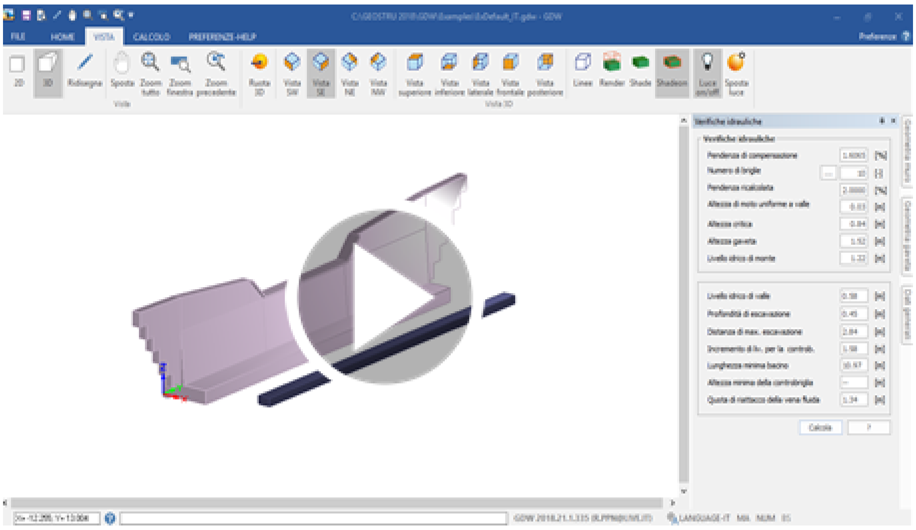
GDW

1 GDW

Software for the design and analysis of gabion walls, simple concrete weirs and gabion weirs in static ad seismic conditions.
GDW has advanced graphics features including the three-dimensional view through which you can examine in detail the inputsmade.

The global stability analysis if performed with **GSA** – *Global Stability analysis.*



Gabion walls, gabion and concrete weirs

Safety checks are carried out for load combinations defined by the user in accordance with the directives imposed by new regulations.

Safety factors in case of:

- *Overturning*
- *Sliding*
- *Limit load*
- *Global stability*
- *Siphoning*

For the **GABION** wall are provided additional security checks, and in particular:

- Sliding safety verification at the interface between gabion and gabion;
- Crush safety verification at the interface between gabion and gabion.

Hydraulic design

- Compensation slope. The compensation slope is the slope of riverbed at which occurs the sedimentation of the material on the reverse side of the weir, and for a fixed design flow rate, the aggregates are in equilibrium
- Height of the notch
- The maximum excavation downstream of the weir, once calculated the heights of the current downstream and upstream of the weir
- The safety factor to siphoning, calculated with the finite element study of the filtration problem in a porous medium
- The maximum depth of excavation calculated with the formula of Schoklitsch
- When an auxiliary weir is present it’s minimum height will be determined as well as the minimum length of it’s upstream basin and the height of the current in correspondence of the auxiliary weir

Output

The software offers highly detailed text and graphics in DXF and DOC formats .

2 Introduction

A weir or dike is a structure used to restrain erosion phenomena in river-beds. In particular, it is used when one wants to change the slope of the river-bed taken into examination, bringing it to a compensation value. There are different technologies used for the execution of weirs. The GDW programme takes into examination the ordinary concrete weirs as well as gabion weirs. Both types are shown in the following figure:

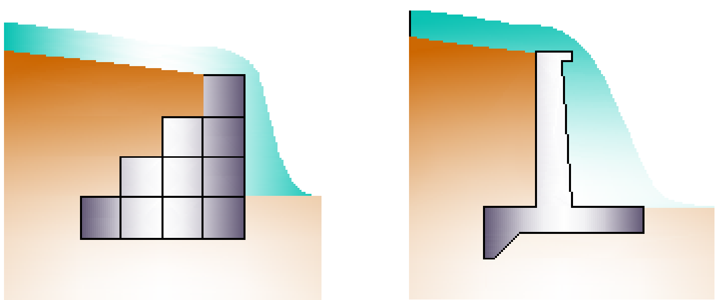


Figure: A gabion weir (left) – A concrete weir

Then calculation executed in the programme concerns two different checks:

1. A hydraulic test:

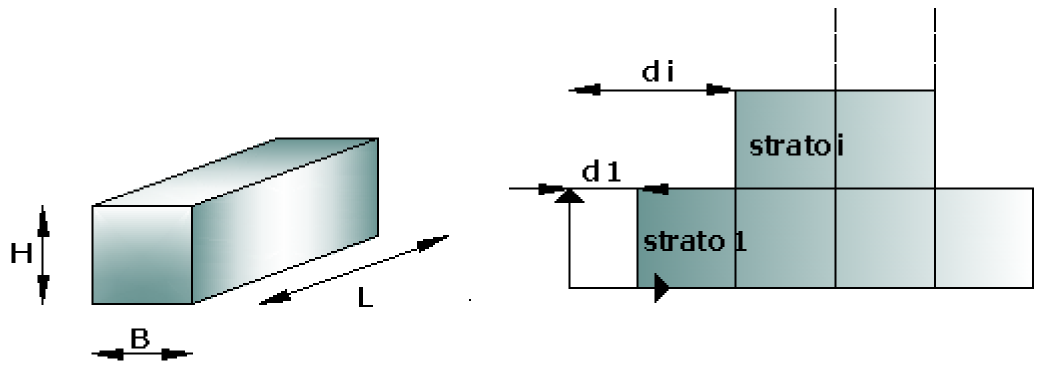
In this case, all the water amounts necessary to assess the goodness of the intervention will be determined. For example, quantities such as the maximum excavation depth, the uniform motion height are calculated amongst others.

2. Check of the global equilibrium:

In this case, the stability of the work is assessed following the classical tests necessary for this kind of structures.

3 Gabion weirs

The geometry of the gabion weirs is defined with reference to the following figure:



Geometrical diagram of the gabion weirs

The gabion weir is defined as an assembly of several gabions. Gabions of different types can be present in the same weir. With reference to the left side of the figure, the type of gabion is defined through the following quantities:

H [m]:

Height of a single gabion

B [m]:

Base of a single gabion

L [m]:

Length of a single gabion

Weight [kN/m³]

The unit weight of the material constituting the gabion.
On the contrary, the gabion weir is defined with reference to the right side of the figure:

Type

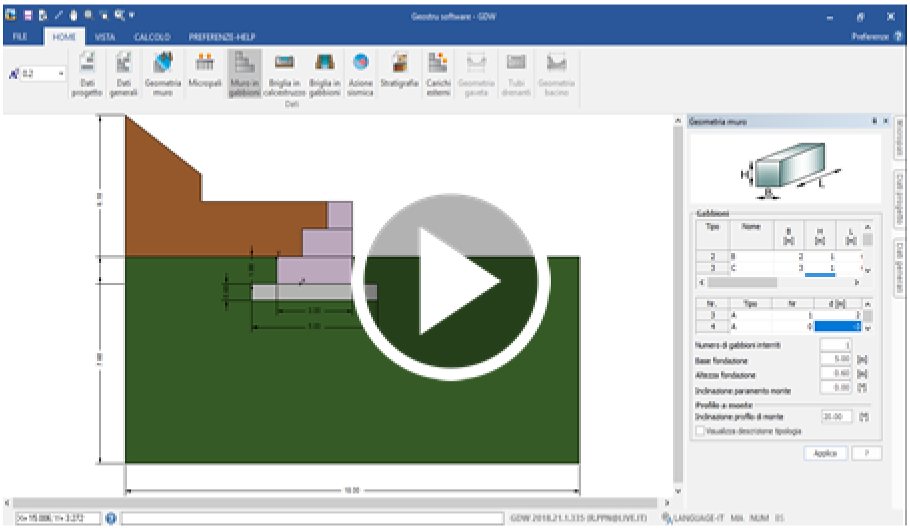
The ith layer of the weir will be constructed using one of the types defined by the user

Number

Number of gabions making up the layer

d [m]

The distance between the first gabion, starting fro the left, of the layer from the chosen reference system
The user must also define the number of silted-up gabions **(NGI)** on the laying of the gabion system.



4 General data

The general data refer mainly to the river pole to be analyzed. For this purpose, the following general data are defined:

DATA RELEVANT TO THE POLE

Upstream pole level [m]:

It is the level, with respect to a reference horizontal plane, of the upstream (highest) point of the river-bed stretch one wants to arrange;

Downstream pole level [m]:

It is the level, with respect to a reference horizontal plane, of the downstream (lowest) point of the river-bed stretch one wants to arrange;

Pole length [m]:

The distance, measured along the projection of the pole on the reference horizontal plane, of the starting point of the pole (upstream point) and the final point of the pole (downstream point);

Width of the river-bed section [m]:

The river-bed section is assumed in the **WEIRS** programme as a rectangular section and consequently the width of the river-bed section coincides with the base of the rectangular section assumed for moulding the river-bed section;

Average diameter of the material constituting the river-bed [m]:

The diameter passing by 50% through the sifting test on the soil constituting the river-bed;

D90 [m]:

Diameter passing by 90% through the sifting test on the soil constituting the river-bed:

Design flow rate [m^3/s]:

Design flow rate determined on the base of the hydrologic features of the basin inside which the pole to be analyzed is contained;

Manning's n value [-]:

The roughness factor of the river-bed bottom used in the formula of the uniform motion for open channels. As a rule, it takes values included between 0.011 and 0.035;

SAFETY FACTORS

Overturning safety factor:

It is the minimum ratio admitted between the stabilizing moment and the overturning moment;

Sliding safety factor:

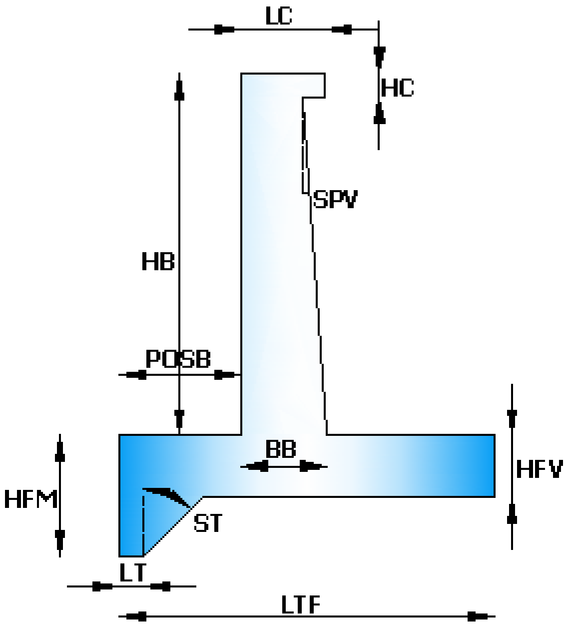
It is the minimum ratio admitted between forces which tend to stabilize by slipping and forces which tend to destabilize by slipping;

Limit load safety factor:

It is the minimum ratio admitted between the limit load of the foundation and the load transmitted by the weir in working conditions.

5 Ordinary concrete weir

The geometry of the weir made of ordinary concrete is defined with reference to the following figure:



Geometrical diagram of the concrete weir

With reference to the figure, the data the user must enter are the following:

HB [m]:

Weir body height

POSB [m]:

Distance between the face upstream the weir and the farthest edge upstream the foundation

LC [m]:

Crowining width

HC [m]:

Crowning height

SPV [°]:

Inclination of the downstream face with respect to the vertical (Angle measured as positive anticlockwise)

HFV [m]:

Downstream foundation height

LTF [m]:

Total foundation length

LT [m]:

Foundation cut-off wall width

ST [m]:

Inclination of the downstream cut-off wall wit respect to the vertical (Angle measured ass positive clockwise)

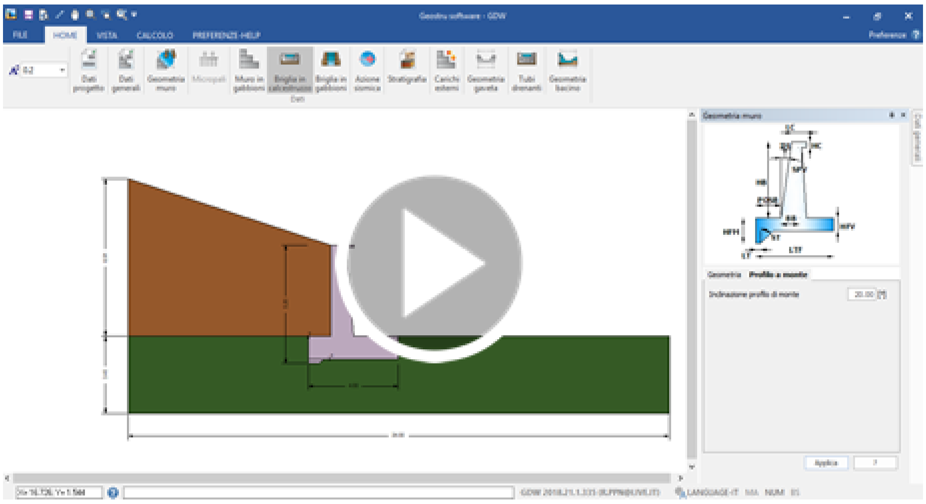
HFM [m]:

Upstream foundation height

BB [m]:

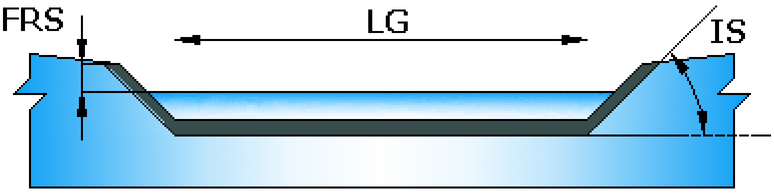
Base of the weir body

Besides, the concrete weir is completely defined when its specific gravity is defined in the general information.



6 Notch

The notch – necessary to allow an outflow so as to avoid the erosion of the banks of the river-bed near the weir – is defined with reference to the following figure:



Geometrical diagram of the notch

LG [m]

Width of the notch lesser base

IS [°]

Inclination of the chutes on the side of the notch *(Angle measured as positive clockwise)*

FRS [m]

Safety freeboard to be guaranteed in the most unfavourable case, measured as the vertical distance between the notch bottom and the highest point of its chutes.

7 Basin

The stilling basin is a work complementary to the weir and is used to dissipate a part of the energy of the stream. A stilling basin is made up of the following elements:

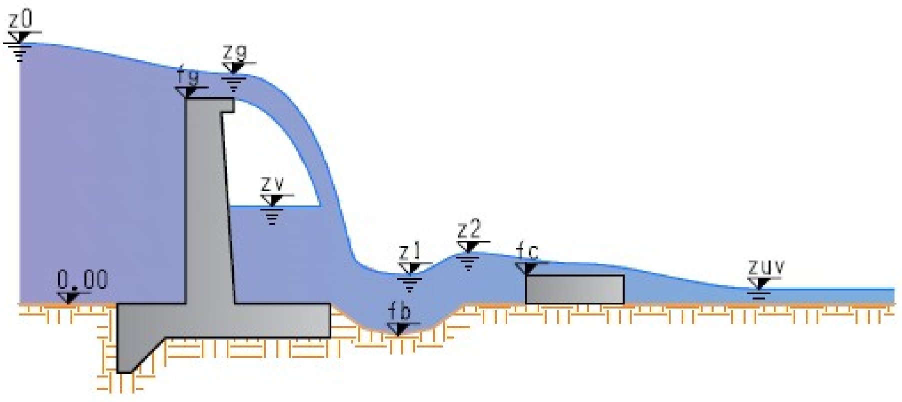
A basin coating

An auxiliary dam

In the framework considered by the GDW programme, we can distinguish four types of basins:

Basin not coated with auxiliary dam

In this case, the formation of the basin is due to the laying of an auxiliary dam downstream the weir. In this case, the basin is not coated (see the figure below):

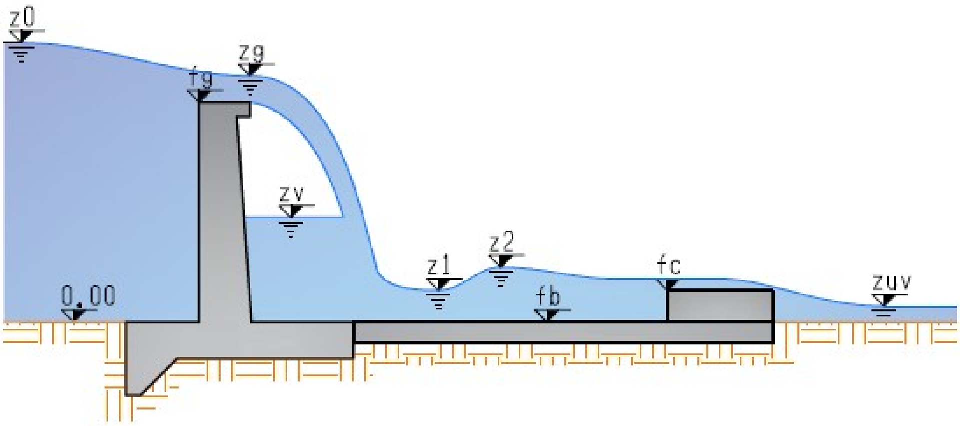


Basin not coated with auxiliary dam

It should be noticed that in this case the phenomenon of erosion is lessened, though not completely removed.

Embankment basin, coated with auxiliary dam

In this case, besides the laying of an auxiliary dam there is also a coating extending on the space included between the auxiliary dam and the downstream foot of the weir foundation (see following figure):

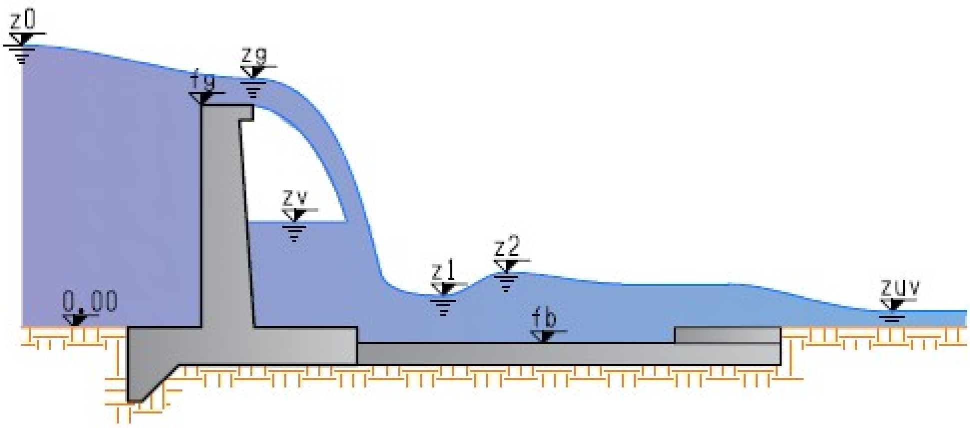


Embankment basin coated with auxiliary dam

In this case, the phenomenon of erosion is completely removed, since the coating material of the basin is extremely erosion-resistant.

Depression basin, coated with auxiliary dam

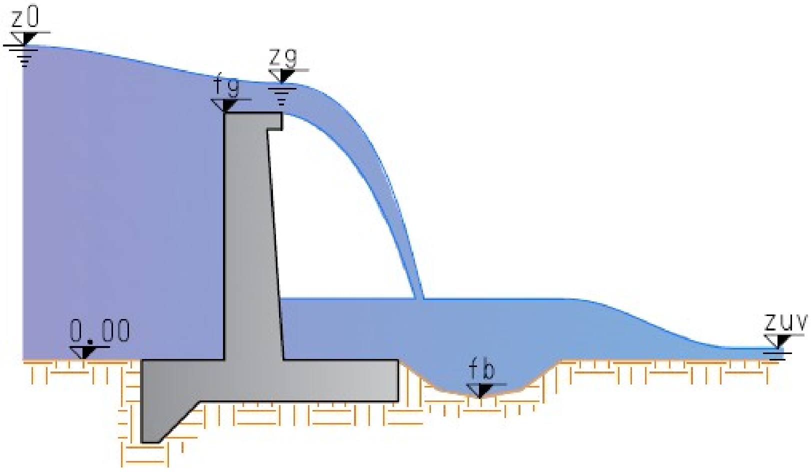
In this case, unlike for the embankment basin, the level of the basin surface is lower than the reference soil level, and the bottom level of the notch n the auxiliary dam coincides with the reference soil level (see following figure):



Depression basin coated with auxiliary dam

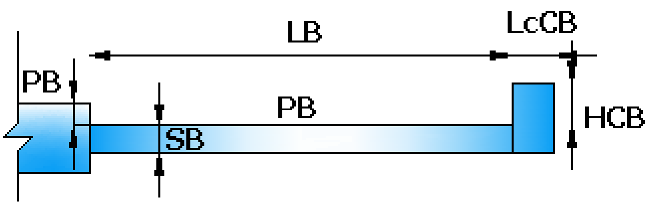
Absence of Basin and auxiliary dam

This is the most unfavourable case in terms of erosion. In fact, not only the bottom has scant capabilities of resistance to the phenomenon of erosion downstream the weir, but there is no stilling device. In this case, the main excavation depths shall be checked:



Absence of basin and auxiliary dam

As regards the input to be entered by the user, please refer to the following figure:



Geometrical data of the stilling basin

Where

LB [m]

Basin length

PB [m]

Basin bottom level with respect to the reference plane represented by the soil.

SB [m]

Basin thickness

HCB [m]

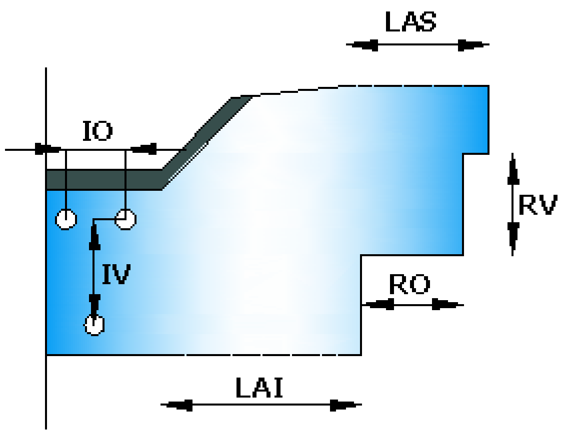
Height of the auxiliary dam measured from the reference plane represented by the soil.

LcCB [m]

Crowning width of the auxiliary dam.

8 Draining pipes

The function of the draining pipes is to lessen the effect of the thrust due to the presence of water, while the function of the anchoring structure is to guarantee that the weir is well anchored to the river banks where it must be installed. The input data relevant to the draining pipes and to the anchoring structures shall be entered according to the following diagram:



Draining pipes and anchoring input diagram

The meaning of the symbols is the following:

IO [m]

Horizontal spacing distance between the draining pipes

IV [m]

Vertical spacing distance between the draining pipes

LAI [m]

Length of the lower anchoring

LAS [m]

Length of the upper anchoring

RV [m]

Vertical offset

RO [m]

Horizontal offset

NB: the working order of a system of draining pipes is temporally limited to the first periods of life of the work, especially in the absence of a suitable maintenance programme. That is why the beneficial effect brought about by a system of draining pipes has been left out in the calculation of the equilibrium of the weir.

9 Stratigraphy

For the analysis of the model, it is necessary to define two layers of material.

A first layer of elevation material, according to which the thrusts are calculated
A second layer of foundation material, according to which the limit load of the foundation is calculated

For both layers, the user must enter the following quantities:

Material name

The name identifying the material

Weight [kN/m³]

The unit weight of the dry material

Saturated Weight [kN/m³]

The unit weight of the saturated material

Fi [°]

Angle of resistance to shearing stress of the soil

C [kN/m²]

Soil cohesion

Delta [°]

Angle of friction on the wall-soil interface

Adhesion [kN/m²]

Wall-soil adhesion

10 Seismic action

The seismic action is taken into account in the calculation through the *Mononobe & Okabe* theory. At the input level, the user must enter the horizontal and vertical earthquake factors:

k_h

Horizontal earthquake factor

k_v

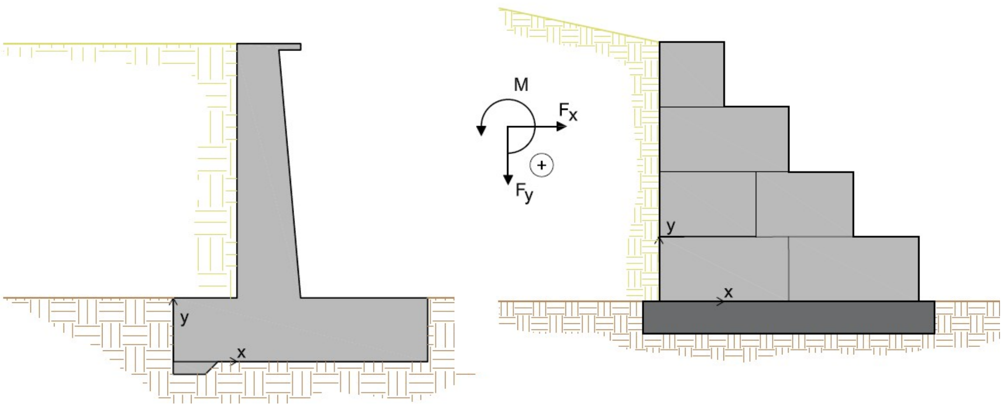
Vertical earthquake factor

xp/h

The ratio of the of the application point height of the seismic increase to the wall thrust height. This value is generally assumed as corresponding to 2/3.

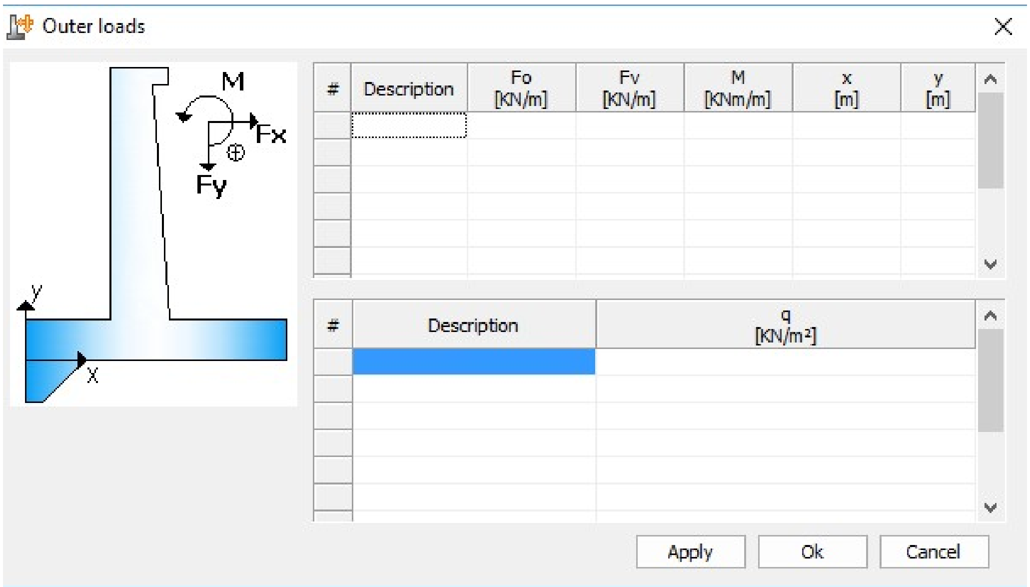
11 Outer loads

The user can enter further loads besides those calculated by default by the **GDW** programme. In particular, the user can enter concentrated horizontal forces, concentrated vertical forces and moments. It is also possible to enter loads uniformly distributed upstream the weir. The convention of positivity and the reference system with regard to which to define the forces are shown in the following figure:

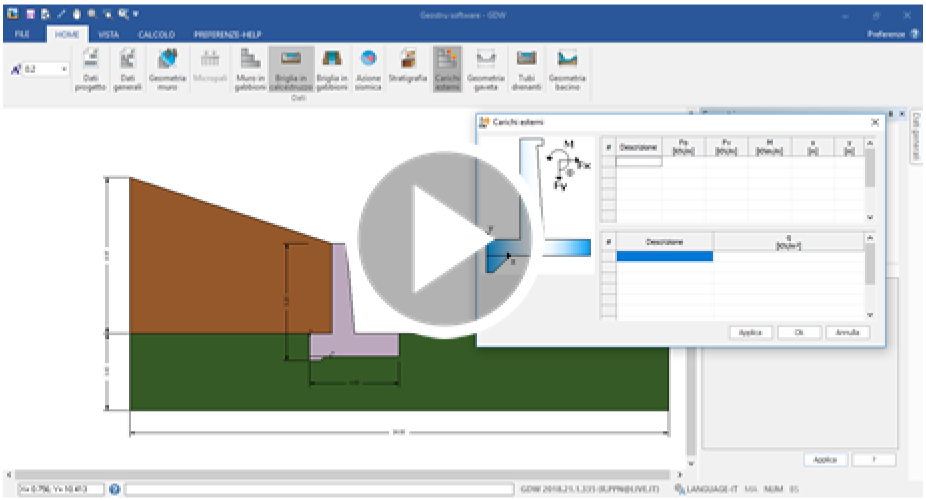


Convention of positivity and reference for the definition of outer loads

For loads distributed horizontally, the same convention of positivity as for concentrated loads (positive, when downwards) is valid. The units of measurement to be used are kN for forces and m for lengths (and consequently kNm for moments), and kN/m for distributed loads.



Environment for the management of the outer loads



12 Hydraulic test

In the hydraulic test, different quantities are calculated according to the type of stilling device adopted. Depending on the different cases, the expected results of the hydraulic calculation are the following:

Basin not coated with auxiliary dam

z0 [m]
Rise in the upstream water level
zg [m]
Water level on the notch *(NB: the water on the notch flows under critical state conditions)*
zv [m]
Reattachment level of the fluid vein on the face downstream
z1 [m]
Water level downstream the weir
fb [m]
Soil profile level at the distance of maximum excavation *(maximum excavation depth)*
z2 [m]
Rise in the water level immediately upstream the auxiliary dam
zum [m]
Current level downstream the weir under uniform motion conditions
lbmin [m]
Basin minimum length
hcbmin [m]
Minimum height of the auxiliary dam

Embankment basin, coated with aux. dam

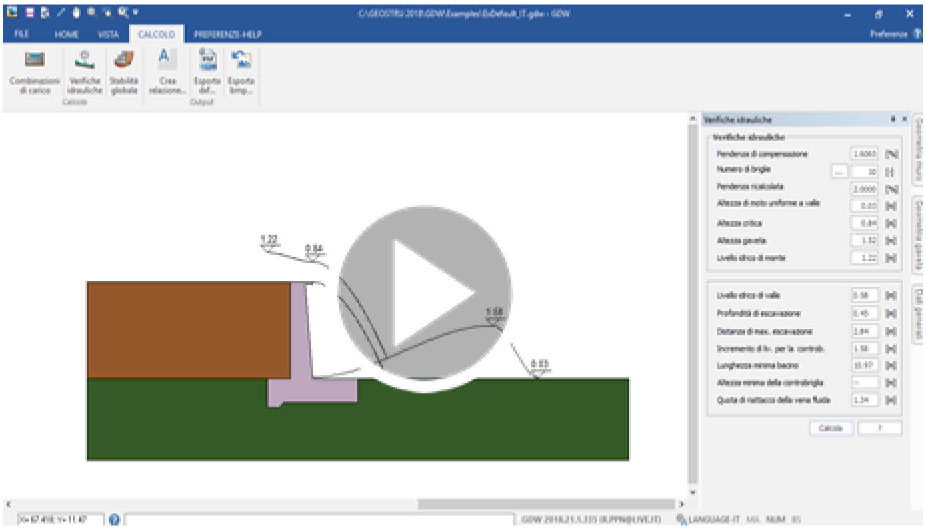
z0 [m]
Rise in the upstream water level
zg [m]
Water level on the notch *(NB: the water on the notch flows under critical state conditions)*
zv [m]
Reattachment level of the fluid vein on the downstream face
z1 [m]
Water level downstream the weir
z2 [m]
Rise in the water level immediately upstream the auxiliary dam
zum [m]
Current level downstream the weir under uniform motion conditions
lbmin [m]
Basin minimum length
hcbmin [m]
Minimum height of the auxiliary dam

Depression basin, coated with auxiliary dam

z0 [m]
Rise in the upstream water level
zg [m]
Water level on the notch *(NB: the water on the notch flows under critical state conditions)*
zv [m]
Reattachment level of the fluid vein on the downstream face
z1 [m]
Water level downstream the weir
z2 [m]
Rise in the water level immediately upstream the auxiliary dam
Zum [m]
Current level downstream the weir under uniform motion conditions
lbmin [m]
Basin minimum length
hcbmin [m]
Minimum height of the auxiliary dam

Absence of basin and auxiliary dam

z0 [m]
Rise in the upstream water level
zg [m]
Water level on the notch *(NB: the water on the notch flows under critical state conditions)*
zv [m]
Reattachment level of the fluid vein on the downstream face
zum [m]
Current level downstream the weir under uniform motion conditions.



13 Global equilibrium check

Overturning check

The overturning hazard is represented by the possibility for the weir to rotate around its point situated further downstream. In the case of the weir, the actions favouring the overturning are the (static and dynamic) earth thrusts as well as the water-related thrusts. The actions opposing the overturning are for the most part those due to the weight of the materials involved in the work (e.g. the weight peculiar to the weir). In terms of figures, the overturning check is executed carrying out a comparison between the stabilizing moment and the destabilizing moment. Expressed in formulas, the overturning check is the following:

$$\frac{M_s}{M_R} \geq FSR$$

Where M_s is the stabilizing moment, M_R is the overturning moment and FSR is the overturning safety factor which as a rule must be no lower than 1.5.

Sliding check

The sliding hazard is represented by the possibility for the resultant of the forces parallel to the soil-foundation contact plane to be higher than the resistance to sliding by friction. The actions favouring the sliding are – as in the previously described case – the (static and dynamic) earth thrusts as well as the water-related thrusts. The actions opposing the sliding, on the contrary, are those originating from the soil-foundation friction and adhesion. In mathematical terms, the sliding check is the following:

$$\frac{F_{rs}}{F_{ss}} \geq FSS$$

Where F_{rs} is the sliding-resistant force, F_{ss} s the sliding soliciting force and FSS is the sliding safety factor which as a rule must be no lower than 1.3.

Crushing check

The crushing hazard is represented by the possibility for the strain induced by the weir upon the foundation laying level to be higher than the strain in whose correspondence the breaking of the soil-foundation complex occurs. So, in mathematical terms, the check is executed by comparing the maximum strain acting upon the soil with the limit load of the soil-foundation complex:

$$\frac{Q_{\lim}}{Q_e} \geq FSQ\lim$$

Where Q_{lim} is the limit load of the foundation, Q_e is the strain transmitted *(for a particular load condition)* to the foundation ground and FSQlim is the crushing safety factor, which as a rule must be no lower than 2.

In case the la weir under examination belongs to the gabion weir type, the programme further carries out another two checks, called inner stability checks, namely:

• Check of the sliding on the interface between gabions

This check is executed I order to prevent – for a given interface between two gabions – the sliding between the group of gabions situated above the interface and the group of gabions situated below the interface from taking place. For each combination, the programme carries out the sliding check of each gabion layer, returning the minimum value of the safety factor. In mathematical terms, the check is executed using a formula similar to that described at the previous point *"Sliding check".*

- **Crushing check of the material making up the gabions**

This check is executed in order to prevent the material making up the gabions from being submitted to excessive compression strains, i.e. being such as to lead to a crisis by compression breaking. For each load combination, the programme carries out a check of each interface, returning the value of the minimum safety factor. In mathematical terms, the check to be carried out is the following:

$$\frac{\sigma_{am}}{\sigma_n} \geq FSch$$

Where sam is the admissible strain of the material and sn is the strain underwent by the material making up the weir, while FSch represents the crushing safety factor.

14 Siphoning check

Siphoning check

The difference in water level existing between the upstream part and the downstream part of the weir involves the possibility for the problem of siphoning to occur. By siphoning we mean that physical phenomenon capable of lifting the part of ground situated on the downstream toe of the weir, generating the collapse hazard for the work. The criterion followed in the programme consists in checking that the speed in the porous means is such – in each point - as not to remove then finest particles of the ground. In mathematical terms - calling the critical piezometric slope ic and the outflow piezometric slope i_e – the siphoning safety factor is expressed by:

$$Fs = \frac{i_c}{i_e}$$

Where:

$$i_c = \frac{\gamma_{sat} - \gamma}{\gamma}$$

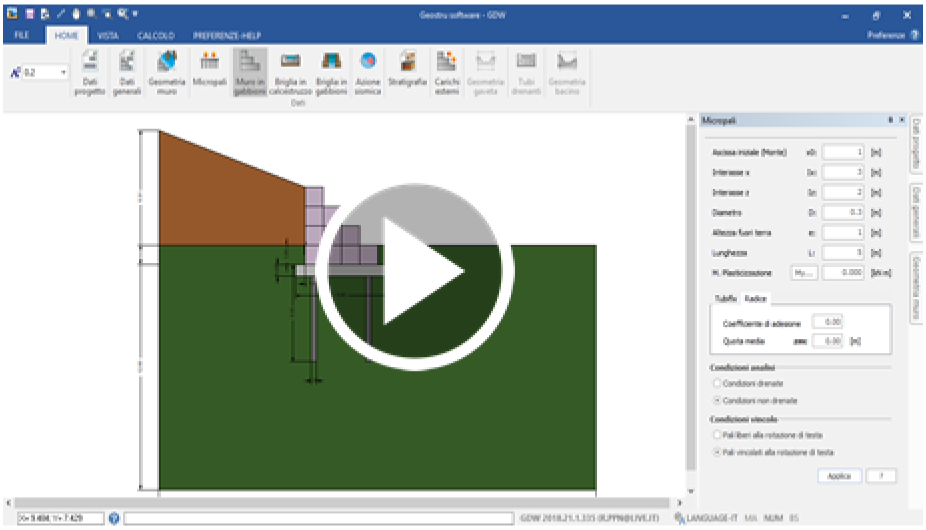
ie is the piezometric water slope calculated in the maximum hazard point for the siphoning, usually on the downstream toe of the work. The siphoning check can be executed with the aid of specially provided software which carries out the analysis of the filtration in a porous means. In order to execute the filtration analysis, proceed as follows:

1. From the calculation menu or from the relevant tool bar, select *"Filtration analysis"*;
2. A window will open through which you can generate a file compatible with the software used for the filtration analysis;
3. In the open window, select the type of weir for which you want to analyze the filtration *(Silted-up weir or Non-silted-up weir)*;
4. At this point, click on the Export button and select the path of the file to be exported;

15 Micropiles Calculation

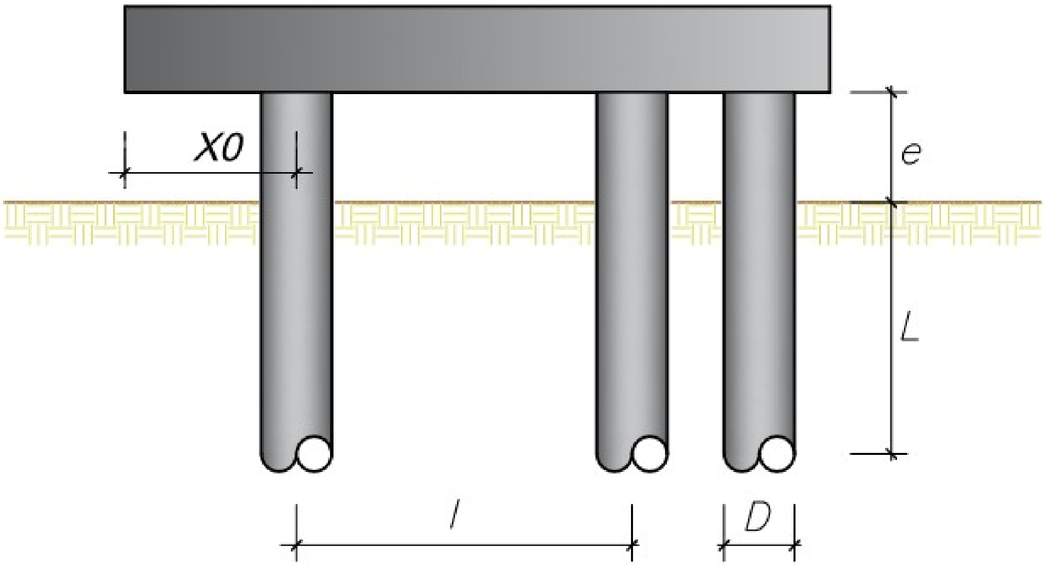
In GDW is possible to have a weir with micropiles.

IS IMPORTANT TO CONSIDER THAT THE SOFTWARE WILL EXECUTEs CHECK BOTH THE CONDITION WITH AND WITHOUT MICROPILES. THEREFORE, EVEN IF YOU WANT VERIFY WEIR (OR WALL) WITH MICROPILES THE SOFTWARE provides a safety factor A OVERTURNING OF SLEADING.

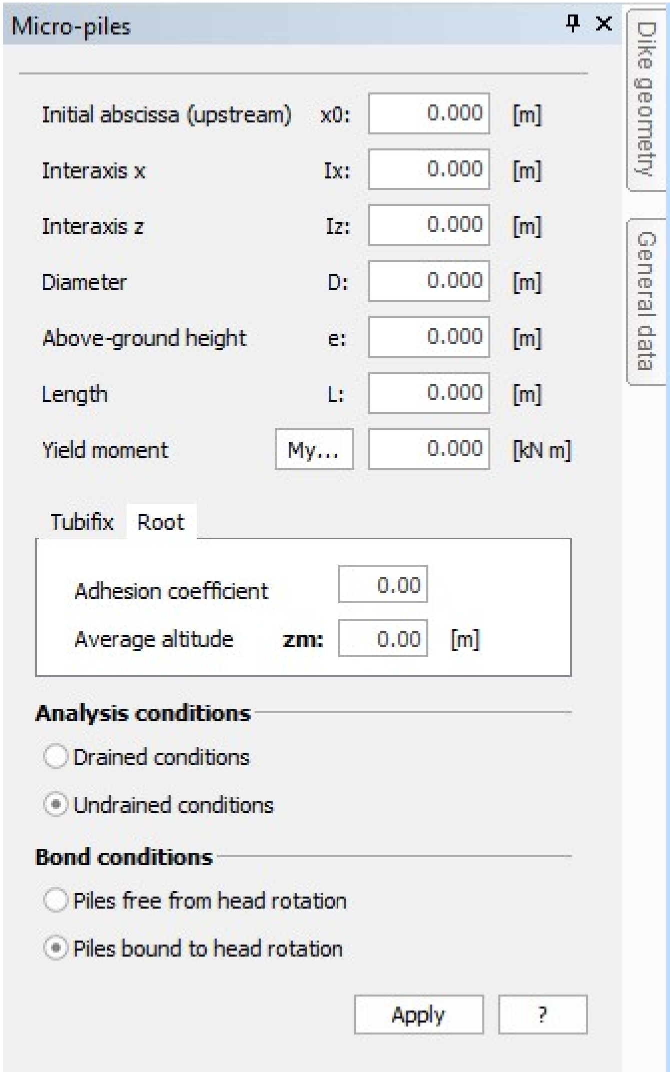


15.1 Input of the micropiles

The environment for the micropiles input management is the following:



Reference diagram for the definition of the micropiles geometry



Environment for the insertion of the micropiles data

The data to be entered are the following:

- **Initial abscissa (x0):**

It is the abscissa in whose correspondence the micropile must be inserted. It is inserted starting from upstream (the thrusting side) and is expressed in m;

- **Spacing distance x (Ix):**

It is the spacing distance between the piles, measured between the geometrical barycentre of the sections associated to the piles, in a horizontal direction (the direction contained in the board plane). It is expressed in m;

- **Spacing distance z (Iz):**

It is the spacing distance between the piles, measured between the geometrical barycentres of the sections associated to the piles in the direction normal to the drawing plane. It is expressed in m;

- **Diameter:**
It is the diameter of the micropiles used in the geotechnical calculation of the micropile (Limit load). It is expressed in m;

- **Above-ground height (e):**
It is the distance between the pile head and the natural surface level. In other words, it is the above-ground height of the pile. It is expressed in m;

- **Length (L):**
It is the working length of the pile (i.e. the length contributing to the resistance by limit load). It is expressed in m;

- **Yield moment (My):**
It is the yield moment of the section. Only steel is considered as reacting. It is expressed in kN per m;

- **Injection type:**
A necessary data for tubifix piles. It can be single or repeated;

- **Menard limit pressure:**
It is the limit pressure of the soil surveyed on site by means of a Menard pressure meter.

- **Alpha:**
It is the correction coefficient to be applied to the soil cohesion in case the micropile is a root-type pile. It is dimensionless.

- **Mean level:**
It is the level of the midpoint of the working length for calculating the limit load of the micropile. It is expressed in m;

- **Drained conditions:**
Tick off this option when you want to mould the ground as cohesive;

- **Undrained conditions:**
Tick off this option when you want to mould the ground as non-cohesive;

- **Pile from head rotation:**

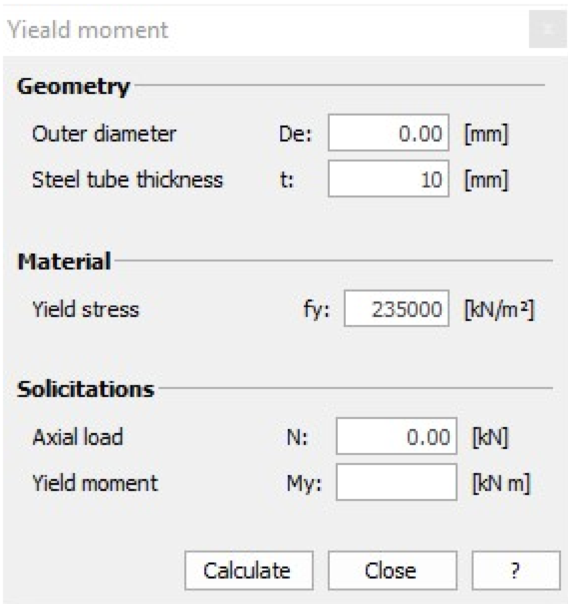
Tick off this option if the boundary conditions of the pile are such as to allow the rotation of the pile head without generating additional reactions.

- **Pile bound to head rotation:**

Tick off this option if the boundary conditions of the pile are such as to allow the rotation of the pile head, and consequently generating embedment reactions.

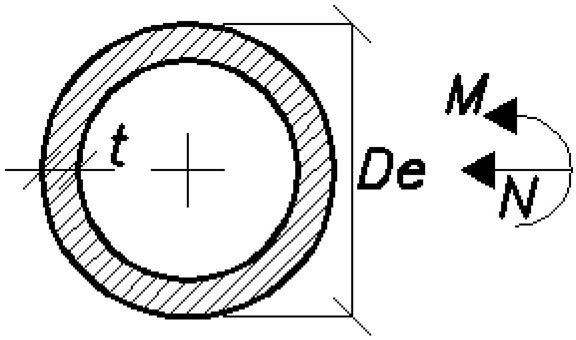
15.2 Calculation of the yield moment

The yield moment is used for calculating the horizontal limit load of the micropiles. An instrument is specially provided for calculating the yield moment. The environment for the calculation of the yield moment is the following:



Environment for the calculation of the yield moment of the micropile

The diagram to refer to is the following:



Geometry of the section and solicitation convention

The data to be entered are the following:

Outer diameter (De):
The outer diameter of the section, expressed in mm;

Tubular rod thickness (t):
It is the thickness of the sheet constituting the tube, expressed in mm;

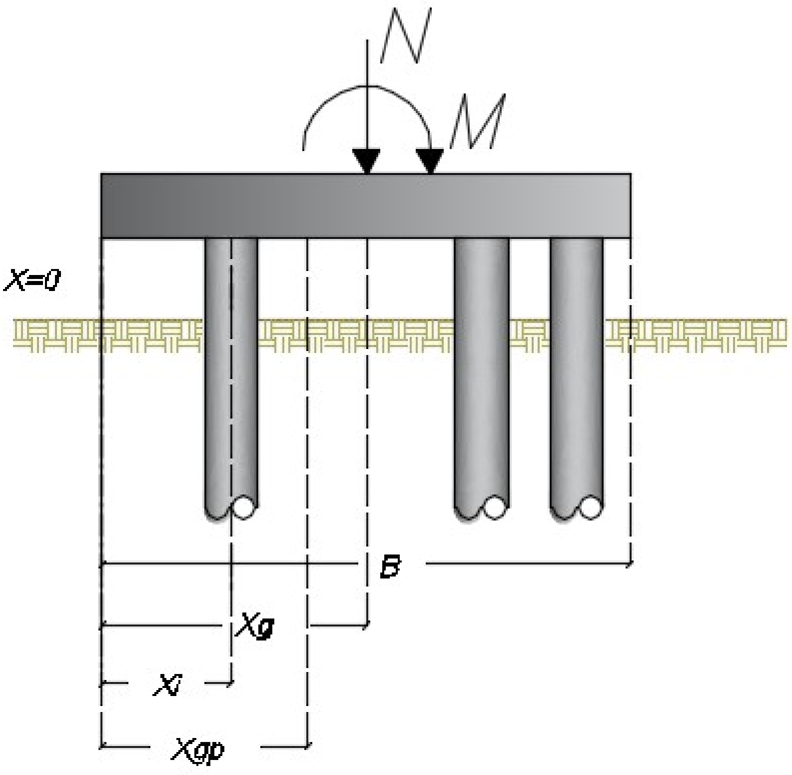
Yield stress:
It is the limit yield stress for the calculation of the moment. This data is adequate since it assumes a constitutive rigid plastic binding for the material.

Normal stress:
It is the outer normal stress in whose correspondence to determine the yield moment. It is expressed in kN

Yield moment:
It is the yield moment searched for. It is expressed in kN per m.
According to the convention, the normal stress is positive when due to compression and the bending moment is positive if it strains the lower fibres of the section.

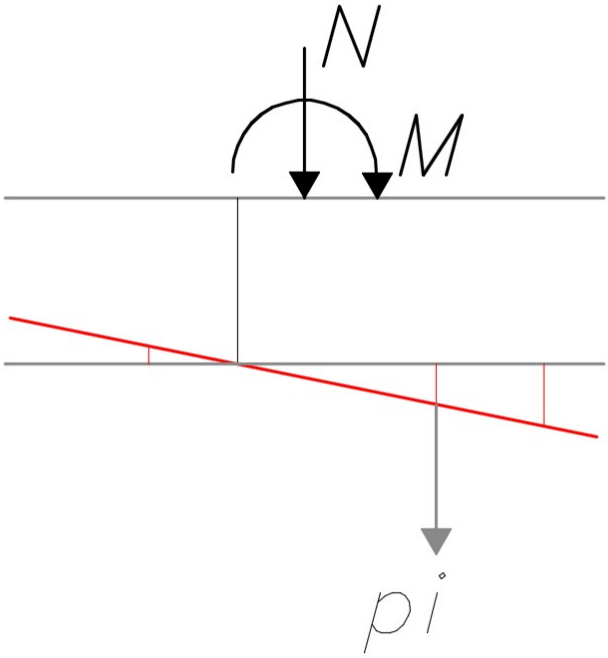
15.3 Distribution of the vertical actions on the micropiles

In order to execute the check on the limit load of the generic micropile it is necessary to determine the rate of vertical rate and moment which is going to be absorbed by the generic micropile. In order to do this, you must refer to the following calculation diagram:



Reference diagram for the distribution of stresses

Where N and M are the actions unloaded by the superstructure *(in this case, the weir body)*. The previous diagram is used to distribute the stresses upon the micropiles. The distribution of stresses is achieved assuming that the foundation connected to the micropiles is infinitely rigid, so that the distribution itself can be considered as having a linear course:



Linear course of the piles reaction

In order to evaluate the stress loaded onto a single micropile it is necessary to previously determine the eccentricity of the normal stress N with respect to the barycentre of the piling *(identified by the coordinate x_{gp})*. Said eccentricity is evaluated through the following formula:

$$e = \frac{M}{N} + \left(x_{gf} - x_{gp}\right)$$

The additional term (x_{gf}-x_{gp}) allows taking into consideration the event that the geometrical barycentre of the piling and the geometrical barycentre of the foundation are not coincident. At this point it is possible to apply the following formula:

$$p_i = \frac{N}{np} + N \cdot e \cdot \frac{\left(x_i - x_{gp}\right)}{J_x}$$

Where np is the number of piles, x_i is the la coordinate x of the ith pile with regard to the global reference origin, pi is the vertical unloading upon the ith pile, J_x is the moment of inertia of the piling with respect to its barycentre, evaluated though the following formula:

15.4 Distribution of the horizontal actions upon the micro-piles

For the determination of the limit load horizontal too it is necessary to distribute the actions at the level of each single micro-pile. In this case, the distribution is carried out using the following formula:

$$H_i = \frac{H_t}{n_p}$$

Where Hi is the horizontal unloading upon each single micro-pile, np is the number of micro-piles and Ht is the total horizontal resting load.

15.5 Vertical ultimate capacity

The evaluation of the vertical ultimate capacity of the micro-pile depends on the type of micro-pile considered. In the present work we consider root-type micro-piles and Tubifix micro-piles.

Root-type micro-piles:

The vertical ultimate capacity is expressed through the following formula:

$$V_{\lim} = \pi \cdot d \cdot L_p \cdot \tau_{\lim}$$

So it is expressed as the product between the side area of the pile and the limit tangential strain on the pile-soil interface. The τ_{lim} is evaluated through the following formula:

$$\tau_{\lim} = \gamma_t \cdot z_m \cdot K_0 \cdot \tan(\phi) + \alpha \cdot c$$

Where γ_t is the specific gravity of the soil, z_m is the level of the midpoint of the pile working length, K_0 is the lateral pressure coefficient at rest, ϕ is the angle of inner friction of the soil, a is a dimensionless adhesion coefficient and c is the foundation soil cohesion.

Tubifix micro-piles:

In this case too, the vertical ultimate capacity is expressed through the following formula:

$$V_{\lim} = \pi \cdot d \cdot L_p \cdot \tau_{\lim}$$

In this case, however, a different method is used to calculate the limit interface t. In particular, Bustamante’s theory is used. According to said theory, the limit tangential strain is calculated as follows:

• **if F is different from zero:**

$$\tau_{\lim} = \frac{p_{\lim}}{10}$$

• **if F is equal to zero and if c is higher than zero:**

Two events can occur depending whether it is a question of a single or repeated injection:

Single injection:

$$\tau_{\lim} = 0.033 + 0.067 \cdot p_{\lim}$$

Should the limit strain so calculated turn out to be lower than the value of 0.5, then the following formula must be used:

$$\tau_{\lim} = 0.133 \cdot p_{\lim}$$

Repeated injection:

$$\tau_{\lim} = 0.095 + 0.085 \cdot p_{\lim}$$

Should the limit strain so calculated turn out to be lower than the value of 0.5, then the following formula must be used:

$$\tau_{\lim} = 0.275 \cdot p_{\lim}$$

In all the previous formulas, $p_{\lim}$ is the limit pressure detected by Ménard's pressure meter inserted in N/mm².

15.6 Horizontal limit capacity

The horizontal limit capacity is evaluated for cohesive soils and non-cohesive soils.

Cohesive soils:

• **Piles not bound to head rotation - short pile breaking mechanism:**

$$H_{\lim} = 9 \cdot c_u \cdot d^2 \cdot \left(-\left(1.5 + \frac{L}{d} + 2 \cdot \frac{e}{d}\right) + \sqrt{\left(2 \cdot \left(\frac{L}{d}\right)^2 + 4 \cdot \left(\frac{e}{d}\right)^2 + 4 \cdot \frac{L \cdot e}{d^2} + 6 \cdot \frac{e}{d} + 4.5\right)} \right)$$

$$M(H_{\lim}) = \left(4.5 \cdot \left(\frac{L}{d}\right)^2 - 10.125\right) \cdot c_u \cdot d^3$$

- **Piles not bound to head rotation - long pile breaking mechanism:**

$$H_{\lim} = -9 \cdot c_u \cdot d^2 \cdot \left(1.5 + \frac{e}{d}\right) + 9 \cdot c_u \cdot d^2 \cdot \sqrt{\left(\left(\frac{e}{d}\right)^2 + 3 \cdot \frac{e}{d} + \frac{2 \cdot My}{9 \cdot c_u \cdot d^3} + 2.25\right)}$$

- **Piles bound to head rotation - short pile breaking mechanism:**

$$H_{\lim} = 9 \cdot c_u \cdot d \cdot (L - 1.5 \cdot d)$$

- **Piles bound to head rotation - long pile breaking mechanism:**

$$H_{\lim} = c_u \cdot d^2 \cdot \left(-13.5 + \sqrt{\left(182.25 + 36 \cdot \frac{My}{c_u \cdot d^3}\right)}\right)$$

Non-cohesive soils:

- **Piles not bound to head rotation - short pile breaking mechanism:**

$$H_{\lim} = \frac{k_p \cdot \gamma_t \cdot d \cdot L^3}{2 \cdot (e + L)}$$

$$M(H_{\lim}) = H_{\lim} \cdot \left(e + \frac{2}{3} \cdot 0.816 \cdot \sqrt{\frac{h}{k_p \cdot \gamma_t \cdot d}}\right)$$

- **Piles not bound to head rotation - long pile breaking mechanism:**

In this case, it is necessary to solve the following third-degree equation in $H_{\lim}$:

$$\frac{H_{\lim}}{k_p \cdot \gamma_t \cdot d^3} \cdot \left(\frac{e}{d} + 0.544 \cdot \sqrt{\frac{H_{\lim}}{k_p \cdot \gamma_t \cdot d^3}}\right) - \frac{My}{k_p \cdot \gamma_t \cdot d^4} = 0$$

- **Piles bound to head rotation - short pile breaking mechanism:**

$$H_{\lim} = 1.5 \cdot L^2 \cdot k_p \cdot \gamma_t \cdot d$$

$$M(H_{\lim}) = \frac{2}{3} \cdot H_{\lim} \cdot L$$

- **Piles bound to head rotation - long pile breaking mechanism:**

$$H_{\lim} = k_p \cdot \gamma_t \cdot d^3 \cdot \left(3.676 \cdot \frac{My}{k_p \cdot \gamma_t \cdot d^4} \right)^{\frac{2}{3}}$$

For the meaning of the symbols, it is advisable to refer to the *"Micro-piles Input"* and *"Yield Moment Calculation"* sections.

16 Geoapp

Geoapp: the largest web suite for online calculations

The applications present in Geostru Geoapp were created to support the worker for the solution of multiple professional cases.
Geoapp includes over 40 applications for: Engineering, Geology, Geophysics, Hydrology and Hydraulics.

Most of the applications are **free**, others require a monthly or annual **subscription**.

Having a subscription means:

- access to the apps from everywhere and every device;
- saving files in cloud and locally;
- reopening files for further elaborations;
- generating prints and graphics;
- notifications about new apps and their inclusion in your subscription;
- access to the newest versions and features;
- support service throught Tickets.

16.1 Geoapp Section

General and Engineering, Geotechnics and Geology

Among the applications present, a wide range can be used for **GDW**. For this purpose, the following applications are recommended:

- Gabion
- Draining trenches
- Hydraulic invariance
- River bed protection, Riprap
- Hydraulic behaviour

17 Contact

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