D-Flow Slide

Slope Liquefaction and Breaching

User Manual

Wettelijk Toets Instrumentarium 2017

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D-FLOW SLIDE, User Manual

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1 General Information

1.1 Introduction

The assessment of the stability of under water slopes in unprotected sandy or silty material is often an important issue for dredging in harbours and fairways, trenching and sand mining. It is also important for natural river- and estuary or lake banks near eroding flows, often related with dike safety.

In this wiki space you can find information about the program D-FLOW SLIDE for analyzing flow sliding in submerged slopes (in Dutch: zettingsvloeiing). A first version was developed in 2012 (beta version 1.0), which was improved in 2014 (stand-alone version 1.2). In 2015 version 2 was released, where some nasty bugs were fixed and improvements were made. With D-FLOW SLIDE version, a safety assessment on flow slides can be performed according to WBI-2017. The program is based on the Toetsmethode zettingsvloeiing (De Bruijn *et al.*, 2016), also described in "Bijlage III: Sterkte en Veiligheid" (Rijkswaterstaat, 2016), which on its turn is based on the Handreiking Toetsen Voorland Zettingsvloeiingen (Rijkswaterstaat, 2012).

For more detailed information about the stability of sandy and silty under water slopes you can also download our brochure.

You can also read (in Dutch) a “Technical report” (De Bruijn *et al.*, 2016), which prescribes the technical safety assessment method for the major failure mechanism of water defenses. Each primary flood defense in Holland must be judged along the methods and rules prescribed in this document. This Technical report is a part of the “Statutory Assessment instrumentation” and is called “The Prescribe Safety assessment for levee’s”.

Figure 1.1: *Examples of damage to a dike due to a flow slide*

Flow slides form a major threat for flood defences along (estuary) coastlines and riverbanks in the Netherlands. Such flow slides may result in severe damage to dikes and structures, eventually leading to flooding of the hinterland (see Figure 1.1). Measures to prevent, mitigate, or even repair flow slides are costly. Due to the complexity of flow slides, methods that enable an accurate quantitative risk assessment are under-developed, especially compared to methods currently available for other failure mechanisms (e.g. piping below the dike or macro-instability of the dike body).

Flow Slide: description of processes

Flow slide is a complex failure mechanism that includes both soil mechanical and hydraulic features, of which the elementary ones are depicted in the flow chart in Figure 1.2. Two important physical (sub-)mechanisms are static soil liquefaction (verwekingsvloeiing) and breaching (bresvloeiing). For most of the documented cases of flow slides it is not clear to what extent static soil liquefaction and/or breaching played a role. Both mechanisms result in a flowing sand-water mixture, that eventually resediments under a very gentle slope.

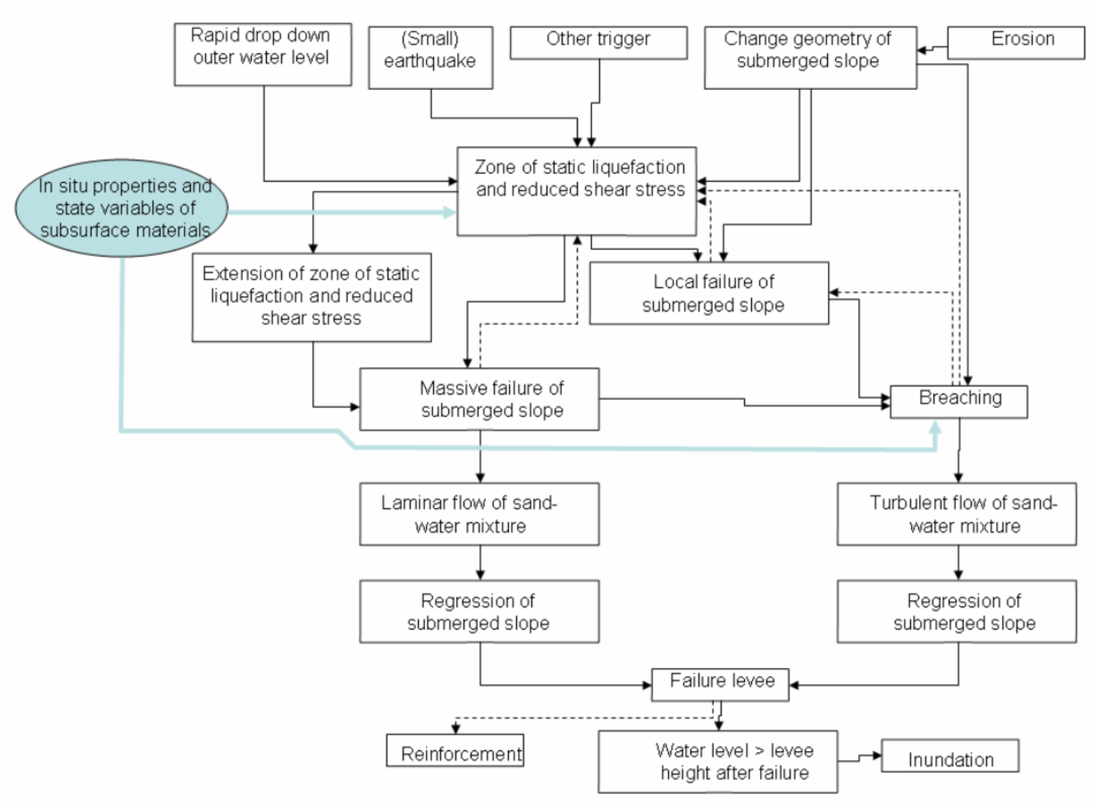


Figure 1.2: *Processes possibly involved in a flow slide*

Static liquefaction entails the sudden loss of strength of loosely packed saturated sand or silt, which may result in a sudden collapse of the sand body. Contrary to "ordinary" slope failure, in which a clear rupture surface can be distinguished over which the instable soil mass slides while staying more or less intact, in a liquefaction flow slide the instable mass of sand (or silt) flows laminar like a viscous fluid.

Unlike liquefaction, ***breaching*** only takes place at the soil surface: a local steep part of the slope retrogresses upslope and generates a turbulent sand-water mixture flow over the sand surface of the under water slope. If the mixture carries enough sand and if the local slope is steep enough, the thickness of the mixture will grow by erosion of the sand surface. Although strongly dependent on the properties of the sand or silt, a breaching flow slide in general takes much more time (several hours) than a liquefaction flow slide (several minutes).

Regardless of the mechanisms involved, a flow slide needs a trigger. Soil liquefaction may be initiated by a rapid drop of outer water level, a small earthquake, or a change in geometry by erosion or local instability, resulting in an unfavourable change of stress conditions within the loosely packed sand or silt. Breaching requires an initial breach, which may be formed by scour, by a local slip failure or by a local liquefaction flow slide. The triggers for both liquefaction and breaching are presented in the top of the flow chart in Figure 1.2.

Figure 1.3: *Resulting scar of a large flow slide (plaatval), Plaat van Walsoorden, 2014*

1.2 Features in D-FLOW SLIDE

D-FLOW SLIDE is a user-friendly software tool developed for performing a safety assessment on the failure mechanism flow slide.
The safety assessment includes a Global assessment method, which is a slightly modified version of the method in the VTV-2006 (Rijkswaterstaat, 2007), and a probabilistic Detailed assessment method.
Furthermore advanced models for static liquefaction (SLIQ2D, see Van den Ham (2009)) and breach flow (HMBreach, see Tabak (2011) and Mastbergen (2009)) have been implemented.

1.3 Minimum System Requirements

The following minimum system requirements are needed in order to install and run the program D-FLOW SLIDE:

- Operations systems
  - Windows 7
  - Windows 10
- Hardware specifications
  - 1 GHz Intel Pentium processor or equivalent
  - 512 MB of RAM
  - 500 MB free hard disk space
  - SVGA videokaart, 1024 x 768 pixels, high colors (16 bits)

Registered users can download the program D-FLOW SLIDE from the download portal of Deltares, by using a password.

1.4 D-FLOW SLIDE and DAM

A preliminary link between D-FLOW SLIDE and the software DAM has been established. Implementation in DAM makes it possible to do automated calculations with D-FLOW SLIDE. This makes it possible to perform scenario analysis, e.g. for evaluating the influence of different (stochastic) subsoil scenario's or evaluating the safety against flow slides for predicted changes of the foreland geometry due to erosion or sedimentation.
This is important information for policy makers.
Flow slide is a failure mode of the foreland of the levee and does not necessarily directly result in failure of the levee and therewith flooding of the hinterland.
However, failure of the foreland may induce a so-called "direct" failure mechanism of the levee, such as overtopping and -flow, backward erosion ("piping") and macro-instability.

Since DAM includes calculation models of several direct failure modes, it is possible to calculate the combined probability on a flow slide and the subsequent failure of the levee by a "direct" failure mode.

2 Getting Started

2.1 Introduction

D-FLOW SLIDE has been developed specifically for geotechnical engineers. It is a tool to perform a (semi-probabilistic) global and (probabilistic) detailed safety assessment on flow sliding in submerged slopes in front of flood defenses. Moreover, it includes two advanced calculation models for analyzing static liquefaction and breach flow, that can be used for a tailor-made safety assessment, if the global and detailed assessments fail.

The graphical interfaces require just a short training period, allowing users to focus their skill directly on the input of the geotechnical data and the subsequent evaluation of the calculated results.

Check your input data!
Please check your input data carefully and discuss the results with Dick Mastbergen or Geeralt van den Ham, experts on flow slides.

In Chapter 4, step for step, the major input screens and windows are explained on the basis of a simple Tutorial (bm-1-1).
The input file can also be downloaded and used if you have a legal version of the program.

2.2 Installation

If you have Administrator privileges you will be able to use the default directory "C:\Program Files (x86)\Deltares\D-Flow Slide\" to install D-FLOW SLIDE.

If not or getting a message that only an administrator can install D-FLOW SLIDE, please select an other directory with read/write permission: For example use:
"D:\Deltares\D-Flow Slide\".

To un-install the program, you need Administrator privileges. The templates files in your personal profile directory will not be removed.

An alternative way, if you do not have administrator privileges, is just remove the directory of the program and remove program from the "Start" menu.

Figure 2.1: *D-Flow Slide Setup window*

2.3 Main Window

When D-FLOW SLIDE is started for the first time, the main window is displayed with a default project as shown in Figure 2.2: a channel of 25 m deep and a dike of 5 m height with three soil layers (dike clay, sand and clay) and all the characteristic points needed to perform a calculation.

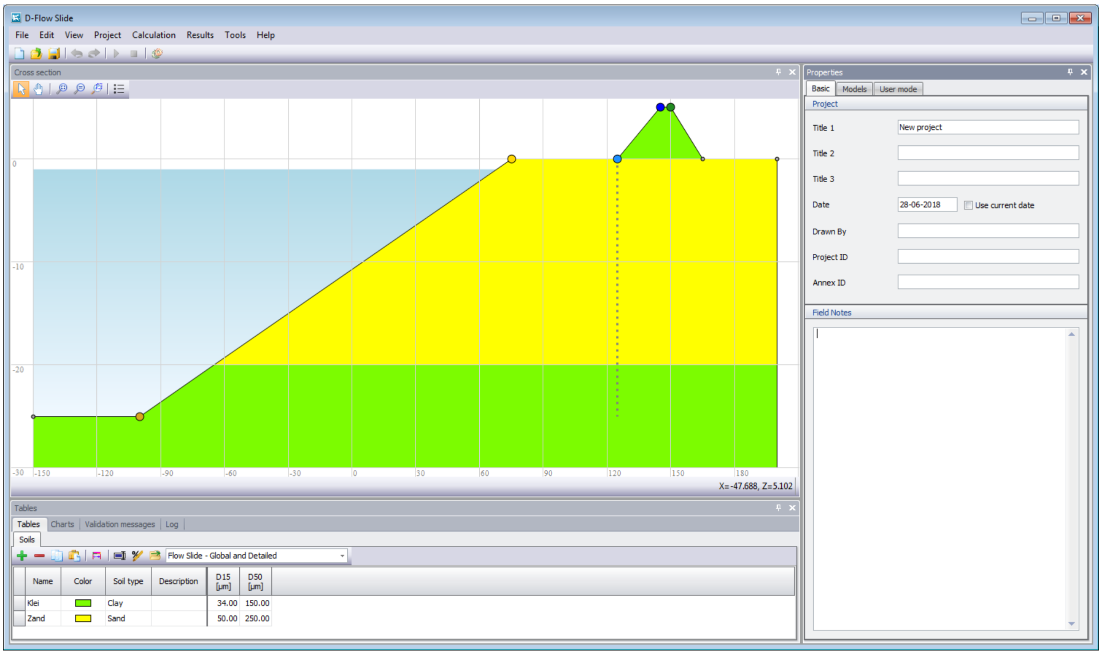


Figure 2.2: *D-Flow Slide main window with a new project*

This window contains a menu bar (section 2.3.1), an icon bar (section 2.3.2), a *Cross Section* window (section 2.3.3) that displays a new or most recently accessed project, a *Tables* window (section 2.3.4) and a *Properties* window (section 2.3.5).

The caption of the main window of D-FLOW SLIDE displays the program name, followed by the project name. When a new file is created, no project name is displayed.

2.3.1 Menu bar

The input windows can be found at the Menu bar.

2.3.2 Icon bar

2.3.3 Cross section

2.3.4 Tables

2.3.5 Properties

2.4 Files

The Project file of D-FLOW SLIDE has the extension *.fsx and it has the following characteristics:

◇ It is a XML-file

- ◇ It contains all input data with the problem definition. The Project file can be reused in subsequent analysis (Please use "Save as" to save each alternative calculation)
- ◇ After a calculation has been performed, all output data will also be stored into the current Project file.

3 User Interface

This chapter describes the different windows of the User Interface:

◇ Section 3.1 "General" describes the general windows
◇ Section 3.2 "Input" describes the input windows
◇ Section 3.3 "Validation and Calculation" describes how to perform a calculation
◇ Section 3.4 "Results" describes the output windows
◇ Section 3.5 "Charts" describes the output charts

3.1 General

3.1.1 File menu

Besides the familiar Windows options for opening and saving files, the *File* menu contains a number of options specific to D-FLOW SLIDE.

◇ *New*
Select this option to create a new default geometry composed of a channel of 25 m deep and a clay dike of 5 m height.
◇ *Import – From DAM csv Files*
Select this option to import a soil profile, a surface line and its corresponding characteristic points from a set of three DAM csv files.

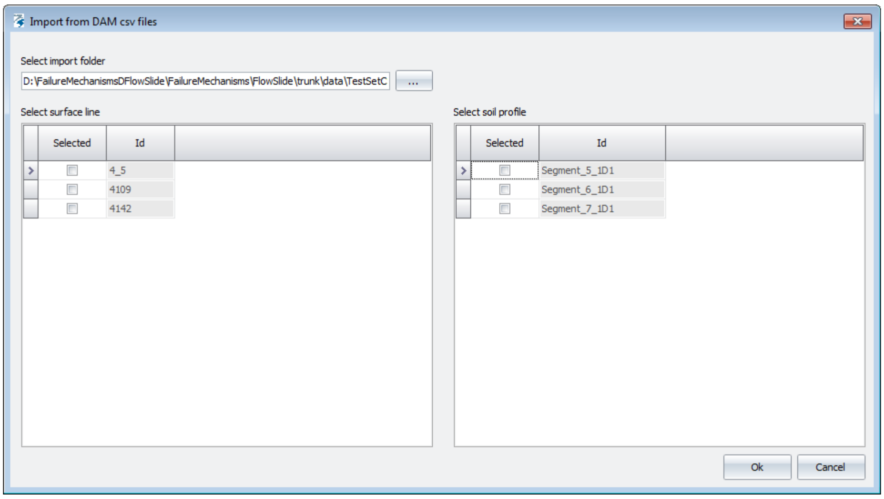


Figure 3.1: *Import from DAM csv files*

3.1.2 Tools menu

On the menu bar, click *Tools* and then choose *Options* to open the corresponding input window. In this window, the user can determine whether a project should be opened or initiated when the program is started.

Last project	Each time D-FLOW SLIDE is started, the last project that has been worked on is opened automatically.
New project	A new project is created with a default geometry, soil profile and characteristic points, as shown in Figure 2.2. **Note:** This option is ignored when the program is started by double-clicking an input file.

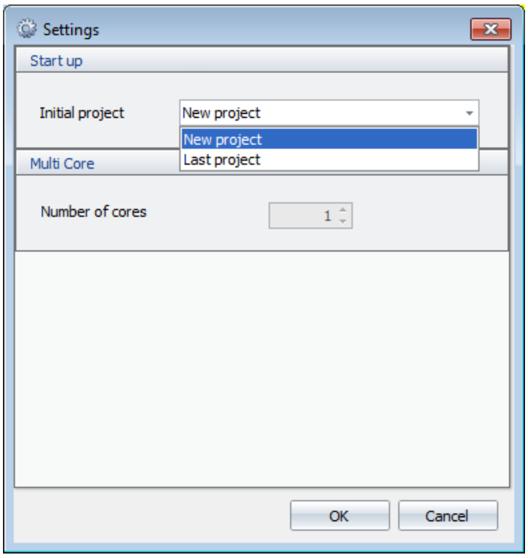


Figure 3.2: *Settings window*

3.1.3 Help menu

Use the *Website* option from the *Help* menu to open the website of D-FLOW SLIDE where all kind of information about D-FLOW SLIDE can be found:

- Background information
- Test Report
- User Manual

Use the *About* option from the *Help* menu to display the *About* window which provides software information (for example the version of the software).

3.2 Input

The menu *Project* contains the input windows for the different assessment methods

3.2.1 Project properties

The *Project properties* option consists of three tabs.

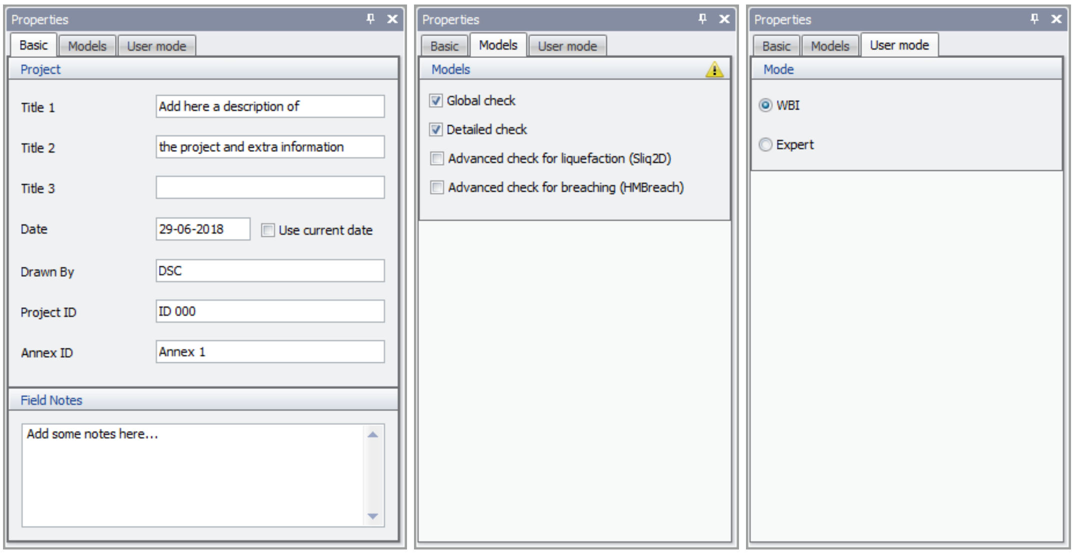


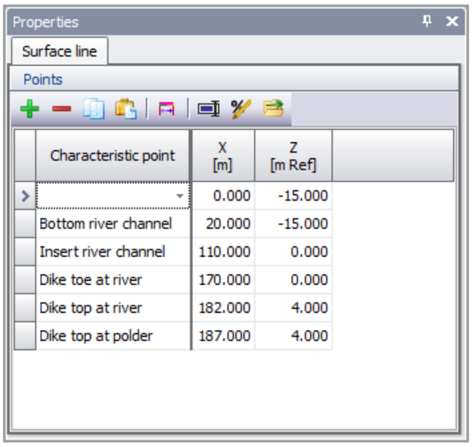
Figure 3.3: *Tabs under Project properties*

Basic	Enter the project titles, the date, the project ID and other information.
Models	Select the assessment model(s) to be used. At least one model is required. Four models are available: ◇ *Global check* ◇ *Detailed check* ◇ *Advanced check for liquefaction (Sliq2D)* ◇ *Advanced check for breaching (HMBreach)* By default the *Global* and *Detailed* assessment models are used and the *Advanced* models are switched off.
User mode	Choose between two modes of calculation: ◇ The *WBI mode* uses the formula prescribed by WBI 2017 ◇ The *Expert mode* allows the user to change the value of some parameters of the Global and Detailed checks (compared to the default calculated value). This *Expert mode* also allows to change all the probabilistic parameters of the Detailed check and all the Advanced parameters for breach flow slide which are fixed values in the *WBI mode*.

3.2.2 Surface line

On the menu bar, click *Project* and then choose *Surface line*. In the *Properties* window at the right side, the corresponding window appears in which the surface line of the project can be defined.

The surface line must have ascending X-value from channel side of the embankment till the dike top at the polder side. The riverside has to be on the left as shown in the figure below.



Properties

Surface line

Points

	Characteristic point	X [m]	Z [m Ref]
>		0.000	-15.000
	Bottom river channel	20.000	-15.000
	Insert river channel	110.000	0.000
	Dike toe at river	170.000	0.000
	Dike top at river	182.000	4.000
	Dike top at polder	187.000	4.000

Figure 3.4: *Surface line*

The original surface line as used in DAM or Ringtoets (WTI) contains a whole set of characteristics points. Flow Slide needs a subset.

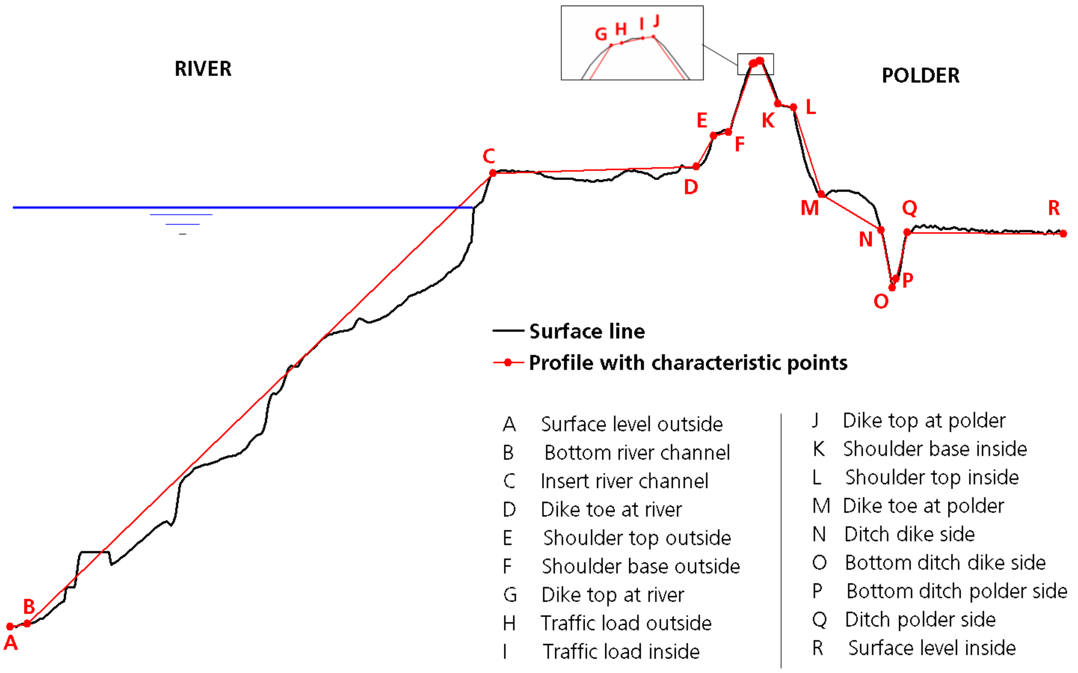


Figure 3.5: *Position of the charateristic points along the surface line*

The following five characteristics points are obligated in D-FLOW SLIDE with increasing x-value.

1 Bottom river channel (B)
2 Insert river channel (C)
3 Dike toe at river (D)
4 Dike top at river (G)
5 Dike top at polder (J)

Besides the five characteristic points, additional points can be of course added to describe the real surface line. Figure 3.6 gives an example of such a surface line. The characteristic points are displayed in large colored points in the *Cross Section* window compare to the other additional points.

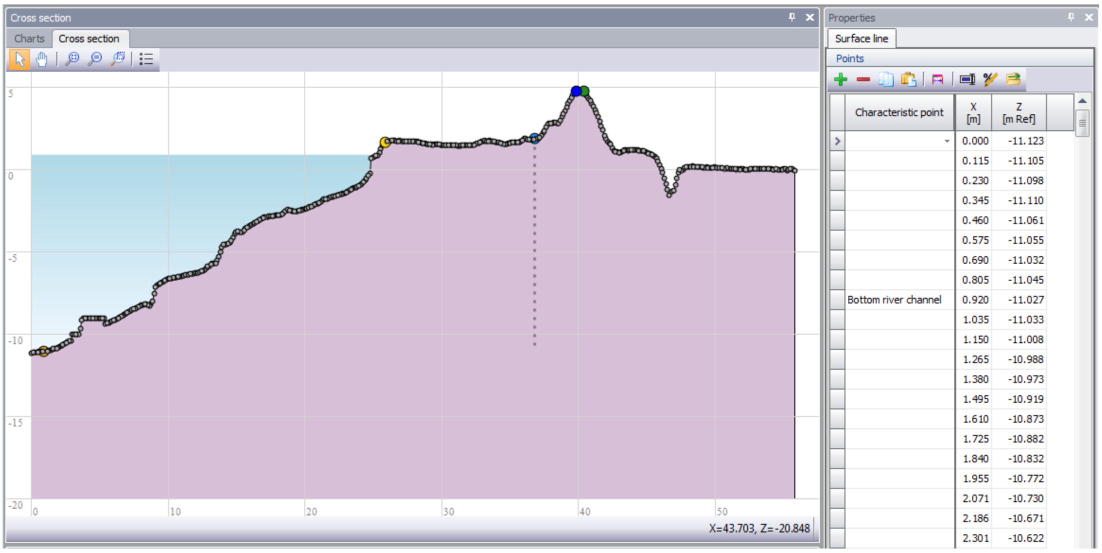


Figure 3.6: *Surface line containing many points*

By clicking on the table header X (length) of Z (height level), you can only filter the points, but not order them.

The program checks on a malformed surface. Messages will be displayed in the "Validation messages" window.

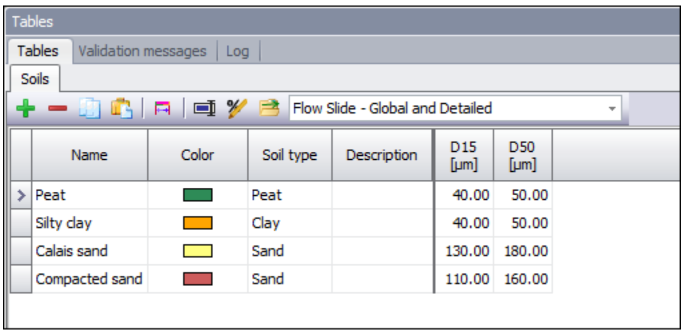
Importing surface line from DAM csv files

It is possible to import a soil profile and a surface line with characteristic points from DAN csv files. For more information, refer to Figure 3.1.

3.2.3 Soils table

The *Soils* table for the *Global* and *Detailed* assessment method (check the filter at the *Soils* tab).
The user can add or remove rows to the soil table or change the properties of the parameters per layer.

Soil parameters for the Global and Detailed assessment method

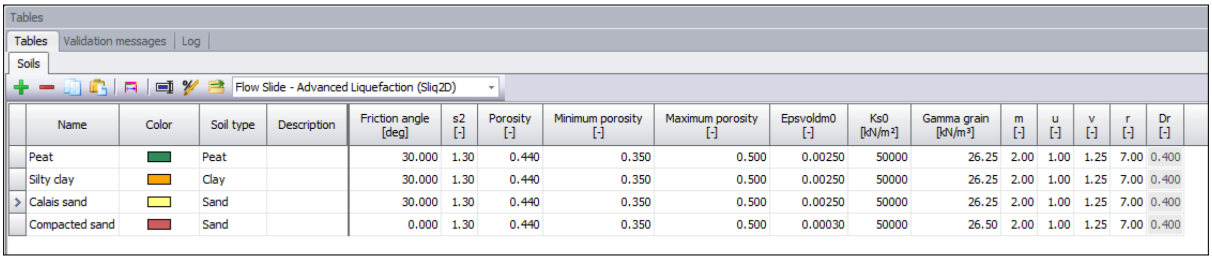


Name	Color	Soil type	Description	D15 [μm]	D50 [μm]
Peat		Peat		40.00	50.00
Silty clay		Clay		40.00	50.00
Calais sand		Sand		130.00	180.00
Compacted sand		Sand		110.00	160.00

Figure 3.7: *Soils tab under Tables window for Global and Detailed assessment methods*

Soil parameters for the Advanced Liquefaction assessment method

Extra parameters has to be specified in the Soil table for the Advanced Liquefaction (Sliq2D). Set the filter in the soil table on *Advanced Liquefaction*.

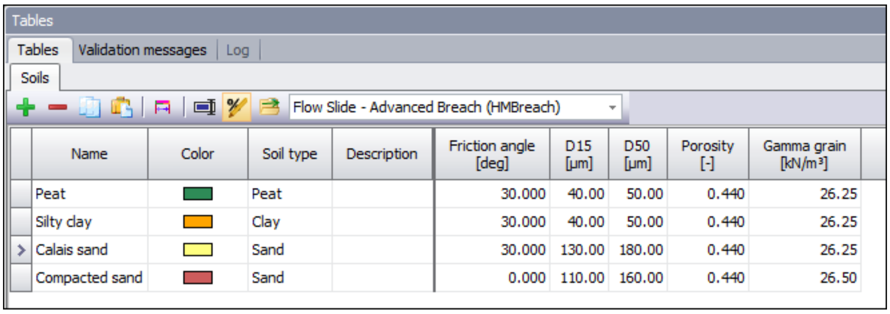


Name	Color	Soil type	Description	Friction angle [deg]	s2 [-]	Porosity [-]	Minimum porosity [-]	Maximum porosity [-]	Epsvoldm0 [-]	Ks0 [kN/m²]	Gamma grain [kN/m³]	m [-]	u [-]	v [-]	r [-]	Dr [-]
Peat		Peat		30.000	1.30	0.440	0.350	0.500	0.00250	50000	26.25	2.00	1.00	1.25	7.00	0.400
Silty clay		Clay		30.000	1.30	0.440	0.350	0.500	0.00250	50000	26.25	2.00	1.00	1.25	7.00	0.400
Calais sand		Sand		30.000	1.30	0.440	0.350	0.500	0.00250	50000	26.25	2.00	1.00	1.25	7.00	0.400
Compacted sand		Sand		0.000	1.30	0.440	0.350	0.500	0.00030	50000	26.50	2.00	1.00	1.25	7.00	0.400

Figure 3.8: *Soils tab under Tables window for Advance Liquefaction assessment method*

Soil parameters for the Advanced Breach assessment method

Also for Advanced Breaching (HMBreach), add extra parameters in the *Soils* table has to be defined.
Set the filter in the soil table on *Advanced Breaching*.



Name	Color	Soil type	Description	Friction angle [deg]	D15 [µm]	D50 [µm]	Porosity [-]	Gamma grain [kN/m³]
Peat		Peat		30.000	40.00	50.00	0.440	26.25
Silty clay		Clay		30.000	40.00	50.00	0.440	26.25
Calais sand		Sand		30.000	130.00	180.00	0.440	26.25
Compacted sand		Sand		0.000	110.00	160.00	0.440	26.50

Figure 3.9: *Soils tab under Tables window for Advanced Breach assessment methods*

Table 3.3: *Definition of the soil parameters*

Name	Dutch name	Description	Symbol	Unit	*Default (range)*	Model
Name	Naam	Material name				All
Color	Kleur	Material color				All
Soil type	Grondtype	Soil type is used to determine if the material is sensitive to liquefaction				All
Description	Beschrijving	A short description of the material can be given				All
Fine diameter D15	Fijne diameter D15	Grain size: (D15 <D50)	D15	μm	0.0 (30-2000)	Global/HMBreach
Median diameter D50	Gemiddelde diameter D50	Median grain size (D50 > D15)	D50	μm	0.0 (30-2000)	Global, Detailed, HMBreach
Friction angle	Hoek van inwendige wrijving	Angle of internal friction	φ	grad	0.0 (0-89)	HMBreach/Sliq2D
Porosity	Porositeit	Porosity, note: $n_{\min} < n < n_{\max}$	n	–	0 (0.30-0.60)	HMBreach/Sliq2D
Minimum porosity	Minimale porositeit	Minimum porosity, $n_{\min} < n_{\max}$	$n_{\min}$	–	0.00 (0.30-0.60)	HMBreach/Sliq2D
Maximum porosity	Maximale porositeit	Maximum porosity, $n_{\min} < n_{\max}$	$n_{\max}$	–	0.00 (0.30-0.60)	HMBreach/Sliq2D
Evoldm0	Evoldm0	Value of $\epsilon_{vol;dm}$ at mean effective stress p0.	$\epsilon_{\text{vol;dm0}}$	–	0.00 (0.0003-0.03)	Sliq2D
Ks0	Ks0	Value of Ks at average stress p0’	Ks0	kN/m2	50000 (10000-140000)	Sliq2D
s2	s2	Value of s at maximum contraction	s_2	–	1.30 (1.1-1.4)	Sliq2D
Gamma grains	Volume gewicht van korrels	Unit weight of grains	γ_{sand}	kN/m3	26.50 (20-30)	HMBreach/Sliq2D
m	m	Parameter describing f(s), defined in equation: f(s) = A sm – B sr / (smax – s)	m	–	2.00 (1.5-3.0)	Sliq2D
u	u	Parameter describing the influence of p’ on Ks defined in equation: Ks = Ks0 (p’ / p0’)u	u	–	1.00 (0.5-1.5)	Sliq2D
v	v	Parameter describing the influence of p’CON on ϵ_{voldm}, defined in equation: $\epsilon_{vol;dm} = \epsilon_{vol;dm0}(pCON'/p0')v$	v	–	1.25 (0.5-1.5)	Sliq2D
r	r	Parameter describing f(s), defined in equation: f(s) = A sm – B sr / (smax – s)	r	–	7.0 Fixed value	Sliq2D

3.2.4 Soil profile

Create the *Soil profile* by selecting soil layers and defining the top or bottom levels of each layer.

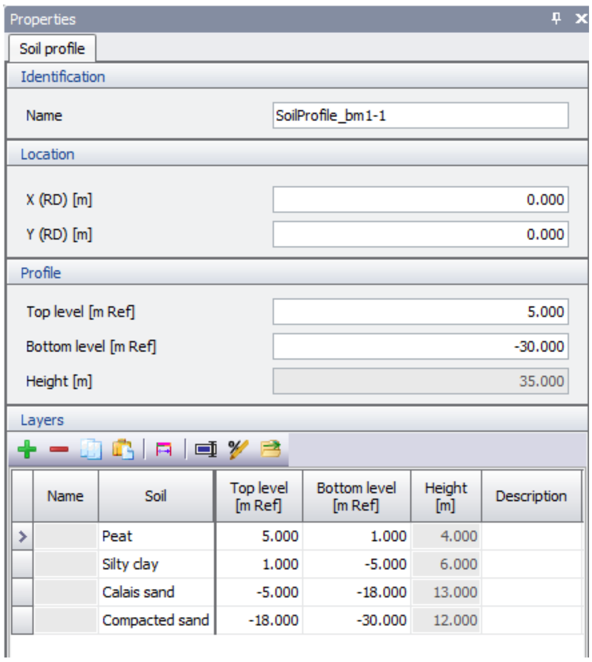


Figure 3.10: *Soil profile*

RD-coordinates X and Y are defined to specify the position of the embankment in global coordinates. D-FLOW SLIDE doesn't need or use these coordinates.
The other parameters speak for themselves.

3.2.5 Additional parameters

3.2.5.1 General parameters

On the menu bar, click *Project* and then choose *Additional parameters*. In the *Properties* window at the right side, select the tab *General parameters* to input the general parameters of the project about *Water*, *Revetment*, *Foreland*, *Soil* and *Influence zone*.

Depending on the selected mode in *User mode* tab (section 3.2.1), the content of the *General parameters* window will be different as shown in Figure 3.11.
If the *Expert mode* was selected, two extra parameters used for step 1a of the Global assessment method can be modified compare to the *WBI mode*:

- the channel depth H
- the assessment level

In Expert mode, the user can still choose to use the values automatically calculated by the WBI mode by not marking the *User defined* checkbox. A Global check in *Expert mode* with both checkbox unmarked is therefore equivalent to a Global check in *WBI mode*.

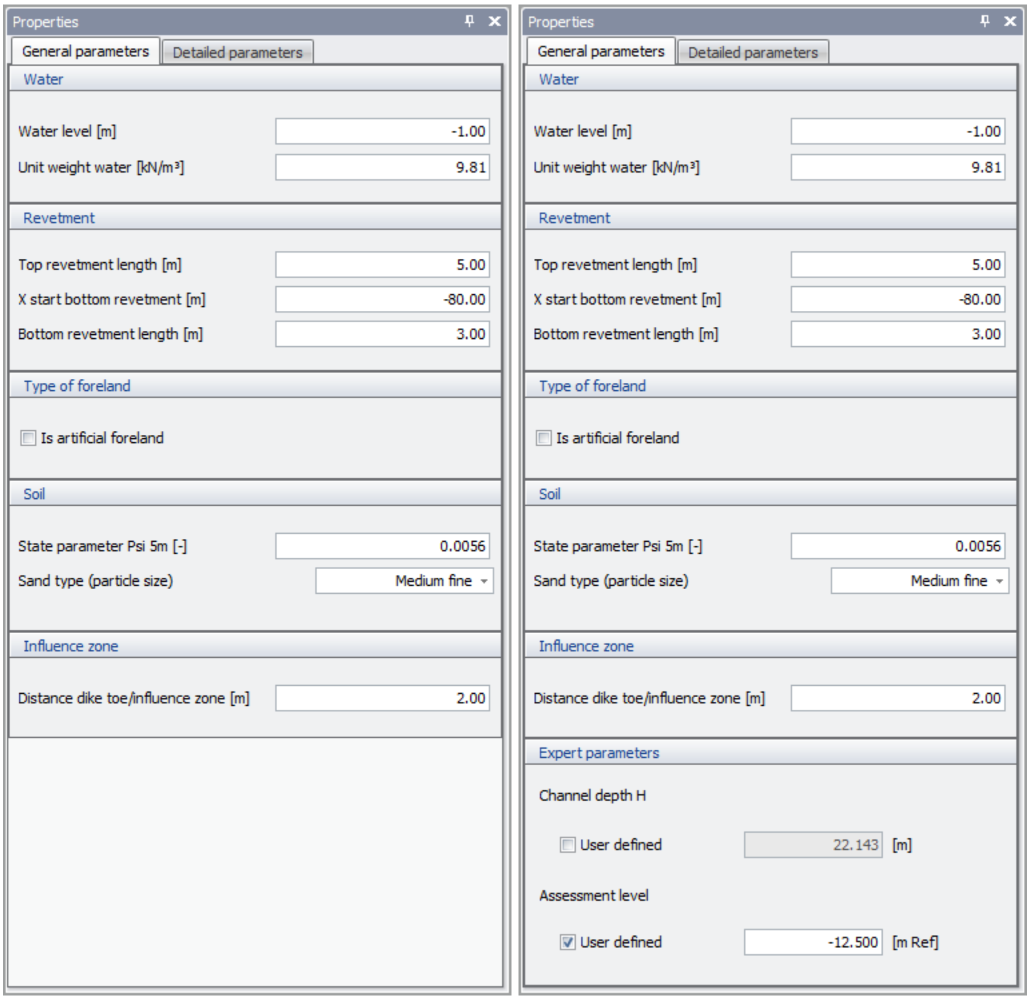


Figure 3.11: *General parameters for WBI mode (left) and Expert mode (right)*

The table below gives a definition of all the parameters and indicates in which model they are used.

Name	Dutch name	Description	Symbol	Unit	Default (range)	Method
Water:						
Water level	Niveau water	The water level.	Z_{water}	m	0.00	Detailed, HM-Breach, Sliq2D
Unit weight water	Soortelijk gewicht water	The unit weight of water.	γ_{w}	kN/m^3	9.81 (5-15)	HMBreach, Sliq2D
Revetment (see Figure 3.12):						
Revetment length dike top	Bekledingslengte vanaf buitenteen dijk	Horizontal projection of the length of the revetment, starting at dike toe at river side.	M_{bestort}	m	0.00 (0-10000)	Global
RX start bottom revetment	RX start vanaf geulbodem, onderste gedeelte van vooroever	Start co-ordinate of the revetment at the bottom of the channel.	$X_{\text{bestort;onder}}$	m	0.00 (-10000-10000)	Global, Detailed
Bottom revetment length	Bekledingslengte onderste gedeelte van vooroever	Horizontal projection of the length of the revetment at the bottom of the channel.	$M_{\text{bestort;onder}}$	m	0.00 (0-10000)	Global, Detailed
Foreland:						
Artificial and non-densified sandy foreland?	Is er sprake van een kunstmatig onder water aangebrachte en niet verdichte zandige of siltige vooroever?	In case of non-natural deposited slopes, both Global and Detailed checks FAIL and it should immediately be switched to the advanced methods.			No	Global
Soil:						
State parameter Psi 5m	State parameter Psi 5m	Parameter describes the state of the soil and is used in the Detailed check.	ψ_{5m}	–	0.0000 (-10-10)	Detailed

Sand type (particle size)	Zand type (korrelgrootte)	Parameter describes the type of sand and is used in the Global check (breach flow criteria is step 1e). Three types of sand are considered: – very fine sand: $D_{50} \leq$ 200 μm and $D_{15} \leq$ 100 μm – medium fine sand: 200 $< D_{50} \leq$ 500 μm and 100 $< D_{15} \leq$ 250 μm – coarse sand and gravel: $D_{50} >$ 500 μm and $D_{15} >$ 250 μm			Fine sand	Global
Distance dike toe/influence zone:						
Distance dike toe / influence boundary	Afstand buiten dijk / invloedslijn	Parameter describes the distance between the dike toe and the boundary of influence zone. It must always be less than the foreland length.		m	0.00 (0-foreland length)	Global, Detailed
Expert parameters:						
Channel depth	Geuldiepte	The channel depth H used in step 1a of the Global assessment method which check if the geometric form of the channel can lead to flow slide damaging for the levee.	H	m	0.00 (0.001-1000)	Global
Assessment level	Beoordelingsniveau	The assessment level used in step 1a of the Global assessment method which check if the geometric form of the channel can lead to flow slide damaging for the levee.	Z_{assess}	m	0.00 (0.001-1000)	Global

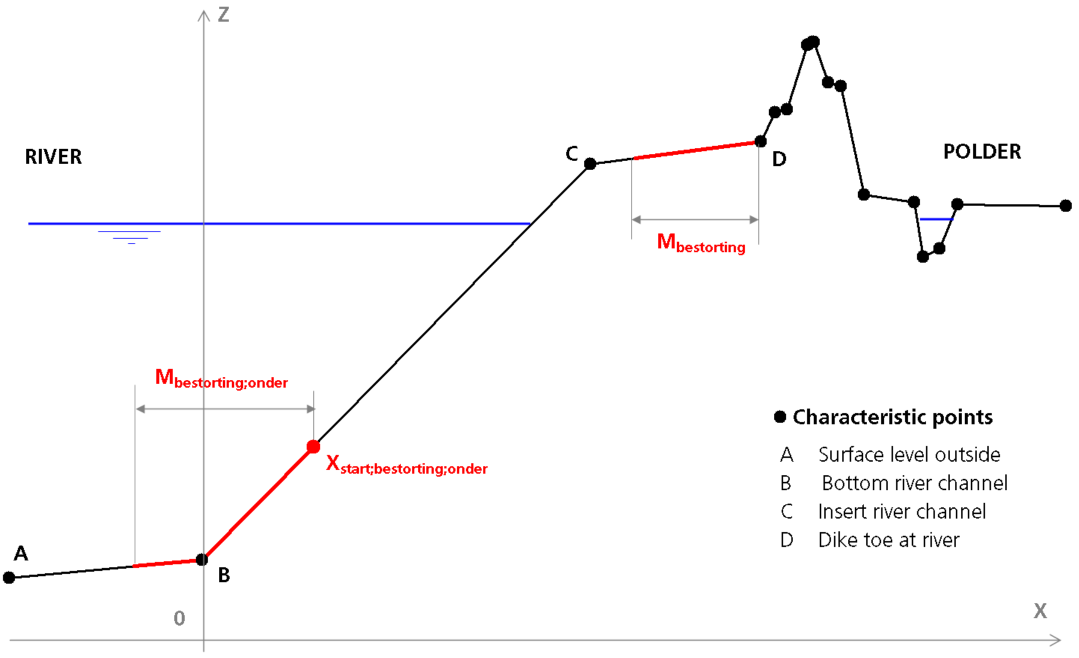


Figure 3.12: *Definition of the revetment parameters*

3.2.5.2 Detailed parameters

On the menu bar, click *Project* and then choose *Additional parameters*. In the *Properties* window at the right side, select the tab *Detailed parameters* to input the parameters for the *Detailed* assessment method.

This tab is visible only if the *Detailed check* was marked in the *Models* tab (section 3.2.1).

Depending on the selected mode in *User mode* tab (section 3.2.1), the content of the *General parameters* window will be different as shown in Figure 3.11.
If the *Expert mode* was selected, four extra parameters can be modified compare to the *WBI mode*:

◇ the channel depth H used for the calculation of the retrogression length
◇ the fictive channel height for liquefaction
◇ the fictive channel height for breaching
◇ the contribution of liquefaction

In Expert mode, the user can still choose to use the values automatically calculated by the WBI mode by not marking the *User defined* checkbox. A Detailed check in *Expert mode* with the four checkbox unmarked and using the default probabilistic parameters is therefore equivalent to a Detailed check in *WBI mode*.

D-FLOW SLIDE applies a stochastic distribution for the four following parameters used for the calculation of the retrogression length L of the damage profile (see also Figure 3.14):

◇ Ratio between the height of the upper steep part (D) and the channel height (H)
◇ The slope of the lower part (cotan γ)
◇ The slope of the upper part (cotan β)
◇ The area ratio (c = Area2 / Area1)

When using the *WBI* mode, these four probabilistic parameters are fixed, only the *Mean* value of the *Area ratio* can be modified, whereas when using the *Expert* mode, all the probabilistic parameters can be modified.

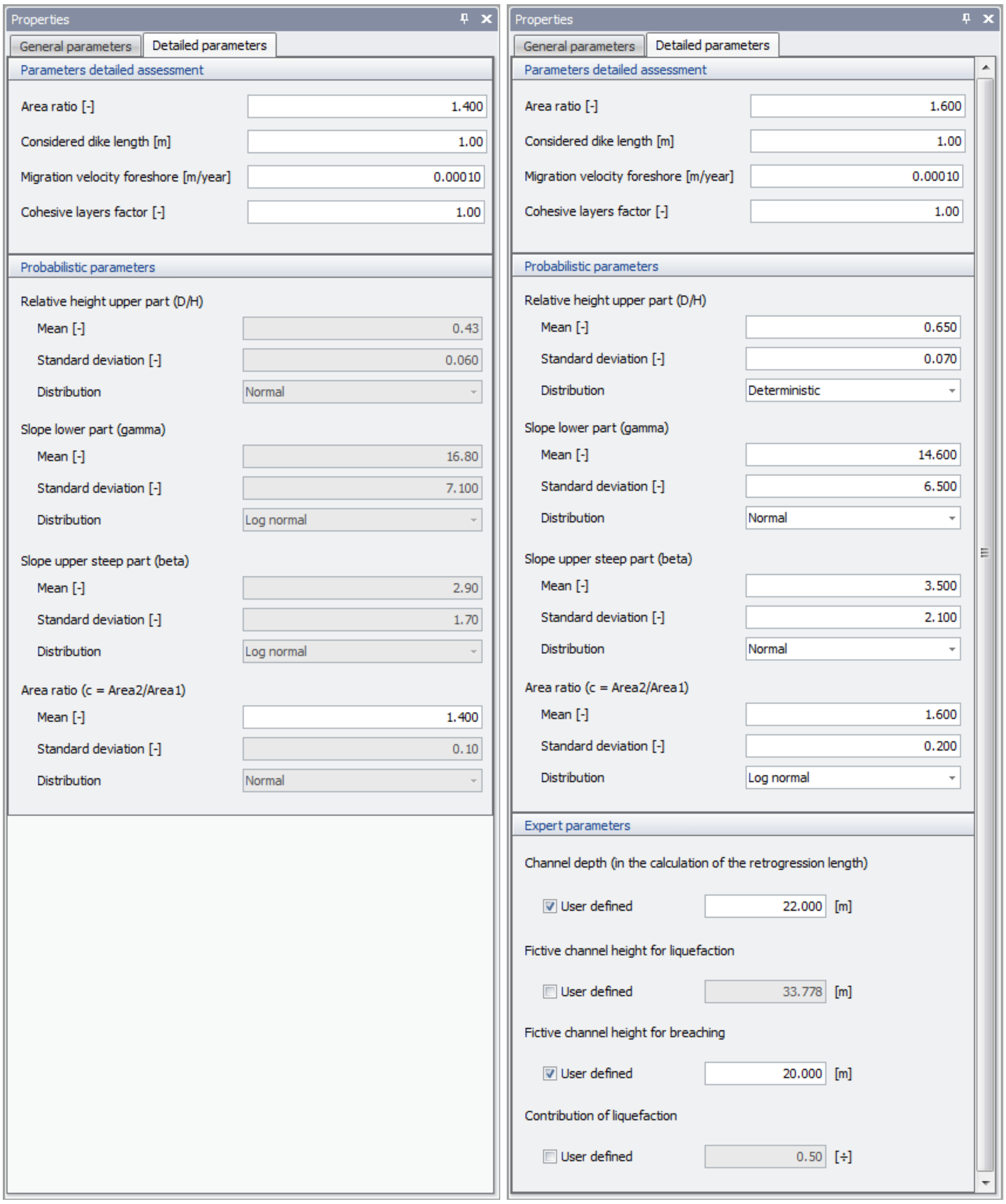


Figure 3.13: *Detailed parameters for WBI mode (left) and Expert mode (right)*

Note: Since version 16.1, the *Allowable probability of failure* is no longer an input parameter. Consequently, no decision can be made whether or not the method meets its failure criteria.

The table below gives a definition of all the parameters.

Name	Dutch name	Description	Symbol	Unit	Default + (range)
Area ratio	Gebiedsratio	Mean value of the area ratio c = Area2 / Area1 where Area1 adn Area2 are the are of the upper and lower parts respectively.	c	–	1.40 (1-5)
Considered dike length	Beschouwde dijk lengte	Length of the dike section	$L_{\text{trajectlengte}}$	m	0.00 (1-10000)
Migration velocity	Migratie snelheid vooroever	Migration velocity of the foreland	V_{mig}	m/year	0.00000 (0.0001-100)
Cohesive layers factor	Cohesieve lagen factor	Factor which evaluates the presence of cohesive layers or peat layers within the sand body. Cohesive and peat layers start to play a role if their (individual) thickness is larger than 0,5 m (CUR113, 2008). If their thickness exceeds 5 m it can be assumed in most situations the breach will be stopped. The following values are proposed: – Virtually no cohesive and/or peat layers (thickness cohesive layers < 0.5 m), then $F_{\text{cohesive layers}}$ = 1/3 – Small number of cohesive and/or peat layers (0.5 m < thickness cohesive layers < 5 m), then $F_{\text{cohesive layers}}$ = 1 – Large number of cohesive and/or peat layers(thickness cohesive layers > 5 m), then $F_{\text{cohesive layers}}$ = 3	$F_{\text{cohesive layers}}$	–	1.00 (0-100)
Relative height upper part	Relatieve hoogte bovenste deel	Ratio between the height of the upper steep part (D) and the channel height (H).	D/H		
Mean	Gemiddelde			–	0.43 (fixed value)
Standard deviation	Standaard afwijking			–	0.060 (fixed value)
Distribution	Verspreiding				Normal (fixed)
Slope lower part	Helling laagste deel	The slope of the lower part.	cotan γ		

Mean	Gemiddelde			–	16.80 (fixed value)
Standard deviation	Standaard afwijking			–	7.100 (fixed value)
Distribution	Verspreiding				Log normal (fixed)
Slope upper steep part	Helling bovenste steile deel	The slope of the upper steep part.	cotan β		
Mean	Gemiddelde			–	2.90 (fixed value)
Standard deviation	Standaard afwijking			–	7.70 (fixed value)
Distribution	Verspreiding				Log normal (fixed)
Area ratio	Gebiedsratio	The area ratio: c = Area2 / Area1	c		
Mean	Gemiddelde			–	1.40 (1-5)
Standard deviation	Standaard afwijking			–	0.10 (fixed value)
Distribution	Verspreiding				Normal (fixed)

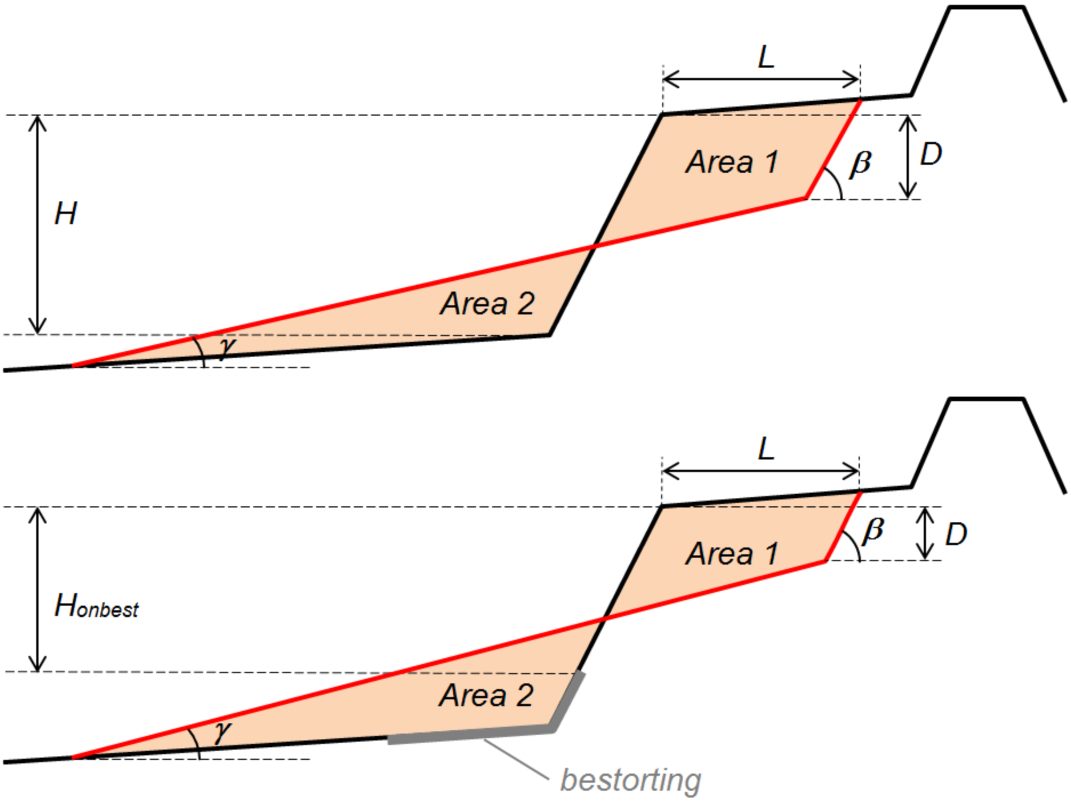


Figure 3.14: *Definition of parameters D, H, β, γ, Area 1 and Area 2 for the probabilistic calculation of the retrogression length L*

3.2.5.3 Advanced parameters liquefaction flow slide (Sliq2D)

On the menu bar, click *Project* and then choose *Additional parameters*. In the *Properties* window at the right side, select the tab *Advanced parameters liquefaction flow slide (Sliq2D)* to input the parameters needed for the *Advanced Liquefaction* assessment method.

This tab is visible only if the *Advanced check for liquefaction (Sliq2D)* was marked in the *Models* tab (section 3.2.1).

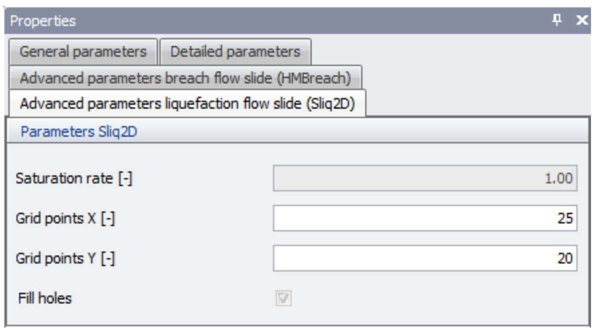


Figure 3.15: *Advanced parameters liquefaction flow slide (Sliq2D)*

The table below gives a definition of all the parameters.

Name	Dutch name	Description	Symbol	Unit	Default (range)
Saturation rate	Verzadigings graad	Degree of saturation	Sr	–	1 (fixed value)
Grid points X	Aantal rasterpunten X	Number of points in the grid in the X direction		–	20 (2-100)
Grid points Y	Aantal rasterpunten Y	Number of points in the grid in the Y direction		–	20 (2-100)
Fill holes	Vul gaten	If true, D-FLOW SLIDE considers the stable points surrounded with unstable points as unstable.		True (fixed value)	

3.2.5.4 Advanced parameters breach flow slide (HMBreach)

On the menu bar, click *Project* and then choose *Additional parameters*. In the *Properties* window at the right side, select the tab *Advanced parameters breach flow slide (HMBreach)* to input the parameters for the *Advanced breach flow* assessment method.

This tab is visible only if the *Advanced breach flow check* was marked in the *Models* tab (section 3.2.1).

Depending on the selected mode in *User mode* tab (section 3.2.1), the content of the *Advanced parameters breach flow slide (HMBreach)* window will be different as shown in Figure 3.16.
When using the *WBI* mode, many parameters are fixed, whereas when using the *Expert* mode, all the parameters can be modified.

The table below gives a definition of all the parameters.

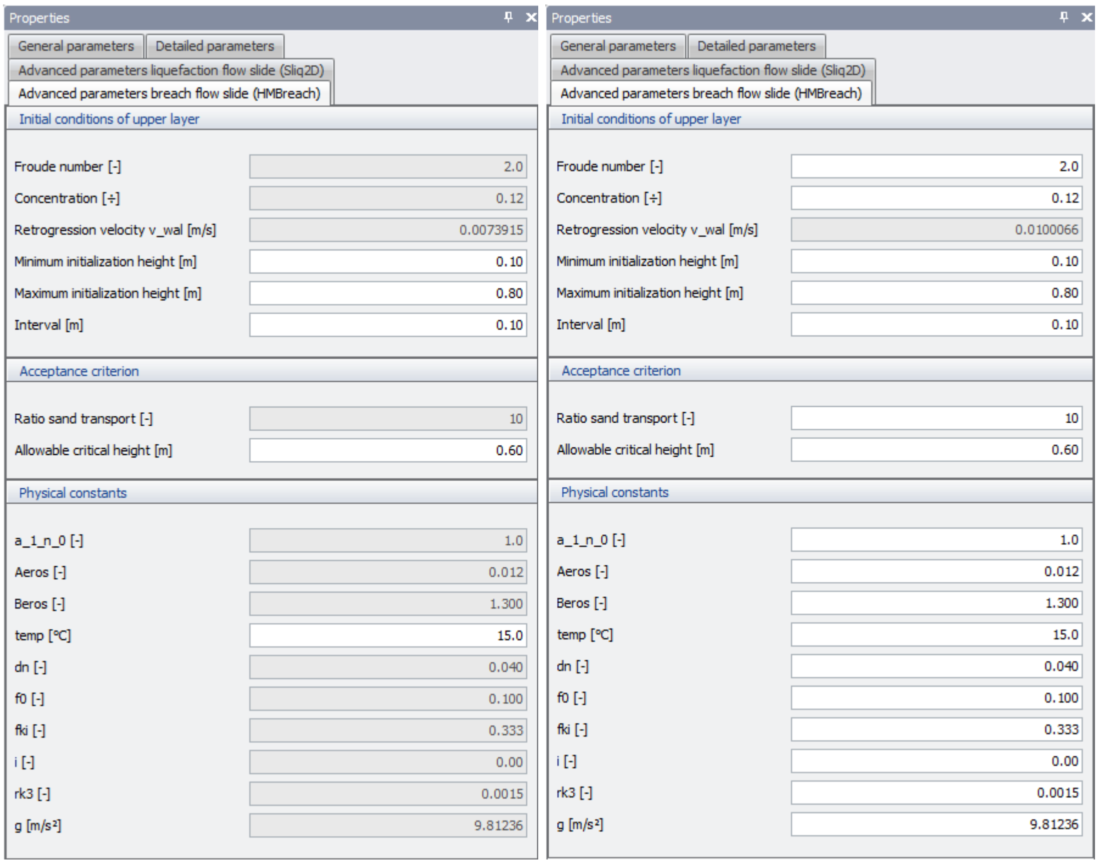


Figure 3.16: *Advanced parameters breach flow slide (HMBreach) for WBI mode (left) and Expert mode (right)*

Name	Dutch name	Description	Symbol	Unit	Default (range)
Initial conditions of upper layer:					
Froude number	Froude getal	The Froude number.	F	–	2 (1.1-4)
Concentration	Concentratie	The concentration.	C	%	12 (10-40)
Retrogression velocity	Walsnelheid	(This is not an input but an output value only available after a calculation) The calculated retrogression velocity.	v_{wal}	m/s	
Minimum initialization height	Minimale initiele hoogte	The minimum initialization height.		m	0.1 (0.1-5.0)
Maximum initialization height	Maximale initiele hoogte	The maximum initialization height.		m	2.5 (0.1-5.0)
Interval	Interval	The interval.		m	0.01 (0.1-1.0)
Approval criterion:					
Ratio sand transport	Verhouding zandtransport	Ratio between the sand transport at the toe and the sand transport at the top of a sand cluster, indicating if the considered initialization height is sufficient to produce a breach flow slide, characterized by a strongly increasing sand transport rate along the slope. The minimal initialization height for which this is the case is defined as the critical height.	RatioZV	–	10 (1-100)
Allowable critical height	Toelaatbare kritische beginhoogte	If the critical initialization height is higher than the allowable critical height, the slope is safe. If not, it means that the probability that a breach flow slide will occur is high.	$h_{\text{allowable}}$	m	1.0 ($-\infty$/$+\infty$)
Physical constants:					
a_1_n0	a_1_n0	Constant in erosion formula.		–	1.0 (0.5-1.5)
Aeros	Aeros	Constant in erosion formula.	A	–	0.012 (0.01-0.03)
Beros	Beros	Constant in erosion formula.	B	–	1.3 (1-2)
temp	temp	Water temperature. Defines viscosity, fall velocity and permeability.	T	°C	15.0 (0.0-30.0)
dn	dn	Porosity increase during dilatancy.	d_n	–	0.04 (0.02-0.10)
f0	f0	Darcy-Weisbach bed friction coefficient.	f_0	–	0.10 (0.01-0.15)
fki	fki	Ratio of bed to internal friction.	f_{ki}	–	0.333 (0.1-0.5)

i	i	Hydraulic gradient.	i	–	0 (0-1)
rk3	rk3	Constant in entrainment model.	rk_3	–	0.0015 (0.001-0.002)
g	g	The acceleration gravity.	g	m/s^2	9.81236 (9.7-10)

3.3 Validation and Calculation

When all parameters have been specified, start the calculation by using the blue arrow-head in the menu bar or press the key F9.

If one of the parameters is out of range or missing, a validation message will be given in the table window *Validation messages*.

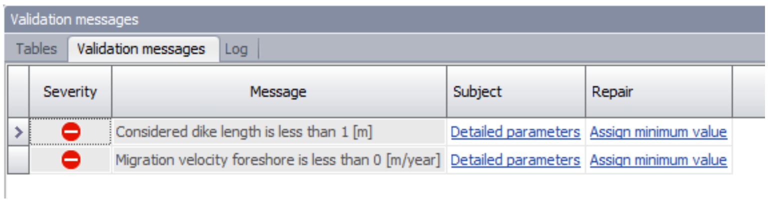


Figure 3.17: *Validation messages*

When no errors are found, the results are available under the *Results* menu.
In this version there is no extended report of the results.

3.4 Results

3.4.1 Overall results

In this case both the Global check fails and Detailed check passes. However, since a very fine sand was selected, the detailed check is formally not applicable. For this reason **the overall result gives a warning**.

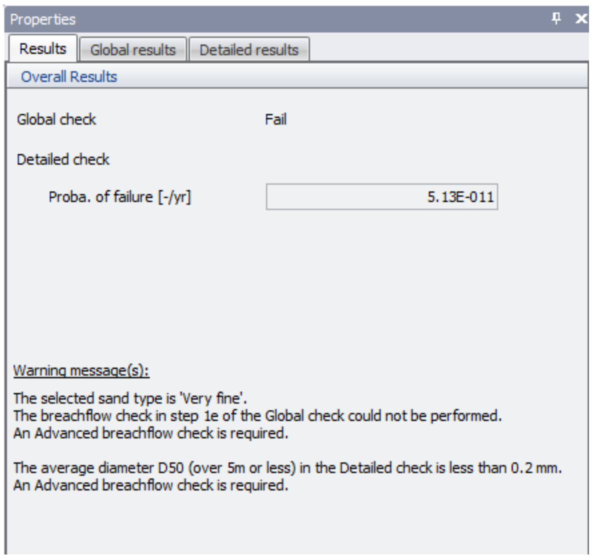


Figure 3.18: *Overall results*

3.4.2 Global results

Use the tab Global results to see the results.
The method itself is described in details in the Background section on the website.

Figure 3.19: *Global results*

3.4.3 Detailed results

Use the tab Detailed results to see the results. The Detailed check is described in detail in the Background section on the website.

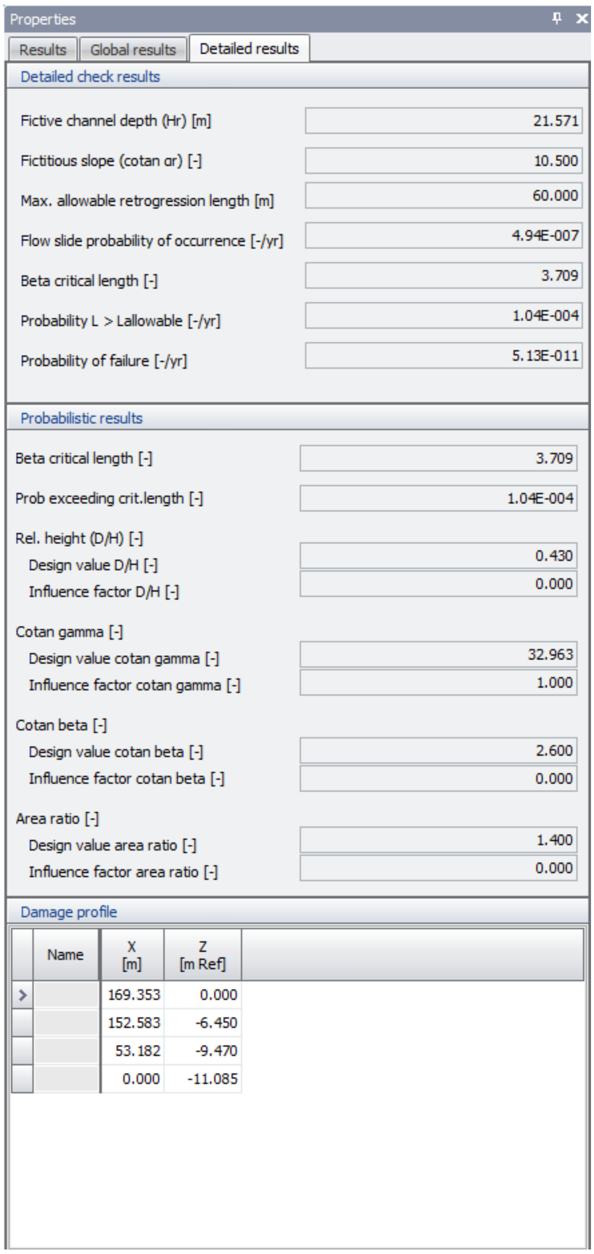
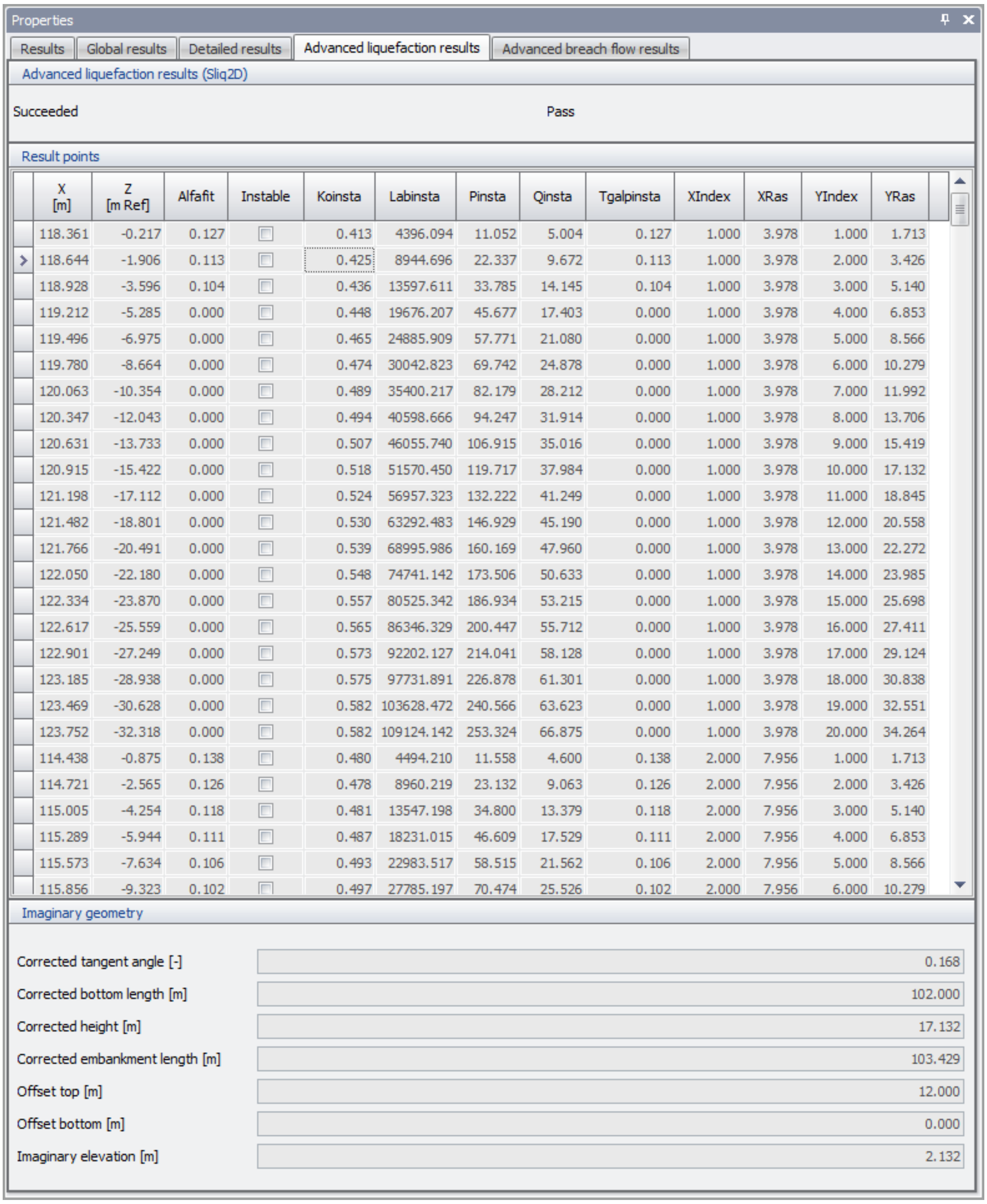


Figure 3.20: *Detailed results*

3.4.4 Advanced liquefaction results

On the menu bar, click *Results* and then choose *Advanced Liquefaction (Sliq2D)* to view the results of the Advanced Liquefaction check. This option is available only if the *Advanced check for liquefaction (Sliq2D)* was marked in the *Models* tab (section 3.2.1).



X [m]	Z [m Ref]	Alfafit	Instable	Koinsta	Labinsta	Pinsta	Qinsta	Tgalpinsta	XIndex	XRas	YIndex	YRas
118.361	-0.217	0.127		0.413	4396.094	11.052	5.004	0.127	1.000	3.978	1.000	1.713
118.644	-1.906	0.113		0.425	8944.696	22.337	9.672	0.113	1.000	3.978	2.000	3.426
118.928	-3.596	0.104		0.436	13597.611	33.785	14.145	0.104	1.000	3.978	3.000	5.140
119.212	-5.285	0.000		0.448	19676.207	45.677	17.403	0.000	1.000	3.978	4.000	6.853
119.496	-6.975	0.000		0.465	24885.909	57.771	21.080	0.000	1.000	3.978	5.000	8.566
119.780	-8.664	0.000		0.474	30042.823	69.742	24.878	0.000	1.000	3.978	6.000	10.279
120.063	-10.354	0.000		0.489	35400.217	82.179	28.212	0.000	1.000	3.978	7.000	11.992
120.347	-12.043	0.000		0.494	40598.666	94.247	31.914	0.000	1.000	3.978	8.000	13.706
120.631	-13.733	0.000		0.507	46055.740	106.915	35.016	0.000	1.000	3.978	9.000	15.419
120.915	-15.422	0.000		0.518	51570.450	119.717	37.984	0.000	1.000	3.978	10.000	17.132
121.198	-17.112	0.000		0.524	56957.323	132.222	41.249	0.000	1.000	3.978	11.000	18.845
121.482	-18.801	0.000		0.530	63292.483	146.929	45.190	0.000	1.000	3.978	12.000	20.558
121.766	-20.491	0.000		0.539	68995.986	160.169	47.960	0.000	1.000	3.978	13.000	22.272
122.050	-22.180	0.000		0.548	74741.142	173.506	50.633	0.000	1.000	3.978	14.000	23.985
122.334	-23.870	0.000		0.557	80525.342	186.934	53.215	0.000	1.000	3.978	15.000	25.698
122.617	-25.559	0.000		0.565	86346.329	200.447	55.712	0.000	1.000	3.978	16.000	27.411
122.901	-27.249	0.000		0.573	92202.127	214.041	58.128	0.000	1.000	3.978	17.000	29.124
123.185	-28.938	0.000		0.575	97731.891	226.878	61.301	0.000	1.000	3.978	18.000	30.838
123.469	-30.628	0.000		0.582	103628.472	240.566	63.623	0.000	1.000	3.978	19.000	32.551
123.752	-32.318	0.000		0.582	109124.142	253.324	66.875	0.000	1.000	3.978	20.000	34.264
114.438	-0.875	0.138		0.480	4494.210	11.558	4.600	0.138	2.000	7.956	1.000	1.713
114.721	-2.565	0.126		0.478	8960.219	23.132	9.063	0.126	2.000	7.956	2.000	3.426
115.005	-4.254	0.118		0.481	13547.198	34.800	13.379	0.118	2.000	7.956	3.000	5.140
115.289	-5.944	0.111		0.487	18231.015	46.609	17.529	0.111	2.000	7.956	4.000	6.853
115.573	-7.634	0.106		0.493	22983.517	58.515	21.562	0.106	2.000	7.956	5.000	8.566
115.856	-9.323	0.102		0.497	27785.197	70.474	25.526	0.102	2.000	7.956	6.000	10.279

Imaginary geometry

Corrected tangent angle [-]	0.168
Corrected bottom length [m]	102.000
Corrected height [m]	17.132
Corrected embankment length [m]	103.429
Offset top [m]	12.000
Offset bottom [m]	0.000
Imaginary elevation [m]	2.132

Figure 3.21: *Advanced liquefaction results*

To copy the table of results, click on one of the cells, press Ctrl+A to select all the cells and then Ctrl+C to copy them. Then, using Ctrl+V, you can paste the table in an Excel sheet for example.

3.4.5 Advanced breach flow results

On the menu bar, click *Results* and then choose *Advanced Breach Flow Slide (HMBreach)* to view the results of the Advanced breach flow check. This tab is visible only if the *Advanced breach flow check* was marked in the *Models* tab (section 3.2.1).

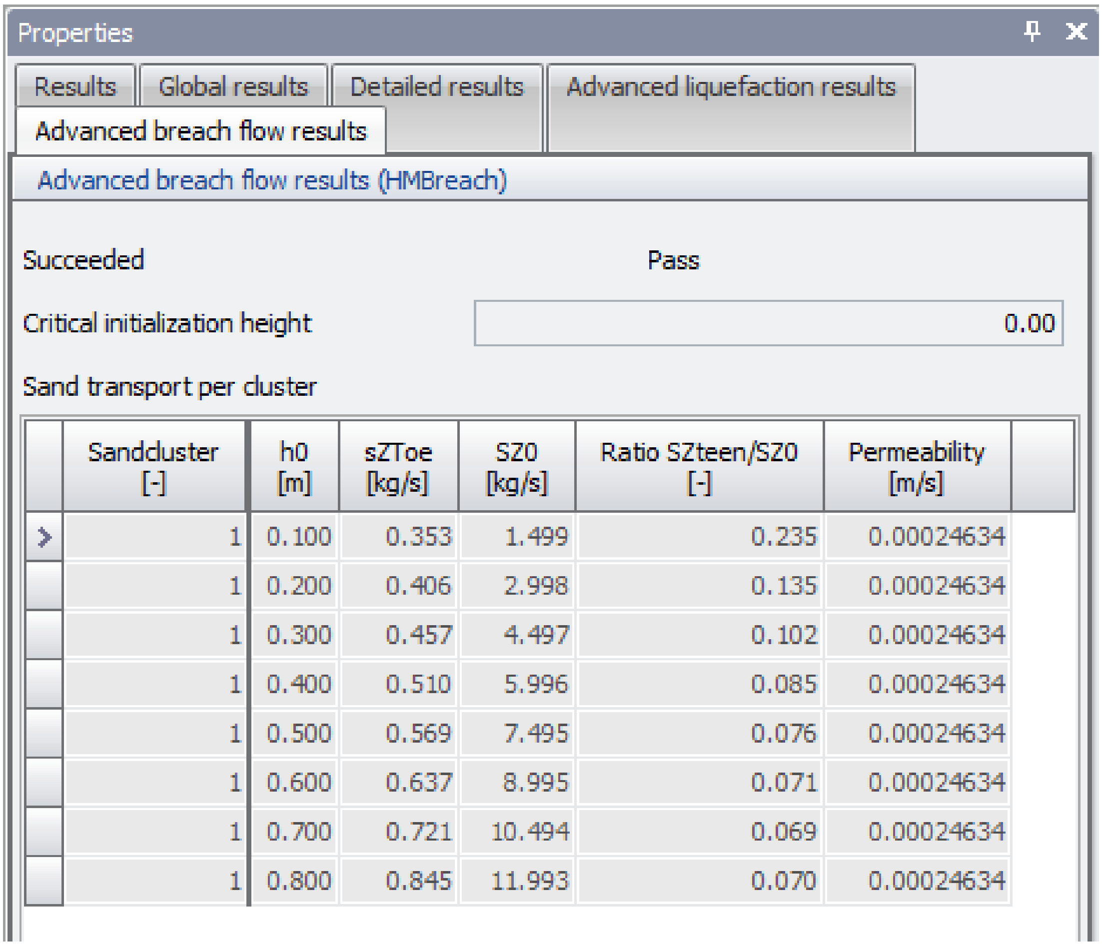


Figure 3.22: *Advanced breach flow results*

To copy the table of results, click on one of the cells, press Ctrl+A to select all the cells and then Ctrl+C to copy them. Then, using Ctrl+V, you can paste the table in an Excel sheet for example.

3.5 Charts

Depending on the selected assessment methods in Project Properties (section 3.2.1), the number of charts displayed in the results will vary: two charts for the Global models and one chart for each other models. Therefore, if only the Global and Detailed models are selected, three charts. If later the Liquefaction or/and Breach flow models are also selected, then four/five charts will be shown.
Figure 3.23 shows the five charts displayed when the four models are selected.

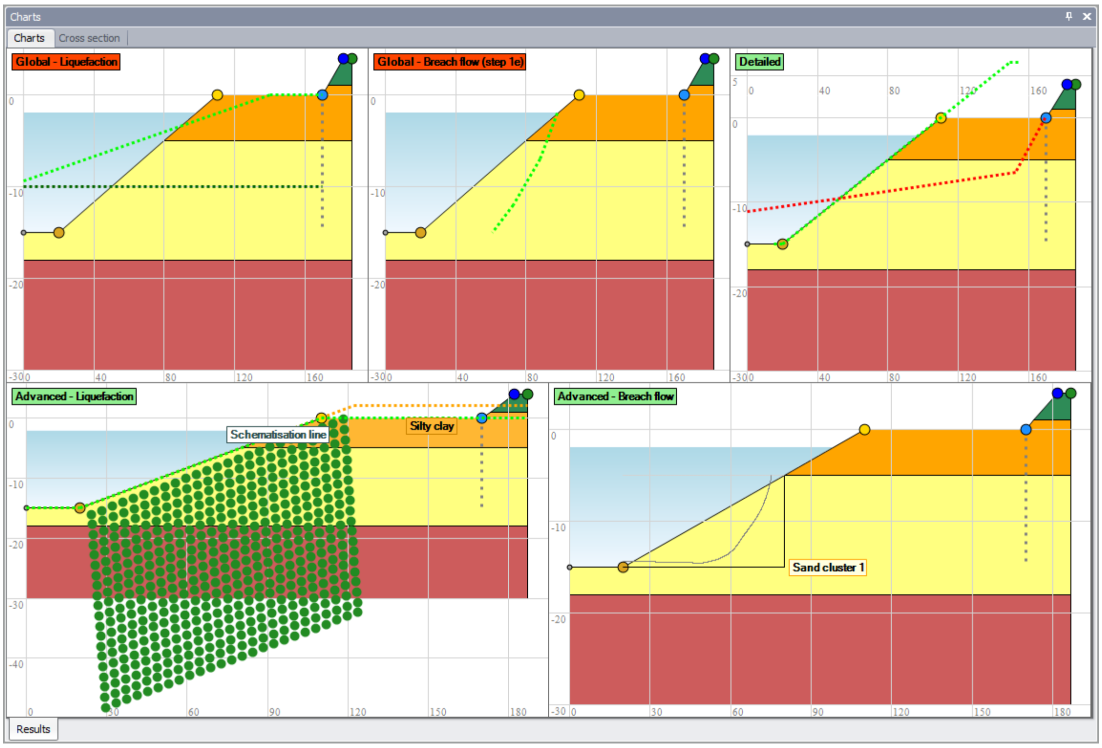


Figure 3.23: *Charts window when the four models are selected*

For each chart, when right-clicking on the mouse, a menu with two options appears (see Figure 3.24 below):

- ◇ Select *Copy* to copy the chart in the clipboard and paste it in an other document
- ◇ Select *Save as ...* to save the chart in different formats (PNG, JPEG, BMP, GIF) and re-use it in an other document

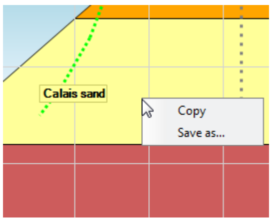


Figure 3.24: *Options menu of the chart*

3.5.1 Charts for Global check

The Global check is exclusively based on geometric characteristics of the under water slope and levee. As a result of the Global calculation, two charts are shown in the *Charts* tab:

◇ The chart "*Global - Liquefaction*" visualizes the check whether a flow slide leads to unacceptable damage to the levee (step 1a).

The dark green horizontal dotted line represents the assessment level;

The light green dotted line represents the observation profile (called "signaleringsprofiel" in Dutch).

Global - Liquefaction On the assessment level, if the actual slope lies landward of the observation profile, this means that a flow slide does lead to unacceptable damage to the levee; the label of the chart is colored in red.

Global - Liquefaction On the assessment level, if the observation profile lies lies landward of the actual slope, this means that a flow slide is not possible; the label of the chart is colored in green.

◇ The chart "*Global - Breach flow (step 1e)*" shows whether a breach flow slide may occur or not at step 1e of the Global assessment.

The light green dotted line represents the critical slope.

Global - Breach flow (step 1e) A breach flow slide can occur if the actual slope lies landward of the green dotted line; the label of the chart is colored in red.

Global - Breach flow (step 1e) A breach flow slide can't occur if the green dotted line lies landward of the actual slope; the label of the chart is colored in green.

Note: In the situation presented in Figure 3.25, the green dotted line lies landward of the actual slope however the label "Global - Breach flow (step 1e)" is red. The reason is that the sand has been indicated to be very fine in the *General parameters* (section 3.2.5.1). In this case, the breach flow check cannot be excluded based on these geometric criteria only and an advanced analysis in HMBreach should be performed.

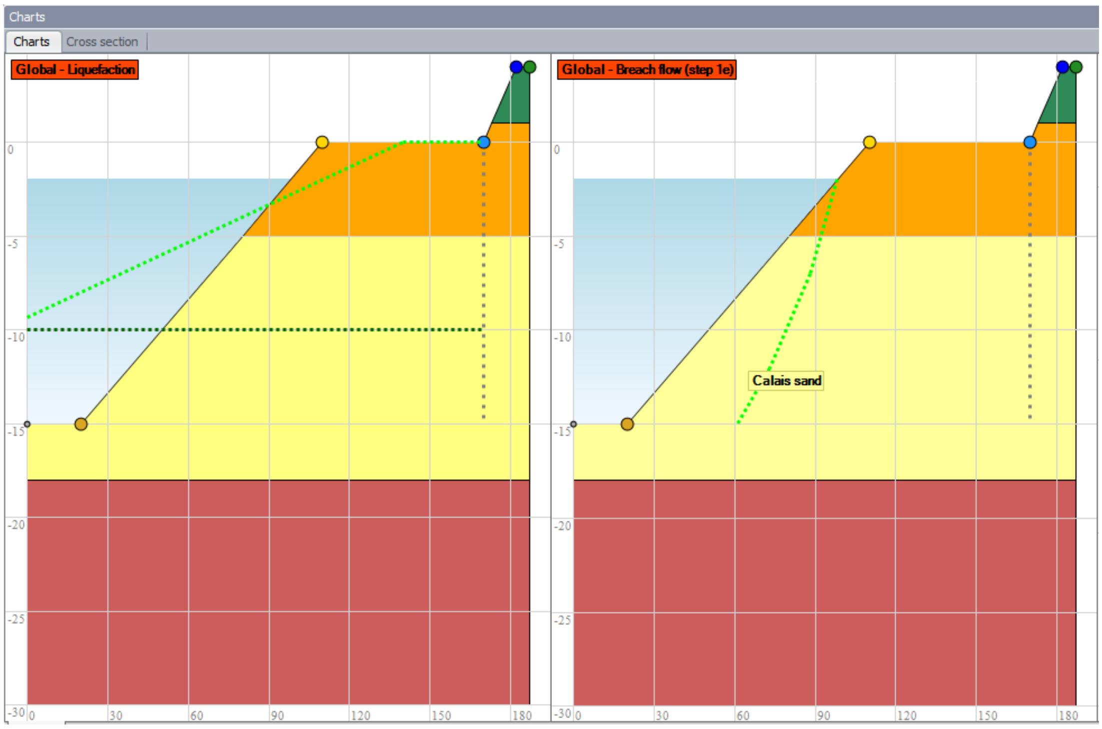


Figure 3.25: *Charts after a Global check*

3.5.2 Chart for Detailed check

As a result of the Detailed calculation, one chart is shown in the *Charts* tab (Figure 3.26).

The light green dotted line represents the fictive profile.

The red dotted line represents the damage profile. The coordinates of the different points of this damage profile can be found in the *Detailed results* tab (section 3.4.3).

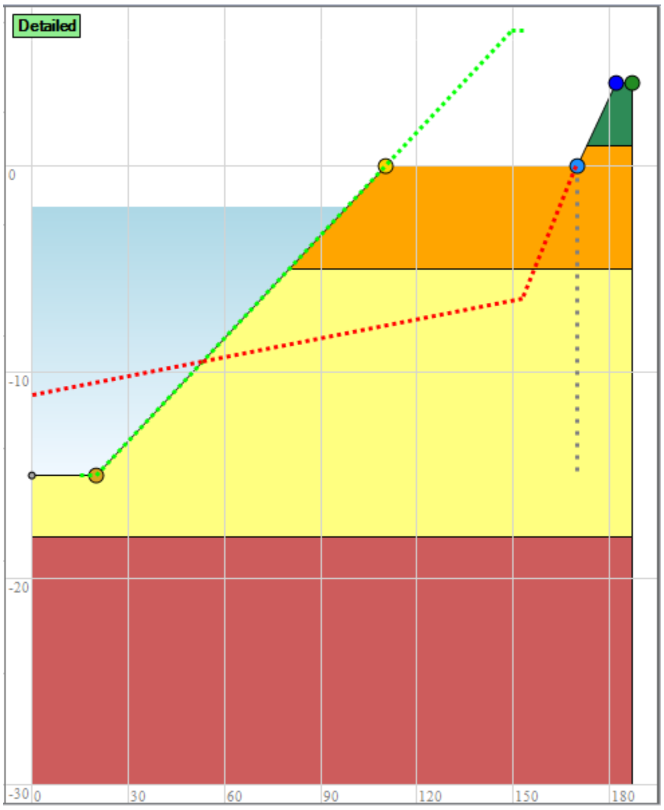


Figure 3.26: *Charts after a Detailed check*

3.5.3 Chart for Advanced Liquefaction check

As a result of the Advanced Liquefaction calculation, one chart is shown in the *Charts* tab (Figure 3.27).

The light green dotted line represents the fictive profile.

The orange dotted line represents the fictive profile.

A green point in the under water slope is a "metastable" point, indicating that liquefaction is very unlikely.

A red point in the under water slope is an "unstable" point, indicating that liquefaction is possible.

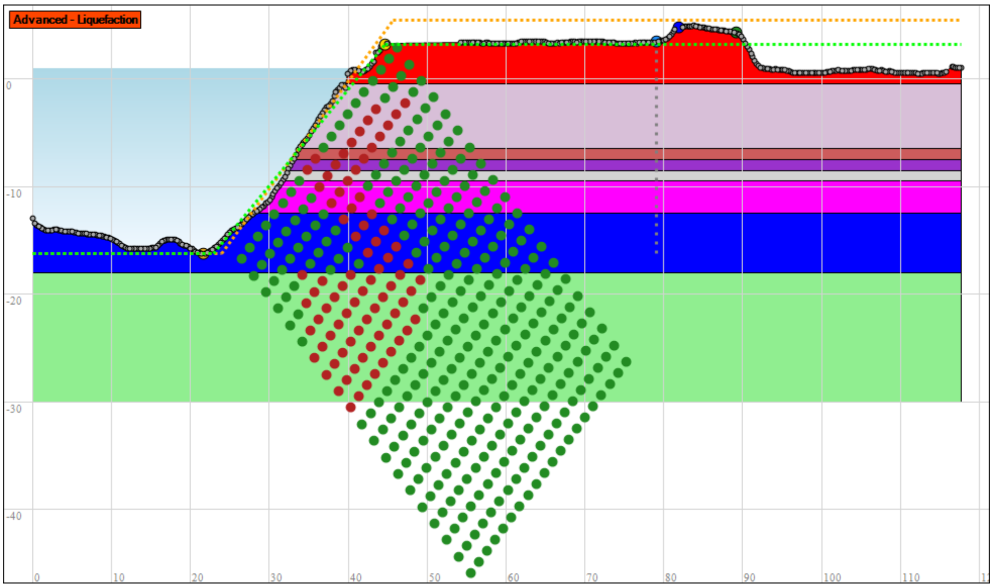


Figure 3.27: *Chart after an Advanced Liquefaction (Sliq2D) check*

3.5.4 Chart for Advanced Breaching check

As a result of the Advanced Breach flow calculation, one chart is shown in the *Charts* tab (Figure 3.28).

The Advanced Breach flow graph shows the sand transport rate along the sand slope (as a function of horizontal distance from the top of the slope), in the case an initial disturbance (initiation height) occurs. One graph is displayed for each cluster of sand layers. Depending on slope geometry and sand properties the HMBreach module in D-FLOW SLIDE computes at which initiation height an erosive self accelerating turbidity current develops that can result in retrogressive breach flow slide damaging the fore shore. If this initiation height is lower than the most probable value for an accidental slope disturbance (called the allowable initiation height), the slope geometry is considered susceptible to breach flow slide. The line in the graph increases in horizontal direction (to the left) in that case.

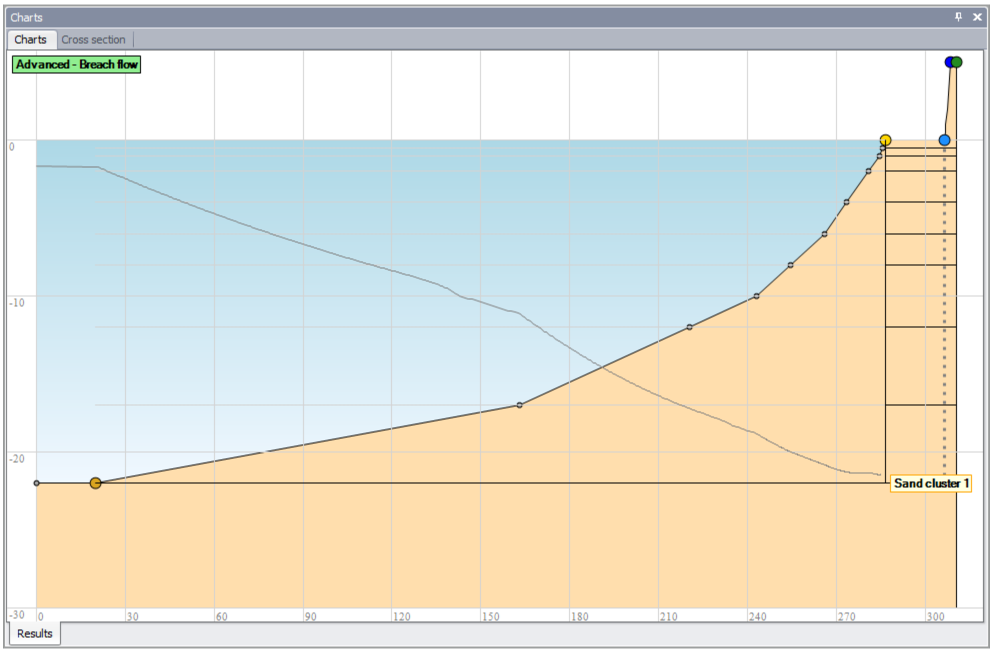


Figure 3.28: *Chart after an Advanced Breach flow (HMBreach) check*

4 Tutorial

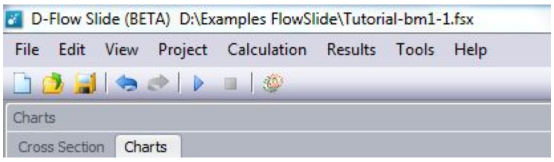
This tutorial describes and explains all input fields for the different assessment methods available in D-FLOW SLIDE:

◇ From Section 4.1 until Section 4.7, the standard assessment methods *Global* and *Detailed*;
◇ In Section 4.8, the *Advanced* assessment methods.

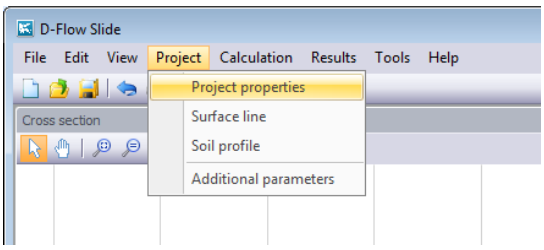
This tutorial is based on the example given in "Annex A - Case Study" of the Deltares report 1200503-001-GEO-0004 "Concept Technisch Rapport Voorland Zettingsvloeiing" of G.A. van den Ham & Co.

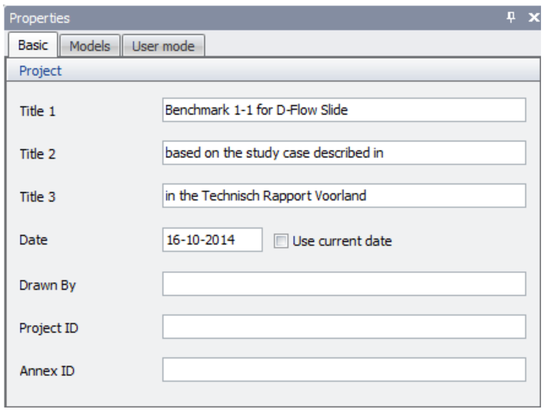
4.1 Assessment methods in D-Flow Slide

The input windows can be found at the Menu bar.



The menu *Project* contains the input windows for the different assessment methods. However, the soil parameters per layer has to be added in the Soil table. By default the Global and Detailed assessment method are used and the advanced models are switched off.





The properties of the "Project properties" consists of three tabs:

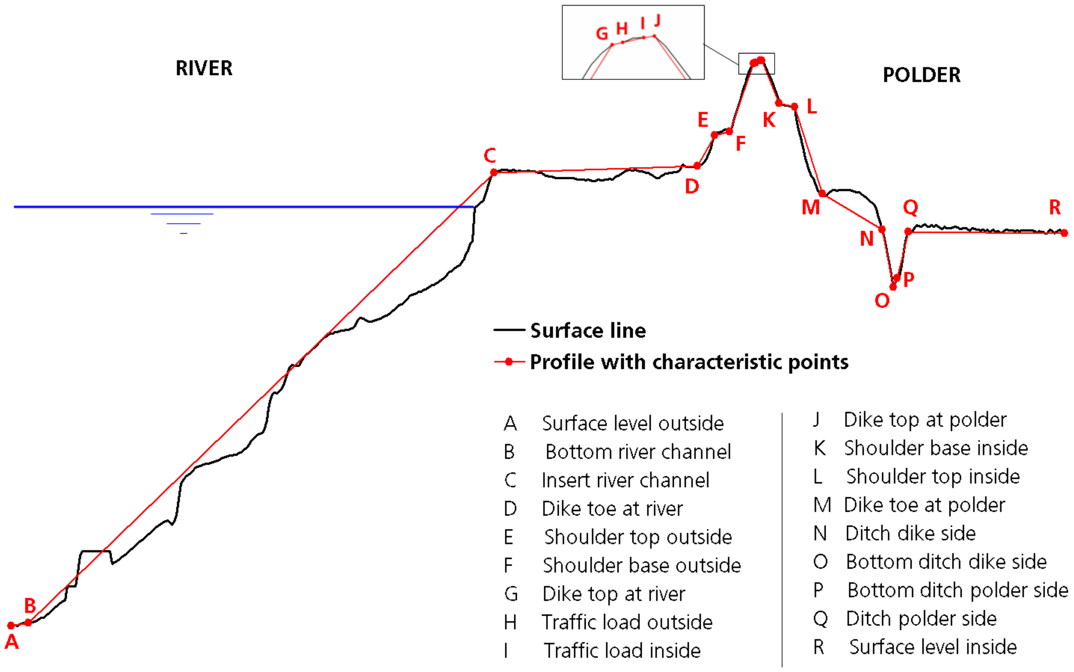
◇ Tab *Basic*: you can enter Project titles, Project ID and other information.
◇ Tab *Models*: you can select or deselect the models. At lease one model is required.
◇ Tab *User Mode*: refer to section 3.2.1.

4.2 Surface line

The basic of the program is the Surface line.

The user has to create a surface line with ascending x-value from channel side of the embankment till the dike top at the polder side.
The riverside has to be on the left as shown in the figure below.

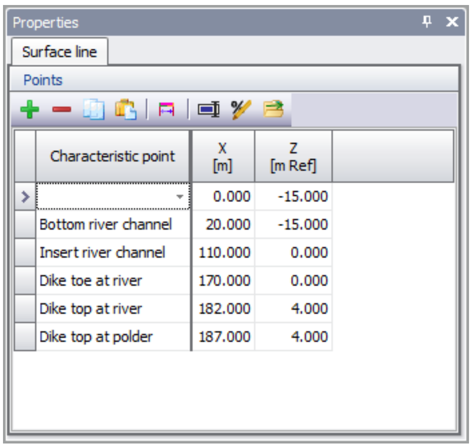
The original surface line as used in DAM or Ringtoets (WTI) contains a whole set of characteristics points. Flow Slide needs a subset.



Please enter your Surface line by using points B, C, D, G and J.

The following 5 characteristics points are obligated in D-FlowSlide with increasing x-value.

1 Bottom river channel (B)
2 Insert river channel (C)
3 Dike toe at river (D)
4 Dike top at river (G)
5 Dike top at polder (J)



Characteristic point	X [m]	Z [m Ref]
	0.000	-15.000
Bottom river channel	20.000	-15.000
Insert river channel	110.000	0.000
Dike toe at river	170.000	0.000
Dike top at river	182.000	4.000
Dike top at polder	187.000	4.000

Figure 4.1: *Input screen for the coordinates L and Z and the characteristic points*

You may, of course add additional points to describe the real surface line.

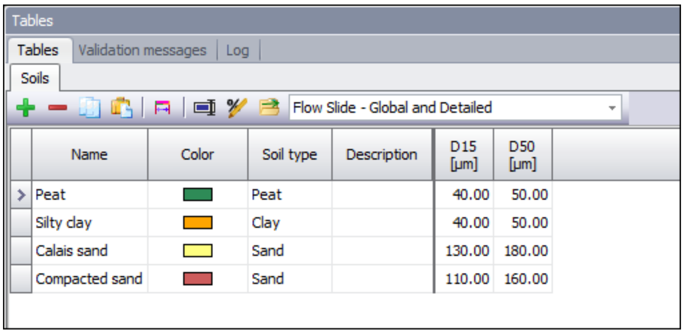
By clicking on the table header X (length) of Z (height level), you can only filter the points, but not order them.

The program checks on a malformed surface.
Messages will be displayed in the window "Validation messages".

4.3 Soil table

The Soils table for the Global and Detailed assessment method (check the filter at the Soils).

The user can add or remove rows to the soil table or change the properties of the parameters per layer.



See section 3.2.3 for a complete description of these parameters.

4.4 Soil profile

Create the Soil profile by selecting soil layers and defining the top or bottom levels of each layer.

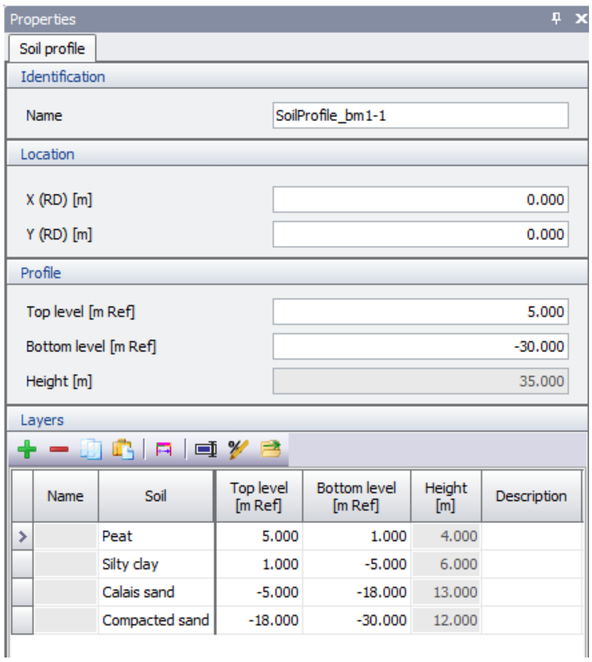


Figure 4.2: *Input screen for the sets of parameters*

RD-coordinates X and Y are defined to specify the position of the embankment in global coordinates.
D-FLOW SLIDE doesn't need or use these coordinates.

The other parameters speak for themselves.

4.5 General parameters for Global and Detailed checks

Add additional parameters for the Global and Detailed assessment method.

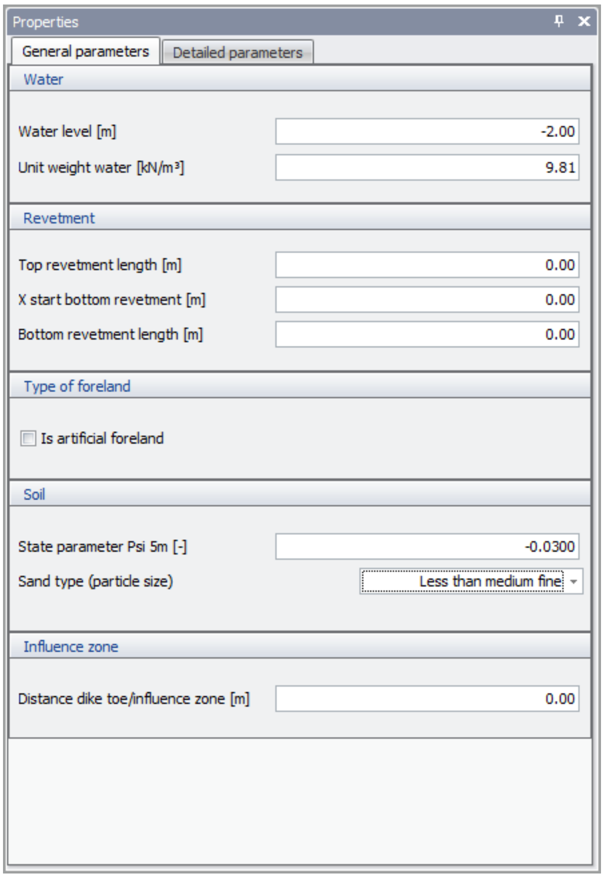


Figure 4.3: *Input screen for the 5 sets of parameters: Water, Revetment, Foreland, Soil and Influence zone*

Note: The state parameter ψ_{5m} entered here is used in the *Detailed* check.

Refer to section 3.2.5.1 for a complete description of these parameters.

In case of non-natural deposited slopes, both Global and Detailed checks FAIL and it should immediately be switched to the advanced methods.

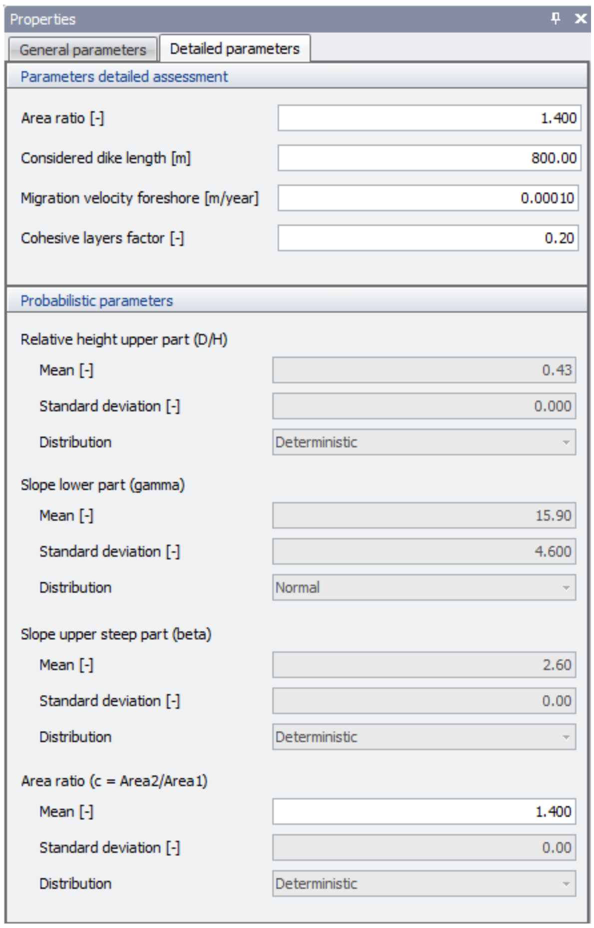


Figure 4.4: *Input screen: The probabilistic parameters are fixed, only the Mean "Area ratio" can be changed (white box)*

4.6 Detailed check parameters

Probabilistic parameters for the Detailed assessment method has to be inputted.

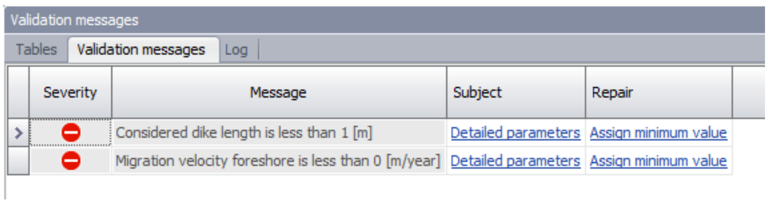
Note: Since version 16.1, the *Allowable probability of failure* is no longer an input parameter. Consequently, no decision can be made whether or not the method meets its failure criteria.

Refer to section 3.2.5.2 for a complete description of these parameters.

4.7 Calculation and Results

When all parameters have been specified, you can start the calculation by using the blue arrow-head in the menu bar or press the key F9.

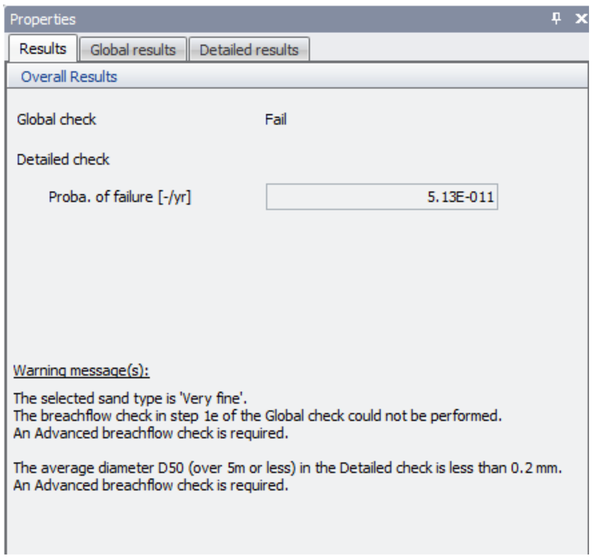
If one of the parameters is out of range or missing, a validation message will be given in the table window "Validation messages".



When no errors are found, the results are presented in the window "Results".
In this version there is no extended report of the results.

4.7.1 Overall results

In this case, the Global check fails and the Detailed check gives a probability of failure of 5.13 $\times$ 10^{-11}. However, since a very fine sand was selected, the detailed check is formally not applicable. For this reason **the overall result gives a warning**.

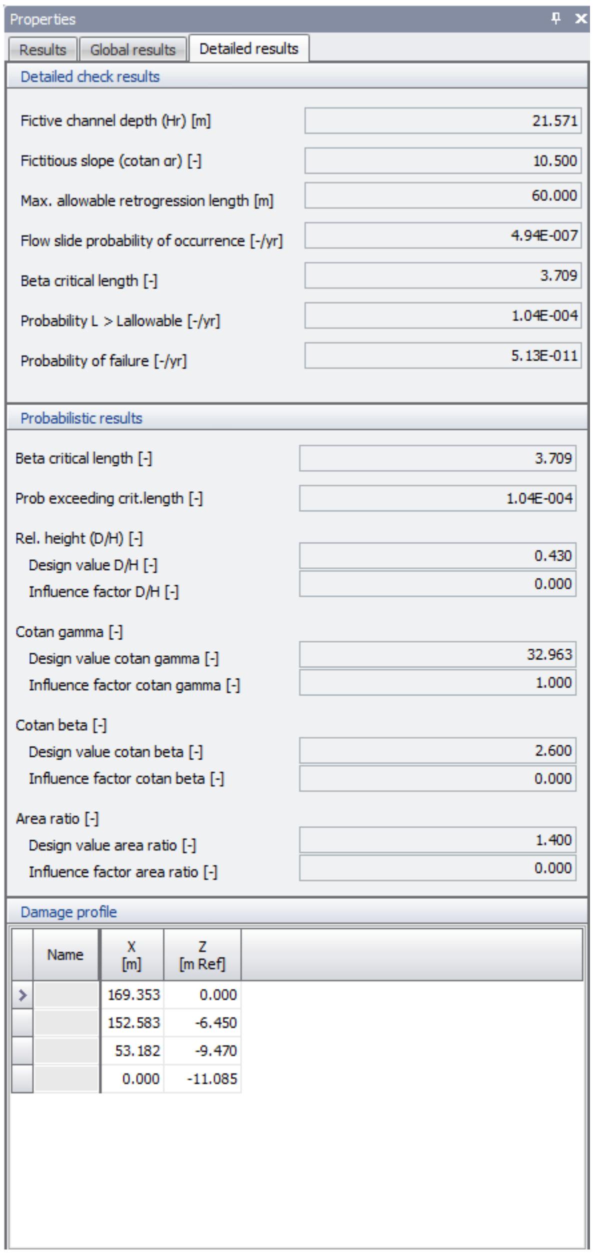


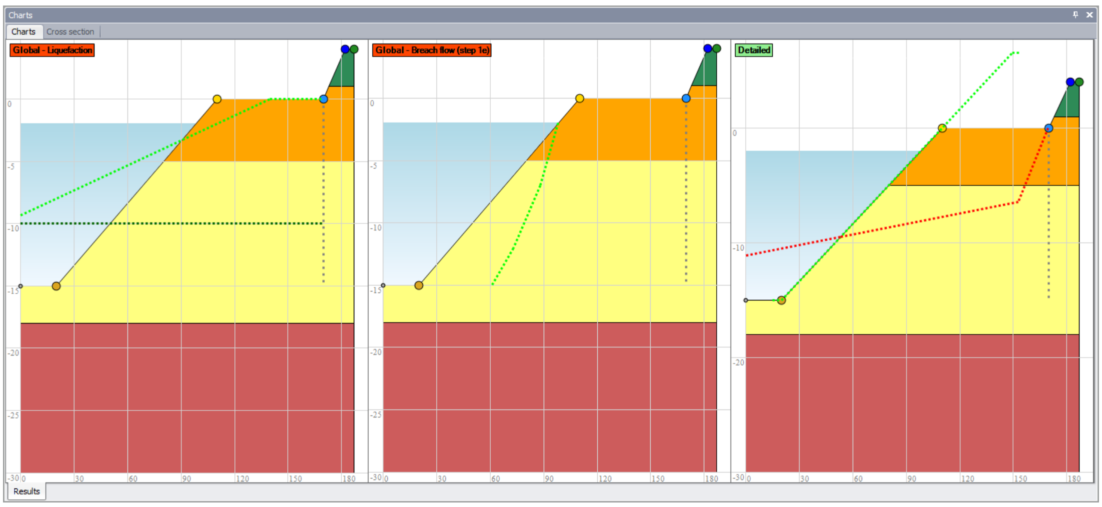
4.7.2 Global results

Use the tab Global results to see the results.
The method itself is described in details in the Background section on the website.

4.7.3 Detailed results

Use the tab Detailed results to see the results. The Detailed check is described in detail in the Background section on the website.


Properties
Results
Global results
Detailed results
Detailed check results
Fictive channel depth (Hr) [m] 21.571
Fictitious slope (cotan αr) [-] 10.500
Max. allowable retrogression length [m] 60.000
Flow slide probability of occurrence [-/yr] 4.94E-007
Beta critical length [-] 3.709
Probability L > Lallowable [-/yr] 1.04E-004
Probability of failure [-/yr] 5.13E-011
Probabilistic results
Beta critical length [-] 3.709
Prob exceeding crit.length [-] 1.04E-004
Rel. height (D/H) [-]
Design value D/H [-] 0.430
Influence factor D/H [-] 0.000
Cotan gamma [-]
Design value cotan gamma [-] 32.963
Influence factor cotan gamma [-] 1.000
Cotan beta [-]
Design value cotan beta [-] 2.600
Influence factor cotan beta [-] 0.000
Area ratio [-]
Design value area ratio [-] 1.400
Influence factor area ratio [-] 0.000
Damage profile
Name
X [m]
Z [m Ref]
169.353 0.000
152.583 -6.450
53.182 -9.470
0.000 -11.085


Charts
Cross section
Global - Liquefaction
Global - Breach flow (step 1e)
Detailed
Results

As a result of the Global calculation, three charts are shown:
The Global check, which is exclusively based on geometric characteristics of the under water slope and levee, fails. The leftmost chart above visualizes the check whether a flow slide leads to unacceptable damage to the levee (step 1a). On the assessment level (horizontal dotted line), the actual slope lies landward of the assessment profile (green dotted line). This means that a flow slide does lead to unacceptable damage to the levee.The middle chart shows whether a breach flow slide may occur or not at step 1e of the Global assessment. A breach flow slide can occur if the actual slope lies landward of the green dotted line. This is not the case in this situation. However, the sand has been indicated to be very fine, which means that a breach flow cannot be excluded based on these geometric criteria only. An advanced analysis in HMBreach (Tabak, 2011; Mastbergen, 2009) should be performed. The rightmost chart visualizes the results of the detailed check, in which also soil properties are taken into account. The red dotted line shows the profile after flow slide occurred, corresponding with a probability given in the tab with the detailed results (in this case 8.88E-05). In this case the calculated probability is smaller than the acceptable probability.

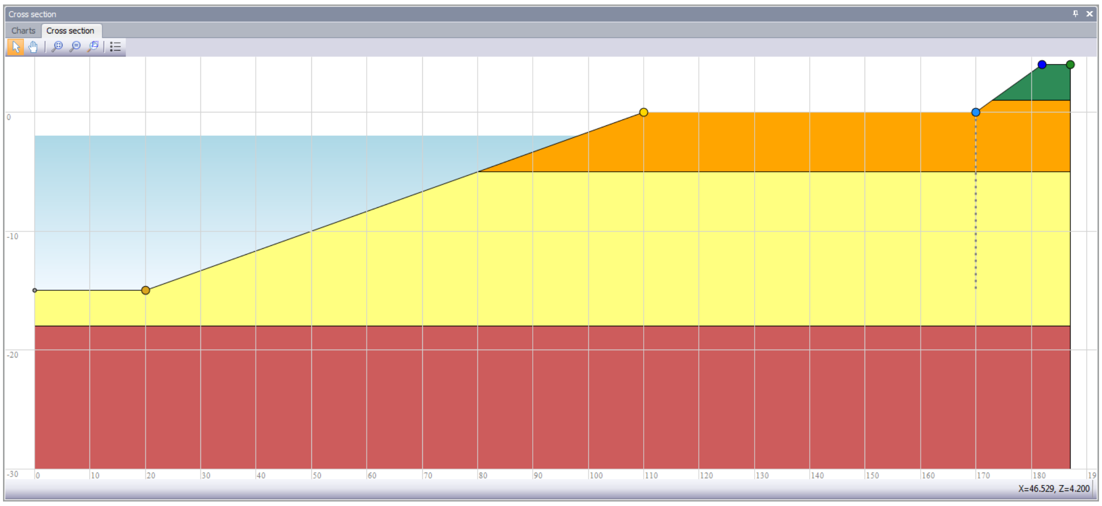
However, when the detailed check is not passed, the advanced models can be used for further analysis of the problem. In the following section the input data of the advanced models are explained.

4.8 Advanced models

D-FLOW SLIDE includes also two advanced models for analyzing static liquefaction and breach flow, that can be used for a tailor-made safety assessment, if the global and detailed assessments fail.

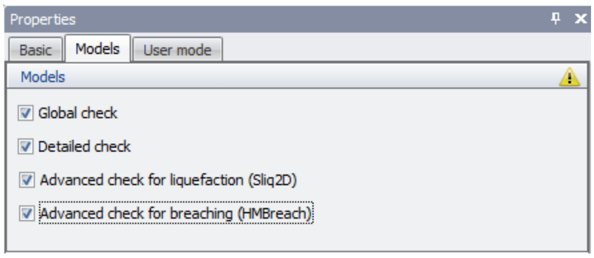
Please check your input data for the advanced models carefully and discuss the results with Dick Mastbergen or Geeralt van den Ham.

We continue the tutorial for the advanced models. For these models extra input data is needed for the Soil table and some additional parameters for the models itself.

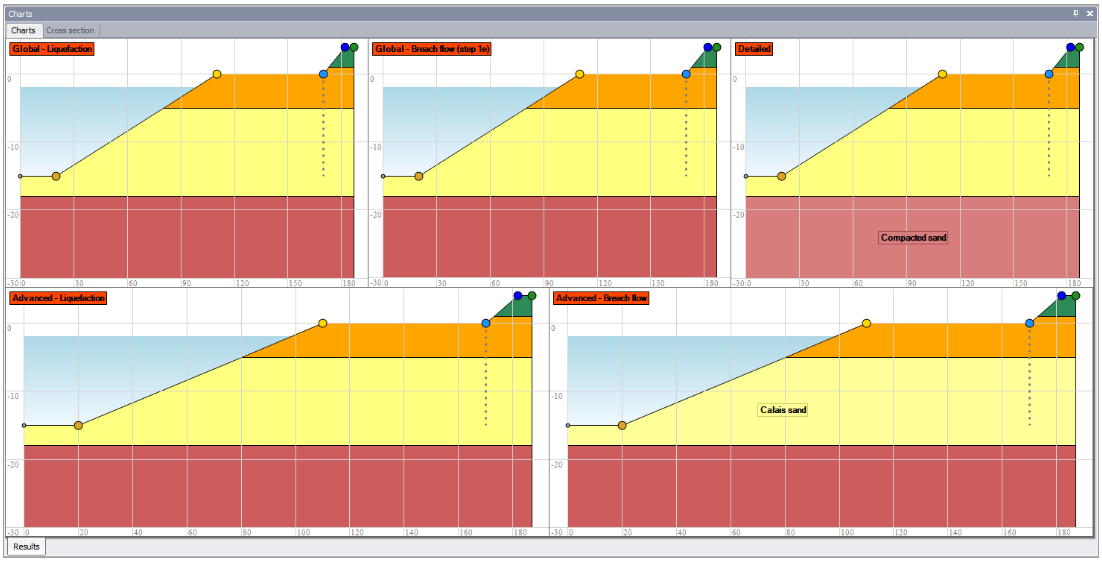


Main Window: The Cross Section of the problem

Select the models for Advanced liquefaction (Sliq2D) and breach flow (HMBreach) at the menu option: Project Properties.



After selecting the advanced models, 5 Charts window will be shown now!



4.8.1 Soil table for the advanced models

Extra parameters has to be specified in the Soil table for the Advanced Liquefaction (Sliq2D). Set the filter in the soil table on **Advanced Liquefaction**.

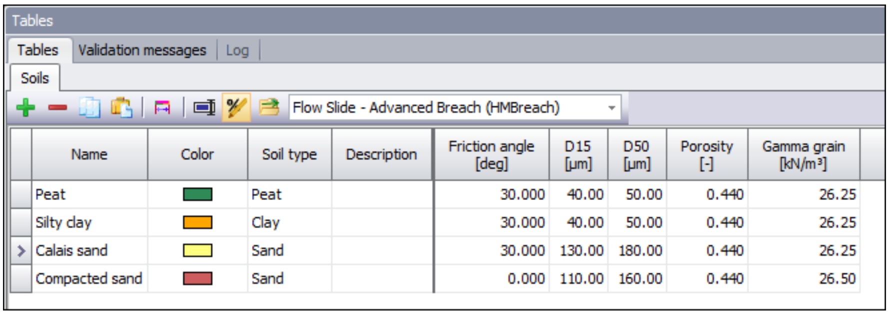
Tables | Validation messages | Log

Soils

Flow Slide - Advanced Liquefaction (Sliq2D)

Name	Color	Soil type	Description	Friction angle [deg]	s2 [-]	Porosity [-]	Minimum porosity [-]	Maximum porosity [-]	Epsvoldm0 [-]	Ks0 [kN/m²]	Gamma grain [kN/m³]	m [-]	u [-]	v [-]	r [-]	Dr [-]
Peat		Peat		30.000	1.30	0.440	0.350	0.500	0.00250	50000	26.25	2.00	1.00	1.25	7.00	0.400
Silty clay		Clay		30.000	1.30	0.440	0.350	0.500	0.00250	50000	26.25	2.00	1.00	1.25	7.00	0.400
Calais sand		Sand		30.000	1.30	0.440	0.350	0.500	0.00250	50000	26.25	2.00	1.00	1.25	7.00	0.400
Compacted sand		Sand		0.000	1.30	0.440	0.350	0.500	0.00030	50000	26.50	2.00	1.00	1.25	7.00	0.400

Also for Advanced Breaching (HMBreach), add extra parameters in the *Soils* table has to be defined.
Set the filter in the soil table on **Advanced Breaching**.



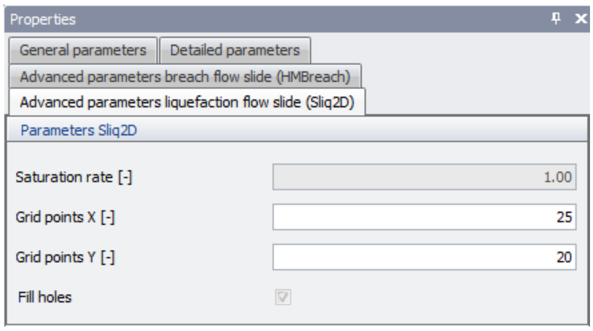
Name	Color	Soil type	Description	Friction angle [deg]	D15 [µm]	D50 [µm]	Porosity [-]	Gamma grain [kN/m³]
Peat		Peat		30.000	40.00	50.00	0.440	26.25
Silty clay		Clay		30.000	40.00	50.00	0.440	26.25
Calais sand		Sand		30.000	130.00	180.00	0.440	26.25
Compacted sand		Sand		0.000	110.00	160.00	0.440	26.50

Refer to section 3.2.3 for a complete description of these parameters.

4.8.2 Parameters for Liquefaction model

Additional parameters for Liquefaction model (Sliq2D) has to be specified.

The greyed input fields are fixed on a default value.

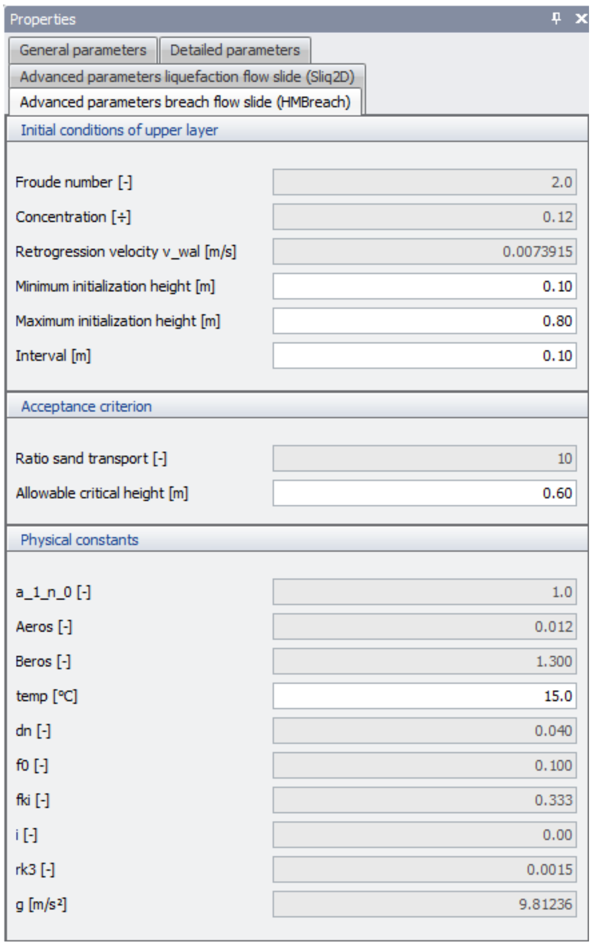


Input screen for the additional Sliq2D parameters

Refer to section 3.2.5.3 for a complete description of these parameters.

4.8.3 Parameters for Breach flow

Additional parameters for breach flow (HMBreach) has to be specified.



Input screen for the 4 sets of additional HMBreach parameters.
The greyed input fields are fixed on a default value.

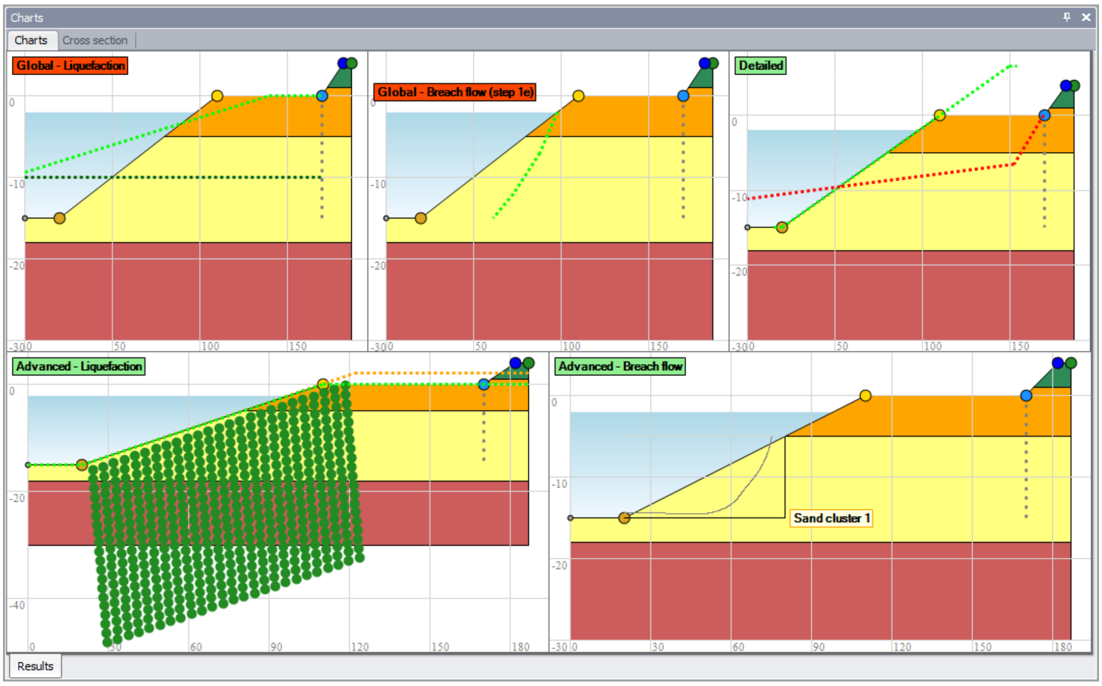
Only the temperature can be changed, other values cannot be adjusted.

Refer to section 3.2.5.4 for a complete description of these parameters.

4.8.4 Results advanced models

If the required parameters for the advanced models are specified, the user can restart the calculation.
The results of all models are shown on the right screen of the program as a property screen, as well as in two additional charts.
In this version, there is no separate report.

In this case the advanced models indicate no failure of the embankment: in the charts the text blocks are green (whereas the results in the global and detailed check are red, indicating failure).
According to the liquefaction model (chart left below), there are no points in the under water slope that are "metastable", indicating that liquefaction is very unlikely.



Sand transport per cluster in Breach flow

The Advanced Breach flow graphs shows the sand transport rate along the sand slope (as a function of horizontal distance from the top of the slope), in the case an initial disturbance (initiation height) occurs.

Depending on slope geometry and sand properties the HMBreach module in D Flow slide computes at which initiation height an erosive self accelerating turbidity current develops that can result in retrogressive breach flow slide damaging the fore shore.
If this initiation height is lower than the most probable value for an accidental slope disturbance (called the allowable initiation height), the slope geometry is considered susceptible to breach flow slide. (FAILS).

The line in the graph increases in horizontal direction (to the left) in that case.

5 Literature

De Bruijn, H., G. De Vries and R. 't Hart, 2016. "Voorschrift Toetsen op Veiligheid, Technisch Deel (rapport 1220078-000-GEO-0009, version 2, 22 feb. 2012, definitif)."

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Rijkswaterstaat, 2007. *Voorschrift Toetsen op Veiligheid - Primaire Waterkeringen (2006)*.

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Rijkswaterstaat, 2016. "Regeling veiligheid primaire waterkeringen 2017 - Bijlage III Sterkte en veiligheid."

Tabak, F., 2011. "Analysis of Breach Flow Slides with HMBreach (Deltares report)."