

# Steel Bracing ST12+

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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.

*Tip: Go back - e.g. after a link to another chapter / document - in the PDF with the key combination "ALT" + "left arrow key".* 



# Application options

The software is suitable for the structural calculation and design of bracing typical in the construction of portal frames:

- Diagonal tying with compression slack diagonal steel struts for buildings with trussed girders

#### Available standards

The internal forces are determined in a second-order analysis with consideration of the failure of the diagonal compression struts. The approach to imperfections is based on the following optional solution methods:

- DIN EN 1993:2010/2015
- ÖNORM EN 1993:2007/2017
- BS EN 1993:2008
- Petersen

For the diagonal tension struts a verification of the cross section is performed and for the compression posts in addition a stability analysis.

A verification of the chord for the additional axial chord force is not performed in this software.

#### Reference literature

- /1/ DIN EN 1993-1-1
- /2/ Petersen: Stahlbau (1990, 2nd improved edition, Braunschweig/ Wiesbaden, Publisher Vieweg & Sohn
- /3/ DIN 4114: Steel construction; stability cases (buckling, tilting, bulging), design principles, guidelines, 1953



## Basis of calculation

## Loading

For the calculation of the internal forces of the braces the following loads and forces are to be considered:

- the wind load at the height of the bracing
- the compressive chord forces of all roof trusses

The axial chord forces are  $\gamma$ -fold results of a previous frame and girder calculation. The  $\gamma$ -fold equivalent load for the bracing system is calculated from the axial chord forces. The bracing system itself is designed for this equivalent load and the additional  $\gamma_w$ -fold wind load.

Additional loads in the bracing plane can considered in the software.

The user can specify the axial force in the compression chord or have it calculated from the internal forces by the software.

The calculation of the axial chord force for double-symmetrical I-shapes is based on /3/:

$$N_{Gurt} = \sigma_d \left( b_1 \cdot t_{f1} + \frac{1}{5} A_w \right) - \frac{N_{Ed}}{2}$$

Second-order influences must be considered in the design of the bracing system.

To do this, assumptions concerning the imperfections have to be made. Because the consideration of imperfections is not clearly defined, you can find different relations in literature.

## Bracing in accordance with Petersen

Petersen replaces the laterally pre-deformed chords with a hinged bar chain. The deviation forces are applied to these hinges.

They are included as node loads acting on the truss. The internal forces are calculated in a second-order analysis with consideration of the failure of the compression members.

The approximation formulae by Petersen apply only to truss systems with a constant span length.

The calculation is based on the initial imperfection  $e = \frac{L}{500}$ .

## Bracing as per DIN EN 1993-1-1

The stabilizing equivalent forces are calculated as constant UDL\* as per DIN EN 1993-1-1, 5.3.3.

The internal forces are calculated in a second-order analysis with consideration of the failure of the compression member.

# Verification of the diagonal tension struts and of the compression members

The verification of the cross-sectional resistance is based on the internal plastic limit forces. Optionally, a stress analysis based on the elastic model can be performed.

For the compression members, the stability verification is performed in accordance with DIN EN 1993-1-1, 6.3.1.

\* uniformly distributed load



## **Basic parameters**

#### Design Standards and Safety Concept

Selection of the standard:

- DIN EN 1993
- BS EN 1993
- ÖNORM EN 1993

Properties		ф
Basic parameter System Loading Output		20
Design Standards and Safety	Concept	0
Design Standard	BS EN 1993:2008	•
Combination equation	(6.10)	-
equal γG for all permanent loads		$\checkmark$
Ultimate Limit State		0

#### Combination equation (BS EN 1993)

Specifies the combination rule to be used in the in the transient/permanent design situation.

#### Consequence class (ÖNORM EN 1993)

Specifies the reliability level (in terms of the respective consequence class) of the partial safety factors.

#### Equal yG for all permanent loads

Check this option if all permanent loads or load cases shall be included with the same partial safety factor ( $\gamma$ G,sup or  $\gamma$ G,inf). Otherwise, all permanent loads or load cases are combined with each other with ' $\gamma$ G,sup' and ' $\gamma$ G,inf'.

#### Ultimate Limit State

Cross-section design

optional selection whether the design of the cross section should be based on the elastic model as per equation 6.1 or on the plastic model as per equation 6.2.



# System

#### Steel

Selection of the steel type and grade for the chords, posts and diagonals.

Steel	0
Туре	Structural steel 🔹
Grade	Structural steel
System	Structural steel annealed Structural steel thermo
Assembly length	Structural steel weather-resistant Heat-resistant steel
Height	Hollow section hot
Span	Hollow section, not, N User defined type

#### System

A		al all
Assembly lenght	the total length of the bracing (span length of the system).	ivision of
		Remarks
Height	the height of the bracing corresponds to the distance of the girders.	about t
Spans	allows you to specify how many cross beams there are	e in total.
Division of the spans	equal span length is the default setting. In addition	
Brusien er trie spans	different/individual span lengths can be selected and	ivision
	entered via a separate "Edit" dialog.	Rema
	The calculation method described by Peters applies only to structural systems with equal span lengths!	abo



Steel		0
Туре	Structural steel	
Grade	S235	-
System		0
Assembly length	[m]	28.00
Height	[m]	5.00
Span		10
ivision of the spans	constant span length	-
Remarks		0
about the system		Z

ivision of the spans	constant span length	•
Remarks	constant span length symmetrical division	
about the system	individual span length	

#### Cross sections

Different cross sections and materials can be defined for each component. Thus, the staggering of e.g. the posts and diagonals is possible depending on the stress.

The button allows you to access the dialog for the selection of the steel cross-section. You can select cross sections separately for the horizontal, vertical and diagonal members from the Frilo Profile Library You can also define a cross-section by selecting 'User-defined'.

See also the document 
Selecting/Defining Cross-Sections - PLUS

you can select among I-shapes and I-shapes with inclined flanges.
in addition to I-shapes and I-shapes with inclined flanges, rectangular and round hollow sections are available.
in addition to the shapes available for girders and posts, round steel, flat steel and thin- walled open profiles are available for selection. For open profiles, you need to define the dimensions
Tick this option if the cross-section is installed rotated by $90^\circ\!.$



Girder (Standard CS)	0
Cross-section	IPE 400
Cross-section rotated	
Material	S235 (Standard)
List of bars Girder	to the table 🛛 🗃 📝
Post (default CS)	0
Cross-section	RO 88.9X3.2
Cross-section rotated	
Material	S235 (Standard) 🔹
List of bars Post	to the table  🔡
Diagonal struts ( default CS	5) 🔕
Cross-section	RND 20
Cross-section rotated	
Material	S235 (Standard) 👻
List of bars Diagonal struts	to the table 🔠 🍞



## Loading

You can access the respective input dialogs via the button

#### Boundary conditions

#### Building/Load characteristics

Height of the terrain level	the altitude of the bracing above the ground level; the wind pressure is calculated for this height level.
Girders	number of girders in the building.
Assemblies	number of braces acting together.
Influence height	the affected height relating to wind action on the bracing plane. The calculated wind

pressure is multiplied with this value.

Building / load characteristics				
Boundary conditions		8		
Height of the terrain level	[m]	3.00		
Girder		5		
Girder spacing	[m]	5.00		
Length of the building	[m]	20.00		
Assemblies		1		
Influence height	[m]	1.50		

#### Wind

Select the federal state and the municipality from a list to determine the associated wind zone as well as the altitude above MSL.

You can uncheck the option "municipality selection", however, to specify these values in the subsequent dialogs.

The corresponding dialogs are only enabled when you uncheck the municipality selection option.

Selection/Input of the <u>wind zone</u>, the <u>terrain category</u>, <u>Basic wind speed</u> - the display value qb0 results from the basic wind speed.

#### Slope H/Lu

Value 'H/Lu' in flow direction with 'H' for the height of the slope and 'Lu' for the length of the slope, see also EN 1991-1-4, A.3 (1).

On isolated mountains, mountain chains or rocks, different wind speeds result from the slope of the ground surface.

#### Orography coefficient

Factor as per EN 1991-1-4, figure A.2 for cliffs or offsets in the ground surface or A.3 for hilltops and hill crests, related to the effective length 'Le' of the windward gradient.

#### Topography coefficient

Indication of the coefficient as per EN 1991-1-4, 4.3.3. At places where the topography (e. G. mountains, cliffs etc.) increases wind speed by more than five percent, the speed increase is to be considered via the topography factor '*co*'.



Boundary conditio	ns				0
Building / load chara	cteristics				1
Wind				1	2
Distribution of wind lo	ad like	Uniformly dis	tributed	load	-
Suction on top chord					
Stabilizing equival	ent force	es			0
Chord force	Nd	[kN]		250.	0 📝
Preforming	V				500
Distribution like		Node load(P	etersen)		÷
Load Cases					0
Standard Load Case	s	to th	e table	誯	2
Additional LC		to th	e table	讄	2
user defined action	ns				0
		Edit			1
Settings of load ca	ses				0
Load case active					•
Settings of load case	s	Notice		[	2
Remarks					0
about the actions					3

Input of the boundary conditions for the determ

Town	Wind	Geomet	ry	Wind loads	
Wind	basic va	lues			0
Wind o	code			DIN EN 1	991 -
Edit va	lues of th	ne municip	ality	Stuttgart	1
Wind r	egion			1	Ŧ
Catego	ory of terr	ain		Category	II +
Basic	wind spe	ed	vb0	[m/s]	22.50
Basic s	speed pre	essure	qb0	[kN/m²]	0.32
Wind	coeffici	ents			۵
Slope	H/Lu		phi		0.000
Orogra	phy coef	ficient	S		1.000
Topog	raphy co	efficient	co		1.000
Wind	load				۵
Speed	pressure	(h=0.0)		[kN/m²] (	0.54



#### Speed pressure (h=0)

The dynamic wind pressure at the altitude of 0.0 m can be modified for further calculations.

#### Stabilizing equivalent forces

Chord force	bracing loads are calculated from ' <i>Nd</i> 'using the method described by [Petersen] or as per DIN EN 1993-1-1, 5.3.3. You can either enter the axial force in the chord directly or have it calculated by the software. The calculation is based on ' <i>Nd</i> ' and ' <i>Md</i> ' which you can specify for the upright member by clicking on the editing button			
	<i>'Nd'</i> is the existing axial force in the girder (axis). <i>'Md'</i> is the existing moment in the girder, used to calculate the chord force.			
Initial imperfection I/500	indication of the imperfections of the supported girders.	2		
Distribution like	the wind load can either be applied as a uniform load [EN 1993-1-1] or nodal loads [Petersen]. By default, wind pressure and wind suction are applied to the upper chord.	1		

Stabilizing equival	ent force	es	0
Chord force	Nd	[kN] 250.	0 📝
Preforming	1/		500
Distribution like		Node load(Petersen)	•
Load Cases		Node load(Petersen) EN1993-1-1(line load)	
Standard Load Case	S	to the table 🔠	2
Additional LC		to the table 🔠	2
user defined action	15		0
		Edit	1
Settings of load ca	ses		۲
Load case active			•
Settings of load case	s	Notice	
Remarks			0
about the actions			1

Properties		?	×
Calculation Chord	Force		
Chord force	[kN]		705.8
Nd in bar	[kN]		50
Md in bar	[kNm]		250.00

Load Cases

Additional LC

Standard Load Cases

user defined actions

Settings of load cases

Settings of load cases

about the actions

Load case active

Remarks

#### User defined actions

User-defined actions can be created in a separate dialog.

#### Load cases

#### Standard load cases

The default load cases are 'wind on gable' and 'equivalent forces'. They are generated automatically from the defined system data, the border conditions and the axial chord force. They cannot be edited but you can disable them via the 'Load case active' option.

#### Additional load cases

Additional load cases are registered in the table. Loads can be entered in a table or in the graphic and be edited there.

Use the "+" button to create a new table row. Load cases can be copied as a template and changed using the "Edit" button.

List	of bars Girder 📃 I	List of bars Post	List of bare	s Diagonal struts	SI SI	andard Load Cases	- E	dditional LC	×
	Description		Action	Alt	Active	Copy loads from load	case	Loads	2
1	Additional load case 1	Wind loads		111		Wind on gable	N	Edit (2)	<b>₽</b>
						 Wind on gable	4		彊
						Model forces			

0

2

0

1

0

.

to the table 🛗 📓

to the table

Switch off all Standard LC

Switch on all standard LC Switch off all Wind LC

All wind load cases on All additional load cases off

All additional load cases on

Edit



## Design

Click on the "Calculate" button. After completion of the calculation, the utilizations are displayed.

## Output



The 'Output' menu item allows you to define the desired scope of data to be put out by checking the corresponding options.

The output document can be accessed by clicking on the 'Document' tab (above the graphic screen).

See Output and printing.

Basic Parameters     System     Load     Output	९ 🔕
General	8
Brief output	
Notes	
System	0
System graphics 2D	
System graphics 3D	
Force the scale	

Properties

Loads	6
Actions	
Load Case Graphics	D
Results	6
Support reaction- characteristic per load case	
Support reactions - design values	E
Result Graphics	D
Resulting intern forces in table	D

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