

THE SOFTWARE FOR STRUCTURAL ANALYSIS OF TALL SLENDER STRUCTURES

Monopoles, chimneys and lattice towers

USER'S MANUAL

December 2016

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1 Introduction

Software EXMACT has been developed for analysis of tall slender structures as towers and chimneys, especially in accordance with European standards. The software allows advanced calculation methods such as the spectral analysis. The determination of wind drag, icing and snow load is included. The generation of project report can be carried out.

2 Analysis capabilities

2.1 Model of the structure

The finite element method is used for the mathematical model of the structure. Plane beam model is used for the monopoles and chimneys, three-dimensional bar model for the lattice towers.

The typical structural systems of lattice towers are prepared for generation of the model, see chapter 7.3.3. Other systems are not supported in this version of the software.

As some structural systems are not theoretically stable using the bar model (nodes supported only in one plane are unstable out of this plane), the "dumb elements" are used as notional bracing. Resultant axial forces in the dumb elements must be zero or close to zero. Otherwise the model cannot be assumed reliable!

The load is applied in the nodes of the structure. Local bending effect due to connection of ancillaries between the nodes is not included to the assessment of members of the structure. The effect depends on the way of ancillary connection. The local bending effect is usually minor, but in case of significant ancillaries connected between nodes of lattice structure, appropriate bars must be additionally checked separately!

2.2 Analysis

The dynamic characteristics of the structure (natural frequencies and mode shapes) are determined by the modal analysis.

The response of the structure due to applied loads is determined using static or dynamic analysis according to the selected method.

The following method can be chosen for the wind response evaluation:

Monopoles and chimneys (or towers modelled as vertical beam)

- Quasi-static analysis according to EN 1991-1-4 [4]
- Equivalent static analysis according to EN 1993-3-1 [8]
- o Simplified spectral analysis
- o Spectral analysis
- Quasi-static analysis according to ČSN 730035 [13]
- Analysis according to ČSN 730035 [13] using mode shapes decomposition
- o Quasi-static analysis according to DIN 4131 [17]



Lattice towers

- o Quasi-static analysis according to EN 1991-1-4 [4]
- o Equivalent static analysis according to EN 1993-3-1 [8]
- o Simplified spectral analysis
- o Quasi-static analysis according to ČSN 730035 [13]
- o Analysis according to ČSN 730035 [13] using mode shapes decomposition
- o Quasi-static analysis according to DIN 4131 [17]

The second order effect can be determined by non-linear static calculation in the software (for monopoles and chimneys in this version only).

3 Responsibility

The software is developed to assist designers in structural analysis of towers and chimneys. User must have an understanding of these structures, good knowledge of the standards and experience with designing and assessment of these structures.

The software has been carefully tested. However, please know that EXCON, a.s. makes no guarantees concerning interpretation of the outputs, accuracy of results or errors as well as damages resulting from the use of this manual and the software.

4 Contact



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6 Installation

6.1 Installation

No installation is needed. The files are copied to created folder in user's computer. Run "EXMACT.exe" to open program. The desktop shortcut may be created to run "EXMACT.exe".

6.2 Hardware and software requirements

Hardware requirements:	$RAM \ge 2GB$
	Disk space \geq 50 MB
Software requirements:	MS Windows (32 bit or 64 bit)
	.NET 4.0
	MS Office Word

7 Manual

7.1 Generally

The Graphical User Interface (GUI) is used to enter input data. The main window of GUI is divided into three main sections: Toolbar, Tree and Panel of input and output data, see *Fig.* 1.

Toolbar provides direct access to the basic function. It is placed at the top of the main window. Toolbar contain 7 items:

New	 Create a new project
Open	 Open an existing project
Save	 Save a current project
Save as	 Save a current project as another
Close	 Close a current project
Word	 Create a report of current project
About	 Show product version number and other information

Note: More projects can be opened at the same time.



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Fig. 1 Graphical user interface

Tree provides direct access to all functions. It is placed at the left side of the main window. Tree is different for poles and lattice towers, see *Fig. 2*.





Fig. 2 Tree window for monopoles and chimneys (left), tree window for lattice towers (right)

The items of the tree and the corresponding panels of input/output data are described in the following chapters.

Colours of boxes

Three colours are used for boxes in the software: white, yellow and gray.

White boxes are to be filled or can be changed by user. If predefine value in white box is changed, colour of box changes to **yellow**. If there is need to change back value in yellow box to Exmact proposed value, delete number in box and press "Enter" or press "CTRL and 0" and then "Enter". **Gray boxes** serve for information and cannot be modified.

ATTENTION: Yellow - manually changed - boxes remain unchanged, when initial parameters are modified.



Example: If different projected areas are set for different wind directions then boxes on page "Wind drag", which differ from page "Ancillaries" change colour to yellow. When afterwards parameters on page "Ancillaries" are modified, all white boxes are automatically modified, while yellow boxes remain unchanged.

7.2 Project, Standards

Project identification information can be assigned to the project. The selection of standards is done on this page, see *Fig. 3*. (General European standards, the Czech National Annex, the German National Annex, the German DIN standards and the old Czech standards ČSN are included in this version)

ample 1 · Monopole Example 2 · Lattice str	ichure	
Project Standards	Project	
- Structure	a second	
Type of the Structure	Title:	Example 1 - Monopole
Tower / Shaft		Parama (E.M. W. Mayara) Haran A
Geometry	Company:	
- Tube Structure Definition		
- Cross Section Characteristics	Project number:	20150001
- Discrete Structure Components		
- Material	Document number:	M801S001
Bolts		
i Connections	Calculated by:	Poláková
Important Points		
Foundation	Checked by:	Lahodný
- Ancillaries		
Calculation Model	Date:	7.9.2015
Loading		
- Load combinations	Revision:	0
E venical Load		
-Wind		
Wind Directions and Drag Types	Standards	
- Wind Speed and Pressure	Standards	
Wind Drag	8429 1928 17 18	
Analysis	European Standards:	EN 1393-3-1, EN 1993-3-2, EN 1991-1-3, EN 1991-1-4 and further
- Shaft Computation Data		
Second Order Effects	Standard:	CSN EN - Czech national annexes
Analysis Method		General FN
- Results		CSN EN - Czech national annexes
- Frequencies		DIN EN - German national annexes
Results	Icing according to ISO 124 94.	CSN
		551

Fig. 3 Page "Project, Standards"

Note: If system of European standards is chosen for analysis and assessment of the structure, the following standards are used: EN 1990 [1], EN 1991-1-1 [2], EN 1991-1-3 [3], EN 1991-1-4 [4], EN 1993-1-1 [5], EN 1993-1-6 [6], EN 1993-1-8 [7], EN 1993-3-1 [8], EN 1993-3-2 [9], EN 1997-1 [10], EN 1090-2 [11]. Standard ISO 12494 [12] is used for icing on structure.

If system of German DIN standards is chosen for anylysis and assessment of the structure, the following standards are used: DIN 4131 [17], DIN 18800-1 [19], DIN 18800-2 [20], DIN 18800-4 [21], DIN 1054 [22]. Standard DIN 1055-5 [18] or ISO 12494 [12] are used for icing on structure.



7.3 Structure

The geometry of the structure, cross section and other characteristics of the structure are defined in this section. The section comprises following pages.

7.3.1 Type of the structure

Page contains 2 main selections, see Fig. 4:

The type of the structure	 "Tower" or "Guyed mast" (guyed mast is not included in this version)
The type of the tower	 "Tube (or another beam)" for monopoles or chimneys or "Triangular lattice tower" or "Square lattice tower"

For lattice structures 3D model is used. 2D model is used for monopoles or chimneys.

Fig. 4 Page "Type of the Structure"

7.3.2 Geometry

User defines the heights of panels of the structure and their division. The panel name can be assigned to each panel. Only white boxes are filled. Grey boxes are for the user's information only, see *Fig. 5*. Unlimited number of panels can be defined.





Fig. 5 Page "Geometry"

7.3.3 Lattice structure definition

The width of lattice tower are determined on this page, see *Fig. 6*. The width of the structure can be set only in the heights, where the slope of the legs changes. These manually filled boxes will be marked (yellow box), other widths are calculated automatically for a constant slope of the legs between yellow boxes.

The division of the panel to elements is subsequently determined. If "Division type" is chosen as "Height", the height of panel is divided equally to element heights. If "Division type" is chosen as "Angle", the heights of elements are calculated with respect of constant slope of the diagonals.



🖹 New 📑 Open 🛃 Save 🛃 Save As 🗙 Cl xample 2 - Lattice structure 🛛 Example 1 - Monopole	ose 🖭 \	Vord Abou	it									
	Geom	etry of the latt e structure din	ice shaft nensions									
Geometry Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles		Panel	Panel number	Panel Height ! number of top point z [m]	Structure width (bottom)	Structure width (top)	Slope of legs	Division	Division type		Panel type	
Bolts	•	A	3	19,900	1 500	1.500	0.00	8	Height	-	< - Tune 121	
Connections		P	2	9 900	1 996	1 500	40.40	2	Angle	-	*. Tupe 24	
Ancillaties		0	-	5,500	0.000	1.000	40,40		Angle		- Type 24	
 → Load combinations → Vertical Load → Snow Load → Ice Load → Horizontal Load → Wind Directions and Drag Types → Wind Speed and Pressure → Wind Drag 												

Fig. 6 Page "Lattice structure definition"

The panel type determines the lattice structural system. The types, which can be used and their type numbers are depicted in *Fig. 7*.



Fig. 7 Panel structural types

Note: Dashed and dotted members in Fig. 7 are optional. If a profile is set on the next page "Lattice cross section characteristics", the dashed or dotted member is used in the model. If the box "profile" on the next page is empty, the member isn't included in the model – in case of the dotted items. In case of the dashed items, the member is included in the model as a "dumb" element.



The secondary bracing members (secondary diagonals and horizontals) can be assumed in calculation. Because these members bear no primary forces, they are not included in the model. But they can be assumed in the wind drag evaluation and in the tower assessment.

Horizontal bracing members are divided into two groups marked I and II, see Fig. 8.



Fig. 8 Horizontal bracing member I and II

7.3.4 Lattice cross section characteristics

The profiles and materials are assigned to members of lattice towers, see *Fig. 9*. The software includes automatic calculation of cross section characteristics for tubes and rods and database of profiles and basic materials. Other user-defined profiles and materials can be added on the page "Materials and Profiles", see chapter 7.3.8. The weight addition can be added to self weight of members.

Inserting of profiles with automatic calculation and profiles from the database:

•	For TUBES write:	TUdiameter*thickness	example: TU89*3,6
•	For RODS write:	RDdiameter	example: RD70
•	For EQUAL-LEG ANGLES write:	Lwidth*thickness	example: L50*5
•	For UNEQUAL-LEG ANGLES write:	Lwidth*width2*thickness	example: L50*30*5



Project, Standards	Lattice	cross	section	o characteristics									
	Lattic	Þ		here	-								
	Lattice				naracteristics	80 							-
Geometry	Lauice	suu	sure	Legs			_		FIUIIIE.	101	10.2		
 Lattice structure definition Lattice cross section characteristics 				Diagonals		Secondary	diagona	Is		Cross section	n area:	50	🗧 mm2
- Discrete Structure Components		otal weight		Horizontals		Secondary	horizont	als					
 Materials and Profiles Bolts 	Total			Horizontal bracin	g members I	Horizontal bracing members II							
- Connections - Foundation - Ancillaries - Calculation Model				Marking	Element number	Profile	Material		Cross section area	Length of single member	Member length per meter	Weight addition	
∃- Loading									[mm]	[mm]	[m/m]	[%]	
- Load combinations		+	19,900	Panel A	9 - 16	TU 89*3.6	S35	•	966			0	
Snow Load		•	9,900 F	Panel B	5.8	TU 89*3.6	\$35	-	966			0	
- Ice Load		10	9,90	0 Panel B - 2	7.8	TU 89*3.6	\$355	-	966			0	
Wind			9,	900 Panel B + 2: V	8	TU 89*3.6	\$355		966	1 088	1,002	0	
- Wind Directions and Drag Types			8,	814 Panel B · 2: A	7	TU 89*3.6	\$355		966	1 223	1,002	0	
Wind Speed and Pressure		•	7,59	3 Panel B · 1	5.6	TU 89*3.6	\$355		966			0	
- Analysis		- 2445	7.	593 Panel B - 1: V	6	TU 89*3.6	\$355	-	966	1 223	1,002	0	
- Shaft Computation Data			6.	373 Panel B - 1: A	5	TU 89*3.6	S355	•	966	1 375	1.002	0	
- Analysis Method			5,000 F	Panel C	1 - 4	TU 89*5	S35	•	1 319			0	
- Frequencies		•	5,00	0 Panel C · 2	3.4	TU 89*5	\$355	+	1 319			0	
Results		- 2415	5,	000 Panel C - 2: V	4	TU 89*5	\$355	+	1 319	1 1 3 4	1,002	0	
Foundation			3,	868 Panel C - 2: A	3	TU 89*5	S355	*	1 319	1 249	1,002	0	
			2,62	1 Panel C - 1	1.2	TU 89*5	\$355	-	1 319			0	
			2,	621 Panel C • 1: V	2	TU 89*5	\$355	+	1 319	1 249	1,002	0	
			1	374 Panel C - 1: A	1	TH 89*5	\$355	-	1.319	1 376	1.002	n	

Fig. 9 Page "Lattice cross section characteristics"

Note: If user click on small plus in first column, elements of panel will show and plus will change to minus. If user click on minus, elements will hide. When some value for panel is filled, the same value is automatically given to all elements of this panel. When value for element is changed to value different from value for panel, box will be yellow marked.

7.3.5 Tube structure definition

The width (diameter) of the structure, thickness of wall and material are defined on page "Tube structure definition", see *Fig. 10.* Width at top and bottom point is defined for tapered panels. One width is entered for straight panels. If a slope of tapered part of the structure is constant through more panels, set only top width and bottom width of this part. Widths in intermediate points are calculated automatically. Different widths beneath and above single node can be set. In this case, first enter top width of panel under the node and then setting of bottom width of upper panel will be allowed.





Fig. 10 Page "Tube structure definition"

7.3.6 Cross section characteristics for monopoles and chimneys

Cross section characteristics and weight additions are defined on page "Cross section characteristics", see *Fig. 11*. For tubes the automatic calculation of cross section characteristics is included. User can input also other profiles. In this case cross section characteristics must be filled manually. Other user-defined materials can be added on the page "Materials and Profiles", see chapter 7.3.8.



龙 Exmact															E	-
🎦 New 📋 Open 🛃 Save 📕 Save As	X Close	e 🗃 Word About														
Example 1 · Monopole Example 2 · Lattice struc	ture Tubes (o	r another beams)														
Structure Type of the Structure	Drees section Assaultainties for huba rapide															
Tower / Shaft Geometry Tube Structure Definition Cross Section Characteristics		Marking	Element number	Height of top point	Tube diameter	Wall thickness	Cross section area	Moment of inertia	Elastic section modulus	Plastic section modulus	Net weight per meter	Net weight	Addition (connections, welds, etc.)	Addition (connections, welds, etc.)	Uniform self weight total	Uniform self weight
- Discrete Structure Components - Material Polite				z [m]	d [mm]	t (mm)	Ap [mm²]	ly (mm²)	Wel [mm²]	Wel [mm ³]	[kg/m]	(kg)	[%]	[kg/m]	[kg/m]	[kg]
Connections		18,000 Panel A	3	18,000	324,00	8.0	7 942	9,919E+07	6,123E+05	7,990E+05	62,34	374	0	0,00	62,34	374
Important Points		12,000 Panel B	2	12,000	500,00	10,0	15 394	4,622E+08	1,849E+06	2,401E+06	120,84	725	0	0,00	120,84	725
- Ancilaries	F	6,000 Panel C	1	6,000	830,00	12,0	30 838	2,580E+09	6,217E+06	8,030E+06	242,08	1 452		0,00	242,08	1 452
Loss continuion Verical Losd Provid Losd Provid Losd Verical Losd Verical Losd Verical Losd Verical Contextual Contextual Verical Contextual Contextual Verical Contextual Contextual Verical Contextual Contextual Second Dider Effects Second Dider Effects Second Dider Effects Reads Reads																
Prequencies Presults Assessment Foundation	Total ne Total we	et weight [kg] 2 eight with additions[kg]: 2	2552 2552													

Fig. 11 Page "Cross section characteristics" for monopoles and chimney

7.3.7 Discrete structure components

The discrete structure components (platforms etc.) are defined on this page, see *Fig. 12*. The height of attachment, the weight, the projected area and the force coefficient are filled for each discrete component. The height of attachment is arbitrary and may not be equal to the height of the nodes of the structure, but it cannot be higher than total height of the structure.

Note: If the height of attachment is equal to height of some node in the structure, user can click on the box in column "height" and choose node of structure in shown offer, see Fig. 13. This procedure works for heights of ancillaries defined in chapter 7.5 too.



Fig. 12 Page "Discrete structure components"



📩 Exmact						
🗄 🎦 New 📋 Open 🛃 Save 🛃 Save As	X Clos	se 藰 Word 🛛 A	bout			
Example 2 - Lattice structure Example 1 - Mono	oole					
Project, Standards	Weight	ts and projected a	reas of discrete structure	e components		
Structure Type of the Structure		Marking	Height	Weight	Projected area	Force coefficient
Geometry			[m]	[kg]	[m²]	
Lattice structure definition	1	Platform		70,00	0,00	0,00
Lattice cross section characteristics Discrete Structure Components	*		19,9 Panel A 9,9 Panel B 5.0 Panel C			
Materials and Profiles			5,0 Fanel C			

Fig. 13 Page "Discrete structure components" – offer of structure nodes is shown

7.3.8 Materials and profiles

Database of basic offered materials and summary of used profiles can be seen on page "Materials and Profiles". User can add new material or profile.

The modulus of elasticity and yield strength are set in the material definition. The type of fabrication is added to the material definition, see upper section in *Fig. 14*.

The cross section area, the diameter or the width, the radiuses of gyration and buckling curves are set in the profile definition, see lower section in *Fig.* 14.

Note: For monopoles and chimneys page includes only upper part "Used materials".

	Used	materials							
Structure	Add	material							
Tower / Shaft Geometry Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles Bots Connections		DescStr Modulus Yield Ultimate Fabrication of strength tensile strength elasticity E f.y f.u [MPa] [MPa] [MPa]		Fabrication	Density [kg/m3]	Standards			
- Bolts	۶	S235	210 000	235	360	HotFinished 🔹	7 850,0	EN-10025-2 (t<=40r	nm)
		S355	210 000	355	490	HotFinished •	7 850,0	EN-10025-2 (t<=40r	nm)
- oundation Ancillaries		S235H	210 000	235	360	HotFinished 🔹	7 850,0	EN-10210-1 (t<=40r	nm)
 Anciliaries Calculation Model Loading Load combinations → Vertical Load 		S355H	210 000	355	510	HotFinished 🔹	7 850,0	EN-10210-1 (t<=40r	nm)
		S235H,coldF	210 000	235	360	ColdFormed •	7 850,0	EN-10219-1 (t<=40r	nm)
		S355H,coldF	210 000	355	510	ColdFormed •	7 850,0	EN-10219-1 (t<=40r	nm)
Snow Load		S235, t⊳40	210 000	215	360	HotFinished 🔹	7 850,0	EN-10025-2 (40mm	(t<=80m
Wind									
Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Analysis Shaft Computation Data	Usec	l profiles d profile							
Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Analysis Shaft Computation Data Analysis Method Zowałe	Usec Ad	l profiles d profile Profile	CrossSectionArea	Diameter	ίν.	iz	iv	Buckling curve Hot Finished	Buckling cur Cold Forme
Wind Directions and Drag Types Wind Drag Wind Drag wind Drag wind Drag Shaft Computation Data Analysis Method Results Frequencies	-Usec	l profiles d profile Profile TU 89"3.6	CrossSectionArea	Diameter 89,0	iy 30,2	iz 30,2	iv 30,2	Buckling curve Hot Finished a	Buckling cur Cold Forme c
Wind Directions and Drag Types Wind Speed and Pressure Wind Orag Nalysis Shaft Computation Data Analysis Method Results Results Results	Usec Ad	l profiles d profile Profile TU 89"3.6 TU 89"4	CrossSectionArea 955.9 1 068,1	Diameter 89,0 89,0	iy 30,2 30,1	iz 30,2 30,1	iv 30,2 30,1	Buckling curve Hot Finished a ¥ a ¥	Buckling cur Cold Forme c
Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Nalyzis Shaft Computation Data Analysis Method Results Frequencies Results Assessment Engradation	Usec Ad	d profiles d profile Profile TU 89"3.6 TU 89"4 L 60"6	CrossSectionArea 965.9 1 068.1 691.0	Diameter 89,0 89,0 60,0	iy 30.2 30,1 18,2	iz 30,2 30,1 18,2	iv 30.2 30,1 11.8	Buckling curve Hot Finished a • a •	Buckling cur Cold Forme c c b
Wind Directions and Drag Types Wind Speed and Pressure Wind Speed and Pressure Wind Drag Shaft Computation Data Analysis Method Results Frequencies Results Assessment Foundation	Usec Ad	profiles d profile Profile TU 89"3.6 TU 89"4 L 60"6 L 70"6	CrossSectionArea 965.9 1 068,1 691.0 815.0	Diameter 89,0 89,0 60,0 70,0	iy 30.2 30.1 18.2 21.3	iz 30,2 30,1 18,2 21,3	iv 30.2 30,1 11.8 13.8	Buckling curve Hot Finished a • b • b •	Buckling cur Cold Forme c c b b
Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Shaft Computation Data Analysis Method Tesults Frequencies Results Assessment Foundation	Usec Ad	Iprofiles d profile Profile TU 89"3.6 TU 89"4 L 60"6 L 70"6 L 50"5	CrossSectionArea 265.9 1 068.1 691.0 891.0 480.0	Diameter 89,0 89,0 60,0 70,0 50,0	iy 30.2 30.1 18.2 21.3 15.1	iz 30,2 30,1 18,2 21,3 15,1	iv 30.2 30.1 11.8 13.8 3.8	Buckling curve Hot Finished a • b • b • b •	Buckling cur Cold Forme c c b b b
Wind Directions and Drag Types Wind Dorections and Drag Types Wind Drag wind Drag Shaft Computation Data Analysis Method Results Frequencies Results Assessment Foundation	Ad	Profile Profile TU 89"3.6 TU 89"4 L 60"6 L 70"6 L 50"5 L 40"4	CrossSectionArea 965.9 1 068,1 691,0 815,0 480,0 306,0	Diameter 89.0 89.0 60.0 70.0 50.0 40.0	iv 30.2 30,1 18,2 21,3 15,1 12,1	iz 30,2 30,1 18,2 21,3 15,1 12,1	iv 30.2 30.1 11.8 13.8 3.8 7.9	Buckling curve Hot Finished a • b • b • b • b •	Buckling cur Cold Forme c c b b b b

Fig. 14 Page "Materials and Profiles"



7.3.9 Bolts

Database of bolts and bolt classes can be seen on page "Bolts". User can add new bolt or bolt class.

The dimensions and cross section areas are set in the bolt definition, see upper part in Fig. 15.

In the lower part of page is bolt class definition. The yield strength, ultimate strength, factor α_v , shear resistance reductiom factor for bolts M12 and M14 in 2 mm clearance holes and modulus of elasticity (only for DIN standards) have to be set.

xample 1 - Monopole Example 2 Educe structe	ire								
Project, Standards	Used	bolts							
Structure Tupo of the Structure	Ad	d bolt							
Tower / Shaft Geometry Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles Bolts		Bolt desc	Nominal diameter d [mm]	Hole diameter d0 [mm]	Cross section area A [mm2]	Tensile stress area A_s [mm2]	Nut diameter d_m [mm]	Washer diameter d_m [mm]	-
Materials and Profiles	•	M12	12	13	113	84,3	20,1	24,000	
Bolts		M16	16	18	201	157,0	25,4	30,000	=
		M20	20	22	314	245,0	31,5	37,000	
Ancillaries		M24	24	26	452	353,0	37,8	44,000	
Calculation Model		M27	27	30	573	459,0	43,1	50,000	
Loading		M30	30	33	707	561,0	48,4	56,000	
- Vertical Load		lune.		~~	ا معم ا	المحيم	أمحم		-
- Snow Load	Used	bolt classes							
	Ad	d bolt class							
Wind Wind Directions and Drag Types Wind Speed and Pressure Wind Drag		Bolt desc	Yield strength	Ultimate strength	Factor	Shear resistance reduction factor			
Analysis Shaft Computation Data Analysis Method			f_yb [MPA]	f_ub [MPA]	alpha				
E- Results	•	4.6	240	400	0,6	1,00			
Frequencies		4.8	320	400	0,5	0,85			
- Hesults Assessment		5.6	300	500	0,6	1,00			
Foundation		5.8	400	500	0,5	0,85			
		6.8	480	600	0,5	0,85			
		8.8	640	800	0,6	0,85			
		The second se	17/00/00	1000000	2010/02/02	24.244.54			

Fig. 15 Page "Bolts"

7.3.10 Connections for lattice structures

Connections of elements are defined on the page "Connections". The main used types of connections are chosen for detail design. There are "Bolted flanged connection" and "Angle legs connection" for legs connections and "Angles connected by one leg" and "Connection of tube" for joints of other elements.

Resistance of representative types of connections according to EN 1993-1-8 [7] is given automatically after determination qualities of connection (such as profile and material of elements, number and type of bolts, dimensions and spacing etc.). Needed inputs are divided in logical groups, see *Fig. 16*. Calculation works only if connection meets design rules, so the minimum spacing is pre-filled for used bolts. On the right, user can see particular resistances of single events, which impacts on total resistance of connection.

Defined connections are matched with single members on page "Assessment", see chapter 7.9.3.





Note: Rows of bolts are assumed parallel to axial force in member, according to [7].

Fig. 16 Page "Connections"

In case of need another type of connection (connections calculated by hand or in special software for connections), user can choose "Other connection" and set only its resistance.

The bolted flanged connection is used for connection of tube legs. The diameter of bolt should not be smaller than 12mm and all bolts should be pre-loaded due to fatigue. If user leaves boxes in input of flange 2 empty, it is supposed that flange 2 is identical to flange 1. Positive influence of possible reinforcement plates is not included in calculation. Dimensions of connection are described in *Fig. 17*.



USER'S MANUAL



Fig. 17 Bolted flanged connection

Angle legs connection is available for equal-leg angles. It is supposed that spacing and bolts are selfsame on both sides of one angle and all bolts are in normal holes. User can choose orthogonal or staggered spacing (can be different in each angle), maximum 2 rows of bolts in one leg of angle are allowed. Dimensions of connection are described in *Fig. 18*.







Angles connected by one leg are used for connection of equal-leg angle to joint plate or another angle. Maximum 2 rows of bolts are allowed, spacing for 2 rows is staggered. Dimensions of connection are described in *Fig. 19*.



Fig. 19 Angle connected by one leg

Inputs of **connection of tube** are the same for three main used arrangements (see *Fig. 20*) of connection of tube to joint plate. Maximum 2 rows of bolts are allowed, spacing for 2 rows is orthogonal. For fillet weld resistance check simplified method is used. Resistance of weld is independent of the orientation of the weld throat plane to the applied force. Total weld length is sum of lengths of one-sided fillet welds. If user leave boxes in part "Tube tearing resistance" empty, it is supposed, that plate 1 tearing from tube can't happen, so this partial resistance is not included in total resistance of connection.



Fig. 20 Connection of tube



7.3.11 Connections for monopoles

Bolted flanged connections according to *Fig. 21* and *Fig. 22* can be defined in the software. Three types of tabs are prepared for monopole connections:

- o "Flange connection of tubes" for connection by two bolted flanges
- "Base flange of tube" for base flange laying on anchor bolts (when bolts bears both tension and compression forces, adjusting nuts are present and concrete support is neglected)
- "Other connections" for connections, the resistances were calculated outside the software Exmact

Both "Flange connection of tubes" and "Base flange of tube" can be set with or without stiffeners.



Fig. 21 Connection of monopole – bolts outside the tube – plan (left), detail of connection of two panels (middle), detail of base flange (right)



USER'S MANUAL



Fig. 22 Connection of monopole – bolts inside the tube - plan (left), detail of connection of two panels (middle), detail of base flange (right)

RECOMMENDATIONS:

 Assume plastic hinge appears in the tube wall above the flange (or above stiffeners, if present), if the tube is of cross section class 4

Set "Assume yielding in tube above flange/stiffeners" to option "yes" in this case.

Do not "count with tube" if two tubes with significantly different diameter are connected.
 Set "Count with tube" to option "no" in this case.

If this option is chosen, the compression forces are borne only by stiffeners. It is supposed, the tube is not sufficiently supported and transfer of compression forces through the tube is neglected (diagram in *Fig. 23* does not contain magenta tube component).

Resistance determination

First, maximum possible force in single bolt is determined. It is minimum value of tension resistance of bolt, punching shear resistance and bending resistance of flange or wall of the tube with the inclusion of prying forces. Program considers following lengths of patterns:

Connection without stiffeners: $2\pi m$, $\pi m + p$, 2p, 4m + 1, 25e, 0, 5p + 2m + 0, 625e, p where p is used for flange and/or wall of tube, if required



Connection with stiffeners: $2\pi m$, 4m + 1, 25e, $2\alpha m$ -(4m + 1, 25e), p where p is used for wall of tube above stiffeners, if required

Symbols correspond to EN 1993-1-8 [7].



Fig. 23 Scheme of connection – substitute tubes and stress diagram

Calculation for "Flange connection of tube"

Afterwards, the position of neutral axis is found by iteration calculation using elastic-plastic behaviour. Bolts acts in tension, tube and stiffeners in compression only. Groups of individual components (i.e. bolts and stiffeners) are substituted for single notional collective tubes with equivalent characteristics, see *Fig. 23*. Centerline of bolt substitute tube passes through centres of bolts. Centerline of stiffener substitute tube passes through middle of width h_s , see *Fig. 21* and *Fig. 22*.

Maximum tension in substitute tube of bolts, marks as $\sigma_{b,max}$, is equivalent to maximum possible force in bolt. Maximum compression in tube is equivalent to yield strength of tube material. Maximum compression in substitute tube of stiffeners is $\sigma_{s,max} = \frac{t_t \cdot f_y}{t_t + t_{t,s}}$, where $t_{t,s}$ is thickness of

substitute tube of stiffeners and t_t is wall thickness of tube. It is assumed, the stress in tube above



stiffeners reach the yield stress. Then, stiffeners take part of forces, but overall force in stiffeners and tube cannot be greater than force corresponding to yield stress in tube above stiffeners.

Calculation for "Base flange of tube"

Only substitute tube of bolts is considered (tension and compression) using elastic behaviour. Maximum stress is equivalent to maximum possible force in bolt.

Comment:

Results of above described calculation were widely compared to full analysis of connections in software IDEA Connection using FEM models. Results have been found safe and conservative. Above mentioned recommendations resulted from this comparison study.

ATTENTION:

Some partial resistances are not included in the calculation. They have to be checked by user.

- o Welds
- Resistance of stiffeners
- o Shear resistance of connection
- o Fatigue*
- Tube wall failure under stiffeners (caused by horizontal or vertical forces from stiffeners), if a stiffening ring under stiffeners is not present and/or if "yielding in tube above stiffeners" is not assumed**.

Note *): Especially fatigue of anchor bolts, which acts in tension even compression, is usually crucial.

Note **): This failure was not crucial for compared examples, if above mentioned recommendations were applied. The attention has to be paid especially when upper and lower tube diameter differs significantly. In this case, it is recommended to use a ring under stiffeners or carry out full analysis of connection.

Because the substitute tubes are used, the calculation is not reliable for small number of bolts (approx. less than 12).

Bending resistances are checked in "Assessment / Connection check" only. Influence of axial (compression) force is neglected.



7.3.12 Important points of chimneys and monopoles

The resultant internal forces, deflections and check of member of chimneys and monopoles are shown in the nodes (at the ends of elements). If other points should be examined (e.g. openings in greater distance from any node), the heights of these points are defined on this page, see *Fig. 24*.



Fig. 24 Page "Important points"

7.4 Foundation

The foundation of tower is defined on the page "Foundation", see *Fig. 25*. Pad has square ground plan and two steps. The dimensions of pad and embedment depth are set in upper part of page. In case of need set another shape of upper step, set width of step B_2 so that volume of the square step was identical to volume of another shaped step. In lower part of page the geotechnical characteristics are defined.

Dimensions of pad for monopoles and for lattices are described in Fig. 26.



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🎦 New 📋 Open 🛃 Save 🛃 Save As	s 🗙 Close 🖳 Word About							
Example 1 - Monopole Example 2 - Lattice str	ucture							
Project, Standards	Dimensions and soil							
E- Structure	200 0 0 0							
Tower / Shaft	Dimensions of square pad							
Geometry	Width of lower step of the pad:	B 1=	4.00 🚖	m	Volume of pad:	V=	128	m3
- Tube Structure Definition) (Gdth of upper stop of the part	 	2.00		Violante of pad:	6 []	- 0,21 + 0,000	LM
- Cross Section Characteristics	width of upper step of the pad.	D_2=	2,00	m	weight of pad:	u_z=	520,0	KIN
Discrete Structure Components Material	Height of lower step of the pad:	h_1=	0,60 💠	m				
Bolts	Height of upper step of the pad:	h 2=	0.80	m				
- Connections	Theight of apport step of the pag.	19 60 -	0.00 💽	ASM				
Important Points	Embedment depth:	h 7=	1 20 🛋	m				
- Foundation		1946 	1,20 💌	All and a second				
- Calculation Model	Height of anchoring above upper step:	h_k=	0.00	m				
🕂 Loading	Countrate many demails		2500 4	kala?				
- Load combinations	Concrete mass density.	no_c=	2000	кулпэ				
- Vertical Load	Inclination of found, base to horiontal: a	alpha=	0	deg				
Lice Load	Type of pad:		concreted into form					
- Horizontal Load								
Wind	Geotechnical parameters							
- Wind Directions and Drag Types	Destaurates of all being and being		250 4	1.0.				
	Design value or soil bering resistance:	H_0=	200 🕎	кга	Soil weight:	6_n=	1/8,5	KN
- Analysis	Weight density: ga	mma=	18 🌩	kN/m3				
- Shaft Computation Data	Bround cohesion:	~	10 📥	4Pa				
- Second Order Effects		6	10	NG				
- Analysis Method	Angle of shearing resistance:	phi=	20 🌲	deg				
- Frequencies	Angle of ground sector	da De	10	dea				
Results	Angle of ground sector. De	aa_0=	10 🐨	ueg				
- Assessment	D							

Fig. 25 Page "Foundation"



Fig. 26 Dimensions of the pad for monopoles and chimneys (left) and for lattice towers (right)

7.5 Ancillaries

The linear and discrete ancillaries are defined on the page "Ancillaries", see *Fig. 27*. The height of attachment (in case of the linear ancillary bottom and top height), the weight, the projected area, the force coefficient and angle of wind incidence are defined. The heights are arbitrary and may not be equal to the height of nodes of the structure, but cannot be higher than total height of the structure.



Project, Standards	Linea	ancillaries						
Structure Type of the Structure Tower / Shaft Geometry Lattice structure definition Lattice cross section characteristics		Marking	Bottom height [m]	Top height (m)	Weight per meter [kg/m]	Projected area per meter [m²/m]	Force coefficient	Angle of wind incidence X
Discrete Structure Components	•	Ladder	0	19,9 Panel A	20,00	0,179	2,00	90,0
- Materials and Profiles		Cables	0	19,9 Panel A	30,00	0,300	2,00	90,0
Bolts Connections								
È-Vertical Load ├─Snow Load └─Ice Load		Marking	Height [m]	Weight [kg]	Projected area [m²]	Force coefficient		
Horizontal Load Wind		Antennas	18	500,00	10,00	1,4	10	
- Wind Directions and Drag Types		Antenna suppo	17,5	440,00	2,81	1,2	20	
- Wind Speed and Pressure		MW antennas	13	20,00	0,14	1,4	40	
Analysis								
Shaft Computation Data Analysis Method								
Results								
Frequencies								

Fig. 27 Page "Ancillaries"

Note: Angle of wind incidence is angle between wind direction and longitudal axis of linear ancillary.

7.6 Calculation model

The basic model of the monopoles or chimneys can be extended on the page depicted in *Fig. 28*. Important points and points with ancillaries can be added to the basic point of the model (ends of elements) and used for creation of mathematical model of the structure.

If an ancillary is placed between nodes and the point, where the ancillary lies, is added to the calculation model, new node is created and the load of ancillary is applied in this point.

If the point, where the ancillary lies, is not added to the calculation model, the load of ancillary is applied in both lower and upper nearest nodes of model (divided according to distances from these nodes). In case of large number of ancillaries in one panel is not usually necessary to divide this panel to large number of additional element.

The resultant internal forces, deflections and check of member of monopoles and chimneys are shown only in the nodes of calculation model.

In case of lattice structure, the load is always applied to the nodes of lattice structure, i.e. load is divided to lower and upper nearest nodes according to distances from these nodes.





Fig. 28 Page "Calculation model"

7.7 Loading

7.7.1 Load combinations

The six basic load combinations according to EN standards are prepared as default, see Fig. 29:

COM 1	 Wind action on the ice-free structure with unfavourable vertical action
COM 2	 Wind action on the ice-free structure with favourable vertical action
COM 3	 Dominant ice and accompanying wind action with unfavourable vertical action
COM 4	 Dominant ice and accompanying wind action with favourable vertical action
COM 5	 Dominant wind and accompanying ice action with unfavourable vertical action
COM 6	 Dominant wind and accompanying ice action with favourable vertical action

The reliability classes are set separately for structure of tower (according to Annex A, EN 1993-3-1 [8]), for foundation – limit state GEO/STR (according to EN 1990 [1]) and for foundation – limit state EQU (according to EN 1990 [1]). The combination factors for ice ψ_{ice} and wind ψ_w are filled automatically according to selected National Annex (see page "Project, Standard", chapter 7.2), alternatively they may be set manually.

Note: For DIN standards only first four combinations are prepared for structure. Load combinations for foundation are not shown, because characteristic values of loads in anchoring level are given.



The corresponding partial factors of load, combination factors and factor k for the wind pressure reduction are set according to EN standards and National Annexes.

User can add other user-defined combination and choose which combinations will be calculated (in the column "Used").

Note: Reliability class according to Annex A, EN 1993-3-1 [8] and according to EN 1990 [1] has different definition. If structure is classified as class 2, foundation doesn't need to be classified as RC2.



Reliability class and partial factors for actions
Standard:
Structure Foundation - STR/GED (set C) Foundation - EQU (set A)
Reliability class: RC2 Factor for action: 1,0 +
Partial factors for actions:
Permanent actions - unfavourable: 1,0
Permanent actions - favourable: 1.0
Variable action - unfavourable: 1.3
Reliability class and partial factors for actions Standard: EN Structure Foundation - STR/DEO (set C [Foundation - EQU (set A)]]
Reliability class: RC2 Factor for action: 1.0
Partial factors for actions:
Permanent actions - unfavourable: 1,1
Permanent actions - favourable:
Variable action - unfavourable: 1.5

Fig. 29 Page "Load combinations"



7.7.2 Snow load

The uniform snow load per meter height and the discrete snow load can be assumed in the calculation, see *Fig. 30*. The characteristic value of snow load (or directly snow load for DIN standards) is set according to selected standard (see page "Project, Standard", chapter 7.2) and selected snow zone. This value and coefficients for snow load can be alternatively set manually by user.

The discrete snow load applies in points, where discrete structure components and discrete ancillaries are placed.

Project, Standards	Snow	load a	according to EN 1991-1-3				
Structure	Sno	w zon	•				
i⊟-Tower / Shaft Geometry	Char	acteri	stic value of snow load on the grou	und: s_	_k=	2,00	kN/m²
- Lattice structure definition	Exposure coefficient:				_e= 0.80		
Discrete Structure Components		The	rmal coefficient:	C <u>.</u>	_t=	1,00 *	
Bolts		Sno	w load shape coefficient:	ji ji	mi=	0,80	
Connections Ecundation	Snor	w load	kN/m²				
 Ice Load Horizontal Load Wind Wind Directions and Drag Types 			Marking	Element number	Uniform snow area	Uniform snow load	
- Wind Speed and Pressure					[m²/m]	[kN/m]	
i Wind Drag ⊒⊢Analysis	•	+	19,900 Panel A	9-16	0.00	0,00	
- Shaft Computation Data		+	9,900 Panel B	5-8	0,00	0,00	
Analysis method Results Frequencies Results		+	5,000 Panel C	1+4	0,00	0,00	

Uniform load Snow load on discrete structure components Snow load on discrete ancillaries Discrete snow load Marking Height Area loaded by snow c_f0 [m²] [kN] [m] 17.4 Platform 2,88 ۲ Snow load on discrete ancillaries Uniform load Snow load on discrete structure components Area loaded Marking Height Discrete snow load by snow c_f0 [m²] [kN] [m] Antennas 18 0,00 0,00 17,5 0,00 Antenna sup.. MW antennas 13 0,00 0,00

Fig. 30 Page "Snow load"



7.7.3 Ice load

Ice load and shape of ice is assumed according to ISO 12494 [12]. The rime or the glaze is assumed for weights and shapes of ice determination. Choice of ice type is situated on the top of page "Ice load", see *Fig. 31*.

Two ice situations are prepared as default "Ice 1-dominant" and "Ice 2-accompanying", which correspond to default definition of load combinations (see page "Load combinations", chapter 7.7.1), see middle section in *Fig. 31*. Other ice situations can be added by user.

The ice is defined separately on the structure, discrete structure components, linear and discrete ancillaries.

Note: For DIN standards glaze ice according to DIN 1055-5 [18] is set as default. It can be changed to ice determination according ISO standard [12].

Note: There can be defined both rime and glaze in one project, but calculation can be run only for Rime ice or only for Glaze ice.

7.7.3.1 Rime ice

The overall ice weight in the panels and rime vane lengths are determined on this page, see *Fig. 31*, *Fig. 32*. The ice weight m_k is set according to selected ice class for rime or it can be set manually by user.

The ice load is evaluated automatically for the lattice structure (*Fig. 31*) and for tubular poles and chimneys (*Fig. 32*). The ice load of discrete structure component, linear and discrete ancillaries must be set manually by user (for all ice situations and wind directions), see *Fig. 33*.

In case of lattice tower user must check default **rime shape types** (according to Fig. 4 in ISO 12494 [12]) (for all required wind directions and the ice situations) and fill **slope of secondary diagonals to horizontal plane** (tab "Secondary diagonals), if these members occur.

Note: For tube is default type set as "AB" (i.e. type A or B according to Fig. 4 in ISO 12494 [12]).

For other profile is default type set as "CD" (i.e. type C or D according to Fig. 4 in ISO 12494 [12]), which gives unfavourable values. Default types can be changed by user to obtain more accurate values.



New 📋 Open 🛃 Save 🛃 Save As	X Close	🗐 Word About											
ple 2 - Lattice structure Example 1 - Monop	iole												
Project, Standards Structure	Type of ic	⊃e: Rime		•									
E Tower / Shaft	Ice class	for rime: B4		•			X=	4					
Geometry Lattice structure definition	Ice weig	ht m	k=	2,8 🕂 kg	'n								
 Lattice cross section characteristics Discrete Structure Components 	Ice dens	itv: gamm	a=	500 ÷ kg/	'm3								
- Materials and Profiles	Wind pre	essure reduction factor: k=		0,55 ÷ (ac	cording to Table	27, ISO 12494)							
Connections													
oundation	Ice actions:												
ncillaries		Ice action											
actuation woder		e 1 - dominant											
- Load combinations													
Mational and	IC	e 2 - accompanying											
The second of the second													
Spowl pad	*												
- Snow Load	•												
- Snow Load	•	_											
Snow Load	Ice weigh	t on lattice structure	d on discrete struct	ture elements Ic	e weight on linea	ar ancillaries Ice	load on discrete	ancillaries					
- Verucal Load - Snow Load - Ice Load - Wind - Wind Directions and Drag Types	• Ice weigh	t on lattice structure Ice Ioa	d on discrete struct	ture elements Ic	e weight on lines	ar ancillaries Ice	load on discrete	ancillaries		footing 0			
Snow Load Ice Load Ice Load Wind Wind Directions and Drag Types Wind Speed and Pressure Vind Speed and Pressure	Ice weigh	t on lattice structure Lice loa	d on discrete struct liagonals Horiz	ture elements Ic ontals Secon	e weight on linea dary horizontals	ar ancillaries Ice]	load on discrete	ancillaries	Wind o	firection: 0			
Vertual Load Snow Load Loe Load Hotizontal Load Wind Directions and Drag Types Wind Speed and Pressure Wind Drag nalysis Shaft Computation Data Analysis Method	Legs	t on lattice structure ice loa Diagonals Secondary o Marking	d on discrete struct liagonals Horiz Element number	ture elements Ic ontals Secon Slope to horizontal	e weight on linea dary horizontals Wind incidence (leg 1)	ar ancillaries Ice 	Vind (leg 3)	wind incidence (leg 4)	Wind c Rime shape Leg 1	firection: 0 Rime shape Leg 2		Rime shape Leg 3	
	+ Ice weigh Legs	t on lattice structure Diagonals Secondary o Marking	d on discrete struct liagonals Horiz Element number	ture elements Ic ontais Secon Slope to horizontai	e weight on linea dary horizontals Wind incidence (leg 1)	arancillaries loe	Wind (leg 3)	Wind incidence (leg 4)	Wind c Rime shape Leg 1	firection: 0 Rime shape Leg 2		Rime shape Leg 3	
Snow Load Snow Load Snow Load Lee Load Wind Directions and Drag Types Wind Speed and Pressure Wind Speed and Pressure Wind Drag Shaft Computation Data Analysis Method tesuits Frequencies Frequencies Resuits	Legs	t on lattice structure Tice loa Diagonala Secondary of Marking	d on discrete struct liagonals Horiz Element number 9. 16	ure elements Ic ontals Secon Slope to horizontal [deg]	e weight on linea dary horizontals Wind incidence (leg 1) [deg]	wind Wind incidence (leg 2)	Wind Wind incidence (leg 3) [deg]	Wind incidence (leg 4)	Wind o Rime shape Leg 1	firection: 0 Rime shape Leg 2		Rime shape Leg 3	
Vertua Load Snow Load Snow Load Loe Load Hotizontal Load Wind Directions and Drag Types Wind Speed and Pressure Wind Speed and Pressure Wind Drag nalysis Shaft Computation Data Analysis Method teults Frequencies Presults Assessment Exandation	Ice weigh	t on lattice structure Tice loa Diagonals Secondary or Marking 19,900 Panel A 19 900 Panel A - 8	d on discrete struct liagonals Horiz Element number 9 - 16 16	ure elements Ic ontais Secon Slope to horizontal [deg] 90.000	e weight on lines dary horizontals Wind incidence (leg 1) [deg] 90.000	ar ancillaries Ice Wind incidence (leg 2) [deg] 90.000	Wind Wind incidence (leg 3) [deg] 90.000	ancillaries Wind incidence (leg 4) [deg]	Wind of Shape Leg 1	firection: 0 Rime shape Leg 2	•	Rime shape Leg 3	
Vertica Load - Snow Load - Lee Load - Wind Directions and Drag Types - Wind Speed and Pressure - Wind Speed and Pressure - Wind Speed and Pressure - Wind Drag - Shaft Computation Data - Analysis Method - Results - Frequencies - Results - Assessment - Foundation	Legs	t on lattice structure ce loa Diagonals Secondary on Marking 19,900 Panel A 19,900 Panel A - 8 18,650 Panel A - 7	d on discrete struct liagonals Horiz Element number 9 - 16 16 15	ture elements I Ic ontals Secon Siope to horizontal [deg] 90.000 90.000	e weight on lines dary horizontals Wind incidence (leg 1) [deg] 90,000 90,000	wind incidence (leg 2) (deg) 90,000 90,000	Wind incidence (leg 3) [deg] 90,000 90,000	wind incidence (leg 4) [deg] 90,000 90,000	Wind of Shape Leg 1	firection: 0 Shape Leg 2	- - A	Rime shape Leg 3 B B	
Venue a Load Snow Load Loe Load Vend Directions and Drag Types Wind Directions and Drag Types Wind Speed and Pressure Wind Speed and Pressure Wind Drag Naylis Shaft Computation Data Analysis Method Results Frequencies Passuts Assessment Foundation	Legs	t on lattice structure ce loa Diagonals Secondary of Marking 19,900 Panel A 19,900 Panel A - 8 18,650 Panel A - 7 17,400 Panel A - 7	d on discrete struct liagonals Horiz Element number 9 - 16 16 15 14	Iure elements I Ic ontals Secon Siope to horizontal [deg] 90,000 90,000 90,000	e weight on lines dary horizontals Wind incidence (leg 1) [deg] 90,000 90,000 90,000	wind incidence (leg 2) (deg) 90,000 90,000 90,000	Wind incidence (leg 3) [deg] 90,000 90,000 90,000	wind incidence (leg 4) [deg] 90,000 90,000 90,000	Wind of Rime shape Leg 1	firection: 0 Rime shape Leg 2 AB AB AB	• A • A • A	Rime shape Leg 3 B B B	•
Snow Load Snow Load Snow Load Loe Load Wind Directions and Drag Types Wind Disections Source Types Wind Disections and Drag Types Wind Disections Wind Dise	Legs	t on lattice structure Tice loa Diagonals Secondary of Marking 19,900 Panel A 19,900 Panel A - 8 18,650 Panel A - 7 17,400 Panel A - 7 17,400 Panel A - 5	d on discrete struct liagonals Hoiz Element number 9 - 16 16 15 14 14 13	Interelements Ic ontais Secon bo horizontal [deg] 90.000 90.000 90.000	e weight on lines day horizontals Wind incidence (leg 1) [deg] 90,000 90,000 90,000	ar ancillaries Ice Wind incidence (leg 2) [deg] 90,000 90,000 90,000	Wind incidence (leg 3) [deg] 90,000 90,000 90,000 90,000	ancilaries Wind incidence (leg 4) [deg] 90,000 90,000 90,000	Wind of Shape Leg 1	firection: 0 Rime shape Leg 2 AB AB AB AB	- A - A - A - A - A	Rime shape Leg 3 B B B B B B B	· · · · · · · · · · · · · · · · · · ·
Venue a Load Snow Load Loe Load Horizontal Load Wind Directions and Drag Types Wind Speed and Pressure Wind Drag nalysis Shaft Computation Data Analysis Method tesults Frequencies Presults Foundation Foundation	Legs	t on lattice structure to be load Diagonals Secondary of Marking 19,900 Panel A 19,900 Panel A - 8 18,650 Panel A - 7 17,400 Panel A - 5 16,150 Panel A - 5	d on discrete struct liagonals Horiz Element number 9 - 16 16 15 14 13 12	ure elements I c ontals Secon Co horizontal [deg] 90.000 90.000 90.000 90.000 90.000	e weight on linea day horizontals Wind incidence (leg 1) (deg) 90.000 90.000 90.000 90.000 90.000	x ancillaries Loe 	Vind incidence (leg 3) (deg) 90,000 90,000 90,000 90,000 90,000	ancillaties Wind incidence [leg 4] 90,000 90,000 90,000 90,000 90,000 90,000	Wind of Shape Leg 1	firection: 0 Rime shape Leg 2 AB AB AB AB AB	• A • A • A • A • A • A	Rime shape Leg 3 B B B B B B B B B B B B	· · · · · · · · · · · · · · · · · · ·
Verwar Load - Snow Load - Ice Load - Wind Directions and Drag Types - Wind Speed and Pressure - Shaft Computation Date - Analysis Method Results - Frequencies - Results - Assessment - Foundation	Legs	t on lattice structure to a loa Diagonals Secondary of Marking 19,900 Panel A 19,900 Panel A - 8 18,650 Panel A - 7 17,400 Panel A - 6 16,150 Panel A - 6 14,300 Panel A - 4 13,560 Panel A - 3	d on discrete struct liagonals Horiz Element number 9 - 16 16 15 14 13 12 11	ure elements lc ontais Secon bo horizontal [deg] 90.000 90.000 90.000 90.000 90.000 90.000	e weight on lines day hoizontals Wind incidence [leg 1] (deg) 90.000 90.000 90.000 90.000 90.000 90.000	x ancillaries Lee Wind incidence [leg 2] [deg] 90,000 90,000 90,000 90,000 90,000 90,000	Wind incidence (leg 3) 90,000 90,000 90,000 90,000 90,000 90,000	ancillaries ////////////////////////////////////	Wind of Shape shape Leg 1 AB • AB • AB • AB • AB • AB • AB • AB •	firection: 0 hine chape chape leg 2 AB AB AB AB AB AB	- A - A - A - A - A - A - A - A	Rime shape Leg 3 B B B B B B B B B B B B B B B	
Verwar Load - Snow Load - Loe Load - Wind Directions and Drag Types - Wind Speed and Pressure - Wind Speed and Pressure - Wind Drag - Maysis - Shaft Computation Data - Analysis Method - Results - Frequencies - Results - Assessment - Foundation	Legs	t on lattice structure tice loa Diagonals Secondary of Marking 19,900 Panel A 19,900 Panel A 19,900 Panel A 19,900 Panel A 19,900 Panel A 19,900 Panel A 19,900 Panel A 10,500 Panel A 11,500 Panel A 11,	d on discrete struct liegonals Hoiz Element number 9 - 16 16 15 14 13 12 11 11 12	ure elements I Ic ontals Secon borizontal [deg] 90,000 90,000 90,000 90,000 90,000 90,000	e weight on lines day horizontals "incidence (leg 1) 90,000 90,000 90,000 90,000 90,000 90,000 90,000	x ancillaries Los incidence (leg 2) (deg) 90,000 90,000 90,000 90,000 90,000	Wind incidence (leg 3) (deg) 90,000 90,000 90,000 90,000 90,000 90,000	ancilaries Wind incidence [leg 4] (deg] 90,000 90,000 90,000 90,000 90,000 90,000	Wind of shape Leg 1 AB • • AB • • AB • • AB • • AB • • AB • • AB • •	firection: 0 Fine shape Leg 2 AB AB AB AB AB AB AB AB	- A - A - A - A - A - A - A - A	Rime shape Leg 3 B B B B B B B B B B B B B B B B B B B	

Fig. 31 Page "Ice load", tab "Ice weight on lattice structure" for rime ice

ample E Lattice structure	nopole										
- Project, Standards	Tupe of	ice:	Bime		•]						
Structure Tupe of the Structure	Rime ice	1	114110								
Tower / Shaft Geometry	Ice clas	s for rime:	R2		•			X=		2	
- Cross Section Characteristics	Ice weight:		m_k	-	0,9 🐳 kg	µ∕m					
Material	Ice den	sity:	gamma=		500÷ kg	ı/m3					
Important Points Foundation	Wind pr	ressure reduc	tion factor: k=		0,45 🕂 (ad	ccording to Table	27, ISO 12494)				
- Ancillaries	Ice action:	s:		7.8 							
- Calculation Model - Loading		lce action									
E-Vertical Load		ce 1 - domina	and line								
La voltodi Loda											
Snow Load	1	ce 2 · accom	panying								
- Snow Load - Ice Load	•	ce 2 - accom	panying								
- Snow Load - Ice Load - Horizontal Load - Wind	•	ce 2 - accom	panying								
	Ice weig	ce 2 - accom ht on structur	panying e Ice load on disc	rete structure eler	nents Ice wei	ght on linear ancill	aries Ice load o	n discrete and	illaries		
Show Load Show Load Lee Load Wind Load Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Wind Drag Wind Drag Wind Drag	Ice weig	ce 2 - accom ht on structur	e Ice load on disc Marking	rete structure eler Element number	nents Ice wei Height factor	ght on linear ancill Tube diameter	aries Ice load o Ice weight to 300mm	n discrete and Ice thickness	illaries Rime vane length		Ice weight
Ince Load Ince Load Ince Load Ince Load Wind Directions and Drag Types Wind Directions and Drag Types Wind Drag Analysis Second Drade Effects Analysis Method	Ice weig	ce 2 - accom	e Ice load on disc Marking	rete structure eler Element number	nents Ice wei Height factor K_h	ght on linear ancill Tube diameter d [mm]	aries Ice load o Ice weight to 300mm psiK_h m [kg/m]	n discrete and Ice thickness t	illaries Rime vane length L [mm]		Ice weight psiK_h m [kg/m]
Analysis Analysis Analysis Analysis Analysis Second Dride Effects Analysis Analysis Analysis Second Dride Effects Analysis Analysis Analysis Second Dride Effects Analysis Analysis Method	Ice weig	te 2 - accom	e Ice load on disc Marking Panel A	rete structure eler Element number 3 - 4	nents Ice wei Height factor K_h 1,197	ght on linear ancill Tube diameter d [mm] 324,0	aries Ice load o Vice weight to 300mm psi K_h m [kg/m] 1,1	n discrete and Ice thickness t [mm]	illaries Rime vane length L [mm] 0	9	lce weight psiK_h m [kg/m] 1,
Analysis Method Second Order Effects Analysis Frequencies Frequencies Results	Ice weig	ce 2 - accom ht on structur 1 18,000 12,000	Panying Ice load on disc Marking Panel A Panel B	rete structure eler Element number 3 - 4 2	nents Ice wei Height factor K_h 1,197 1,127	ght on linear ancill Tube diameter d [mm] 324,0 508,0	aries Ice load o Vice weight to 300mm psi K_h m [kg/m] 1,1 1,0	n discrete and Ice thickness t [mm]	illaries Rime vane length L (mm) 0	9	lce weight psiK_h m [kg/m] 1,

Fig. 32 Page "Ice load", tab "Ice weight on structure" for monopoles and chimneys for rime ice



I	ce weigl	ht on lattice struc	ture Ice I	oad on di:	screte struct	ture (elements	ce w	eight on linear a	incillaries	Ice load	l on discrete	e ancillaries
		Marking	Hei	ght	Height factor		lce weight		lce weight total				
			[r	[m] K_		K_h M_di,i [kg]			psi K_h M_di,i [kg]				
	•	Platform	17,4	1		1,19		9,50	1	1,31			
	i Ice weigl	ht on lattice struc	ture Ice	Ice load on discrete structure elem			elements	ce w	eight on linear a	ncillaries	Ce load	l on discrete	e ancillaries
		Marking		Bottom height			Top height		lce weight	Redu ice we	ced eight		
					[m]	[m]			m_la,i [kg/m]	psim [kg/	_la,i m]		
	•	Ladder		0		19,	9 Panel A		2,00		2,00		
		Cables		0		19,	9 Panel A		1,80		1,80		
	lce weigl	ht on lattice struc	ture Ice	oad on di:	screte struct	ture (elements	ce w	eight on linear a	ncillaries	Ice load	l on discrete	e ancillaries
		Marking	He	ght	Height factor		Ice weight		lce weight total				
]]	n]	K_h		M_di,i [kg]		psi K_h M_di,i [kg]				
	•	Antennas	18		1	,20	120),00	14	3,67			
		Antenna sup	17,5		1	,19	95	5,00	11	3,17			
		MW antennas	13		1	,14	2	2,00		2,28			

Fig. 33 Page "Ice load", tabs: Ice weight on linear ancillaries, discrete ancillaries and discrete structure components for rime ice

7.7.3.2 Glaze ice

The overall ice weight in the panels and glaze width are determined on this page, see *Fig. 34, Fig. 35*. The ice thickness *t* is set according to selected ice class for glaze or it can be set manually by user.

The ice load is evaluated automatically for the lattice structure (*Fig. 34*) and for tubular poles and chimneys (*Fig. 35*). The ice load of discrete structure component, linear and discrete ancillaries must be set manually by user (for all ice situations and wind directions), see *Fig. 36*.



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Example 2 - Lattice structure Example 1 - Mono	pole							
- Project, Standards	Type of ice: Glaze		-					
E Structure	Glaze ice							
Tower / Shaft						14		
Geometry	Ice class for glaze: G4		•			X=	4	1
Lattice structure definition	Glaze thickness:	t=	40,0 👘 mn	m				
Discrete Structure Components	Ice density: gamm	a=	900 🔶 kg	g/m3				
- Materials and Profiles	Wind pressure reduction factor:	k=	0.55 A	coording to Table 27	ISD 124941			
Bolts				energing to there at the				
Connections	Ice actions:							
- Ancillaries	lce							
Calculation Model	action							
🖨 Loading	lce 1 - dominant							
- Load combinations	Ice 2 - accompanying							
Spowload	•							
Ice Load								
- Horizontal Load	Ice weight on lattice structure	d an diaarata atruat	ura alamanta 🛛	oo waiaht oo lixoor o	noillarian Lloo Ior	ud on disorato anai	Incina	
Wind	The maight of haddle of declare The IDE	a on discrete struct	ure elements it	ce weight on inteal al	riciliaries ice iua	iu on uiscrete anci	lailes	_
- Wind Directions and Drag Types	Legs Diagonals Secondary of	liagonals Horiz	ontals Secor	ndary horizontals	Wind	d direction: 0		-
Wind Drag		-			1923	74585		
🖻 Analysis	Marking	Liement	Ice	uilaze	lce weight	lce weight	l otal ice weight	Ê
- Shaft Computation Data		THE ST		addition	inoight.	per meter	per meter	
Analysis Method						(Legs)	(all members)	1
🖻 Results							membersj	Н
- Frequencies			t. farml	L	m Reader 1	11 Jay 1	(L	
Assessment	10,000 D. 14	0.10	friend	found	[Kg/m]	[Kg/m]	[Kg/III]	
Foundation	- 19,300 Panel A	9.16		-		0,0		L
	19,300 Panel A - 8	16	40,0	0,08	14,6	58,4	196,9	
	18,650 Panel A - 7	15	40,0	0,08	14,6	58,4	190,0	
	17,400 Panel A - 6	14	40,0	0,08	14,6	58,4	196,9	
2 III III	L sources u.e.	10			100		100.0	4117

Fig. 34 Page "Ice load", tab "Ice weight on lattice structure" for glaze ice



Fig. 35 Page "Ice load", tab "Ice weight on structure" for monopoles and chimneys for glaze ice



Ice we	ight on lattice stru	icture Ice load on di	screte structure e	elements Ice weight	on linear ancillaries Ice load on discrete ancillaries
	Marking	Height	Ice weight	lce weight total	
		[m]	M_di,i [kg]	psi M_di,i [kg]	
•	Platform	17,4	20,00	20,00	

Ice weight on lattice structure Ice load on discrete structure elements Ice weight on linear ancillaries Ice load on discrete ancillaries

	Marking	Bottom height	Top height	lce weight	Reduced ice weight
		[m]	[m]	m_la,i [kg/m]	psim_la,i [kg/m]
	Ladder	0	19,9 Panel A	5,00	5,00
•	Cables	0	19,9 Panel A	10,00	10,00

Ice weight on lattice structure	Ice load on discrete structure elements	Ice weight on linear ancillaries	Ice load on discrete ancillaries	

	Marking	Height	lce weight	lce weight total
		[m]	M_di,i [kg]	psiM_di,i [kg]
	Antennas	18	50,00	50,00
	Antenna sup	17,5	60,00	60,00
•	MW antennas	13	20,00	20,00

Fig. 36 Page "Ice load", tabs: Ice weight on linear ancillaries, discrete ancillaries and discrete structure components for glaze ice

7.7.4 Wind load

7.7.4.1 Basic wind characteristics

Wind zone, basic wind speed (for mean return period of 50 years or different) and terrain category are defined on the page "Wind". Settings of wind characteristics according to Czech national annex [CZE4] are shown on *Fig. 37*, according to German national annex [DEU2] on *Fig. 38*.

For DIN standards fundamental wind pressure and altitude are set, see Fig. 39.


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Example 2 - Lattice structure Example 1 - Monop	ole				
Project, Standards	Wind area and basic wind speed				
E Structure ── Type of the Structure	National Annex. Czech natio	onal annex	•		Wind zone:
Tower / Shaft	Fundamental value of the wind speed:	v(b,0)=	27,5	m/s	
 Lattice structure definition Lattice cross section characteristics 	Directional factor:	c(dir)=	1,0		
- Discrete Structure Components	Season factor:	c(season)=	1,0 🚔		
Materials and Profiles Bolts	Basic wind speed:	v(b)=	27,5	m/s	(for mean return period of 50 years)
Foundation	Basic wind speed for different mean return p	eriod			
Ancillaries Calculation Model	Mean return period:		50	years	
- Loading	Annual exceedence of probability:	p=	0,02		
- Load combinations	Parameters:	K=	0,2 🚔		
Snow Load		n=	0,5 🜩		
- Horizontal Load	Probability factor:	c(prob)=	1,00		
Wind Wind Directions and Drag Types	Basic wind speed:	v(b,prob)=	27,5	m/s	
- Wind Speed and Pressure	Terrain category				
Analysis	Terrain category:	I	•		
- Analysis Method	Roughness length:	z0=	0,050		
E Results	Minimum height:	z(min)=	2,00		
Results	Roughness height for terrain catego	ry II: z(0,11)=	0.05		
Assessment Foundation	Terrain factor:	k(r)=	0,19		

Fig. 37 Page "Wind", settings according to Czech national annex

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Example 1 - Monopole Example 2 - Lattice structu	re							
Project, Standards	Wind area and basic wind speed	1						
E- Structure	National Annex:	German national annex	•		Wind zone:	WZ1		•
Tower / Shaft Geometry	Fundamental value of the w	ind speed: v(b,0)=	22.5	m/s	Altitude:	H_s=		800 🜩 m a.s.l.
- Lattice structure definition - Lattice cross section characteristics	Directional factor:	c(dir)=	1,0		Altitude incr	ement factor:		1.0
- Discrete Structure Components	Season factor:	c(season)=	1,0 🚔					
Materials and Profiles Bolts	Basic wind speed:	v(b)=	22,5	m/s	(for mean retu	rn period of 50 ye	ars]	
	Basic wind speed for different me	ean return period						
- Ancillaries	Mean return period:		50 🚔	years				
E- Loading	Annual exceedence of pro	bability: p=	0.02					
- Load combinations	Parameters:	K=	0,1 🚔					
Snow Load		n=	10					
Ice Load	D I I D C		1.00 4					
Horizontal Load	Probability ractor:	c(prob)=	1,00					
- Wind Directions and Drag Types	Basic wind speed:	v(b,prob)=	22,5	m/s				
Wind Speed and Pressure Wind Drag	Terrain category							
- Analysis	Terrain category:		•					
- Shart Computation Data - Analysis Method	Roughness length:	z0=	0,050					
Erequencies	Minimum height:	z(min)=	4,00					
Results	Profile exponent:	alpha=	0,16					
	Wind turbulence exponent	: epsilon=	0,26					

Fig. 38 Page "Wind", settings according to German national annex





Fig. 39 Page "Wind", settings according to DIN 4131 [17]

7.7.4.2 Wind directions and wind drag types

The wind direction assumed in calculation are defined on the page "Wind directions", see Fig. 40.

Three wind drag types are prepared as default "Wind drag 1" for ice-free structure, "Wind drag 2 + Ice 1" for dominant ice and accompanying wind and "Wind drag 2 + Ice 2" for dominant wind and accompanying ice. Other types of wind drag can be alternatively added by user.





Fig. 40 Page "Wind directions"

7.7.4.3 Wind velocity and pressure

The wind velocity and pressure are shown on the page depicted in *Fig. 41*. The orography factor can be set there (differently for all wind drag types and wind directions).

For DIN standards application of constant wind pressure for towers up to 50 m can be switched on. Additional pressure in obedience to DIN 4131 [17] can be set, see *Fig. 42*.



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Example 2 - Lattice structure Example 1 - Monopo	le										
Project, Standards Type of the Structure Type of the Structure Geometry Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles Bolts Connections Foundation	Mean w Averag Turbule Air den Basic v	vind ing I ence sity: reloc	speed, ime for factor: ity pres	turbulence intenz the mean wind sp sure: Wind drag 1	ity and peak velocity beed T= Kli p= q_b=	pressure	600 🔹 1,00 🔹 1,25 🔄 0,47 🛬	s kg/m² kN/m²			
Ancillaries Calculation Model	Wind d	irecl	ion:	0	•						
- Loading											
Load combinations ⊡- Vertical Load Snow Load				Marking	Element number	Roughness factor	Orography factor	Mean wind velocity	Turbulence intensity	Peak velocity pressure	Exposure factor
Ice Load ⊡- Horizontal Load						c_r(z)		v_m(z) [m/s]	l_v(z) [m/s]	q_p(z) [kN/m²]	c_e(z)
Wind Directions and Drag Types	*	+	19,90	10 Panel A	9 - 16	1,137	1,000	31,3	0,167	1,327	2,81
- Wind Speed and Pressure		+	9,900	l Panel B	5 - 8	1,005	1,000	27,6	0,189	1,109	2,35
- Wind Drag		+	5,000	I Panel C	1 - 4	0,875	1,000	24,1	0,217	0,912	1,93
Shaft Computation Data Analysis Method Frequencies Results Assessment Foundation											

Fig. 41 Page "Wind speed and pressure" for Eurocode

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ample 1 - Monopole Example 2 - Lattice structu	ile 🔤								
Project, Standards Structure	Peak v	eloci	ly pressure			20 1			
Type of the Structure Tower / Shaft	Height		e tower.	1	1=	20	111. 		
Geometry	Air den:	sity:		F	>=	1,25	kg/m3		
 Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles Bolts 	Use co	nsta	nt wind pressure for towe	ərs <50m:					
Connections	Wind d	rag:	Wind drag 1		•				
Foundation	000000000	00.70 	(
Ancillaries	Wind d	irect	on: [0		•				
Calculation Model	~								
⊢ Load combinations ⊖- Vertical Load ⊢ Snow Load ⊢ Ice Load			Marking	Element number	Additional pressure	Additional pressure (multiple of q)	Peak velocity pressure	Peak velocity pressure with additions	Peak wind velocity
Wind Directions and Drag Types					delta q [kN/m²]		q(z) [kN/m²]	q(z) [kN/m²]	v_max(z) [m/s]
 Wind Speed and Pressure Wind Drag 		4	19,900 Panel A	9 - 16	0,000	0,0	1,326	1,326	46,1
- Analysis		+	9,900 Panel B	5-8	0,000	0,0	1,296	1,296	45,5
			5,000 Panel C	1 - 4	0,000	0,0	1,282	1,282	45,3
Results		+	5,000 Panel C - 2	3 - 4	0,000	0,0	1,282	1,282	45,3
Frequencies		+	2,621 Panel C - 1	1.2	0,000	0,0	1,275	1,275	45,2
Results Assessment Foundation									

Fig. 42 Page "Wind speed and pressure" for DIN standard



7.7.4.4 Wind drag

The wind drag of lattice towers is determined according to chapter B.2.1.3, Annex B, EN 1993-3-1 [8] or according to chapter A.1.3, Annex A, DIN 4131 [17]. The flow regime of iced tubular members of lattice towers depends on the shape of ice. The default setting for rime is flow regime for flat items, which is unfavourable. In case of small rime vane length the flow regime can be changed manually to "subcritical" (or "circular" for DIN standards with ice according to ISO 12494 [12]), see page depicted in *Fig. 43*.



Fig. 43 Page "Wind drag", tabs: Structure-lattice, Flow regime of iced legs

The projected areas of plates in joints or stiffeners can be set on page depicted in Fig. 44.



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Example 2 - Lattice structure Example 1 - Monopo	le													
Project, Standards Structure Structure Geometry Lattice structure definition Lattice cross section characteristics Oracle Structure definition Lattice cross section characteristics Oracle Structure Components Materials and Profiles Consections Consections Cacluation Model Loading Cade dombinations Oracle Load Gonv Load Gonv Load Sonv Load Gonv Load Sonv Load	Wind dra Wind dire Structu Memt	g: action: ne - lattice pers length	Wind drag 1 0 Discrete structure ek Width - legs Width - secondar Width - horizonta Width - secondar	ements Linear an y diagonals ls y horizontals	cillaries Discreto Projected are Wind force co	Kinematic viscos v= () a ancillaries To a normal to face sefficient	ly of the air:),0000150 (슈퍼) - 1 tal wind drag Average stru	nit/s	1,788 📩 n	Y				
			Marking	Element number	Projected area normal to face (Legs)	Projected area normal to face (Diagonals)	Projected area normal to face (Diagonals2)	Projected area normal to face (Horizontals)	Projected area normal to face (Horizontals2)	Projected area normal to face (Plates)	Total projected area (flat) A_f [mm2/mm]	Total projected area (subcritical) A_c (mm2/mm1	Total projected area (supercritical) A_c.sup [rmp2/mm]	Total projected area normal to face A_S
Wind		19.90	0 Panel A	9.16	function of	(minerining)	function of	franzerung	tunnin und	0.040	(minerinity)	[min2: min]	[initial initial	franzistad
- Wind Directions and Drag Types - Wind Speed and Pressure		19,	,900 Panel A - 8	16	0,178	0,094		0,060		0,040	0,194	0,178	0,000	0,372
Wind Drag		18,	,650 Panel A - 7	15	0,178	0,094		0,048		0,040	0,182	0,178	0,000	0,360
Analysis		17,	,400 Panel A - 6	14	0,178	0,094		0,060		0,040	0,194	0,178	0,000	0,372
Analysis Method		16,	150 Panel A - 5	13	0,178	0,094		0,048		0,040	0,182	0,178	0,000	0,360
Besults		14,	.900 Panel A - 4	12	0,178	0,094		0,060		0,040	0,194	0,178	0,000	0,372
- Frequencies		13,	,650 Panel A - 3	11	0,178	0,094		0,048		0,040	0,182	0,178	0,000	0,360
Assessment		12,	400 Panel A · 2	10	0,178	0,109		0,060		0,040	0,209	0,178	0,000	0,387
- Foundation		11,	,150 Panel A - 1	9	0,178	0,109		0,048		0,040	0,197	0,178	0,000	0,375
		+ 9,900) Panel B	5.8						0,020				
		+ 5.000) Panel C	1 - 4						0,020				

Fig. 44 Page "Wind drag", tabs: Structure-lattice, Projected area normal to face

Force coefficient of the structure is calculated automatically on page shown in *Fig. 45*. The addition of overall width of the tower (e.g. parts of ancillaries or platforms extended beyond the face of the structure) is set by user on this page.

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Cantor 2 - Cancor and color Example 1 - Monopol Project: Standards Shucture Tower / Shaft Generatly Lattice structure definition Lattice careaction characteristics Disorder Shucture Components Materials and Photles Bolte Connections Foundation	Wind dra Wind dire Structu	9: Wind drag 1 ction: 0 bescrete structure el width - legs Width - diagonals Width - secondar Width - secondar Width - secondar	v ements Linear ar b y diagonals Is	Incilaries Discret Projected are Wind force of	Kinematic viscos v= 1 le ancilaries Tc sa normal to face oefficient	ity of the air: 0,0000150 ‡ r tal wind drag	²/s	1,788 🏂 r	n					
Foundation Ancillaties Ancillaties Calculation Model Loadi Load combinations Vertical Load Ison Load Ice Load Hotomula Load		Width - seconda Marking	y horizontals Element number	Width of structure b [m]	Addition b	Solidity ratio phi	Force coefficient (flat) c_f.0,f	Force coefficient (subcritical) c_f.0,c	Force coefficient (supercritical) c_f,0,c,sup	Overall wind force coefficient c_f.S.0	KI	K2	Wind incidence factor Kq	Kq*c_f,S,0
	•	- 19,900 Panel A	9 - 16		0,000									
- Wind Directions and Drag Types		19,900 Panel A - 8	16	1,589	0,000	0,234	2,787	1,631	1,301	2,234	0,670	0,234	1,000	2,234
Wind Speed and Pressure		18,650 Panel A • 7	15	1,589	0,000	0,226	2,818	1,646	1,303	2,238	0,674	0,226	1,000	2,238
Analysis		17,400 Panel A · 6	14	1,589	0,000	0,234	2,787	1,631	1,301	2,234	0,670	0,234	1,000	2,234
- Shaft Computation Data		16,150 Panel A - 5	13	1,589	0,000	0,226	2,818	1,646	1,303	2,238	0,674	0,226	1,000	2,238
Analysis Method		14,900 Panel A - 4	12	1,589	0,000	0,234	2,787	1,631	1,301	2,234	0,670	0,234	1,000	2,234
E Commente		13,650 Panel A - 3	11	1,589	0,000	0,226	2,818	1,646	1,303	2,238	0,674	0,226	1,000	2,238
Frequencies Results		12,400 Panel A · 2	10	1,589	0,000	0,244	2,747	1,613	1,298	2,226	0,665	0,244	1,000	2,226
- Results				(0.000	0.236	2.778	1.627	1.300	2,232	0,669	0,236	1.000	2,232
		11,150 Panel A - 1	9	1,589	0,000	0,200								
		11,150 Panel A - 1 + 9,900 Panel B	9 5-8	1,589	0,000	0,200								

Fig. 45 Page "Wind drag", tabs: Structure-lattice, Wind force coefficient

The projected areas and force coefficients of iced discrete structure components, iced linear and discrete ancillaries must be set manually by user (for all wind directions and wind drag types), see *Fig. 46*.





Fig. 46 Page "Wind drag", tabs: Wind drag of discrete structure components, linear and discrete ancillaries

The shielding factor for ancillaries and discrete structure components can be taken account, see previous *Fig. 46*. This factor takes into consideration shielding of one ancillary by other ancillary or ancillaries without influence of the structure.

The shielding of the ancillaries by the structure itself may be taken into consideration using reduction factors K_A according to B.2.3., EN 1993-3-1 [8]. Default values of reduction factors are 1.0, see *Fig.* 47. The values can be changed manually according to conditions given in B.2.3., EN 1993-3-1 [8].

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Example 1 - Monopole Example 2 - Lattice struct	lure																
	Wind di Wind di Struct Red Tot	rag: Wind drag 1 iection: 0 sure - lattice Discrete structure luction factors al c_1^A_ref Total c_1	elements Linear 'A_S (DIN)	n ancilaries Discre	Kinematic viscos v= 1 te ancillaries 10	ity of the air: 0,0000150 🜲 ा tal wind drag	nè/s										
- Botts - Connections - Foundation - Calculation Model ■ Loading - Load combinations ⊕ Vertical Load		Marking	Element number	Comparison of projected areas [linear]	Comparison of projected areas [total]	Total projected area normal to face A_S [mm2/mm]	Kq"c_(.S.0	Reduction factor (structure) K_S,L [linear]	Total projected area (structure) A_S.D [m2]	Total force coefficient (structure) C_f(SD,0 [discrete]	Reduction factor (structure) K_S,D [discrete]	Total projected area (ancilaries) A_AL [m2/m]	Total force coefficient (anciliaries) C_FA,0 [inear]	Reduction factor (ancillaries) K_A,L [linear]	Total projected area (ancilaries) A_A,D [m2]	Total force coefficient (ancilaries) C_(AD,0 [discrete]	Reduction factor (ancilaries) K_A,D (discrete)
- Snow Load		- 19,900 Panel A	9-1	6													_
Horizontal Load		19,900 Panel A - 8	1	6 Linear AA < AS	Total AA > AS	0,372	2,234	1,0	0,000	0,000	1,0	0,314	2,000	1,0	0,000	0,000	1.0
Wind Wind Directions and Drag Tunes		18,650 Panel A - 7	1	5 Linear AA < AS	Total AA > AS	0,360	2,238	1,0	0,000	0,000	1,0	0,314	2,000	1,0	5,025	1,391	1,0
- Wind Speed and Pressure		17,400 Panel A - 6	1	4 Linear AA < AS	Total AA > AS	0,372	2,234	1,0	0,000	0,000	1,0	0,314	2,000	1,0	7,785	1,334	1,0
Wind Drag		16,150 Panel A - 5	1	3 Linear AA < AS	Total AA < AS	0,360	2,238	1.0	0.000	0.000	1.0	0,314	2,000	1,0	0.000	0.000	1.0
- Shaft Computation Data		14,900 Panel A · 4	1	2 Linear AA < AS	Total AA < AS	0,372	2,234	1,0	0,000	0,000	1,0	0,314	2,000	1,0	0,000	0,000	1,0
Analysis Method		13,650 Panel A - 3	1	1 Linear AA < AS	Total AA > AS	0,360	2,238	1,0	0,000	0.000	1.0	0.314	2,000	1,0	0,067	1,400	1.0
E-Results		12,400 Panel A · 2	1	0 Linear AA < AS	Total AA < AS	0,387	2,226	1,0	0,000	0,000	1,0	0,314	2,000	1,0	0,073	1,400	1,0
Results		11,150 Panel A · 1		9 Linear AA < AS	Total AA < AS	0,375	2,232	1,0	0,000	0,000	1,0	0,314	2,000	1,0	0,000	0,000	1.0
Assessment		+ 9,900 Panel B	5.	8													
Poundation		+ 5,000 Panel C	1.	4													

Fig. 47 Page "Wind drag", tabs: Total wind drag, Reduction factors



Project, Standards Etructure Type of the Structure Tower / Shaft	Wind drag Wind dire	g: ction:	Wind drag 1 45	•		Kinematic viscosi v= 0	ty of the air:),0000150 🚔 m	7/s
Geometry	Shuchur	o . latt	ice Discrete structure e	ements Linear an	cillariae Discret	e ancillaries To	tal wind drag	
 Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles Bolts 	Reduce Total	ction fa	actors A_ref Total c_f*A	_S (DIN)				
Connections oundation sncillaries Calculation Model			Marking	Element number	Linear reference area	Discrete reference area	Total wind force coefficient	Total wind force coefficient
oading Load combinations					A_ref [m2/m]	A_ref [m2]	_C_f [linear]	C_f [discrete]
Vertical Load	•	1	19,900 Panel A	9 - 16				
			19,900 Panel A - 8	16	0,815	0,000	2,266	0,000
- Horizontal Load			18,650 Panel A - 7	15	0,803	5,025	2,260	1,391
			17,400 Panel A - 6	14	0,815	7,785	2,266	1,334
- Wind Directions and Drag Types			16,150 Panel A - 5	13	0,803	0,000	2,260	0,000
Wind Drag			14,900 Panel A · 4	12	0,815	0,000	2,266	0,000
nalysis 			13,650 Panel A - 3	11	0,803	0,067	2,260	1,400
- Analysis Method			12,400 Panel A - 2	10	0,831	0,073	2,274	1,400
esults			11,150 Panel A - 1	9	0,819	0,000	2,268	0,000
Frequencies		+	9,900 Panel B	5-8				
- Assessment		+	5 000 Papel C	1.4				

Fig. 48 Page "Wind drag", tab Total wind drag acc. to [CZE8]





Fig. 49 Page "Wind drag", tab Total wind drag acc. to [DEU4]

Total wind drag of lattice tower is shown on page depicted in *Fig. 48* for Czech national annex [CZE8], resp. *Fig. 49* for German national annex [DEU4].

The wind drag of monopoles and chimneys is determined according to chapter 7.9.2, EN 1991-1-4 [4] or chapter A.1.3, Annex A, DIN 4131 [17] if the shape of the shaft is tubular. If not, an appropriate force coefficient can be set manually, see *Fig. 50*. Force coefficients of iced tubular monopoles or chimneys are determined according to ISO 12494 [12] or chapter A.1.3, Annex A, DIN 4131 [17].



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ample 2 · Lattice structure Example 1 · Mon	opole											
– Project, Standards		(
Structure	Wind drag:	Wind drag 1		•	Kinema	ic viscosity of	the air:					
- Type of the Structure	Wind direc	tion: 0		-	V=	0.000	0150 🌰 m²/:	8				
E I ower / Shart		(-	07.01					
Cross Section Characteristics	Structure	tubes Discrete structure e	lements Line	ar ancillaries [iscrete ancilla	ries						
- Discrete Structure Components	Wind d	ag										
Material	Height	and diameter: From	structure geor	netry	-	Avera	age structure w	vidth:	1,155 🚔 🛛	m		
- Important Points		Height of the structure:	E 이		18.00 m							
Foundation		noight of the dualotato.			10,00							
Ancillaries		Average tube diameter:	b=		0,50 ÷ m							
Loading		Circular cylinders >50m:	g=		25 ÷							
- Load combinations		Canadas autodass of East			20 +							
- Vertical Load		circular cylinders (rom.	11=		-00							
Snow Load	Effectiv	e slenderness:	g=		35 ≑							
Ice Load	End eff	ect factor:	× a=		0.84							
- Horizontal Load			1971 OL									
		Marking	Flement	Peak	Tube	Beunold's	Equivalent	KOverB	Force	Force	Shielding	Width
Wind Speed and Pressure Wind Drag			number	wind velocity	diameter	number	surface roughness		coefficient	coefficient	factor	with ancillaries
Analysis Shaft Computation Data				v_max(z)	b	Re	k	k/b	c_f,0	c_f		Ь
- Second Order Effects		10.000 0	2.4	[IIIVS]	[hund]	0.005.05	[1000]	0175.04	0.001	0.071	1.00	[1111]
- Analysis Method	P	To,000 ManerA	3-4	40,5	324,0	3,83E+05	0,20	6,17E-U4	0,801	0,671	1,00	2,096
Results		18,000 Panel A	4	45,5	324,0	9,83E+05	0,20	6,17E-04	0,801	0,671	1,00	3,501
- Frequencies		16,700 Discrete an	3	45,1	324,0	9,74E+05	0,20	6,17E-04	0,800	0,670	1,00	1,707
nesulis Assessment		12,000 Panel B	2	43,2	508,0	1,46E+06	0,20	3,94E-04	0,794	0,665	1,00	0,608
1 100000011018			4	20.2	0.000	1.705.00	0.00	2.025.04	0.700	0.050	1.00	0.700

Fig. 50 Page "Wind drag", tab Structure-tubes

The tabs for definition of the wind drag of the discrete structure components, linear and discrete ancillaries are identical for both lattice towers and monopoles, see *Fig. 46*.

7.8 Analysis

7.8.1 Shaft computation data

The overall review of input data for analysis is shown on the page "Shaft computation data", see *Fig. 51*.

Lo Luc La ba visita	100														
mple 2 - Lattice structure Example 1 - Monopi	ole														
Project, Standards	Shaft	computation data	<u> </u>												
- Structure Type of the Structure	Load	combination:	COM	3		•									
Tower / Shaft Depretry	Wind	direction:	288			•									
Lattice structure definition Lattice cross section characteristics Discrete Structure Components Materials and Profiles		Marking		Element number	Top height	Dead load	Discrete snow load	Ice weight	Orography factor	Discrete wind drag	Uniform dead load	Uniform snow load	Uniform ice load	Uniform wind drag	Width including ancillaries
Bolts					z [m]	Q [N]	Q_\$ [N]	Q_ice [N]	c[0]_z	cf*Aref [m2]	q [N/m]	q_s [N/m]	q_ice [N/m]	cf*Aref [m2/m]	b [m]
Connections joundation incillarise Jaculation Model optime	•	19,900 Panel	x - 8	16	19,900	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,387E+03	0,000E+00	4,782E+02	2,498E+00	1,589E+00
		18,650 Panel	۸-7	15	18,650	2,752E+03	0,000E+00	0,000E+00	1,00	6,990E+00	1,258E+03	0,000E+00	4,723E+02	2,483E+00	1,589E+00
		17,400 Panel	4 - 6	14	17,400	7,348E+03	2,880E+03	0,000E+00	1,00	1,038E+01	1,323E+03	0,000E+00	4,664E+02	2,489E+00	1,589E+0
- Load combinations		16,150 Panel	4-5	13	16,150	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,258E+03	0,000E+00	4,606E+02	2,474E+00	1,589E+0
Vertical Load		14,900 Panel	4 - 4	12	14,900	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,387E+03	0,000E+00	4,549E+02	2,480E+00	1,589E+0
Snow Load		13,650 Panel	٨-3	11	13,650	9,600E+01	0,000E+00	0,000E+00	1,00	9,408E-02	1,258E+03	0,000E+00	4,492E+02	2,465E+00	1,589E+0
Horizontal Load		12,400 Panel	1-2	10	12,400	1,040E+02	0,000E+00	0,000E+00	1,00	1,019E-01	1,384E+03	0,000E+00	4,437E+02	2,482E+00	1,589E+0
Wind		11,150 Panel	x-1	9	11,150	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,319E+03	0,000E+00	4,382E+02	2,468E+00	1,589E+0
Wind Directions and Drag Types Wind Speed and Pressure		9,900 Panel B	• 2: V	8	9,900	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,379E+03	0,000E+00	5,618E+02	2,689E+00	1,633E+0
Wind Drag		8,814 Panel B	- 2: A	7	8,814	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,505E+03	0,000E+00	5,487E+02	2,717E+00	1,726E+0
nalysis Shoth Computation Dista		7,593 Panel B	• 1: V	6	7,593	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,170E+03	0,000E+00	4,310E+02	2,620E+00	1,825E+0
Analysis Method		6,373 Panel B	- 1: A	5	6,373	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,505E+03	0,000E+00	5,355E+02	2,789E+00	1,930E+0
esults		5,000 Panel C	• 2: V	4	5,000	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,481E+03	0,000E+00	4,315E+02	2,708E+00	2,031E+0
- Frequencies - Besults		3,868 Panel C	- 2: A	3	3,868	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,891E+03	0,000E+00	5,578E+02	2,910E+00	2,127E+00
Assessment		2,621 Panel C	• 1: V	2	2,621	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,481E+03	0,000E+00	4,214E+02	2,757E+00	2,228E+00
- Foundation		1,374 Panel C	- 1: A	1	1,374	0,000E+00	0,000E+00	0,000E+00	1,00	0,000E+00	1,891E+03	0,000E+00	5,441E+02	2,969E+00	2,334E+00
				0	0.000	0.000E+00	0.000E+00	0.000E+00	1.00	0.000E+00					

Fig. 51 Page "Shaft computation data"



7.8.2 Second order effects

The software allows evaluation of second order effects. The imperfections of the structure are set on page "Second order effects", see *Fig. 52*. The imperfections are determined according to chapter 5.3.2 (3), EN 1993-1-1 [5] and chapter 5.2.2 (1), EN 1993-3-2 [9] or chapter 2, DIN 18800-2 [20]. Nonlinear static calculation is done for sum of the initial imperfection and maximum deflection obtained from static or dynamic analysis. Accuracy of nonlinear static calculation and upper limit of number of iterations is set in tab "Calculation" placed in the middle of the page.

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ample 2 · Lattice structure Example 1 · Mor	opole							
- Project, Standards	Imperfe	ctions according to EN 1993-1	-1, 5.3.2 (3)					
Structure	Ultima	te limit state (ULS)				Serviceable lin	nit state (SLS)	
Type or the Structure Tower / Shaft	Globa	initial inclination				Global initial inclin	ation (erection t	olerances acc. to EN
Geometry	Daviau	n Innaan meninaation Islue		1		obilor - 1 / 100		Metances acc. to Et
- Cross Section Characteristics	Dasic v	aue pr		,	1.000	phi_er = 17	JU	T
	Reduct	ion factor for height	alpha_h= 0,6	7	A. 			
Important Points	Global i	initial inclination	phi = 1 / 300	1	(A) (90)			
Foundation								
Ancillaries	Helatr	ve initial local bow imperi	ection	N/N N				
Calculation Model	Produc	tion procedure	Cold formed (bu	ckling curve c)	•			
Loading - Load combinations	Analysi	s	plastic		*			
Vertical Load	Balativ	e initial local how imperfectic e	0/1 = 1 / [15]	1	- AC			
Snow Load	Trelative	e inidal local bow imperieduc ej		1	10			
Le Load								
- Horizontal Load	Calcula	ition						
	Max. in	acurracy of resulting deflection	at the top	1	e m	10		
- Wind Speed and Pressure	Mauina	m itaratiana		10		1.X		
Wind Drag	Maximu	im iterations		10	a training			
Analysis					112012 01	10 17 17		
- Shart Computation Data Second Order Effects	-	Marking	Element	Height	Global	Relative initial local	Total initial	Total initial
- Analysis Method			TURBOT	point	inclination	imperfection	for ULS	for SLS
Results				2				
- Frequencies				[m]	[mm]	[mm]	[mm]	[mm]
Results		- 18,000 Panel A	3-4	18,000	60	240	300	18
Foundation		18,000 Panel A	4	18,000	60	240	300	18
		16,700 Discrete ancil	3	16,700	56	207	262	17
	8	12 000 Panal P		12 000	40	107	147	12
		12,000 Fariel D	-					

Fig. 52 Page "Second order effects"



7.8.3 Analysis method

Modal characteristics (natural frequencies and mode shapes) of the tower are calculated first.

The number of calculated natural frequencies is set and upper limit of the frequency range, in which the natural frequencies are searched.

The mode shapes of 3D lattice tower for all wind directions and appropriated perpendicular directions are evaluated. The resultant mode shape in given direction is determined as a combination of couple of perpendicular mode shapes with identical frequency.

Than setting of the selected analysis method can be done or default setting modified. Different methods can be used for response determination of the tower.

a) Quasi-static analysis according to EN 1991-1-4 [4]

This method can be used for monopoles and chimneys designed according to EN 1993-3-2 [9]. The method may be used if criteria given in 6.3., EN 1991-1-4 [4] are met. Otherwise, spectral analysis or simplified spectral analysis is to be used.

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Example 1 · Monopole Example 2 · Lattice struct	sture					
Project, Standards	Analysis	method				
Structure Type of the Structure Type of the Structure	Method:	Quasistatic analy	sis according to EN 19	991-1-4 🔹 🖌 🖌	yaa	
Geometry	Modal ar	nalysis				
Tube Structure Definition Cross Section Characteristics	Number	of frequencies:	3 🔹		Upper limit	
Discrete Structure Components Material Bolts Connections		Frequency index	Structural damping	Damping due to special devices	of calculate natural freq	id juencies: 20 × Hz
Important Points	•	1	0,012	0,000	E	
Foundation Ancillaries		2	0,012	0,000		
Calculation Model		3	0.012	0.000	-	
Load combinations Vertical Load Snow Load Ice Load Horizontal Load Wind Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Shaft Computation Data Second Order Effects Analysis Method Results Frequencies Results Assessment Foundation	Uuassa Detei Refei Orogi	tic analysis according rmination of structural rence height: raphy factor at referer	factor c_s c_d using A	nnex: B z_s= 10,800 c0(z_s)= 1,00	m Ar	

Fig. 53 Page "Analysis method", setting of quasistatic analysis according to EN 1991-1-4 [4]

Approach for determination of structural factor (according to Annex B or C, EN 1991-1-4 [4]), reference height (default setting is 0,6x overall height of tower) and orography factor at reference height are set, see *Fig. 53*.



b) Equivalent static analysis according to B.3, EN 1993-3-1 [8]

This method can be used for lattice structures designed according to EN 1993-3-1 [8]. The method may be used if criteria given in B.3.1., EN 1993-3-1 [8] are met. Otherwise, spectral analysis or simplified spectral analysis is to be used.

Approach for determination of structural factor (according to Annex B or C, EN 1991-1-4 [4]), reference height (default setting is 0,6x overall height of tower) and orography factor at reference height and other characteristics are set, see *Fig. 54*.

analad Manaada e 1 o .		-	4							
cample 1 - Monopole Example 2 - Lattice stru	cture	64								
- Project, Standards	Analysis	method								
E Structure	Method	Equivalent static	analysis according to EN 19	93-3-1 👻 Analy	UZB					
Tower / Shaft										
Geometry	Modal a	nalusis								
- Tube Structure Definition	Number	of fraguenoise:	2 *							
- Cross Section Characteristics	Number	or nequencies.	3		Upper limit of calculated					
- Discrete Structure Components		Frequency	Structural Da	mping	natural frequencies: 20 - Hz					
Material		index	damping d	ue to						
- Bolts			st	ecial vices	÷					
Important Points			0.010	0.000						
- Foundation		1	0,012	0,000						
- Ancillaries		2	0,012	0,000						
- Calculation Model		3	0.012	0.000	*					
🖹 Loading	Equivale	nt static analysis acc	arding to EN 1993-3-1							
- Load combinations	- quir de									
E Vertical Load	· · ·			-						
	Dete	rmination of structura	factor c_s c_d using Annex:	В	—					
Horizontal Load	Refe	rence height:	Z	s= 10,800	🔿 m					
Wind	Oroc	ranhu factor at refere	ace beight c0(z -)= 100						
 Wind Directions and Drag Types 			ioo noight	1.20						
 Wind Speed and Pressure 										
	Den	situ of the material of t	ne tower structure:	7850	ka/m3					
Wind Drag	DOIL	sky of the material of t	ic tower structure.	1000	The second secon					
Analysis			3620 ·	0.001						
- Wind Drag Analysis - Shaft Computation Data - Second Drder Effects	Volu	me/resistance consta	nt	0,001						
Wind Drag Analysis Shaft Computation Data Second Order Effects Analysis Method	Volu Dep	me/resistance consta h in the direction of th	nt: ve wind:	830.000						
- Wind Drag Analysis Second Order Effects - Analysis Method Results	Volu Dep	me/resistance consta h in the direction of th	nt: e wind:	830,000						
Wind Drag Analysis - Shaft Computation Data - Second Order Effects - Analysis Method - Results - Frequencies	Volu Dep	me/resistance consta h in the direction of th	n: ie wind:	830,000	x.					
- Wind Drag - Analysis - Shaft Computation Data - Second Order Effects - Analysis Method - Results - Frequencies - Results	Volu Dep	me/resistance consta h in the direction of th	nt: ne wind:	830,000	A. V					
Wind Drag Analysis Analysis Second Order Effects Analysis Method Results - Results - Assessment Craved using	Volu Dep	me/resistance consta	nt ie wind:	830,000						
Wind Drag Analysis Analysis Second Order Effects Analysis Method Results Frequencies Results Assessment Foundation	Volu Dep	me/resistance consta	nt e wind:	830,000						
Wind Drag Analysis Analysis Second Order Effects Analysis Method Results Frequencies Results Assessment Foundation	Volu Dep	me/resistance consta h in the direction of th	nt: le wind:	830,000						
Wind Drag Analysis Analysis Analysis Method Results Results Results Assessment Foundation	Volu Dep	me/resistance consta h in the direction of th	nt: ie wind:	830,000						

Fig. 54 Page "Analysis method", setting of equivalent static analysis according to EN 1993-3-1 [8]



c) Simplified spectral analysis according to [16]

This method can be used for monopoles, chimneys and lattice structures. The method is described in chapter 3, [16].

The power spectral density of wind velocity for along and cross wind turbulence can be chosen as well as coherence function and admittance of individual panels, see *Fig. 55*.

For background response determination of the number of load cases can be set. If the number equal to the number of the panels is selected, the most accurate results are obtained.

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Example 1 - Monopole Example 2 - Lattice struct	ture					
- Project, Standards	Analysis method					
Structure Type of the Structure	Method: Simplified spectr	al analysis	Analyze			
Tower / Shaft						
- Lieometry	Modal analysis					
- Cross Section Characteristics	Number of frequencies:	3			Upper limit of calculated	
— Discrete Structure Components — Material — Bolts — Connections	Frequency index	Structural damping	Damping due to special devices		natural frequencies:	20 📩 Hz
Important Points	b 1	0.012	0,000			
- Foundation	2	0,012	0,000			
- Calculation Model	3	0.012	0.000	*		
🖨 Loading	Simplified spectral analysis					
- Load combinations	Background response					
Snow Load	Determination of background	factor B^2 using Ann	•			
Le Load	M				()]	
Wind	Number of load cases for the	background response	evaluation.	equal to the number o	r paneis 🔹	
 Wind Directions and Drag Types Wind Speed and Pressure Wind Drag 	Orography factor at reference	height	c0(z_s)=	1,00		
🖨 Analysis	Resonant response - Cha	racteristics of alo	ng wind turbulence			
	Power spectral density of wind	l speed:	EN 1991-1-4		*]
Analysis Method	Coherence function:		Davenport, Cy a Cz a	icc. to EN 1991-1-4	+	
- Frequencies	Admittance of individual panel	s:	EN 1991-1-4_Annex I	В	-]
Hesults Assessment	Resonant response - Cha	racteristics of cro	ss wind turbulence		Yes 💌	
Foundation	Power spectral density of wind	speed:	Kaimal			Ĵ
	Coherence function:		Davenport, Cy a Cz a	cc. to Vickery	•]
	Admittance of individual panel	s:	EN 1991-1-4_Annex B	B	*]
			<i>B</i>			

Fig. 55 Page "Analysis method", setting of simplified spectral analysis



d) Spectral analysis

This method can be used for monopoles, chimneys and lattice structures. The method is described e.g. [15] or briefly in chapter 2, [16].

The power spectral density of wind velocity for along and cross wind turbulence can be chosen as well as coherence function and admittance of individual panels, see *Fig. 56*.

- Project, Standards	Analysis m	ethod							
- Structure Type of the Structure	Method: Spectral analysis								
☐ Tower / Shaft	Modal ana	lysis							
 Tube Structure Definition Cross Section Characteristics 	Number of	frequencies:	3		ų	pper limit			
 Discrete Structure Components Material Bolts Connections 		Frequency index	Structural damping	Damping due to special devices	of na	r calculated atural frequencies:	20 🐑 Hz		
Important Points) E	1	0.0	0,000					
- Foundation		2	0,0	12 0,000					
- Calculation Model		3	0.0	12 0.000	*				
Loading									
- Load combinations	Spectral a	nalysis							
🚊 Vertical Load	Paramet	ers for calculation	n						
	Fraguista	u otop:		d - 0.005		U-			
Ice Load	Frequenc	y step.		d_1= 0,005		ΠZ			
Horizontal Load	Upper lim	it of investigated freq	uency range:	f_max= 10,00		Hz			
-Wind Directions and Drag Types	Along w	ind turbulence ch	aracteristics						
 Wind Speed and Pressure 	Power sp	ectral density of wind	speed:	EN 1991-1-4		•			
Wind Drag Analysis	Coherenc	e function:		Davenport, Cy a Cz acc. to EN	1991-1-4	•			
- Shaft Computation Data	Admittanc	e of individual panels	o.,	EN 1991-1-4 Anney P					
- Second Urder Effects				En 1991 I TOURORD					
- Besults	Cross w	ind turbulence ch	aracteristics		Y	'es 🔻			
- Frequencies	Power spe	ectral density of wind	speed:	Kaimal		•			
Hesults Assessment	Coherenc	e function:		Davenport, Cy a Cz acc. to Vick	ery	•]			
Foundation	A de Sterrer								
	Admittanc	e or individual panels	S.	EN 1991-1-4_Annex B		•			

Fig. 56 Page "Analysis method", setting of spectral analysis



e) Quasi-static analysis according to P 2.8, ČSN 730035 [13]

This method can be used for monopoles, chimneys and lattice structures designed according to standard ČSN 730035 [13]. The method may be used for towers, which met the description given in chapter P 2.8, ČSN 730035 [13], i.e. for towers with uniformly distributed mass, rigidity and wind drag. This method is included in the software only for comparisons. The standard ČSN is not valid at present.

Note: The wind drag and ice load determined in previous chapters (according EN and ISO standards) will be used for this analysis. The strictly correct calculation according to ČSN standard must be done for wind drag and ice load determined according to ČSN. This input must be set manually.

Wind zone, type of terrain and type of structure are set according to ČSN 730035 [13], see *Fig. 57*.

Disjant Chandrada	An alusia a	atha d					
- Structure	Analysis m	lethod					
Type of the Structure Tower / Shaft	Method:	Quasistatic anal	vsis according to CSN 7				
Geometry	Modal ana	alysis					
 Tube Structure Definition Cross Section Characteristics 	Number o	frequencies:	3			Upper limit	
— Discrete Structure Components — Material — Bolts — Connections		Frequency index	Structural damping	Damping due to special devices	*	of calculated natural frequencies: 20	Hz
Important Points	Þ	1	0.012	0.000	÷.		
- Foundation - Ancillaries		2	0,012	0,000			
Calculation Model		3	0.012	0.000	*		
Loading Loading Vertical Load Snow Load Load Horizontal Load Wind Directions and Drag Types Wind Speed and Pressure Wind Drag Analysis Analysis Method Frequencies Results Assessment Foundation	Wind : Funda Type o	cone: mental wind pressur of the terrain: of the strucure:	e: 450 A	V/m2	2		

Fig. 57 Page "Analysis method", setting of quasistatic analysis according to ČSN 730035 [13]



f) Analysis according to P 2.9 – P 2.16, ČSN 730035 [13] using mode shape decomposition method

This method can be used for monopoles, chimneys and lattice structures designed according to standard ČSN 730035 [13]. This method is included in the software only for comparisons. The standard ČSN is not valid at present.

Note: The wind drag and ice load determined in previous chapters (according EN and ISO standards) will be used for this analysis. The strictly correct calculation according to ČSN standard must be done for wind drag and ice load determined according to ČSN. This input must be set manually.

Wind zone, type of terrain and type of structure are set according to ČSN 730035 [13], see *Fig. 58*.

- Project, Standards	Analysis r	nethod					
- Structure	Method:	Analysis accordin	a to ČSN 730035 usine	mode shar 💌	Analyze		
Type of the Structure Tower / Shaft		(may be according	g	1			
Geometry	Modal an	alysis					
- Tube Structure Definition	Number o	Number of frequencies: 3				Linner limit	
- Cross Section Characteristics	1					of calculated	
- Material		Frequency	Structural	Damping	*	natural frequencies: 20 🚑 Hz	
Bolts		index	damping	due to special			
- Connections				devices	11		
Important Points	•	1	0,01,2	0,000			
- Foundation		2	0,012	0,000			
- Calculation Model		3	0.012	0.000			
Loading		· · · · · · · · · · · · · · · · · · ·	0051				
- Load combinations	Analysis a	ccording to USN 730	035				
Vertical Load	ALC: A	23238	[m				
	wind	zone.	Lm.	•			
	Funda	mental wind pressure	450		N/m2		
Wind	Туре	of the terrain:	A	•]			
- Wind Directions and Drag Types	0800		6.				
Wind Drag	Tune	of the structure:		_]			
Analysis	Type	or the structure.	a	•)			
- Shaft Computation Data							
 Second Order Effects 							
- Analysis Method							
- Frequencies							
Results							
Assessment							
Foundation							
	11						

Fig. 58 Page "Analysis method", setting of analysis according to ČSN 730035 [13] using mode shape decomposition method



g) Quasi-static anylysis according to chapter A.2.1, DIN 4131 [17]

This method can be used for monopoles , chimneys and lattice structures designed in accordance with DIN standards.

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Example 1 - Monopole Example 2 - Lattice structu	re		
Project, Standards	Analysis method		
Type of the Structure Tower / Shaft	Method: DIN 4131	✓ Antalyze	
Tower / Shaft Geometry Lattice structure definition Lattice cross section characteristics Discrete Structure Components Bolts Connections Connections Connections Conduction Model Loading Load combinations Vertical Load Vertical Load Horizontal Load Wind Directions and Drag Types Wind Drag Analysis Frequencies Results Frequencies Results Foundation	Modal analysis Number of frequencies:	3	Upper limit of calculated natural frequencies: 20 + Hz
	Analysis according to DIN 4131 Structure height: Size factor: Logarithmic decrement of damping:	h= 19,9 ny= 1,000 delta_B= 0,100	m T

Fig. 59 Page "Analysis method", setting of analysis according to DIN 4131 [17]

7.9 Results

7.9.1 Natural frequencies and mode shapes

The review of calculated natural frequencies and mode shapes is shown on the page "Frequencies" depicted in *Fig. 60* for lattice towers and in *Fig. 61* for monopoles and chimneys.

The mode deflections as well as mode internal forces can be seen in graphical or numerical version (tabs "Visualization" or "Data").

The logarithmic decrements of damping and structural factor $c_s c_d$ or size factor and gust factor are shown for all combinations and wind directions.





This window can be used also for graphical modifications of the structure and the ancillaries.

Fig. 60 Page "Frequencies" for lattice towers



USER'S MANUAL



Fig. 61 Page "Frequencies" for monopoles and chimneys

7.9.2 Response of the tower

The review of calculated response is shown on the page "Results" depicted in *Fig. 62* for lattice towers and in *Fig. 63* for monopoles and chimneys.

The deflections as well as internal forces can be seen in graphical or numerical version (tabs "Visualization" or "Numerical results") for all load combinations, load cases and wind directions. Maximum and minimum values are found.

This window can be used also for graphical modifications of the structure and the ancillaries.

Notes for using visualisation:

Clicking on tower, characteristics of panels are shown on the right side of page, where these values can be changed (panel which is shown is marked orange).

For lattice towers on the left of scheme of tower there are horizontal sections of the tower (squares or triangles), clicking on them cross section characteristics of members in elements are shown (shown element is marked orange). In scheme of the structure members with set profile are lined dark grey, dumb elements are blue and members where profile has to be set but it is not set are red lined.

Using button "Ancillaries" on the left side of page user can show or hide defined ancillaries. Clicking on them characteristics of ancillaries are shown (and can be changed) on the right.

Using other buttons on the left user can show or hide shapes of rotation, horizontal deflection and internal forces in members. Clicking on shape scale will show.





Fig. 62 Page "Results" for lattice towers





Fig. 63 Page "Results" for monopoles and chimneys

7.9.3 Assessment – lattice towers

The resistance of members of lattice structure and their check is determined on the page "Assessment", see *Fig. 64*.

The page is composed of several tabs: "Buckling length", "Buckling resistance", "Notional forces", "Profile check", "Connections" and "Dumb element check. These tabs are prepared for all types of members, i.e. Legs, Diagonals, Secondary diagonals, Horizontals, Secondary horizontals, Horizontal bracing members I and II.

Buckling lengths of members and effective slenderness factors according to Annex G, EN 1993-3-1 [8] are defined on page "Buckling length", see *Fig. 64*. The default values of buckling lengths are stated according to the structure geometry and can be changed manually. Secondary bracing members are not included in automatic buckling lengths evaluation. Buckling lengths of members supported by secondary members must be set manually. In case of diagonals of X-type, the default value of diagonal buckling lengths is for unconnected diagonals. In case of connected diagonal, the buckling lengths can be changed manually.

Default values of effective slenderness factors are prepared for typical geometries for tubes and angles. Default values can be changed manually.

For DIN standards effective slenderness factors are set to value 1,0. Buckling length can be changed directly in columns "buckling length" or by changing effective slenderness factor.



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Project Structure Project Structure Type of the Structure Tover / Shaft Geometry Lattice structure definition Lattice structure definition Lattice structure definition Materials and Profiles Bolts Connections —Ancillaries	Analyze Members Dumb elements Partial factors of material. Members Bucking resistance forces Dumb element check. garma_M0= 1.00 Image: Sector of primary and notional forces Image: Sector of horizontal deflection: Partial factors of notacional forces Bucking resistance Limiting factor of rotation: 1.00 Image: Sector of total or rotation: Diagonals: Diagonals: Diagonals: Diagonals: Utilization overview Total Profile Connections Easting: Utilization overview											
Calculation Model Loading Load combinations Vertical Load Snow Load		Marking	Element number	Height of top point	Profile	Buckling length	Buckling length	Buckling length	Effective slenderness factor	Effective slenderness factor	Effective slenderness factor	*
Ice Load				(m)		[mm]	[mm]	[mm]	[mm]	[mm]	[mm]	
Wind		• 19,900 Panel A	9 - 16	19,900	L 60*6							
Wind Directions and Drag 1		19,900 Panel A - 8	16	19,900	L 60*6	1 953	1 953	1 953	1,11	1,11	0,86	
Wind Speed and Pressure		18,650 Panel A · 7	15	18,650	L 60*6	1 953	1 953	1 953	1,11	1,11	0,86	
🖃 Analysis		17,400 Panel A · 6	14	17,400	L 60*6	1 953	1 953	1 953	1,11	1,11	0,86	
Shaft Computation Data		16,150 Panel A - 5	13	16,150	L 60*6	1 953	1 953	1 953	1,11	1,11	0,86	E
E- Results		14,900 Panel A - 4	12	14,900	L 60*6	1 953	1 953	1 953	1,11	1,11	0,86	81
- Frequencies		13,650 Panel A - 3	11	13,650	L 60*6	1 953	1 953	1 953	1,11	1,11	0,86	
Hesults		12,400 Panel A · 2	10	12,400	L 70*6	1 953	1 953	1 953	1,18	1,18	0,89	
Foundation		11,150 Panel A - 1	9	11,150	L 70*6	1 953	1 953	1 953	1,18	1,18	0,89	
		- 9,900 Panel B	5-8	9,900	L 50*5							
		· 9,900 Panel B · 2	7 - 8	9,900	L 50*5							
		9,900 Panel B - 2: V	8	9,900	L 50*5	1 320	1 320	1 320	1,21	1,21	0,90	
		8,814 Panel B · 2: A	7	8,814	L 50*5	1 485	1 485	1 485	1,15	1,15	0,88	
		- 7,593 Panel B - 1	5-6	7,593	L 50*5							
		7,593 Panel B - 1: V	6	7,593	L 50*5	1 485	1 485	1 485	1,15	1,15	0,88	
		6,373 Panel B - 1: A	5	6,373	L 50*5	1 669	1 669	1 669	1,10	1,10	0,86	
		• 5,000 Panel C	1 - 4	5,000	L 60*6							
		 5.000 Panel C + 2 	3-4	5,000	L 60*6							

Fig. 64 Page "Assessment" for lattice towers, tab "Buckling length". Tab for diagonals is shown.

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non intercepti - Califer 2 Califer model Proper, Stradade Structure - Tope of the Structure - Tope of the Structure - Lafter anturuter definition - Califer - Calife	ure Partial f gami gami gami gami gami gami gami gami	alyze actors of material meM0= 100 meM1= 100 1.25 internal forces: Genetate of primary ar tactor of horizontal deflection: z / factor of rotation:	nd notional forces 50 (1) 1,00 (1) de	Members Members Lens Diagona Horizont Bracing 19 Utilizatio Total	s selection Diagonal le Horizontz Bracing 2 n overview Profiles C	Resistu and ch Bucklin is 2 Notione Profile : Connections	a length g resistance k forces sheck tion check	Dumb elemen Dumb elemen 1.00 element 1.00 element Deflections Horizontal de Rotation che	nt check t check force kN effection check eck							
- Anchaines - Calculation Model - Load combinations - Load combinations - Vertical Load - Snow Load - Snow Load		Matking	Element number	Height of top point	Bolt connection of single angles	Max slenderness lambda max	Slenderness of 4th class angles lambda p	Reduction factor for 4th class angles rho	Effective slenderness ratio	Effective slenderness ratio	Effective slenderness ratio	Buckling curve	Phi	Reduction factor	Reduction factor for bolt connection	Design buckling resistance N b R d
Horizontal Load		10.000 0 11	0.40	[m]	0.45.1	-		4 000		200				-		[kN]
Wind Wind Directions and Dress Tunner	•	 19,900 Panel A 	9-16	19,900	BothEnds •	0		1,000				ь -			0,8	
- Wind Directions and Drag Types - Wind Speed and Pressure		19,900 Panel A - 8	16	19,900	BothEnds	165		1,000	1,563	1,563	1,866	b •	2,524	0,237	0,8	4
Wind Drag		18,650 Panel A - 7	15	18,650	BothEnds	165		1,000	1,563	1,563	1,866	b •	2,524	0,237	0,8	4
Analysis 		17,400 Panel A - 6	14	17,400	BothEnds •	165		1,000	1,563	1,563	1,866	b •	2,524	0,237	0,8	
- Analysis Method		16,150 Panel A - 5	13	16,150	BothEnds •	165		1,000	1,563	1,563	1,866	b •	2,524	0,237	0,8	
Results		14,900 Panel A - 4	12	14,900	BothEnds •	165		1,000	1,563	1,563	1,866	b •	2,524	0,237	0,8	-
Frequencies		13,650 Panel A - 3	11	13,650	BothEnds •	165		1,000	1,563	1,563	1,866	b •	2,524	0,237	0,8	-
- Assessment		12,400 Panel A · 2	10	12,400	BothEnds •	141		1,000	1,420	1,420	1,646	b •	2,101	0,294	0,8	
Foundation		11,150 Panel A - 1	9	11,150	BothEnds •	141		1,000	1,420	1,420	1,646	b -	2,101	0,294	0,8	
		 9,900 Panel B 	5.8	9,900	BothEnds •	0		1,000				b 🕶			0,8	
		9,900 Panel B - 2	7-8	9,900	BothEnds •	0		1,000				b •			0,8	
		9,900 Panel B + 2: V	8	9,900	BothEnds •	134		1,000	1,381	1,381	1,581	b •	1,984	0,314	0,8	
		8,814 Panel B · 2: A	7	8,814	BothEnds •	151		1,000	1,481	1,481	1,734	b 🕶	2,263	0,269	0,8	
		 7,593 Panel B - 1 	5-6	7,593	BothEnds •	0		1,000				b 🕶			0,8	
		7,593 Panel B + 1: V	6	7,593	BothEnds •	151		1,000	1,481	1,481	1,734	b •	2,263	0,269	0,8	
		6.373 Panel B • 1: A	5	6,373	BothEnds •	170		1,000	1,593	1,593	1,905	b -	2,605	0,228	0,8	
		 5,000 Panel C 	1 - 4	5,000	BothEnds •	0		1,000				b 🕶			0,8	
		5.000.RandlC_2	2.1	5.000	RothEndo .	0		1.000				h *			0.0	

Design buckling resistances are shown in tab "Buckling resistance", see Fig. 65.

Fig. 65 Page "Assessment" for lattice towers, tab "Buckling resistance". Tab for diagonals is shown.



Notional forces according to chapter H.4, EN 1993-3-1 [8] are determined in dependence on the angle of member to leg or using "notional load ratio", which gives a relationship between the leg force and the bracing force, see *Fig. 66*. This can be used for example in case of complicated secondary bracing system.

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Example 1 - Monopole Example 2 - Lattice struct	ure									
Project. Standards		-1		Members				Dumb element	s	
E Structure	Partial I	alyze		Momboro	adaption	Resista	nce forces	Dumb elemen	tcheck	
- Type of the Structure	r aruari nam	ma MO= 1.00		Members	selection	and che	CK	Dunb cicilion	K CHOCK	
⊡ Tower / Shaft Geometry	gom		length	Dumb element	check force					
- Lattice structure definition	gamma M2- 1.25								KN	
- Lattice cross section characteristics	yanı			Horizontal	s Horizontals	2 Notional	forces	Deflections		
- Discrete Structure Components	Maxima	I internal forces. Greater of primary ar	nd notional forces	Bracing 1	Bracing 2	Profile cl	neck	Horizontal del	flection check	
	Limiting	factor of horizontal deflection: z /	50 🚔			Connect	ion check	Rotation che	sk	
Connections	Limiting	factor of rotation:	1,00 📄 de	g Utilization	overview	-		-	_	
Foundation				Total	Profiles Con	nections				
Ancillaries				(manufacture)						
		Marking	Element	Height	Percentage	Notional	Angle	Notional	Notional	*
- Load combinations			number	of top point	of leg axial	load	of member to lea	load ratio	axial forces	
Vertical Load				1.200	force		0.000	10000	12512-021	
				z						
Horizontal Load				[m]						
Wind	•	• 19,900 Panel A	9 · 16	19,900						
- Wind Directions and Drag Types		19,900 Panel A - 8	16	19,900	1,63	0,02	50,19	1,30	0,02	
Wind Speed and Pressure		18,650 Panel A - 7	15	18,650	1,63	0,17	50,19	1,30	0,22	
- Analysis		17,400 Panel A - 6	14	17,400	1,63	0,52	50,19	1,30	0,67	Ξ
- Shaft Computation Data		16,150 Panel A - 5	13	16,150	1,63	0,98	50,19	1,30	1,27	
Analysis Method		14,900 Panel A - 4	12	14,900	1,63	1,47	50,19	1,30	1,92	
- Frequencies		13,650 Panel A - 3	11	13,650	1,63	2,00	50,19	1,30	2,61	
Results		12,400 Panel A - 2	10	12,400	1,63	2,56	50,19	1,30	3,34	
- Assessment		11.150 Panel A · 1	9	11.150	1.63	3.15	50.19	1.30	4.10	
1 oundation		- 9.900 Panel B	5-8	9.900				10.877		
		- 9 900 Panel 8 - 2	7.8	9 900						
		9.900 Panel B - 2- V		9,900	1.52	3.61	36.92	1 92	6.94	
		9 914 Panel P - 2: A	7	9,914	1,52	2.02	26.92	1.92	7.26	
		7 500 Denel D - 1	5.0	7,500	1,01	3,03	30,32	1,32	7,30	
		- 7,000 Panel B - 1	3-6	7,593	4 .04	1.07	00.00	1.00	7.00	
		7,593 Panel B - 1: V	6	7,593	1,61	4,37	36,92	1,66	7,28	
		6,373 Panel B - 1: A	5	6,373	1,71	4,65	36,92	1,92	8,93	
		5 000 Papel C	1-4	5.000						

For DIN standards, notional forces are determined according to chapter 2, DIN 18800-2 [20].

Fig. 66 Page "Assessment" for lattice towers, tab "Notional forces". Tab for diagonals is shown.

The buckling resistances and axial forces are shown in tab "Profile check", see *Fig. 67*. The primary forces resulting from static or dynamic calculation are shown as well as notional forces. Maximal internal forces can be determined as only the primary forces, greater value of the primary and the notional forces or as sum of the primary and the notional forces, see (5) H.4, EN 1993-3-1 [8].

Subsequently, the slenderness check is done according to recommendations given in Annex H, EN 1993-3-1 [8] and check of member resistance.



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<pre>kample 1 - Monopole Example 2 - Lattice structu</pre>	re			3533 - 33				240 - 554 - 57K	204		
Project, Standards	Analyze Dumb elements Dumb elements										
Structure	Partial fa	actors of material:		Members	selection	and ch	eck	Dumb elemer	nt check		
Tower / Shaft	gamm	na_M0= 1,00 🚔		Legs		Bucklin	a length	Dumb element	check force		
Geometry	gamm	na_M1= 1.00 🚔		Diagonals	Diagonals 2	Bucklin	resistance	1,00	kN		
- Lattice structure definition	gamm	na_M2= 1,25 🚔		Horizonta	le Horizontale	2 Notiona	forces	Deflections	10.11		
- Discrete Structure Components	Maximal	internal forces: Greater of primary a	nd notional forces 👻	Duration 1	Dessive 2	Profile c	heck	Horizontal de	flection check		
Materials and Profiles	Limiting	factor of horizontal deflection: z /	50 🚔	bracing i	bracing 2	Course of	Secretaria		-		
Bolts	Limiting	factor of rotation:	1,00 🔶 deg	(Connection check Rotation check					
Econnections			() Contraction () Contraction ()	Utilization overview							
Ancillaries				Total	Profiles	nections					
Calculation Model		Madrica	Floment	Haiaht	Design	Drimonu	Motional	M nuine un	Clandomosa	Utilization	Utilization
ii- Loading		Maiking	number	of top	buckling	axial	axial	axial	check	(Diagonals)	check
- Load combinations - Vertical Load				point	resistance	force	forces	force			
Snow Load				7							
Ice Load				z [m]	N_bH_d [kN]	N_sd [kN]		N_sd [kN]	<=180		
Horizontal Load	*	19,900 Panel A	9 - 16	19,900					ok		satisfied
Wind Directions and Drag Types		19,900 Panel A - 8	16	19,900	46	1,24	0,02	1,24	ok	0,03	satisfied
Wind Speed and Pressure		18,650 Panel A - 7	15	18,650	46	12,99	0,22	12,99	ok	0,28	satisfied
Analysis		17,400 Panel A - 6	14	17,400	46	28,56	0,67	28,56	ok	0,61	satisfied
- Shaft Computation Data		16,150 Panel A - 5	13	16,150	46	30,50	1,27	30,50	ok	0,66	satisfied
- Analysis Method		14,900 Panel A - 4	12	14,900	46	32,35	1,92	32,35	ok	0,70	satisfied
- Frequencies		13,650 Panel A - 3	11	13,650	46	34,23	2,61	34,23	ok	0,74	satisfied
- Results		12,400 Panel A - 2	10	12,400	68	36,06	3,34	36,06	ok	0,53	satisfied
Assessment		11.150 Panel A · 1	9	11.150	68	37.72	4.10	37.72	ok	0.56	satisfied
- I buildation		- 9 900 Panel B	5-8	9.900					nk		satisfied
		- 9 900 Panel B - 2	7.8	9,900					ok		satisfied
		9 900 Panel B - 2 V	8	9 900	43	16.95	6.94	16.95	ok.	0.40	eatisfied
		0.014 Panal P - 2- 4	7	0.014	40	17.02	7.00	17.02	ok	0,40	optiofied
		7 E02 Danal D 1		7 500	57	17,03	7,30	17,05	ek	0,43	soustieu
		7,033 Panel B • 1	5.6	7,093		10.00	7.00	10.00	UK	0.00	saushed
		7,593 Panel B - 1: V	6	7,593	3/	16,80	7,28	16,80	OK	0,46	satished
		6,373 Panel B - 1: A	5	6,373	31	17,93	8,93	17,93	ok	0,58	satisfied

Fig. 67 Page "Assessment" for lattice towers, tab "Profile check". Tab for diagonals is shown.

The check of joints is carried out in tab "Connections", see *Fig. 68*. The connection resistances are defined on page "Connections", see *Fig. 16*. In column "connection" user selects connection for single member from connections defined on page "Connections".



Fig. 68 Page "Assessment" for lattice towers, tab "Connections". Tab for diagonals is shown.



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xemple 1 - Monopole Example 2 - Lattice struct Project, Standards - Structure - Tower / Shaft - Geometry - Lattice structure definition -	Analyze Patial factors of material: gamma_M0= 1.00 gamma_M1= 1.25 gamma_M2= 1.25					selection	Resistance force and check Buckling length Buckling resistance	Dumb elements Dumb element check Dumb element check force 1.00 kN
Eatice cross section characteristics Origonetic Components Materials and Profiles Bolts Connections Foundation	Maxim Limiting Limiting	al inte 9 facto 9 facto	nal forces: Greater of primary a or of horizontal deflection: z / or of rotation:	nd notional forces 50 1,00 ¢ de	Bracing 1 g Utilization	Bracing 2 Bracing 2	Horizontal deflection check	
 Anoillaries Calculation Model Loading Load combinations Vertical Load Snow Load Loc Load 			Marking	Element number	Height of top point z [m]	Primary axial force N_sd [kN]	Dumb element check	
Wind			12,400 Panel A - 2	10	12,400	0,82		
Wind Directions and Drag Types			11,150 Panel A - 1	9	11,150	0,75		
- Wind Drag		- 5	9,900 Panel B	5-8	9,900			
🖨 Analysis		- 20	9,900 Panel B - 2	7 - 8	9,900			
- Shaft Computation Data			9,900 Panel B - 2: V	8	9,900	17,11		
E Results			8,814 Panel B - 2: A	7	8,814	0,64		
Frequencies		•	7,593 Panel B - 1	5-6	7,593			
Hesults Assessment			7,593 Panel B - 1: V	6	7,593	0,00	ok	
Foundation			6,373 Panel B - 1: A	5	6,373	0,61		
		-	5,000 Panel C	1 - 4	5,000			
		-	5,000 Panel C - 2	3 - 4	5,000			
			5,000 Panel C - 2: V	4	5,000	0,00	ok	
			3,868 Panel C - 2: A	3	3,868	0,49		
			2,621 Panel C - 1	1-2	2,621			
			2,621 Panel C - 1: V	2	2,621	0,00	ok	
			1,374 Panel C - 1: A	1	1,374	0,39		

Primary axial forces in dumb elements are checked in tab "Dumb element check", see Fig. 69.

Fig. 69 Page "Assessment" for lattice towers, tab "Dumb element check". Tab for horizontals is shown.



Horizontal deflection check and rotation check is carried out in tabs depicted in Fig. 70, resp. Fig. 71.

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Example 1 - Monopole Example 2 - Lattice struc	ture									
Project, Standards	Δn	aluze		Members				Dumb elemen	its	
E Structure	Partial	actors of material:		Members	s selection	Resista and ch	nce forces eck	Ces Dumb element check		
Type of the Structure Tower / Shaft	gam	na_M0= 1,00 🚖		Legs	Legs Buckling length				check force	
Geometry	gam	na_M1= 1.00 🚖		Diagonal	Diagonals 2	Buckling	g resistance] 1,00 🔿 kN		
Lattice structure definition Lattice cross section characteristics	gamma_M2= 1.25 🚔 Horizontals Horizont						l forces	Deflections		
- Discrete Structure Components	Maxima	Horizontal de	eflection check							
Materials and Profiles	Limiting	Rotation che	ck							
Connections	Limiting factor of rotation: 1,00 👘 deg Utilization overview									
Foundation				Total	Profiles Con	nections				
- Ancillaries - Calculation Model										
Loading Load combinations		Marking	Element number	Height of top	Horizontal deflection	Limiting value	Horizontal deflection	Check	<u>^</u>	
Vertical Load				point			Guizadori			
Snow Load				z						
- Horizontal Load				[m]	[mm]					
Wind		• 19,900 Panel A	9-16	19,900	110	398	0.00	satisfied	-	
Wind Speed and Pressure		13,300 Panel A - 8	15	19,300	115	338	0,29	satisfied		
Wind Drag	-	17,600 Panel A - 7	15	17,400	105	373	0,20	sausned	-	
Shaft Computation Data		10,400 Fanel A - 6	19	17,400	33	340	0,27	satisfied		
Analysis Method		14,900 Panel A - 4	13	14,900	71	298	0,23	satisfied	5	
Hesults Frequencies		13,650 Panel A - 3	11	13.650	60	230	0,24	satisfied		
- Results		12 400 Panel A - 2	10	12 400	50	248	0.20	satisfied		
- Assessment		11,150 Panel A • 1	9	11,150	40	223	0,18	satisfied		
- Constant		- 9,900 Panel B	5-8	9,900		198		satisfied		
		- 9,900 Panel B - 2	7-8	9,900		198		satisfied		
		9,900 Panel B - 2: V	8	9,900	31	198	0,16	satisfied		
		8,814 Panel B - 2: A	7	8,814	24	176	0,14	satisfied		
		- 7,593 Panel B - 1	5.6	7,593		152		satisfied		
		7,593 Panel B - 1: V	6	7,593	18	152	0,12	satisfied		
		6 373 Panel R . 1· A	5	6 373	12	127	0.09	satisfied	*	

Fig. 70 Page "Assessment" for lattice towers, tab "Horizontal deflection"



Fig. 71 Page "Assessment" for lattice towers, tab "Rotation"



Ultilization overwiew of profiles and connections is depicted in tabs presented in *Fig. 72*, resp. *Fig. 73*. Overall check review is shown in tab "Total", see *Fig. 74*.

w _ open m odve m odve As	n close	and word woodt									
xample 1 - Monopole Example 2 - Lattice struct Project. Standards Structure - Type of the Structure - Geometry - Lattice cross section characteristics - Discrete Structure Components - Materials and Profiles - Bolts - Connections		ze tors of material: 	and notional forces / 50 1,00 deg deg	Members Members Legs Diagonals Horizonta Bracing 1	Members Members selection Legs Diagonals Diagonals Horizontals Bracing 1 Bracing 2 Fittilization overview			Dumb element Dumb element 1,00 = Deflections Horizontal de Rotation che	umb elements Jumb element check Jumb element check force Jumb element check force Jumb element check force kN tellections Horizontal deflection check. Rotation check		
- Foundation - Anciliaries - Calculation Model - Loading - Load combinations - Vertical Load - Snow Load - Load		Marking	Total Height of top point Z [m]	Profiles Coni Utilization (Legs)	Utilization (Diagonals)	Utilization (Diagonals2)	Utilization (Horizontals)	Utilization (Horizontals2)	Utilization (Bracing1)	Utilization (Bracing2)	
- Horizontal Load		12,400 Panel A - 2	10	12,400	0,50	0,53		0,07			
-Wind Directions and Drag Types		11,150 Panel A - 1	9	11,150	0,62	0,56		0,21			
- Wind Speed and Pressure		- 9,900 Panel B	5.8	9,900							
alysis		- 9,900 Panel B - 2	7-8	9,900							
Shaft Computation Data		9,900 Panel B - 2: V	8	9,900	0,74	0,40		0,47			
Analysis Method ults		8,814 Panel B · 2: A	7	8,814	0,76	0,49	r.	0,05	i	0,04	
Frequencies		- 7,593 Panel B - 1	5.6	7,593							
Results		7,593 Panel B - 1: V	6	7,593	0,87	0,46					
Foundation		6,373 Panel B · 1: A	5	6,373	0,89	0,58		0,07		0,06	
		- 5,000 Panel C	1 - 4	5,000							
		- 5,000 Panel C - 2	3 · 4	5,000							
		5,000 Panel C · 2: V	4	5,000	0,74	0,22					
		3,868 Panel C - 2: A	3	3,868	0,75	0,26		0,09		0,08	
		- 2,621 Panel C - 1	1-2	2,621							
		2,621 Panel C - 1: V	2	2,621	0,82	0,25					
		1.374 Panel C - 1: A	1	1.374	0.84	0.30		0.11		0.10	

Fig. 72 Page "Assessment" for lattice towers, tab Utilization overview of "Profiles"



Fig. 73 Page "Assessment" for lattice towers, tab Utilization overview of "Connections"



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Example 1 - Monopole Example 2 - Lattice struct	ure												
Project, Standards Structure Toye of the Structure Toye of the Structure Tower / Shaft General Constructure definition Lattice trocs section characteristics Discrete Structure Components Materials and Profiles Rote	An Partial f gamr gamr gamr Maxima Limiting	alyze na_M na_M na_M inter facto	of material: 0= 1.00 1= 1.00 1.25 mal forces: Greater of primary an of forces: Greater of primary and for forces: Gre	id notional forces	Members Members Legs Diagonals Horizonta Bracing 1	selection Diagonals 2 Horizontals Bracing 2	Resista and chu Bucklin 2 Notiona Profile c Connec	Resistance forces and check Buckling length Buckling resistance Notional forces Profile check Connection check		Dumb elements Dumb element check Dumb element check I,00			
Connections	Limiting	facto	r of rotation:	1,00 😭 deg	Iltilization	overview				_			
Foundation					Total	Profiles Con	inections						
Anotheries Calculation Model Calculation Model Load combinations Vertical Load Formulaad Formulaad Formulaad Formulaad			Marking	Element number	Height of top point z [m]	Horizontal deflection utilization	Rotation utilization	Maximum profile utilization	Maximum Dumb connection element utilization check		Slenderness check	Check	*
- Wind	Þ	1	19,900 Panel A	9 - 16	19,900						exceeds	satisfied	
-Wind Directions and Drag Types			19,900 Panel A - 8	16	19,900	0,29	0,51	0,027	0,026	ok	ok	satisfied	
- Wind Directions and Drag Types - Wind Speed and Pressure - Wind Drag			18,650 Panel A - 7	15	18,650	0,28	0,51	0,301	0,269	ok	exceeds	satisfied	
Analysis			17,400 Panel A - 6	14	17,400	0,27	0,52	0,615	0,592	ok	ok	satisfied	
- Shaft Computation Data			16,150 Panel A - 5	13	16,150	0,25	0,51	0,656	0,632	ok	exceeds	satisfied	
			14,900 Panel A - 4	12	14,900	0,24	0,50	0,696	0,671	ok	ok	satisfied	
Frequencies			13,650 Panel A - 3	11 13,650 0,22	0,48	0,737	37 0,710 ok	ok	exceeds	satisfied			
Results			12,400 Panel A - 2	10	12,400	0,20	0,44	0,531	0,748	ok	ok	satisfied	
- Foundation			11,150 Panel A • 1	9	11,150	0,18	0,41	0,620	0,782	ok	exceeds	satisfied	
		*	9,900 Panel B	5 - 8	9,900						ok	satisfied	
		*	9,900 Panel B - 2	7.8	9,900						ok	satisfied	
			9,900 Panel B • 2: V	8	9,900	0,16	0,38	0,743	0,448	ok	ok	satisfied	
			8,814 Panel B + 2: A	7	8,814	0,14	0,28	0,758	0,467	ok	ok	satisfied	
		-	7,593 Panel B - 1	5.6	7,593						ok	satisfied	
			7,593 Panel B - 1: V	6	7,593	0,12	0,28	0,866	0,440	ok	ok	satisfied	
			6,373 Panel B - 1: A	5	6,373	0,09	0,18	0,889	0,731	ok	ok	satisfied	
		10	5,000 Panel C	1 - 4	5,000						ok	satisfied	-

Fig. 74 Page "Assessment" for lattice towers, tab "Total"

7.9.4 Assessment – monopoles and chimneys

The resistance of members and their check is determined on the page "Assessment", see Fig. 75.

The page is composed of several tabs. Tabs "Cross section classification", "Resultant characteristics", "Characteristic buckling resistance in compression", "Characteristic buckling resistance in shear", "Resistance of cross-sections", "Maximum forces" and "Cross section check" are prepared for bottom and top points of elements.

Cross sections are classified and openings can be defined first. It is assumed that edges of opening are stiffened and rigidity of stiffener allows use the same class as for cross section without opening.





Fig. 75 Page "Assessment" for monopoles and chimneys, tab "Cross section classification". Tab for bottom points is shown.

The cross section characteristics with influence of opening are evaluated in tab "Resultant characteristics", see *Fig. 76*.





Fig. 76 Page "Assessment" for monopoles and chimneys, tab "Resultant characteristics". Tab for bottom points is shown.

If class of cross section is 4, the cross section resistance is determined according to EN 1993-1-6 [6] or DIN 18800-4 [21]. The buckling resistances in compression and shear are calculated in tabs "Characteristic buckling resistance in compression", see *Fig.* 77 and "Characteristic buckling resistance in shear", see *Fig.* 78.

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Example 1 - Monopole Example 2 - Lattice stru	cture																	
Protect Standards Sta	Ander Diddy Partial cost of material gomes.Mr 1.10 0 Limitry tactor of hotizered deficience 2 / 50 0 Limitry tactor of hotizered deficience 2 / 50 0 Limitry tactor of hotizered deficience Limitry ta				Tess sectors chanfication Sealar a characteristics Sealar a characteristics Sealar a characteristics Sealar and the sealar and													
		Marking	Element rumber	Criteria for resistance evaluation	Cylinder length	Cylinder length	Equivalent diameter for compression	Relative length peremeter	Parameter of boundary conditions C_x.b	Factor	Meridional elastic critical buckling stress s.x.Rcr Buttal	Fabrication quality perameter	Characteristic impertection emplitude Dw_k	Meridional elastic imperfection reduction factor ax	Plastic limit relative stendemess	Relative shell slenderness	Buckling reduction factor	Meridional characteristic buckling stress s.x.Rk
Horizontal Load		18.000 Panel A	3.4	met	found	fumi	[mm]		1		(Pir-a)	1600	(um)					[Mr a]
- Wind	1	18000 Panel A	4	met			324.0		1			16.00						
- Wind Speed and Pressure		16,700 Discrete ancillary: A	3	met			324,0		1			16,00						
- Wind Drag		12,000 Panel B	2	tem			600,1		1			16,00						
Analysis Shaft Computation Data		6,000 Panel C	1	met	6000	6002	1 000,4	85,26	1	0,600	1540	16,00	4,40	0,391	0,989	0,391	0,855	200,924
- Second Order Effects - Analysis Method ⊖ Regulancies - Reguencies - Reguencies - Results - Assessment - Foundation																		

Fig. 77 Page "Assessment" for monopoles and chimneys, tab "Characteristic buckling resistance in compression". Tab for bottom points is shown.





Fig. 78 Page "Assessment" for monopoles and chimneys, tab "Characteristic buckling resistance in shear". Tab for bottom points is shown.

The resitances of cross sections of class 1-3 are determined according to EN 1993-1-1 [5] or DIN 18800-1 [19]. The review of cross section resistances is shown in tabs "Bottom resistance of cross sections", see *Fig. 79*, and "Top resistance of cross sections".



Fig. 79 Page "Assessment" for monopoles and chimneys, tab "Resistance of cross sections". Tab for bottom points is shown.



The recapitulation of maximamum forces is shown in tabs "Maximum forces" for bottom and top points of panels, see *Fig. 80*.



Fig. 80 Page "Assessment" for monopoles and chimneys, tab "Maximum forces". Tab for bottom points is shown.

Utilization of cross section is shown in tab "Cross section check", see Fig. 81.





Fig. 81 Page "Assessment" for monopoles and chimneys, tab "Cross section check". Tab for bottom points is shown.

The check of joints is carried out in tab "Connections", see Fig. 82. The connection resistances are defined on page "Connections", see chapter 7.3.11. In column "connection" user selects connection for single node from connections defined on page "Connections".



Fig. 82 Page "Assessment" for monopoles and chimneys, tab "Connection check"



Horizontal deflection check and rotation check is carried out in tabs depicted in Fig. 83, resp. Fig. 84.



Fig. 83 Page "Assessment" for monopoles and chimneys, tab "Horizontal deflection check"



Fig. 84 Page "Assessment" for monopoles and chimneys, tab "Rotation check"



🛓 Exmact - -🛅 New 🕤 Open 🛃 Save 🛃 Save As ... 🗙 Close 🗐 Word 🛛 About Example 1 - Monopole Example 2 - Lattice structure Project, Standards Disnlau Analyze Cross section classification -Structure Bottom points - Type of the Structure Partial factor of material: gamma_M1= 1,10 Resultant characterisitics E Tower / Shaft Top points Geometry Characteristic buckling resistance in compression Limiting factor of horizontal deflection: Tube Structure Definition Characteristic buckling resistance in shear **Cross Section Characteristics** z/ 50 * Resistance of cross-sections Discrete Structure Components Material Maximum forces 1,00 ≑ deg Limiting factor of rotation: Bolts Cross section check Connections - Important Points Connection check Horizontal deflection check Rotation check Overall Check Foundation Ancillaries Horizontal deflection utilization Cross section utilization Rotation utilization Marking Element number Connection utilization Check Calculation Model 🗄 Loading - Load combinations - Vertical Load Snow Load Ice Load - Horizontal Load 18,000 Panel A 3-4 0,00 Does not satisfy Wind 18,000 Panel A 0,66 1,64 0,01 4 Does not satisfy Wind Directions and Drag Types Wind Speed and Pressure 16,700 Discrete ancillary: A 3 0.60 1.64 0.91 0.421 Does not satisfy Wind Drag 12.000 Panel B 2 0,35 0,94 0,69 0,666 Satisfies 🗄 Analysis Shaft Computation Data 6,000 Panel C 1 0,13 0,27 0,58 0,722 Satisfies Second Order Effects Analysis Method - Results Frequencies Results Assessment Foundation

Overall check review is shown in tab "Check", see Fig. 85.

Fig. 85 Page "Assessment" for monopoles and chimneys, tab "Check"

7.9.5 Foundation

Resistance of foundation base and stability of tower and pad according to EN 1997-1 [10] is checked on this page. Limit state GEO (bearing resistance and sliding resistance in foundation base) is situated on the left side of page, on the right side there is limit state EQU (overall stability), see *Fig. 86*. On upper part of page user can see design values of loads in anchoring level. Impact of loads is computed for all wind directions and load combinations. Maximum utilization of both limit states is given on the top of page.

In case of towers, where only wind direction 0° is computed (monopoles and chimneys), for tower assessment direction 45° is added for foundation assessment.

For DIN standards characteristic value of loads in anchoring lever are given. Foundation is checked according to [22] using safety factors showed on left upper side of page, see Fig. 87.

ATTENTION: Calculation does not include influence of groundwater. If groundwater is present, the foundation assessment cannot be used.


	Close word About				
ample 1 - Monopole Example 2 - Lattice struct	ure				
Project, Standards	Results				
Structure	Wind direction: 0	✓ An	alyze	Overall check: Satisfied	49 C
Tower / Shaft	In the line for the			Max. utilization: 0,77	
Geometry	Load combination: LUM1	•		Eccentricity OK	
- Tube Structure Definition	Load in anchoring level			122202	
- Cross Section Characteristics	Design values	STR/GEU (set C)		EQL	j (set Aj
- Discrete Structure Components	Vertical force: N_d=	47,30	kN	N_d=	52,25 🔶 kN
Material	Bending moment: M_d=	587,74	kNm	M_d=	678,16 🚔 kNr
- Connections	Horizontal force: H_d=	41,94 🌲	kN	H_d=	48,39 🔶 kN
Important Points	Weight of pad and soil above pad:	498,47 👙	kN		548,31 🔶 kN
Foundation		50		The second mate in the second	
Ancillaries	Bearing resistance check			Overall stability check	
Calculation Model	Vertical force in found, base - design value;	N Ed.tot= 545.	77 – kN	Destabilizing actions moment: M d	st.d= 745.91 🔶 kNr
Loading	Bending mom in found base - design value:	M Editot= 646	15 kN	Stabilizing actions moment: M	et d= 1201.13 + kNn
- Vertical Load	Eccentricity of loads:	Eve 1	18 m	Ctability shack configurate Mide //	Add 1001010 V Kill
	Eccentricity of loads:	Eu- 01	10 . m	Stability check coencient. Mustri	4st=
Ice Load	Eccontrol y of roads.	-y- 0,	20 <u>10</u> 11		Satisfies
🖻 Horizontal Load	Eccentricity check:	Satisfies			
Wind Directions and Drag Tuppe	Effective base check:	A_e,f= 6,5	2 🗧 m2		
Wind Speed and Pressure	Design value of vertical stress in found, base:	sigma_d= 83,8	5 🗧 kPa		
Wind Drag	Utilization of foundation base: sigma	d/R d= 0,3	33		
Analysis Shaft Computation Data	Satisfies				
- Second Order Effects	Sliding resistance check				
- Analysis Method	Design value of horizontal force:	H d= 41.3	4 🗧 kN		
- Frequencies	Design value of sliding resistance	B dh= 2631	38 - kN		
- Results	Utilization: H d	/B db = 0	16		
Assessment		Catiofier			

Fig. 86 Page "Foundation" for EN standard

mple 1 - Monopole Example 2 - Lattice structu			
Project, Standards	esults		
Structure	/ind direction: 0 Analyze Overall check: Not satisfied		
Tower / Shaft	And exploration: 1.50		
Geometry	Eccentricity OK		
- Lattice structure definition	oad in anchoring level		
- Lattice cross section characteristics	haracteristic values Safety factors		
- Discrete Structure Components	/ertical force: N_d= 45,02 kN Compression etha_p= 2,00 km		
- Materials and Profiles	Bending moment: M_d= 847,02 kNm Sliding etha_g= 1,50 Image: state st		
Connections	Horizontal force: H_d= 65,14 ↔ kN Stability etha_k= 1,50 ↔		
- Foundation	Veight of pad and soil above pad: 862,08 👘 kN		
- Ancillaries			
Calculation Model	learing resistance check		
- Loading	Vertical force in found, base - char, value: N_Ek,tot= 907,10 🔆 kN		
Vertical Load	Bending mom. in found, base - char, value: M_Ek,tot= 964.27 KNm Forces outside cross-section core:		
- Snow Load	ccentricity of loads Ex= 1.05 m 1.59 m		
Ice Load	coentricity of loads Fue 0.00 m 0.00 m		
🖻 Horizontal Load			
	coontroly check. Satisfies		
Wind Speed and Pressure	iffective base check: A_e,f= 14.37 m2 9.05 m m2		
- Wind Drag	Design value of vertical stress in found. base: sigma_d= 126,25 + kPa 100,18 + kPa		
- Analysis	Itilization of foundation base: sigma_d / R_d= 0.84 💠 0.45 💠		
	Satisfies Satisfies		
- Results	iliding resistance check		
- Frequencies	Design value of borizontal force: H d= 97.71 kN Destabilizing actions moment M det d= 1/46.40 kV	Nm	
- nesults - Assessment	Teoring value of sliding resistance: B db- 23016 / VN Ctabilizing setime memory M at d- 2267.74 / V	Nes	
Foundation		300	
	Satisfies Satisfies	Satisfies	

Fig. 87 Page "Fondation" for DIN standard



8 Report

The report is automatically created. Report templates are prepared in directory "Templates". The templates can be alternatively changed according to user requirements. This function is not available in Demo version.

9 Acknowledgement

The partial support was provided by the project of the Ministry of Industry and Trade of Czech Republic No. MPO TIP FR-TI3/654 "Advanced methods in design, monitoring and assessment of slender dynamically loaded structures".

10 Literature

10.1 General

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[7] EN 1993-1-8 Eurocode 3 – Design of steel structures – Part 1-8: Design of joints, 2013

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10.2 National annexes of eurocode

10.2.1 Czech Republic

- [CZE1] ČSN EN 1990/NA: 2015-05
- [CZE2] ČSN EN 1991-1-1/NA: 2004-03
- [CZE3] ČSN EN 1991-1-3/NA: 2013-06
- [CZE4] ČSN EN 1991-1-4/NA: 2013-07
- [CZE5] ČSN EN 1993-1-1/NA: 2011-07
- [CZE6] ČSN EN 1993-1-6/NA: 2008-09
- [CZE7] ČSN EN 1993-1-8/NA: 2013-11
- [CZE8] ČSN EN 1993-3-1/NA: 2008-09
- [CZE9] ČSN EN 1993-3-2/NA: 2008-09

[CZE10] ČSN EN 1997-1/NA: 2006-09



10.2.2 Germany

[DEU1] DIN EN 1990/NA: 2010-12

[DEU2] DIN EN 1991-1-4/NA: 2010-12

[DEU3] DIN EN 1993-1-1/NA: 2015-08

[DEU4] DIN EN 1993-3-1/NA: 2015-11

[DEU5] DIN EN 1993-3-2/NA: 2010-12

