INTRODUCTION TO “Stratigrafia”

The code in the workbook “stratigrafia” computes

- **longitudinal profiles;**
- **water surface elevation;**
- **sediment transport rates;**
- **time for the flow and the sediment transport to reach equilibrium**

in a water – feed laboratory flume.

When sediment is modeled as a mixture of different grain sizes, the code also computes

- **grain size distribution of the active (surface) layer;**
- **grain size distribution of the bedload;**
- **stratigraphy of deposits;**

INTRODUCTION TO “Stratigrafia”

Hypotheses

a) The flume is straight and its width, B, is constant;

b) The flume is long enough so that entrance and exit regions can be neglected;

c) The flow is always subcritical;

d) The volume transport rate of sediment is always much smaller than that of water;

e) The sediment is not cohesive;

f) The suspended load can be neglected;

g) Lower regime plane bed;

INTRODUCTION TO “Stratigrafia”

Active layer approximation

When sediment is modeled as a mixture of different grain sizes the active layer approximation is introduced to model how the sediment is exchanged between the bed and the bedload.

The bed is divided in two regions:

- **the active layer whose particles have the same and finite probability to be entrained into bedload. In absence of bedforms its thickness, L_a, is computed as $n_a \cdot D_{s90}$, where n_a is a number that varies between 1 and 2 and D_{s90} is the size such that the 90% of the sediment in the active layer is finer;**
- **the substrate whose particles can not be entrained into bedload.**

INTRODUCTION TO “Stratigrafia”

Equations

a) Backwater to compute the water depth everywhere in the flume;

b) Load relation to compute the sediment transport rate everywhere in the flume. For sediment mixture the grain size distribution of the bedload is also evaluated;

c) Exner to compute the new longitudinal profile;

d) For sediment mixtures only, conservation of mass of sediment in each grain size range to update the grain size distribution of the active layer everywhere in the flume

INTRODUCTION TO “Stratigrafia”

Water – feed flumes

SEDIMENT FEED FLUME: the total amount of sediment in the system is not constant. Equilibrium depends on the discharge and on the sediment feed rate. Downstream water elevation has to be specified to compute water depth with the backwater equation.

SEDIMENT RECIRCULATING FLUME: the total amount of sediment in the system is constant. Equilibrium depends on the discharge and on the water elevation set by the tail gate at the downstream end of the flume

INTRODUCTION TO “Stratigrafia”

Input parameters and boundary conditions are given in the worksheets “input_parameters_1” and “input_parameters_2”.

Input parameters are written in light blue cells.

Yellow cells contain useful information.

When the worksheet “input_parameters_1” is completed the command button at rows 48 – 49 has to be clicked to set up the worksheet “input_parameters_2”

The code is run from the worksheet “input_parameters_2”

INTRODUCTION TO “Stratigrafia”

Output parameters are plotted in 24 graphs and are written in five worksheets:

-“comments” contains the clock and different messages to describe the results;

-“output_1” contains longitudinal profiles, channel slope, water surface elevations, sediment transport rates, the channel slope at the upstream and downstream end of the flume and the water discharge;

The other three worksheets are for mixtures only:

-“output_2” contains the grain size distribution of the active (surface) layer and of the bedload;

-“output_4” contains the grain size distribution of the substrate;

-“output_5” contains the grain size distribution of the active (surface) layer and the final longitudinal profile

THE WORKSHEET “input_parameters_1”

The command button

deletes all the input parameters and prepares the code for a new run.

THE WORKSHEET “input_parameters_1”

First group of parameters

General information has to be specified:

Choose the type of flume (1 for sediment feed and 2 for sediment recirculating)	1
Choose the type of sediment (1 for uniform and 2 for mixture)	2
"tol": tolerance for the condition of equilibrium	0.030

The code assumes that the flow and the sediment transport reach equilibrium when the coefficient of variation of the sediment transport rate (ratio between the sediment transport rate averaged on the flume length and the standard deviation) is smaller than the tolerance specified in the third row.

Calculation stops when the flow and the sediment transport reach equilibrium.

THE WORKSHEET “input_parameters_1”

First group of parameters

General information has to be specified:

If you want to remove wall effects write 1	1
If you have an inital input hydrograph, write 1	1

A procedure to remove wall effects is implemented to consider the different roughness between bed and walls. If the cell is not 1 calculations will be done without wall correction.

If the water discharge is not constant the code does not compute the time for the flow and the sediment transport to reach equilibrium and the run lasts for the ‘maximum duration of calculation’, specified in the fourth group of parameters.

THE WORKSHEET “input_parameters_1”

Second group of parameters

If a boundary condition varies when the flow and the sediment transport reach equilibrium, the run will continue and the time for the flow and the sediment transport to reach a new equilibrium will be computed

WHEN THE FLOW AND THE SEDIMENT TRANSPORT REACH EQUILIBRIUM, WRIGHT	
1 if the water elevation set by the tail gate varies	
2 if the constant water discharge varies	
3 if you have an input hydrograph	

When the new boundary condition is an hydrograph, the time for the flow and the sediment transport is not computed and the run lasts for the ‘maximum duration of calculation’.

THE WORKSHEET “input_parameters_1”

Third group of parameters

Flume geometry and initial longitudinal profile have to be specified:

FLUME GEOMETRY AND INITIAL CONDITIONS			
L	Channel length	11.80	m
B	Channel width	0.61	m
η_a	Initial bed elevation averaged over length of flume	0.19	m
S_{in}	Initial bed slope	0.0000	m/m

For sediment mixtures, the initial bed and its stratigraphy can be read from worksheets “output_4” and “output_5” to continue a previous run.

THE WORKSHEET “input_parameters_1”

Fourth group of parameters

Spatial and temporal step length have to be specified

SPATIAL AND TEMPORAL STEP LENGTH			
Δx	Spatial step length	0.10	m
N_{node}	Number of nodes, smaller than 1001	119	
Δt	Temporal step length	1.00	sec
Maximum duration of calculation		5.00	hours
Number of profiles to plot (not larger than 17)		10	

If mobile – bed equilibrium is not reached by the maximum duration of calculation the message ‘The flow and the sediment transport will reach equilibrium in a longer time’ will be given in the worksheet “comments”.

THE WORKSHEET “input_parameters_1”

Fifth group of parameters

Some auxiliary parameters to be specified

α_r	Coefficient in Manning-Strickler resistance relation	8.10
n_k	Parameter to evaluate roughness height	2.50

The friction coefficient is computed with a Manning – Strickler formulation:

$$C_f^{-1/2} = \alpha_r \cdot \left(\frac{R_H}{k_s} \right)^{1/6}$$

where R_H is the hydraulic radius and k_s is the roughness height computed as $n_k \cdot D_{s90}$, where n_k is a parameter that generally varies between 1.5 and 3.

THE WORKSHEET “input_parameters_1”

Fifth group of parameters

Some auxiliary parameters to be specified

λ_p	Bed porosity	0.35	
ρ_w	Water density	1.00	t/m^3
ρ_s	Sediment density	2.58	t/m^3
R	Submerged specific gravity of sediment	1.58	

Bed porosity appears in the equations of conservation of mass for sediment.

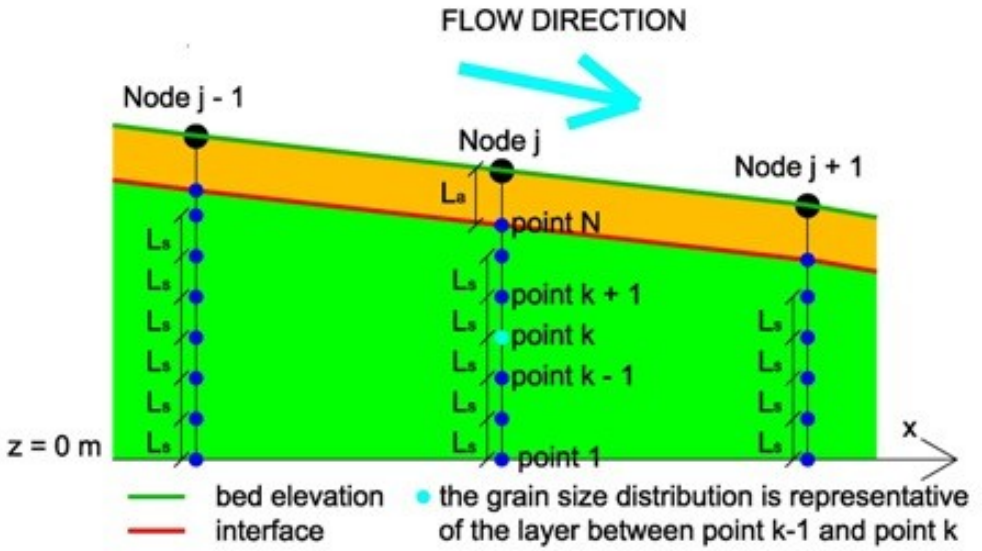
The submerged specific gravity of sediment is necessary to compute the bedload transport rate.

THE WORKSHEET “input_parameters_1”

Sixth group of parameters

These parameters are for sediment mixtures only

L_s	Grid thickness for the storage of stratigraphy	0.01	m



Stratigraphy is stored in a grid whose thickness, L_s, is a user specified parameter.

THE WORKSHEET “input_parameters_1”

Sixth group of parameters

These parameters are for sediment mixtures only

If you want to continue a previuos run write 1	1

When you continue a previous run the initial longitudinal profile and the grain size distribution of the substrate and of the active (surface) layer are read from worksheets “output_4” and “output_5”. The spatial step length, the grain size ranges and the thickness of the grid to store the stratigraphy have to be the same of the previous run.

THE WORKSHEET “input_parameters_1”

Sixth group of parameters

These parameters are for sediment mixtures only

If you want to write the text files with the stratigraphy, write 1	1
Where do you want to save the files with the stratigraphy?	
C:\Documents and Settings\Admin\Documenti\feed	
Name of the file with the stratigraphy	
12hy2	

Stratigraphy is printed in a .txt file with 11 columns. The first column contains the streamwise coordinate, the second column contains the elevation above a datum and the other 9 columns respectively contain the D_{10}, D_{20}, D_{30}, D_{40}, D_{50}, D_{60}, D_{70}, D_{80} and D_{90} of the grain size distribution associated to each node of the grid.

THE WORKSHEET “input_parameters_1”

When the worksheet “input_parameters_1” is completed, click the command button to

Set up the worksheet "input parameters 2"

THE WORKSHEET “input_parameters_2”

More auxiliary parameters for sediment mixtures

n_a	Parameter to evaluate active layer thickness	
α	Parameter governing grain size distibution	
	trasferred to substrate during bed aggradation	

The fraction of material in each grain size range at the active (surface) layer – substrate interface, f_{li}, during bed aggradation is computed averaging the fraction of material in the same size range of the active (surface) layer, F_i, and of the bedload, p_i:

$$f_{li} = \alpha \cdot F_i + (1-\alpha) \cdot p_i$$

α varies between 0 and 1.

THE WORKSHEET “input_parameters_2”

Load relations for uniform sediment

CHOOSE A LOAD RELATION

1 $q_s^* = \alpha_s (\tau^* - \tau_c^*)^{nt}$

2 Ashida and Michiue (1972)

3 Parker (1990)

4 Wilcock and Crowe (2003)

5 New version of Ashida and Michiue (2007)

If cell I7 = 1 these parameters have to be specified

α_s	Coefficient in load relation	
n_t	Exponent in load relation	
τ_c^*	Critical Shields stress	

THE WORKSHEET “input_parameters_2”

Parameters to describe uniform sediment

D_{50}	Median size		mm
D_g	Geometric mean size		mm
D_{90}	Size such that the 90% is finer		mm
Sf	Percent sand		

D_{50} is read when the sediment transport rate is computed with the relation

$$q_s^* = \alpha_s \cdot \left(\tau^* - \tau_c^*\right)^{nt}$$

D_g is read for the other load relations

D_{90} is read to evaluate the roughness height

Sf is read to evaluate the critical Shields number for the relation of Wilcock and Crowe

THE WORKSHEET “input_parameters_2”

Load relations for sediment mixtures

CHOOSE A LOAD RELATION

2 Ashida and Michiue (1972)

3 Parker (1990)

4 Wilcock and Crowe (2003)

5 New version of Ashida and Michiue (2007)

THE WORKSHEET “input_parameters_2”

Grain size distributions for sediment mixtures

D	bed	feed
(mm)	F	F
0.01	0.00	0.00
0.50	0.00	0.00
1.00	0.11	0.11
1.18	5.98	5.98
2.00	24.67	24.67
4.00	61.76	61.76
6.35	82.94	82.94
9.42	99.92	99.92
13.33	100.00	100.00

Up to 20 size ranges can be specified.

F is the percent finer

The code assumes that at the beginning of the run the bed material is everywhere equal to the grain size distribution specified in the column “bed”.

When stratigraphy is read from worksheets “output_4” and “output_5” the column bed is not drawn.

In the column “feed” the grain size distribution of the sediment input rate has to be specified. This column is not drawn for the sediment recirculating flume.

THE WORKSHEET “input_parameters_2”

Sediment feed rate

The sediment feed rate has to be specified in a sediment feed flume

SEDIMENT FEED RATE		**g/min**

THE WORKSHEET “input_parameters_2”

Downstream water elevation

WATER ELEVATION SET BY THE TAIL GATE: $\xi_d = \xi_{do} + A \cos(\omega t)$			
Initial	ξ_{do}		m
If water elevation is constant leave cell I44	A		
and cell I45 blank.	ω		s^{-1}
New	ξ_{do}		m
If water elevation is constant leave cell I48	A		
and cell I49 blank.	ω		s^{-1}

When the tail gate elevation does not vary when the flow and the sediment transport reach equilibrium the last three cells are not drawn

THE WORKSHEET “input_parameters_2”

Constant water discharge

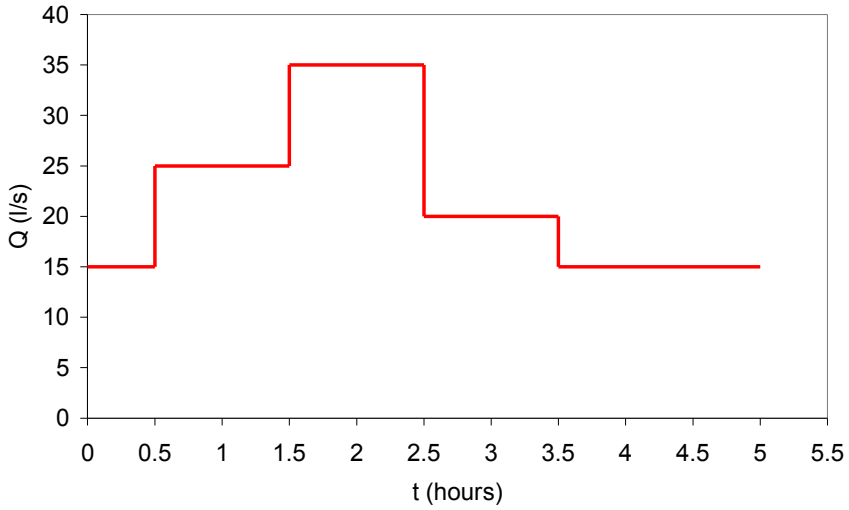
CONSTANT WATER DISCHARGE			
Initial	Q		l/s
New	Q		l/s

When the constant water discharge does not vary when the flow and the sediment transport reach equilibrium the second cell is not drawn

THE WORKSHEET “input_parameters_2”

Hydrograph

t (min)	Q (l/s)
30	15
90	25
150	35
210	20
300	15

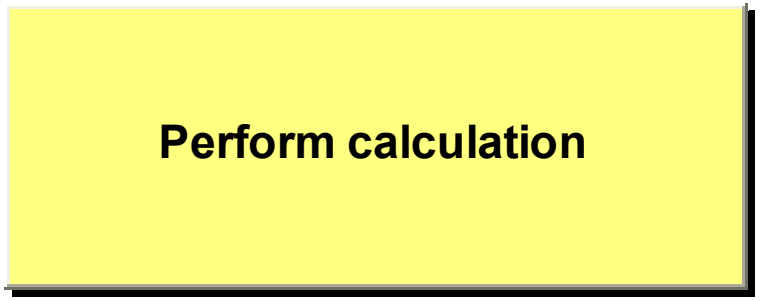


Up to 10 values can be specified.

Time is computed from the beginning of the hydrograph. If the last time is smaller than the maximum duration of calculation, the run continue for a time equal to the maximum duration of calculation with a constant discharge equal to the last value of the hydrograph (15 l/s) in the example.

THE WORKSHEET “input_parameters_2”

When the worksheet “input_parameters_2” is completed, click the command button to



THE WORKSHEET “comments”

Error messages

These messages are given when input parameters are not properly given

Which water-feed flume are you using?

How are you modeling the sediment?

You can not change a boundary condition when you have an initial input hydrograph

Which boundary condition do you want to change when the flow and the sediment transport reach equilibrium?

When do the flow and the sediment transport reach equilibrium?

You should specify when do the flow and the sediment transport reach equilibrium because I need to know when the boundary condition has to be changed

THE WORKSHEET “comments”

Error messages

These messages are given when input parameters are not properly given

The number of profiles to plot should be smaller than 17

Grid thickness for the storage of stratigraphy has to be specified!

Which load relation are you using?

Water elevation set by the tail gate has to be specified!

The new water elevation set by the tail gate has to be specified!

The initial slope has to be smaller because the flow is supposed Froude subcritical

The bed can be considered fixed

THE WORKSHEET “comments”

Information

These messages are given during the run

THE CLOCK:

Time : 1.2 hours

Mass balance is satisfied

Time required to reach equilibrium 12.6 hours

Mass balance is not satisfied
and this is reasonable because you have a sediment feed flume

The flow and the sediment transport will reach equilibrium in a longer time

New equilibrium will be reached in a longer time

You have to wait for other 3.8 hours for the flow and sediment transport to reach equilibrium again