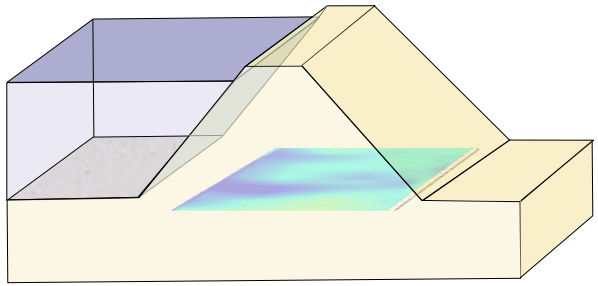
Large Jet Erosion Test

Maxime Boucher, Rémi Beguin, geophyConsult

Jean-Robert Courivaud, EDF

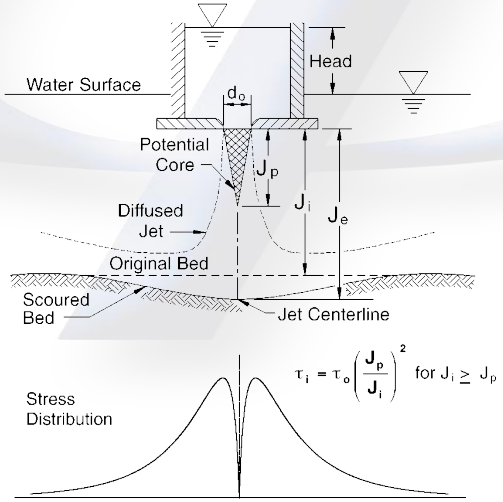


Outline

1. Introduction
2. Description of the device
3. Comparison with classical USDA-ARS JET
4. Application to coarse soils
5. Perspectives

1. Introduction

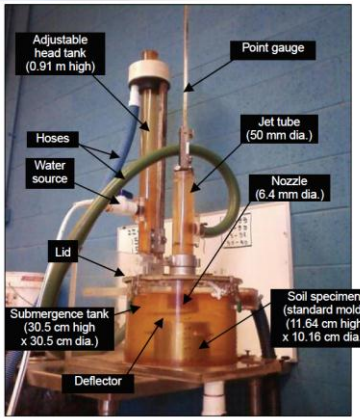
- **Jet Erosion Test :**
  - Estimation of erodibility parameters by analysis of the scour depth evolution during a water jet impact on the soil
  - Initially developed for cohesive soil. Used in various applications : for breach erosion modelling, streambed erosion…



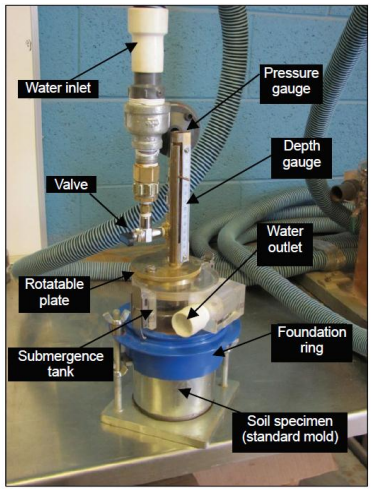
1. Introduction

- **Evolution of the size of the apparatus**

Hanson (1990, 1991)
ASTM D5852
d_0 = 1/2 ” ≈ 12,7 mm



« Classical » JET
Hanson&Cook (2004)
d_0 = 1/4 ” ≈ 6,35 mm

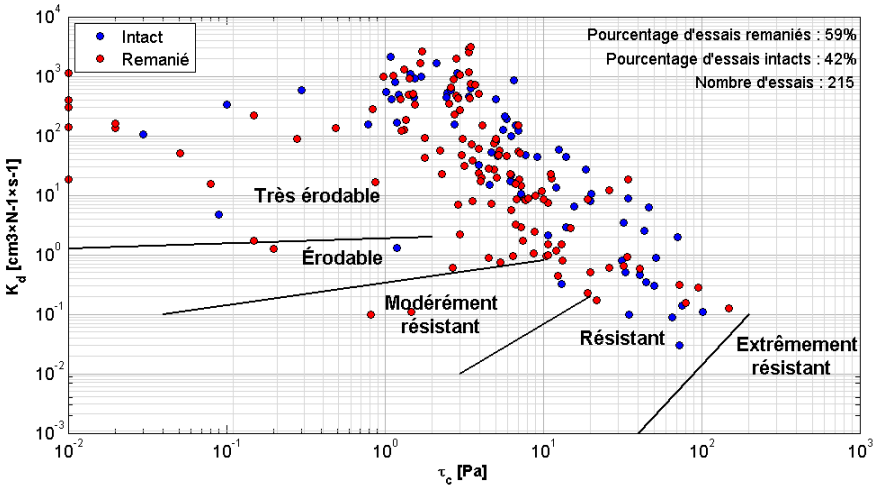


(b) “Mini” JET device

Mini-JET
Al-Madhhachi (2013)
d_0 = 1/8 ” ≈ 3,2 mm

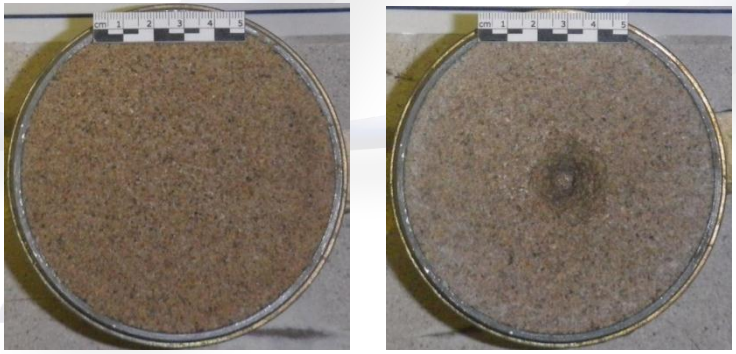
1. Introduction

- **Apparatus used by geophy*Consult* :**
  - ***"Classical" device d_0=6,35mm***
  - ***About 280 tests perfomed mainly for engineering purpose***



1. Introduction

- **Current widening of the scope of the JET :**
  1. **The JET can answer a need to control the erodibility of treated soils, but…**
     - **"classical JET" supplied by a gravity flow has a limited maximum hydraulic load that can be applied → no erosion on treated soil.**



Lime-treated soil

1. Introduction

- **Current widening of the scope of the JET :**
  2. **Need to model overtopping of coarse soils : one possibility is to use models based on erosion parameters obtained with a JET test, but…**
     - **"classical JET" is suitable for soil with no or few particles >5mm… how to test coarser soils ?**

Norway overtopping large scale test

1. Introduction

- Current widening of the scope of the JET :
  3. Need of more robustness and comprehension in the interpretation of the test (see debate on erosion law, fitting method…), but…
     - few parameters are measured in the "classical JET", and manually measured… to increase repeatability and make possible the application of more complex model, automatic measurement of more parameters is needed

1. Introduction

- How to test treated soil ?
- How to test coarser soils ?
- How to expand the measures ?

→ Large Jet Erosion Test

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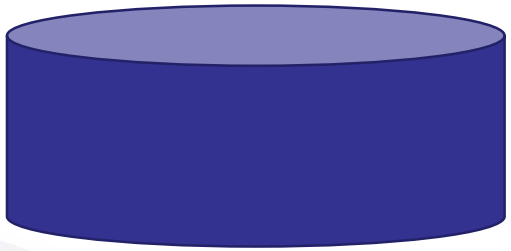
2. Description of the device

- **Hydraulics**

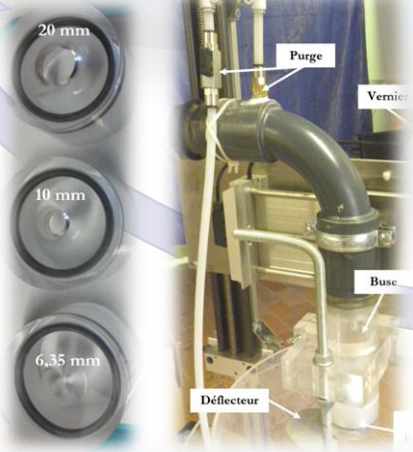
Overflow tank



3 m^3 water storage

Hydraulic load regulated at +/- 0,1kPa of the setpoint

3-way pneumatic valve



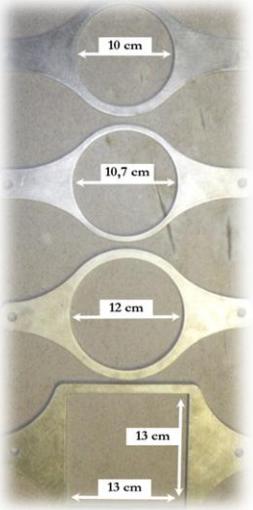
Nozzle head with 3 different diameters

2. Description of the device

- Mechanics

- Bidirectional mobility of the nozzle:
  - Vertically to fit the nozzle/sample distance
  - Horizontally to switch between jet and scour depth measurement

System to center the sample

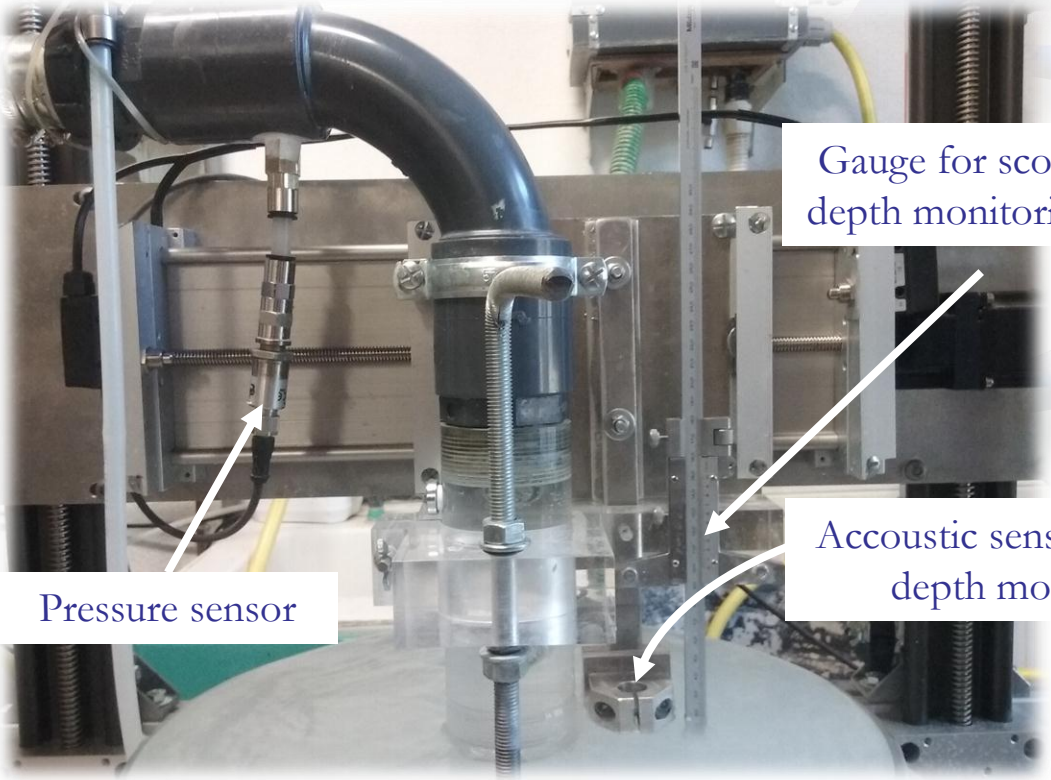


2. Description of the device

- **Measurements**

Flowmeter

Possibility to add a weighing machine and turbidimeter



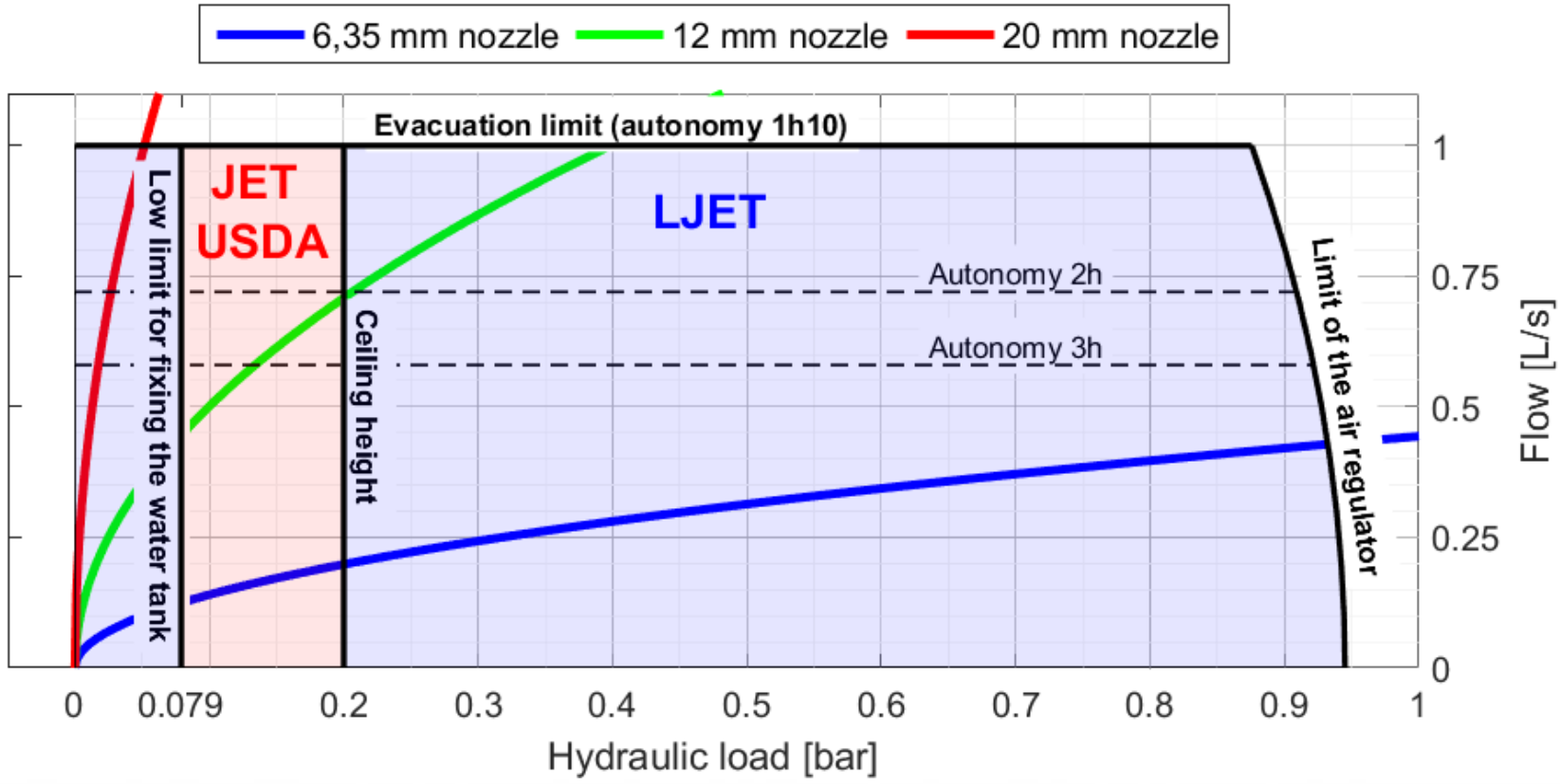
Gauge for scour depth monitoring

Pressure sensor

Accoustic sensor for scour depth monitoring

2. Description of the device

- Operating range



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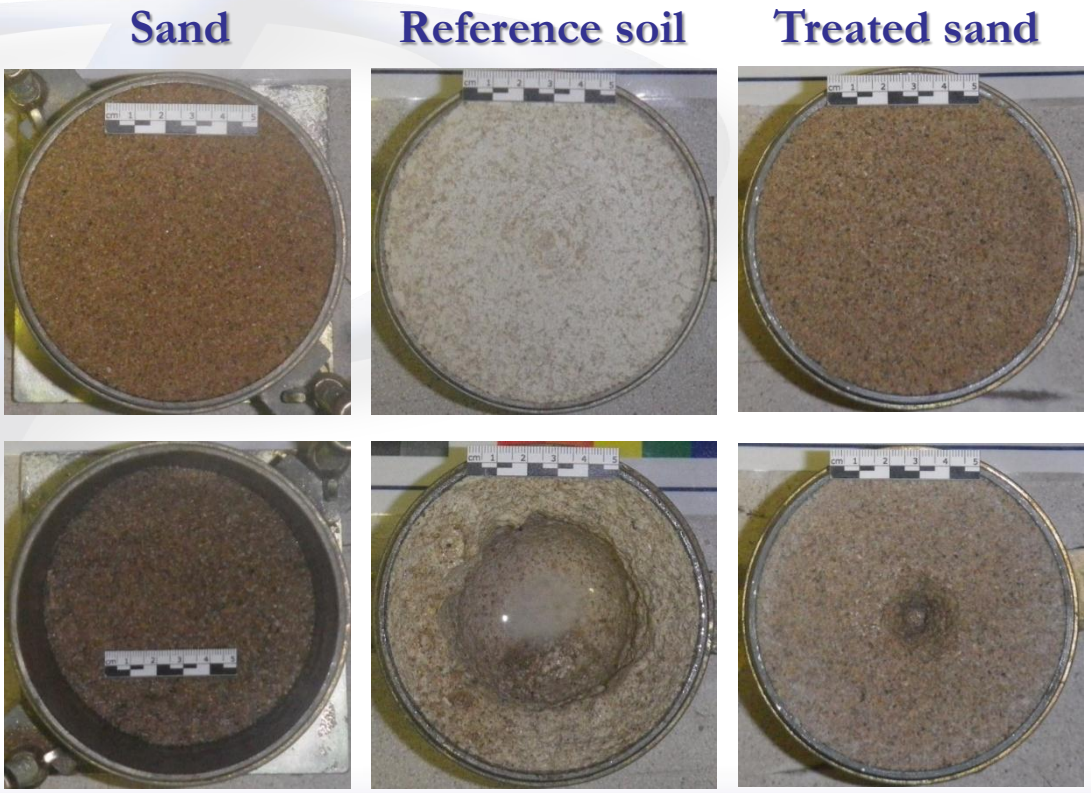
3. Comparison with classical "Hanson" JET

- 3 artificial soils tested to compare both device, which a wide range of erodibility

Nozzle diameter : 6,35 mm

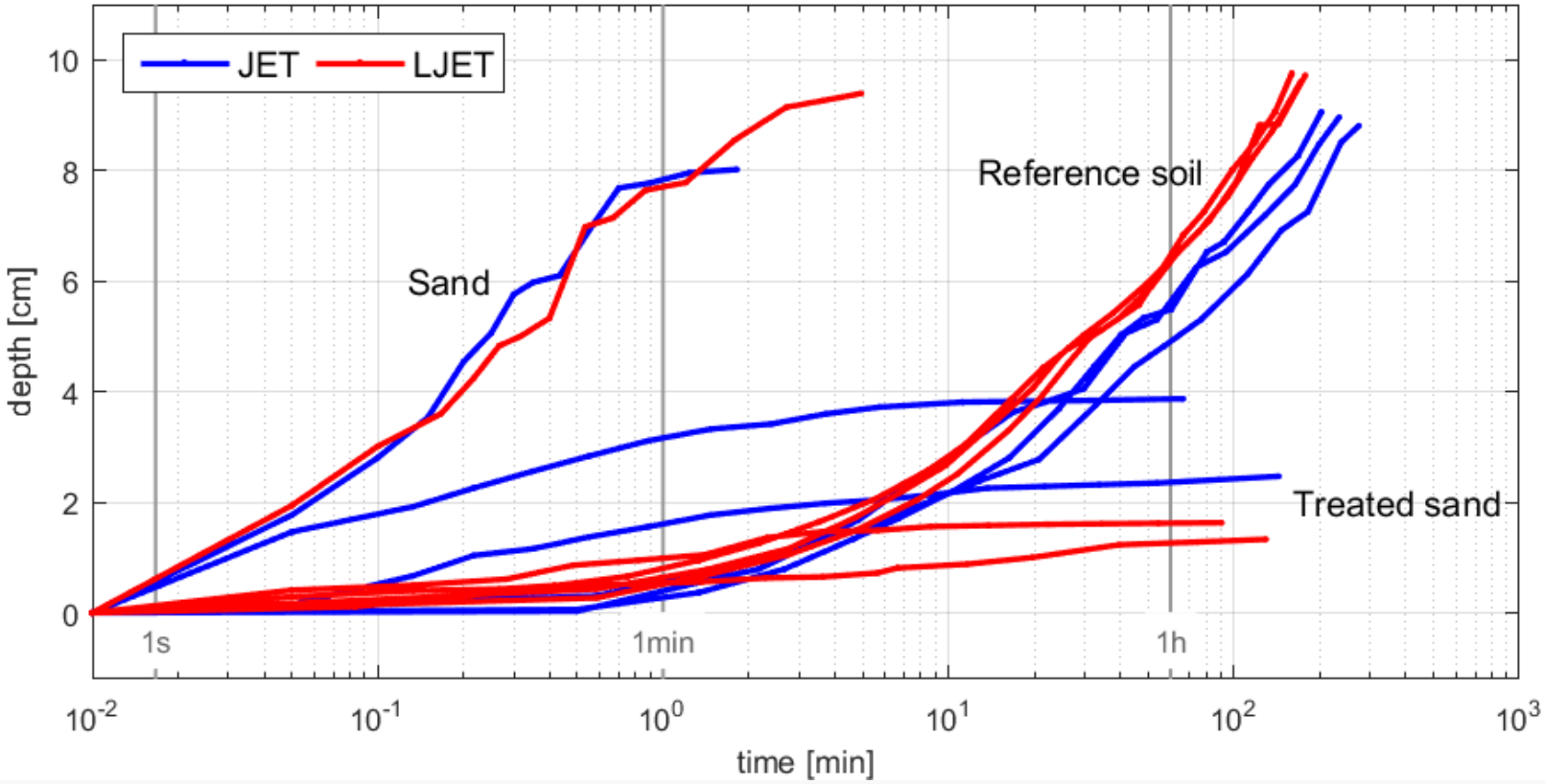
Sample distance :4 cm

Hydraulic load : ~ 0,2 bar



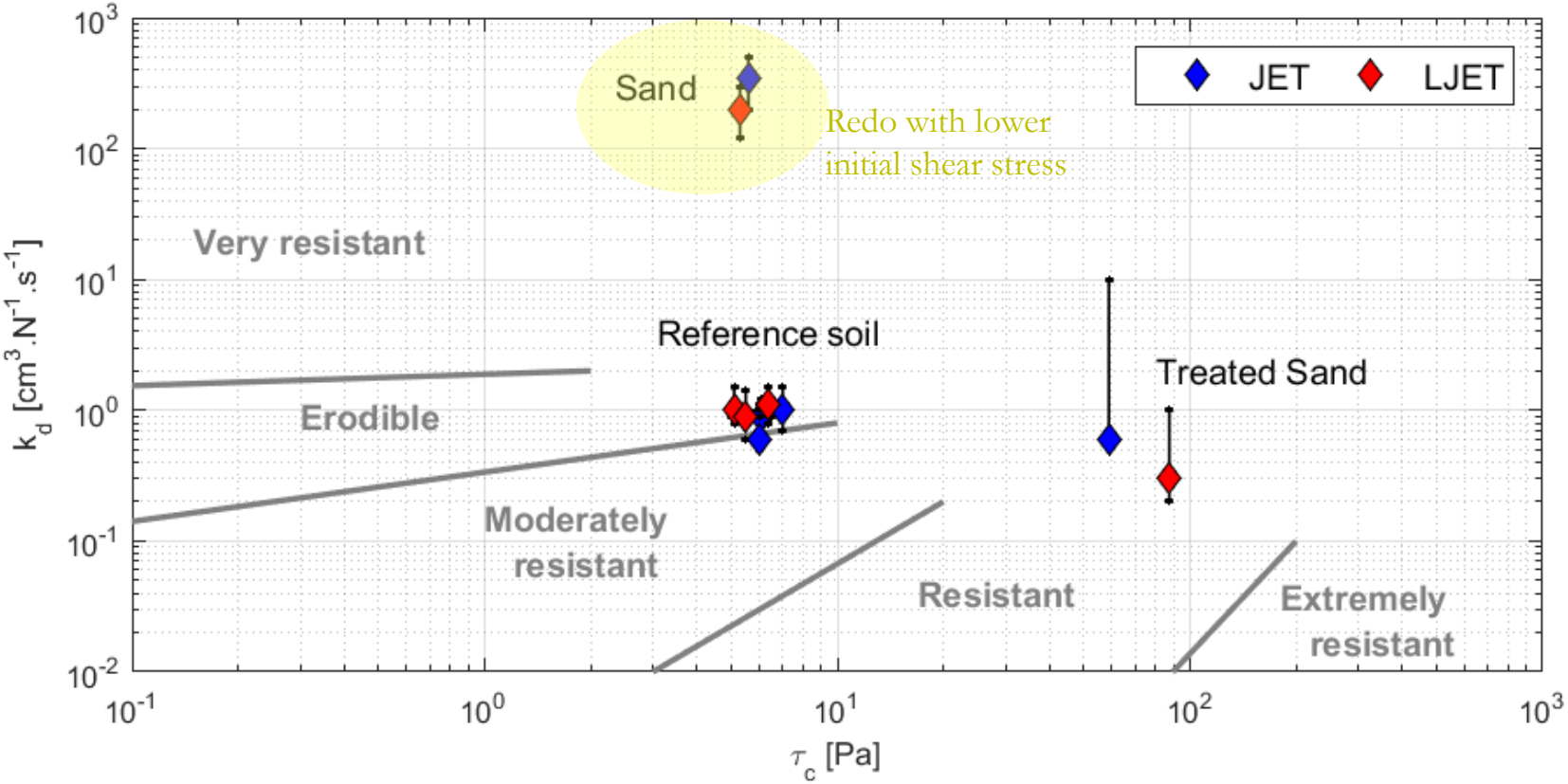
3. Comparison with classical "Hanson" JET

- Measured scour depths :



3. Comparison with classical "Hanson" JET

- **Results in the Hanson soil classification :**



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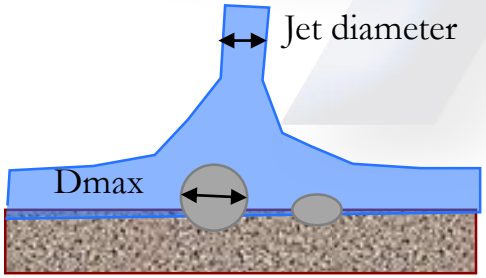
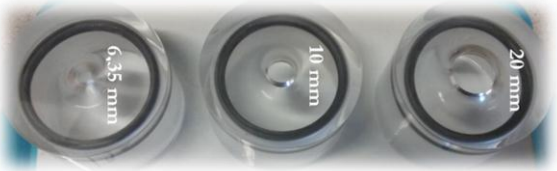
4. Application to coarse soils

- **What are the issues raised by a JET test on a soil with particles > 5 mm ?**

4. Application to coarse soils

1. **What happens when the size of the particles are egal or larger than jet diameter ?**
   - **Influence of the jet diameter when testing a fine soil ?**
   - **Influence of the jet diameter when testing a coarse soil ?**

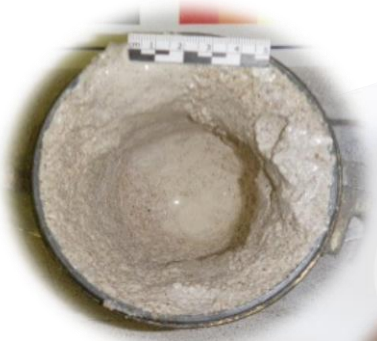




Different diameters of nozzle head

4. Application to coarse soils

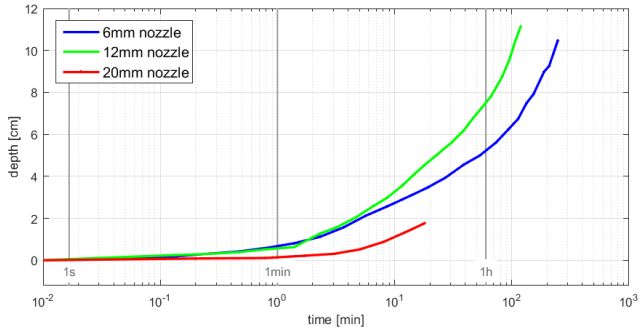
- Our first results comparing test on fine soil with 6,35 to 20 mm nozzle show similar results in the Hanson classification

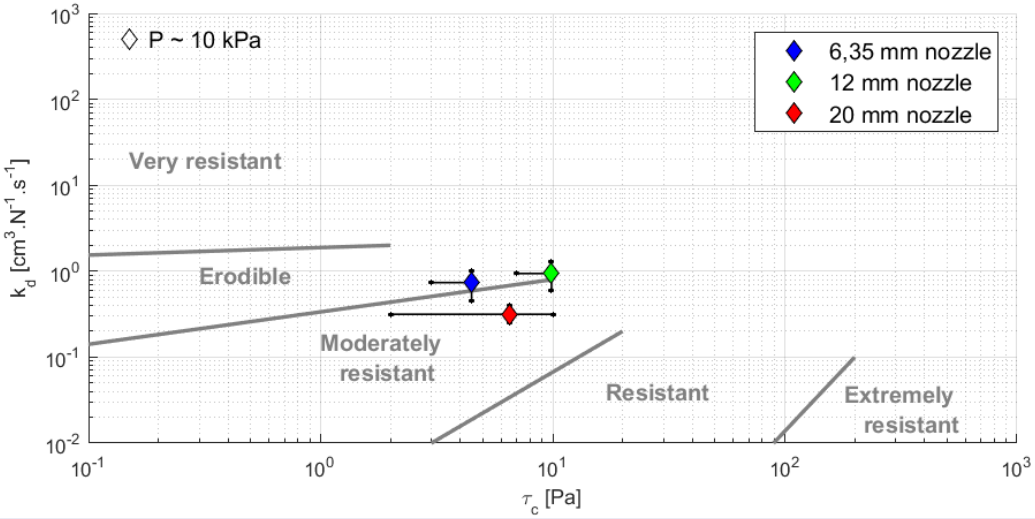


6,35 mm nozzle

20 mm nozzle

12 mm nozzle

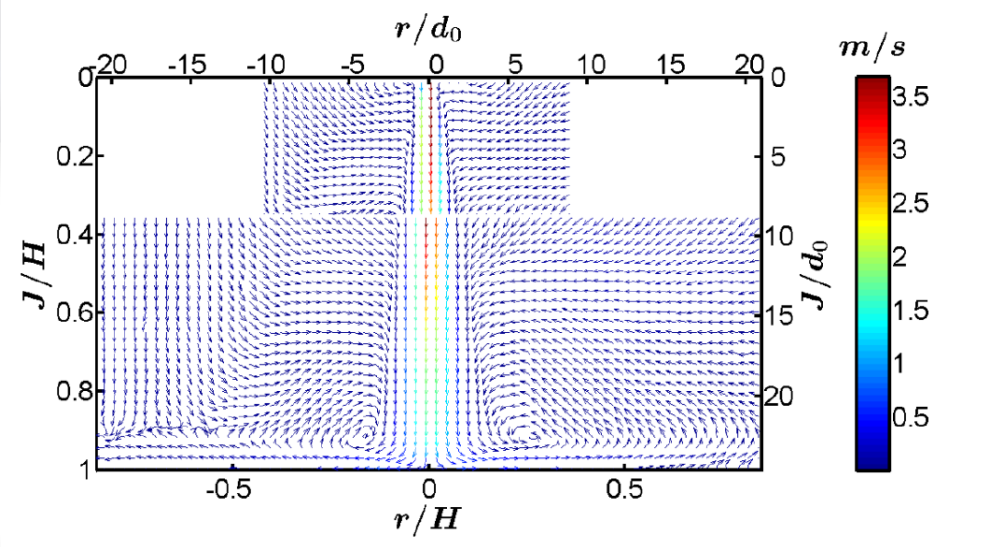




4. Application to coarse soils

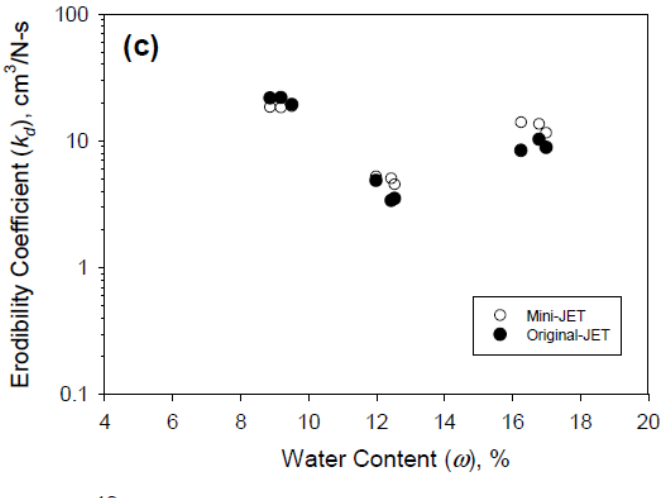
2. Influence of the size of the submergence tank on the jet characteristics (bed-shear stress, turbulence) has been shown by Ghaneeizad, 2015

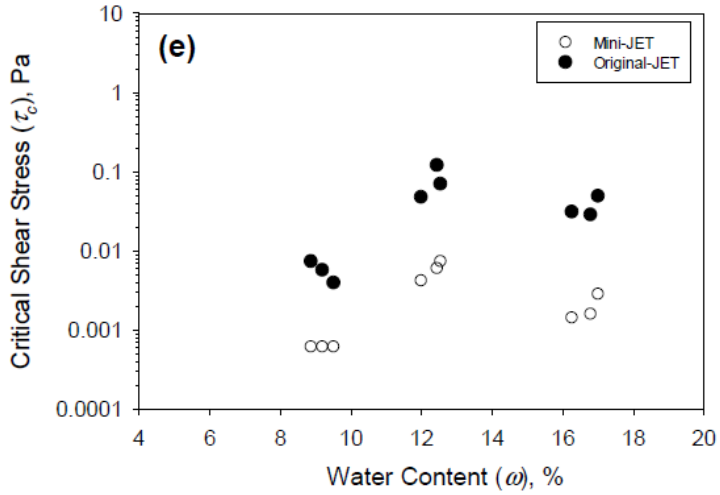
- Maintain the confinement ratio (box area to nozzle area) constant ?
- Take into account the effect in the bed-shear stress calculation ?



4. Application to coarse soils

- Results on the Mini-JET (Al-Madhhachi, 2013) show no difference in k_d but a systematic difference in τ_c for a change of the nozzle diameter (3,2 to 6,35 mm) and confinement ratio
  - The difference can be corrected by a factor





4. Application to coarse soils

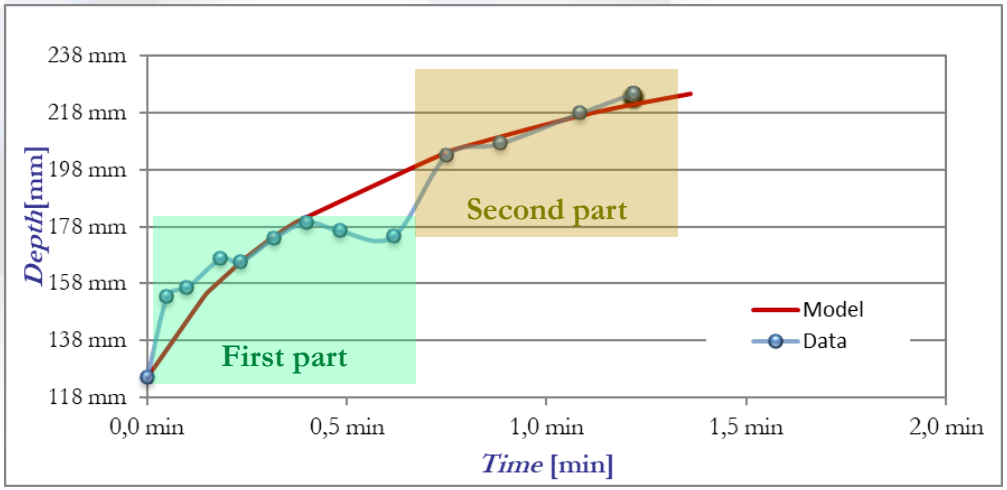
3. **The jet is not able to clear the coarsest particles from the scour hole. The erosion is limited by the transport capacity of the jet and armouring is observed**
   - **Do nothing, it is the process observed on-site ?**
   - **Test the samples inclined ? Same slope as in-situ ? Vertical to maximise transport ?**
   - **Withdraw manually the detached particles ?**

Vertical sample Whal, 2014

4. Application to coarse soils

Preliminary test

- In the first part, classical test -> armouring
- In the second part, gravels withdrawn manually



4. Application to coarse soils

- Similar average values (with a significant scatter) obtained by Whal, 2014 on gravelly fine grained soil tested vertical in 3 ways: 1) not sieved, 2) sieved at 4,7 mm and 3) sieved at 0,4 mm
  - ➢ Can we reproduce this results for other kind of coarse soil ?

Whal, 2014

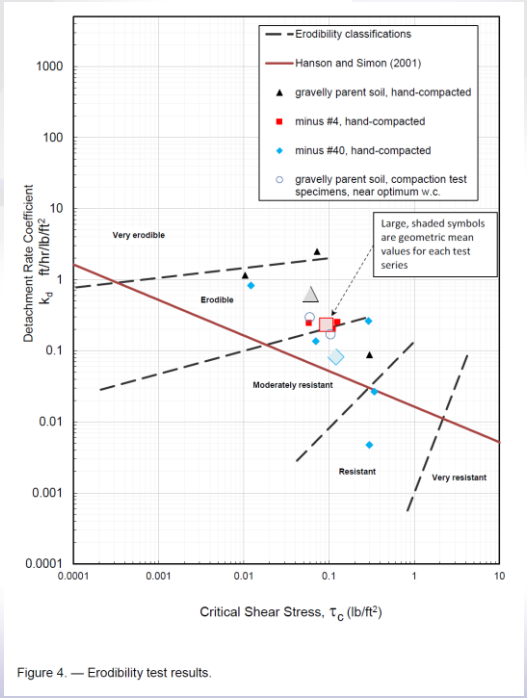


Figure 4. — Erodibility test results.

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5. Conclusions / Perspectives

- **Large Jet Erosion Test has been developed and validated by comparison with classical JET : it provides wider operating range and expands measurement possibilities**
- **To perform JET on coarse soil, these are our current thinking :**
  - **In which cases can we perform test on soil < 5 mm and use the result to predict behaviour of the initial soil ?**
  - **What is the influence of the nozzle diameter on JET results for fine soils ? for coarse soils ? Which diameter should be used ?**
  - **What is the best method to deal with coarse particles that stay into the scour hole ?**

→ Test campaign planned in 2018

… thanks you for your attention…

… and is looking forward to listening to your questions…

Contacts

Headquarters / « *Fibre Optics monitoring* » and « *Geophysical surveys* » departments

- ✓ administration@geophy*Consult*.com
- ✓ FO_monitorin@geophy*Consult*.com
- ✓ geophysics@geophy*Consult*.com
- ✓ geophy*Consult* SAS – 150, quai des Allobroges – 73 000 Chambéry – France
- ✓ Headquarters tel. : +33 6 85 81 79 68
- ✓ F.O. monitoring *dpt* tel. : +33 6 52 97 74 33
- ✓ Geophysical surveys *dpt* tel. : +33 6 31 35 02 26
- ✓ Fax : +33 9 56 67 61 37

« *Erosion Tests Lab* »

- ✓ labo@geophy*Consult*.com
- ✓ Sup'Agro – geophy*Consult* SAS – 2, place P. Viala – 34 060 Montpellier cedex 2 – France
- ✓ Tel. : +33 7 81 01 51 88
- ✓ Fax : +33 9 56 67 61 37

5. Perspectives

- In which cases can we perform test on soil < 5 mm and use the result to predict behaviour of the initial soil ?
- What is the influence of the nozzle diameter on JET results for fine soils ? for coarse soils ? Which diameter should be used ?
- What is the best method to deal with coarse particles that stay into the scour hole ?

1. Introduction

- **Evolutions of the test :**

Dunn (1959), etc…

Hanson (1990, 1991) ASTM D5852

Hanson (1992)

Mazurek (2000), Regazzoni,

Al-Madhhachi (2013)

JET Index
d_0 = 13 mm

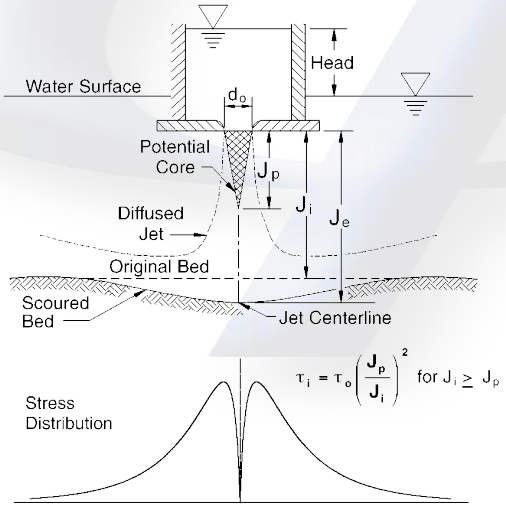
$$\dot{\epsilon} = kd(\tau - \tau_c)$$
d_0 = 6,35 mm

Mini-JET :
d_0 = 3,2 mm

Hanson (1990, 1991)
ASTM D5852
d_0 = ½ " ≈ 13 mm

4. Application to coarse soils

- Theoretically, if the ratio J_i/d_0 (with J_i=initial jet orifice height) and hydraulic head are identical for two different nozzle :
  - Distance to potential core (Ji/Jp) is identical (and should be >1)
  - Initial shear stress on the soil is identical



$$\tau_i = \tau_o \left(\frac{J_p}{J_i}\right)^2$$

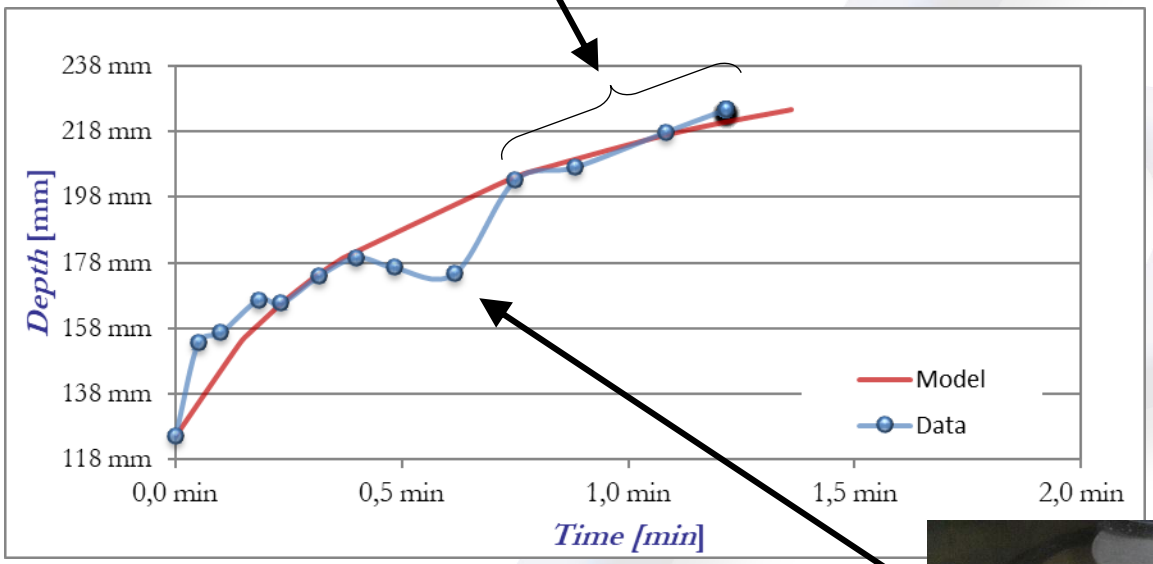
$$J_p = C_d \, d_o$$

$$\tau_o = C_f \, \rho \, U_o^2$$

$$U_o = \sqrt{2gh}$$

4. Application to coarse soils

Manual withdraw of the detached particles



Armoring

4. Application to coarse soils

1. How to collect and test intact samples ?
   - in-situ test
   - sonic drilling to collect intact samples ?
   - If not possible tests on remolded samples can be done

4. Application to coarse soils