

# Mast Foundation FDM+

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#### Basic Documentation – Overview

In addition to the individual program manuals, you will find basic explanations on the operation of the programs on our homepage <u>www.frilo.com</u> 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 "Gebrauchstauglichkeitsund 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.

Properties		7
Basic parameter ⊕ System ⊕ Loading Design Output	٩	0
Basic Parameters		0
Reinforced concrete	DIN EN 1992:2015	•
	EN 1992:2013 EN 1992:2014 ONORM EN 1992:2018 BS EN 1992:2015 PN EN 1992:2010 DIN EN 1992:2010 DIN EN 1992:2011 ONORM EN 1992:2011 ONORM EN 1992:2011 BS EN 1992:2010 DIN 1045-1:2009 EN 1992:2010 DIN 1045-1:2001 DIN 1045-1:2001 DIN 1045-1:2001	Ş-01



### 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 <u>assistant</u> (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 <u>Basic Operating Instructions-PLUS</u>.

**Basic parameters** 

#### **Reinforced Concrete**

Select the desired reinforced concrete standard.

Properties	д
Basic parameter	9.0
i System	
🗄 - Loading	
Design	
Output	

Basic Parameters		0
Reinforced concrete	DIN EN 1992:2015	•
	DIN EN 1992:2015 EN 1992:2014 ONORM EN 1992:2018 BS EN 1992:2015 NF EN 1992:2010 DIN EN 1992:2010 DIN EN 1992:2013 DIN EN 1992:2012 DIN EN 1992:2011 ONORM EN 1992:2011 BS EN 1992:2009 EN 1992:2010 DIN 1045-1:2008 DIN 1045-1:2001 DIN 1045-1:2001 DIN 1045-1:2001	6-01



### 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 *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.

specific weight of the concrete

#### Column

Density y

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

#### Soil

#### Soil properties

Stroke weight γ	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.			



Properties			<b></b>
Basic parameter - System - Column - Column - Ground water - Surface - Loading - Design - Output			Q (2)
First soil layer			0
Charles unitable	1.1	R-51/71	20.00

γ [kN/m<sup>3</sup>]

Density

25.00 \$

Dialog		0	pen	
Cohesion	c'	[kN/m <sup>2</sup> ]	0.00	+
Effective friction angle	φ	["]	30.0	+
Buoyant unit weight	Y'	[kN/m <sup>3</sup> ]	10.00	+
Stroke weight	γ	[kN/m <sup>3</sup> ]	20.00	+



#### 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	Properties			<b>ņ</b>
	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.	Basic parameter System Foundation Column	er Q n		8
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.	Soil Ground water Surface Loading Design Output			
Anchoring depth	Embedment depth of the foundation body.	General			3
Terrain load	Additional characteristic permanent ground load on the bearing capacity figure, which increases the characteristic punching shear	Ground level above mean sea level	[m]	0.00	+
		All around the same			~
		Surface		3	0
		Anchoring depth	[m]	2.00	+
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.	Terrain load	[kN/m²]	0.00	+
		Slope	broken		•
		Embankment sections () 1/1	0 🛃 🗙	油	Z
		Length Ixi	[m]	1.00	+
		Height Izi	[m]	0.18	+
		Inclination B	[°]	10.0	÷
	- Broken:	Rise 1:		5.67	÷
	Entry of the slope sections. A new table row is created for a further section using the "+" syn height or inclination or gradient (the height adju inclination).	nbol. Parameters are length, ists automatically based on t	:he		



#### Loads

Self-weight γ	The self-weight is automatically considered. If there	Properties	<b></b>
	is groundwater above the base, the dead weight cannot be deactivated.	er Basic parameter ⊕ System	۹0
Delete horizontal loads	the button allows you to delete all horizontal loads with a mouse click! This function is helpful when you have imported	il… Load Cases il… Design ig. Output	
	many load cases from other application programs	Loading	٥
		Self-weight y	$\checkmark$
right-handed coordinate sy	ystem (new standard)	Delete horizontal loads	
	Coordinate system, which is also known as the right-	right-handed coordinate system	$\checkmark$
	handed coordinate system or right-hand rule. It	Accidental snow	
	corresponds to the sign definition of technical	Remarks	0
	mechanics. Positive moments rotating around the X	to the effects	
	generate pressure to the right or in the positive X area option is deactivated (previous definition in the progra generate pressure at the top right or in the positive X/X the graphic, the numbers for both variants are shown v the arrows are used to show the actual direction of ac input fields and in the output are signed. If the sign def of the moments around the X axis changes.	of the foundation. If this m), positive moments ( area of the foundation. In with their absolute values, tion. The numbers in the finition is changed, the sign	
Accidental snow	If the option is selected, the snow loads are also consi in addition to the normal design situations. The load fa snow loads can be freely specified or automatically de The default value is 2.3.	dered as accidental effects actor for the accidental stermined by the program.	

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



0

-

10.0 0.00 33.33 6.7 0.0 0 0 0 0 0

Load case 1

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L RENT

Permanent loads

90

Properties

≟.- System ⊟.- Loading .... Load Ca

⊕ Design ⊕ Output

Load Cases

Load case

Description

Action

Column loads

Normal force in 7

Basic parameter

#### 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 Load case tab.

Load case toolbar: Load case 0 1/2 0 👍 × 🗃 🗃 🌌 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.

Decorintion	allows you to optor a short designation for the	Normal Norde III 2	IX.	fixed
Description		Moment at x	Th.1.0,k	[kNm]
	IDau Case	Moment at y	Th.1.0,k	[kNm]
Action	category or kind of action of the load	Horizontal force in	x Th.1.0,k	[kN]
		Horizontal force in	y Th.1.0,k	[kN]
Vertical force in z	vertical force (characteristic value)	Grouping		
Moment about x/y	moment (characteristic value) about the x/y-axis	Combined group		
		Alternative group		
Simultaneous group	direction assignment of the load to a group of loads acting	simultaneously.	The grou	p is
	defined by a group number entered by the user. Loads that are assigned to the same concurrent g simultaneously. Loads in a concurrent group must group.	roup always app also be membe	ly r of an ac	tion
Alternative group	assignment of the load to a group of loads exclud The group is defined by a group number entered b	ing each other. y the user.		

#### Load value compilation

By clicking on the arrow icon would 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 *solution*, to enter your own <u>comments</u>.

Properties	<del>д</del>
Basic parameter	00
÷. System	10
🗄 - Loading	
🚊 Design	
Reinforcement	
Foundation engineering	
Earth pressure	
. Output	

Bending	
Minimum eccentricity	
Minimum reinforcement compression members	$\checkmark$
Serviceability	0
Perm. sway imperfection	] ‡
Remarks	0
to the results	



0

90

cV,u cV,s	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. Laying measure of the specified reinforcement on the outer sides of the foundation	Properties Basic parameter System - Loading - Design - Reinforcement - Foundation engineering - Earth pressure		
cV,o	Laying measure of the specified reinforcement on the	Properties         Properties         Basic parameter         body according to this         body according to this         cs are created based on         einforcement on the         einforcement on the         einforcement on the         einforcement on the         for the reinforced         g up the durability dialog,         lameter with which the         With this diameter, the         cement that covers the         mum and maximum bar         he selected diameter,         beselected diameter,         brocement.		
	upper side of the foundation.	Keinforcement		
Reinforcement layer	Center of gravity of the reinforcement at the bottom in the	Shifting measure below		
-	X or Y direction. This value is used for the reinforced	Shifting measure on the side		
cV,oLaying measure of the specified reinforcement on the upper side of the foundation.Reinforcement layerCenter of gravity of the reinforcement at the bottom X or Y direction. This value is used for the reinforcement concrete verifications. After calling up the durability this value is adjusted if necessary.Longitudinal diameterList selection of the longitudinal diameter with whic reinforcement is to be generated. With this diamete program starts to generate reinforcement that cove required reinforcement. If the minimum and maximu spacing cannot be achieved with the selected diameter are used.	concrete verifications. After calling up the durability dialog,	Shifting measure above		
	this value is adjusted if necessary.	Layer of reinforcement x,be		
Longitudinal diameter	List selection of the longitudinal diameter with which the	Layer of reinforcement y,be		
	rainforcement is to be generated. With this diameter, the	Layer of reinforcement x,o		
	program starts to generate reinforcement that covers the	Layer of reinforcement y,o		
	required reinforcement. If the minimum and maximum bar	Layer of reinforcement la		
	spacing cannot be achieved with the selected diameter	Longitudinal diameter		
	larger diameters are used.	Bracket diameter		
Braket diameter Minimum diameter of stirrup reinforcement.		Durability		
Durability	Use the button it to call up the dialogs for durability. If you the concrete covers, reinforcement layers and diameters are necessary.	exit this dialog with OK, checked and adjusted if		

#### Reinforcement

#### 3.0 ≑ re below cV,u 3.0 韋 re on the side cV,s cV,o 3.0 🗘 re above 5.0 2 rcement x,below 5.0 ≑ rcement y,below 5.0 2 x,oben rcement 5.0 ‡ y,oben rcement lateral 5.0 2 rcement ameter 14 mm + • 8 mm ter XC2/X0 🗹 log with OK, d adjusted if

#### 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.

Properties	Ф
Basic parameter	0.0
⊕ System	
🗄 - Loading	
📴 - Design	
Reinforcement	
- Foundation engineering	
Earth pressure	
. Output	
General	6

General		0
Verification format	User defined	•
GEO - bearing capacity- precise	User defined exact	
Stability	active	•
SLS - serviceability		0
Rotation	active	•



#### Earth pressure

Earth pressure type	The earth pressure can be calculated either for the active or the resting state.	Properties Basic parameter	s म् parameter ् ू		
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.		<ul> <li>System</li> <li>Loading</li> <li>Design</li> <li>Reinforcement</li> <li>Foundation engineering</li> <li>Earth pressure</li> <li>Output</li> </ul>			
Tension from cohesion	Calculated tensile stresses from cohesion		0		
	may not be used for walls that are not	Earth pressure type	Active earth pressur		
	supported or only flexibly supported and	Increased active earth pressure	Active earth pressure		
	that rotate around their base or a lower	Proportion of active earth pressure	0.50		
	point (EAB EB4, paragraph 3). For building	Percentage of earth pressure at rest	0.50		
	pit walls that are not supported flexibly and	Apply tension from cohesion			
	tensile stresses from cohesion may be	Apply minimum earth pressure	~		
	used to verify the need for the minimum	Apply compaction earth pressure			
	earth pressure (EAB EB4, paragraph 5). The	Settings			
	program calculates the earth pressure for	Earth pressure	0		
	walls that rotate around their base, which is	Use earth pressure	~		
	why tensile stresses from cohesion should	Wall friction angle Sa	2/3φ ·		
	not normally be used.	Earth resistance enabled			
Apply minimum earth press	sure If the minimum earth pressure is taken	Earth resistance	0		
	into account, it is verified in each cohesive	Wall friction angle δp	-2/3φ •		
	soil layer whether the earth pressure	Relocate earth resistance			
	resulting from the soil's own weight and a	Ep mob	1.00 🖨		
	shear strength corresponding to $\varphi = 40^{\circ}$ c	given neutral axis	[m] 1.16		
	= U IS decisive. Calculation according to	Enable curved sliding surface			
Apply compaction earth pr	essure If soil is installed in layers and then interpressure increases beyond the earth pressure The parameters for compaction earth pressure "Settings" button: The compaction earth pressure for intensive according to DIN 4085:2017. The approach for with an operating mass of up to 250 kg) accord to the approach according to Franke (Franke, light compaction, BAUTECHNIK 85 (2008) No Curved sliding surfaces: the depth zp from with pressure is applied is determined by comparing with the passive earth pressure. The correspon coefficient can be determined assuming linear	nsively compacted, the earth e from the soil's own weight. re can be defined using the and light compaction is calcu or light compaction (vibration ording to DIN 4085:2017 corre , D., Compaction earth pressur o. 3, pp. 197 - 198). hich the full compaction earth ing the compaction earth press onding passive earth pressure ar or curved sliding surfaces.	lated plate sponds e for sure		
δρ	Wall friction angle.				
Relocate the earth resistan	ce Relocate the earth resistance according to I	DIN 1054:2021 Figure A 6.5.4.			
Ep mob	The mobilized component of the characterist	tic earth resistance.			
Default neutral axis	Specify the neutral axis here. Normally the ne of the horizontal loads of 0.	eutral axis is where it produces	s a sum		
Apply curved sliding surfac	tes For passive earth pressure, the assumption longer applicable under the following condition earth pressure coefficients for curved sliding to DIN 4085 Appendix C. The representation	of linear sliding surfaces is non- ons: $ \alpha + \delta  < \beta$ and $\phi > 35^\circ$ . The surfaces are determined according always linear.	o ne ording		



## 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.

rages bootname □ 2 System : □ 2 Plan view : □ 2 Foundation : □ 2 Sol : □ 2 Sol	Self-weight is taken 4.050 m <sup>2</sup> / 101.3 ki not considered. <u>Superposition</u> Combinations	n into a N. Horiz	ccount in the calculation. Density Concrete : y = 25 contai loads act on the upper edge of the base or th	.00 kN/m <sup>2</sup> . Total Foundation without he column. Torsion from horizontal lo	mast bads is	
	No.	DS	Superposition			
Superposition	1 2 3	P P P	$\begin{array}{c} 1.35 \times (1) + 1.5 \times (2) + 0.75 \times (3) \\ 1.0 \times (1) + 1.0 \times (2) + 0.5 \times (3) \\ 1.35 \times (1) + 0.9 \times (2) + 1.5 \times (3) \end{array}$			
	DS: design situat The load case nu	ton P: P umbers a	ermanent are listed in parentheses.			
Preview Checks	Results Preview Checks					
Faith pressure X	Check			Superposition	η	
Earth pressure Y	Stability Serviceability			1 2	0.78 0.52	
	Preview Reinforcer	ment				
Internal forces X	Туре			Superposition	cm <sup>2</sup>	
Internal forces Y	Bending vertically	y on eac	ch side As, z	3	0.1	
	Earth pressure	kWm²	60/m² 60/m² 60/m50/m² 60/m 60/m² 60/m² 60	n <sup>4</sup> kN/m <sup>4</sup> 17.10 ep1, ep1(02.60 1)	32.60	