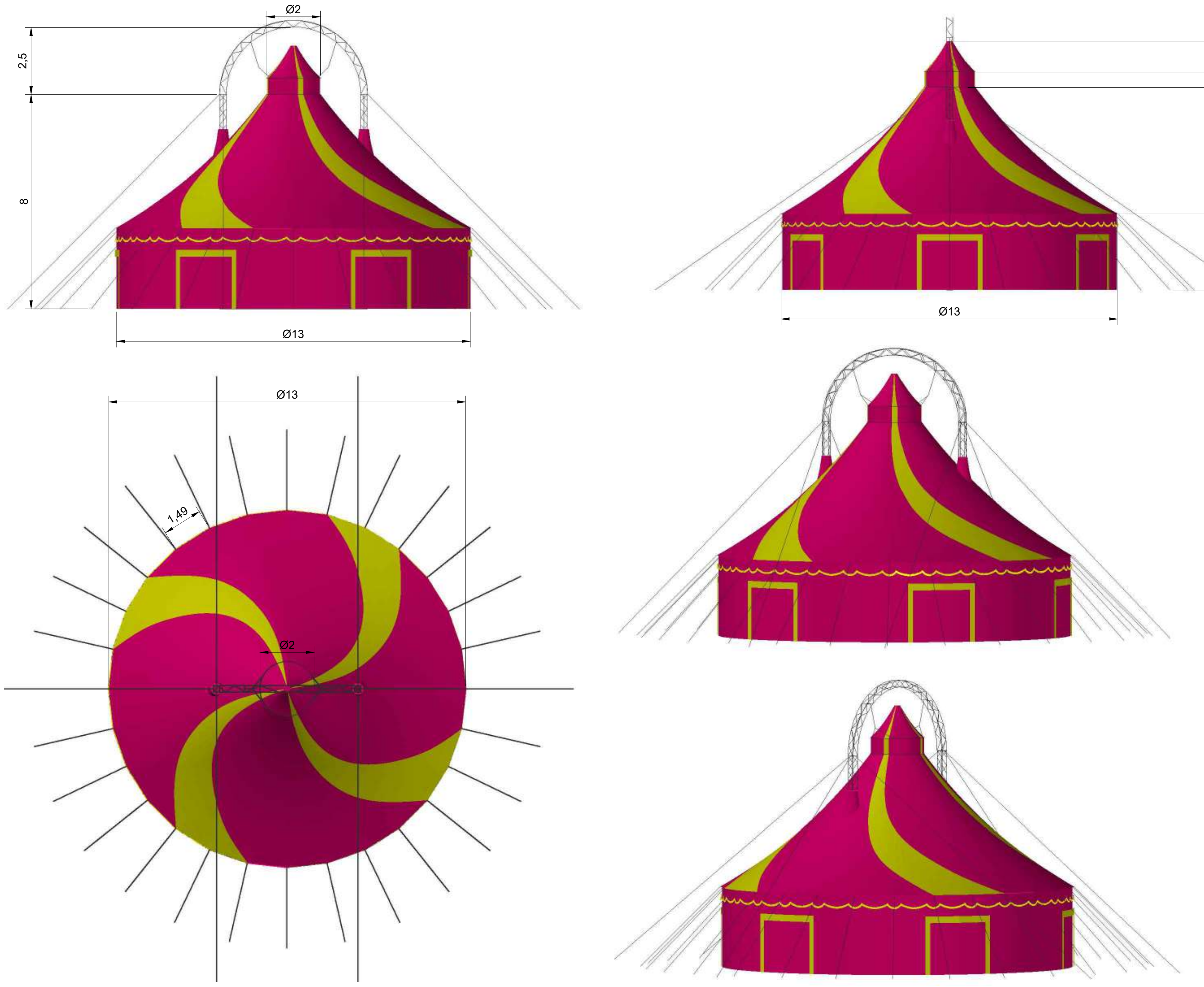


CLIENTE

JULIEN AUGER
Circus I love you

CONTENUTO

CIRCO Ø13 mt
cupola Ø2 mt

RIF.

COD.373

DISEGNO

IP. 01

DATA	00/00/00

CIRCUS Ø13_mt
Client "JULIEN AUGER - Circus I love you"

Object:

ANALYSIS OF STRUCTURAL VERIFICATION

Document LS 10/2020 del 16.10.2020

SUMMARY

1. POURPOSE

The object of this document is the structural preliminary analysis of a circus 13 meters of external diameter.

The analysis will be performed according to the European Technical Regulations (Eurocodes) and EN 13782:2015-Temporary structure.

All checks will be carried out with semi-probabilistic limit state approach.

The actions considered are permanent and live loads (Wind and Snow effects), vice versa seismic action has not considered, because is lowest than other actions.

2. DESCRIPTION OF THE STRUCTURES

The structure has plan dimension 13mt of external diameter, and a total height of about 10,5 mt.

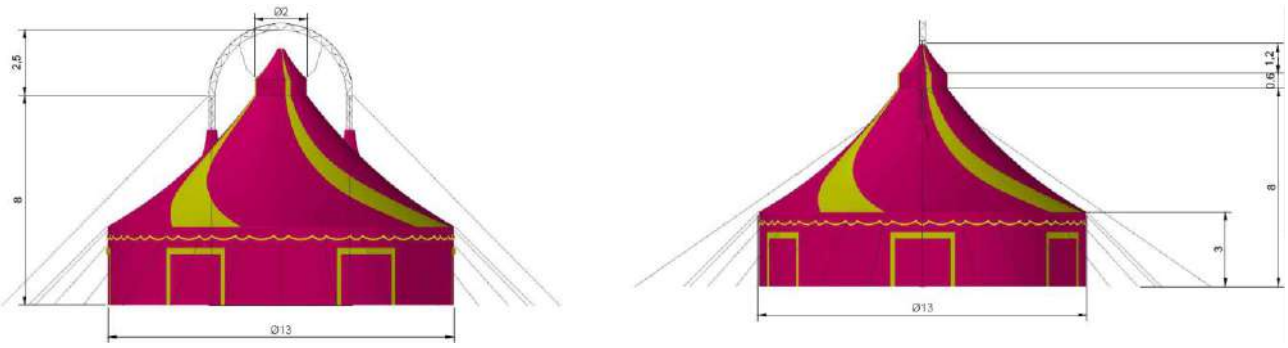
The main structure has 2 steel masts linked by a ladders arch.

On the perimeter, the membrane is supported by poles in structural steel, 3,0mt of height.

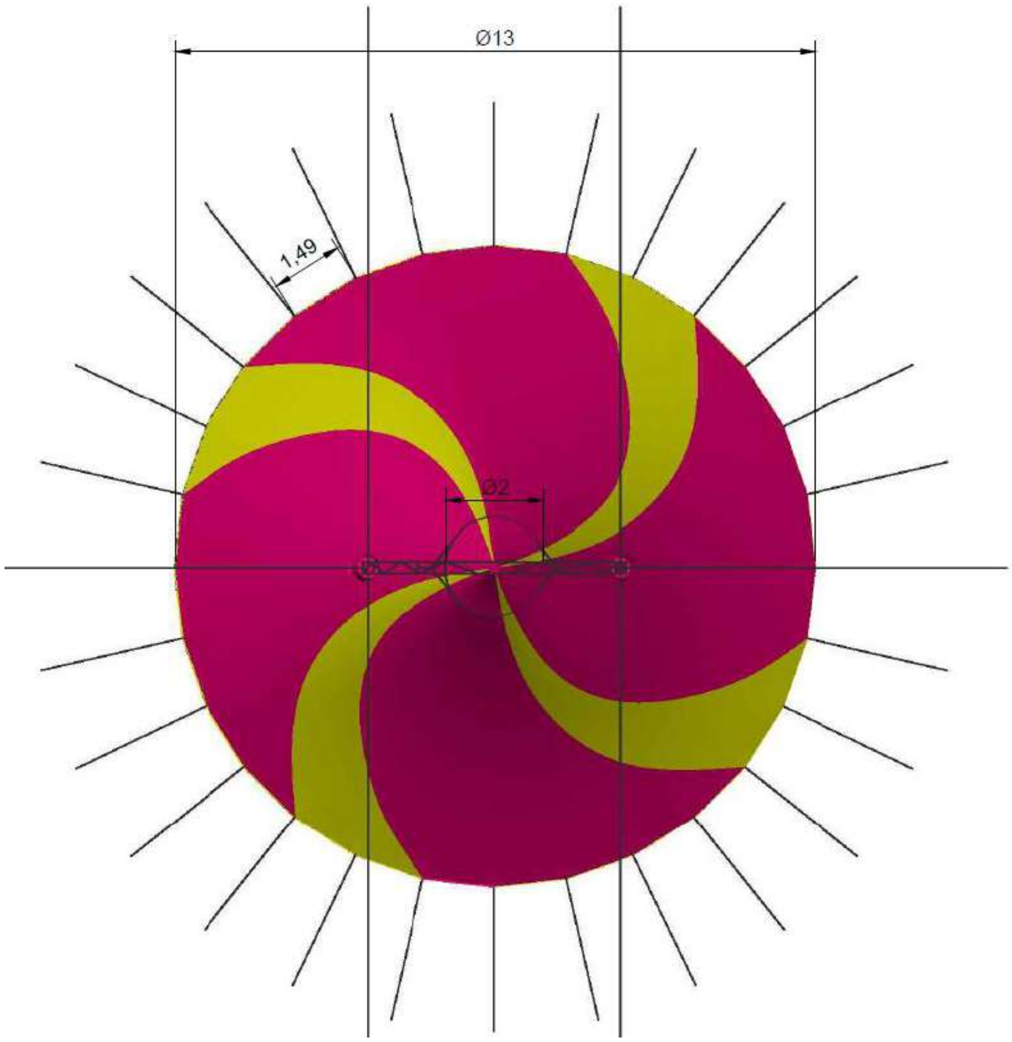
On the images here below it is possible to find some general views of structure:

View of circus (overall)

View of circus (lateral)



View of circus (lateral)



View of circus (top)

3. NORMS AND LAWS

3.1 European Reference Eurocodes

- **Eurocode 0: Basis of Structural design**

UNI EN 1990:2006;

- **Eurocode 1: Actions on Structures**

EN 1991-1-1:2002 Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings

EN 1991-1-2:2002 Eurocode 1. Actions on structures. General actions. Actions on structures exposed to fire

EN 1991-1-3:2003 Eurocode 1. Actions on structures. General actions. Snow loads

EN 1991-1-4:2005 Eurocode 1. Actions on structures. General actions. Wind actions

EN 1991-1-5:2003 Eurocode 1. Actions on structures. General actions. Thermal actions

EN 1991-1-6:2005 Eurocode 1. Actions on structures. General actions. Actions during execution

EN 1991-1-7:2006 Eurocode 1. Actions on structures. General actions. Accidental actions

- **Eurocode 2: Design of Concrete structures**

EN 1992-1-1:2004 Eurocode 2: Design of concrete structures. General rules and rules for buildings

- **Eurocode 3: Design of Steel structures**

EN 1993-1-1:2005 Eurocode 3. Design of steel structures. General rules and rules for buildings

EN 1993-1-3:2006 Eurocode 3. Design of steel structures. General rules. Supplementary rules for cold-formed members and sheeting

EN 1993-1-5:2006 Eurocode 3. Design of steel structures. Plated structural elements

EN 1993-1-8:2005 Eurocode 3. Design of steel structures. Design of joints

EN 1993-1-10:2005 Eurocode 3. Design of steel structures. Material toughness and through-thickness properties.

- **EN 13782:2015-Temporary structure**

4. MATERIALS

4.1 Steel structures works

The nominal values of material properties given in this section should be adopted as characteristic values in design calculations.

The nominal values of the yield strength f_y and the ultimate strength f_u for structural steel should be obtained by table below.

Standard and steel grade	Nominal thickness of the element t [mm]			
	t ≤ 40 mm		40 mm < t ≤ 80 mm	
	f_y [N/mm^2]	f_u [N/mm^2]	f_y [N/mm^2]	f_u [N/mm^2]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	AC2 490 AC2	335	470
S 450	440	550	410	550
EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530
EN 10025-5				
S 235 W	235	360	215	340
S 355 W	355	AC2 490 AC2	335	490
EN 10025-6				
S 460 Q/QL/QL1	460	570	440	550

Bolts, nuts and washers

The yield strength f_{yb} and the ultimate tensile strength f_{ub} for bolt classes 4.6, 4.8, 5.6, 5.8, 6.8, 8.8 and 10.9 are given in Table following, These values should be adopted as characteristic values in design calculations:

Nominal values of the yield strength f_{yb} and the ultimate tensile strength f_{ub} for bolts

Bolt class	4.6	4.8	5.6	5.8	6.8	8.8	10.9
f_{yb} (N/mm²)	240	320	300	400	480	640	900
f_{ub} (N/mm²)	400	400	500	500	600	800	1000

Welded connections

Fillet welds may be used for connecting parts where the fusion faces form an angle of between 60° and 120°. Angles smaller than 60° are also permitted. However, in such cases the weld should be considered to be a partial penetration butt weld. For angles greater than 120° the resistance of fillet welds should be determined by testing in accordance with EN 1990 Annex D: Design by testing. Fillet welds finishing at the ends or sides of parts should be returned continuously, full size, around the corner for a distance of at least twice the leg length of the weld, unless access or the configuration of the joint renders this impracticable.

Intermittent fillet welds should not be used in corrosive conditions. In an intermittent fillet weld, the gaps (L1 or L2) between the ends of each length of weld Lw should fulfil the requirement given in Figure following. In an intermittent fillet weld, the gap (L1 or L2) should be taken as the smaller of the distances between the ends of the welds on opposite sides and the distance between the ends of the welds on the same side. In any run of intermittent fillet weld there should always be a length of weld at each end of the part connected. In a built-up member in which plates are connected by means of intermittent fillet welds, a continuous fillet weld should be provided on each side of the plate for a length at each end equal to at least three-quarters of the width of the narrower plate concerned.

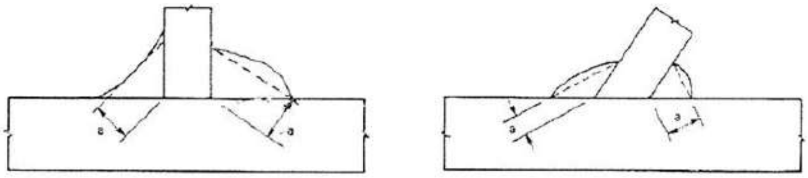


Figure 4.3: Throat thickness of a fillet weld

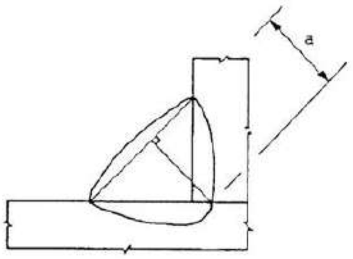


Figure 4.4: Throat thickness of a deep penetration fillet weld

it has taken into account the following steel materials:

- Pipe, H and box sections: ***S235*** (UNI EN 10025-2)
- Bolts: **CLASSE 8.8**

4.2 Cables

The features of cables are summarized in the following tables:

CLASSE
216 Fili + anima polipropilene
6x36 WS + PP
trefoli compattati
crociata destra

RESISTENZA
2160 N/mm²

Diametro fune	Diametro fili esterni	Peso per metro	Carico rottura minimo	
mm	mm	Kg	kN	Kg
10,5	0,64	0,495	85,0	8.670

CLASSE
133 Fili
7(12+6+1)
crociata destra

RESISTENZA
1770 N/mm²

Diametro fune	Diametro fili esterni	Peso per metro	Carico rottura minimo	
mm	mm	Kg	kN	Kg
3,0	0,20	0,035	6,0	610
4,0	0,26	0,061	10,5	1.070
5,0	0,32	0,096	17,7	1.800
6,0	0,40	0,140	26,0	2.650
7,0	0,46	0,185	35,5	3.620
8,0	0,50	0,244	42,5	4.330
9,0	0,60	0,308	54,5	5.560
10,0	0,65	0,381	66,0	6.730
12,0	0,77	0,548	94,0	9.590
14,0	0,93	0,746	129,5	13.210
16,0	1,07	0,974	168,0	17.130
18,0	1,20	1,230	212,0	21.620
20,0	1,33	1,520	263,0	26.820

4.3 Belts

NASTRO POLIESTERE mm 50 kg 7500

Cod. 13705001-13705011-13705051-

LARGHEZZA / width (mm)	SPESSORE / thickness (mm)	PESO / weight (g/m)	RESISTENZA / Breack strenght (daN)	ALLUNGAMENTO A.. / Elongation at..
50,00	3,20	130,00	7.500	< 7% @ 1/3 R
/- 2,00	/- 0,50	/- 14,00		
/+ 2,00	/+ 0,50	/+ 14,00		

4.4 Tensile membrane structures

MEMBRANES (Membrane Ferrari Precontraint 702)

The allowable stresses for the membrane are defined as here following:

Caractéristiques techniques	Technical data	Technische Daten	Précontraint® 702	
Fil	Yarn	Garn	**1100 Dtex PES HT**	TERSUISSE
Poids au m²	Weight sqm	Gewicht m²	**830 g/m²**	*EN ISO 2286-2*
Largeur	Width	Breite	**180 cm**	
Résistance rupture (chaîne/trame)	Tensile strength (warp/weft)	Reisskraft (Kette/Schuss)	**280/280 daN/5cm**	*EN ISO 1421*
Résistance déchirure (chaîne/trame)	Tear strength (warp/weft)	Weiterreisskraft (Kette/Schuss)	**30/28 daN**	*DIN 53.363*
Adhérence	Adhesion	Haftung	**10 daN/5 cm**	*EN ISO 2411*
Opacité	Blackout	Opak	**> 99%**	
Finition	Finish (Varnish)	Behandlung (Schlusslack)	**Vernis BIFACE**	
Réaction au feu	Flame retardancy	Brennverhalten	NFP 92-507 **M2** - **NFPA 701 Test 2** - **CSFM T19** DIN 4102-1 **B1** - **BS 7837** - **AS/NZS 1530.3** - **SIS 650082 SITAC** - UNE 23.727 - **M2**	
Températures maximum d'utilisation	Temperature extremes (while handling)	Maximale Anwendungs-temperaturen	**-30°C / +70°C**	
Système d'assurance qualité	Quality Insurance	Qualitätssicherung	**ISO 9001**	
Les caractéristiques techniques indiquées sont des valeurs moyennes	**Technical data are average values**	**Die angegebenen technischen Daten sind Mittelwerte**		

Technique d'enduction Précontraint® FERRARI	**Précontraint® FERRARI coating technology**	**Beschichtungstechnik Précontraint® FERRARI**
Stabilité dimensionnelle exceptionnelle	**Exceptional dimensional stability**	**Ausserordentliche Flächenstabilität**
Durabilité supérieure	**Longer durability**	**Höhere Haltbarkeit**
Excellente soudabilité	**Excellent welding**	**Sehr gute Verschweissbarkeit**
Opacité spéciale chapiteaux	**Special blackout for big tops**	**Spezielle Opak-Textilien für Zirkuszelte**

TEXYLOOP®
Membranes et textiles composites 100% recyclables

PRECONTRAINT GARANTIE GARANTIE FERRARI

Studio Ferrari FGD108 JAN 05 / V2.01

PRECONTRAINT® 702

FERRARI

FERRARI SA
BP 54
F 38352 LA TOUR DU PIN cedex
FRANCE
Tél. + 33 (0)4 74 97 41 33
Fax + 33 (0)4 74 97 67 20
www.ferrari-textiles.com

5. LOADS AND ACTIONS

5.1 Permanent loads

5.1.1 Self weight

For the evaluation of self weight of the materials have been adopted the following densities:

- *Carbon steel:* ***78,5_kN/m³***

The permanent loads on the structures (**G_1**) are:

- *Weight of main membrane:* ***1,0_dN/m²***

Membrane Pretension (Pre)

For make in tension a membrane we need to put inside a pretension, this value could be change, and depends from type of material and form of structure. Cable pretension it's considered inside to this factor.

- *Average pretension in the analysis oh main structures (<5% max. tensile strength):* ***1,0_kN/m****.*

5.1.2 Vertical load

The total loads of equipment are:

- *Scenic apparatus on every mast:* **2_kN;**

6. WIND ACTIONS

6.1 Basic velocity

- Wind Load:

  $V_{b.ext}$ = 28 m/s (100km/h)

6.2 Wind Forces

According to EC1 (UNI EN 1991 1-4:2005-E) The wind force Fw is determined directly by vectorial summation over the individual structural elements by using Expression below:

$$F_w = c_s c_d \cdot \sum_{elements} c_f \cdot q_p(z_e) \cdot A_{ref}$$

where:

- **$c_s c_d$** is the structural factor;
- **c_f** is the force coefficient for the structure;
- **$q_p(z_e)$** is the peak velocity pressure at reference height z_e;
- **A_{ref}** is the reference area of the structure.

6.2.1 Peak velocity pressure

The peak velocity pressure qp(ze), which includes mean and short-term velocity fluctuations, will be determined by:

$$q_p(z) = [1 + 7 \cdot I_v(z)] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

where:

- **ρ** is the air density, which depends on the altitude, temperature and barometric pressure to be expected in the region during wind storms (1,25kg/m^3);
- **$c_e(z)$** is the exposure factor.

$V_m(z)$ is mean wind velocity, at a height z above the terrain depends on the terrain roughness and orography and on the basic wind velocity, **vb**, and will be determined using Expression below:

$$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

where:

$$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right) \quad \text{for} \quad z_{min} \le z \le z_{max}$$

$$c_r(z) = c_r(z_{min}) \quad \text{for} \quad z \le z_{min}$$

z_0 is the roughness length

k_r terrain factor depending on the roughness length z_0 calculated using

$$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}} \right)^{0{,}07}$$

$z_{0,II}$ = 0,05 m (terrain category II, Table 4.1)

z_{min} is the minimum height defined in Table 4.1

z_{max} is to be taken as 200 m

The wind pressure acting on the external surfaces, we, should be obtained from Expression:

$$w_e = q_p(z_e) \cdot c_{pe}$$

where:

$q_p(z_e)$ is the peak velocity pressure

z_e is the reference height for the external pressure

c_{pe} is the pressure coefficient for the external pressure

In particular, in compliance with EN 13782:

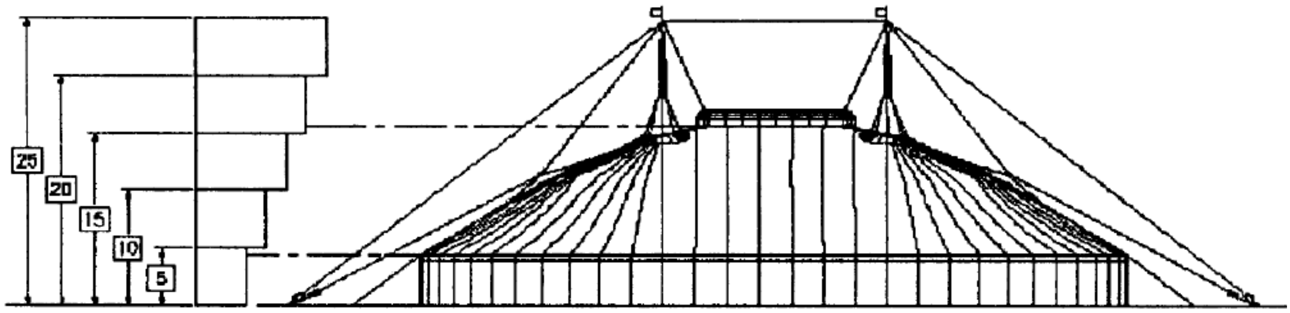
c_{TEM} = 0,8

T_r = 10 years

c_d = 1

c_{ALT} = 1

As simplification, the values given in Table 1 may be applied with the distribution shown in figures following:

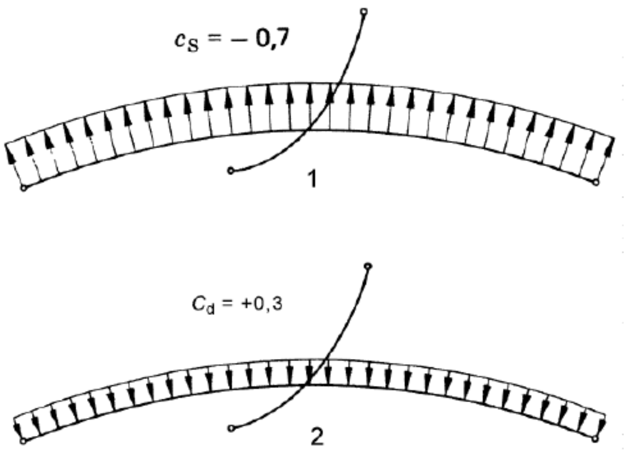


6.3 Wind pressure on surfaces

The shape coefficients may be taken according to EN 1991-1-4, or to wind tunnel test.

Wind tunnel testing shall be done by an experienced laboratory in accordance with the relevant Part of Eurocode 1.

Wind coefficients are presented in Figure below:



6.3.1 Aerodynamic coefficients for round shape tents

The final pressure is:

$$q = q_p x C_{pe}$$

Where C_{pe} Aerodynamic coefficient.

	H,c	B,x	A,x	q	C_G	V,x	M,y
	m	*m*	*m^2*	*kN/m*		*kN*	*kNm*
Poles	*3,0*	*13,0*	*39,0*	*0,50*	*0,80*	*15,62*	*23,43*
H1	*3,9*	*11,6*	*10,9*	*0,50*	*0,59*	*3,24*	*12,76*
H2	*4,9*	*10,3*	*9,6*	*0,50*	*0,59*	*2,86*	*13,93*
H3	*5,8*	*8,9*	*8,3*	*0,60*	*0,59*	*2,97*	*17,25*
H4	*6,8*	*7,5*	*7,0*	*0,60*	*0,59*	*2,51*	*16,93*
H5	*7,7*	*6,1*	*5,7*	*0,60*	*0,59*	*2,05*	*15,75*
H6	*8,6*	*4,8*	*4,5*	*0,60*	*0,59*	*1,59*	*13,70*
H7	*9,6*	*3,4*	*3,2*	*0,60*	*0,59*	*1,13*	*10,79*
Hmax	*10,5*	*2,0*	*1,9*	*0,66*	*0,80*	*0,99*	*10,41*

7. SNOW LOADS

According to EC1 (UNI EN 1991 1-3:2004-E), the snow load on roofs shall be determined as follows:

a) for the persistent / transient design situations:

$$s = \mu_i \; C_e \; C_t \; s_k$$

b) for the accidental design situations where exceptional snow load is the accidental action:

$$s = \mu_i \; C_e \; C_t \; s_{Ad}$$

Where:

μ_i	is the snow load shape coefficient
s_k	is the characteristic value of snow load on the ground
s_{Ad}	is the design value of exceptional snow load on the ground for a given location
C_e	is the exposure coefficient
C_t	is the thermal coefficient

For C_e coefficient it is possible adopted the indications in the following table

Topography	C_e
Windswept [a]	0,8
Normal [b]	1,0
Sheltered [c]	1,2

[a] *Windswept topography*: flat unobstructed areas exposed on all sides without, or little shelter afforded by terrain, higher construction works or trees.

[b] *Normal topography*: areas where there is no significant removal of snow by wind on construction work, because of terrain, other construction works or trees.

[c] *Sheltered topography*: areas in which the construction work being considered is considerably lower than the surrounding terrain or surrounded by high trees and/or surrounded by higher construction works.

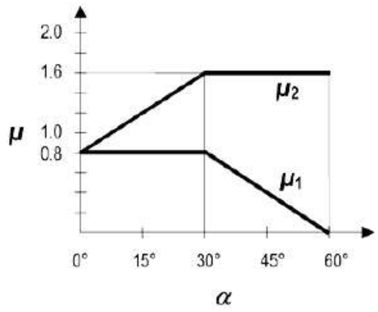
The thermal coefficient C_t should be used to account for the reduction of snow loads on roofs with high thermal transmittance (>1W/m^{2}K), in particular for some glass covered roofs, because of melting caused by heat loss. For all other cases:

C_t =1,0.

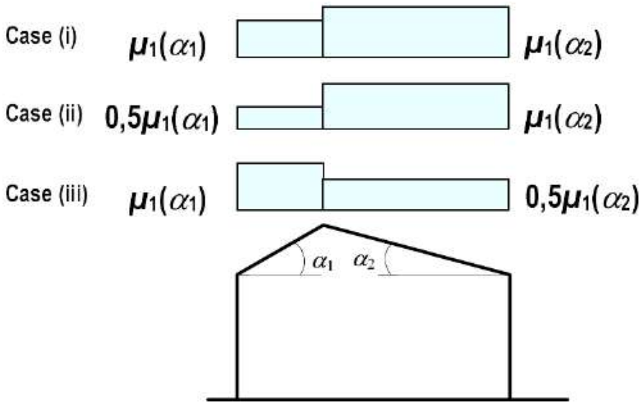
7.1 Roof shape coefficients

The snow load shape coefficient μ_1 that should be used for monopitch roofs is given in Tables and shown in figures below:

Angle of pitch of roof α	$0° \leq \alpha \leq 30°$	$30° < \alpha < 60°$	$\alpha \geq 60°$
μ_1	0.8	$0.8(60 - \alpha)/30$	0.0
μ_2	$0.8 + 0.8\,\alpha/30$	1.6	--



The values apply when snow is not prevented from sliding off the roof. Where snow fences or other obstructions exist or where the lower edge of the roof is terminated with a parapet, then the snow load shape coefficient should not be reduced below 0,8.



The snow load shape coefficients that should be used for roofs abutting to taller construction works are given in the following expressions:

$\mu_1 = 0{,}8$ (assuming the lower roof is flat)

$\mu_2 = \mu_S + \mu_W$

where:

μ_S is the snow load shape coefficient due to sliding of snow from the upper roof

For $\alpha \leq 15°$, $\mu_S = 0$,

For $\alpha > 15°$, μ_S is determined from an additional load amounting to 50 % of the maximum total snow load, on the adjacent slope of the upper roof calculated according to 5.3.3

μ_W is the snow load shape coefficient due to wind

$$\mu_w = (b_1 + b_2)/2h \leq \gamma h/s_k, \quad (5.8)$$

where:

γ is the weight density of snow, which for this calculation may be taken as 2 kN/m^3

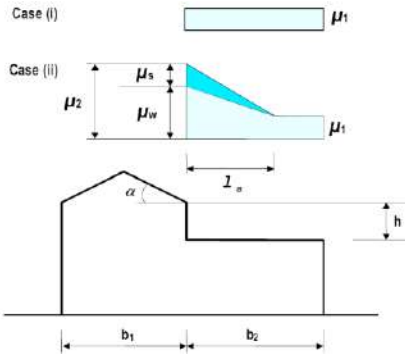
An upper and a lower value of μ_w should be specified.

The recommended range is $0,8 < \mu_w < 4$.

The drift length is determined as follows:

$l_s = 2h$

A restriction for ls may be given in the National Annex. The recommended restriction is $5 < l_s < 15$ m.



Snow Load Summary on the roof

Q_{sk} $=S_{ad}$= 0,1_kN/m^2, without Wind Action

In the winter time, it is recommendable to use a heater to produce indoor temperature, below the membranes, about 10-15°C, to avoid the snow accumulation.

In case of sand/dust accumulation on the membrane the value is lowest of snow

Anyway, as soon possible, it is mandatory to remove the snow, sand or dust on the circus tent.

8. COMBINATIONS OF ACTIONS

The following ultimate limit states shall be verified as relevant :

EQU : Loss of static equilibrium of the structure or any part of it considered as a rigid body, where :

– minor variations in the value or the spatial distribution of actions from a single source are significant, and

– the strengths of construction materials or ground are generally not governing ;

STR : Internal failure or excessive deformation of the structure or structural members, including footings, piles, basement walls, etc., where the strength of construction materials of the structure governs ;

GEO : Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance ;

The general format of effects of actions shall be:

$$E_d = \gamma_{Sd} E \{ \gamma_{g,j} G_{k,j} ; \gamma_p P ; \gamma_{q,1} Q_{k,1} ; \gamma_{q,i} \psi_{0,i} Q_{k,i} \} \quad j \geq 1 ; i > 1$$

Fundamental combinations

The design values of the actions shall be combined in the following way:

$$\gamma_G G_K + \gamma_F Q_{k,1}$$

$$\gamma_G G_K + \sum \gamma_F Q_{k,i}$$

All cases shall be checked, where:

γ_G = 1,35 partial safety factor for unfavourable permanent actions;

γ_G = 1,0 partial safety factor for favourable permanent actions;

γ_F = 1,5 partial safety factor for only one variable action;

γ_F = 1,35 partial safety factor for more variable actions;

G_k characteristic value of permanent action;

$Q_{k,i}$ characteristic value of one of the variable actions.

Verification of stability and equilibrium

With the following recommended factors:

Loading		γ
1	Favourably acting proportions of the dead load	1
2	Unfavourably acting proportions of the dead load	1,1
3	Unfavourably acting wind loads	1,2
4	Unfavourably acting proportions of loads other than the loads listed in items 2 and 3	1,3
NOTE If loads are resolved into components, then these components should be multiplied by the same value of γ.		

— The safety against overturning shall be calculated from:

$$\sum \gamma M_{ST,k} \geq \sum \gamma M_{K,k}$$

where

γ is the safety factor in accordance with Table 2;

$M_{ST,k}$ are the stabilising moment proportions (service load);

$M_{K,k}$ are the overturning moment proportions (service load).

— The safety against sliding shall be calculated from

$$\sum \gamma \mu N \geq \sum \gamma H$$

where

γ is the safety factor in accordance with Table 2;

N is the vertical load component (service load);

H is the horizontal load component (service load);

μ is the coefficient of friction in accordance with Table 3.

	Wood	Steel	Concrete
Wood	0,4	0,4	0,6
Steel	0,4	0,1	0,2
Concrete	0,6	0,2	0,5
Clay [a]	0,25	0,2	0,25
Loam [a]	0,4	0,2	0,4
Sand and gravel	0,65	0,2	0,65

[a] At least of stiff consistency in accordance with ENV 1997-1.

In particular, we will have the following combinations:

F_1= 1,35(1)P ± 1,5(0)V + 1,5x0,7(0)Q +1,5x0,5(0)S +1,2x(1)Pre

F_2= 1,35(1)P ± 1,5x0,7(0)V + 1,5(0)Q +1,5 x0,5 (0)S +1,2x(1)Pre

F_3= 1,35(1)P ± 1,5x0,7(0)V + 1,5x0,7(0)Q +1,5(0)S +1,2x(1)Pre

F_4= 1,35(1)P ± 1,5x0,7(0)V + 1,5x0,7(0)Q +1,5x0,5(0)S +1,2x(1)Pre

where:

P, permanent action

Q, variable action

V, wind action

S, snow action

Pre, pretension

9. CALCULATION AND ANALYSIS

The structural analysis has been performed in a 3-dimensional model, by a finite element method approach.

The f.e.m analysis model has been involved in elastic linear field by following Structural Components:

- Joints, SAP2000 automatically create joints at structural object intersections or internal joints when meshing structural objects. Joint coordinates and information may be displayed on screen in the model window or in tabular format;
- Frames, the frame element uses a general, three-dimensional, beam-column formulation which includes the effects of biaxial bending, torsion, axial deformation, and biaxial shear deformations. SAP2000 has a built-in library of standard concrete, steel and composite section properties of both US and International Standard sections;
- Shells, the shell element is a type of area object that is used to model membrane, plate, and shell behavior in planar and three-dimensional structures. The shell material may be homogeneous or layered throughout; material nonlinearity can also be considered when using the layered shell;
- Restraint releases and constraints, for define the structural behaviour in the space.

In the adopted model the mechanic features for the materials have been:

Steel - $E=210x10^6$_kN/m^2, Poisson coefficient ν=0,3 and α= $1,2x10^{-5}°C^{-1}$;

The Force Load is used to apply concentrated forces and moments at the joints. Values may be specified in a fixed coordinate system (global or alternate coordinates) or the joint coordinate system.

Sap2000 f.e.m. program does not allow the exact analysis of the tissue, for the large deformations of membrane. The shell element is used only to distribute the external actions on the resistant elements (dome, antennas, edge poles, etc.). The tensional verification of the tissue is obtained through simplified formulations, considering the most stressed band.

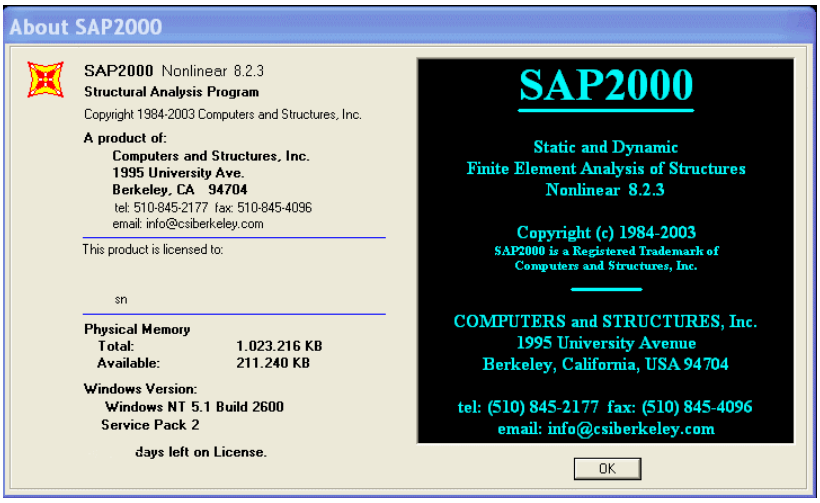
9.1 Software used

For the analysis has been adopted SAP2000 f.e.m. softaware, produced by Computers and Structures, Inc.1995 University Avenue, Berkeley, California 94704.

In effect, the SAP2000 name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object based graphical modeling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now you can harness the power of SAP2000 for all of your analysis and design tasks, including small day-to-day problems. Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards.

The models are implemented by input files, in text or graphic mode, while the output stress and deformations results are generated in text mode and in graphic shape.



Version of program used and System of mainframe

To facilitate the results reading, it follows a typical output list for beams and shells elements:

TABLE: Element Forces - Frames									
Frame	**Station**	**OutputCase**	**CaseType**	**P**	**V2**	**V3**	**T**	**M2**	**M3**
Text	m	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
488	0	PP	LinStatic	-0,003568	-0,204	0,001726	-0,0004268	0,0007819	-0,0007219
488	0,1025	PP	LinStatic	-0,003568	-0,17	0,001726	-0,0004268	0,000605	0,0185
488	0,205	PP	LinStatic	-0,003568	-0,135	0,001726	-0,0004268	0,000428	0,0341

where:

- **Frame:** elements considered
- **Station:** output value location
- **OutputCase:** load condition or combination
- **CaseType:** type of condition or combination (static, dynamic, modal, etc.)
- **P (kN):** axial force in kN, (if negative means compression)
- **V2 (kN):** shear force in kN, long axis 2,
- **V3 (kN):** shear force in kN, long axis 3,
- **T (kNm):** torsional force in kNm,
- **M2 (kNm):** bending moment in kNm, long axis 3,
- **M3 (kNm):** bending moment in kNm, long axis 2,

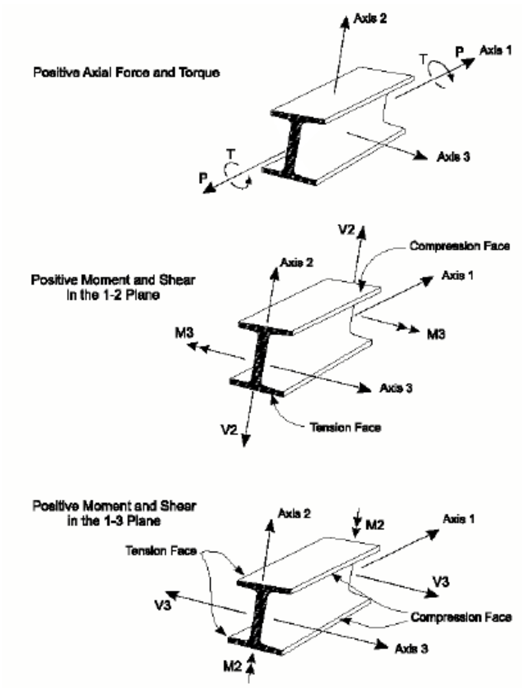
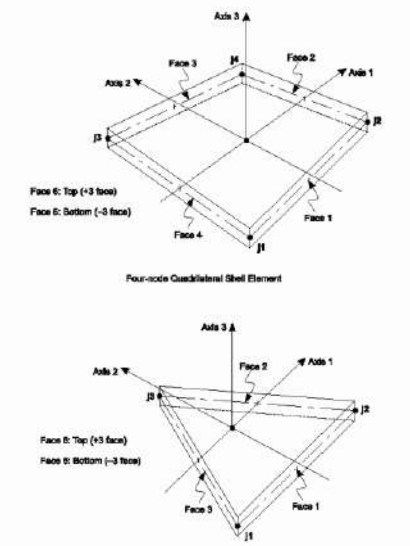


TABLE: Element Forces - Area Shells										
Area	**AreaElem**	**ShellType**	**Joint**	**OutputCase**	**CaseType**	**F11**	**F22**	**F12**	**FMax**	**FMin**
Text	Text	Text	Text	Text	Text	KN/m	KN/m	KN/m	KN/m	KN/m
421	282	Shell-Thin	67	PP	LinStatic	-34,61	10,43	-23,22	20,26	-44,43
421	282	Shell-Thin	69	PP	LinStatic	-10,37	14,07	9,71	17,46	-13,76
421	282	Shell-Thin	539	PP	LinStatic	-13,96	-9,92	11,39	-0,38	-23,5
421	282	Shell-Thin	538	PP	LinStatic	-38,21	-13,56	-21,55	-1,06	-50,7

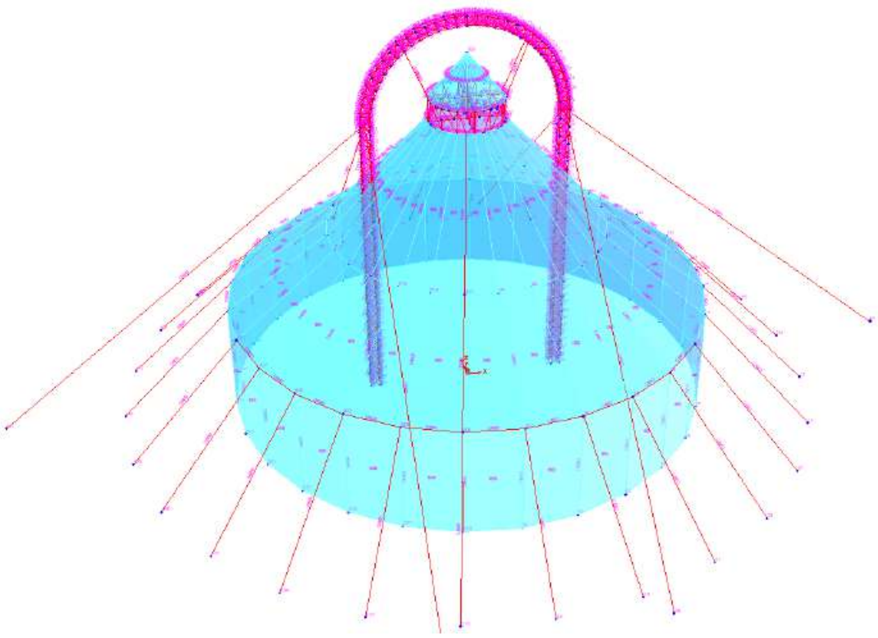
FAngle	FVM	M11	M22	M12	MMax	MMin	MAngle	V13	V23	VMax	VAngle
Degrees	KN/m	KN-m/m	KN-m/m	KN-m/m	KN-m/m	KN-m/m	Degrees	KN/m	KN/m	KN/m	Degrees
-67,064	57,31	-18,0207	-26,5658	-2,2484	-17,4652	-27,1213	-13,878	-29,82	39,3	49,33	127,187
70,755	27,1	-15,8181	-2,2405	-3,753	-1,2721	-16,7864	-75,533	-26,92	39,3	47,64	124,406
50,037	23,32	32,3898	-0,5078	-1,3026	32,4413	-0,5593	-2,264	-26,92	-18,43	32,62	-145,602
-59,887	50,18	35,9149	9,8049	0,202	35,9165	9,8034	0,443	-29,82	-18,43	35,05	-148,281

where:

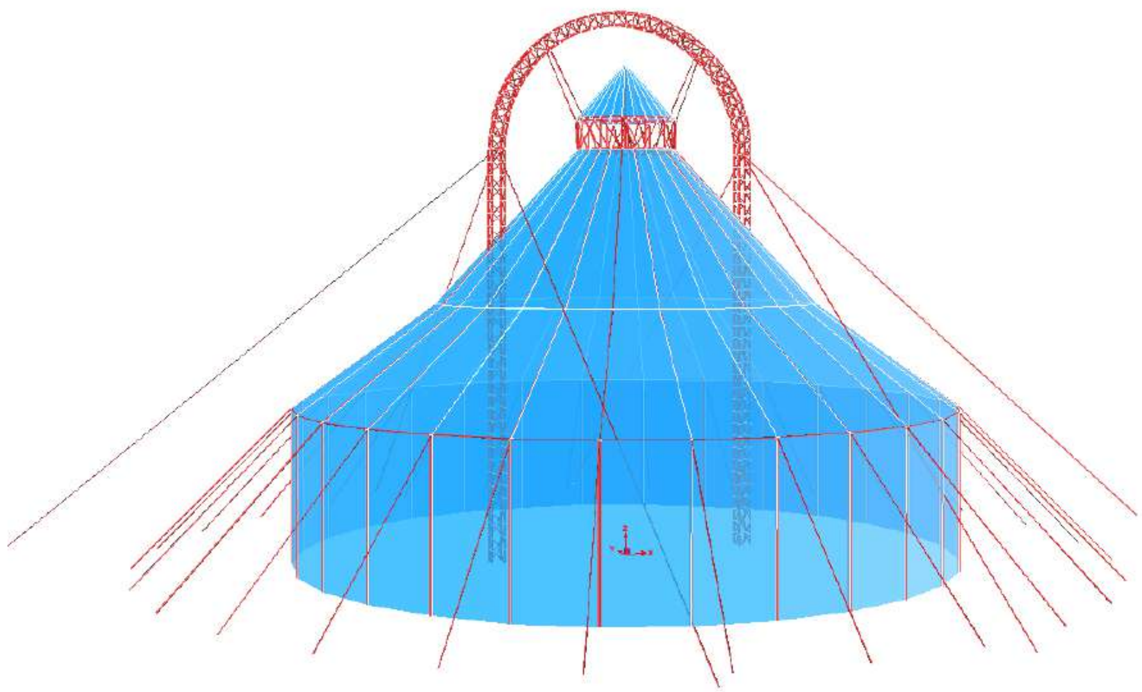
- **AreaElem:** shell elements
- **Joint:** reading output joints
- **OutputCase:** load condition or combination
- **CaseType:** type of condition or combination (static, dynamic, modal, etc.)
- **F11 (kN/m):** axial force in kN/m long 1-1 direction
- **F22 (kN/m):** axial force in kN/m long 2-2 direction
- **F12=F21 (kN/m):** axial force in kN/m long 1-2/2-1 direction
- **Fmax/Fmin (kN/m):** absolute minimum/maximum axial force in kN/m
- **M11 (kNm/m):** bending moment in kNm/m, long axis 1-1
- **M22 (kNm/m):** bending moment in kNm/m, long axis 2-2
- **M12=M21 (kNm/m):** bending moment in kNm/m, long axis 1-2/2-1
- **Mmax/Mmin (kNm/m):** absolute minimum/maximum bending moment in kNm/m
- **V13 (kN/m):** shear force in kN/m long 1-3 direction
- **V23 (kN/m):** shear force in kN/m long 2-3 direction



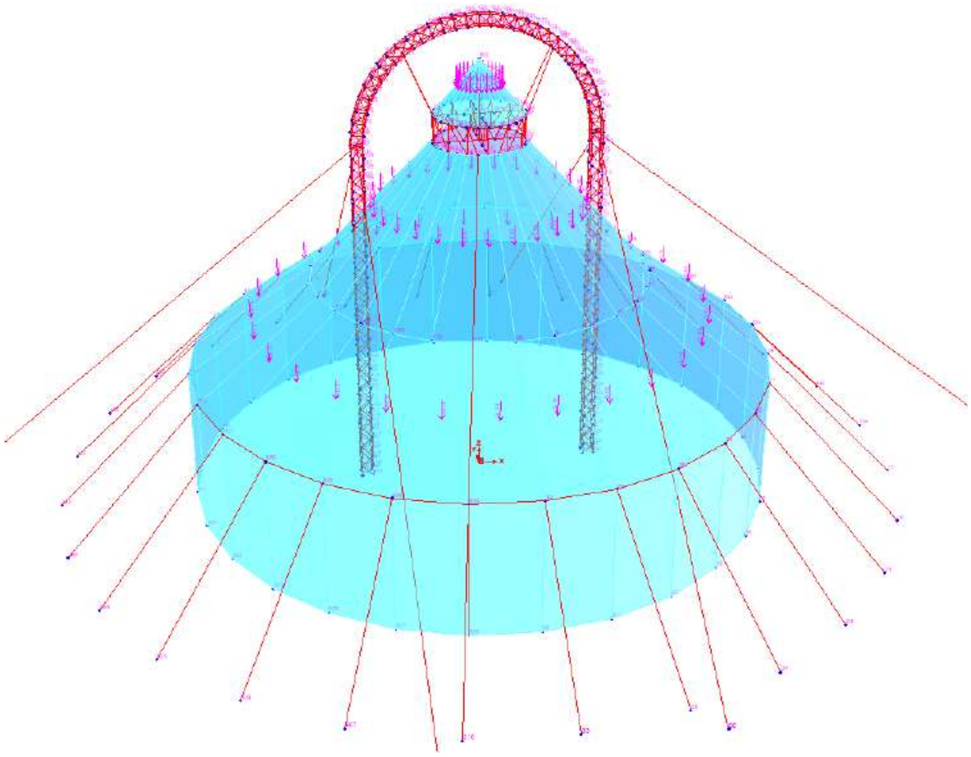
It follows the pictures of principals geometrical features of the models:



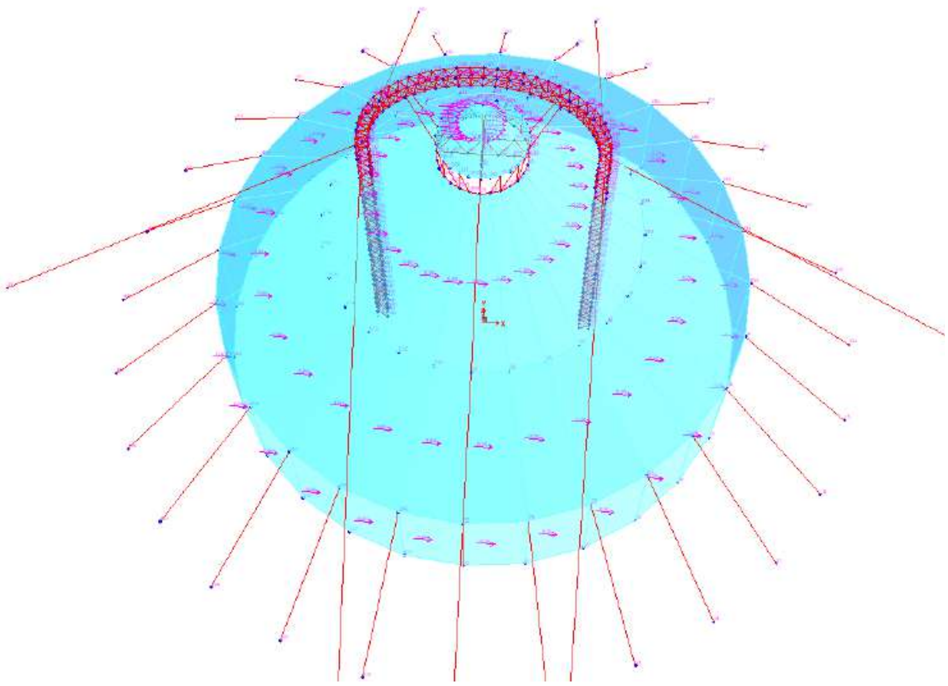
F.e.m. model (joints, beams and shells)



F.e.m. model (solid extrusion)



F.e.m. model (Snow loads)



F.e.m. model (Wind loads)

10. VERIFICATION OF STRUCUTURE

10.1 Steel structures

Eurocode 3 has been taken into account for the verification procedure. Checks have been performed according to Chapter 6 of Eurocode 3.

Design resistance shall be evaluated in accordance with the following equation:

$$R_d = \frac{R_k}{\gamma_M}$$

where

R_d is the design value of material properties;

R_k is the characteristic value of material properties;

$\gamma_M = 1,1$ is the partial safety factor for material property in static load combinations for steel.

In particular, will be used the following formulas:

Tension Check

The axial tension check at each output station shall satisfy:

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1.0 \qquad \text{(EC3 6.2.3(1))}$$

where the design tension resistance, $N_{t,Rd}$ is taken as the smaller of:

- the design plastic resistance, $N_{pl,Rd}$ of the gross cross-section

$$N_{pl,Rd} = \frac{Af_y}{\gamma_{M0}} \qquad \text{(EC3 6.2.3(2)a)}$$

- the design ultimate resistance, $N_{u,Rd}$ of the net cross-section

$$N_{u,Rd} = \frac{0.9 A_{net} f_u}{\gamma_{M2}} \qquad \text{(EC3 6.2.3(2)b)}$$

The values of A and A_{net} are defined in Section 5.1.

Compression Check

The axial compression check at each output station shall satisfy:

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1.0 \qquad \text{(EC3 6.2.4(1))}$$

where the design compression resistance, $N_{c,Rd}$ for Class 1, 2, 3, a nd 4 sections is taken as:

$$N_{c,Rd} = \frac{Af_y}{\gamma_{M0}} \qquad \text{for Class 1, 2, or 3 cross-sections} \quad \text{(EC3 6.2.4(2))}$$

$$N_{c,Rd} = \frac{A_{eff} f_y}{\gamma_{M0}} \qquad \text{for Class 4 cross-sections} \quad \text{(EC3 6.2.4(2))}$$

Axial Buckling Check

The axial buckling check at each output station shall satisfy:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1.0 \qquad \text{(EC3 6.3.1.1(1))}$$

where the design compression resistance, $N_{b,Rd}$ for Class 1, 2, 3, and 4 sections is taken as:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{MI}} \qquad \text{for Class 1, 2, and 3 cross-sections} \quad \text{(EC3 6.3.1.1(3))}$$

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{MI}} \qquad \text{for Class 4 cross-sections} \quad \text{(EC3 6.3.1.1(3))}$$

The reduction factor, χ for the relevant buckling mode is taken as:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \leq 1.0 \qquad \text{(EC3 6.3.1.2(1))}$$

where the factor, Φ and the non-dimensional slenderness, $\bar{\lambda}$ are taken as:

$$\Phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right] \qquad \text{(EC3 6.3.1.2(1))}$$

$$\bar{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{1}{\lambda_1}, \quad \text{for Class 1, 2 and 3 cross-sections} \quad \text{(EC3 6.3.1.3(1))}$$

$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{\sqrt{A_{eff}/A}}{\lambda}, \quad \text{for Class 4 cross-sections} \quad \text{(EC3 6.3.1.2(1))}$$

Bending and axial compression

(4) Members which are subjected to combined bending and axial compression should satisfy:

$$\frac{N_{Ed}}{\frac{\chi_y N_{Rk}}{\gamma_{M1}}} + k_{yy}\frac{M_{y,Ed} + \Delta M_{y,Ed}}{\chi_{LT}\frac{M_{y,Rk}}{\gamma_{M1}}} + k_{yz}\frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_{M1}}} \leq 1 \qquad (6.61)$$

$$\frac{N_{Ed}}{\frac{\chi_z N_{Rk}}{\gamma_{M1}}} + k_{zy}\frac{M_{y,Ed} + \Delta M_{y,Ed}}{\chi_{LT}\frac{M_{y,Rk}}{\gamma_{M1}}} + k_{zz}\frac{M_{z,Ed} + \Delta M_{z,Ed}}{\frac{M_{z,Rk}}{\gamma_{M1}}} \leq 1 \qquad (6.62)$$

where N_{Ed}, $M_{y,Ed}$ and $M_{z,Ed}$ are the design values of the compression force and the maximum moments about the y-y and z-z axis along the member, respectively

$\Delta M_{y,Ed}$, $\Delta M_{z,Ed}$ are the moments due to the shift of the centroidal axis according to 6.2.9.3 for class 4 sections, see Table 6.7,

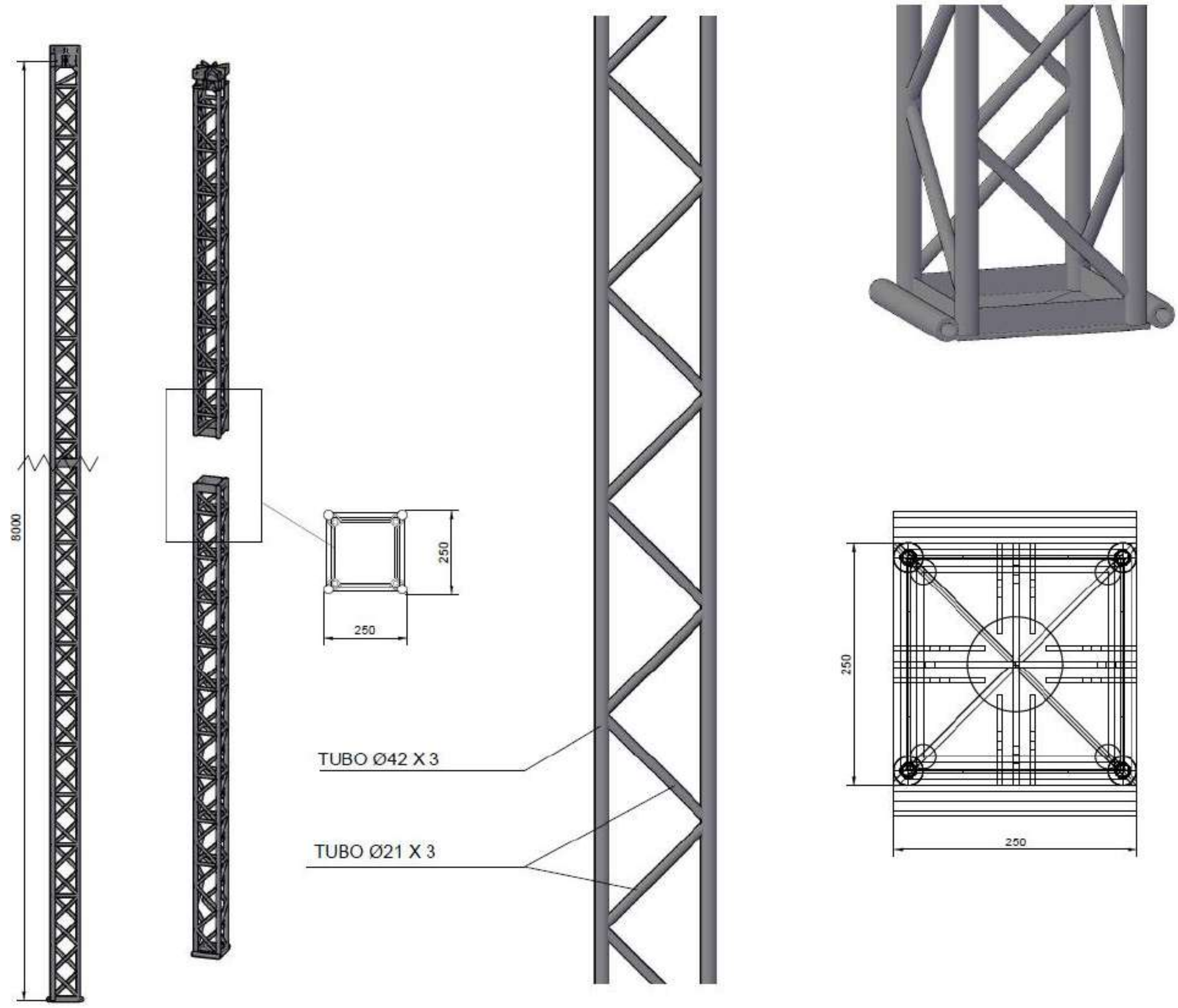
χ_y and χ_z are the reduction factors due to flexural buckling from 6.3.1

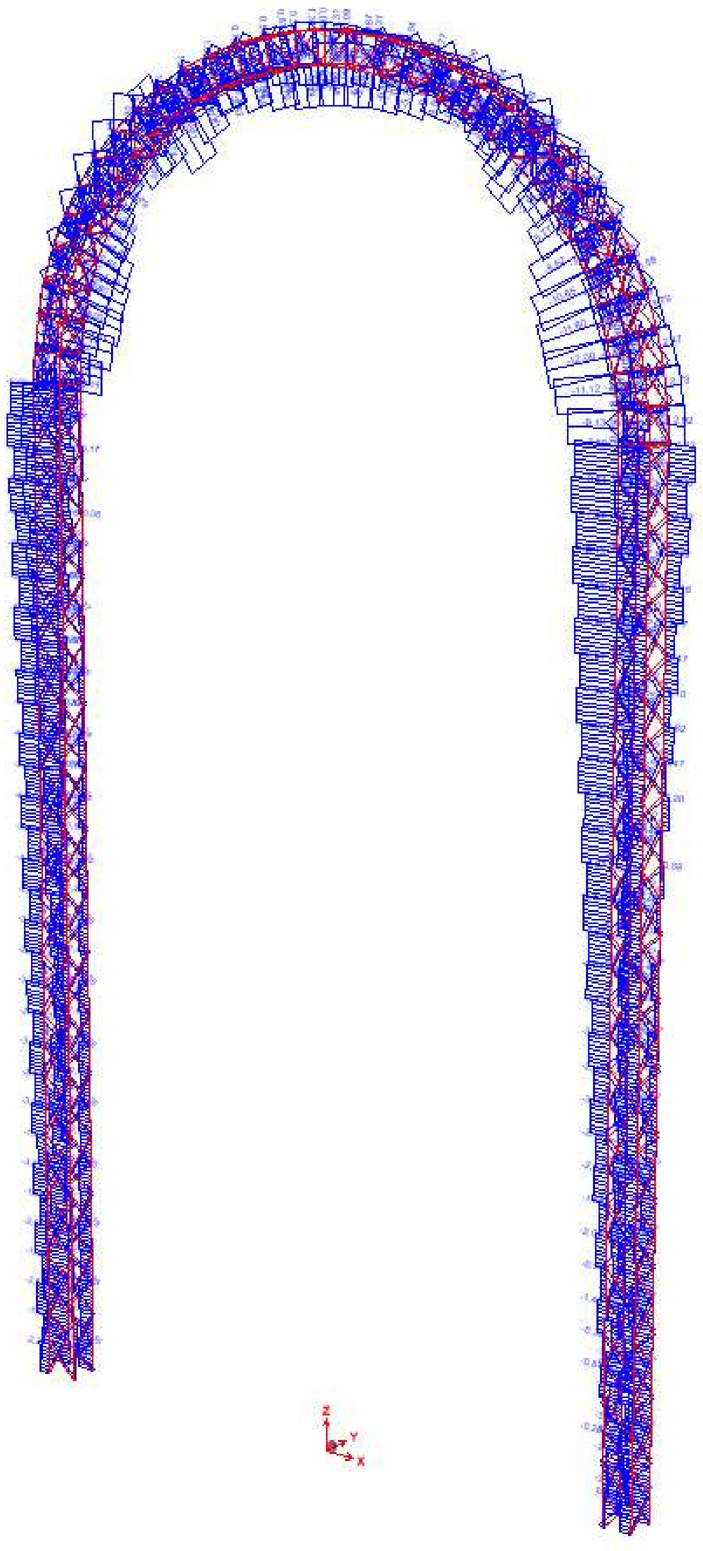
χ_{LT} is the reduction factor due to lateral torsional buckling from 6.3.2

k_{yy}, k_{yz}, k_{zy}, k_{zz} are the interaction factors

The check-factors has been calculated by a excel routine according to the Eurocode 3 approach.

10.2 Mast Verification





f.e.m model of antennas - axial force (envelope values kN)

To take account of the slenderness of the column, it was used a simplified approach based on the coefficient of the critical load (see point 6.4 Uniform built-up compression members of EC3)

(6) For a member with two identical chords the design force $N_{ch,Ed}$ should be determined from:

$$N_{ch,Ed} = 0,5N_{Ed} + \frac{M_{Ed} h_0 A_{ch}}{2I_{eff}} \qquad (6.69)$$

where $M_{Ed} = \dfrac{N_{Ed} e_0 + M^I_{Ed}}{1 - \dfrac{N_{Ed}}{N_{cr}} - \dfrac{N_{Ed}}{S_v}}$

$N_{cr} = \dfrac{\pi^2 EI_{eff}}{L^2}$ is the effective critical force of the built-up member

where $M_{Ed} = \dfrac{N_{Ed} e_0 + M^I_{Ed}}{1 - \dfrac{N_{Ed}}{N_{cr}} - \dfrac{N_{Ed}}{S_v}}$

$N_{cr} = \dfrac{\pi^2 EI_{eff}}{L^2}$ is the effective critical force of the built-up member

N_{Ed} is the design value of the compression force to the built-up member

M_{Ed} is the design value of the maximum moment in the middle of the built-up member considering second order effects

M^I_{Ed} is the design value of the maximum moment in the middle of the built-up member without second order effects

h_0 is the distance between the centroids of chords

A_{ch} is the cross-sectional area of one chord

I_{eff} is the effective second moment of area of the built-up member, see 6.4.2 and 6.4.3

S_v is the shear stiffness of the lacings or battened panel, see 6.4.2 and 6.4.3.

(2) For chords the buckling verification should be performed as follows:

$$\frac{N_{ch,Ed}}{N_{b,Rd}} \leq 1,0 \qquad (6.71)$$

where $N_{ch,Ed}$ is the design compression force in the chord at mid-length of the built-up member according to 6.4.1(6)

and $N_{b,Rd}$ is the design value of the buckling resistance of the chord taking the buckling length L_{ch} from Figure 6.8.

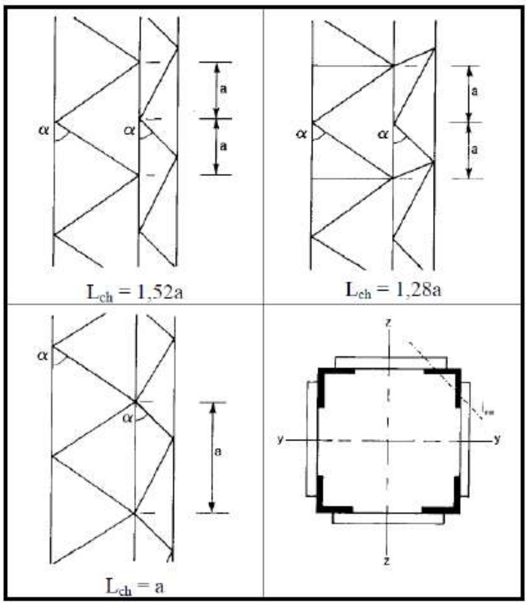


Figure 6.8: Lacings on four sides and buckling length L_{ch} of chords

	42	mm
	3	mm
A_{ch} =	367,4	mm^2
n_p =	**2**	
r_{y-y} =	13,83	mm
r_{z-z} =	13,83	mm
r_{min} =	13,83	mm
$J_{ch,z}$ =	70261	mm^4
$J_{ch,y}$ =	70261	mm^4
$J_{ch,min}$ =	70261	mm^4
L =	**8,00**	m
β_z =	**1**	
L_z =	8000	mm
β_y =	1,0	
L_y =	8000	mm
a =	**500**	mm
h_0 =	**250**	mm
$J_{eff,z}$ =	22961250	mm^4
	21	mm
	3	mm
A_d =	169,6	mm^2
A_v =	169,6	mm^2
N_{Ed} =	**70**	kN
M_{Ed}^{I} =	**0**	kNm

e_0 =	40,00	mm
	2	
L_{ch} =	640,00	mm
$N_{cr'}$ =	347,06	kN
$\lambda_{rid,z}$ =	0,499	
Φ =	0,656	
Χ =	0,925	
κ_2 =	1,000	
$N_{ch,Rd,z}$ =	70,30	N
$N_{cr,z}$ =	725,89	kN
	1	
n =	**1**	
d =	353,55	mm
	24579	kN
S_V =	12.289	kN
M_{Ed} =	3,12	kNm
$N_{ch,Ed,z}$ =	**23,7**	kN

For verification of singular vertical beam the previous value is increased of a 1,5 coefficient:

Pipe	**42**	***(Diameter mm)***
tk:	**3**	***mm***
Steel	**S 235**	
f_{yk}= 235,00		*N/mm²*

A	**3,67**	*cm^2: area*
J_x	**7,03**	*cm^4: J - X direction*
W_x	**3,35**	*cm^3: W- X direction*
$W_{x,pl}$	**4,57**	*cm^3: Wpl- X direction*
J_P	**14,05**	*cm^4: J - Z direction*
i_x	**1,38**	*cm: radius X*
Pp,profilo	**2,9**	kg/m
L_x	**0,50**	*m: length axis x*
λ_x	**36,16**	*slenderness x*
α_x	***a*** **--->**	**0,21** *:fatt. di imperfezione*

N_{ed}	**35,60**	*kN: axial force*
$V_{Ed, a}$	**0,00**	*kN: share force X*
$M_{Ed, xx}$	**0,00**	*kNm: bending moment X-X axis*
$M_{Ed, tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$\sigma_{cr,x}$	**1554**	*N/mm^2: critical eulerian value dir.X*
$N_{cr,x}$	**571**	*Critical value of N*
χ_x	**0,96**	*slenderness coefficient X,* *whit ΦX=* **0,59**
$\lambda°_x$	**0,39**	*instability value X*

Classe	***1***	
$N_{Rd, comp}$	**79**	*kN: axial compression resistance*
$N_{pl,Rd}$	**82**	*kN: axial tensile resistance*
$V_{c,Rd,an}$	**30**	*kN: shear resistance*
$M_{c,Rd,x}$	**1,02**	*kNm: flexural resistance*
$M_{N,x,Rd}$	**0,96**	*kNm: flexural and axial resistance*
$M_{p,Rd}$	**1,5**	*kNm: torsional resistance*

n= 0,43	**$1/k_x$= *0,83***	**μ_x= *-0,46***
a= 0,50	**ρ_V= *0***	**ε= *1,00***

η= ***0,45*** ***---> Section Verified***

The value check of diagonal beam is obtained of vertical value/4:

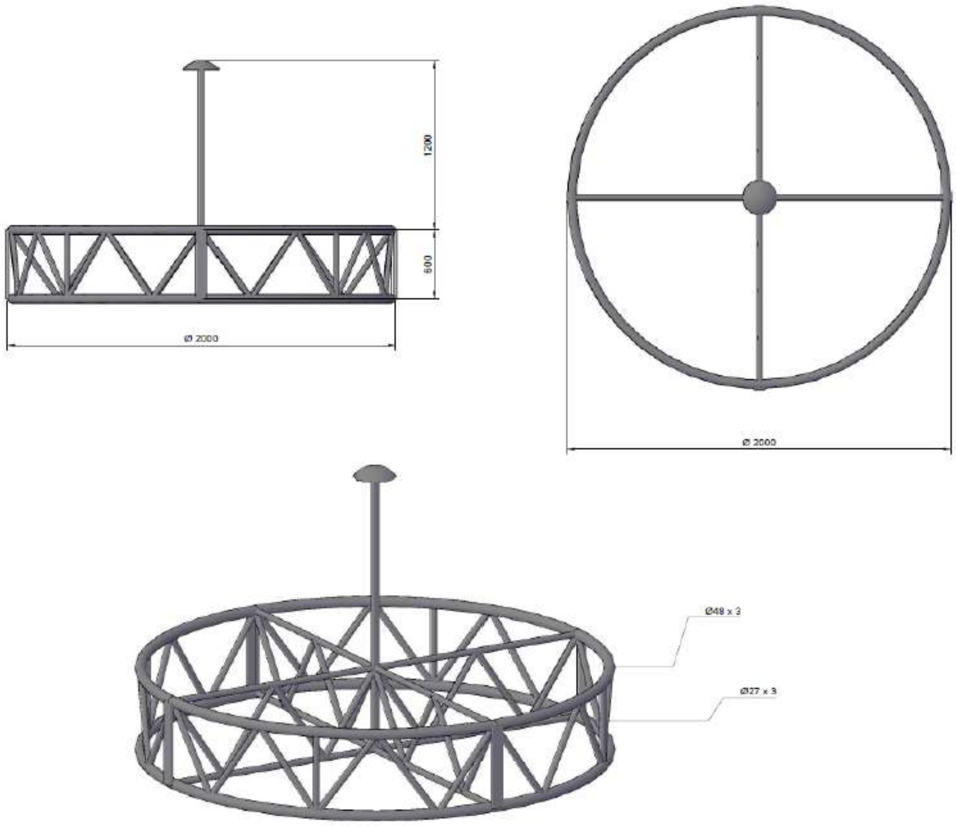
Pipe	**21**	***(Diameter mm)***
tk:	**3**	***mm***
Steel	**S 235**	
f_{yk}= 235,00		*N/mm²*
A	**1,70**	*cm²: area*
J_x	**0,71**	*cm⁴: J - X direction*
W_x	**0,67**	*cm³: W- X direction*
$W_{x,pl}$	**0,98**	*cm³: Wpl- X direction*
J_P	**1,41**	*cm⁴: J - Z direction*
i_x	**0,65**	*cm: radius X*
Pp,profilo	**1,3**	kg/m
L_x	**0,50**	*m: length axis x*
λ_x	**77,50**	*slenderness x*
α_x	***a*** **---> 0,21**	*:fatt. di imperfezione*
N_{ed}	**8,90**	*kN: axial force*
$V_{Ed,a}$	**0,00**	*kN: share force X*
$M_{Ed,xx}$	**0,00**	*kNm: bending moment X-X axis*
$M_{Ed,tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$\sigma_{cr,x}$	**338**	*N/mm²: critical eulerian value dir.X*
$N_{cr,x}$	**57**	*Critical value of N*
χ_x	**0,78**	*slenderness coefficient X, whit ΦX=* **0,91**
$\lambda°_x$	**0,83**	*instability value X*
Classe	***1***	
$N_{Rd,comp}$	**30**	*kN: axial compression resistance*
$N_{pl,Rd}$	**38**	*kN: axial tensile resistance*
$V_{c,Rd,an}$	**14**	*kN: shear resistance*
$M_{c,Rd,x}$	**0,22**	*kNm: flexural resistance*
$M_{N,x,Rd}$	**0,19**	*kNm: flexural and axial resistance*
$M_{p,Rd}$	**0,3**	*kNm: torsional resistance*

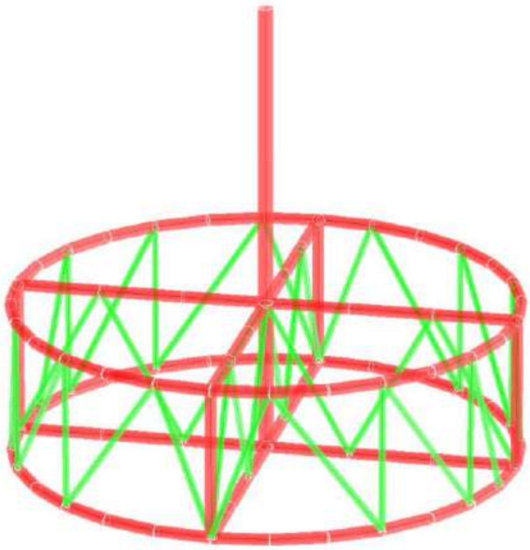
n= 0,23 ***$1/k_x$= 0,78*** ***μ_x= -0,99***

a= 0,50 ***ρ_V= 0*** ***ε= 1,00***

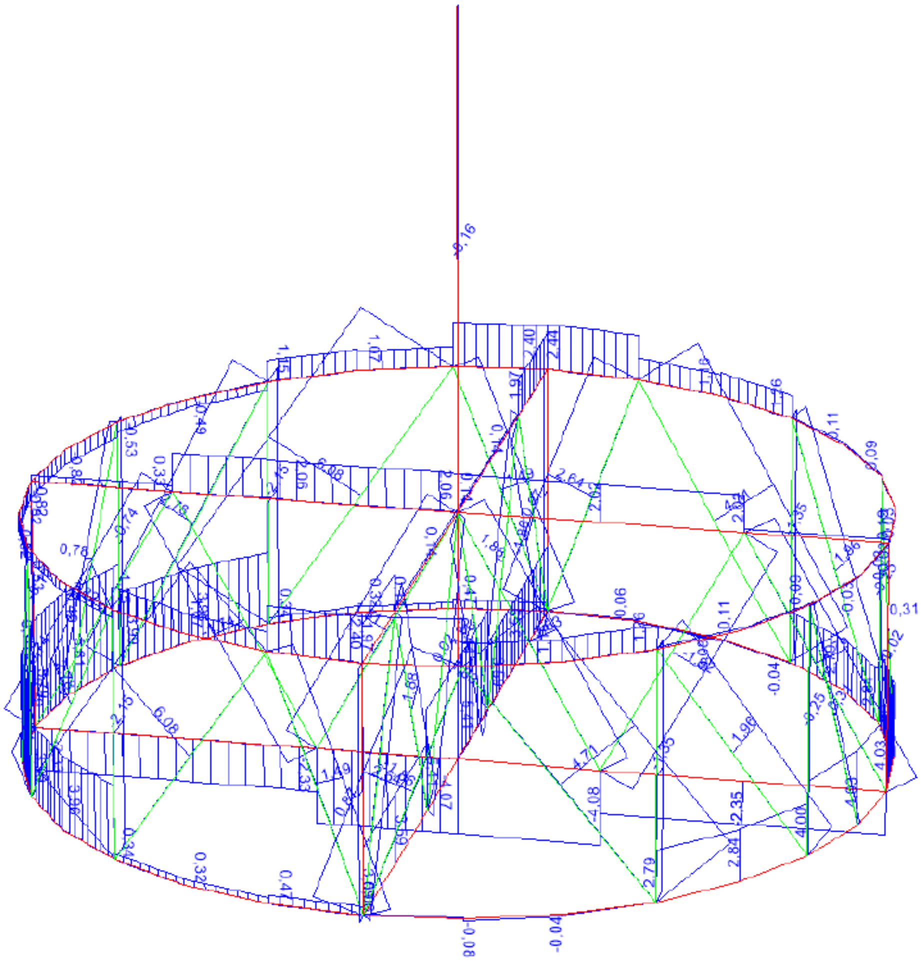
η= ***0,30*** ***---> Section Verified***

10.3 Upper rings Verification





f.e.m model of upper ring



f.e.m model of upper ring - axial force (envelope values kN)

Pipe	**48**	***(Diameter mm)***
tk:	**3**	***mm***
Steel	**S 235**	
f_{yk}= **235,00**		*N/mm²*

A	**4,24**	*cm^2: area*
J_x	**10,78**	*cm^4: J - X direction*
W_x	**4,49**	*cm^3: W- X direction*
$W_{x,pl}$	**6,08**	*cm^3: Wpl- X direction*
J_P	**21,56**	*cm^4: J - Z direction*
i_x	**1,59**	*cm: radius X*
Pp,profilo	**3,3**	kg/m
L_x	**0,50**	*m: length axis x*
λ_x	**31,36**	*slenderness x*
α_x	***a*** **---> 0,21**	*:fatt. di imperfezione*

N_{ed}	**56,00**	*kN: axial force*
$V_{Ed,a}$	**0,00**	*kN: share force X*
$M_{Ed,xx}$	**0,00**	*kNm: bending moment X-X axis*
$M_{Ed,tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$\sigma_{cr,x}$	**2066**	*N/mm^2: critical eulerian value dir.X*
$N_{cr,x}$	**876**	*Critical value of N*
χ_x	**0,97**	*slenderness coefficient X, whit ΦX=* **0,57**
$\lambda°_x$	**0,33**	*instability value X*

Classe	***1***	
$N_{Rd,comp}$	**92**	*kN: axial compression resistance*
$N_{pl,Rd}$	**95**	*kN: axial tensile resistance*
$V_{c,Rd,an}$	**35**	*kN: shear resistance*
$M_{c,Rd,x}$	**1,36**	*kNm: flexural resistance*
$M_{N,x,Rd}$	**1,27**	*kNm: flexural and axial resistance*
$M_{p,Rd}$	**2,0**	*kNm: torsional resistance*

n= 0,59	**$1/k_x$= *0,81***	**μ_x= *-0,40***
a= 0,50	**ρ_V= *0***	**ε= *1,00***

η= ***0,61*** ***---> Section Verified***

Pipe	**27**	***(Diameter mm)***
tk:	**3**	***mm***
Steel	**S 235**	
f_{yk}= 235,00		*N/mm²*

A	**2,26**	*cm²: area*
J_x	**1,65**	*cm⁴: J - X direction*
W_x	**1,22**	*cm³: W- X direction*
$W_{x,pl}$	**1,74**	*cm³: Wpl- X direction*
J_P	**3,31**	*cm⁴: J - Z direction*
i_x	**0,86**	*cm: radius X*
Pp,profilo	**1,8**	kg/m
L_x	**0,50**	*m: length axis x*
λ_x	**58,47**	*slenderness x*
α_x	***a***	***--->*** **0,21** *:fatt. di imperfezione*

N_{ed}	**36,00**	*kN: axial force*
$V_{Ed, a}$	**0,00**	*kN: share force X*
$M_{Ed, xx}$	**0,00**	*kNm: bending moment X-X axis*
$M_{Ed, tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$\sigma_{cr,x}$	**594**	*N/mm²: critical eulerian value dir.X*
$N_{cr,x}$	**134**	*Critical value of N*
χ_x	**0,88**	*slenderness coefficient X, whit ΦX=* **0,74**
$\lambda°_x$	**0,62**	*instability value X*

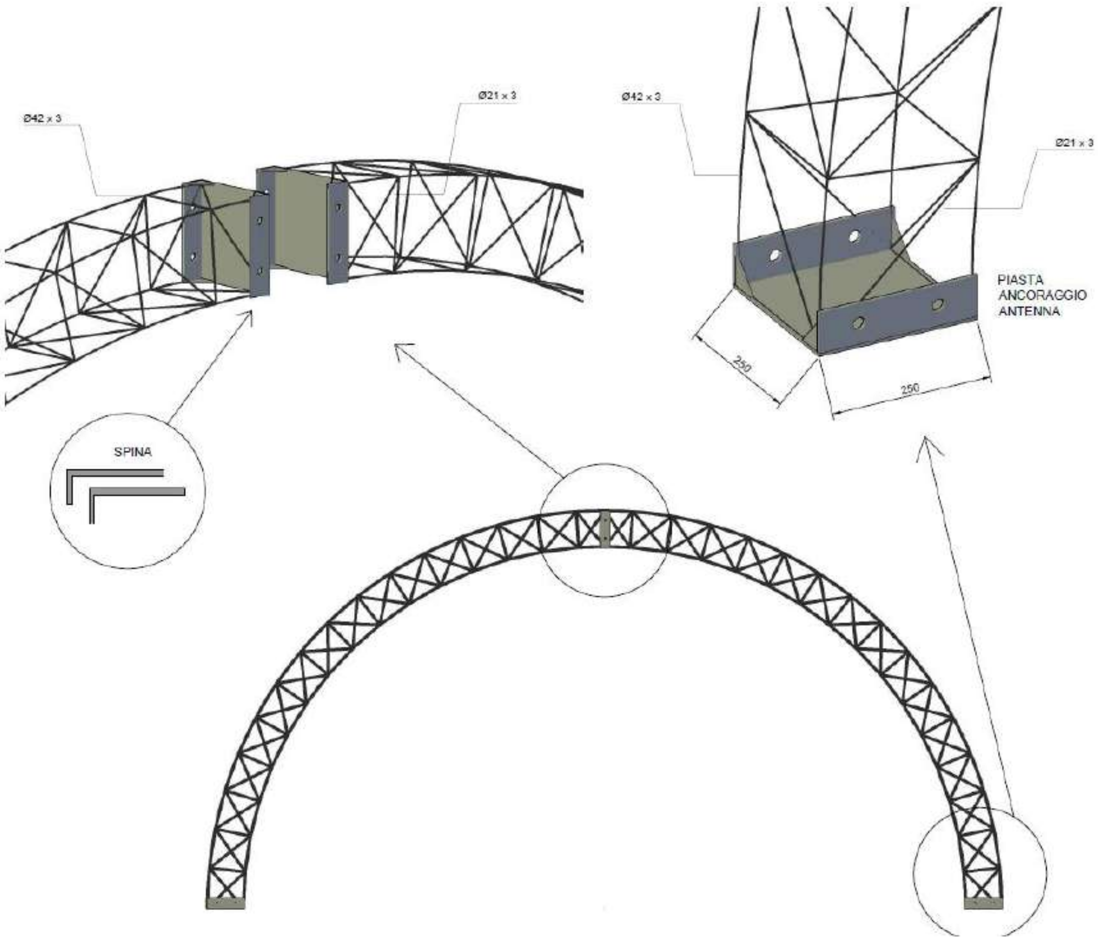
Classe	***1***	
$N_{Rd, comp}$	**45**	*kN: axial compression resistance*
$N_{pl,Rd}$	**51**	*kN: axial tensile resistance*
$V_{c,Rd,an}$	**19**	*kN: shear resistance*
$M_{c,Rd,x}$	**0,39**	*kNm: flexural resistance*
$M_{N,x,Rd}$	**0,28**	*kNm: flexural and axial resistance*
$M_{p,Rd}$	**0,5**	*kNm: torsional resistance*

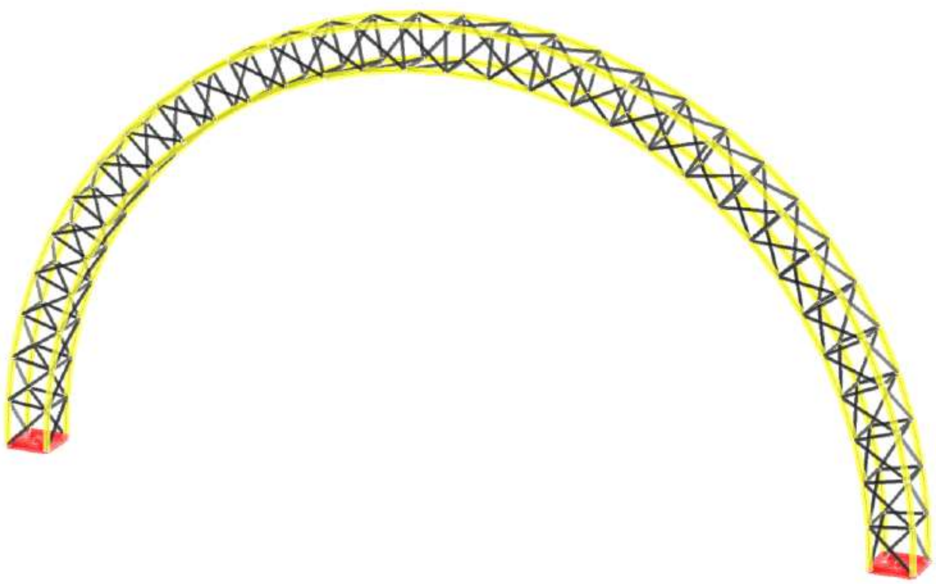
n= 0,71 **$1/k_x$=** ***0,64*** **μ_x=** ***-0,75***

a= 0,50 **ρ_V=** ***0*** **ε=** ***1,00***

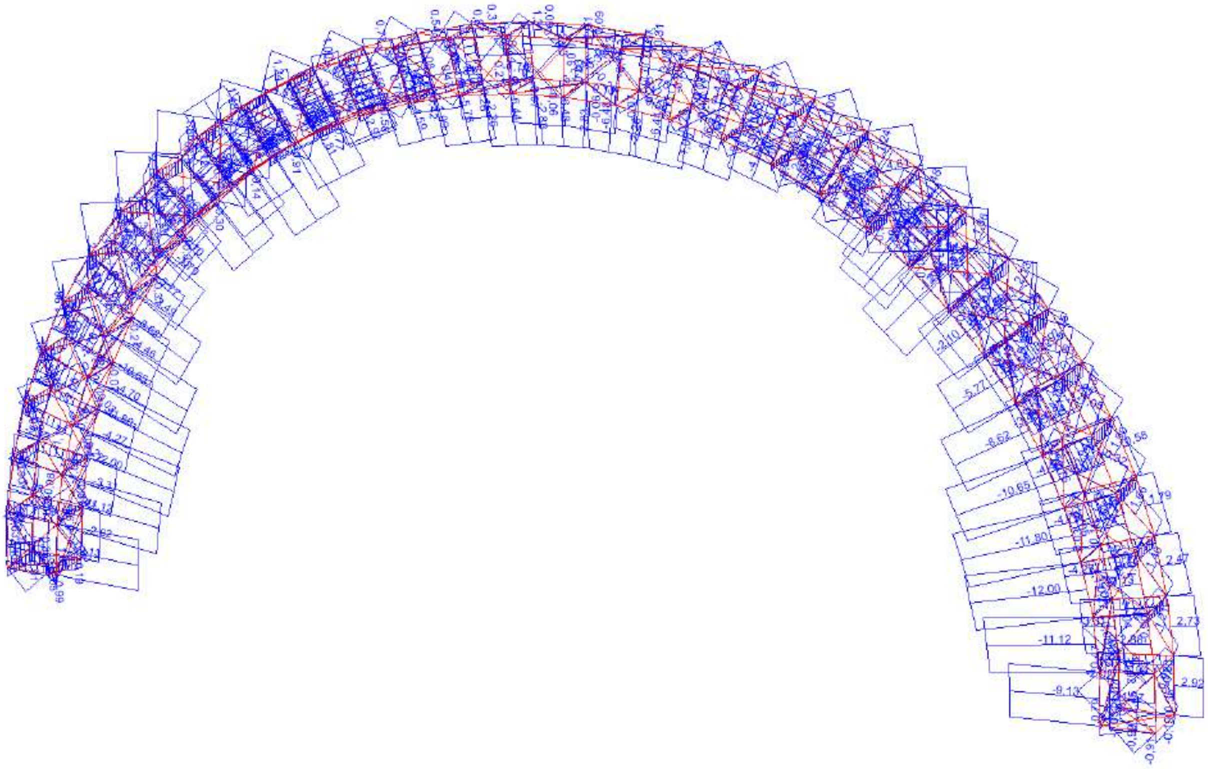
η= ***0,81*** ***---> Section Verified***

10.4 arch Verification





f.e.m. model



- axial force (envelope values kN)

Pipe	**42**	***(Diameter mm)***
tk:	**3**	***mm***
Steel	**S 235**	
f_{yk}= 235,00		*N/mm²*

A	**3,67**	*cm²: area*
J_x	**7,03**	*cm⁴: J - X direction*
W_x	**3,35**	*cm³: W- X direction*
$W_{x,pl}$	**4,57**	*cm³: Wpl- X direction*
J_P	**14,05**	*cm⁴: J - Z direction*
i_x	**1,38**	*cm: radius X*
Pp,profilo	**2,9**	kg/m
L_x	**0,25**	*m: length axis x*
λ_x	**18,08**	*slenderness x*
α_x	***a***	**--->** **0,21** *:fatt. di imperfezione*

N_{ed}	**78,00**	*kN: axial force*
$V_{Ed,a}$	**0,00**	*kN: share force X*
$M_{Ed,xx}$	**0,00**	*kNm: bending moment X-X axis*
$M_{Ed,tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$\sigma_{cr,x}$	**6215**	*N/mm²: critical eulerian value dir.X*
$N_{cr,x}$	**2283**	*Critical value of N*
χ_x	**1,00**	*slenderness coefficient X, whit ΦX=* **0,52**
$\lambda°_x$	**0,19**	*instability value X*

Classe	***1***	
$N_{Rd,comp}$	**82**	*kN: axial compression resistance*
$N_{pl,Rd}$	**82**	*kN: axial tensile resistance*
$V_{c,Rd,an}$	**30**	*kN: shear resistance*
$M_{c,Rd,x}$	**1,02**	*kNm: flexural resistance*
$M_{N,x,Rd}$	**0,99**	*kNm: flexural and axial resistance*
$M_{p,Rd}$	**1,5**	*kNm: torsional resistance*

n= 0,95 **$1/k_x$= *0,83*** ***μ_x= -0,23***

a= 0,50 ***ρ_V= 0*** ***ε= 1,00***

η= ***0,95*** ***---> Section Verified***

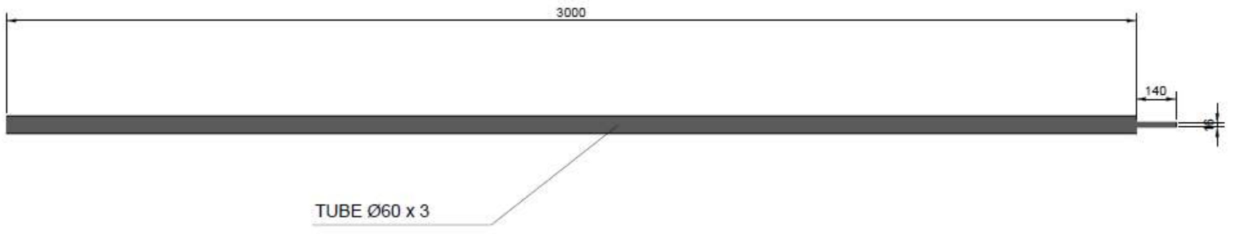
Pipe	**21**	***(Diameter mm)***	
tk:	**3**	***mm***	
Steel	**S 235**		
f_{yk}= 235,00		*N/mm²*	

A	**1,70**	*cm²: area*	
J_x	**0,71**	*cm⁴: J - X direction*	
W_x	**0,67**	*cm³: W- X direction*	
$W_{x,pl}$	**0,98**	*cm³: Wpl- X direction*	
J_P	**1,41**	*cm⁴: J - Z direction*	
i_x	**0,65**	*cm: radius X*	
Pp,profilo	**1,3**	kg/m	
L_x	0,35	*m: length axis x*	
λ_x	**54,25**	*slenderness x*	
α_x	***a***	***--->*** **0,21**	*:fatt. di imperfezione*

N_{ed}	26,00	*kN: axial force*	
$V_{Ed,a}$	0,00	*kN: share force X*	
$M_{Ed,xx}$	0,00	*kNm: bending moment X-X axis*	
$M_{Ed,tr}$	0,00	*kNm: torsional moment Z-Z axis*	
$\sigma_{cr,x}$	**690**	*N/mm²: critical eulerian value dir.X*	
$N_{cr,x}$	**117**	*Critical value of N*	
χ_x	**0,90**	*slenderness coefficient X,*	*whit* ΦX= **0,71**
$\lambda°_x$	**0,58**	*instability value X*	

Classe	***1***		
$N_{Rd,comp}$	**34**	*kN: axial compression resistance*	
$N_{pl,Rd}$	**38**	*kN: axial tensile resistance*	
$V_{c,Rd,an}$	**14**	*kN: shear resistance*	
$M_{c,Rd,x}$	**0,22**	*kNm: flexural resistance*	
$M_{N,x,Rd}$	**0,17**	*kNm: flexural and axial resistance*	
$M_{p,Rd}$	**0,3**	*kNm: torsional resistance*	
	n= 0,69	**1/k$_x$=** ***0,67***	μ_x= ***-0,69***
	a= 0,50	ρ_V= ***0***	ε= ***1,00***
η=	***0,76***	***---> Section Verified***	

10.5 Lateral poles Verification



Here below it is possible to find the verification that take into account the load of membrane and the wind pressure.

For the wind action was used the following formulas:

M_{SW}= 1,5x1/8x3^2xF_W = 0,045 kNm

Where F_W is wind force on the pole, in kN/m

F_W= 1,2x0,5x0,06= 0,04 kN/m

height: *h* m	pressure: *q* N/m^2
$h \leq 5$	500
$5 < h \leq 10$	600
$10 < h \leq 15$	660
$15 < h < 20$	710
$20 < h \leq 25$	760

The maximum flexural bendig is:

M_{SD}= M_{SW} + NsDxL/500 = 0,93_kNm
Where

N_{SD} ,8 kN, maximum axial force, from f.e.m model.

Pipe	**60**	***(Diameter mm)***
tk:	**3**	***mm***
Steel	**S 235**	
f_{yk}= 235,00		*N/mm²*

A	**5,37**	*cm^2: area*
J_x	**21,87**	*cm^4: J - X direction*
W_x	**7,29**	*cm^3: W- X direction*
$W_{x,pl}$	**9,76**	*cm^3: Wpl- X direction*
J_P	**43,73**	*cm^4: J - Z direction*
i_x	**2,02**	*cm: radius X*
Pp,profilo	**4,2**	kg/m
L_x	**3,00**	*m: length axis x*
λ_x	**148,66**	*slenderness x*
α_x	***a*** **--->** **0,21**	*:fatt. di imperfezione*

N_{ed}	**8,00**	*kN: axial force*
$V_{Ed, a}$	**0,00**	*kN: share force X*
$M_{Ed, xx}$	**0,09**	*kNm: bending moment X-X axis*
$M_{Ed, tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$\sigma_{cr,x}$	**92**	*N/mm^2: critical eulerian value dir.X*
$N_{cr,x}$	**49**	*Critical value of N*
χ_x	**0,34**	*slenderness coefficient X, whit ΦX=* **1,90**
$\lambda°_x$	**1,58**	*instability value X*

Classe	***1***	
$N_{Rd, comp}$	**41**	*kN: axial compression resistance*
$N_{pl,Rd}$	**120**	*kN: axial tensile resistance*
$V_{c,Rd,an}$	**44**	*kN: shear resistance*
$M_{c,Rd,x}$	**2,18**	*kNm: flexural resistance*
$M_{N,x,Rd}$	**1,83**	*kNm: flexural and axial resistance*
$M_{p,Rd}$	**3,3**	*kNm: torsional resistance*

n= 0,07 **$1/k_x$=** ***0,74*** **μ_x=** ***-1,90***

a= 0,50 **ρ_V=** ***0*** **ε=** ***1,00***

η= ***0,32*** ***---> Section Verified***

10.6 Load to the ground

The maximum exercise axial force of the back belts is 16 kN on the direction of the belts with an inclination of 45°.

Here below it possible to find the maximum load for that can be transmitted to the ground for a soil with good mechanical properties

Calculations were done for a single post with Ø40 mm and a length pushed in the terrain of 160cm.

So the maximum load is equal:

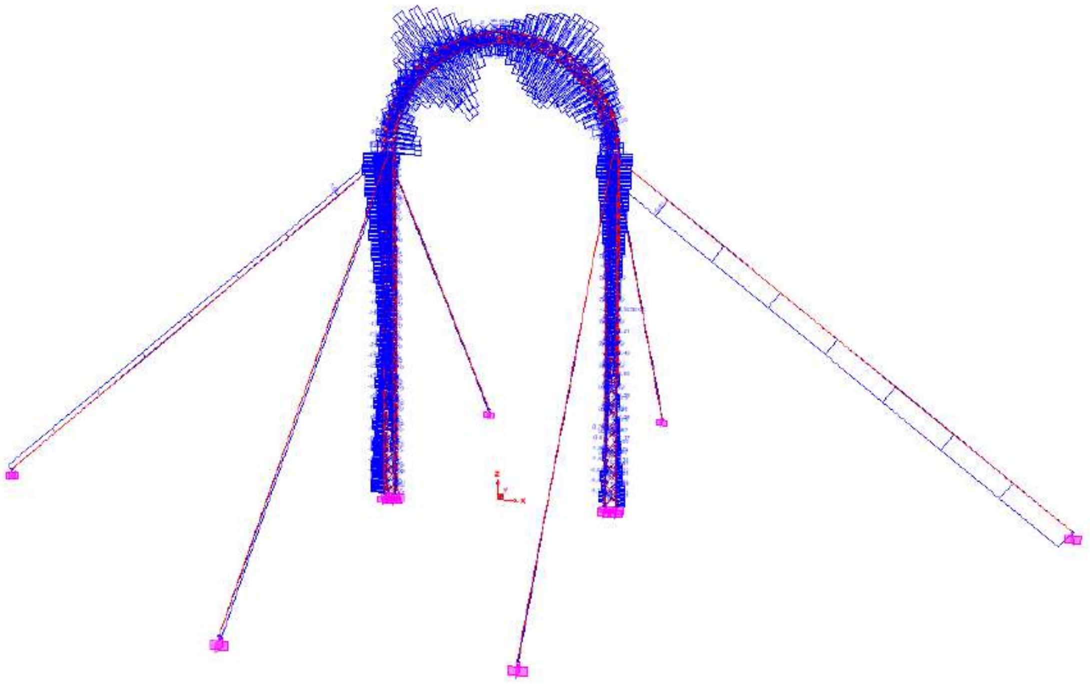
$$Z_d = 17 \cdot d \cdot l$$

Z_d= 9,52 kN.

For every pole are necessary almost 2 pickets Ø40x1200mm

It is mandatory test almost 3 pickets (by 1,5 exercise force), see, for example, the imagine below:

10.7 Cables Verification



Cables- maximum axial force (values kN)

The maximum value on the **cable Φ12** is:

N_{ed} -35_kN

CLASSE
133 Fili
7(12+6+1)
crociata destra

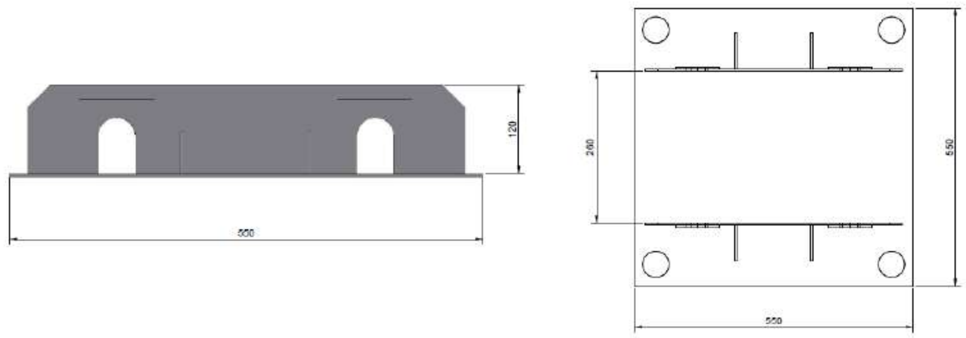
RESISTENZA
1770 N/mm²

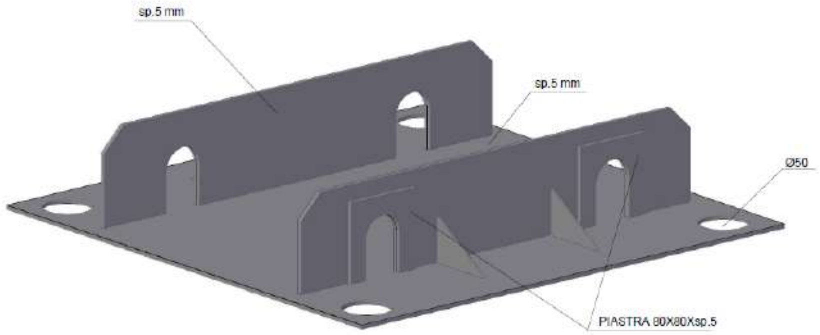
Diametro fune	Diametro fili esterni	Peso per metro	Carico rottura minimo	
mm	mm	Kg	kN	Kg
3,0	0,20	0,035	6,0	610
4,0	0,26	0,061	10,5	1.070
5,0	0,32	0,096	17,7	1.800
6,0	0,40	0,140	26,0	2.650
7,0	0,46	0,185	35,5	3.620
8,0	0,50	0,244	42,5	4.330
9,0	0,60	0,308	54,5	5.560
10,0	0,65	0,381	66,0	6.730
12,0	0,77	0,548	94,0	9.590
14,0	0,93	0,746	129,5	13.210
16,0	1,07	0,974	168,0	17.130
18,0	1,20	1,230	212,0	21.620
20,0	1,33	1,520	263,0	26.820

$N_{Rd}= N_{max}/2$ = -47_kN

η= 0,75---> **Check OK**

10.8 Contact pressure on the ground





The structure bases oneself on the ground by support below each mast.

The maximum stress is:

N_{ed} ***= 70_kN = 7000_kg***

The support plate resistance is:

$P_{Rd} = \sigma_c x A_p$.

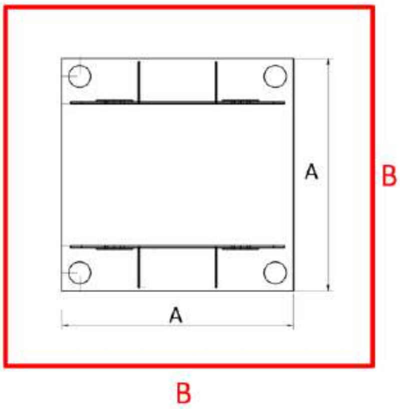
Where σ_c is the ground allowable stress and A_p is the contact area.

It is possible taken into account da follow table, where:

A is the side of plate (in mm)

B is the side of additional steel plate under the column-plate (in mm)

σ_c is the ground allowable stress (N/mm^2)



N_{max} *kN*	σ_c *N/mm²*	A *mm*	B_{min} *mm*	A_{min} *cm²*
70	0,10	800	800	6400
	0,15	700	700	4900
	0,20	600	600	3600
	0,25	550	550	3025
	0,30	550	550	3025

11. CONCLUSION AND REQUIREMENTS

All analyses completed showed that steel structures, cables and tensile membrane are verified in order to resistance and deformation state.

The maximum live loads for the site, shall be the following:

- *Snow/sand = 10,00_daN/m^2*
- *Wind = 28_m/s.*

The maximum weight of suspend equipment is:

- *Equipment hanging on the upper ring: 500_kg*
- *Equipment hanging on each antenna: 200_kg.*

Periodically, it is necessary checked and monitored the structures, cables and tensile membrane.

In particular:

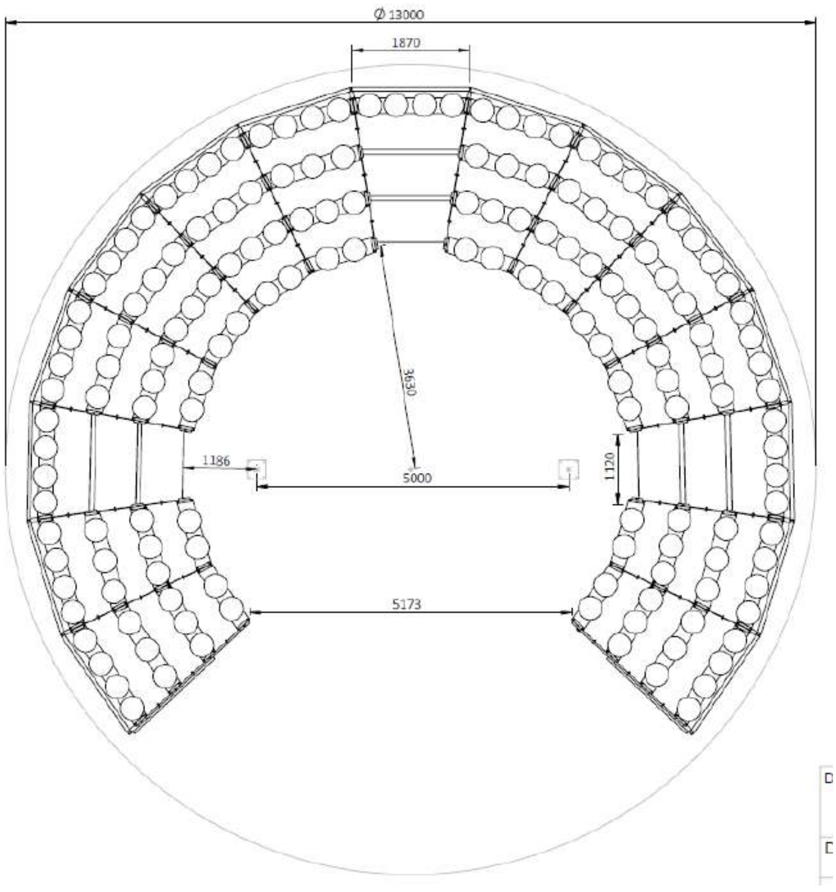
- *Check of all steel joints and connection;*
- *Check of membrane integrity.*

Stand Seats for a circus Ø13m
Client "JULIEN AUGER - Circus I love you"

***Oggetto*:**

TECHNICAL REPORT OF STRUCTURAL VERIFICATION

Document LS 11/2020 del 16.10.2020



INDEX

1. POURPOSE

The object of this document is the structural verification of inside stand seats for a circus of 13 meters of diameters.

The analysis will be performed according to the European Technical Regulations (Eurocodes).

All checks will be carried out with semi-probabilistic limit state approach.

The actions considered are live and permanent loads, vice versa seismic action has not considered due to the temporary nature of the installation.

Due the structures are indoor installation wind and snow actions have no take into account.

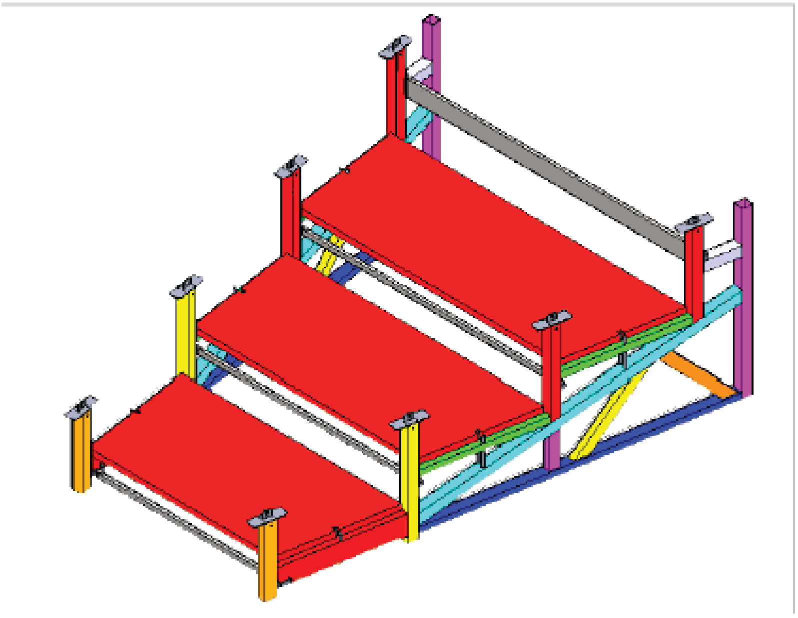
2. DESCRIPTION OF THE STRUCTURES

The structure, scope of the work, is a frame of beams and pillars.

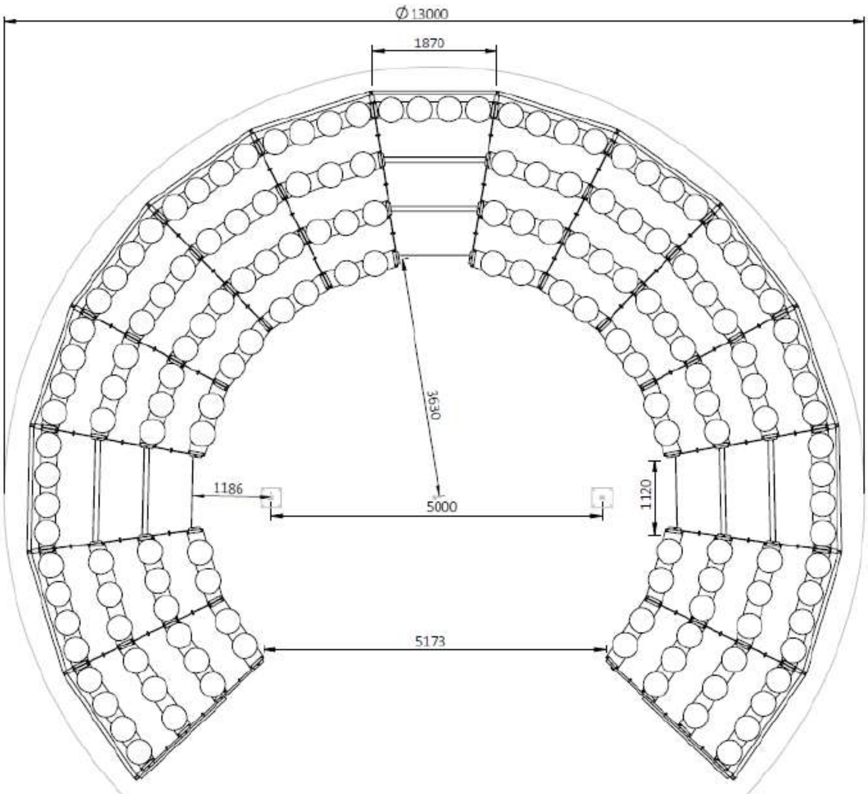
The materials used are:

- lateral and rear safety railings in carbon steel;
- vertical supports and main span in aluminium alloy.

Each frame has a wedge shape and it is linked at others to form a semicircle.



View of stand seats structures



Top View of stand seats structures

3. NORMS AND LAWS

3.1 European Reference Eurocodes

- **Eurocode 0: Basis of Structural design**

UNI EN 1990:2006;

- **Eurocode 1: Actions on Structures**

EN 1991-1-1:2002 Eurocode 1. Actions on structures. General actions. Densities, self-weight, imposed loads for buildings

EN 1991-1-2:2002 Eurocode 1. Actions on structures. General actions. Actions on structures exposed to fire

EN 1991-1-3:2003 Eurocode 1. Actions on structures. General actions. Snow loads

EN 1991-1-4:2005 Eurocode 1. Actions on structures. General actions. Wind actions

EN 1991-1-5:2003 Eurocode 1. Actions on structures. General actions. Thermal actions

EN 1991-1-6:2005 Eurocode 1. Actions on structures. General actions. Actions during execution

EN 1991-1-7:2006 Eurocode 1. Actions on structures. General actions. Accidental actions

- **Eurocode 2: Design of Concrete structures**

EN 1992-1-1:2004 Eurocode 2: Design of concrete structures. General rules and rules for buildings

- **Eurocode 3: Design of Steel structures**

EN 1993-1-1:2005 Eurocode 3. Design of steel structures. General rules and rules for buildings

EN 1993-1-3:2006 Eurocode 3. Design of steel structures. General rules. Supplementary rules for cold-formed members and sheeting

EN 1993-1-5:2006 Eurocode 3. Design of steel structures. Plated structural elements

EN 1993-1-8:2005 Eurocode 3. Design of steel structures. Design of joints

EN 1993-1-10:2005 Eurocode 3. Design of steel structures. Material toughness and through-thickness properties.

- **Eurocode 9: Design of aluminium structures**

EN 1999-1-1: General structural rules

EN 1999-1-2: Structural fire design

EN 1999-1-3: Structures susceptible to fatigue

EN 1999-1-4: Cold-formed structural sheeting

EN 1999-1-5: Shell structures

- **EN 13782:2015-Temporary structure**

4. MATERIALS

4.1 Steel structures works

The nominal values of material properties given in this section should be adopted as characteristic values in design calculations.

The nominal values of the yield strength f_y and the ultimate strength f_u for structural steel should be obtained by table below.

Standard and steel grade	Nominal thickness of the element t [mm]			
	t ≤ 40 mm		40 mm < t ≤ 80 mm	
	f_y [N/mm^2]	f_u [N/mm^2]	f_y [N/mm^2]	f_u [N/mm^2]
EN 10025-2				
S 235	235	360	215	360
S 275	275	430	255	410
S 355	355	AC2 490 AC2	335	470
S 450	440	550	410	550
EN 10025-3				
S 275 N/NL	275	390	255	370
S 355 N/NL	355	490	335	470
S 420 N/NL	420	520	390	520
S 460 N/NL	460	540	430	540
EN 10025-4				
S 275 M/ML	275	370	255	360
S 355 M/ML	355	470	335	450
S 420 M/ML	420	520	390	500
S 460 M/ML	460	540	430	530
EN 10025-5				
S 235 W	235	360	215	340
S 355 W	355	AC2 490 AC2	335	490
EN 10025-6				
S 460 Q/QL/QL1	460	570	440	550

Bolts, nuts and washers

The yield strength f_{yb} and the ultimate tensile strength f_{ub} for bolt classes 4.6, 4.8, 5.6, 5.8, 6.8, 8.8 and 10.9 are given in Table following, These values should be adopted as characteristic values in design calculations:

Nominal values of the yield strength f_{yb} and the ultimate tensile strength f_{ub} for bolts

Bolt class	4.6	4.8	5.6	5.8	6.8	8.8	10.9
f_{yb} (N/mm²)	240	320	300	400	480	640	900
f_{ub} (N/mm²)	400	400	500	500	600	800	1000

Welded connections

Fillet welds may be used for connecting parts where the fusion faces form an angle of between 60° and 120°. Angles smaller than 60° are also permitted. However, in such cases the weld should be considered to be a partial penetration butt weld. For angles greater than 120° the resistance of fillet welds should be determined by testing in accordance with EN 1990 Annex D: Design by testing. Fillet welds finishing at the ends or sides of parts should be returned continuously, full size, around the corner for a distance of at least twice the leg length of the weld, unless access or the configuration of the joint renders this impracticable.

Intermittent fillet welds should not be used in corrosive conditions. In an intermittent fillet weld, the gaps (L1 or L2) between the ends of each length of weld Lw should fulfil the requirement given in Figure following. In an intermittent fillet weld, the gap (L1 or L2) should be taken as the smaller of the distances between the ends of the welds on opposite sides and the distance between the ends of the welds on the same side. In any run of intermittent fillet weld there should always be a length of weld at each end of the part connected. In a built-up member in which plates are connected by means of intermittent fillet welds, a continuous fillet weld should be provided on each side of the plate for a length at each end equal to at least three-quarters of the width of the narrower plate concerned.

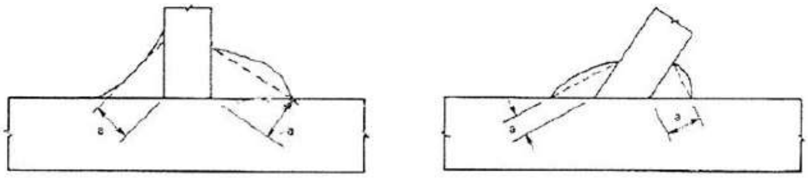


Figure 4.3: Throat thickness of a fillet weld

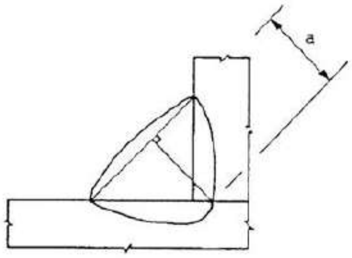


Figure 4.4: Throat thickness of a deep penetration fillet weld

it has taken into account the following steel materials:

- Pipe and box sections: ***S235*** (UNI EN 10025-2)
- Bolts: **CLASSE 8.8**

4.2 Aluminium structures works

The nominal values of material properties given in this section should be adopted as characteristic values in design calculations.

The nominal values of the yield strength f_0 and the ultimate strength f_u for structural steel should be obtained by table below.

Designazione della lega		Forma del semilavorato	Classe di Durabilità[2)]
Numerica	Alfanumerica		
EN AW-3004	EN AW-AlMn1Mg1	SH, ST, PL	A
EN AW-3005	EN AW-AlMn1Mg0,5	SH, ST, PL	A
EN AW-3103	EN AW-Al Mn1	SH, ST, PL, ET, EP, ER/B	A
EN AW-5005/5005A	EN AW-AlMg1(B)/(C)	SH, ST, PL	A
EN AW-5049	EN AW-AlMg2Mn0,8	SH, ST, PL	A
EN AW-5052	EN AW-Al Mg2,5	SH, ST, PL, ET[1)], EP[1)], ER/B, DT	A
EN AW-5083	EN AW-Al Mg4,5Mn0,7	SH, ST, PL, ET[1)], EP[1)], ER/B, DT, FO	A
EN AW-5454	EN AW-Al Mg3Mn	SH, ST, PL, ET[1)], EP[1)], ER/B	A
EN AW-5754	EN AW-Al Mg3	SH, ST, PL, ET[1)], EP[1)], ER/B, DT, FO	A
EN AW-6060	EN AW-Al MgSi	ET,EP,ER/B,DT	B
EN AW-6061	EN AW-Al Mg1SiCu	SH, ST,PL,ET,EP,ER/B,DT	B
EN AW-6063	EN AW-Al Mg0,7Si	ET, EP, ER/B,DT	B
EN AW-6005A	EN AW-Al SiMg(A)	ET, EP, ER/B	B
EN AW-6082	EN AW-Al Si1MgMn	SH, ST, PL, ET, EP, ER/B, DT, FO	B
EN AW-6106	EN AW-AlMgSiMn	EP	B
EN AW-7020	EN AW-Al Zn4,5Mg1	SH, ST, PL, ET, EP, ER/B, DT	C
EN AW-8011A	EN AW-AlFeSi	SH, ST, PL	B

Legenda: SH - Foglio (EN 485)
ST - Nastro (EN 485)
PL - Piastra (EN 485)
ET – Tubo Estruso (EN 755)
EP – Profilato Estruso (EN 755)
ER/B – Asta o Barra Estrusa (EN 755)
DT – Tubo Trafilato (EN 754)
FO - Forgiato (EN 586)
[1)] Soltanto sezioni piene estruse (aperte) o tubi senza saldatura (mandrino foratore)
[2)] Vedi Capitolo VII-2

Lega EN AW-	Stato fisico	Spessore	f_0	f_u	A_{50}	$f_{0,haz}$	$f_{u,haz}$	Fattore HAZ		BC	n_p
		mm	N/mm²		%	N/mm²		$\rho_{0,haz}$	$\rho_{u,haz}$		
3004	H14|H24/H34	≤ 6|3	180|170	220	1|3	75	155	0.42|0.44	0.70	B	23|18
	H16|H26/H36	≤ 4|3	200|190	240	1|3			0.38|0.39	0.65	B	25|20
3005	H14|H24	≤ 6|3	150|130	170	1|4	56	115	0.37|0.43	0.68	B	38|18
	H16|H26	≤ 4|3	175|160	195	1|3			0.32|0.35	0.59	B	43|24
3103	H14|H24	≤ 25|12.5	120|110	140	2|4	44	90	0.37|0.40	0.64	B	31|20
	H16|H26	≤ 4	145|135	160	1|2			0.30|0.33	0.56	B	48|28
5005	O/H111	≤ 50	35	100	15	35	100	1	1	B	5
	H12|H22/H32	≤ 12.5	95|80	125	2|4	44	100	0.46|0.55	0.80	B	18|11
	H14|H24/H34	≤ 12.5	120|110	145	2|3			0.37|0.40	0.69	B	25|17
5052	H12|H22/H32	≤ 40	160|130	210	4|5	80	170	0.50|0.62	0.81	B	17|10
	H14|H24/H34	≤ 25	180|150	230	3|4			0.44|0.53	0.74	B	19|11
5049	O/H111	≤ 100	80	190	12	80	190	1	1	B	6
	H14|H24/H34	≤ 25	190|160	240	3|6	100	190	0.53|0.63	0.79	B	20|12
5454	O/H111	≤ 80	85	215	12	85	215	1	1	B	5
	H14|H24/H34	≤ 25	220|200	270	2|4	105	215	0.48|0.53	0.80	B	22|15
5754	O/H111	≤ 100	80	190	12	80	190	1	1	B	6
	H14|H24/H34	≤ 25	190|160	240	3|6	100	190	0.53|0.63	0.79	B	20|12
5083	O/H111	≤ 50	125	275	11	125	275	1	1	B	6
		50<t≤80	115	270	14*	115	270			B	
	H12|H22/H32	≤ 40	250|215	305	3|5	155	275	0.62|0.72	0.90	B	22|14
	H14|H24/H34	≤ 25	280|250	340	2|4			0.55|0.62	0.81	A	22|14
6061	T4/T451	≤ 12.5	110	205	12	95	150	0.86	0.73	B	8
	T6/T651	≤ 12.5	240	290	6	115	175	0.48	0.60	A	23
	T651	12.5<t≤80	240	290	6*						
6082	T4/T451	≤ 12.5	110	205	12	100	160	0.91	0.78	B	8
	T61/T6151	≤12.5	205	280	10	125	185	0.61	0.66	A	15
	T6151	12.5<t≤100	200	275	12*			0.63	0.67	A	14
	T6/T651	≤ 6	260	310	6			0.48	0.60	A	25
		6<t≤12.5	255	300	9			0.49	0.62	A	27
	T651	12.5<t≤100	240	295	7*			0.52	0.63	A	21
7020	T6	≤ 12.5	280	350	7	205	280	0.73	0.80	A	19
	T651	≤ 40			9*						
8011A	H14|H24	≤ 12.5	110|100	125	2|3	37	85	0.34|0.37	0.68	B	37|22
	H16|H26	≤ 4	130|120	145	1|2			0.28|0.31	0.59		33|33

- Pipe and box sections: AW-3103 H16 (f_0=145 MPa).

5. LOADS AND ACTIONS

5.1 Permanent loads

5.1.1 Self weight

For the evaluation of self weight of the materials have been adopted the following densities:

- *Carbon steel:* ***78,5_kN/m³***
- *Structural Wood (Nordpan):* ***5,5_kN/m³***
- *Aluminium Alloy:* ***27,5_kN/m³***

The permanent loads on the structures (**G_1**) are:

- *Weight of benches and footrests:* ***0,3_kN/m²***

5.2 Live Loads

5.2.1 Vertical load

The load of people on the structures, inclusive of dynamic coefficient, is:

- *Crowd:* **5,0_kN/m².**

5.2.2 Horizontal load

The horizontal thrust on the safety railing is

- **2,0_kN/m,** *applied on the upper barrier or at 1,0_m from the base.*

6. COMBINATIONS OF ACTIONS

The following ultimate limit states shall be verified as relevant :

EQU : Loss of static equilibrium of the structure or any part of it considered as a rigid body, where :

– minor variations in the value or the spatial distribution of actions from a single source are significant, and

– the strengths of construction materials or ground are generally not governing ;

STR : Internal failure or excessive deformation of the structure or structural members, including footings, piles, basement walls, etc., where the strength of construction materials of the structure governs ;

c) GEO : Failure or excessive deformation of the ground where the strengths of soil or rock are significant in providing resistance ;

The general format of effects of actions shall be:

$$E_d = \gamma_{Sd} E \{ \gamma_{g,j} G_{k,j} \; ; \gamma_p P \; ; \gamma_{q,1} Q_{k,1} \; ; \gamma_{q,i} \psi_{0,i} Q_{k,i} \} \quad j \geq 1 \; ; i > 1$$

With the following Recommended values for correlation factors:

Action	ψ_0	ψ_1	ψ_2
Imposed loads in buildings, category (see EN 1991-1-1)			
Category A : domestic, residential areas	0,7	0,5	0,3
Category B : office areas	0,7	0,5	0,3
Category C : congregation areas	0,7	0,7	0,6
Category D : shopping areas	0,7	0,7	0,6
Category E : storage areas	1,0	0,9	0,8
Category F : traffic area, vehicle weight ≤ 30kN	0,7	0,7	0,6
Category G : traffic area, 30kN < vehicle weight ≤ 160kN	0,7	0,5	0,3
Category H : roofs	0	0	0
Snow loads on buildings (see EN 1991-1-3)*			
Finland, Iceland, Norway, Sweden	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H > 1000 m a.s.l.	0,70	0,50	0,20
Remainder of CEN Member States, for sites located at altitude H ≤ 1000 m a.s.l.	0,50	0,20	0
Wind loads on buildings (see EN 1991-1-4)	0,6	0,2	0
Temperature (non-fire) in buildings (see EN 1991-1-5)	0,6	0,5	0

NOTE The ψ values may be set by the National annex.
* For countries not mentioned below, see relevant local conditions.

And the following Design values:

Persistent and transient design situations	Permanent actions		Leading variable action	Accompanying variable actions (*)	
	Unfavourable	Favourable		Main (if any)	Others
(Eq. 6.10)	$\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$	$\gamma_{Q,1}Q_{k,1}$		$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$

Persistent and transient design situations	Permanent actions		Leading variable action (*)	Accompanying variable actions (*)	
	Unfavourable	Favourable	Action	Main	Others
(Eq. 6.10a)	$\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$		$\gamma_{Q,1}\psi_{0,1}Q_{k,1}$	$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$
(Eq. 6.10b)	$\xi\gamma_{Gj,sup}G_{kj,sup}$	$\gamma_{Gj,inf}G_{kj,inf}$	$\gamma_{Q,1}Q_{k,1}$		$\gamma_{Q,i}\psi_{0,i}Q_{k,i}$

(*) Variable actions are those considered in Table A1.1

NOTE 1 The choice between 6.10, or 6.10a and 6.10b will be in the National annex. In case of 6.10a and 6.10b, the National annex may in addition modify 6.10a to include permanent actions only.

NOTE 2 The γ and ξ values may be set by the National annex. The following values for γ and ξ are recommended when using expressions 6.10, or 6.10a and 6.10b.
$\gamma_{Gj,sup} = 1,35$
$\gamma_{Gj,inf} = 1,00$
$\gamma_{Q,1} = 1,50$ where unfavourable (0 where favourable)
$\gamma_{Q,i} = 1,50$ where unfavourable (0 where favourable)
$\xi = 0,85$ (so that $\xi\gamma_{Gj,sup} = 0,85 \times 1,35 \cong 1,15$).
See also EN 1991 to EN 1999 for γ values to be used for imposed deformations.

NOTE 3 The characteristic values of all permanent actions from one source are multiplied by $\gamma_{G,sup}$ if the total resulting action effect is unfavourable and $\gamma_{G,inf}$ if the total resulting action effect is favourable. For example, all actions originating from the self weight of the structure may be considered as coming from one source ; this also applies if different materials are involved.

NOTE 4 For particular verifications, the values for γ_G and γ_Q may be subdivided into γ_g and γ_q and the model uncertainty factor γ_{Sd}. A value of γ_{Sd} in the range 1,05 to 1,15 can be used in most common cases and can be modified in the National annex.

7. CALCULATION AND ANALYSIS

The structural analysis has been performed in a 3-dimensional model, by a finite element method approach.

The f.e.m analysis model has been involved in elastic linear field by following Structural Components:

- Joints, SAP2000 automatically create joints at structural object intersections or internal joints when meshing structural objects. Joint coordinates and information may be displayed on screen in the model window or in tabular format;
- Frames, the frame element uses a general, three-dimensional, beam-column formulation which includes the effects of biaxial bending, torsion, axial deformation, and biaxial shear deformations. SAP2000 has a built-in library of standard concrete, steel and composite section properties of both US and International Standard sections;
- Shells, the shell element is a type of area object that is used to model membrane, plate, and shell behavior in planar and three-dimensional structures. The shell material may be homogeneous or layered throughout; material nonlinearity can also be considered when using the layered shell;
- Restraint releases and constraints, for define the structural behaviour in the space.

In the adopted model the mechanic features for the materials have been:

Steel - $E=210x10^6$_kN/m^2, Poisson coefficient $\nu=0,3$ and $\alpha= 1,2x10^{-5}°C^{-1}$;

Aluminium alloy- $E=75x10^6$_kN/m^2, Poisson coefficient $\nu=0,3$ and $\alpha= 1,1x10^{-5}°C^{-1}$;

The Loading system will automatically generate and apply seismic and wind loads based on various domestic and international codes. SAP2000 also has a sophisticated moving load generator that allows users to apply moving loads to lanes on frame and shell elements.

The Force Load is used to apply concentrated forces and moments at the joints. Values may be specified in a fixed coordinate system (global or alternate coordinates) or the joint coordinate system. The types of loads are:

Force/Moment, Displacement, Temperature, Strain, Pore Pressure, etc.

In our case has been modelled five complete adjacent sector whit safety barriers.

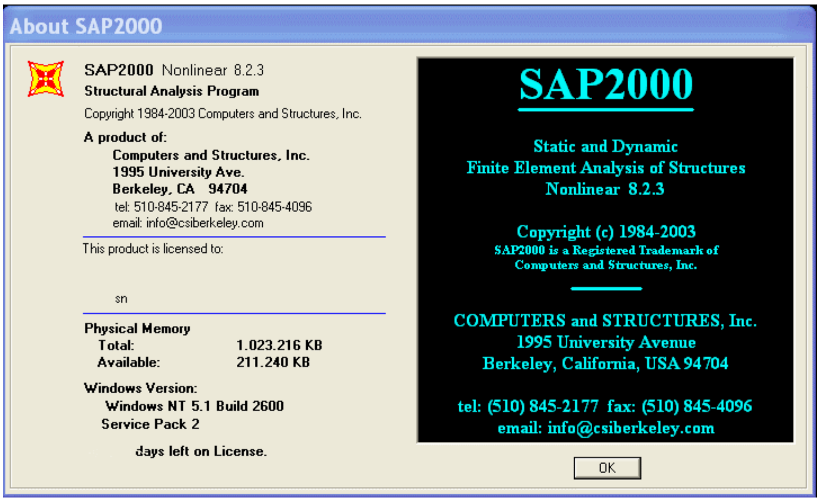
7.1 Software used

For the analysis has been adopted SAP2000 f.e.m. softaware, produced by Computers and Structures, Inc.1995 University Avenue, Berkeley, California 94704.

In effect, the SAP2000 name has been synonymous with state-of-the-art analytical methods since its introduction over 30 years ago. SAP2000 follows in the same tradition featuring a very sophisticated, intuitive and versatile user interface powered by an unmatched analysis engine and design tools for engineers working on transportation, industrial, public works, sports, and other facilities.

From its 3D object based graphical modeling environment to the wide variety of analysis and design options completely integrated across one powerful user interface, SAP2000 has proven to be the most integrated, productive and practical general purpose structural program on the market today. This intuitive interface allows you to create structural models rapidly and intuitively without long learning curve delays. Now you can harness the power of SAP2000 for all of your analysis and design tasks, including small day-to-day problems. Complex Models can be generated and meshed with powerful built in templates. Integrated design code features can automatically generate wind, wave, bridge, and seismic loads with comprehensive automatic steel and concrete design code checks per US, Canadian and international design standards.

The models are implemented by input files, in text or graphic mode, while the output stress and deformations results are generated in text mode and in graphic shape.



Version of program used and System of mainframe

To facilitate the results reading, it follows a typical output list for beams and shells elements:

TABLE: Element Forces - Frames									
Frame	**Station**	**OutputCase**	**CaseType**	**P**	**V2**	**V3**	**T**	**M2**	**M3**
Text	m	Text	Text	KN	KN	KN	KN-m	KN-m	KN-m
488	0	PP	LinStatic	-0,003568	-0,204	0,001726	-0,0004268	0,0007819	-0,0007219
488	0,1025	PP	LinStatic	-0,003568	-0,17	0,001726	-0,0004268	0,000605	0,0185
488	0,205	PP	LinStatic	-0,003568	-0,135	0,001726	-0,0004268	0,000428	0,0341

where:

- **Frame:** elements considered
- **Station:** output value location
- **OutputCase:** load condition or combination
- **CaseType:** type of condition or combination (static, dynamic, modal, etc.)
- **P (kN):** axial force in kN, (if negative means compression)
- **V2 (kN):** shear force in kN, long axis 2,
- **V3 (kN):** shear force in kN, long axis 3,
- **T (kNm):** torsional force in kNm,
- **M2 (kNm):** bending moment in kNm, long axis 3,
- **M3 (kNm):** bending moment in kNm, long axis 2,

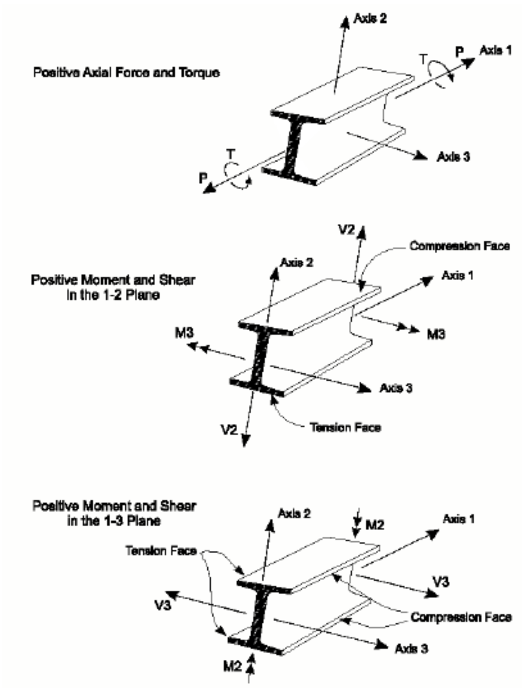
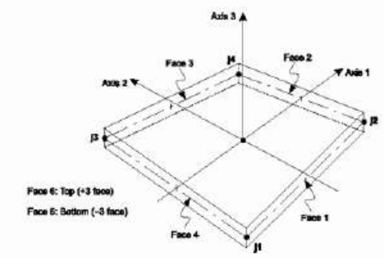


TABLE: Element Forces - Area Shells										
Area	**AreaElem**	**ShellType**	**Joint**	**OutputCase**	**CaseType**	**F11**	**F22**	**F12**	**FMax**	**FMin**
Text	Text	Text	Text	Text	Text	KN/m	KN/m	KN/m	KN/m	KN/m
421	282	Shell-Thin	67	PP	LinStatic	-34,61	10,43	-23,22	20,26	-44,43
421	282	Shell-Thin	69	PP	LinStatic	-10,37	14,07	9,71	17,46	-13,76
421	282	Shell-Thin	539	PP	LinStatic	-13,96	-9,92	11,39	-0,38	-23,5
421	282	Shell-Thin	538	PP	LinStatic	-38,21	-13,56	-21,55	-1,06	-50,7

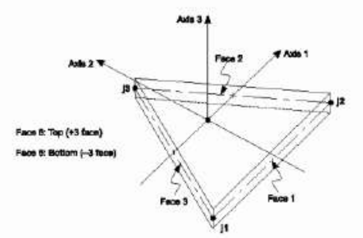
FAngle	**FVM**	**M11**	**M22**	**M12**	**MMax**	**MMin**	**MAngle**	**V13**	**V23**	**VMax**	**VAngle**
Degrees	KN/m	KN-m/m	KN-m/m	KN-m/m	KN-m/m	KN-m/m	Degrees	KN/m	KN/m	KN/m	Degrees
-67,064	57,31	-18,0207	-26,5658	-2,2484	-17,4652	-27,1213	-13,878	-29,82	39,3	49,33	127,187
70,755	27,1	-15,8181	-2,2405	-3,753	-1,2721	-16,7864	-75,533	-26,92	39,3	47,64	124,406
50,037	23,32	32,3898	-0,5078	-1,3026	32,4413	-0,5593	-2,264	-26,92	-18,43	32,62	-145,602
-59,887	50,18	35,9149	9,8049	0,202	35,9165	9,8034	0,443	-29,82	-18,43	35,05	-148,281

where:

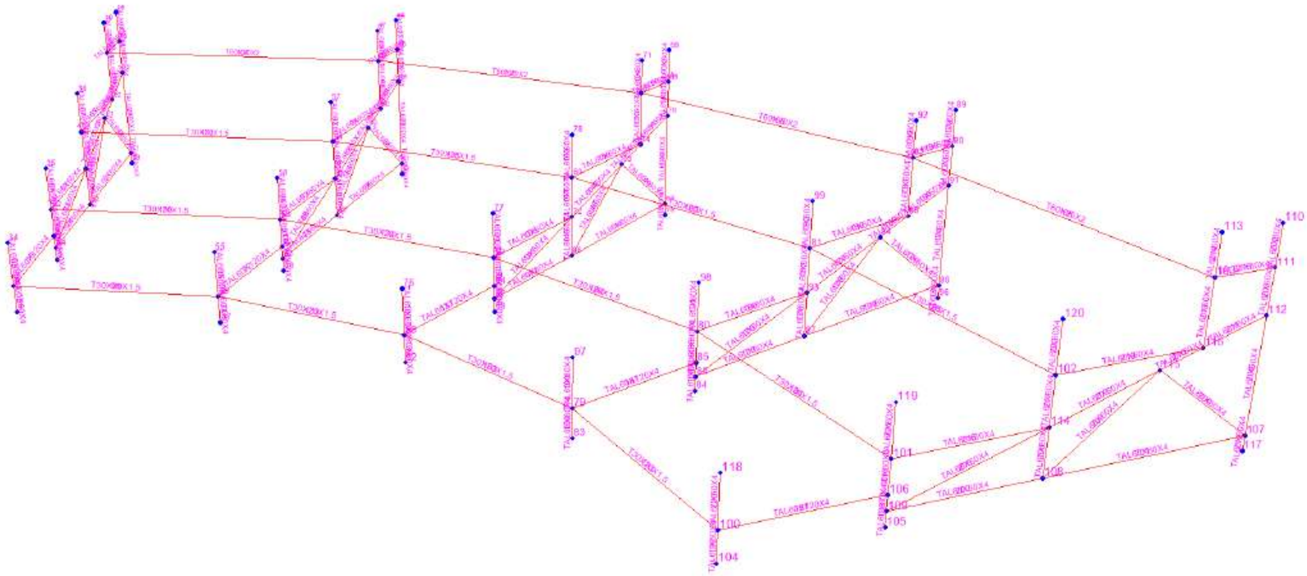
- **AreaElem:** shell elements
- **Joint:** reading output joints
- **OutputCase:** load condition or combination
- **CaseType:** type of condition or combination (static, dynamic, modal, etc.)
- **F11 (kN/m):** axial force in kN/m long 1-1 direction
- **F22 (kN/m):** axial force in kN/m long 2-2 direction
- **F12=F21 (kN/m):** axial force in kN/m long 1-2/2-1 direction
- **Fmax/Fmin (kN/m):** absolute minimum/maximum axial force in kN/m
- **M11 (kNm/m):** bending moment in kNm/m, long axis 1-1
- **M22 (kNm/m):** bending moment in kNm/m, long axis 2-2
- **M12=M21 (kNm/m):** bending moment in kNm/m, long axis 1-2/2-1
- **Mmax/Mmin (kNm/m):** absolute minimum/maximum bending moment in kNm/m
- **V13 (kN/m):** shear force in kN/m long 1-3 direction
- **V23 (kN/m):** shear force in kN/m long 2-3 direction



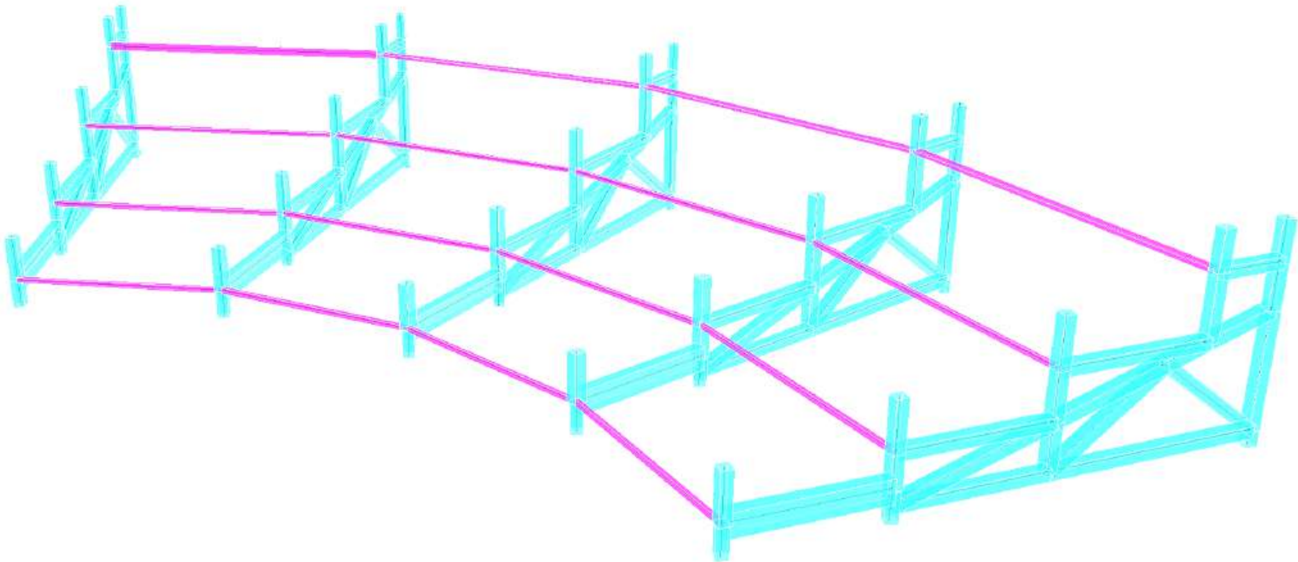
Four-node Quadrilateral Shell Element



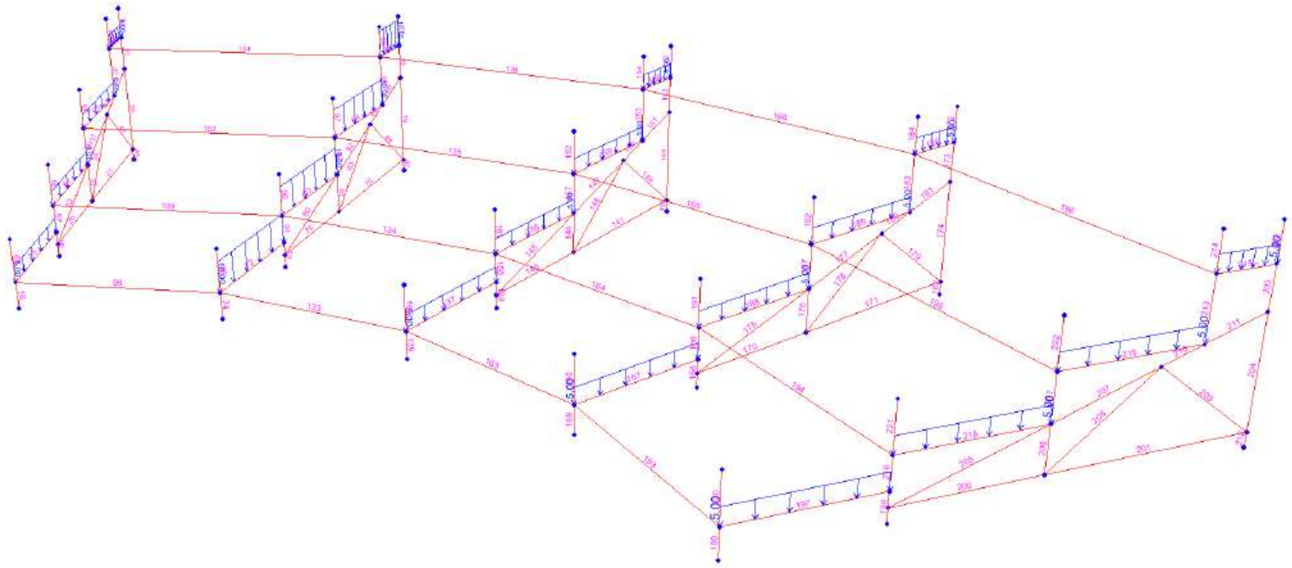
It follows the pictures of principal geometrical features of the models:



F.e.m. model (joints and beam)



F.e.m. model (solid extrusion)



F.e.m. model (vertical loads)

8. VERIFICATION OF STRUCUTURE

8.1 Steel structures

Eurocode 3 has been taken into account for the verification procedure. Checks have been performed according to Chapter 6 of Eurocode 3.

In particular, will be used the following formulas:

Tension Check

The axial tension check at each output station shall satisfy:

$$\frac{N_{Ed}}{N_{t,Rd}} \leq 1.0 \qquad \text{(EC3 6.2.3(1))}$$

where the design tension resistance, $N_{t,Rd}$ is taken as the smaller of:

- the design plastic resistance, $N_{pl,Rd}$ of the gross cross-section

$$N_{pl,Rd} = \frac{Af_y}{\gamma_{M0}} \qquad \text{(EC3 6.2.3(2)a)}$$

- the design ultimate resistance, $N_{u,Rd}$ of the net cross-section

$$N_{u,Rd} = \frac{0.9A_{net}f_u}{\gamma_{M2}} \qquad \text{(EC3 6.2.3(2)b)}$$

The values of A and A_{net} are defined in Section 5.1.

Compression Check

The axial compression check at each output station shall satisfy:

$$\frac{N_{Ed}}{N_{c,Rd}} \leq 1.0 \qquad \text{(EC3 6.2.4(1))}$$

where the design compression resistance, $N_{c,Rd}$ for Class 1, 2, 3, and 4 sections is taken as:

$$N_{c,Rd} = \frac{Af_y}{\gamma_{M0}} \qquad \text{for Class 1, 2, or 3 cross-sections} \quad \text{(EC3 6.2.4(2))}$$

$$N_{c,Rd} = \frac{A_{eff}f_y}{\gamma_{M0}} \qquad \text{for Class 4 cross-sections} \quad \text{(EC3 6.2.4(2))}$$

Axial Buckling Check

The axial buckling check at each output station shall satisfy:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1.0 \qquad \text{(EC3 6.3.1.1(1))}$$

where the design compression resistance, $N_{b,Rd}$ for Class 1, 2, 3, and 4 sections is taken as:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{MI}} \qquad \text{for Class 1, 2, and 3 cross-sections} \qquad \text{(EC3 6.3.1.1(3))}$$

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{MI}} \qquad \text{for Class 4 cross-sections} \qquad \text{(EC3 6.3.1.1(3))}$$

The reduction factor, χ for the relevant buckling mode is taken as:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \leq 1.0 \qquad \text{(EC3 6.3.1.2(1))}$$

where the factor, Φ and the non-dimensional slenderness, $\bar{\lambda}$ are taken as:

$$\Phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right] \qquad \text{(EC3 6.3.1.2(1))}$$

$$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{1}{\lambda_1}, \quad \text{for Class 1, 2 and 3 cross-sections} \qquad \text{(EC3 6.3.1.3(1))}$$

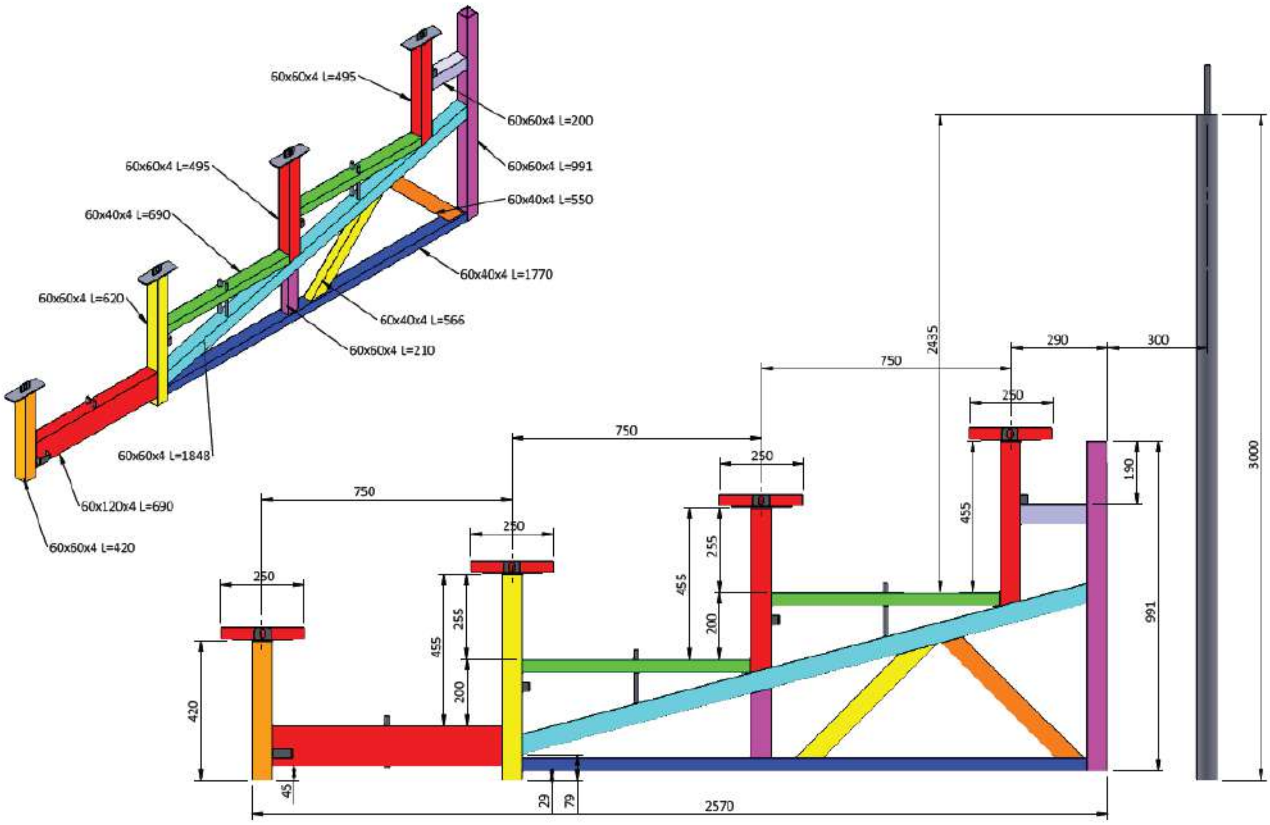
$$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}} = \frac{L_{cr}}{i}\frac{\sqrt{A_{eff}/A}}{\lambda}, \quad \text{for Class 4 cross-sections} \qquad \text{(EC3 6.3.1.2(1))}$$

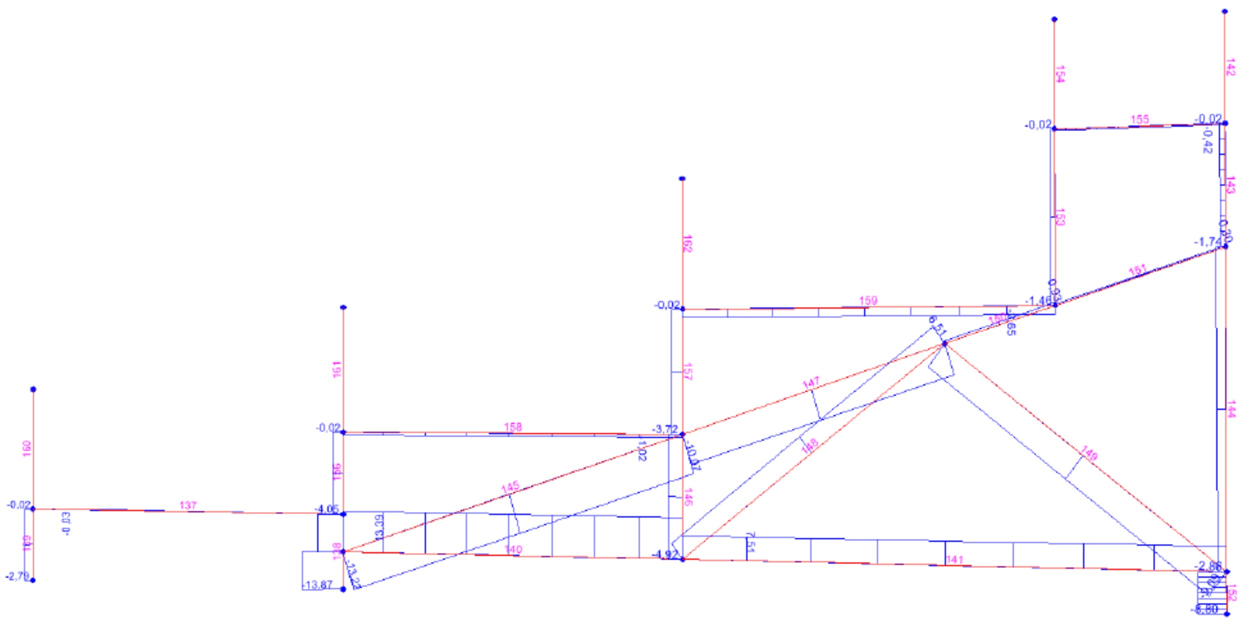
The utilization factors has been calculated by a excel routine according to the Eurocode 3 approach.

8.2 Aluminium structures

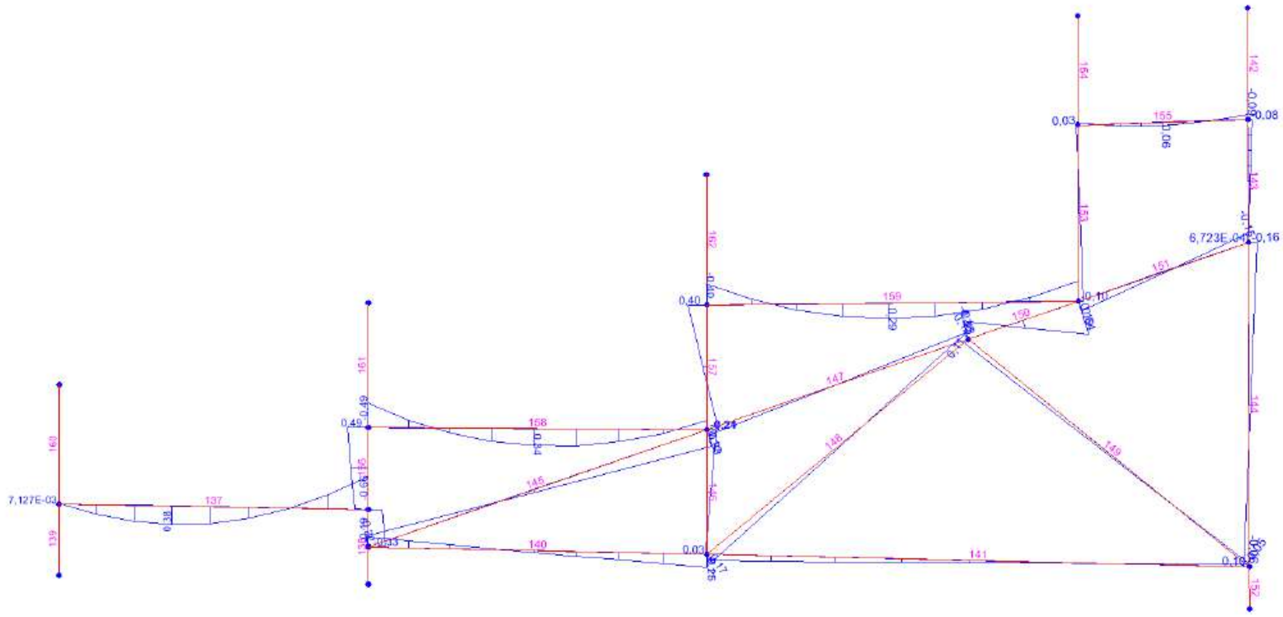
Eurocode 9 has been taken into account for the verification procedure. Checks have been performed according to Chapter 4 of Eurocode 9.

8.3 Main span verification





Main span- axial force (values kN)



Main span- bending moment (values kNm)

SECTION		
Base:	**60**	*mm*
height:	**60**	*mm*
t_k:	**4**	*mm*
ALLUMINIUM ALLOY	**AW-3103**	
f_0= 145,00		*N/mm²*

A	**8,96**	*cm²: area*
J_x	**47,07**	*cm⁴: dir. X*
J_y	**47,07**	*cm⁴: dir.Y*
W_x	**15,69**	*cm³: dir X*
W_y	**15,69**	*cm³: dir. Y*
$W_{x,pl}$	**18,83**	*cm³:dir. X*
$W_{y,pl}$	**18,83**	*cm³: dir. Y*
J_P	**94,14**	*cm⁴: dir. Z*
i_x	**2,3**	*cm: radius X*
i_y	**2,3**	*cm: radius Y*
$P_{S,W}$	**2,5**	kg/m
L_x	**0,78**	*m: length axis x*
L_y	**0,78**	*m: length axis y*
λ_x	**34,03**	*slenderness x*
λ_y	**34,03**	*slenderness y*
N_{ed}	**13,20**	*kN: axial force*
$V_{Ed,x}$	**1,50**	*kN: share force X*
$V_{Ed,y}$	**0,00**	*kN: share force Y*
$M_{Ed,xx}$	**1,20**	*kNm: bending moment X-X axis*
$M_{Ed,yy}$	**0,00**	*kNm: bending moment Y-Y axis*
$M_{Ed,tr}$	**0,00**	*kNm: torsional moment Z-Z axis*
$N_{cr,x}$	**1754**	*N/mm²: critical eulerian value dir.X*
$N_{cr,y}$	**1754**	*N/mm²: critical eulerian value dir.Y*
χ_x	**0,98**	*slenderness coefficient X, whit Φ;* **0,55**
$\lambda°_x$	**0,28**	*instability value X*
χ_y	**0,98**	*slenderness coefficient Y, whit Φ* **0,55**
$\lambda°_y$	**0,28**	*instability value Y*

Class	***1***	
$N_{Rd,comp}$	**121**	*kN: axial compression resistance*
$N_{pl,Rd}$	**124**	*kN: axial tensile resistance*
$V_{c,Rd,x}$	**34,5**	*kN: shear resistance X*
$V_{c,Rd,y}$	**34,5**	*kN: shear resistance Y*
$M_{c,Rd,x}$	**2,6**	*kNm: flexural resistance X*
$M_{c,Rd,y}$	**2,6**	*kNm: flexural resistance Y*
$M_{N,x,Rd}$	**2,6**	*kNm: flexural and axial resistance X*
$M_{N,y,Rd}$	**2,6**	*kNm: flexural and axial resistance Y*
$M_{p,Rd}$	**4,3**	*kNm: torsional resistance*
η=	***0,58***	***---> Section Verified***

SECTION

Base:	40	mm
height:	60	mm
t_k:	4	mm

ALLUMINIUM ALLOY **AW-3103**

f_0= 145,00 N/mm^2

A	7,36	cm^2: area
J_x	34,50	cm^4: dir. X
J_y	17,80	cm^4: dir.Y
W_x	11,50	cm^3: dir X
W_y	8,90	cm^3: dir. Y
$W_{x,pl}$	13,80	cm^3:dir. X
$W_{y,pl}$	10,68	cm^3: dir. Y
J_P	35,60	cm^4: dir. Z
i_x	2,2	cm: radius X
i_y	1,6	cm: radius Y
$P_{S,W}$	2,0	kg/m
L_x	0,78	m: length axis x
L_y	0,78	m: length axis y
λ_x	36,02	slenderness x
λ_y	50,16	slenderness y
N_{ed}	13,40	kN: axial force
$V_{Ed, x}$	1,10	kN: share force X
$V_{Ed, y}$	0,00	kN: share force Y
$M_{Ed, xx}$	0,00	kNm: bending moment X-X axis
$M_{Ed, yy}$	0,95	kNm: bending moment Y-Y axis
$M_{Ed, tr}$	0,00	kNm: torsional moment Z-Z axis
$N_{cr,x}$	1565	N/mm^2: critical eulerian value dir.X
$N_{cr,y}$	807	N/mm^2: critical eulerian value dir.Y
χ_x	0,98	slenderness coefficient X, whit Φ; 0,56
$\lambda°_x$	0,30	instability value X
χ_y	0,95	slenderness coefficient Y, whit Φ 0,61
$\lambda°_y$	0,42	instability value Y

Class	1	
$N_{Rd, comp}$	96	kN: axial compression resistance
$N_{pl,Rd}$	102	kN: axial tensile resistance
$V_{c,Rd,x}$	34,5	kN: shear resistance X
$V_{c,Rd,y}$	23,0	kN: shear resistance Y
$M_{c,Rd,x}$	1,9	kNm: flexural resistance X
$M_{c,Rd,y}$	1,5	kNm: flexural resistance Y
$M_{N,x,Rd}$	1,9	kNm: flexural and axial resistance X
$M_{N,y,Rd}$	1,4	kNm: flexural and axial resistance Y
$M_{p,Rd}$	2,5	kNm: torsional resistance
η=	0,82	---> **Section Verified**

SECTION

Base:	60	mm
height:	120	mm
t_k:	4	mm

ALLUMINIUM ALLOY **AW-3103**

f_0= 145,00 *N/mm²*

A	13,76	*cm²: area*
J_x	255,20	*cm⁴: dir. X*
J_y	84,77	*cm⁴: dir.Y*
W_x	42,53	*cm³: dir X*
W_y	28,26	*cm³: dir. Y*
$W_{x,pl}$	51,04	*cm³:dir. X*
$W_{y,pl}$	33,91	*cm³: dir. Y*
J_P	169,53	*cm⁴: dir. Z*
i_x	4,3	*cm: radius X*
i_y	2,5	*cm: radius Y*
$P_{S,W}$	3,8	kg/m
L_x	0,75	*m: length axis x*
L_y	0,75	*m: length axis y*
λ_x	17,42	*slenderness x*
λ_y	30,22	*slenderness y*
N_{ed}	1,40	*kN: axial force*
$V_{Ed, x}$	1,30	*kN: share force X*
$V_{Ed, y}$	0,00	*kN: share force Y*
$M_{Ed, xx}$	0,00	*kNm: bending moment X-X axis*
$M_{Ed, yy}$	1,30	*kNm: bending moment Y-Y axis*
$M_{Ed, tr}$	0,00	*kNm: torsional moment Z-Z axis*
$N_{cr,x}$	6697	*N/mm²: critical eulerian value dir.X*
$N_{cr,y}$	2224	*N/mm²: critical eulerian value dir.Y*
χ_x	1,00	*slenderness coefficient X, whit Φ ;* **0,50**
$\lambda°_x$	0,15	*instability value X*
χ_y	0,99	*slenderness coefficient Y, whit Φ* **0,54**
$\lambda°_y$	0,25	*instability value Y*

Class	*1*	
$N_{Rd, comp}$	188	*kN: axial compression resistance*
$N_{pl,Rd}$	190	*kN: axial tensile resistance*
$V_{c,Rd,x}$	69,0	*kN: shear resistance X*
$V_{c,Rd,y}$	34,5	*kN: shear resistance Y*
$M_{c,Rd,x}$	7,0	*kNm: flexural resistance X*
$M_{c,Rd,y}$	4,7	*kNm: flexural resistance Y*
$M_{N,x,Rd}$	7,0	*kNm: flexural and axial resistance X*
$M_{N,y,Rd}$	4,6	*kNm: flexural and axial resistance Y*
$M_{p,Rd}$	7,8	*kNm: torsional resistance*
η=	***0,29***	***---> Section Verified***

SECTION

Base:	60	*mm*
height:	60	*mm*
t_k:	4	*mm*

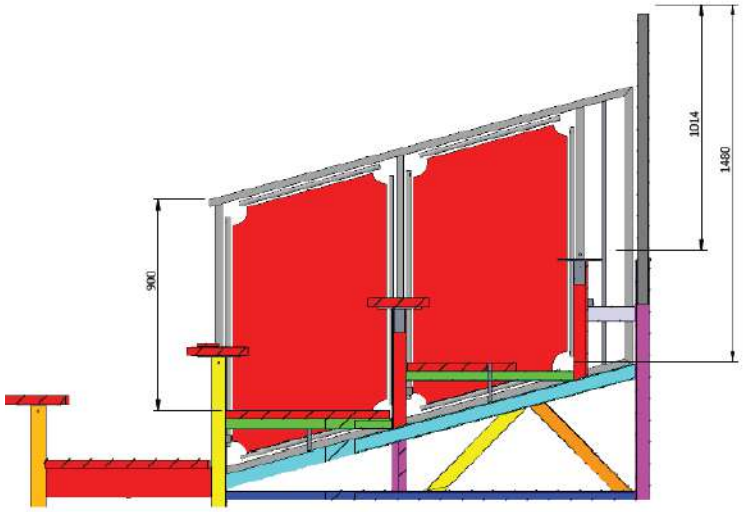
ALLUMINIUM ALLOY **AW-3103**

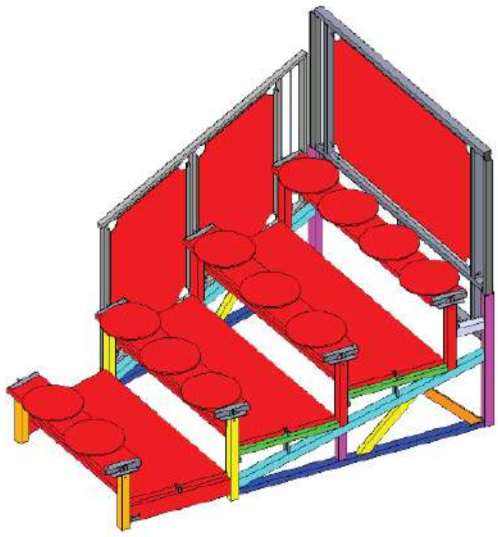
f_0= 145,00 *N/mm²*

A	8,96	*cm²: area*
J_x	47,07	*cm⁴: dir. X*
J_y	47,07	*cm⁴: dir.Y*
W_x	15,69	*cm³: dir X*
W_y	15,69	*cm³: dir. Y*
$W_{x,pl}$	18,83	*cm³:dir. X*
$W_{y,pl}$	18,83	*cm³: dir. Y*
J_P	94,14	*cm⁴: dir. Z*
i_x	2,3	*cm: radius X*
i_y	2,3	*cm: radius Y*
$P_{S,W}$	2,5	kg/m
L_x	0,45	*m: length axis x*
L_y	0,45	*m: length axis y*
λ_x	19,63	*slenderness x*
λ_y	19,63	*slenderness y*
N_{ed}	5,00	*kN: axial force*
$V_{Ed,x}$	2,00	*kN: share force X*
$V_{Ed,y}$	0,00	*kN: share force Y*
$M_{Ed,xx}$	0,00	*kNm: bending moment X-X axis*
$M_{Ed,yy}$	0,70	*kNm: bending moment Y-Y axis*
$M_{Ed,tr}$	0,00	*kNm: torsional moment Z-Z axis*
$N_{cr,x}$	5269	*N/mm²: critical eulerian value dir.X*
$N_{cr,y}$	5269	*N/mm²: critical eulerian value dir.Y*
χ_x	1,00	*slenderness coefficient X, whit Φ;* **0,51**
$\lambda°_x$	0,16	*instability value X*
χ_y	1,00	*slenderness coefficient Y, whit Φ* **0,51**
$\lambda°_y$	0,16	*instability value Y*

Class	***1***	
$N_{Rd,comp}$	124	*kN: axial compression resistance*
$N_{pl,Rd}$	124	*kN: axial tensile resistance*
$V_{c,Rd,x}$	34,5	*kN: shear resistance X*
$V_{c,Rd,y}$	34,5	*kN: shear resistance Y*
$M_{c,Rd,x}$	2,6	*kNm: flexural resistance X*
$M_{c,Rd,y}$	2,6	*kNm: flexural resistance Y*
$M_{N,x,Rd}$	2,6	*kNm: flexural and axial resistance X*
$M_{N,y,Rd}$	2,6	*kNm: flexural and axial resistance Y*
$M_{p,Rd}$	4,3	*kNm: torsional resistance*
η=	***0,31***	***---> Section Verified***

8.4 Safety barriers verification





SECTION		
Base:	40	*mm*
height:	60	*mm*
t_k:	3	*mm*
STEEL	S235	
f_0=	**235,00**	*N/mm²*

A	**5,64**	*cm²: area*
J_x	**27,39**	*cm⁴: dir. X*
J_y	**14,31**	*cm⁴: dir.Y*
W_x	**9,13**	*cm³: dir X*
W_y	**7,16**	*cm³: dir. Y*
$W_{x,pl}$	**10,95**	*cm³:dir. X*
$W_{y,pl}$	**8,59**	*cm³: dir. Y*
J_P	**28,63**	*cm⁴: dir. Z*
i_x	**2,2**	*cm: radius X*
i_y	**1,6**	*cm: radius Y*
$P_{S,W}$	**4,4**	kg/m
L_x	1,00	*m: length axis x*
L_y	1,00	*m: length axis y*
λ_x	**45,38**	*slenderness x*
λ_y	**62,77**	*slenderness y*
α_x	***a***	**--->** **0,21**

N_{ed}	0,00	*kN: axial force*
$V_{Ed, x}$	2,40	*kN: share force X*
$V_{Ed, y}$	0,00	*kN: share force Y*
$M_{Ed, xx}$	2,40	*kNm: bending moment X-X axis*
$M_{Ed, yy}$	0,00	*kNm: bending moment Y-Y axis*
$M_{Ed, tr}$	0,00	*kNm: torsional moment Z-Z axis*
$N_{cr,x}$	**986**	*N/mm²: critical eulerian value dir.X*
$N_{cr,y}$	**515**	*N/mm²: critical eulerian value dir.Y*
χ_x	**0,93**	*slenderness coefficient X, whit Φ;* **0,65**
$\lambda°_x$	**0,48**	*instability value X*
χ_y	**0,86**	*slenderness coefficient Y, whit Φ* **0,77**
$\lambda°_y$	**0,67**	*instability value Y*

Class	***1***	
$N_{Rd, comp}$	**109**	*kN: axial compression resistance*
$N_{pl,Rd}$	**126**	*kN: axial tensile resistance*
$V_{c,Rd,x}$	**41,9**	*kN: shear resistance X*
$V_{c,Rd,y}$	**27,9**	*kN: shear resistance Y*
$M_{c,Rd,x}$	**2,5**	*kNm: flexural resistance X*
$M_{c,Rd,y}$	**1,9**	*kNm: flexural resistance Y*
$M_{N,x,Rd}$	**2,3**	*kNm: flexural and axial resistance X*
$M_{N,y,Rd}$	**1,7**	*kNm: flexural and axial resistance Y*
$M_{p,Rd}$	**3,2**	*kNm: torsional resistance*
η=	***0,98***	***---> Section Verified***

8.5 Wooden benches verification

the wooden benches are made by NORDPAN system.

The resistance in order of maximum load permitted (kg/mq) is explained in the table below:

Spessore mm	Pannello NORDPAN								
	Flessione ammessa l/300								
	Interasse in mm								
	400	500	600	800	1000	1200	1500	2000	2500
13	646,48	330,60	191,30	80,44	41,20	23,54	11,77	4,91	2,94
16	1.262,55	646,48	373,76	157,94	80,44	47,09	23,54	9,81	4,91
19	2.211,17	1.132,07	655,31	276,64	141,26	81,42	42,18	17,66	8,83
22	3.581,63	1.833,49	1.061,44	447,34	229,55	132,44	67,69	28,45	14,72
27	7.079,88	3.624,80	2.097,38	884,86	453,22	261,93	134,40	56,90	29,43
32	8.571,98	4.388,99	2.539,81	1.071,25	548,38	317,84	162,85	68,67	35,32
35	11.957,41	6.122,42	3.543,37	1.495,04	765,18	442,43	226,61	96,14	49,05
42	23.657,80	12.112,41	7.009,25	2.956,73	1.513,68	876,03	448,32	189,33	97,12
49	42.318,38	21.667,35	12.539,14	5.289,55	2.708,54	1.567,64	802,46	338,45	173,64
60	65.687,76	33.632,60	19.463,04	8.210,97	4.203,59	2.432,88	1.245,87	525,82	268,79
	kg/m^2	kg/m^2	kg/m^2	kg/m^2	kg/m^2	kg/m^2	kg/m^2	kg/m^2	kg/m^2

Where:

“Spessore” = thickness (mm)

“interasse” = span (mm)

It will adopted a thickness of 35_mm.

8.6 Contact pressure on the ground

The structure bases oneself on the ground by eight support.

The maximum stress is:

N_{ed} ***= 11,6_kN = 11600N***

The support plate resistance is:

$P_{Rd} = \sigma_c x A p$

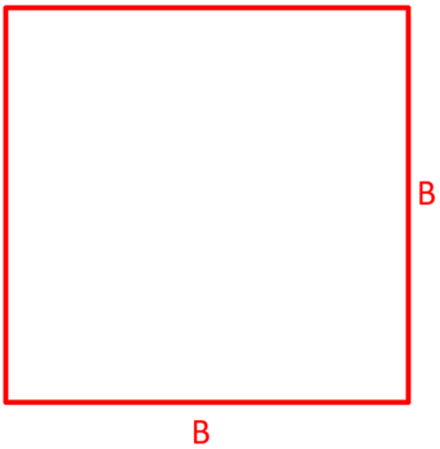
Where σ_c is the ground allowable stress and Ap is the contact area.

It is possible taken into account da follow table, where:

A is the side of plate (in mm)

B is the side of additional steel plate under the column-plate (in mm)

σ_c is the ground allowable stress (N/mm^2)



N_{max} kN	σ_c N/mm^2	A mm	B_{min} mm	A_{min} cm^2
11,6	0,10	340	340	1156
	0,15	280	280	784
	0,20	250	250	625
	0,25	250	250	625
	0,30	200	200	400

In case the soil capacity very smood, the contact plate must be expanded, nevertheless this arrangement must be taken into account in case of failure of the supports.

9. CONCLUSION AND REQUIREMENTS

All analyses completed showed that steel and aluminium structures are verified in order to resistance and deformation state.

The maximum live loads for the site, shall be the following:

- *4 person for bench.*

Periodically, it is necessary checked and monitored the structures:

In particular:

- *Check of all joint connection;*
- *Check of members integrity.*

In addition, the structure must be supported by a soil of sufficient consistency, so as to avoid any type of failure located in correspondence of the ground.

Type Approval and decision on production control

0524/94

Précontraint 702, 702 Blackout, 832, 1002, 1202, 1502

Holder/Issued to

Serge Ferrari S.A.S

FR- 38352, La Tour-du-Pin Cedex, France
VAT number: FR 38 300 821 873
Phone: +33 (0)4 74 83 52 59, Fax: +33 (0)4 74 83 59 73
E-mail: ferrari@sergeferrari.com, Web: www.sergeferrari.com

Product description

Précontraint 702, 702 Blackout, 832, 1002, 1202 och 1502.
PVC-coated polyester fabrics.

Type of fabric	*Thickness (mm)*	*Area weight (g/m^2)*	*Fire thechnical class according EN 13501-1*
702	0,59 + 10 %	750 + 5 %	B-s2, d0
702 Blackout	0,63 + 10 %	830 + 5 %	B-s2, d0
832	0,67 + 10 %	850 + 5 %	B-s2, d0
1002	0,83 + 10 %	1050 + 5 %	B-s2, d0
1202	0,90 + 10 %	1050 + 5 %	C-s2, d0
1502	1,2 + 10 %	1500 + 5 %	C-s2, d0

Intended use

Fabric material used as ceiling and wall linings in tent buildings.

Trade name

Précontraint 702, 702 Blackout, 832, 1002, 1202 och 1502.

Approval

The products satisfy the requirements set forth in chapter 8, 4 § 2 PBL, in respect to and under conditions stated in this certificate, and are therefore approved in accordance with the provisions of the following sections of the Building Regulations issued by the National Board of Housing, Building and Planning (BBR):

Fire technical class B-s2, d0 alt. C-s2, d0 according EN 13501-1	5:521
Fire technical class E	5:521

Associated documents

-

RISE Research Institutes of Sweden AB | Certification
Box 857, SE-501 15 Borås, Sweden
Phone: +46 10-516 50 00
certifiering@ri.se| www.ri.se

8P00542

Ackred. nr 1002 Certifiering ISO/IEC 17065

Control

The factory production control (FPC) is monitored by an independent inspection body.
Control agreement: 210-97-0873. Inspection body: RISE Research Institutes of Sweden.

When the building proprietor performs inspection at the building site, he shall check the markings to ensure that the correct products have been supplied and that they are used in accordance with the requirements stated in the approval. He must also check that the product is accompanied by a manufacturing assurance, which certifies that the product has been manufactured in accordance with the documents on which this certificate is based.

Manufacturing place

Production control includes the following place:
Serge Ferrari S.A.S., La Tour-du-Pin Cedex, France.

Marking

The products are to be marked at the factory. The marking consists of a label on every product/packing/documentation supplied and includes:

Holder	Serge Ferrari S.A.S.
Manufacturing place	La Tour-du-Pin Cedex, France
Boverket´s registered trade mark	
Certification body and accreditation number	RISE Certifiering 1002
Product type designation	e. g. Précontraint 702
Type approval number	0524/94
Fire class	e. g. B-s2, d0 / E
Consecutive manufacture no./date of production	No/date
Inspection body	RISE

Tent manufacturers who use the product should lable the tent parts with the following information:
Name of tent fabric manufacturer, name of manufacturer of the complete tent, tent fabric type designation, tent fabric approval number and tent fabric consecutive manufacture number or date of production.

Basis for judgement/approval

Classification reports according to EN 13501-1, RA14-008, RA16-007, RA16-0089 and RA16-0242 from CSTB.
Classification report according to EN 13501-1, EFR-17-001038A from Efectis.
Classification report according to EN 13501-1, KB-Hoch-160231 from Prüfinstitut Hoch.

Comments

This approval supersedes the previous approval with the same number dated 2018-001-30.

Validity
Valid through 2023-02-06.

The validity of this approval expires when the characteristics included in this approval shall be CE-marked according to the Construction Products Regulation (EU) 305/2011.

Stefan Coric

Magnus Sturesson

This is a translation from the Swedish original document. In the event of any dispute as to its content, the Swedish text shall take precedence.

Typgodkännande med beslut om tillverkningskontroll

0524/94

Précontraint 702, 702 Blackout, 832, 1002, 1202, 1502

Innehavare/Utfärdat för

Serge Ferrari S.A.S
FR- 38352, La Tour-du-Pin Cedex, Frankrike
VAT nummer: FR 38 300 821 873
Tel: +33 (0)4 74 83 52 59, Fax: +33 (0)4 74 83 59 73
E-post: ferrari@sergeferrari.com , Hemsida: www.sergeferrari.com

Produktbeskrivning

Précontraint 702, 702 Blackout, 832, 1002, 1202 och 1502.
PVC-belagda polyestervävar.

Vävtyp	*Tjocklek (mm)*	*Ytvikt (g/m^2)*	*Brandteknisk klass enligt EN 13501-1*
702	0,59 + 10 %	750 + 5 %	B-s2, d0
702 Blackout	0,63 + 10 %	830 + 5 %	B-s2, d0
832	0,67 + 10 %	850 + 5 %	B-s2, d0
1002	0,83 + 10 %	1050 + 5 %	B-s2, d0
1202	0,90 + 10 %	1050 + 5 %	C-s2, d0
1502	1,2 + 10 %	1500 + 5 %	C-s2, d0

Avsedd användning

Dukmaterial för tak och väggytor i tältbyggnader.

Handelsnamn

Précontraint 702, 702 Blackout, 832, 1002, 1202 och 1502.

Godkännande

Produkterna uppfyller kraven i 8 kap, 4 § 2 PBL i de avseenden och under de förutsättningar som anges i detta bevis och godkänns därför enligt bestämmelserna i följande avsnitt i Boverkets byggregler (BBR):

Brandteknisk klass B-s2, d0 alt. C-s2, d0 enligt EN 13501-1	5:521
Brandteknisk klass E enligt EN 13501-1	5:521

Tillhörande handlingar

-

Kontroll

Tillverkarens egenkontroll övervakas av ett oberoende kontrollorgan.
Kontrollavtal: 2013-06-13., Kontrollorgan: RISE Research Institutes of Sweden.

RISE Research Institutes of Sweden AB | Certifiering
Box 857, SE-501 15 Borås, Sverige
Tel: 010-516 50 00
certifiering@ri.se| www.ri.se

Vid byggherrens kontroll på byggarbetsplatsen skall genom identifiering med hjälp av märkningen tillses att rätt produkter levererats och att de används enligt förutsättningarna givna i godkännande. Dessutom skall kontrolleras att produkten åtföljs av en tillverkarförsäkran som intygar att tillverkning skett i enlighet med de handlingar som legat till grund för detta godkännande.

Tillverkningsställe

Tillverkningskontrollen omfattar följande tillverkningsställe:
Serge Ferrari S.A.S., La Tour-du-Pin Cedex, Frankrike.

Märkning

Produkterna skall vid fabrik förses med märkning. Märkningen utgörs av etikett på varje levererad förpackning och omfattar:

Innehavare	Serge Ferrari S.A.S.
Tillverkningsställe	La Tour-du-Pin Cedex, Frankrike
Boverkets inregistrerade varumärke	
Certifieringsorgan och ackrediteringsnummer	RISE Certifiering 1002
Produktens typbeteckning	t ex Précontraint 702
Typgodkännandets nummer	0524/94
Brandteknisk klass	t ex B-s2, d0/ E
Löpande tillverkningsnummer eller datum	nr/datum
Kontrollorgan	RISE

Tälttillverkare som använder produkten bör märka tältets olika delar med följande uppgifter: Materialtillverkarens namn, tälttillverkarens namn, materialets beteckning, typgodkännandebevisets nummer samt materialets tillverkningsnummer eller tillverkningsdatum.

Bedömningsunderlag

Klassifikationsrapporter enligt EN 13501-1, RA14-008, RA16-007, RA16-0089 och RA16-0242 från CSTB.
Klassifikationsrapport enligt EN 13501-1, EFR-17-001038A från Efectis.
Klassifikationsrapport enligt EN 13501-1, KB-Hoch-160231 från Prüfinstitut Hoch.

Kommentarer

Detta godkännande ersätter tidigare godkännande med samma nummer daterat 2018-01-30.

Giltighetstid

Giltigt till och med 2023-02-06.

Detta typgodkännande upphör att gälla när egenskaper som ingår i detta bevis skall CE-märkas enligt Byggproduktförordningen CPR (EU) 305/2011.

Stefan Coric　　　　Magnus Sturesson

Räddningsplan/Emergency plan

Andelslaget Sirkus Aikamoinen

2254329-2

Karjalankatu 9 A 15 00520 Helsinki

Kontaktperson: Oskar Rask, 0407659220

För föreställningen

Circus I love you - Utopia

18-21.8 Marknadsplanen i Raseborg

Med tält 13m diameter

Background / regulations

Denna dokumentation avser andelslaget Sirkus Aikamoinens säkerhetsarbete för turné med föreställningen Utopia.

Denna dokumentation är i hädanefter i huvudsak författad på engelska då detta är det språk som i högsta grad genomgripande talas och förstås av bolagets personal, vilket gör det lämpligast för tillämpningen av dessa rutiner.

IN ENGLISH

This documentation concerns the security work by the company Sirkus Aikamoinen for the tour of the performance Utopia.

This documentation is as it follows mainly written in english as this is the language which to the highest level by everyone is understood and spoken by the staff of the company, which makes it most suitable for the realisation of these routines.

General description of the building

Name and address of the owner :
CIRCUS I LOVE YOU ab // c/o Tillö / Nytorgsgatan 15 A / 116 22 STOCKHOLM / SWEDEN

Type of building :
Circus tent. Metal frame. The tent has been built following the EU norm EN 13782:2015-Temporary structure.

Constructor :
FG MEMBRANE // Via Cartigliana, 14636061 - BASSANO DEL GRAPPA / info@fgsrl.com - www.fgsrl.eu

Dimensions :
13 m diameter. 8 m under the cupola, 10,5 m high in total with the arch.
2 king poles of 8 m high attached to the floor by 6 metallic cables to 6 metal stakes.
26 sides poles of 3 m high. 2 entrances

Building cover :
A flexible tarp. Colors : pink and yellow. Attached to the floor by 24 metal stakes.

Tribune :
Audience capacity : 149 seats. Step racks made in aluminium and attached together in one tribune. Seats made in planks of wood. 4 rows of seats in total.

Stage :
One circular stage of 5m diameter and 65cm high. One rectangular platform of 2m width and 3m long.

Location of the building :
The location of the building is always changing according to the circus's activity of travelling to several places. The building is generally located in a town in a place accessible for the audience. The floor has to be flat with a maximum 2% slope. The tent can be raised on grass or concrete floor.

General description of the type of work performed and their risks

Type of work performed in the building :
The main activity is to perform circus shows on the stage of the building with audience seating around in the tribune. The duration of the show is 1 hour. The content of the show is acrobatics and music. The team performing on stage is composed of 5 acrobats and musicians.

Hotspots of the building :
- The stage is connected to a 32A electrical board in order to supply the amplified sound of the music of the lights of the show.
- A popcorn machine is placed at the ticket office, next to the entrances, inside the tent.
- A fuel heater is placed outside when needed 5m from the tent and heats the tent inside, connected by a ventilation pipe.

These are the 3 hotspots of the building.

The distribution of responsibility for the fire protection

The fire responsibility is carried out by the company.

A member of the team has the french diploma SSIAP 1 *(Service de sécurité incendie et d'assistance à personnes - Fire security service and persons assistance)*.

During the shows, this person is not performing on stage but is always outside of the stage and available :
To prevent fires; For an early intervention on a starting fire; To send the alarm of evacuation of the audience; To organise the evacuation in order and safety; To give the alert to the local firemen and welcome them.

Outside of the performing times, this person is :

Raising the team's awareness about fire safety; Checking the basic maintenance of extinguishers.

The team's members are reactive and ready to help to organise an evacuation or to send the alarm of evacuation to the audience if needed.

Description of technical fire protection measures

Emergency exit paths :

- 2 emergency exits of 2,60m each and 2m high materialized by visible white bands. The exits are closed by a tarp opening that can be opened by a simple and easy manoeuvre.
- 2 emergency exit signs placed at each emergency exit visible in both light and darkness.
- A path of 6m long accessible in front of each emergency exit.

Fire and emergency alarm :

- The size of the tent makes that the alarm can be given by the entire team on stage, off stage or on the platform by voice alert.

Evacuation :

- If the wind goes to 100 km/h or more.
- if the snowfall exceeds 4 centimeters and the accumulation could not be avoided on the cover (by heating, clearing ...)

Extinguishing means :

- The company provides 1 powder extinguisher and 2 water extinguishers placed at strategic points within the tent, accessible and usable by everyone.

Protection against the spreading of fire and fire gas via the ventilation systems :

- The flexibility of the cover of the building makes it possible to open the bottom of the tarp or to open the tarp openings at the entrances for a natural ventilation of the tent.

Fire protection for the structure part of the building :

- The construction elements of the building and the tribune have a mechanical resistance to the fire. They were built following the norm EN 13782

  This European Standard specifies safety requirements which need to be observed at design, calculation, manufacture, installation, maintenance, of mobile, temporary installed tents with more than 50 m2 ground area.

- The type of the cover of the building is a tarp of type Precontraint 702 Opaque.

  - Fire technical class B-s2, d0 alt. C-s2, d0 according EN 13501-1 Fire technical class E
  - Meeting the DIN 4102 (B2) requirements

Fire protection towards adjacent buildings :

- The tent is placed at a reasonable distance from other buildings to prevent the risk of fire transmission (8meters).
- An open path of 3m width and 3,50m high is accessible on at least half of the tent so the firemen can access it if needed.

Plan for education and exercises

The member of the team with the SSIAP diploma has to do an update of the first aid training every 2 years and an update of the SSIAP 1 training every 3 years.
The member of the team with the SSIAP diploma is proposing one fire evacuation exercise at the beginning of each tour.

Plan for maintenance and control of all fire protection measures

The extinguishers are checked each year by the competent company.