# Mast Foundation FDM+

## Contents



## Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage www.frilo.com in the Campus-download-section.

# Application options

Mast foundations are typically pad foundations that are embedded in the ground. The foundations are loaded by moment in the first place. Their stability is ensured by the earth resistance. The serviceability analysis of these foundations is performed in accordance with the subgrade reaction modulus method published by Sulzberger in Switzerland in 1945. The subgrade reaction modulus depends on the foundation thickness and the angle of inner friction (equation (3) in the article by Steckner mentioned below). It is determined by the software in accordance with this method. Sebastian Steckner published the article “Gebrauchstauglichkeits- und Standsicherheitsnachweis für eingespannte Blockfundamente” (serviceabilty verification and stability verification of restrained pad foundations) in the Bautechnik magazine (66/1989, p. 55). In this article, he corrects the discrepancies in Sulzberger's theory and makes clear what happens in the transition area when the base friction is overcome. Furthermore, he enhances Sulzberger's method in regard to sloped ground surfaces and establishes a relation between the subgrade reaction modulus and the earth pressure coefficient. Moreover, he describes a calculation model for the stability verification. The verifications of the serviceability and the stability are performed in accordance with the specifications of this article. In addition to these verifications, the software performs the design of the foundation. Uniaxially loaded pad foundations (loaded by N, M, H) with dimensions in the range of 2/3 < D/A <= 4 (A = width in loading direction and D = foundation thickness) can be verified with the method described by Steckner. These criteria help distinguishing the foundations to be verified from flat foundations, mast footings and wall-type foundations.

In addition to Steckner's article, the FDM+ program identifies biaxially loaded systems. Any number of soil layers and four-sided different terrain as well as groundwater can be defined. The procedure differs from the article as follows: The two design directions X and Y are determined depending on the sign of the resulting moment at the column base. The earth pressure acting on each of the four outer sides is then determined and the foundation is clamped into the ground all around. Active and passive earth pressure act to clamp the foundation in place, friction acts on the respective front sides via earth pressure at rest and base friction is also activated and overcome if necessary. The percentage of a foundation side that is subject to active or passive earth pressure or earth pressure at rest is determined using the angle omega of the resulting moment in the plan view. The height of a neutral axis is determined iteratively, in which the sum of the horizontal forces at the angle omega is close to 0. The resisting moment is then calculated from the resulting earth pressures and compared with the acting moment in the stability analysis. The safety factors for actions and resistances of the selected design standard are used. The serviceability is verified using averaged soil layer parameters, as in the article. Optionally, the output in the program's output profile can be made step by step more detailed, so that the calculation result is derived from the intermediate results and the formulas used. The passive earth pressure above the neutral axis can optionally be relocated and limited as a percentage. It is also subject to a limit determined by the program, so that no lifting base pressure resultant can occur mathematically.

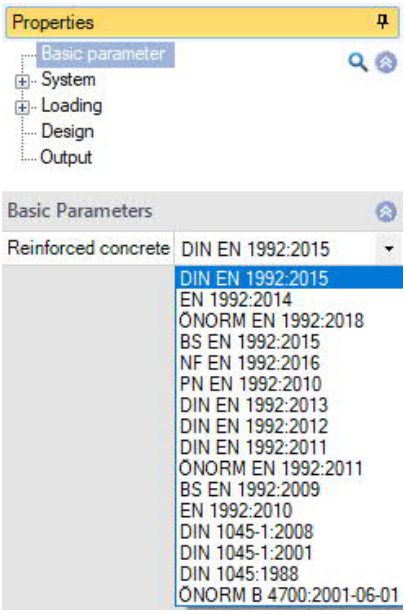
!! *Attention:* *The FDM+ Mast Foundation software allows you to verify foundations of all kinds of masts and towers as well as of columns for noise-protection walls, signal boards and similar structures. If the defined loads and dimensions of the structural system produce a deviating load-bearing behaviour another calculation method is required and you should use the appropriate application program.*

# Basis of calculation

## Available standards

Select the desired reinforced concrete standard here. All other required standards will automatically be used in the correct version.

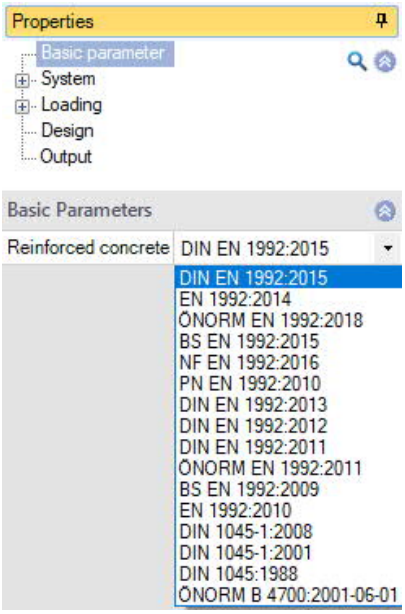
- EN 1992: 2010/2014
- DIN EN 1992: 2011/2012/2013/2015
- ÖNORM EN 1992: 2011/2018
- BS EN 1992: 2004/2009/2015
- NF EN 1992:2016
- PN EN 1992: 2010




- Bautechnik 66 (1989), H. 2
- Older standards (DIN 1045-1, ÖNORM B4700) are also available for selection.
- Bautechnik 66 (1989) H.2 Wilhelm Ernst & Sohn Publishing House for Architecture and Technical Sciences

FDM+ offers support for all 3 verification methods according to Eurocode 7, adjustable for all national annexes.

# Data entry




You can enter values and define control parameters in the menu on the left screen section. The effect of the entered values is immediately shown in the graphical representation on the right screen section. Before entering any data, you can edit the dimensional units (cm, m ...) via the options File
▸ Program options.

## Assistant/Wizard

The assistant (formely called wizard) is automatically launched when you start the software. You can disable the wizard in the settings menu.

## Input options in the three-dimensional GUI

The data entry via the GUI is described in the document
Basic Operating Instructions-PLUS.

# Basic parameters

## Reinforced Concrete

Select the desired reinforced concrete standard.

# Structural system

## Material

Selection of normal or lightweight concrete as well as the concrete quality and reinforcement steel grade for the foundation.

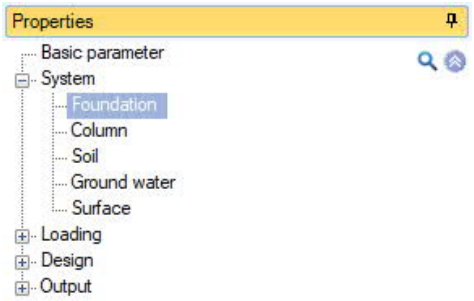
## Location foundation

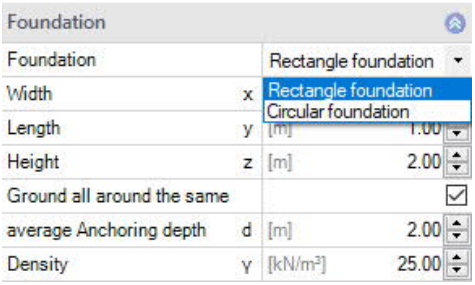
The global position related to the foundation axis is only required for communication with other programs such as GEO and SBR+.

## Remarks

Click on the  button, to enter your own comments to the system.

## Foundation

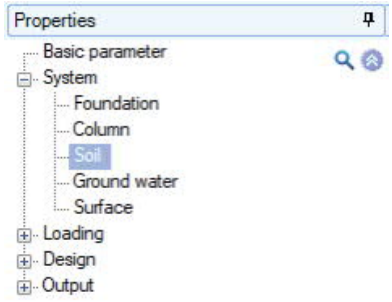



In the foundation plan view, the x-axis (positive) runs from the left to the right and the y-axis (positive) from the bottom to the top.

| | |
|---|---|
| Foundation | rectangle or circle |
| Width | foundation dimension in the x-direction |
| Length | foundation dimension in the y-direction |
| Diameter | foundation dimensions for circular shape |
| Height | foundation height |
| Ground all around the same | Define here whether the terrain around the foundation should be equal everywhere. This setting influences the earth pressure calculation and can influence the ground failure calculation. |
| Average Anchoring depth | Minimum foundation depth below ground level. |
| Density $\gamma$ | specific weight of the concrete |

## Column




Information about the column (rectangular or circular, geometry and reinforcement layer).

## Soil

### Soil properties

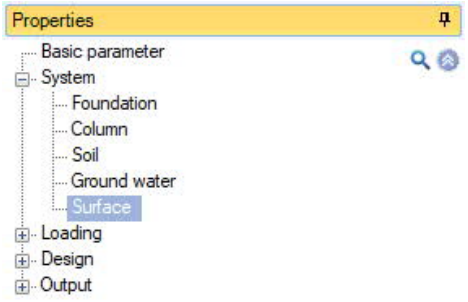

| | |
|---|---|
| Stroke weight $\gamma$ | specific weight of the soil |
| Buoyant unit weight | Effective weight density of the soil layer. Define groundwater to use this input value. |
| Base friction angle $\phi$ | friction angle of the soil above or underneath the foundation base. |
| Cohesion c′ | Cohesion intercept |

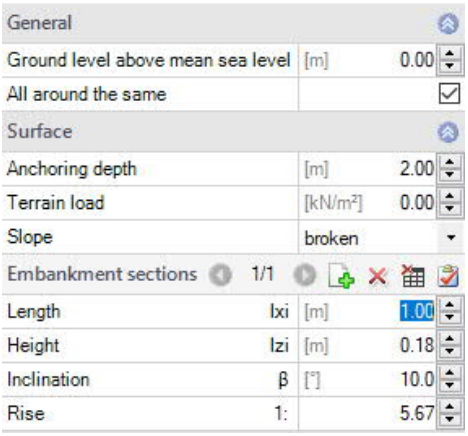
Use the dialog button to open a table for entering (further) soil layers.

## Ground water

For groundwater, select the Groundwater present option and enter the groundwater level. Define negative values for groundwater below the foundation level.

## Surface




Ground level above sea level
: The ground level above sea level refers to the upper edge of the earth embankment on the left side of the foundation or in the negative X area. It is positive for ground above sea level.

All around the same
: The ground can be defined differently for each of the four foundation front sides. To do this, remove the tick from the "All around the same" option - the input will be expanded accordingly.

Anchoring depth
: Embedment depth of the foundation body.

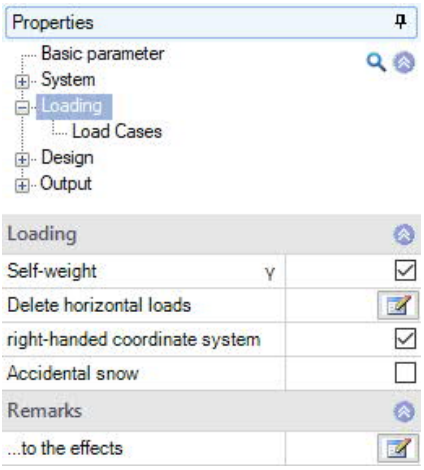
Terrain load
: Additional characteristic permanent ground load on the bearing capacity figure, which increases the characteristic punching shear resistance.

Slope
: The top edge of the ground can be modeled horizontally, with a continuous inclination or a broken slope.

- Continuous:
Here you can define a berm and the inclination.

- Broken:
Entry of the slope sections. A new table row is created for a further section using the "+" symbol. Parameters are length, height or inclination or gradient (the height adjusts automatically based on the inclination).

## Loads




Self-weight γ
: The self-weight is automatically considered. If there is groundwater above the base, the dead weight cannot be deactivated.

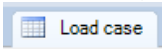
Delete horizontal loads
: the button allows you to delete all horizontal loads with a mouse click!
This function is helpful when you have imported many load cases from other application programs (GEO, B5 etc.).

right-handed coordinate system (new standard)
: Coordinate system, which is also known as the right-handed coordinate system or right-hand rule. It corresponds to the sign definition of technical mechanics. Positive moments rotating around the X axis generate pressure at the bottom or in the negative Y area of the foundation. Positive moments rotating around the Y axis generate pressure to the right or in the positive X area of the foundation. If this option is deactivated (previous definition in the program), positive moments generate pressure at the top right or in the positive X/Y area of the foundation. In the graphic, the numbers for both variants are shown with their absolute values, the arrows are used to show the actual direction of action. The numbers in the input fields and in the output are signed. If the sign definition is changed, the sign of the moments around the X axis changes.

Accidental snow
: If the option is selected, the snow loads are also considered as accidental effects in addition to the normal design situations. The load factor for the accidental snow loads can be freely specified or automatically determined by the program. The default value is 2.3.

*Note:* *The horizontal loads of the individual load cases can be defined and edited via the menu item "Load cases".*

## Load cases

Enter the data of the first load case either in the corresponding data-entry mask or directly in the load case table, which you can display below the graphic by activating the 

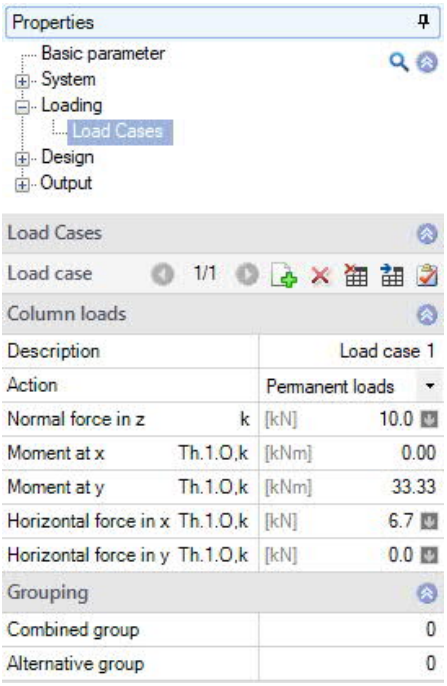
tab.

Load case toolbar: 

see Data entry via tables (Basic Operating Instructions).

To add load cases, always set up a new load case first by activating the  button (a data-entry mask for the new load case is displayed each time).

*Tip:* *A description is displayed in the status line each time you click into a particular data-entry field.*



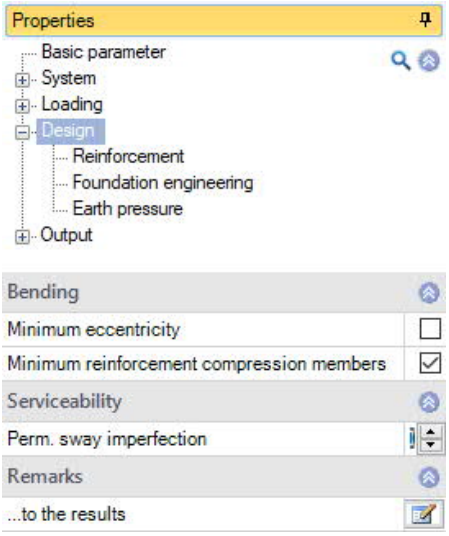

| | |
|---|---|
| Description | allows you to enter a short designation for the load case |
| Action | category or kind of action of the load |
| Vertical force in z | vertical force (characteristic value) |
| Moment about x/y | moment (characteristic value) about the x/y-axis |
| Horizontal force in x/y | horizontal force (characteristic value) in the x/y-direction |
| Simultaneous group | assignment of the load to a group of loads acting simultaneously. The group is defined by a group number entered by the user.<br>Loads that are assigned to the same concurrent group always apply simultaneously. Loads in a concurrent group must also be member of an action group. |
| Alternative group | assignment of the load to a group of loads excluding each other.<br>The group is defined by a group number entered by the user. |

## Load value compilation

By clicking on the arrow icon  you can access a load value compilation.

# Design

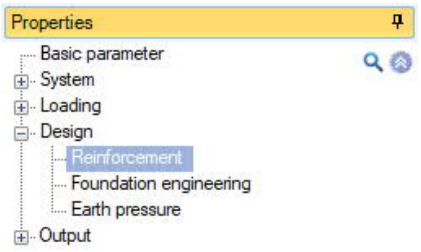
| | |
|---|---|
| Minimum eccentricity | Consideration of minimum eccentricities for compression members according to EN 1992-1-1 6.1 (4). |
| Minimum of reinforcement | minimum reinforcement for a ductile behaviour of the structural component |
| Perm. Sway imperfection | For the obliquity of the foundation, values of 0.01 for overhead line masts or 0.005 for overhead line masts can be permitted. However, at 0.01, displacements are already reached that can lead to the development of the full passive earth pressure and thus to permanent deformation of the soil. Wherever a permanent obliquity is undesirable, values greater than 0.005 should not be permitted. |

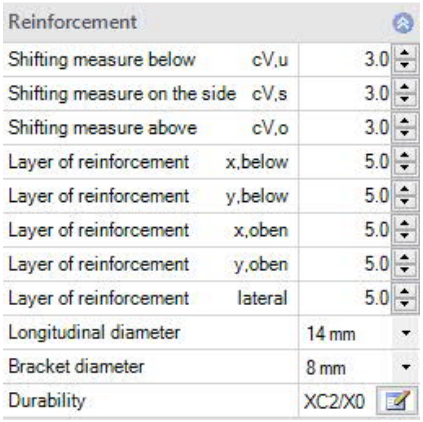



## Remarks

Click on the  button, to enter your own comments.

## Reinforcement




cV,u
: Laying measure of the specified reinforcement on the underside of the foundation. The specified reinforcement is constructed into the foundation body according to this laying measure. 2D and 3D graphics are created based on this.

cV,s
: Laying measure of the specified reinforcement on the outer sides of the foundation.

cV,o
: Laying measure of the specified reinforcement on the upper side of the foundation.

Reinforcement layer
: Center of gravity of the reinforcement at the bottom in the X or Y direction. This value is used for the reinforced concrete verifications. After calling up the durability dialog, this value is adjusted if necessary.

Longitudinal diameter
: List selection of the longitudinal diameter with which the reinforcement is to be generated. With this diameter, the program starts to generate reinforcement that covers the required reinforcement. If the minimum and maximum bar spacing cannot be achieved with the selected diameter, larger diameters are used.

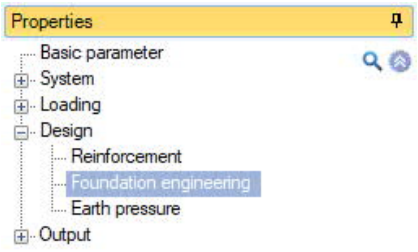
Braket diameter
: Minimum diameter of stirrup reinforcement.

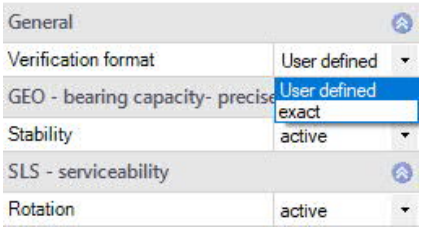
Durability
: Use the button  to call up the dialogs for durability. If you exit this dialog with OK, the concrete covers, reinforcement layers and diameters are checked and adjusted if necessary.

## Foundation engineering

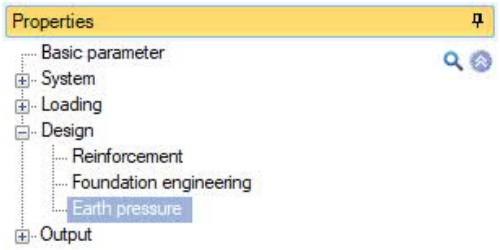
Verification format
: Define here whether a
- precise verification or a
- user-defined verification

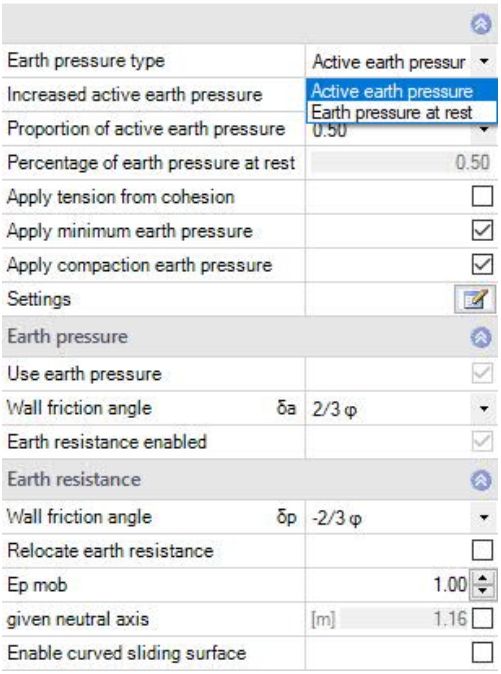
should be carried out.
The precise verification format includes a bearing capacity verification, a sliding safety verification and a settlement calculation.



## Earth pressure




Earth pressure type
The earth pressure can be calculated either for the active or the resting state.

Increased active earth pressure
Increased active earth pressure must be applied if the wall movement is not sufficient to trigger the active earth pressure limit state or to maintain it throughout the entire service life of the structure.

Tension from cohesion...
Calculated tensile stresses from cohesion may not be used for walls that are not supported or only flexibly supported and that rotate around their base or a lower point (EAB EB4, paragraph 3). For building pit walls that are not supported flexibly and where a relocation is expected, calculated tensile stresses from cohesion may be used to verify the need for the minimum earth pressure (EAB EB4, paragraph 5). The program calculates the earth pressure for walls that rotate around their base, which is why tensile stresses from cohesion should not normally be used.

Apply minimum earth pressure
If the minimum earth pressure is taken into account, it is verified in each cohesive soil layer whether the earth pressure resulting from the soil's own weight and a shear strength corresponding to φ = 40 ° c = 0 is decisive. Calculation according to EAB (= recommendations of the "Building pits" working group), 5th Edition.

Apply compaction earth pressure
If soil is installed in layers and then intensively compacted, the earth pressure increases beyond the earth pressure from the soil's own weight.
The parameters for compaction earth pressure can be defined using the "Settings" button:
The compaction earth pressure for intensive and light compaction is calculated according to DIN 4085:2017. The approach for light compaction (vibration plate with an operating mass of up to 250 kg) according to DIN 4085:2017 corresponds to the approach according to Franke (Franke, D., Compaction earth pressure for light compaction, BAUTECHNIK 85 (2008) No. 3, pp. 197 - 198).
Curved sliding surfaces: the depth zp from which the full compaction earth pressure is applied is determined by comparing the compaction earth pressure with the passive earth pressure. The corresponding passive earth pressure coefficient can be determined assuming linear or curved sliding surfaces.

δp
Wall friction angle.

Relocate the earth resistance
Relocate the earth resistance according to DIN 1054:2021 Figure A 6.5.4.

Ep mob
The mobilized component of the characteristic earth resistance.

Default neutral axis
Specify the neutral axis here. Normally the neutral axis is where it produces a sum of the horizontal loads of 0.

Apply curved sliding surfaces
For passive earth pressure, the assumption of linear sliding surfaces is no longer applicable under the following conditions: $|\alpha + \delta| < \beta$ and $\varphi > 35°$. The earth pressure coefficients for curved sliding surfaces are determined according to DIN 4085 Appendix C. The representation is always linear.

# Output

## Output scope and options

By selecting the various options, you determine the scope of the text output. The font size and scale can be adjusted for the graphics.

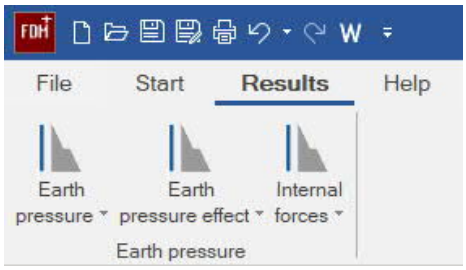
## Output as PDF document

Activating the Document tab allows you to display the document in PDF format.

See also the document Output and printing.

## Result graphics

You can view result graphics via the “Results” tab.




## Allplan Export

Under File – Export you can export a file that can be imported into Allplan.