : adsorbed water on external surfaces

w_i : interlayer water

w_f : free water

MX-80 bentonite, ρ_d = 1.80 Mg/m^3 → $w_f = 0.011\,w$ Bradbury & Baeyens (2003)

FEBEX bentonite, ρ_d = 1.65 Mg/m^3 → $w_f = 0.015\,w$ Fernández et al. (2004)

It is assumed w_f = 0

Weighted water density

$$\rho_w^* = \frac{m_w^i + m_w^e}{V_w^i + V_w^e} = \frac{w}{\frac{w_i}{\rho_w^i} + \frac{w_e}{\rho_w^e}}$$

m_w^i : mass of interlayer water

m_w^e : mass of external water

V_w^i : volume of interlayer water

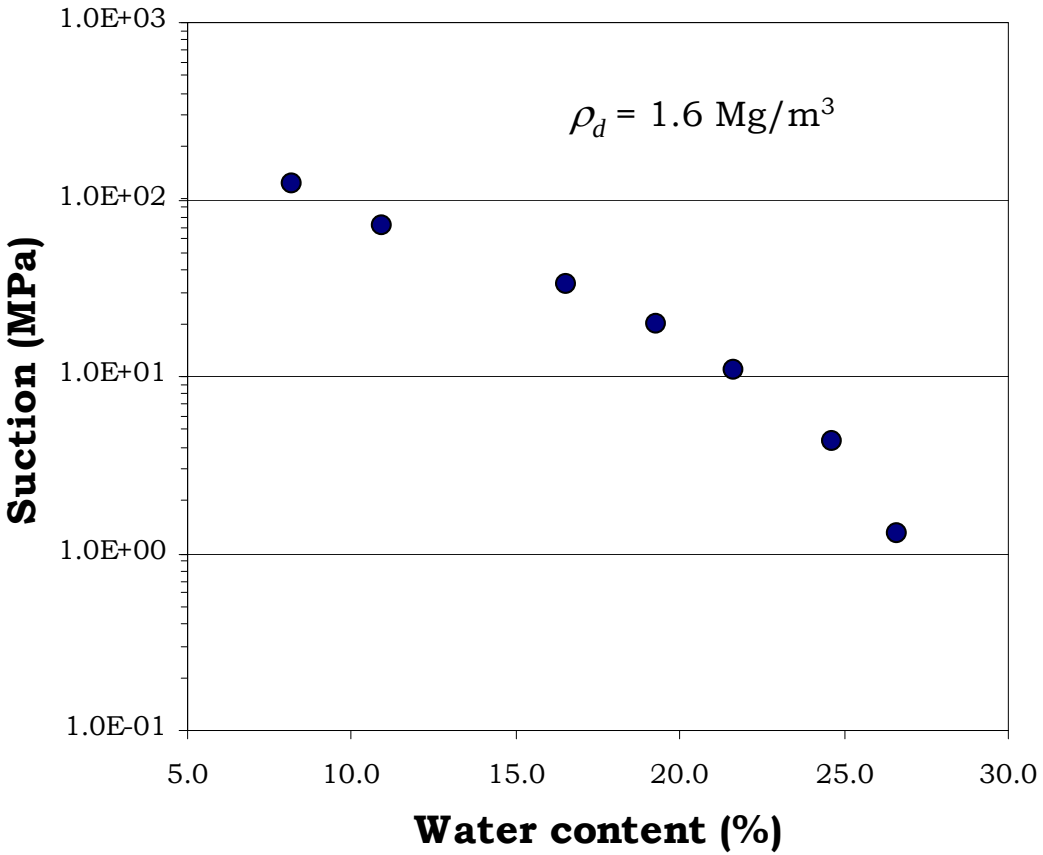
V_w^e : volume of external water

ρ_w^e = 1.0 Mg/m^3 **unknown:** ρ_w^i, w_e, w_i

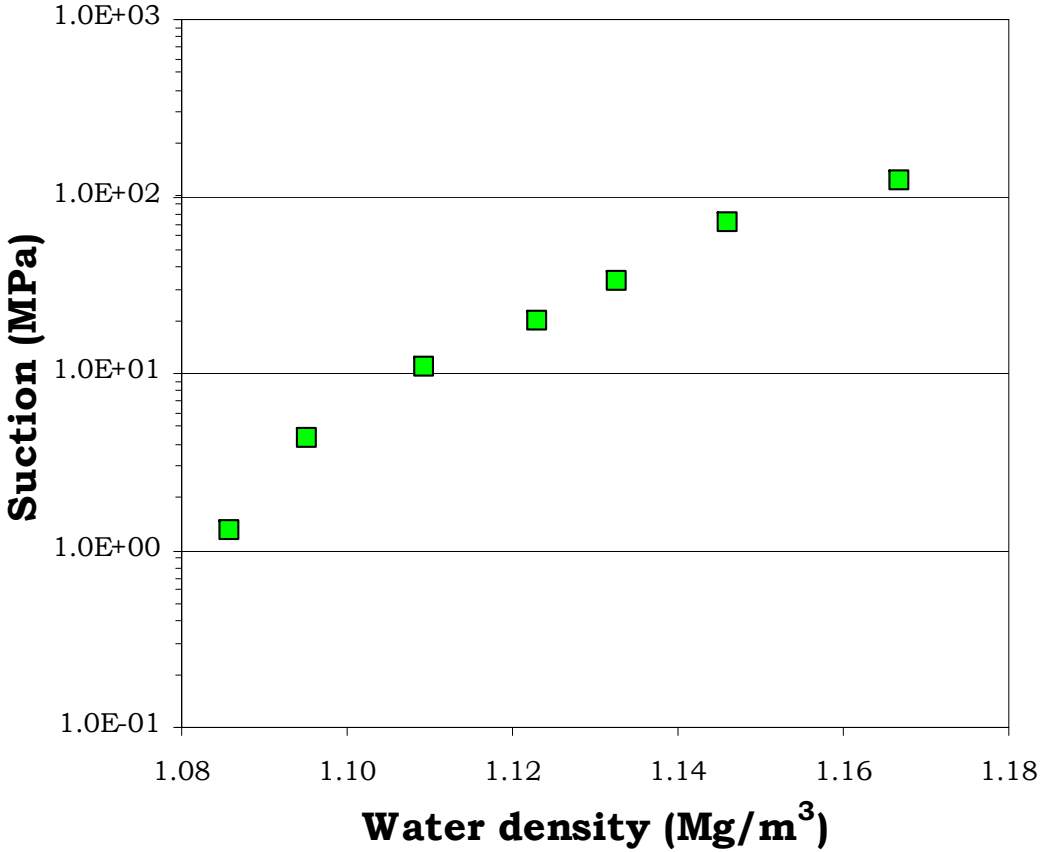
Jacinto et al. (2012) - Géotechnique

WATER DENSITY IN COMPACTED SAMPLES

Weighted water density



$$\rho_w^* = \frac{w}{\frac{w_i}{\rho_w^i} + \frac{w_e}{\rho_w^e}}$$



MX-80 bentonite

Villar (2005)

HYDRATION OF A COMPACTED SAMPLE

Application. Experimental set-up

MX-80 bentonite

Villar et al. (2006)

ϕ = 0.05 m

h = 0.10 m

w_i = 11 %

ρ_d = 1.60 Mg/m^3

Final state

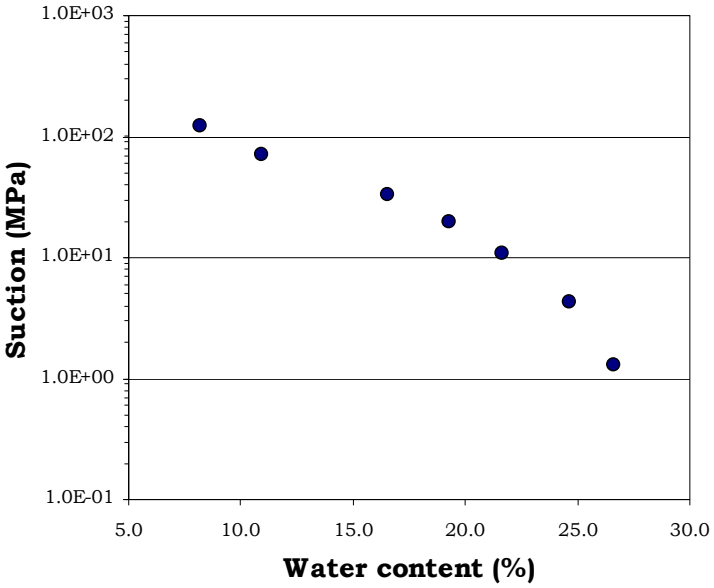
HYDRATION OF A COMPACTED SAMPLE

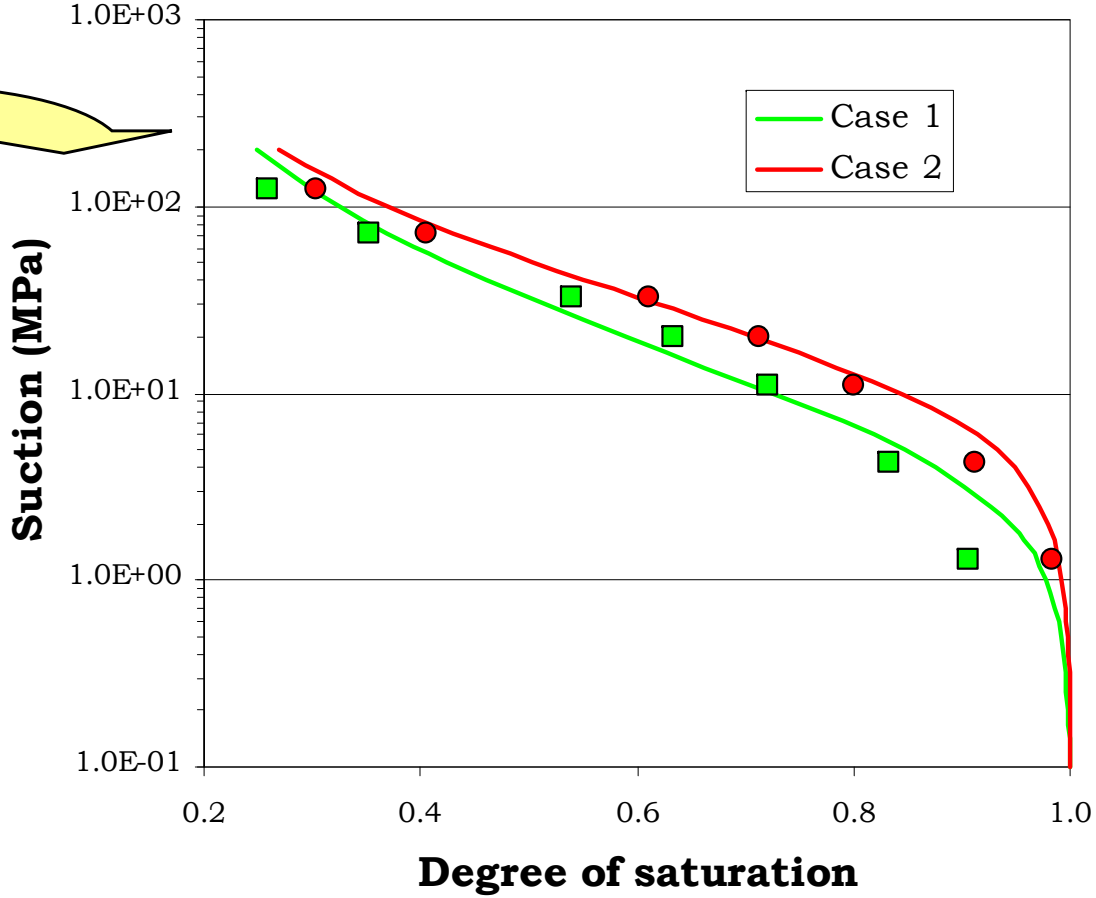
Application. Numerical analysis

- 1D geometry
- BExM
- Code_Bright

ρ_w^*

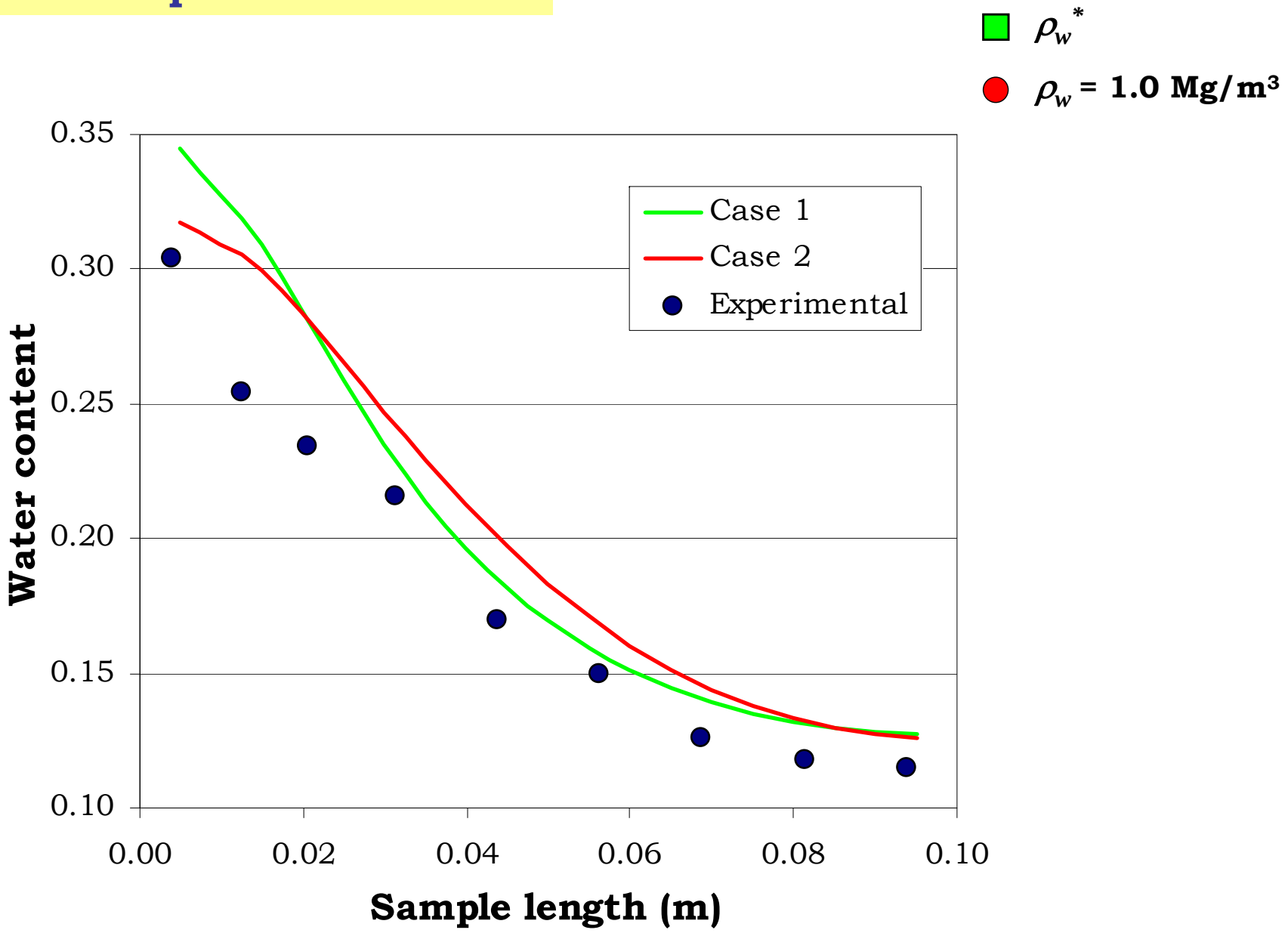
ρ_w = 1.0 Mg/m³





HYDRATION OF A COMPACTED SAMPLE

Application. Comparison of results



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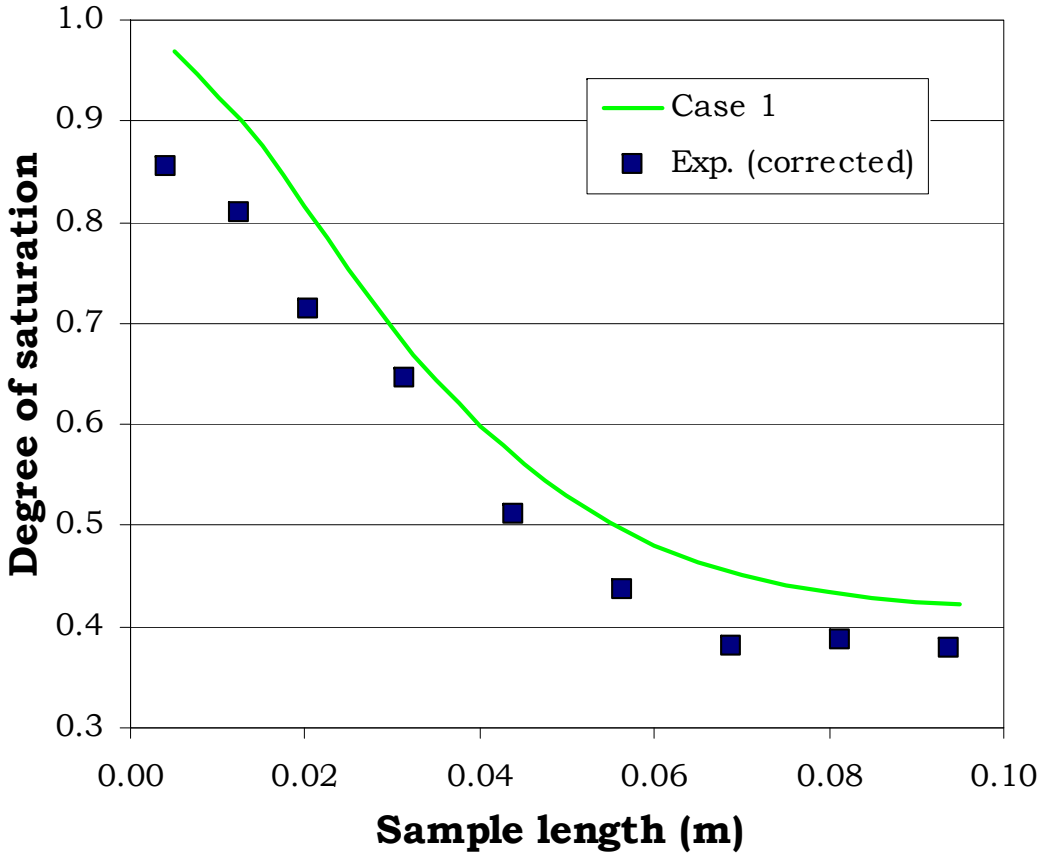
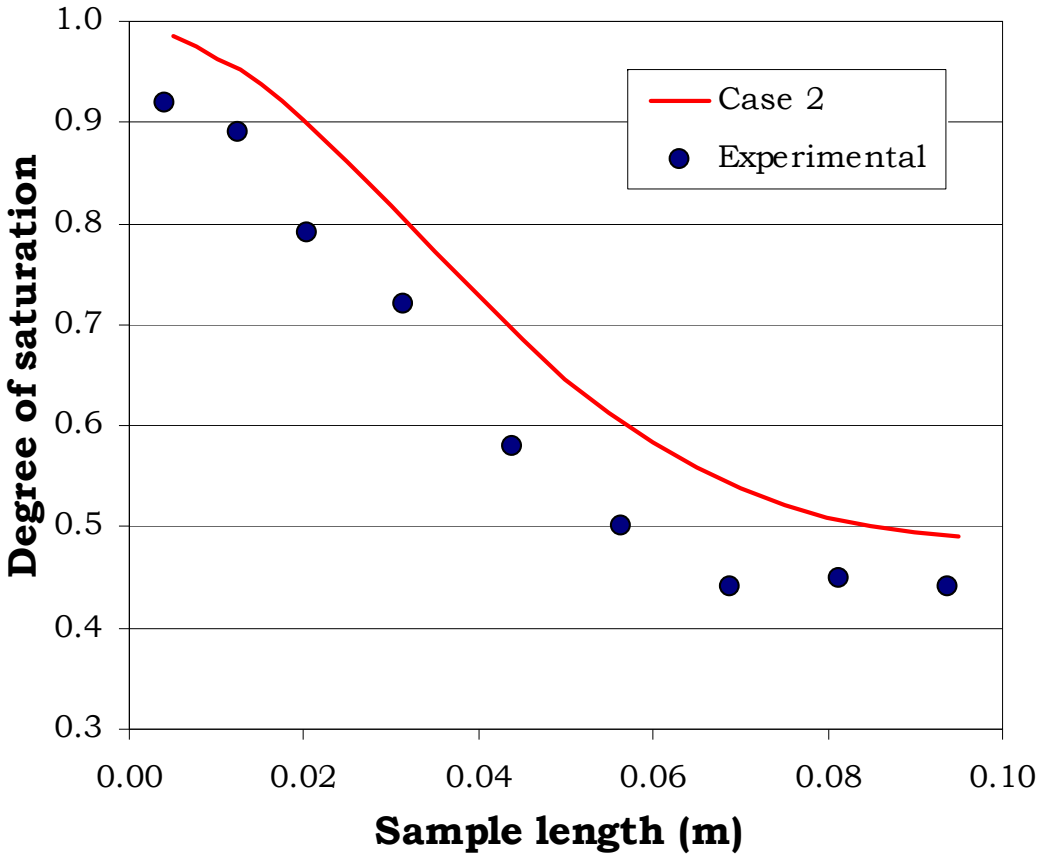


ρ_w^*

ρ_w = 1.0 Mg/m³



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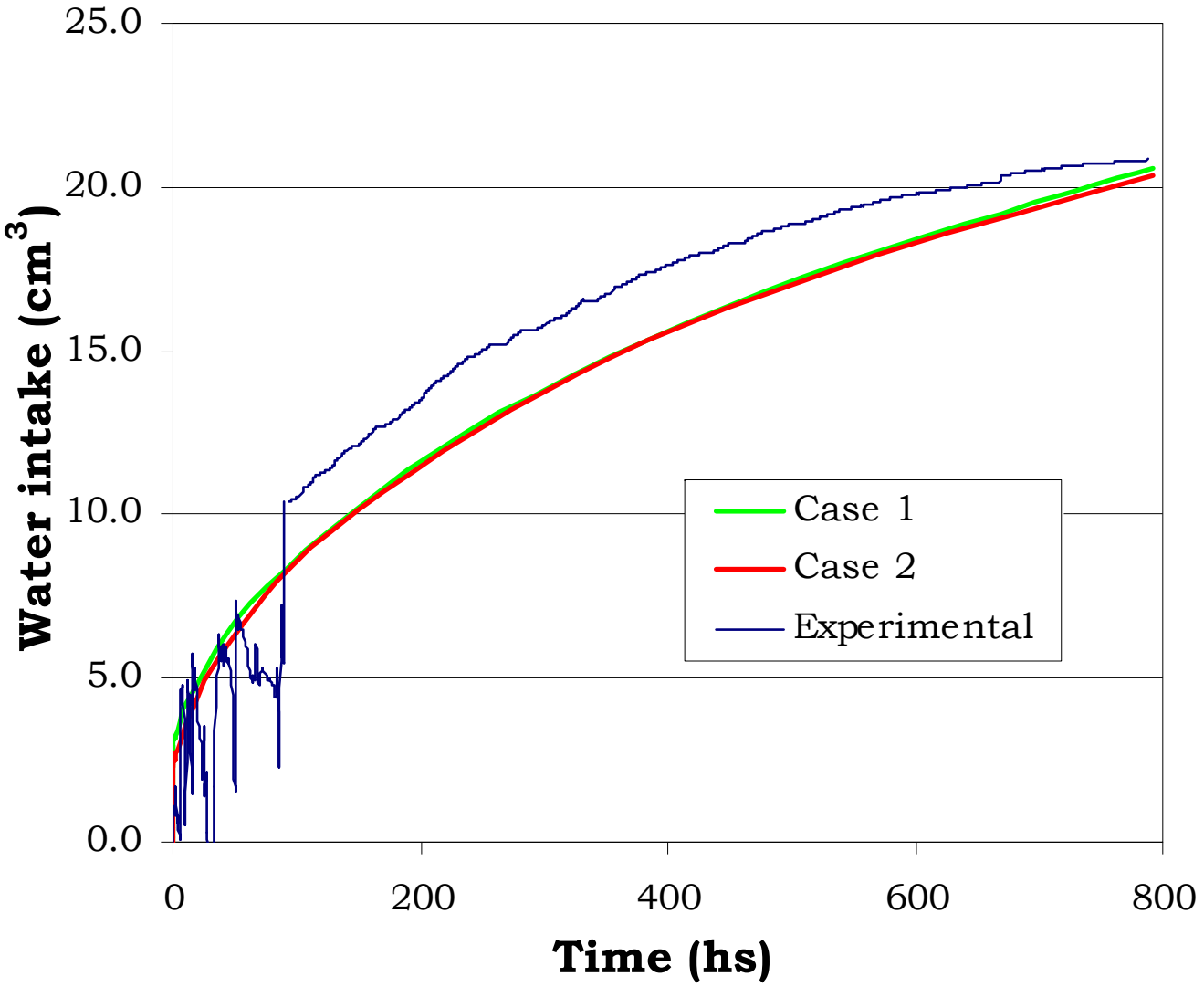
Application. Comparison of results

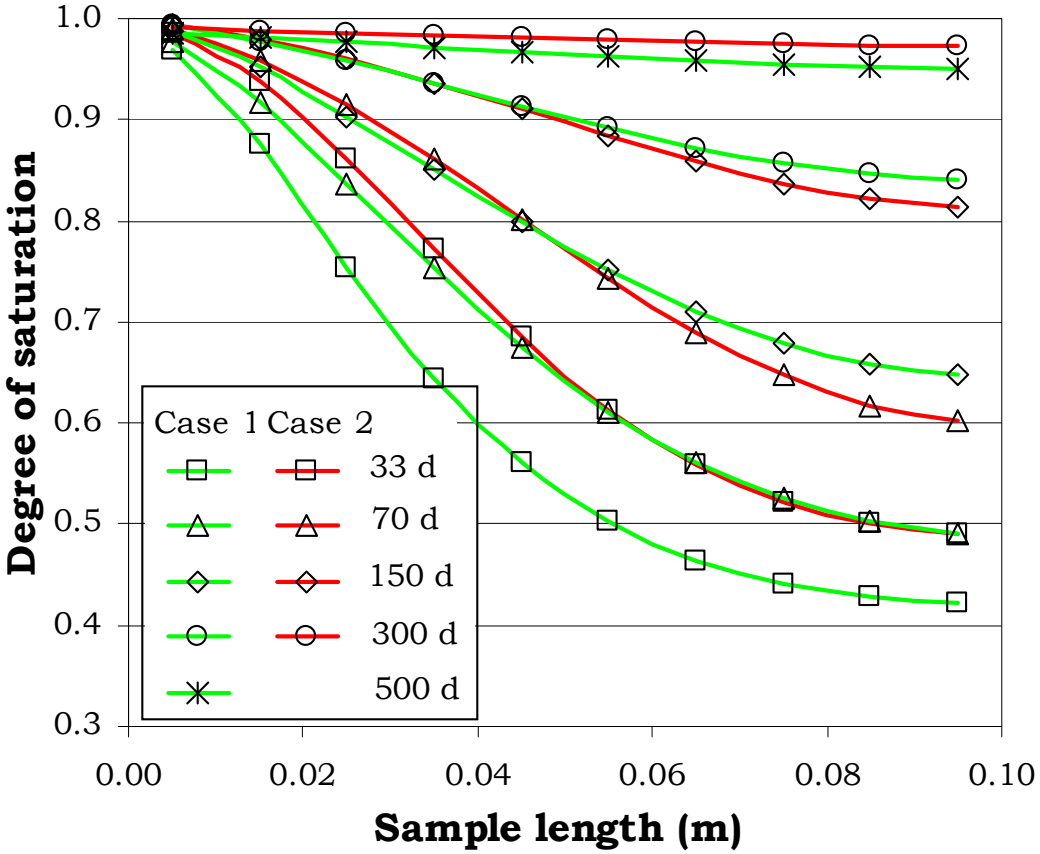


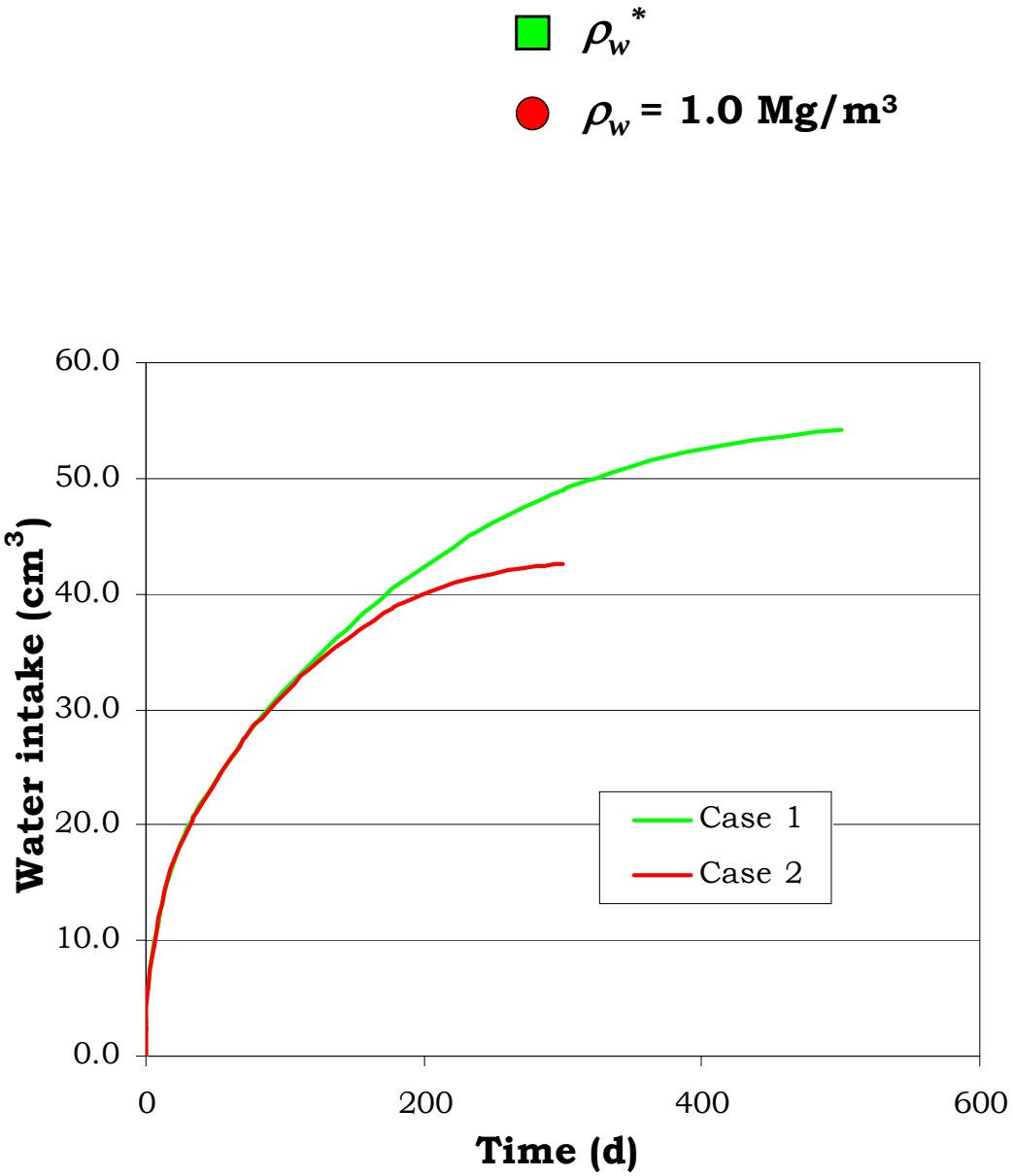
ρ_w^*

ρ_w = 1.0 Mg/m³

HYDRATION OF A COMPACTED SAMPLE

Application. Numerical test





CONCLUDING REMARKS

- **Experimental data indicate that density of water attached to clay minerals is bigger than 1.0 Mg/m^3.**

- **Experimental results of an hydration test were reproduced using a weighted water density that incorporates the clay-water interaction.**

- **Numerical test suggests that full hydration of a compacted bentonite sample requires more water and saturation time than predicted using the bulk water density.**