Erosion Tests Laboratory

Jet Erosion Tests on samples coming from Hedwige-Prosperpolder

Summary: The present report is devoted to the results of Jet Erosion Test campaigns carried out by geophy*Consult* on soil samples coming from Hedwige-Prosperpolder.

The 6 tests carried out give relatively similar erosion parameters, with critical stresses between ~ 40 and 140 Pa, and Hanson's erosion coefficient between ~ 5 and 50 cm^3/(Ns).

Addressee: -... .... Mario van den Berg, TUDelft

Execution of the tests:	Guillaume Davion, *Technician*	
Drafter:	Maxime Boucher, *Engineer*	
Controller:	Rémi Béguin, *Fibre Optics expert*	

Report number:	**Issue date**:
geophy00409BPE01	**28/05/2021**

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Change history

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28/05/2021	Initial report	**geophy00409BPE01**

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Erosion Tests Laboratory

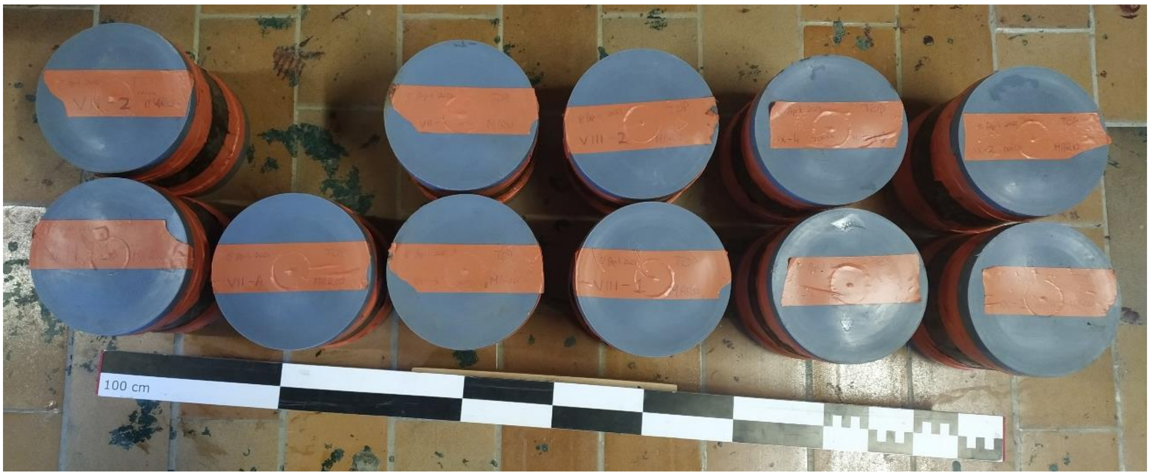
Jet Erosion Tests on samples coming from Hedwige-Prosperpolder

1 Introduction

On January 22, 2021, TUDelft commissioned geophy*Consult* to quantify the jet erosion resistance parameters of 6 soil samples from Hedwige-Prosperpolder (order no. P2112020278). This report is geophy*Consult*'s response to that command. It is divided up into four parts: first, the samples received are presented and the test program recalled (§2); then the results of the identification tests (§3) and the jet erosion tests (§4) are detailed; finally, a summary discussion is conducted around the results presented (§5).

2 Description of samples and test program

The samples were taken on April 8, 2021 by Mario van den Berg using the sample kits provided by geophy*Consult*. The samples were then transported to the geophy*Consult* laboratory in Montpellier by highway carrier. The samples were delivered on April 19, 2021 and tested between April 23 and May 25, 2021.



Picture 1. Samples received on April 19, 2021.

3 Identification results

3.1 Water contents

geophy*Consult* usually measures the water content on spare material available from the part of the drilling not used for the test. In the case of these samples, delivered directly in their test tube (core cutters), no additional materials were available. The water content could therefore not be measured.

3.2 Densities

Wet densities were obtained from the dimensions and masses measurements of the core cutters. The results are given in Table 1.

As no water content was measured, dry densities could not be calculated.

4 Jet Erosion Tests results

4.1 Sample's preparation

All the samples were tested intact, with their roots, inside their core cutters. The upper face was subjected to erosion, as that would be the case on site.

4.2 Operating procedure and apparatus

The tests were carried out using the public water provided by the city of Montpellier, after an immersion time of the order of one hour, using a jet diameter of 12 mm and an initial applied hydraulic stress around 250 Pa.

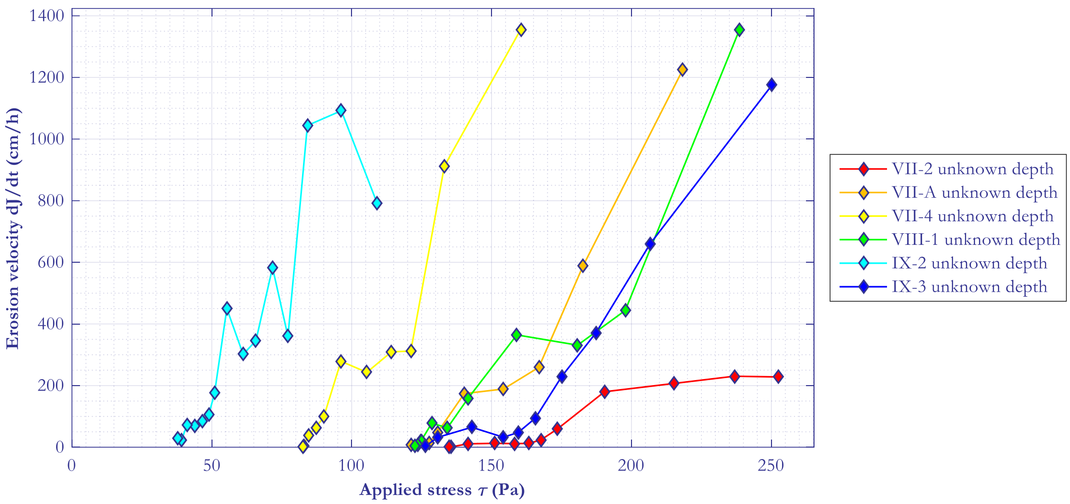
The immersion time was extended compared to Greg Hanson standard (10 minutes) to ensure a realistic saturation level of the samples with the erosion conditions that prevail on site.

The jet diameter was also enlarged compared to Greg Hanson standard (6,35 millimeters) in order that the jet diameter is significantly larger than the characteristic size of the roots.

The initial hydraulic stress applied was dimensioned by TUDelft as the maximum hydraulic stress that can be exerted on site.

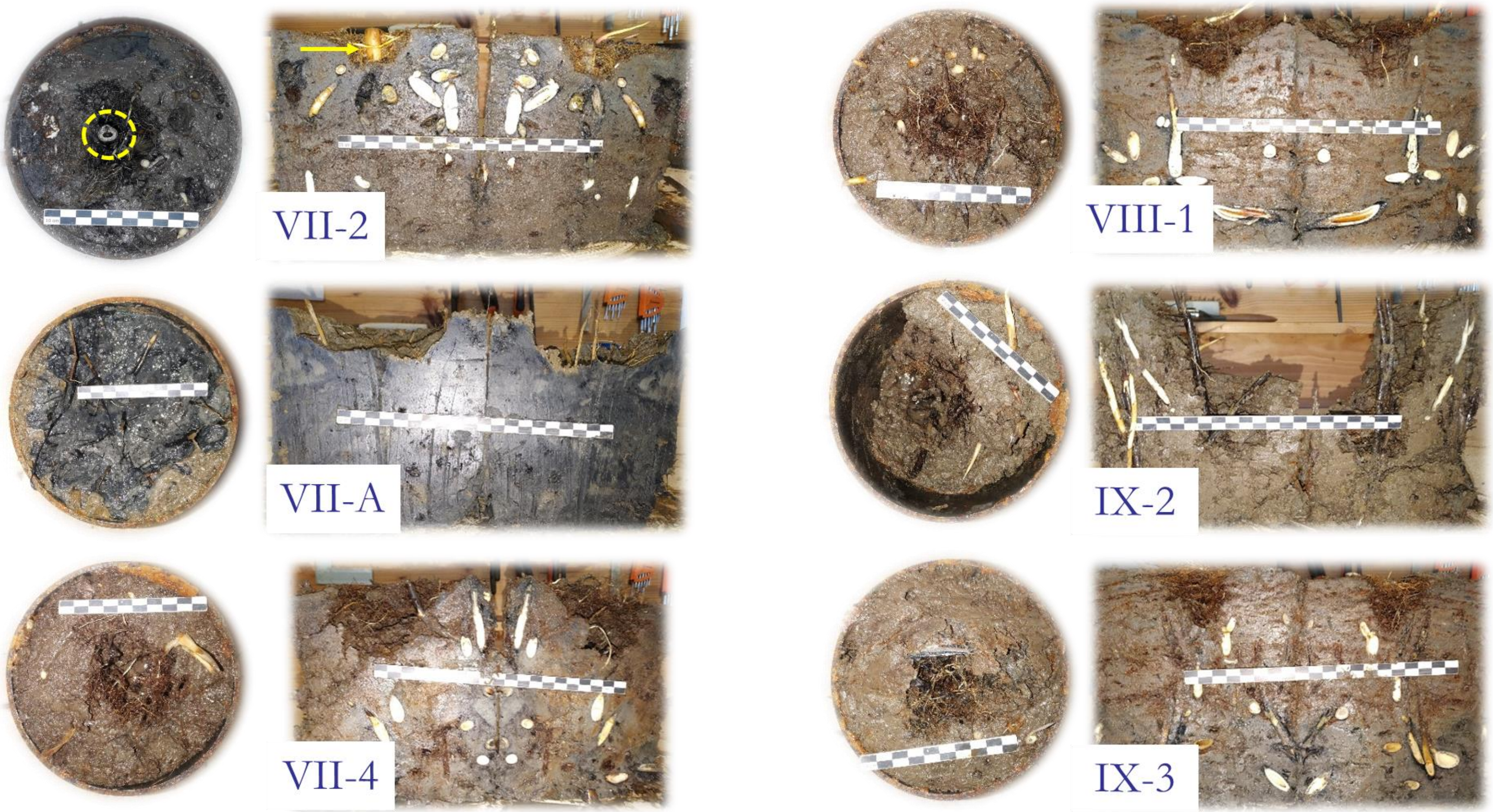
4.3 Results

The observed erosion rates could be correctly modeled by linear erosion laws on the ranges of stresses covered (Picture 2). Test VII-2 has slightly slower erosion kinetics than the other tests. Tests VII-4 and XI-2, on the other hand, have slightly lower critical stresses than the other tests.

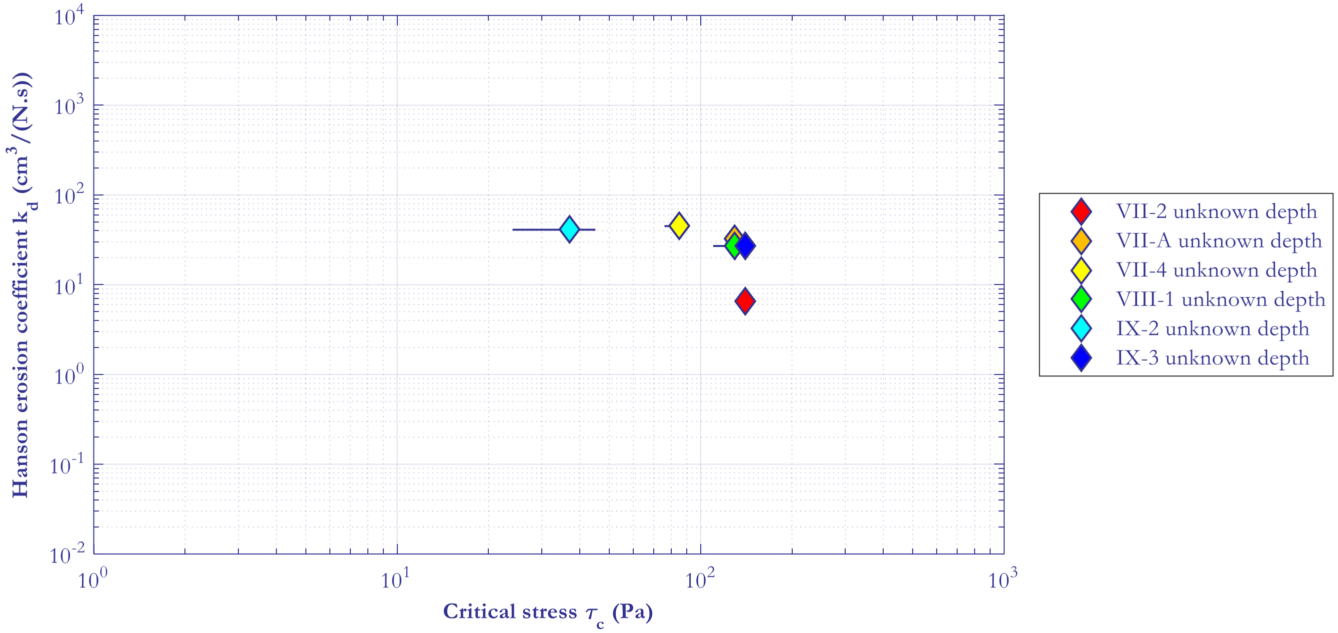


Picture 2. Erosion law observed in tests.

All test results are summarized in Picture 4 and Table 1, and a sectional view of the samples after testing is given in Picture 3.



Picture 3. Samples after tests, top view and sectional view.



Picture 4. Jet Erosion Test results.

Localisation		Characteristics of the sample					Test configuration		Measuring range		Critical stress (τc)		Hanson erosion coefficient (Kd)	
Drill hole	Depth	Sample type	Water content	Wet density	Removed fraction	Sample heigh	Jet diameter	Hydraulic load applied	Generated scour range	Modeled scour range	**Retenue**	Intervalle de confiance	**Retained**	Confidence interval
VII-2	unknown depth	Intact	-	1.14	-	18.0 cm	12 ± 1 mm	3.16 ± 0.05 mCe	0.0 - 2.9 cm	0.0 - 2.9 cm	**140 Pa**	130 - 150 Pa	**6.5 cm3/(N.s)**	5.1 - 7.8 cm3/(N.s)
VII-A	unknown depth	Intact	-	1.53	-	18.0 cm	12 ± 1 mm	3.38 ± 0.04 mCe	0.0 - 3.4 cm	0.0 - 3.4 cm	**130 Pa**	120 - 140 Pa	**33 cm3/(N.s)**	25 - 40 cm3/(N.s)
VII-4	unknown depth	Intact	-	1.34	-	18.0 cm	12 ± 1 mm	3.40 ± 0.04 mCe	0.0 - 5.8 cm	1.4 - 5.8 cm	**85 Pa**	76 - 92 Pa	**45 cm3/(N.s)**	35 - 55 cm3/(N.s)
VIII-1	unknown depth	Intact	-	1.28	-	18.0 cm	12 ± 1 mm	3.40 ± 0.03 mCe	0.0 - 3.7 cm	0.0 - 3.7 cm	**130 Pa**	110 - 140 Pa	**27 cm3/(N.s)**	19 - 35 cm3/(N.s)
IX-2	unknown depth	Intact	-	1.39	-	18.0 cm	12 ± 1 mm	3.39 ± 0.04 mCe	0.0 - 13.1 cm	4.2 - 13.1 cm	**37 Pa**	24 - 45 Pa	**41 cm3/(N.s)**	30 - 52 cm3/(N.s)
IX-3	unknown depth	Intact	-	1.16	-	18.0 cm	12 ± 1 mm	3.38 ± 0.03 mCe	0.0 - 3.7 cm	0.0 - 3.7 cm	**140 Pa**	130 - 150 Pa	**27 cm3/(N.s)**	20 - 33 cm3/(N.s)

Table 1. Jet Erosion Tests results. The unit "mCe" corresponds to meters of water column (also called mH2O)

5 Discussions

The density measurements underlined that one sample was much denser than the others (VII-A). This observation was confirmed when cutting the samples after testing (Picture 3: darker material, more sticky to the touch, and devoid of large roots).

For 5 of the 6 samples, the Hanson erosion coefficients obtained are very close to each other, with values between 27 and 45 $cm^3/(Ns)$. On the other hand, the sixth sample, VII-2, showed a somewhat lower value (6.5 $cm^3/(Ns)$). One of the possible explanations for this difference is the presence, in large numbers, of large roots in the eroded zone (which was not the case for the 5 other samples). These large roots (Picture 3, yellow arrow: including a vertical, parallel to the jet) could have dissipated the jet and thus reduced the stress actually applied to the soil.

For 5 of the 6 samples, the critical stress obtained are very close to each other, with values between 85 and 140 Pa. The sixth sample, IX-2, on the other hand showed a somewhat lower value (37 Pa). This poorer resistance can also be deduced from the photos after tests (Picture 3). At equivalent load, the test eroded much more than the others.

6 Appendix 1: The "Jet Erosion Test" implemented by geophy*Consult*

The « Jet Erosion Test » implemented at geophy*Consult*

1 Introduction

Overtopping occurs when the water level in a reservoir exceeds the height of crest of its closing structure. Water then flows over its downstream face. Unless this face is made of not erodible thin material, erosion starts and develops into successive small steps which behave like successive waterfalls that progressively grow and lead to a staircase shape which, under certain, conditions, is likely to lead at a partial or total breach of the structure.
The Jet Erosion Test is aimed at reproducing this phenomenon in the laboratory for thin soils, by applying a permanent vertical water flows over the surface of a core extracted from the structure. It quantifies the erodibility of the tested soil, that is its resistance to erosion when it is subject to a perpendicular water flow.

Figure 1. Essai de JET en laboratoire (à gauche) et essai de JET *in-situ* (à droite).

Originally developed by Greg Hanson from USDA in the USA, it has been standardized in 2007 (see [1]). The apparatus has slightly evolved afterwards, until Hanson made rather well an

accomplished version of his system described in [1][2], which is now routinely used all over the world. geophy*Consult* started to commercialize this test in 2008.
The JET is now acknowledged by many teams throughout the world and thousands of tests have been carried out, leading to quite important a database of tests. Its simplicity and the fact it has become a worldwide reference have lead people to use not only to characterize the resistance to overtopping, but also to help optimize at which dose of cement or lime vulnerable to erosion surfaces are to be reinforced with soils mixing solutions. It is also commonly used for the commissioning of structures (by specifying that they have to present JET erosion parameters within predefined ranges), or for simulating the expected erosion of riverbanks, etc.

2 Experimental protocol

It is recommended to test intact soils, rather than reworked soils.

Intact soils are inserted into Protor moulds (if necessary, after having been cut) and paraffin sealed. Reworked soils are generally first dried up and cut to 5 mm, before they are rehumidified and inserted in a Proctor mould in which they are compacted at their original value.
The sample is then submerged into water during 10 min, before it is subject to a vertical water jet which is applied to the axis of the core. The water height of the applied jet is set to a value which is as close to the field hydraulic head as possible, as long as this value remains compatible with the practical constraints of the apparatus (min. applied hydraulic head = 2 Pa, max = 800 Pa) and as long as it enables to simultaneously trigger erosion and fully describe the erosion curve that is needed to lead to satisfactory modelization.

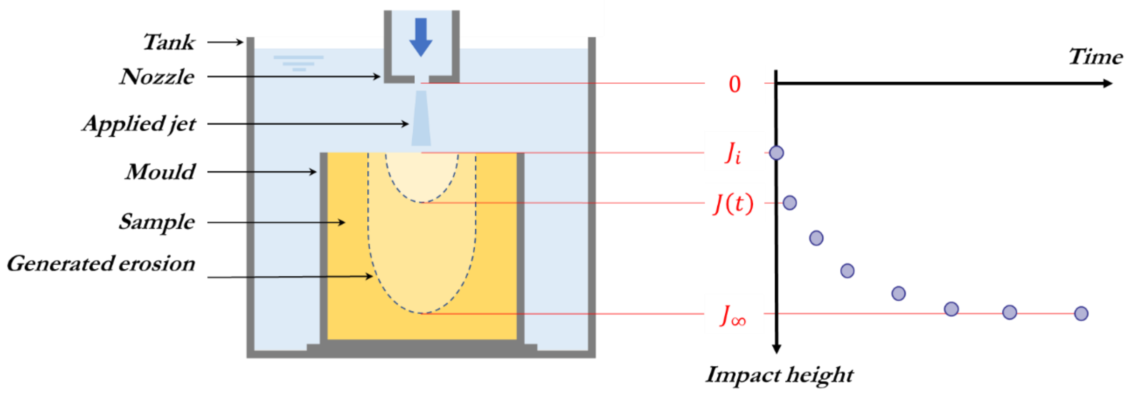


Figure 2. Test principle.

The scour depth *J(t)* is recorded all along the test and represented as a function of time *t* (Figure 2).

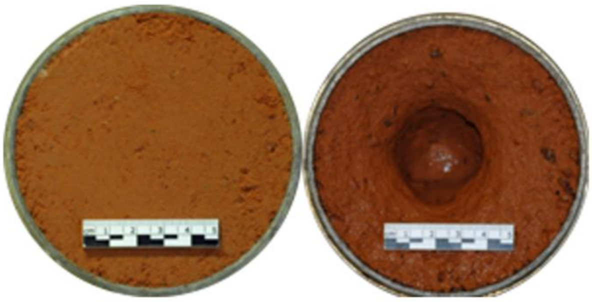


Figure 3. Sample surface before and after test.

3 Test modeling

Provided the applied jet generates a shear stress that is higher than the intrinsic critical shear stress of the sample (below which no erosion is triggered) the score depth evolves proportionally to the applied shear stress and follows a simple law:

$$\frac{dJ}{dt} = k_d(\tau - \tau_c),$$

where:

J is the jet impact heigh (m),
t is the time that last since the beginning of the test (s),
$\boldsymbol{k_d}$ is the Hanson erosion coefficient ($m^3/(N.s)$),
$\boldsymbol{\tau}$ is the applied shear stress (Pa),
$\boldsymbol{\tau_c}$ is the critical shear stress of the tested soil (Pa);

with:

$$\tau = \tau_0 \frac{J_P{}^2}{J^2} \qquad \tau_0 = C_f \rho U_0{}^2 \qquad J_p = C_d d_0 \qquad U_0 = \sqrt{2gh},$$

where:

$\boldsymbol{\tau_0}$ is the applied shear stress at t=0 (Pa),
C_f is a diffusion coefficient,
C_d is a friction coefficient,
ρ represents the water density,
g represents the gravity at the earth surface (m/s^2),
h is the applied hydraulic head (mCe).

The delivered erodibilty parameters $\boldsymbol{\tau_c}$ (critical shear stress, below which no erosion occurs) and $\boldsymbol{k_d}$ (Hanson kinetic erosion coefficient) are determined by a linear regression of the erosion law (Figure 4) deduced from the experimental points (Figure 2).

The discretization in stress not being regular (because of the uncontrolled evolution of the test), a rediscretization of the range of stress covered is made before proceeding with the linear regression.

In addition to the recommended values for the erosion parameters (k_d, τ_c), confidence intervals, based on Student laws using level of confidence of 95%, are proposed.

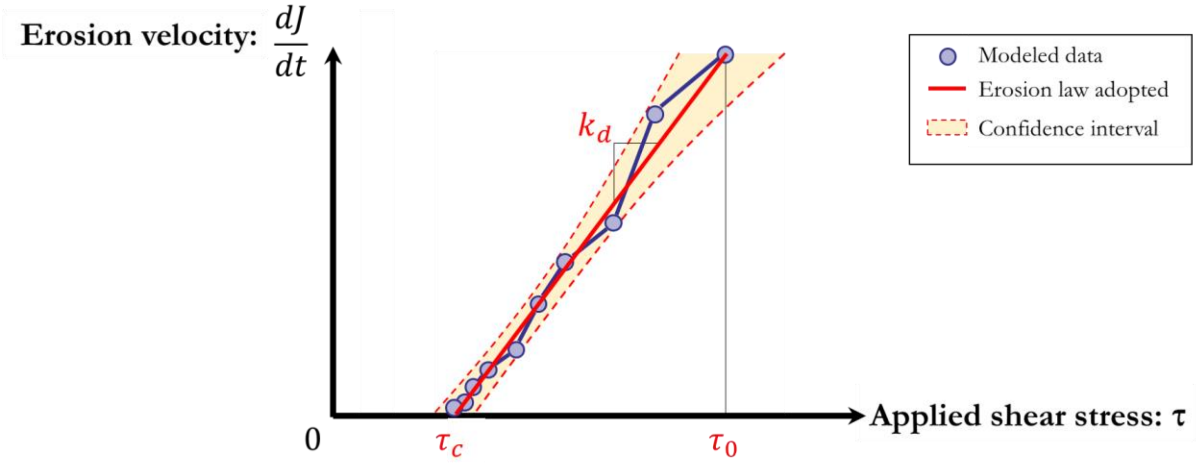


Figure 4. Adjustment of the erosion parameters (k_d, τ_c) on the erosion law.

4 Test interpretation

JET results can be used to:

- to quantitatively assess the resistance to erosion of a soil and compare it with other already tested soils,
- to model a breach by injecting the delivered values of τ_c and k_d in an erosion model like Windam (see [4] and http://go.usa.gov/cupCF) or HR-Breach and calculating breach hydrograms to be used in safety assessments,
- to estimate the expected erosion velocity in case the structure is subject to a given hydraulic head,
- to qualitatively assess the characteristics of the tested soil: is it homogeneous or stratified, does it comes apart or expands when submerged,

The quality of the test can be estimated by comparing the final scour depth to J_∞ and other experimental parameters.

5 References

[1] ASTM D5852-00(2007) e1, Standard Test Method for Erodibility Determination of Soil in the Field or in the Laboratory by the Jet Index Method (Withdrawn 2016), ASTM International, West Conshohocken, PA, 2007,

[2] Hanson and Cook (2004), *Apparatus, test procedures and analytical methods to measure soil erodibility in situ*. Applied engineering in agriculture, 20 (4): 455-462.

[3] Pinettes, Patrick & Courivaud, Jean-Robert & Fry, Jean-Jacques & Mercier, Fabienne & Bonelli, Stephane. (2011). *First introduction of Greg Hanson "Jet Erosion Test" in Europe: return on experience after 2 years of testing*. 31st Annual USSD Conference, San Diego, USA, 11-15 April 2011, 11/04/2011 - 15/04/2011, San Diego, USA

[4] USDA-ARS and –NRCS and Kansas State University: WinDAM B. (2012). WinDAM-B, Version 1.1, Computer Program Release.

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[6] Maliheh Karamigolbaghi, Seyed Mohammad Ghaneeizad, Joseph F. Atkinson, Sean J. Bennett, Robert R. Wells (2017), *Critical assessment of jet erosion test methodologies for cohesive soil and sediment*, Geomorphology (2017), doi: 10.1016/j.geomorph.2017.08.005

[7] Mercier, F., S., Bonelli, P., Pinettes, F. Golay, F. Anselmet and P. Philippe, Comparison of computational fluid dynamic simulations with experimental Jet Erosion Test results, J. Hydrau. Eng., 140, 2014.

[8] Van-Nghia Nguyen; Jean-Robert Courivaud; Patrick Pinettes; Hanène Souli; and Jean-Marie Fleureau, Using an Improved Jet-Erosion Test to Study the Influence of Soil Parameters on the Erosion of a Silty Soil, J. Hydraul. Eng., 143-8, 2017

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[10] Beguin, R., Moras, C., Boucher, M., Vinay, C., Courivaud, J.-R., Pinettes, P., & Picault, C. (2019). Retour d'expérience sur 10 années de réalisation d'essais d'érosion sur des sols provenant d'ouvrages hydrauliques. Digues 2019 : 3ème Colloque sur les digues maritimes et fluviales de protection contre les inondations, Aix-en-Provence, 20-21 mars 2019

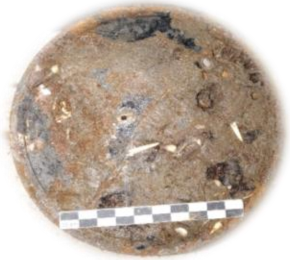
7 Appendix 2: JET results

Jet Erosion Test

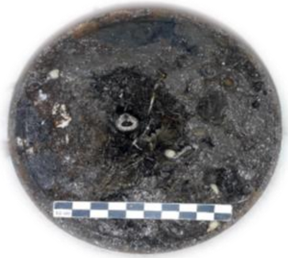
Report:	geophy00409	**Customer:**	TUDelft
Project manager:	Maxime Boucher	**Site:**	Prosperpolder
Operator:	Guillaume Davion	**Drill hole:**	VII-2
Date of the test:	12/05/2021	**Depth:**	unknown depth

Description of the sample

Before the test



After the test

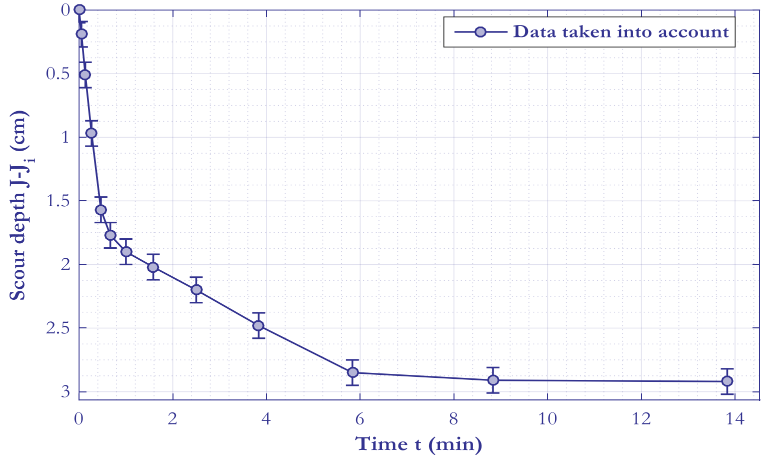


Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Many roots in the soil
Change of camera for shooting after test (explaining the color differences)

Progress of the test



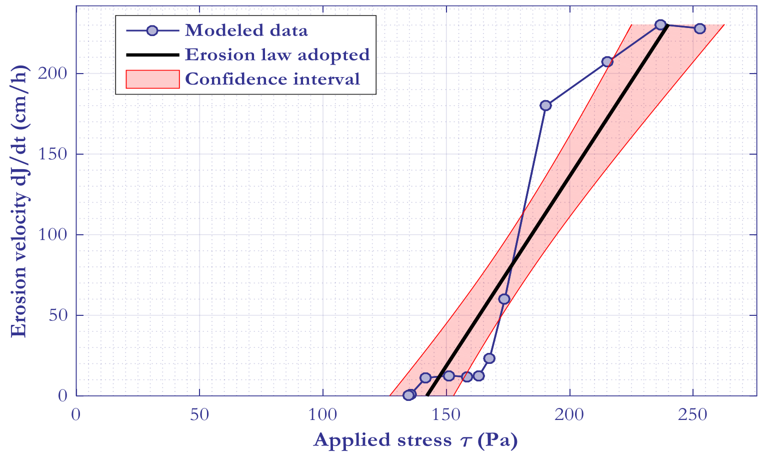
Test parameters	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.16 ± 0.05	mCe
Initial impact heigh:	Ji	7.5 ± 0.1	cm

Observation during the test

No specific observation

Test modeling

$dJ/dt = kd(\tau - \tau c)$



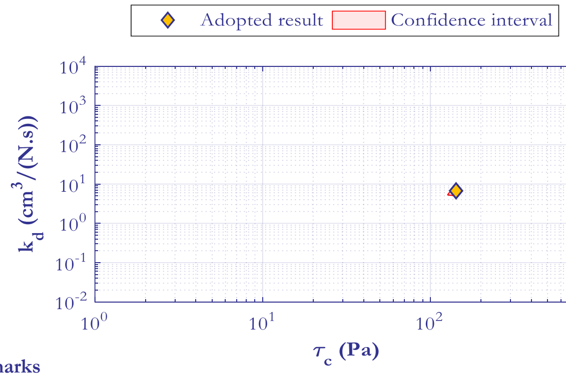
Modeling parameters	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s²
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

Results	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	130	**140**	150	Pa
Hanson erosion coefficient:	k_d	5.1	**6.5**	7.8	cm3/(Ns)
Max. scour depth according to the model:	J∞ - Ji		2.6		cm
Characteristic erosion time:	t95		1.2		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil

Jet Erosion Test

Report: geophy00409
Project manager: Maxime Boucher
Operator: Guillaume Davion
Date of the test: 24/05/2021
Customer: TUDelft
Site: Prosperpolder
Drill hole: VII-A
Depth: unknown depth

Description of the sample

Before the test

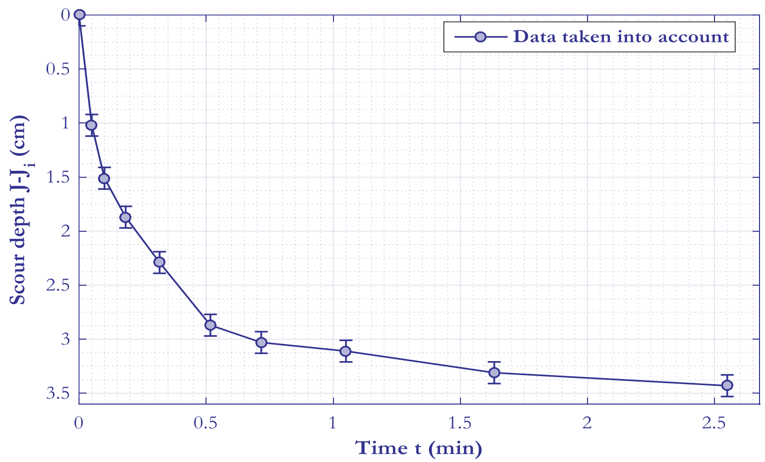
After the test

Sample type:	Intact	Water content:	%
Removed fraction:	- %	Dry density:	
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil

Progress of the test



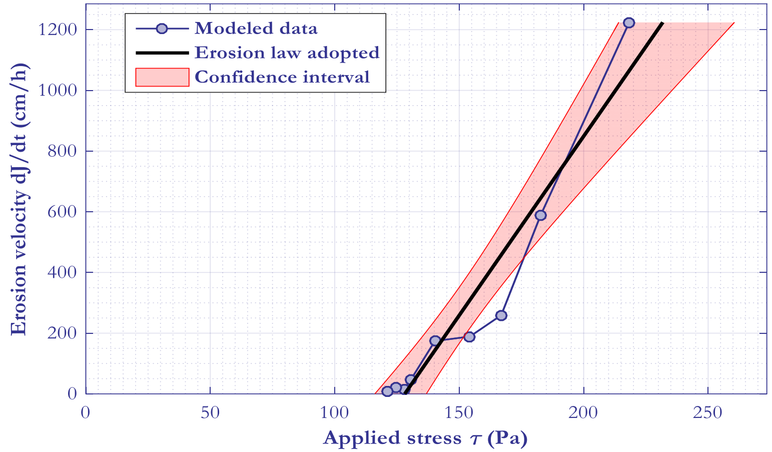
Test parameters	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.38 ± 0.04	mCe
Initial impact heigh:	Ji	8.0 ± 0.1	cm

Observation during the test

No specific observation

Test modeling

$dJ/dt = kd(\tau - \tau c)$



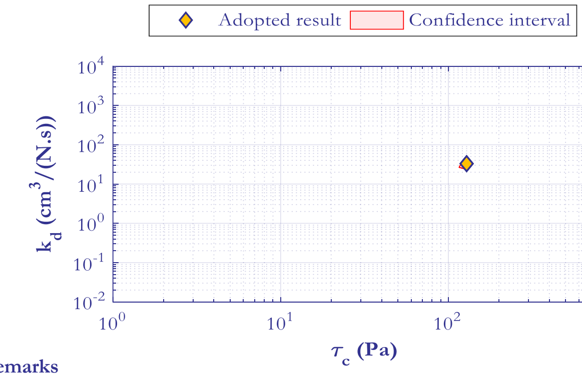
Modeling parameters	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s²
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

Results	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	120	**130**	140	Pa
Hanson erosion coefficient:	k_d	25	**33**	40	cm3/(Ns)
Max. scour depth according to the model:	J∞ - Ji		3.1		cm
Characteristic erosion time:	t95		0.3		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil

Jet Erosion Test

Report: geophy00409
Project manager: Maxime Boucher
Operator: Guillaume Davion
Date of the test: 25/05/2021

Customer: TUDelft
Site: Prosperpolder
Drill hole: VII-4
Depth: unknown depth

Description of the sample

Before the test

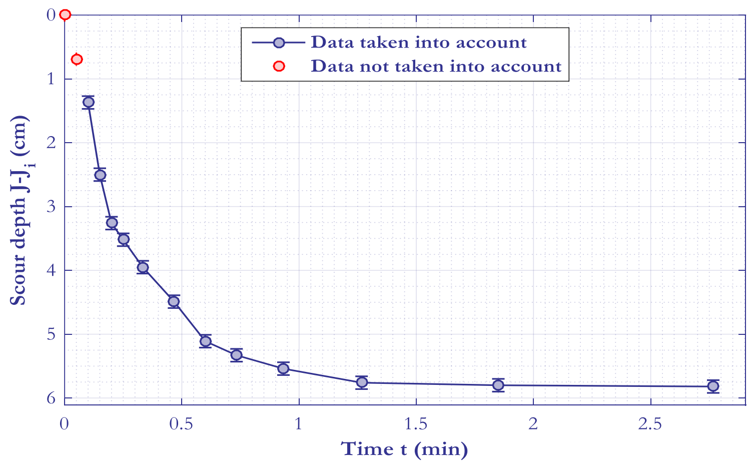
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil

Progress of the test



Test parameters

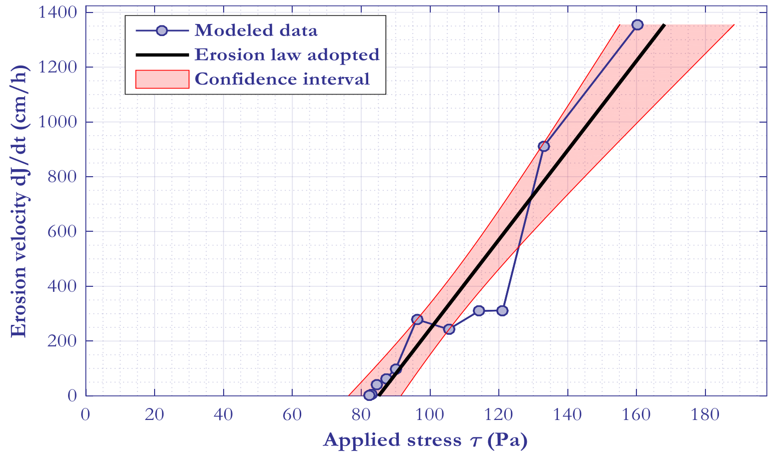
	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.40 ± 0.04	mCe
Initial impact heigh:	Ji	8.1 ± 0.1	cm

Observation during the test

First two points not retained. They exhibit slower erosion kinetics than the rest of the test

Test modeling

dJ/dt = kd(τ - τc)



Modeling parameters

	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s^2
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

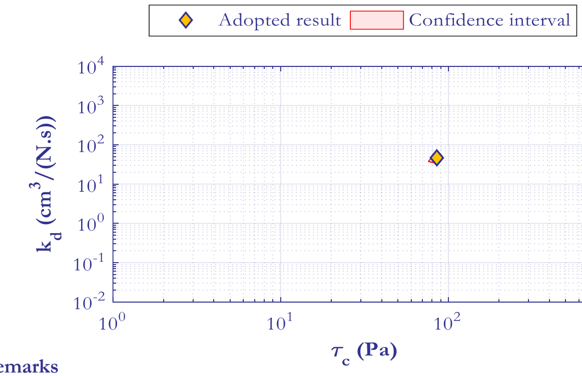
Results

	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	76	85	92	Pa
Hanson erosion coefficient:	k_d	35	45	55	cm3/(Ns)
Max. scour depth according to the model:	J_∞ - Ji		5.6		cm
Characteristic erosion time:	t95		0.5		min

Modeling remarks

No specific observation

Database



Overall remarks

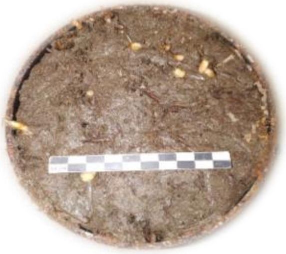
Very rooty soil

Jet Erosion Test

Report:	geophy00409	**Customer:**	TUDelft
Project manager:	Maxime Boucher	**Site:**	Prosperpolder
Operator:	Guillaume Davion	**Drill hole:**	VIII-1
Date of the test:	11/05/2021	**Depth:**	unknown depth

Description of the sample

Before the test



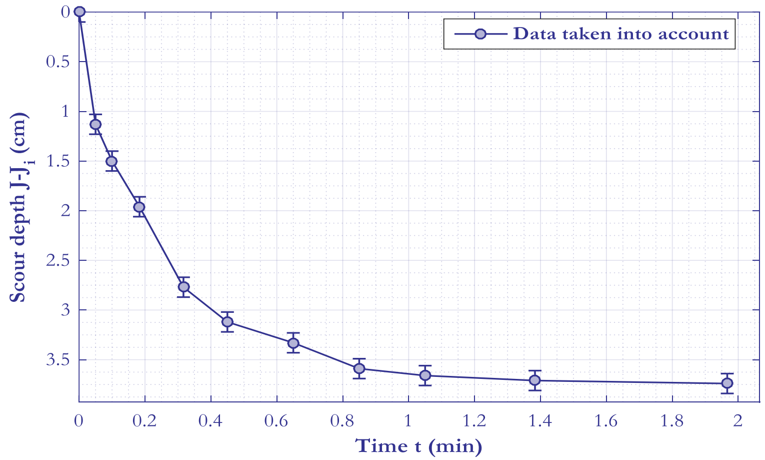
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil

Progress of the test



Test parameters

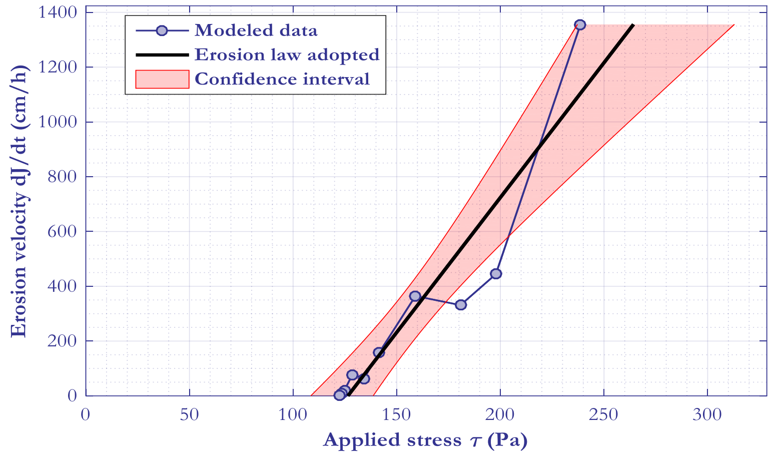
	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.40 ± 0.03	mCe
Initial impact heigh:	Ji	7.6 ± 0.1	cm

Observation during the test

No specific observation

Test modeling

$dJ/dt = kd(\tau - \tau c)$



Modeling parameters

	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s²
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

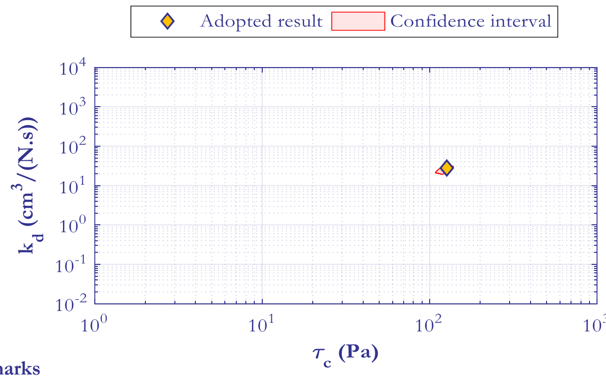
Results

	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	110	**130**	140	Pa
Hanson erosion coefficient:	k_d	19	**27**	35	cm3/(Ns)
Max. scour depth according to the model:	J_∞ - Ji		3.6		cm
Characteristic erosion time:	t95		0.4		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil

Jet Erosion Test

Report: geophy00409
Project manager: Maxime Boucher
Operator: Guillaume Davion
Date of the test: 24/05/2021
Customer: TUDelft
Site: Prosperpolder
Drill hole: IX-2
Depth: unknown depth

Description of the sample

Before the test

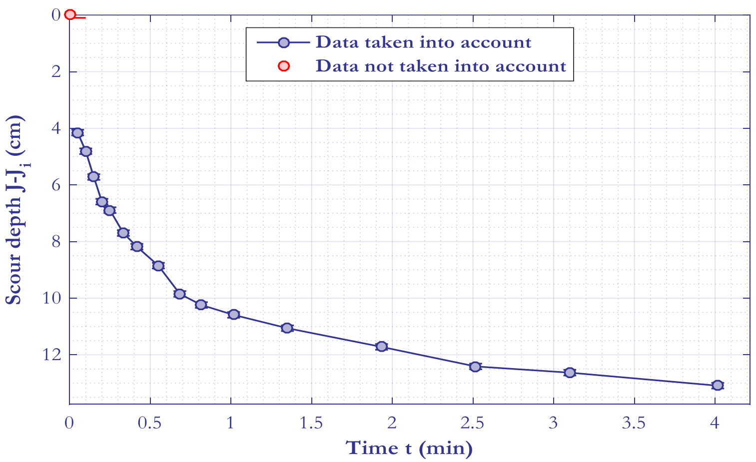
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil.
Asymmetric erosion profile

Progress of the test



Test parameters

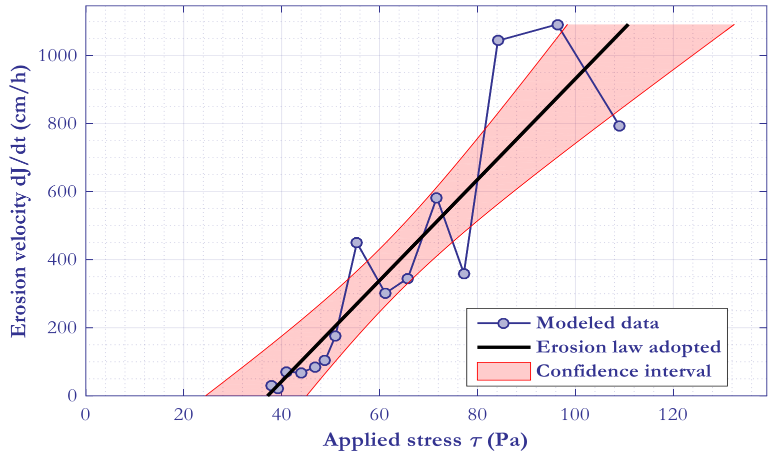
	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.39 ± 0.04	mCe
Initial impact heigh:	Ji	7.6 ± 0.1	cm

Observation during the test

First point not taken into account: high uncertainty compared to the other points (more than 4 cm eroded in 3 seconds)

Test modeling

$dJ/dt = kd(\tau - \tau c)$



Modeling parameters

	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s^2
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

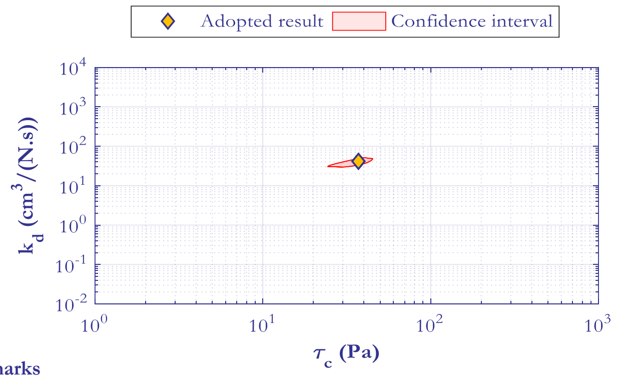
Results

	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	24	37	45	Pa
Hanson erosion coefficient:	k_d	30	41	52	cm3/(Ns)
Max. scour depth according to the model:	J∞ - Ji		13.1		cm
Characteristic erosion time:	t95		1.9		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil.
Asymmetric erosion profile

Jet Erosion Test

Report:	geophy00409	**Customer:**	TUDelft
Project manager:	Maxime Boucher	**Site:**	Prosperpolder
Operator:	Guillaume Davion	**Drill hole:**	IX-3
Date of the test:	12/05/2021	**Depth:**	unknown depth

Description of the sample

Before the test

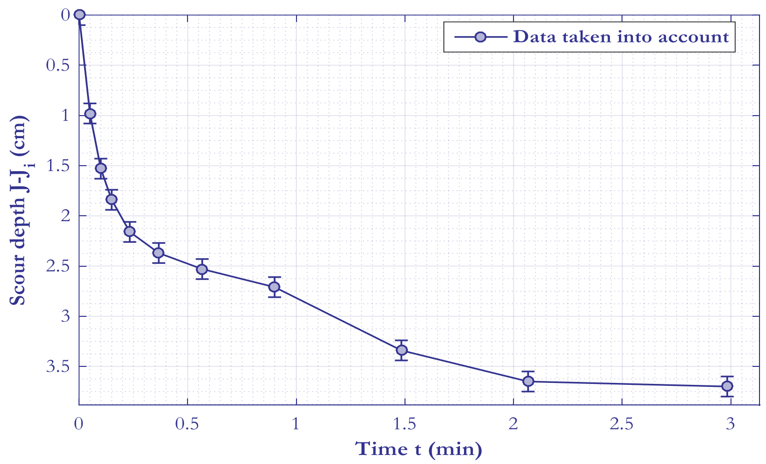
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil

Progress of the test



Test parameters

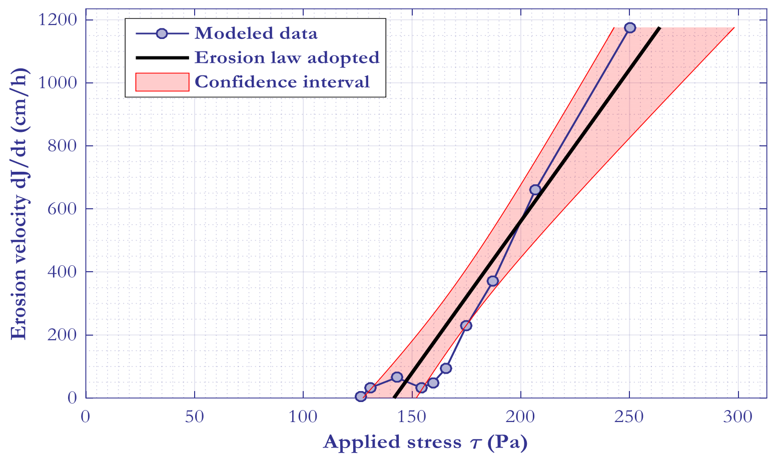
	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.38 ± 0.03	mCe
Initial impact heigh:	Ji	7.5 ± 0.1	cm

Observation during the test

No specific observation

Test modeling

$dJ/dt = kd(\tau - \tau c)$



Modeling parameters

	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s^2
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

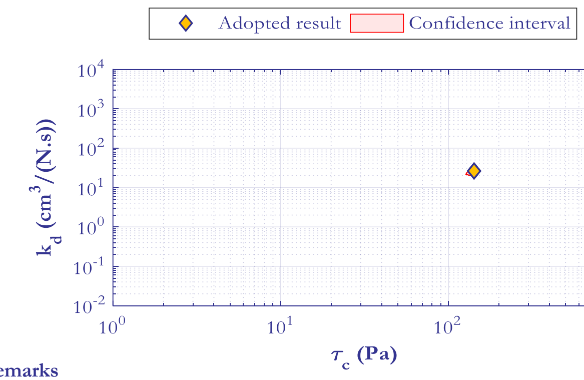
Results

	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	130	**140**	150	Pa
Hanson erosion coefficient:	k_d	20	**27**	33	cm3/(Ns)
Max. scour depth according to the model:	J∞ - Ji		3.1		cm
Characteristic erosion time:	t95		0.3		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil

Jet Erosion Test

Report: geophy00409
Project manager: Maxime Boucher
Operator: Guillaume Davion
Date of the test: 23/04/2021

Customer: TUDelft
Site: Prosperpolder
Drill hole: VII-1
Depth: unknown depth

Description of the sample

Before the test

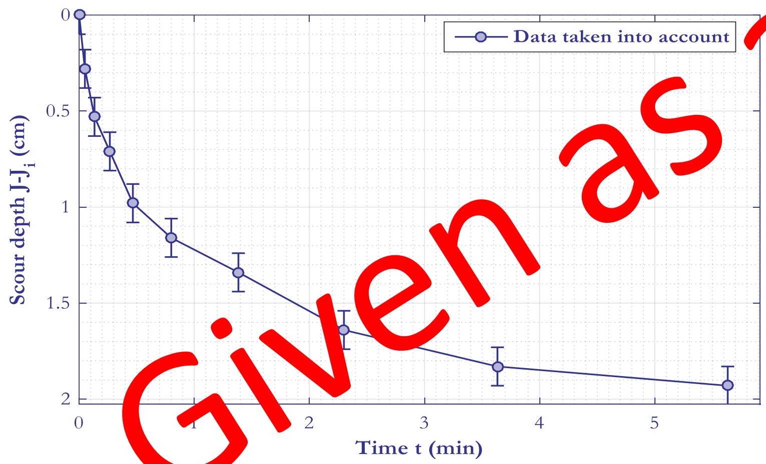
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil

Progress of the test

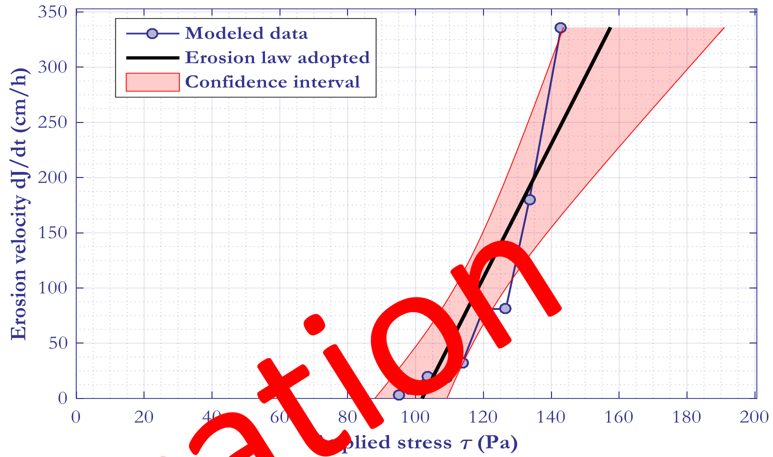


Test parameters	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	1.83 ± 0.02	mCe
Initial impact heigh:	Ji	7.6 ± 0.1	cm

Observation during the test

No specific observation

Test modeling $dJ/dt = kd(\tau - \tau c)$



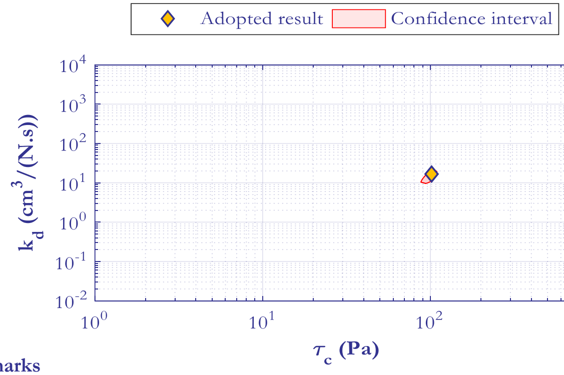
Modeling parameters	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s²
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

Results	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	88	100	110	Pa
Hanson erosion coefficient:	k_d	9.6	17	23	cm3/(Ns)
Max. scour depth according to the model:	J∞ - Ji		1.6		cm
Characteristic erosion time:	t95		0.5		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil

Jet Erosion Test

Report:	geophy00409	**Customer:**	TUDelft
Project manager:	Maxime Boucher	**Site:**	Prosperpolder
Operator:	Guillaume Davion	**Drill hole:**	VII-3
Date of the test:	11/05/2021	**Depth:**	unknown depth

Description of the sample

Before the test

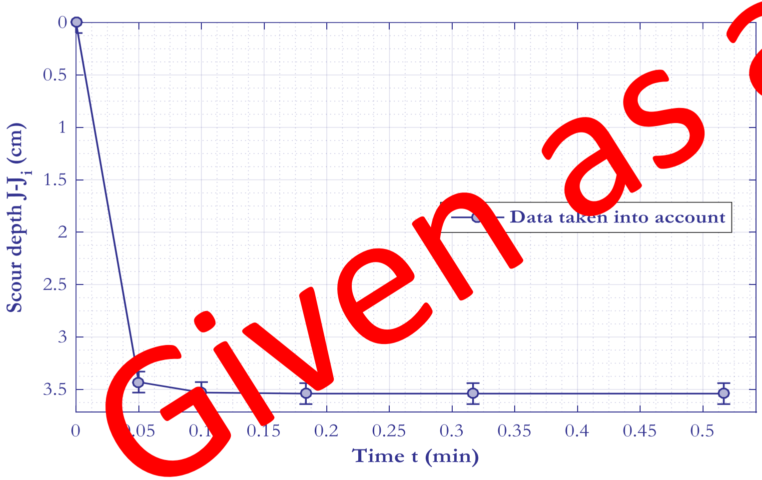
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil
Change of camera for shooting after test (explaining the differences in color)

Progress of the test



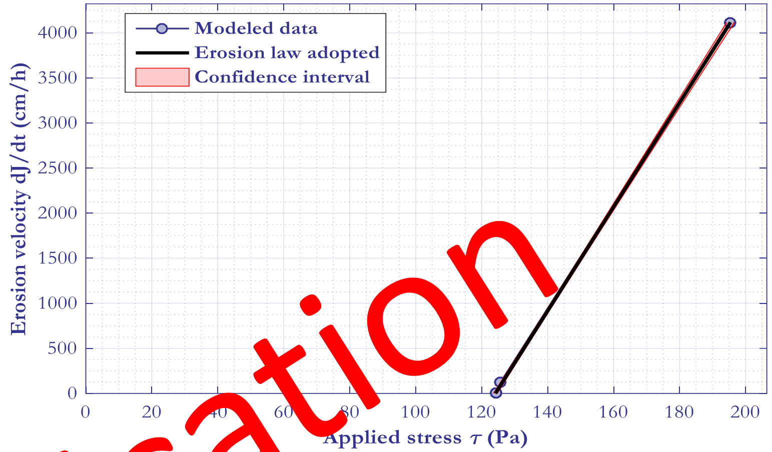
Test parameters	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.39 ± 0.03	mCe
Initial impact heigh:	Ji	7.7 ± 0.1	cm

Observation during the test

No specific observation

Test modeling

$dJ/dt = kd(\tau - \tau c)$



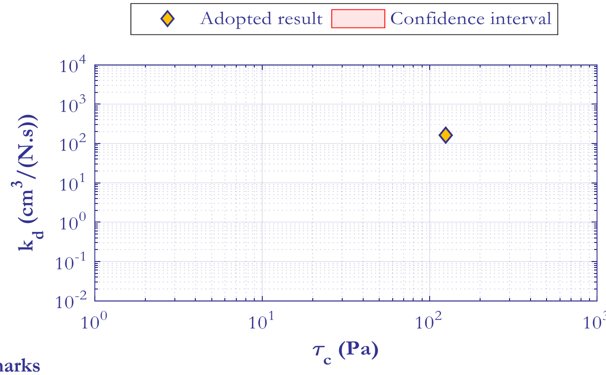
Modeling parameters	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s²
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

Results	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	120	120	120	Pa
Hanson erosion coefficient:	k_d	160	160	160	cm3/(Ns)
Max. scour depth according to the model:	J∞ - Ji		3.5		cm
Characteristic erosion time:	t95		0.1		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil

Jet Erosion Test

Report: geophy00409
Project manager: Maxime Boucher
Operator: Guillaume Davion
Date of the test: 12/05/2021

Customer: TUDelft
Site: Prosperpolder
Drill hole: IX-1
Depth: unknown depth

Description of the sample

Before the test

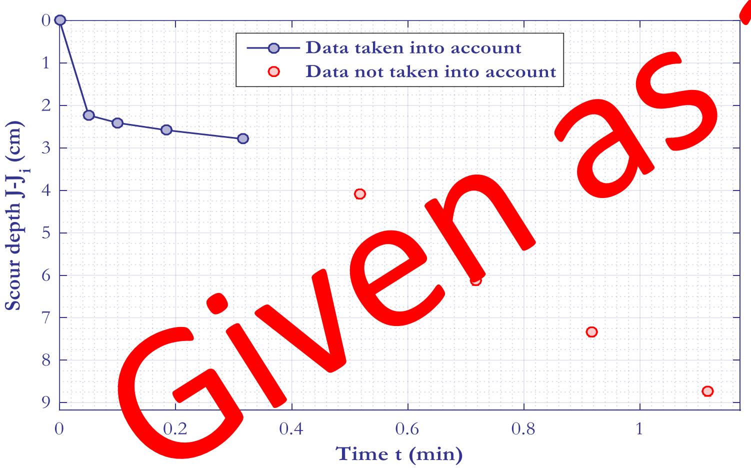
After the test

Sample type:	Intact	Water content:	- %
Removed fraction:	- %	Dry density:	-
Sample heigh:	18.0 cm		

Observation before and after test

Very rooty soil

Progress of the test



Test parameters

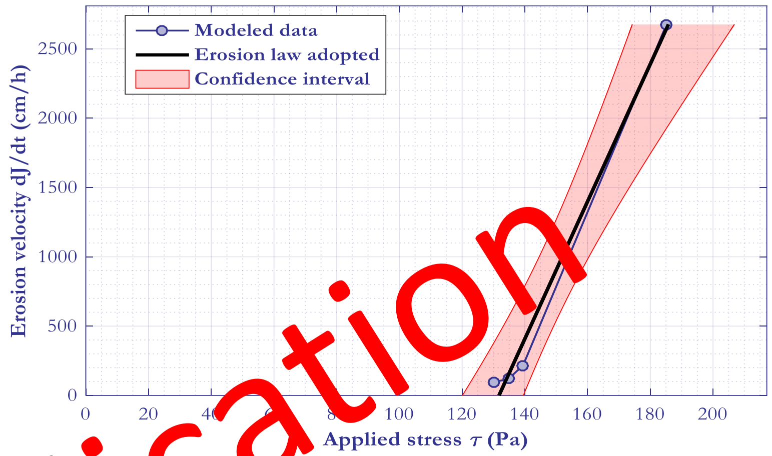
Test parameters	Symbols	Values	Units
Jet diameter:	d_0	12 ± 1	mm
Hydraulic load applied:	h	3.35 ± 0.05	mCe
Initial impact heigh:	Ji	8.3 ± 0.1	cm

Observation during the test

No specific observation

Test modeling

$dJ/dt = kd(\tau - \tau c)$



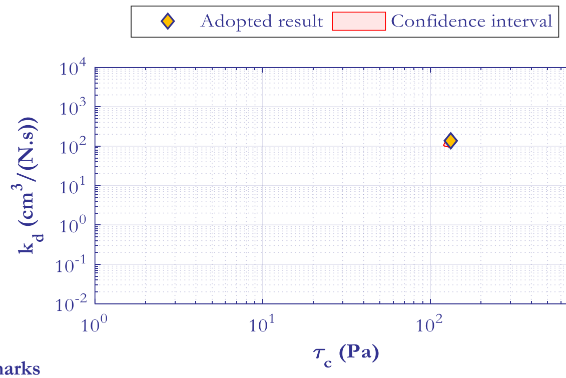
Modeling parameters	Symbols	Values	Units
Gravity acceleration:	g	9.81	m/s²
Water density:	ρ	1000	kg/m3
Diffusion coefficient:	Cd	6.3	-
Friction coefficient:	Cf	0.00416	-
Level of confidence	Nc	0.95	-

Results	Symbols	Minimum	Retained	Maximum	Units
Critical stress:	τ_c	120	**130**	140	Pa
Hanson erosion coefficient:	k_d	95	**140**	170	cm3/(Ns)
Max. scour depth according to the model:	$J_\infty - J_i$		2.6		cm
Characteristic erosion time:	t_{95}		0.1		min

Modeling remarks

No specific observation

Database



Overall remarks

Very rooty soil