

QC/QA with the Panda and GTR Soil Classification – The Pavement Cases

Miguel-Angel Benz-Navarrete ⁽¹⁾ and Younes Haddani ⁽²⁾

Department of Research & Innovation

Sol-Solution Géotechnique Réseaux

(1) Phd. Msc. Research and Innovation Manager. mbenz@sol-solution.com

(2) Phd. Msc. Innovation and Work Diagnosis Manager. yhaddani@sol-solution.com

Sol-Solution Géotechnique Réseaux
ZA des Portes de Riom Nord – BP 178
63204 Riom Cedex – France
e-mail : contact@sol-solution.com
Phone : +33 (0)4 73 64 74 84

Introduction

Background

Compaction Control

The importance of compaction control

The stability of roads and their durability depend a lot on the dimensioning and evenmore on the structural pavement layers.



The **mechanical behavior of the pavement layers** is by the nature of the materials, the thickness of the layers and **the level/quality of compaction**.

Since Proctor's studies, trenches control is made with the following

- ✓ Mesure du poids volumique sec (γ_d) et comparaison à une référence (OPN et/ou OPM)

Introduction

Background

The Compaction Control

The importance of compaction control

The methods of compaction control :



Direct methods (*gamma densitometer, densitometer ...*)

Indirect methods (*load plate test, bearing capacity, penetrometers...*)



Backfills are done layer per layer :

✓ **Horizontal variability**

✓ **Vertical variability**

Introduction

Background

Dynamic Penetrometer for the Compaction Control



SPT – Standard Penetration Test
(63.5 kg. hammer drops 760 mm)



DPSH
(63.5 kg. hammer drops 760 mm)



DCP
(8 kg. hammer drops 575 mm)



PANDA 2®
(Variable drops & energy)

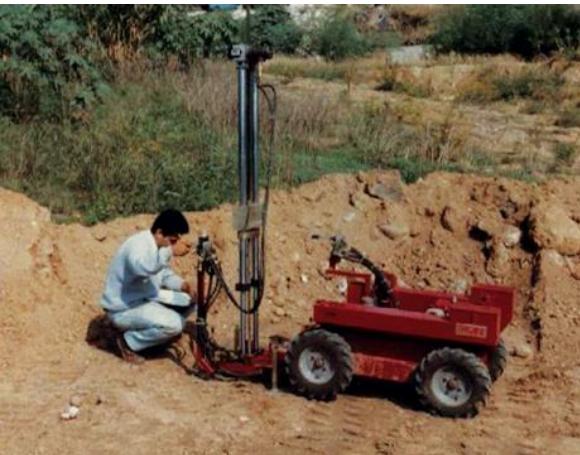
In the classical geotechnical field, dynamic penetration is one of the most popular test around the world (*quick, cost effective, simple...*).

- In-Situ Shallow Characterization ...
- Control, Acceptance and diagnosis of backfills ...

Introduction

Background

Dynamic Penetrometer for the Compaction Control





Introduction

Background

Dynamic Penetrometer for the Compaction Control

However ...

Wide variety of devices (lack of standards)

Empirical interpretation (it is soft or hard...)

Different relationship (CBR, E_{LDFW} , E, DCPI ...) are available ...

No devices measures the compaction degree

Introduction

Background

The French Experiences – LCPC Rouen The PDG-1000



Developed in France (80's – 90's)
by the CER Rouen

Compaction Control Quality
according to the French Standard

The Idea : "For each type of soil used in backfill and for each compaction degree a relationship between density and cone index must be established"

Introduction

Background

The French Experiences – LCPC Rouen The PDG-1000 – Labs Calibration



Réalisation de la tranchée



Chargement du matériau



Premier compactage avec la plaque



Second compactage avec le BW100



Marquage des points de mesure

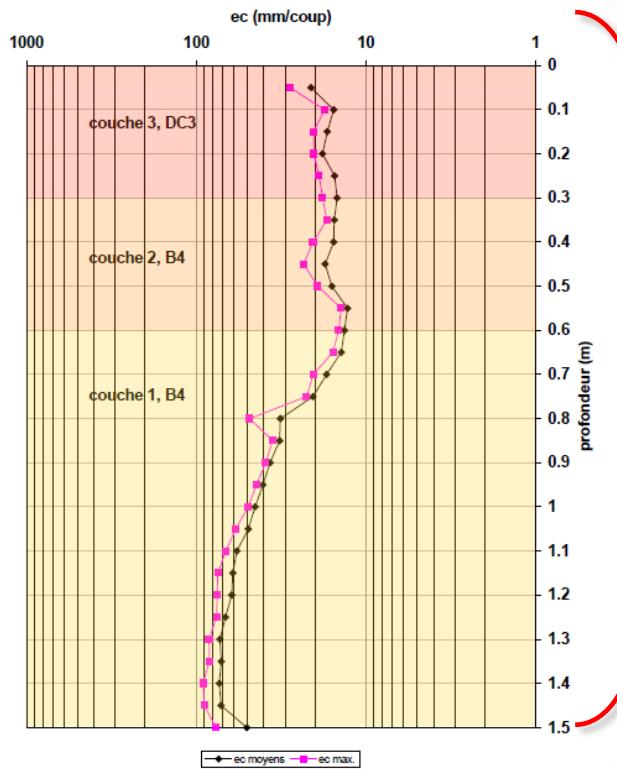


Introduction

Background

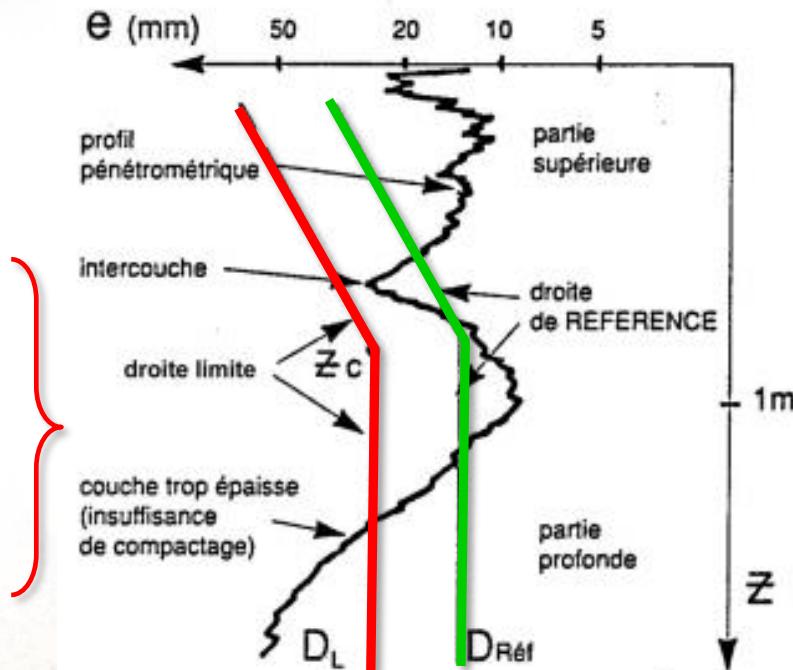
The French Experiences – LCPC Rouen Control Principle

enfoncement du Pdg1000
dans les graves DC3 et B4



Soil Data Base GTR

- ✓ Soil type (GTR)
- ✓ Compaction requirement



References Curves for Soil "X" &
"Y%" Compaction Degree

Introduction

Background

The French Experiences – LCPC Rouen Control Principle



Difficulties related to PDG-100

The Device is Bulky and Heavy

Test Execution Time : Important

High Penetration (low precision in soft soils)

Thickness Detection : Not Easy

The Device and the Test is not Cheaper

...

Introduction

Compaction Control

The Panda Use for the Compaction Control Background

LE PANDA



Pénétromètre dynamique léger
à énergie variable
pour la reconnaissance des sols

Roland Gourvès - LABORATOIRE DE GENIE CIVIL - OISTT - UNIVERSITE BLAISE-PASCAL DE CLERMONT-FERRAND - FRANCE
BP 206 - 63174 AUBIERE CEDEX - TEL: 73 40 75 20 - TELECOPE: 73 40 75 10

Created in 1989 by Roland Gourvès
(Gourvès et Barjot, 1991)

- ✓ Develop a light dynamic penetrometer completely automatic
- ✓ Driving : Variable Energy
- ✓ Automatically interpretation (by PC)

Improvement of the quality
and quantity measurements

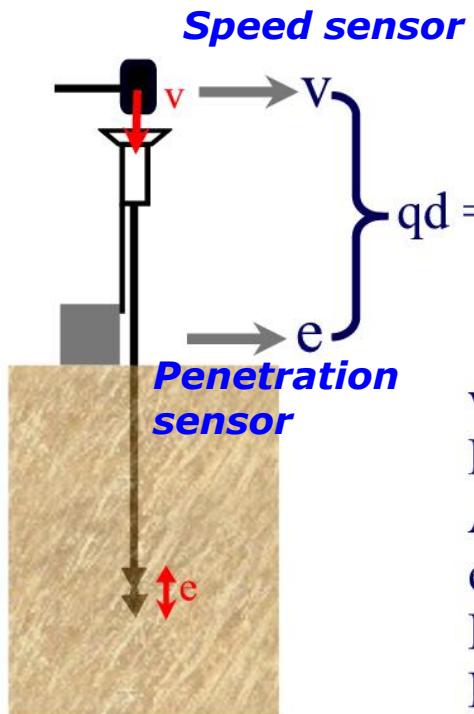


QC/QA with Panda®

Compaction Control

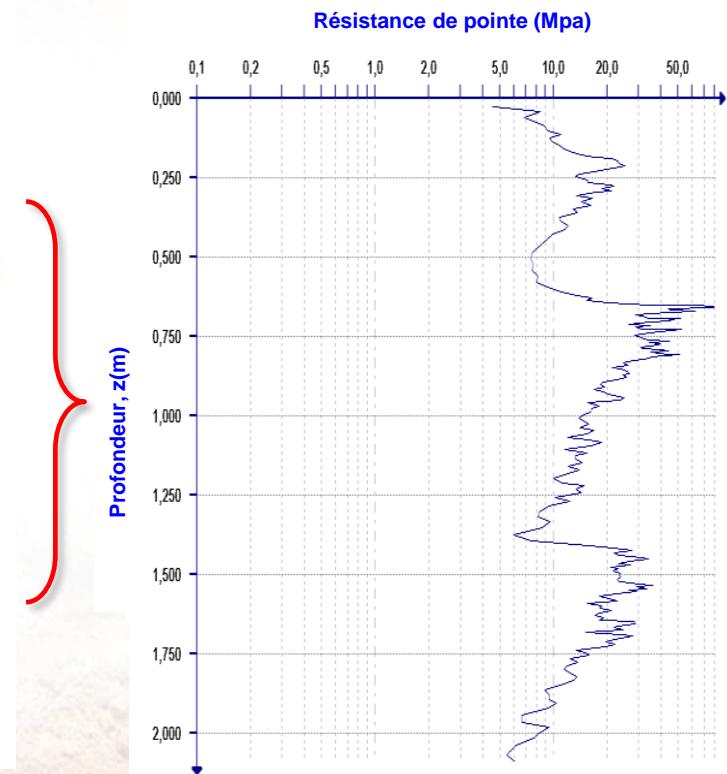
The Panda Use for the Compaction Control Background

Measuring Principle



Soil resistance qd calculated from Dutch Formula

v Speed of the hammer
M Mass of the hammer
A Cone cross section
e Settlement
P Struck mass
M Striking mass



"The qd soil tip resistance is a mechanical measurement of soil state (Chaigneau, 2002)"

L'innovation sur de solides appuis

Planning

Schedule

Introduction

The Panda Use for the Compaction Control

- a. **Background** (*Measuring principle, Panda 1, Panda 2...*)
- b. **Measuring Principle** (*Micromechanical approach, density-qd relationship...*)
- c. **Calibration Panda** (*Calibration Curves : How to obtain it?*)
 - Laboratory – Calibration Chamber
 - In-Situ Test – Test Beds
 - Mathematical Models
- d. **Reference Controls Curves** (*How to determine it?*)
 - Compaction Requirements (NF P 94-063)
- e. **Control Test : Interpretation**
 - Anomaly Detection (Compaction Defects)
 - Thickness Determination
- f. **Use Panda for Compaction Control** (*Software Panda Windows ...*)

Application Example (*In-situ Test at Urbana*)

Planning

Schedule

Introduction

The Panda Use for the Compaction Control

- a. Background (*Measuring principle, Panda 1, Panda 2...*)
- b. Measuring Principle (*Micromechanical approach, density-qd relationship...*)
- c. Calibration Panda (*Calibration Curves : How to obtain it?*)
 - Laboratory – Calibration Chamber
 - In-Situ Test – Test Beds
 - Mathematical Models
- d. Reference Controls Curves (*How to determine it?*)
 - Compaction Requirements (NF P 94-063)
- e. Control Test : Interpretation
 - Anomaly Detection (Compaction Defects)
 - Thickness Determination
- f. Use Panda for Compaction Control (*Software Panda Windows ...*)

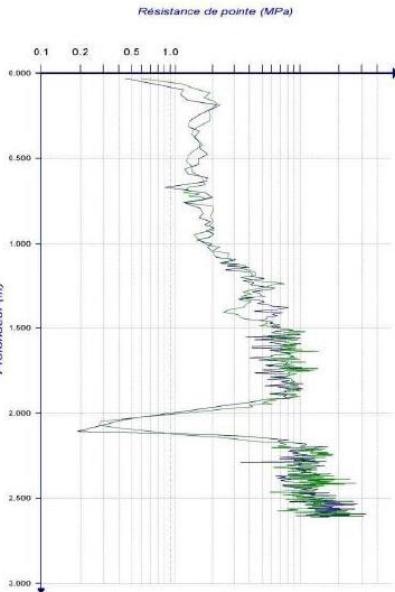
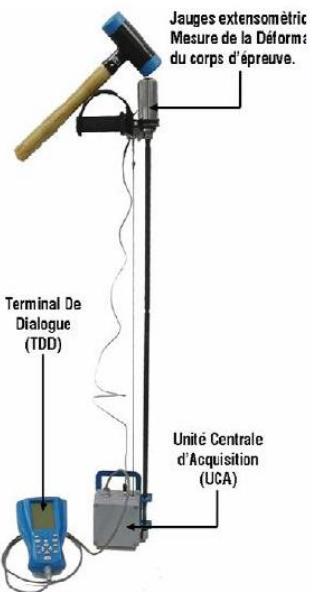
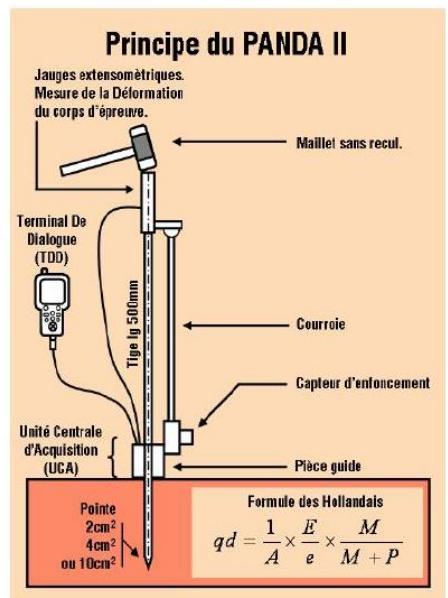
Application Example (*In-situ Test at Urbana*)



QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control Background



Compaction control (NF P 94-105) fast and easy to obtain :

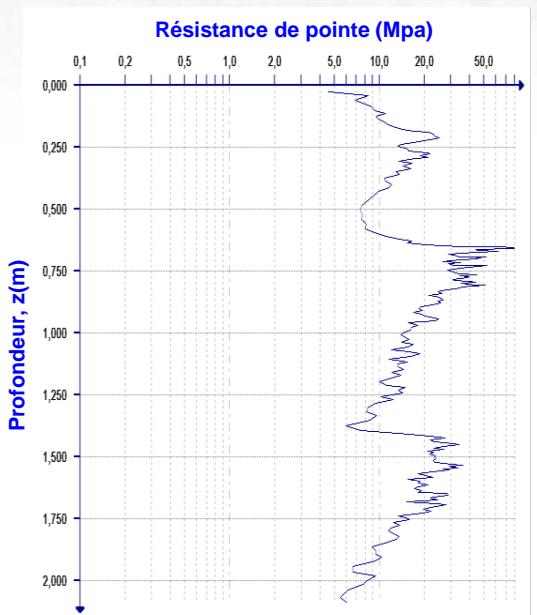
- ✓ Thickness layers detection
- ✓ Compaction quality control
- ✓ Anomalies detection in depth



QC/QA with Panda®

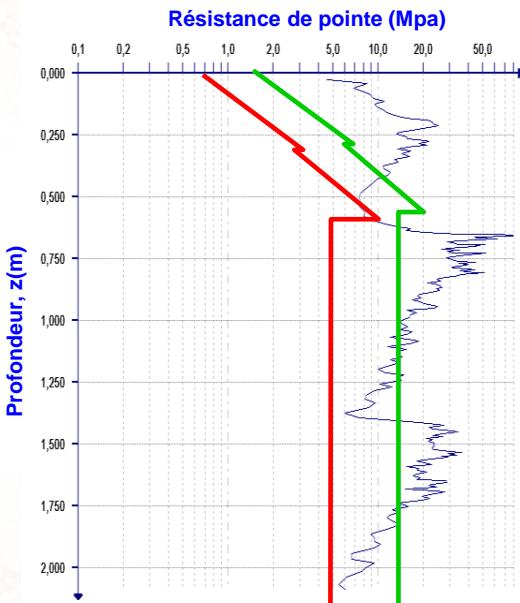
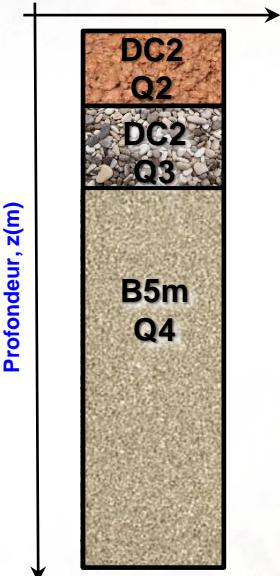
Compaction Control

The Panda Use for the Compaction Control Background



(1) In-situ Test →

(2) Log $q_d(z)$ obtained



→ (3) Input specifications (GTR)

→ (4) Control and Interpretation
NF P 94-105

- ✓ **Type of Soil (GTR)**
- ✓ **Thickness of Layers**
- ✓ **Compaction Requirement**

Planning

Schedule

Introduction

The Panda Use for the Compaction Control

a. Background (*Measuring principle, Panda 1, Panda 2...*)

→ b. Measuring Principle (*Micromechanical approach, density-qd relationship...*)

c. Calibration Panda (*Calibration Curves : How to obtain it?*)

- Laboratory – Calibration Chamber
- In-Situ Test – Test Beds
- Mathematical Models

d. Reference Controls Curves (*How to determine it?*)

- Compaction Requirements (NF P 94-063)

e. Control Test : Interpretation

- Anomaly Detection (Compaction Defects)
- Thickness Determination

f. Use Panda for Compaction Control (*Software Panda Windows ...*)

Application Example (*In-situ Test at Urbana*)

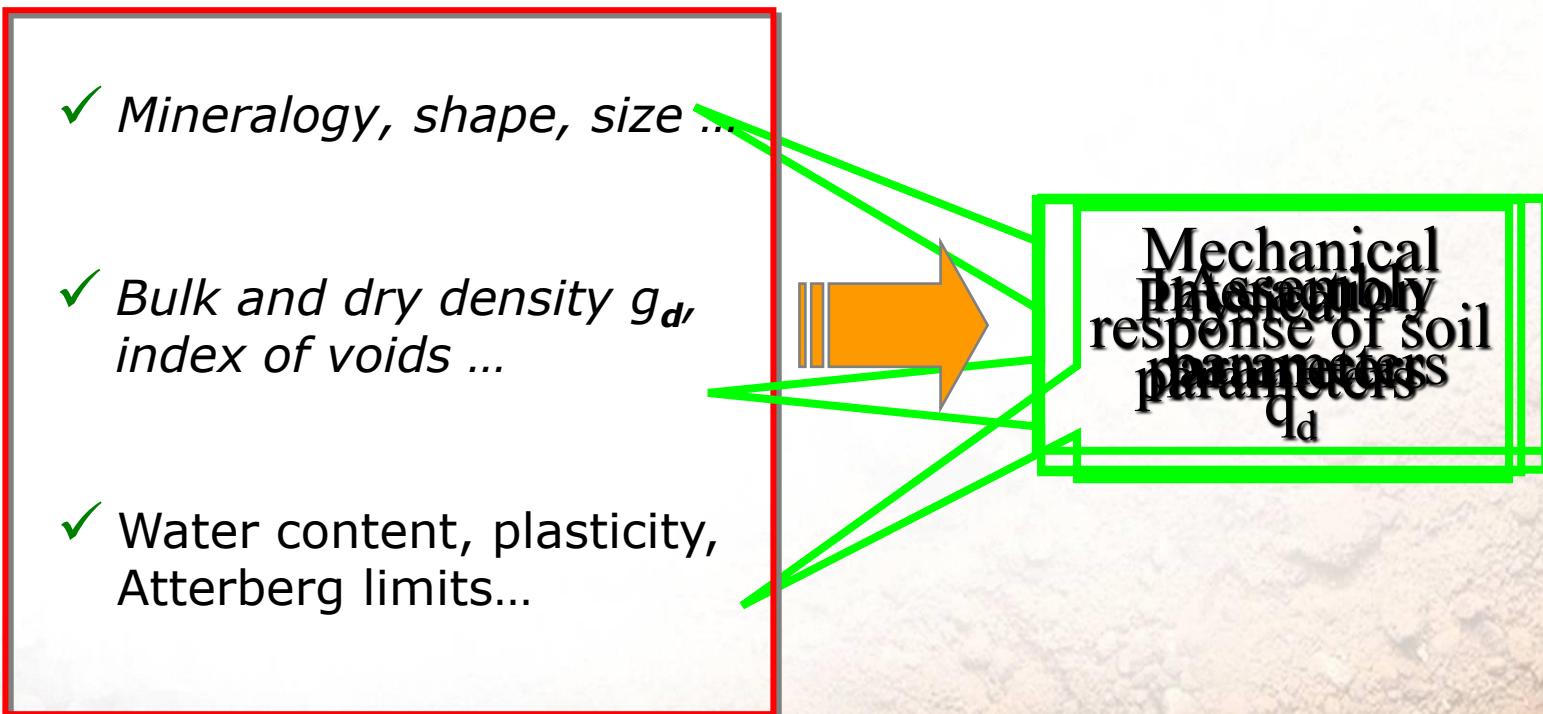


QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control Measurement Principle (Chaigneau, 2002)

Classification parameters used to describe the soil according to the micromechanical approach :





QC/QA with Panda®

Compaction Control

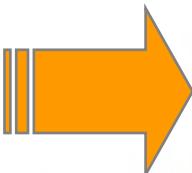
The Panda Use for the Compaction Control Measurement Principle (Chaigneau, 2002)

If the parameter controlled is the qd tip resistance of soil

Knowledge of :

- ✓ Mineralogy, shape, size, particle-size distribution
...
- ✓ Tip resistance $qd(z)$
- ✓ Water content, plasticity, Atterberg limits...

Allows to determine ...



Dry density in depth
 $\gamma_d(z)$

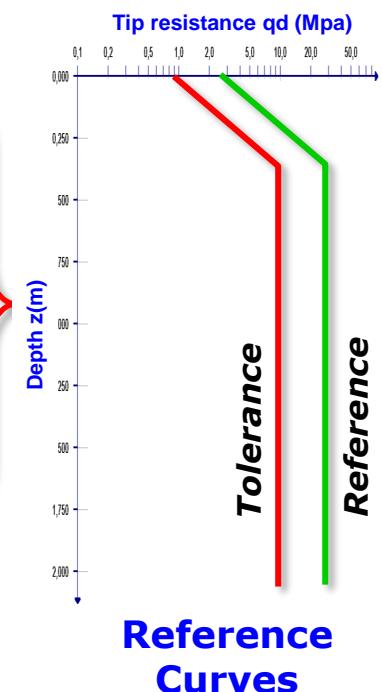
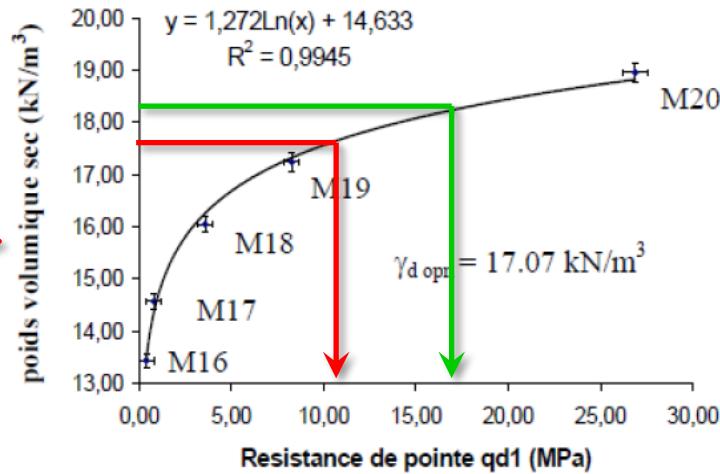
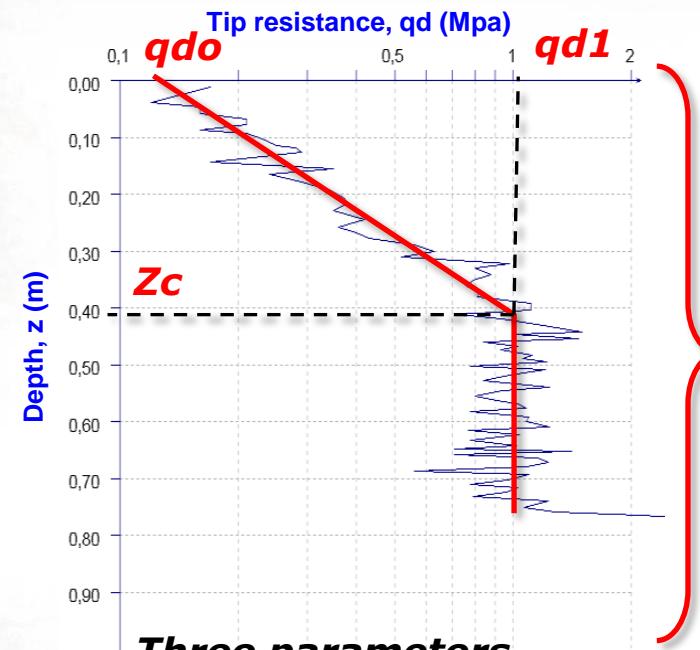


QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control Measurement Principle

In fact, (Zhou, 1997) & (Chaigneau, 2002) showed that there is a very close relationship between dry density and tip soil résistance qd ...



SOL
OLUTION

qd
Zc
qd1

Planning

Schedule

Introduction

The Panda Use for the Compaction Control

a. Background (Measuring principle, Panda 1, Panda 2...)

b. Measuring Principle (Micromechanical approach, density-qd relationship...)

→ c. Calibration Panda (Calibration Curves : How to obtain it?)

- Laboratory – Calibration Chamber
- In-Situ Test – Test Beds
- Mathematical Models

d. Reference Controls Curves (How to determine it?)

- Compaction Requirements (NF P 94-063)

e. Control Test : Interpretation

- Anomaly Detection (Compaction Defects)
- Thickness Determination

f. Use Panda for Compaction Control (Software Panda Windows ...)

Application Example (In-situ Test at Urbana)



QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control Measurement Principle

Reference curves : How to obtain it?

Laboratory - calibration chamber

Calibration Method in (*NF 94-105*)



In-situ test – Test Beds

In-situ Method – Function C (*NF 94-105*)



Mathematical models

Under process



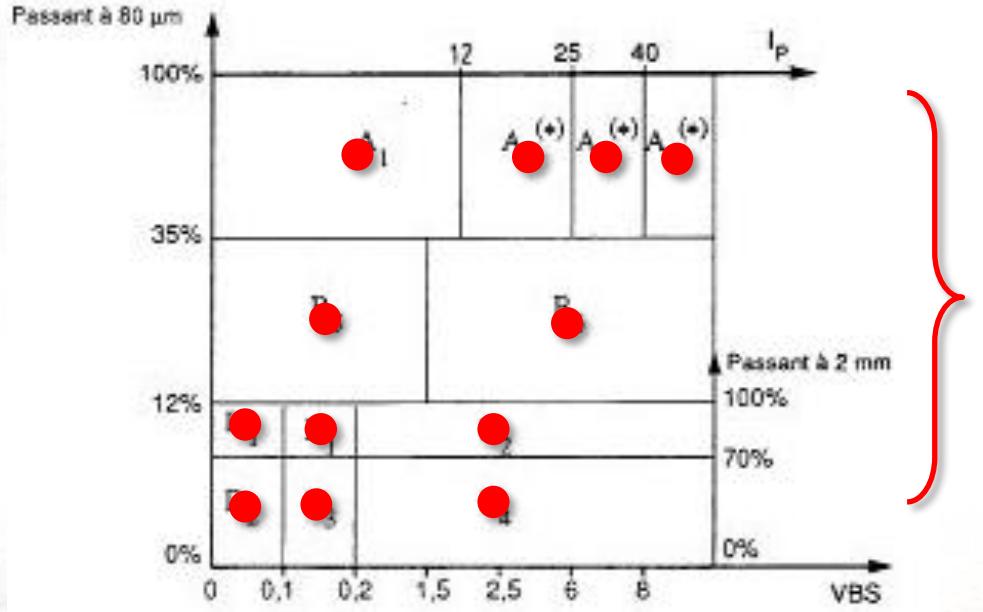
QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

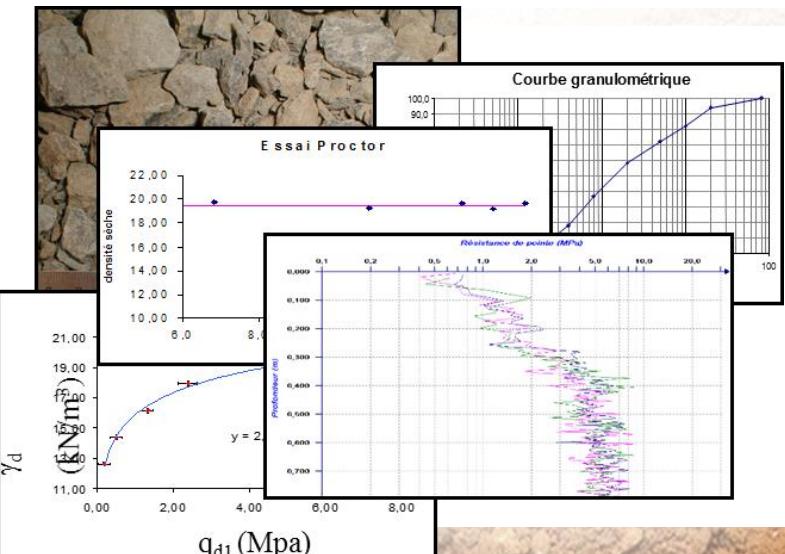
Calibration Panda – Building a Soils Database (Labs)

Calibration Curves : Determination (*Chaigneau, 2002*)



GTR Soil Classification Chart

(D_{max} < 50mm)





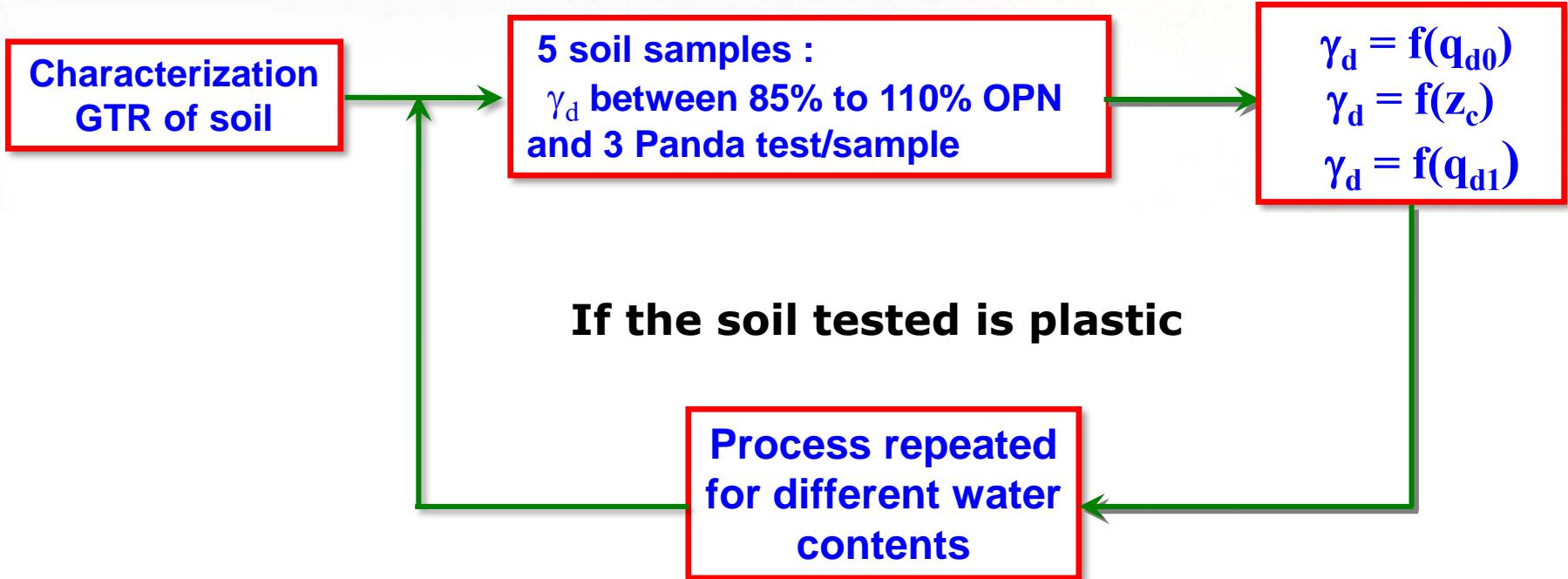
QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – Building a Soils Database (Labs)

— Calibration Curves : Determination (Chaigneau, 2002) —



Completion time for a soil : 1 month / 2 operator

8 plastic soil tested = more than 100 samples



QC/QA with Panda®

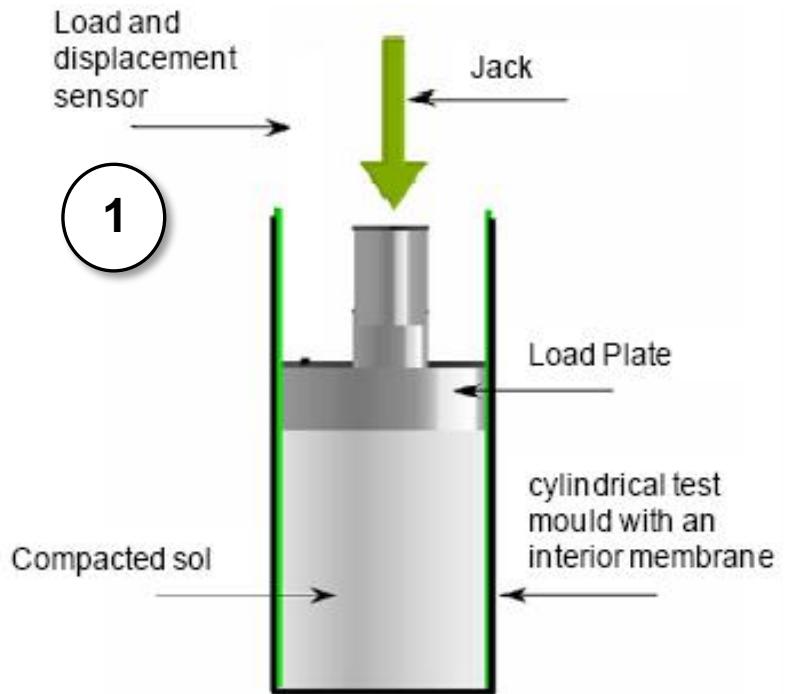
Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – Building a Soils Database (Labs)

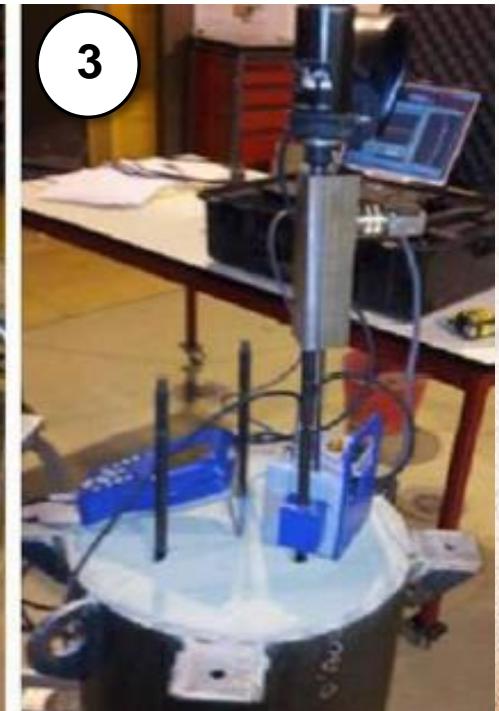
— Calibration Curves : Determination (Chaigneau, 2002) —

The samples of soil is carried out in a calibration chamber 400mm x 800mm according to French standard NF P 94-105



Sample Compaction Process

L'innovation sur de solides appuis



Compaction Process



QC/QA with Panda®

Compaction Control

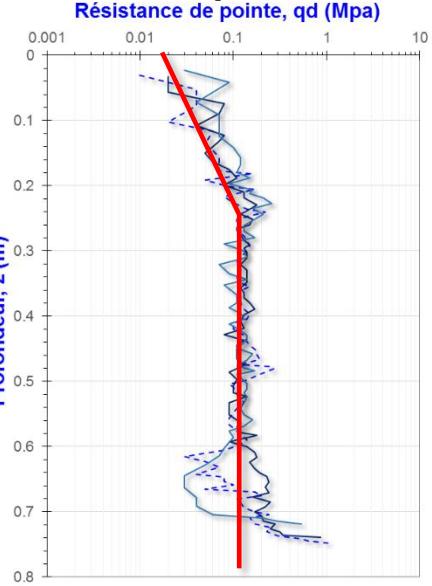
The Panda Use for the Compaction Control

Calibration Panda – Building a Soils Database (Labs)

— Calibration Curves : Determination (Chaigneau, 2002) —

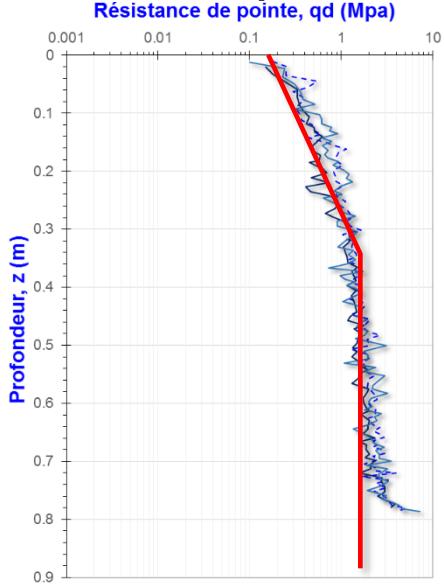
Fontainebleau Sand (GTR = D1 ; USCS = SP ; AASHTO = A-3)

Sample 2



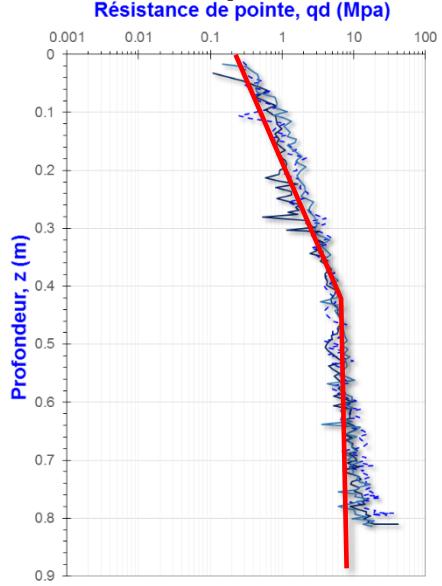
$qdo : 0,03 \text{ Mpa}$
 $Zc : 0,23 \text{ m}$
 $qd1 : 0,14 \text{ Mpa}$

Sample 3



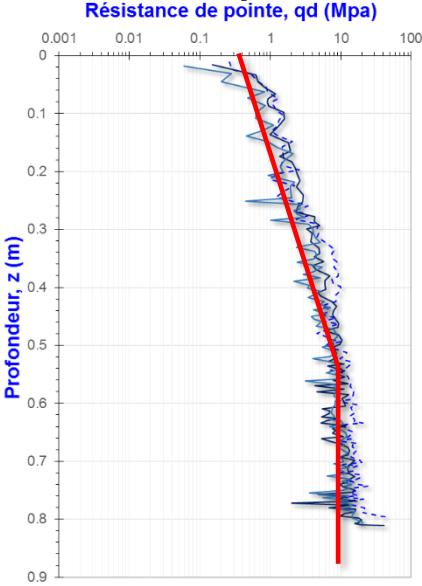
$qdo : 0,24 \text{ Mpa}$
 $Zc : 0,31 \text{ m}$
 $qd1 : 1,65 \text{ Mpa}$

Sample 4



$qdo : 0,40 \text{ Mpa}$
 $Zc : 0,48 \text{ m}$
 $qd1 : 8,56 \text{ Mpa}$

Sample 5



$qdo : 0,69 \text{ Mpa}$
 $Zc : 0,55 \text{ m}$
 $qd1 : 14,21 \text{ Mpa}$



QC/QA with Panda®

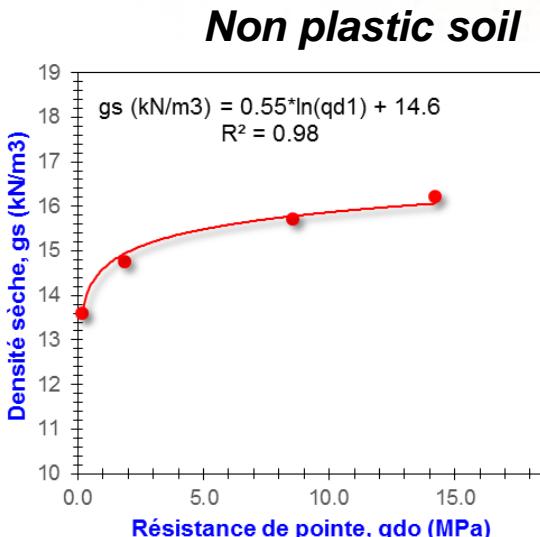
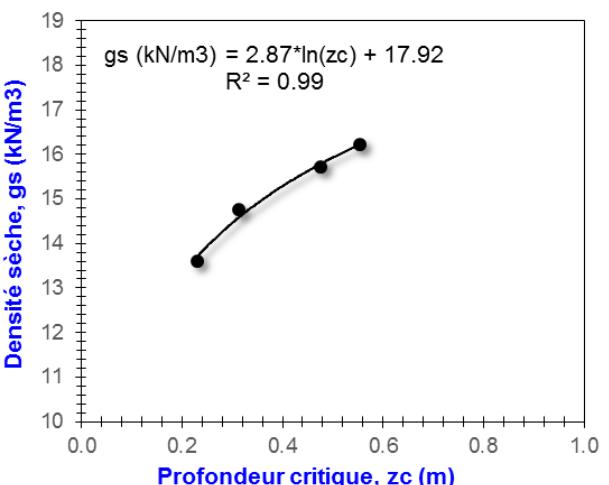
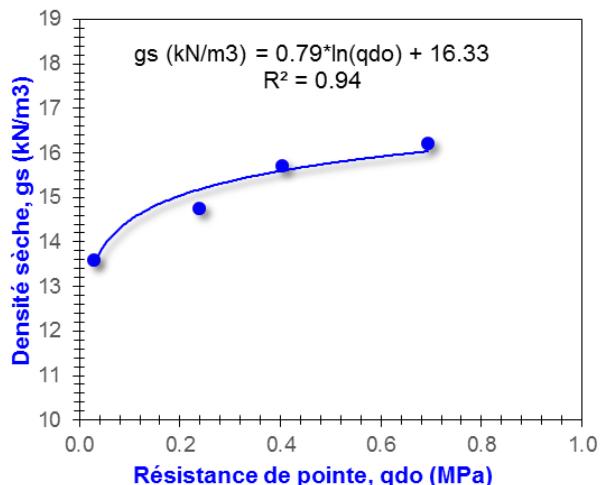
Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – Building a Soils Database (Labs)

— Calibration Curves : Determination (Chaigneau, 2002) —

Fontainebleau Sand (GTR = D1 ; USCS = SP ; AASHTO = A-3)



Calibration Curves – Density-penetrometer characteristic relationship



QC/QA with Panda®

Compaction Control

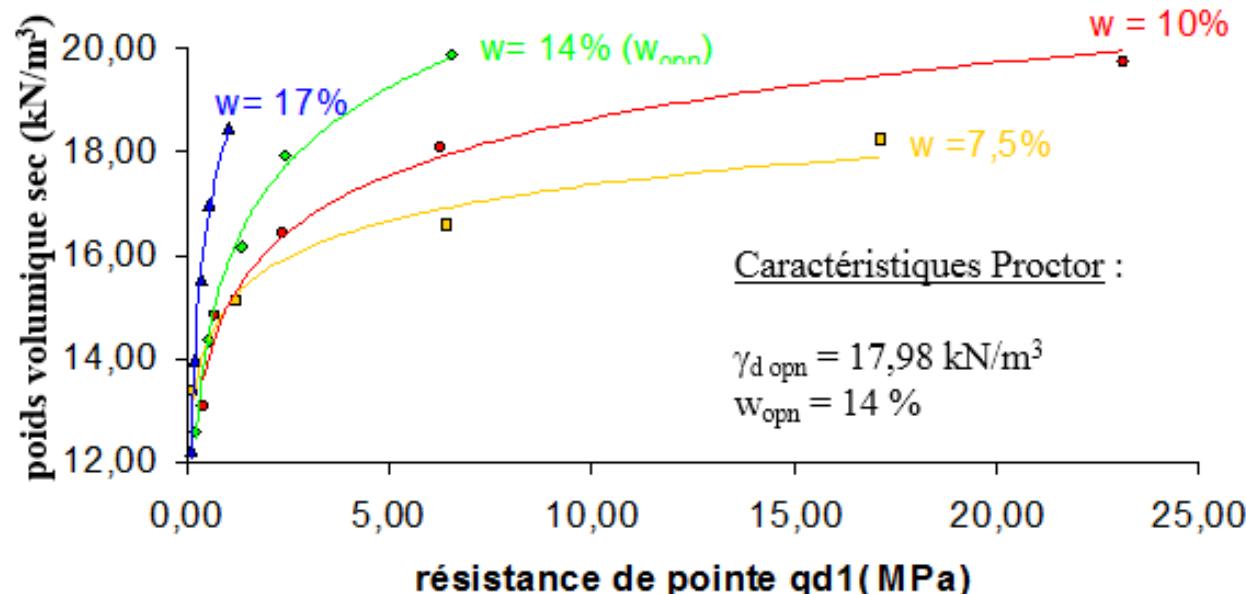
The Panda Use for the Compaction Control

Calibration Panda – Building a Soils Database (Labs)

— Calibration Curves : Determination (Chaigneau, 2002) —

For plastic soils – 5 samples / different water contents

Process repeated for
different water
contents



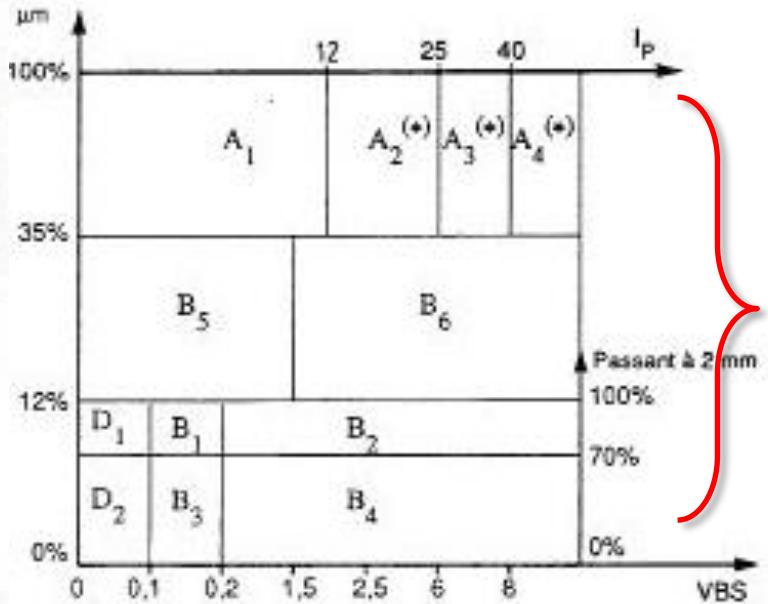


QC/QA with Panda®

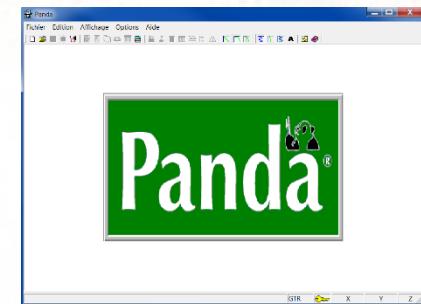
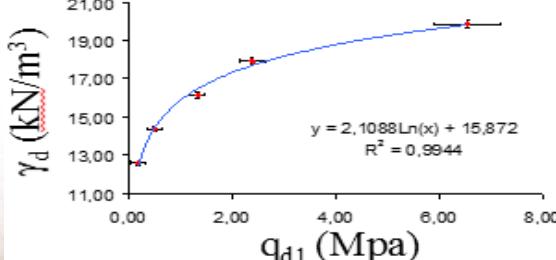
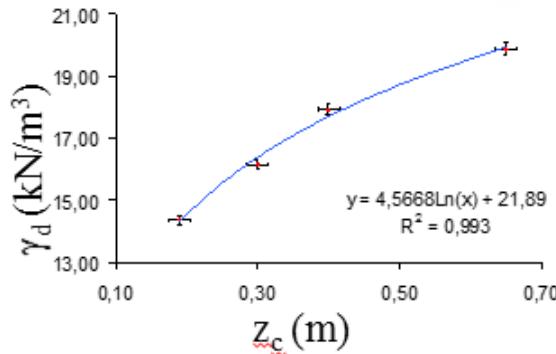
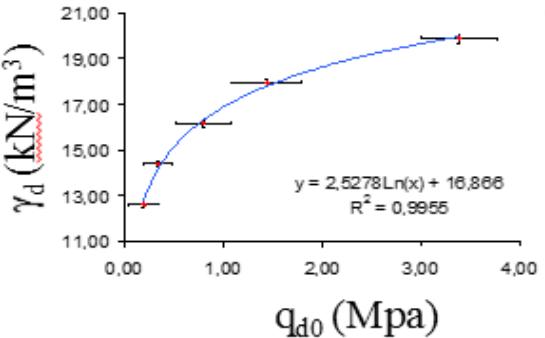
Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – Building a Soils Database



Calibration Curves



**Soil Data Base in
PandaWin
Software for :**

~ 30 GTR Soil

**+ 180 Reference
curves**



QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – In-situ Test Beds (Testing Field)

Calibration Curves : Experimental Determination

Reference Curves from Testing Field – C Function (NF P 94-105)



(a) Backfill – Test Beds



(b) Soil
Characterization



(c) Panda Test after
compaction



QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

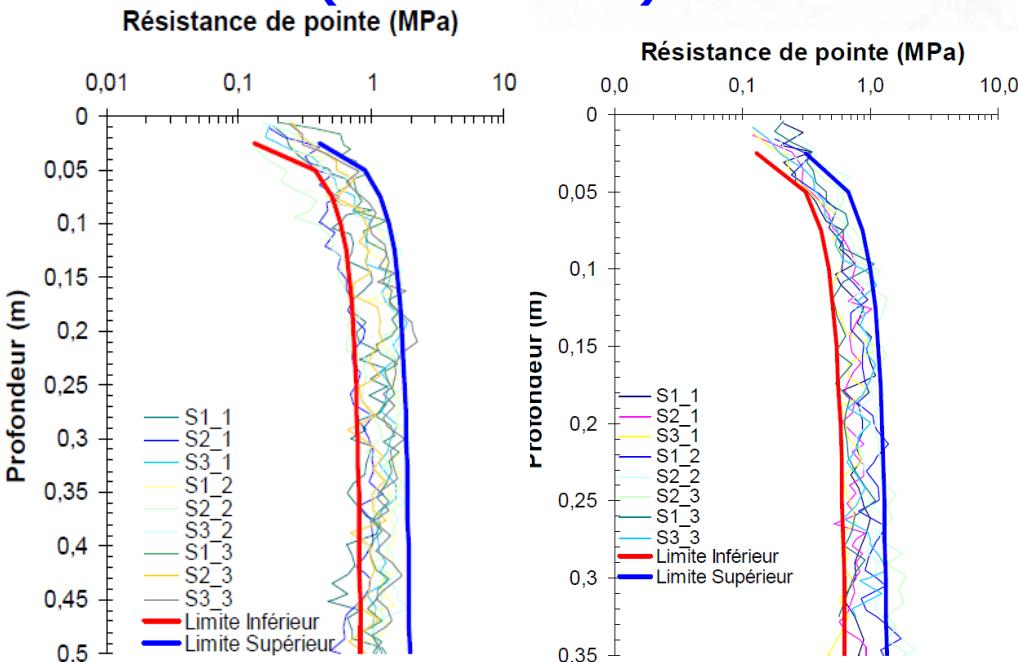
Calibration Panda – In-situ Test Beds (Testing Field)

Calibration Curves : Experimental Determination

Reference Curves from Test Beds – Function C (NF P 94-105)



(a) Backfill – Test Beds.
Patagonia, Chile



(b) Result : In-situ Reference
Curves for 95%OPN



QC/QA with Panda®

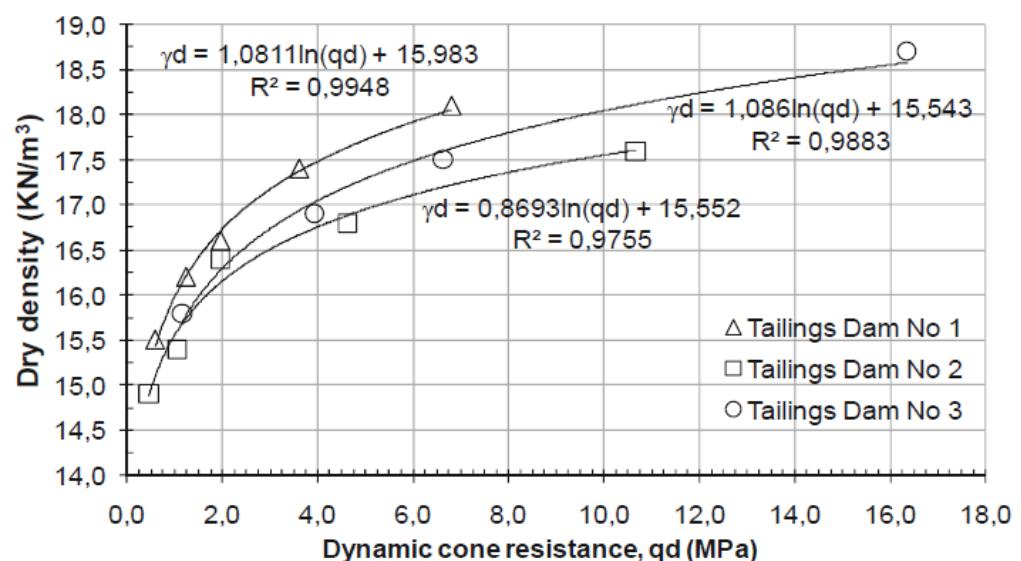
Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – In-situ Test Beds (Testing Field)

Calibration Curves : Experimental Determination

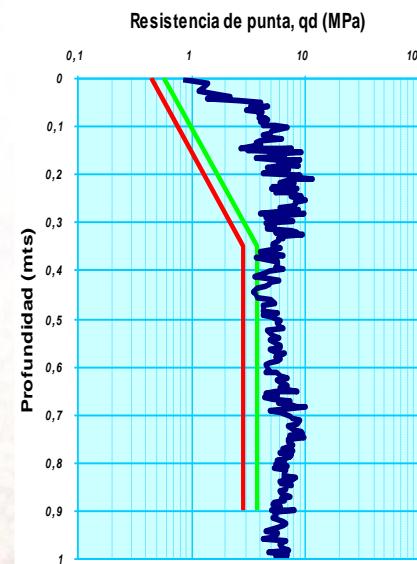
Reference Curves from Test Beds – Function C (NF P 94-105)



(a) Calibration Curves in-situ Test Beds, Chileans Tailings Dams



(b) Panda Test in tailing Dams



(c) Reference Curves and Control



QC/QA with Panda®

Compaction Control

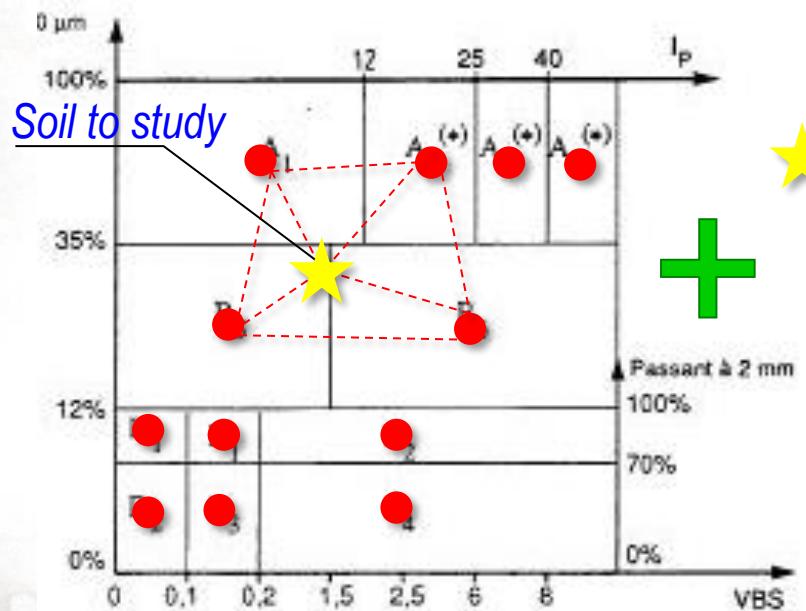
The Panda Use for the Compaction Control

Calibration Panda – Mathematical Model

Calibration Curves : Based on Soil Characteristics

under process

→ $\gamma_d = A \ln(qd_1) + B$



★ Soil Characteristics

- ✓ Particle size distribution
- ✓ Water Contents
- ✓ Void Index
- ✓

Mathematical Model to predict “Calibration Curves” γ_d - qd for X soil (*EI Fathou, 2012*)

GTR Soil Classification Chart (Dmax < 50mm)



QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – Mathematical Model

Calibration Curves : Based on Soil Characteristics

under process

One premier analytical model has been proposed for the granular materials (*El Fathou, 2012*)

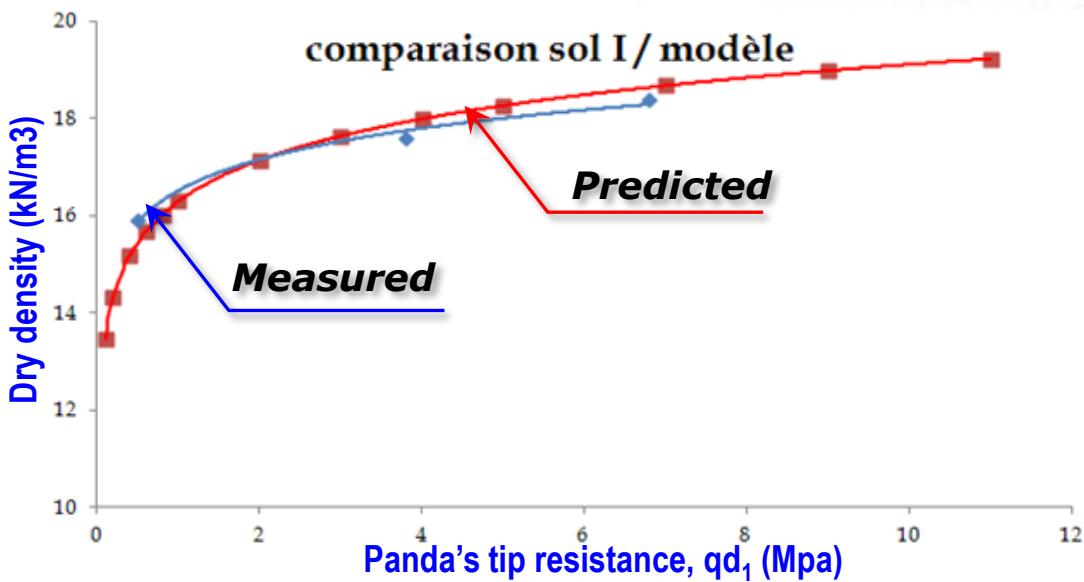
Density - qd Model for granular soils

$$\gamma_d = A \ln(qd_1) + B$$

$$A = f(C_C, 5\text{mm}, 2\text{mm}, D_{60}, D_{30}, D_{10})$$

$$B = f(C_H, G_C)$$

$$G_C = (1 - \% 2\text{mm}) * (\%4.65\text{mm})$$



$$A = 0,304.C_C - 0,044.D_{60} - 0,036.D_{30} + 0,051.D_{10} - 0,01.5\text{mm} + 0,002.2\text{mm}$$

$$B = 0,0591.C_H + 0,221.G_C + 13,548$$



QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda – Mathematical Model

Calibration Curves : Based on Soil Characteristics

under process

One premier analytical model has been proposed for the granular materials (*El Fathou, 2012*)

Density - qd Model for granular soils

$$\gamma_d = A \ln(qd_1) + B$$

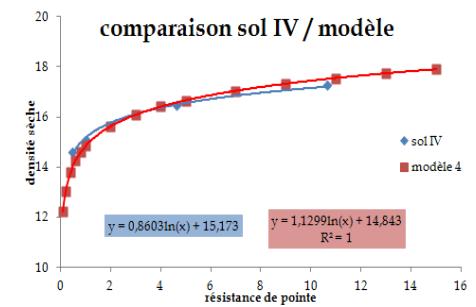
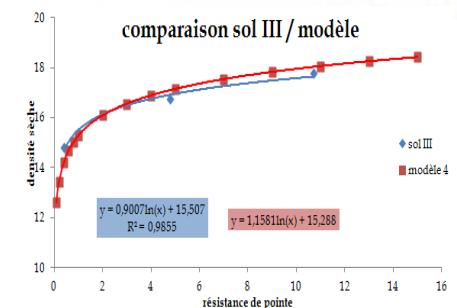
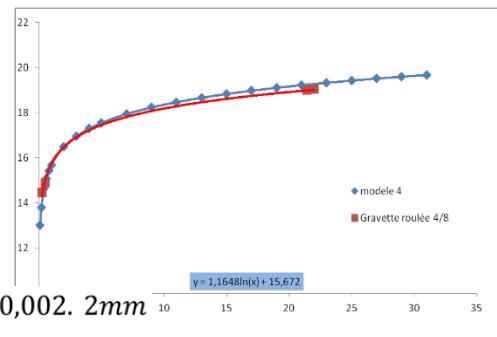
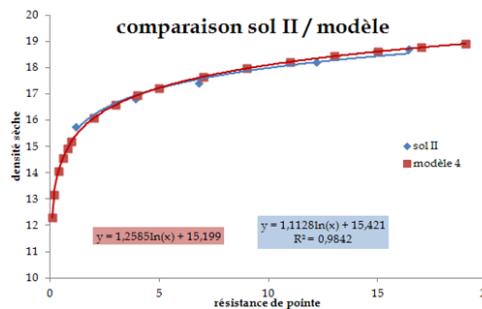
$$A = f(C_C, 5\text{mm}, 2\text{mm}, D_{60}, D_{30}, D_{10})$$

$$B = f(C_H, G_C)$$

$$G_C = (1 - \% 2\text{mm}) * (\%4.65\text{mm})$$

$$A = 0.304.C_C - 0.044.D_{60} - 0.036.D_{30} + 0.051.D_{10} - 0.01.5\text{mm} + 0.002.2\text{mm}$$

$$B = 0.0591.C_H + 0.221.G_C + 13.548$$



Planning

Schedule

Introduction

The Panda Use for the Compaction Control

- a. Background (*Measuring principle, Panda 1, Panda 2...*)
- b. Measuring Principle (*Micromechanical approach, density-qd relationship...*)
- c. Calibration Panda (*Calibration Curves : How to obtain it?*)
 - Laboratory – Calibration Chamber
 - In-Situ Test – Test Beds
 - Mathematical Models
- d. Reference Controls Curves (*How to determine it?*)
 - Compaction Requirements (NF P 94-063)
- e. Control Test : Interpretation
 - Anomaly Detection (Compaction Defects)
 - Thickness Determination
- f. Use Panda for Compaction Control (*Software Panda Windows ...*)

Application Example (*In-situ Test at Urbana*)



QC/QA with Panda®

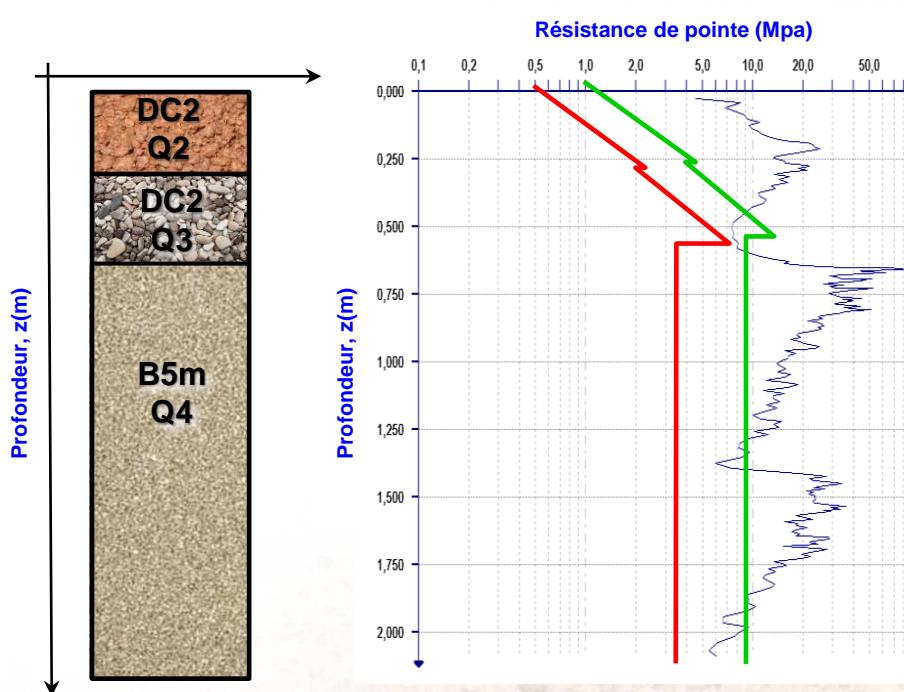
Compaction Control

The Panda Use for the Compaction Control

Calibration Panda

Reference Controls Curves ([NF P 94-105](#))

How to determine it ?





QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda

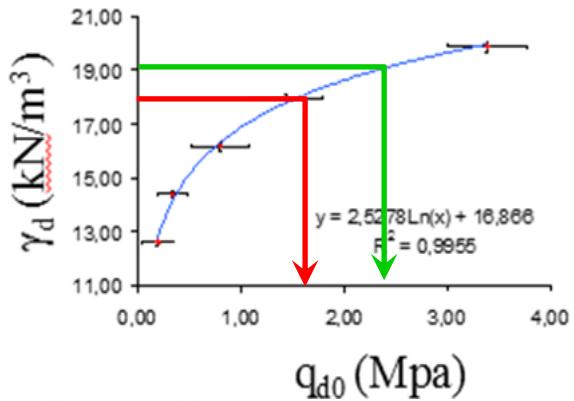
Reference Controls Curves (NF P 94-105)

How to determine it ?

Compaction requirement (density kN/m³) = X% OPN

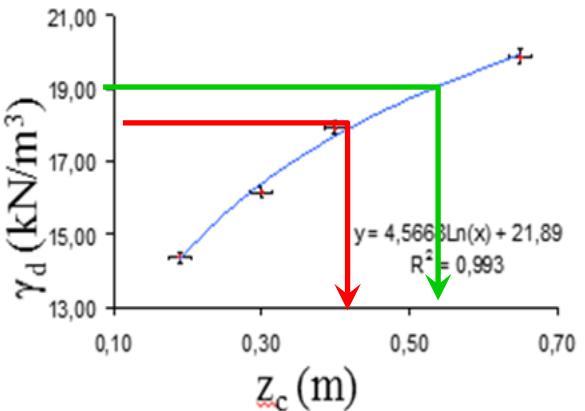
— Reference

— Tolerance



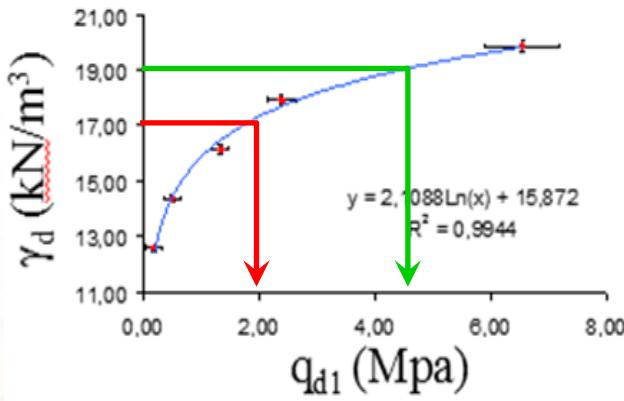
— qdo R

— qdo L



— Zc R

— Zc L



— qd1 R

— qd1 L



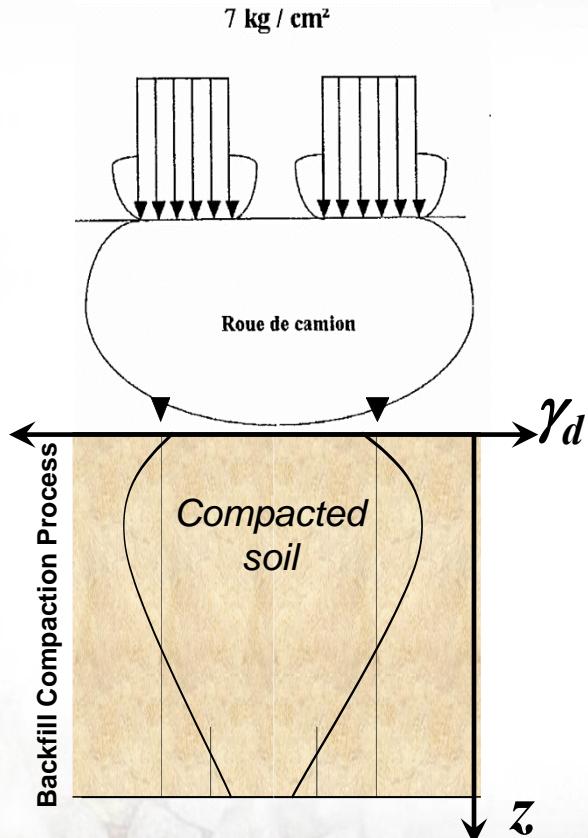
QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda

Compaction Requirements (*NF P 94-093*)



French Compaction Requirements According to *NFP 94-093*

Compaction Quality Level	Application Zone	Required Density (Average)	Required Density (Bottom of the Layer)
Q1	Civil/Important Structures	100% of Modified Proctor Density	98% of Modified Proctor Density
Q2	Road Structure	97% of Modified Proctor Density	95% of Modified Proctor Density
Q3	Superior part of the Road Base	98,5% of Standard Proctor Density	96% of Standard Proctor Density
Q4	Inferior part of the Road Base	95% of Standard Proctor Density	92% of Standard Proctor Density
Q5	Coating Zone (in trench) for HT > 1,30m	90% of Standard Proctor Density	87% of Standard Proctor Density



QC/QA with Panda®

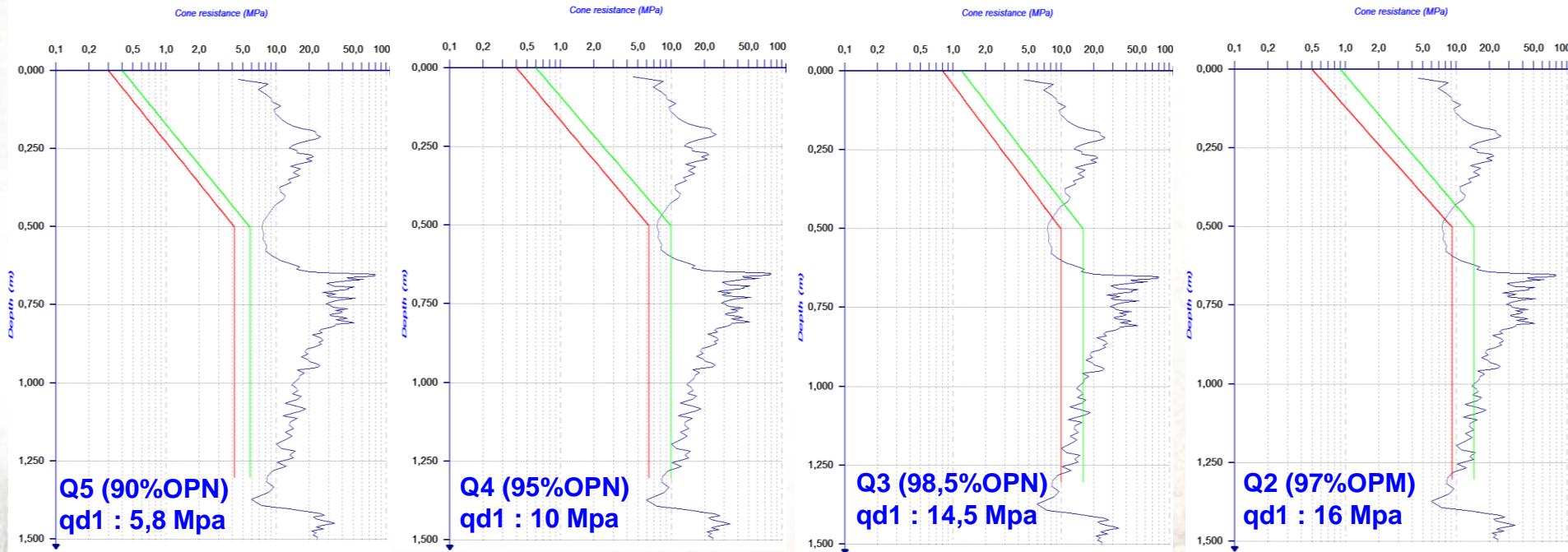
Compaction Control

The Panda Use for the Compaction Control Calibration Panda

Reference Controls Curves (NF P 94-105)

Example of Reference Control Curves : Homogeneous Soil (DC1 – GW)

Compaction Requirements : Q5, Q4, Q3 & Q2



Gravel Well Graded (GW)



QC/QA with Panda®

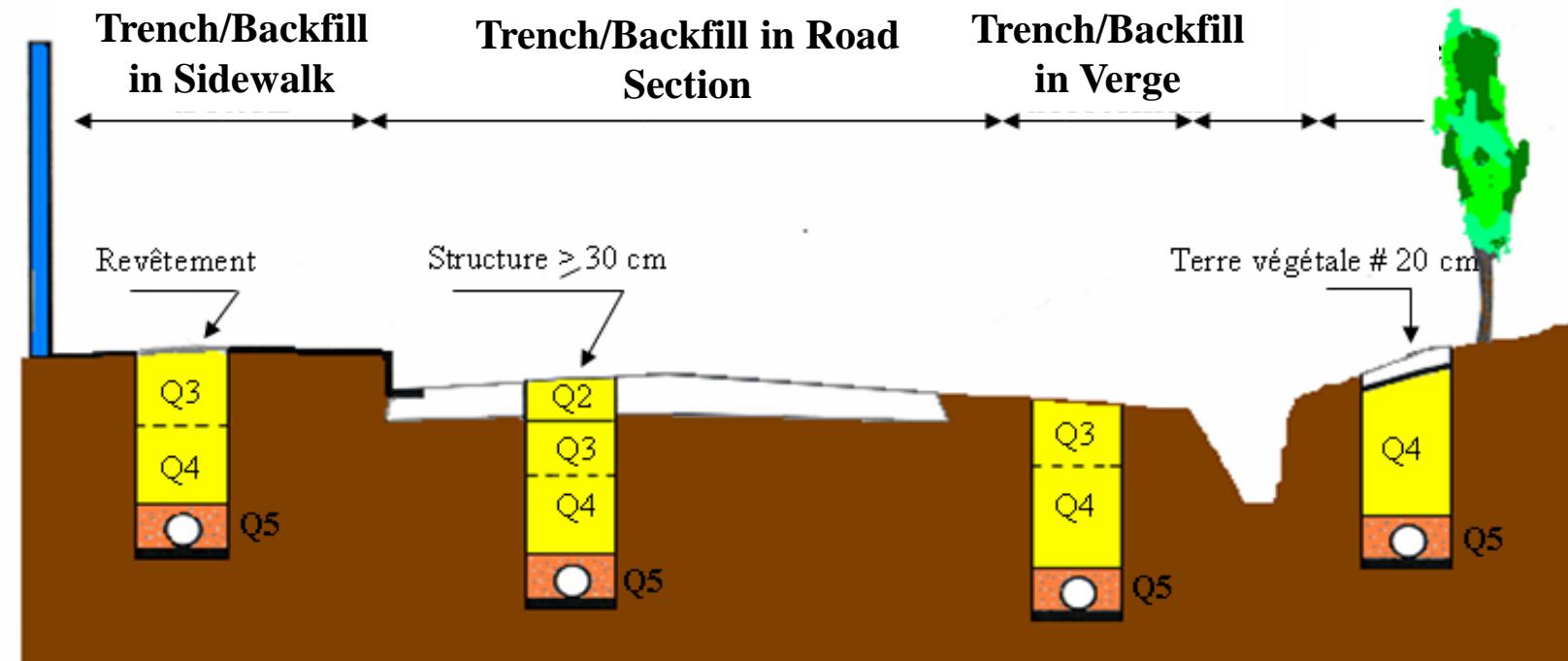
Compaction Control

The Panda Use for the Compaction Control

Calibration Panda

Compaction Requirements (*NF P 94-093*)

Example of typical Trench/Backfills according to French requirements





QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Calibration Panda

Reference Controls Curves (*NF P 94-105*)

Example of Reference Control Curves : Typical Backfill Profile Requirements

Asphalt Pavement



DC1 (GW)

0,30m

D2 (SW)

0,60m

D1 (SP)

1,00m

B3 (SW)

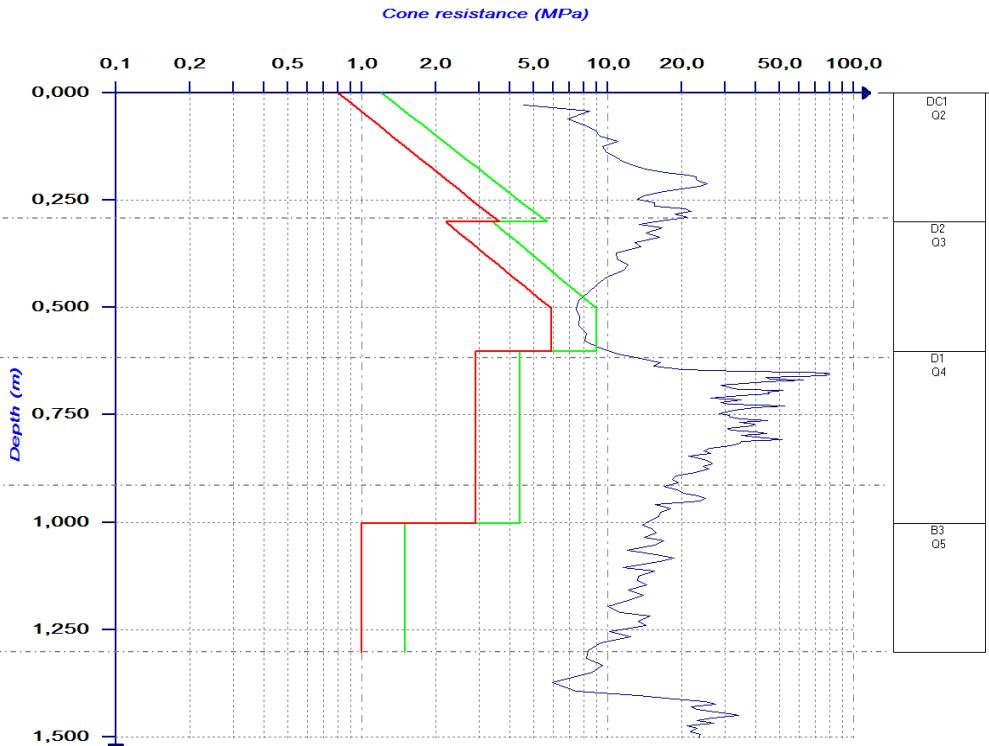
1,30m

Trench/Backfill
Type I

SOL

OLUTION

L'innovation sur de solides appuis





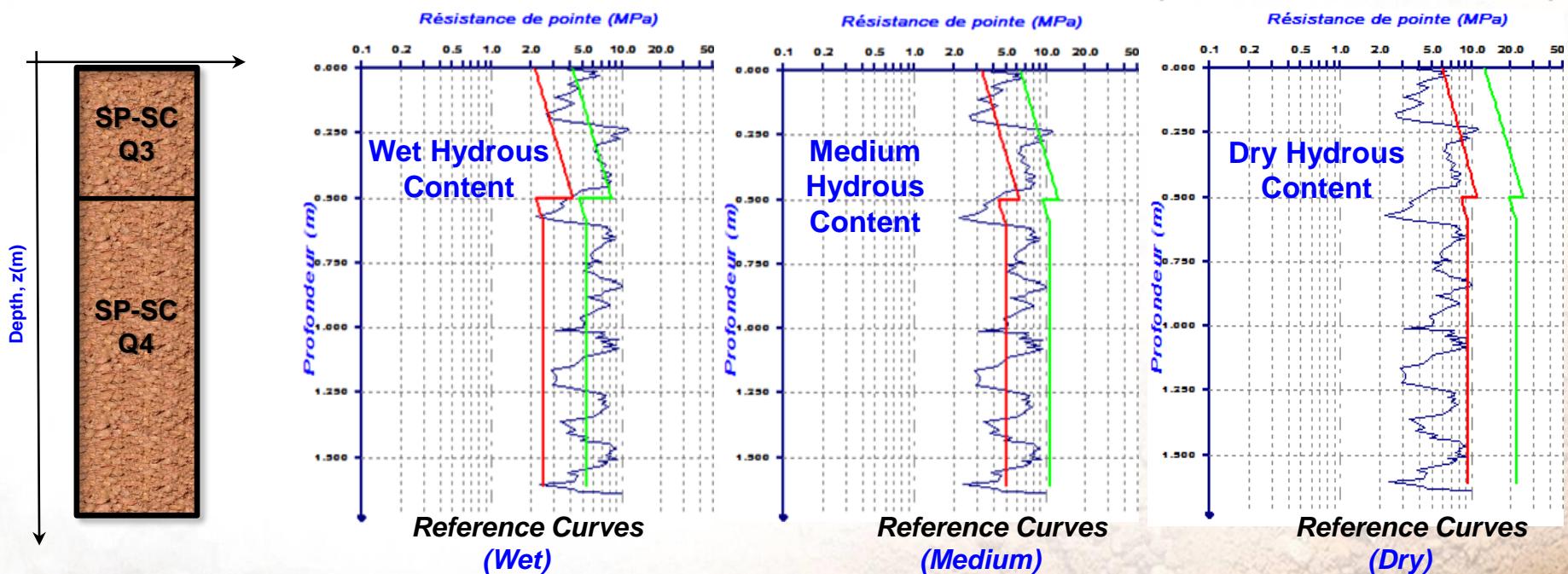
QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control Calibration Panda

Reference Controls Curves (NF P 94-105)

The Influence of Water Contents in the Compaction Requirements



The Water Contents (Hydrous State) is the One at the Time of Compaction Control



The Panda Use for the Compaction Control

Calibration Panda

Reference Controls Curves (*NF P 94-105*)

In Brief ...

- ✓ One Control Test (Panda in-situ)
- ✓ Technical specifications (Backfill, materials, compaction requirements ...)
- ✓ PandaWin Software & Soil Data Base.

- The Panda Soil Data Base are :

~ 30 GTR Soil
+ 180 Reference curves } + USCS, AASHTO, DIN ... Soil Classifications

Planning

Schedule

Introduction

The Panda Use for the Compaction Control

- a. Background (*Measuring principle, Panda 1, Panda 2...*)
- b. Measuring Principle (*Micromechanical approach, density-qd relationship...*)
- c. Calibration Panda (*Calibration Curves : How to obtain it?*)
 - Laboratory – Calibration Chamber
 - In-Situ Test – Test Beds
 - Mathematical Models
- d. Reference Controls Curves (*How to determine it?*)
 - Compaction Requirements (NF P 94-063)
- e. Control Test : Interpretation
 - Anomaly Detection (Compaction Defects)
 - Thickness Determination
- f. Use Panda for Compaction Control (*Software Panda Windows ...*)

Application Example (*In-situ Test at Urbana*)

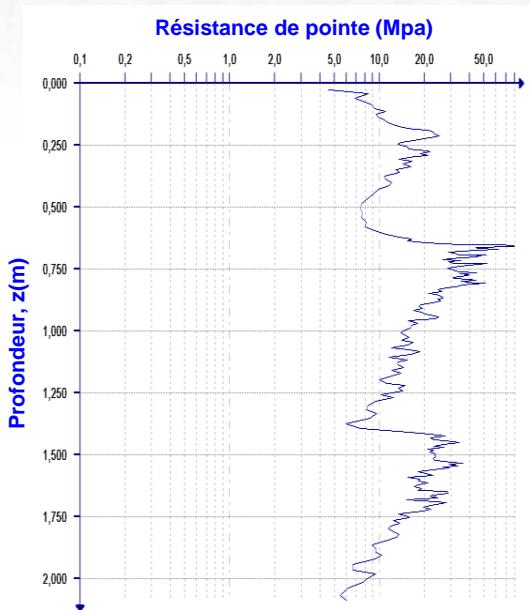


QC/QA with Panda®

Compaction Control

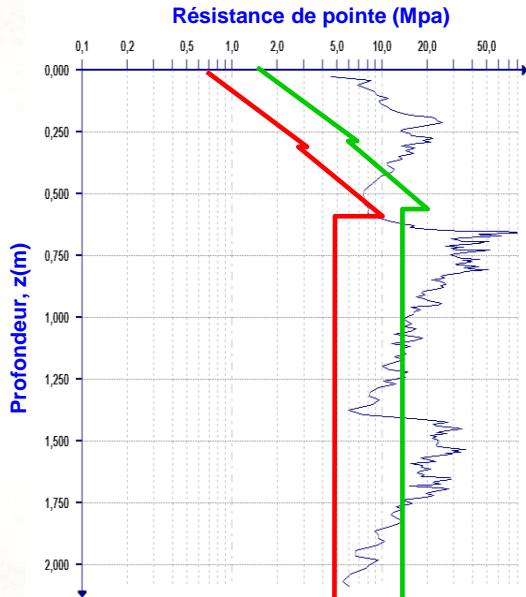
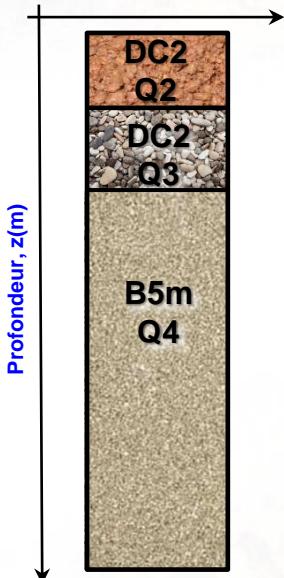
The Panda Use for the Compaction Control Summary

Control Principle with the Panda (NF P 94-105)



(1) In-situ Test →

(2) Log $q_d(z)$ obtained



→ (3) Input specifications (GTR)

→ (4) Control and Interpretation
NF P 94-105

- ✓ **Type of soil (GTR)**
- ✓ **Thickness of layers**
- ✓ **Compaction requirement**



The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

Anomaly of Compaction According to the French standard

“Anomalies are defined by the position of the pénérogramme control relative to References Curves”

4 Anomalies are defined

Résultat	Type d'anomalie	Zone de remblai	Zone d'enrobage
- le pénérogramme se trouve toujours en dépassement de q_L . - les épaisseurs de couche sont conformes aux prescriptions.	Sans anomalie	Essai acceptable	Essai acceptable
- le pénérogramme se trouve toujours en dépassement de q_L . - les épaisseurs de couche sont systématiquement supérieures de plus de 20% aux valeurs prescrites.	Anomalie de type 1	Essai acceptable	Essai acceptable
- le pénérogramme est inférieur à q_L d'un écart « a » inférieur à la distance « b » entre q_L et q_R et au total sur une hauteur de moins de 30% de la profondeur contrôlée.	Anomalie de type 2	Essai acceptable	Essai non acceptable
- le pénérogramme est inférieur à q_L d'un écart « a » supérieur à la distance « b » entre q_L et q_R , ou au total sur une hauteur de plus de 30% à 50% de la profondeur contrôlée, quelle que soit l'importance du dépassement.	Anomalie de type 3	Essai non acceptable	Essai non acceptable
- le pénérogramme est inférieur à q_L sur plus de 50% de la profondeur contrôlée.	Anomalie de type 4	Essai non acceptable	Essai non acceptable



QC/QA with Panda®

Compaction Control

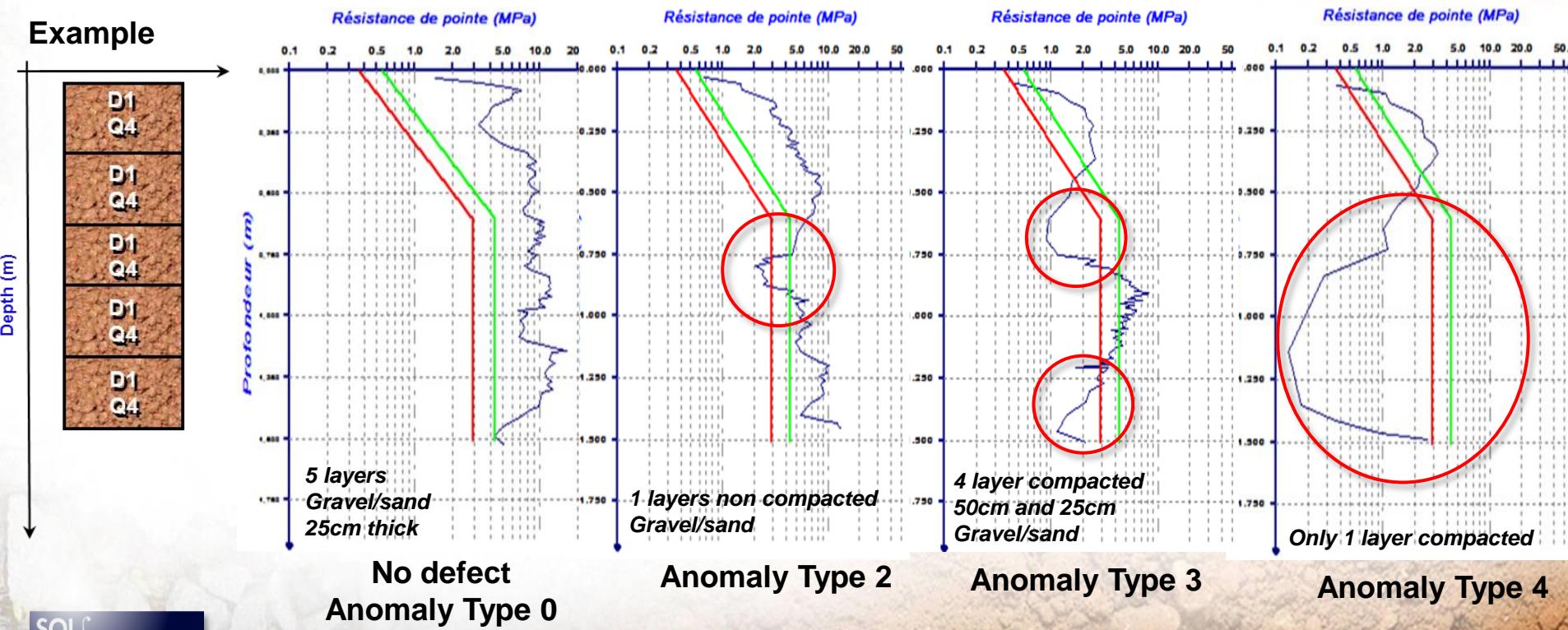
The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

Anomaly of Compaction According to the French standard

Example





QC/QA with Panda®

Compaction Control

The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

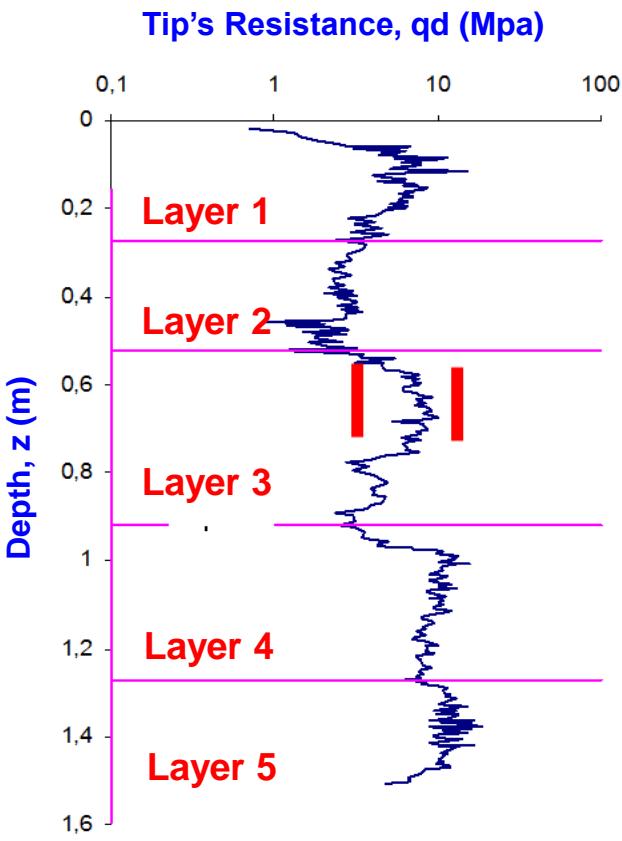
Layer Thickness Detection

- ✓ The signal is regular if is it within :

$$\liminf = \overline{\ln(qd)} - k \cdot Cv$$

$$\limsup = \overline{\ln(qd)} + k \cdot Cv$$

- ✓ Curvature of the boundary signal
- ✓ Position on a local minimum





QC/QA with Panda®

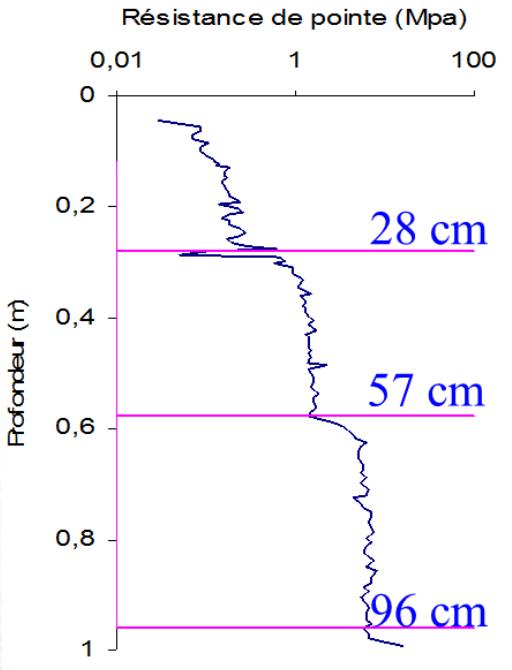
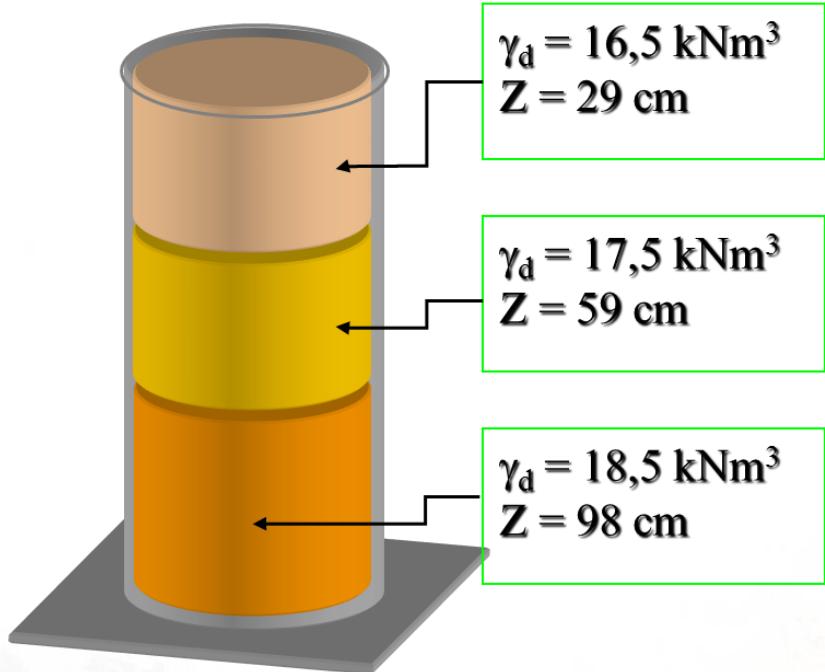
Compaction Control

The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

Layer Thickness Detection



Sensitivity of the compaction method and the penetration measurement (density and thickness of layers)



QC/QA with Panda®

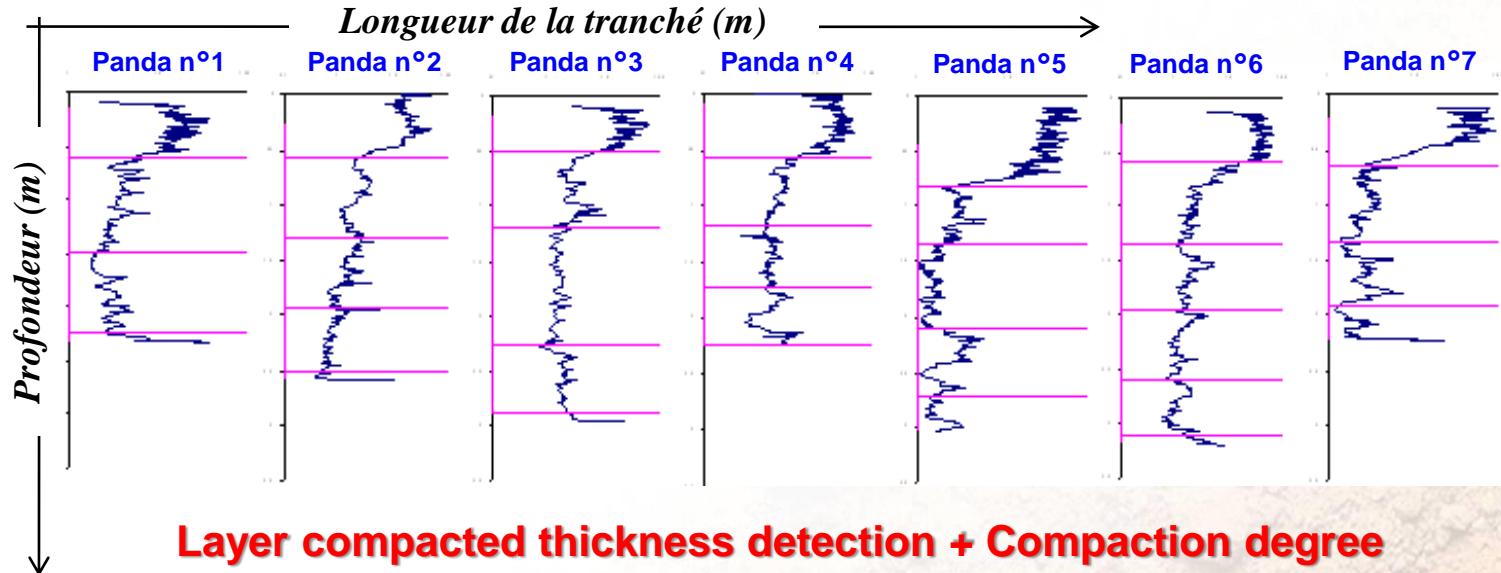
Compaction Control

The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (*NF P 94-105*)

Layer Thickness Detection



Sensitivity of the compaction method and the penetration measurement (density and thickness of layers)



QC/QA with Panda®

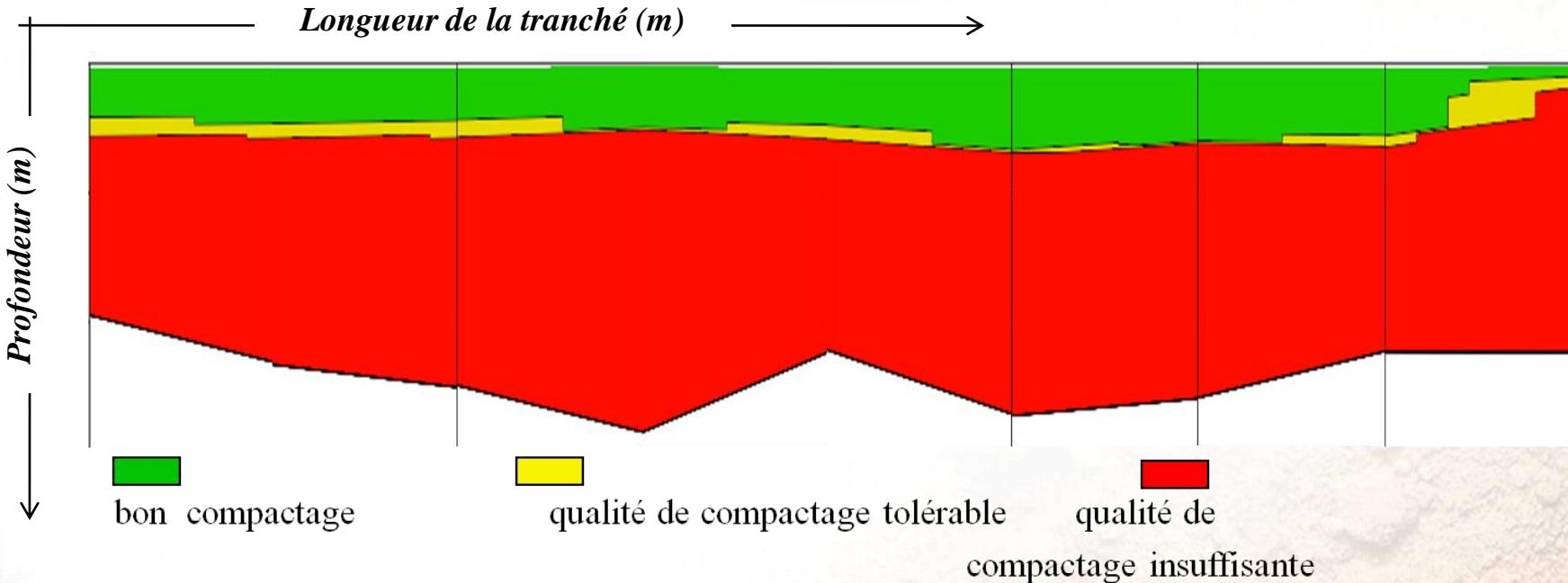
Compaction Control

The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

Layer Thickness Detection



Sensitivity of the compaction method and the penetration measurement (density and thickness of layers)



QC/QA with Panda®

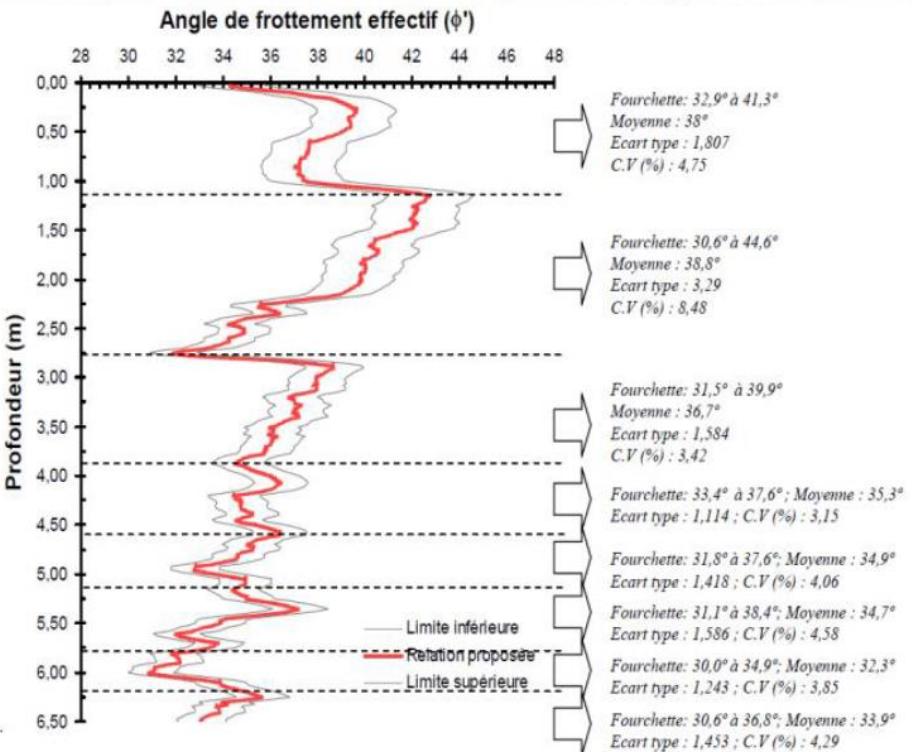
Compaction Control

The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

Layer Thickness Detection



Example : Layer detection in Chilean Tailing Dams & Internal Friction angle estimation



QC/QA with Panda®

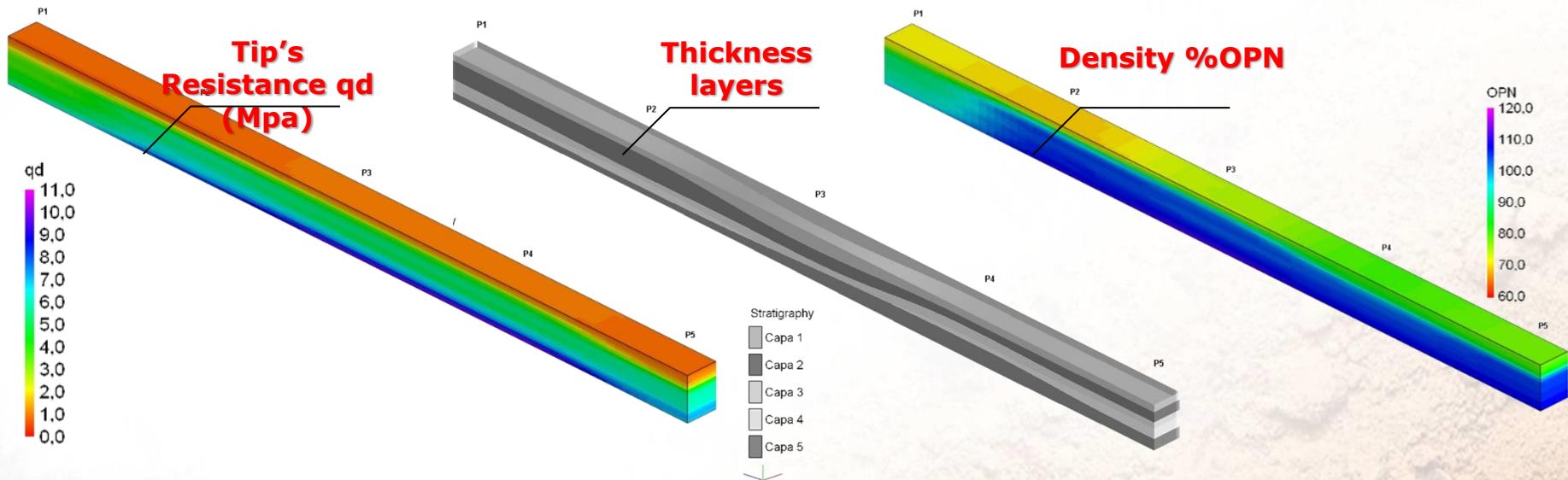
Compaction Control

The Panda Use for the Compaction Control

Process of Compaction Control with Panda

Control test : Interpretation (NF P 94-105)

Layer Thickness Detection



Profils 3D (Villavicencio, 2012)

Example : Layer detection in Chilean Tailing Dams & Internal Friction angle estimation