

STRUCTURAL CALCULATION FOR PENSILSOLE

Structure covered with solar panels

This calculation report refers to one carport with aluminium supporting structure designed by the company **Giulio Barbieri S.r.l. in Poggio Renatico (FERRARA), Italy.** The structure has the following dimensions:

- distance between uprights 6.00 m;
- upright inclination 18°- 40°- 20°;
- beam length 6.00 m;
- purlin length 12.00 m;
- height of the lower part 2.50 m ;
- height of the upper part 4.72 m;

The complete structure consists of one basic module. The carport cover is made up of solar panels with 18° inclination. The structure nodes are made from specific galvanised steel or aluminium elements in order to strengthen the junction points. The following pictures show the finite element modelling of the structure created through the calculation program.

General description of the structure

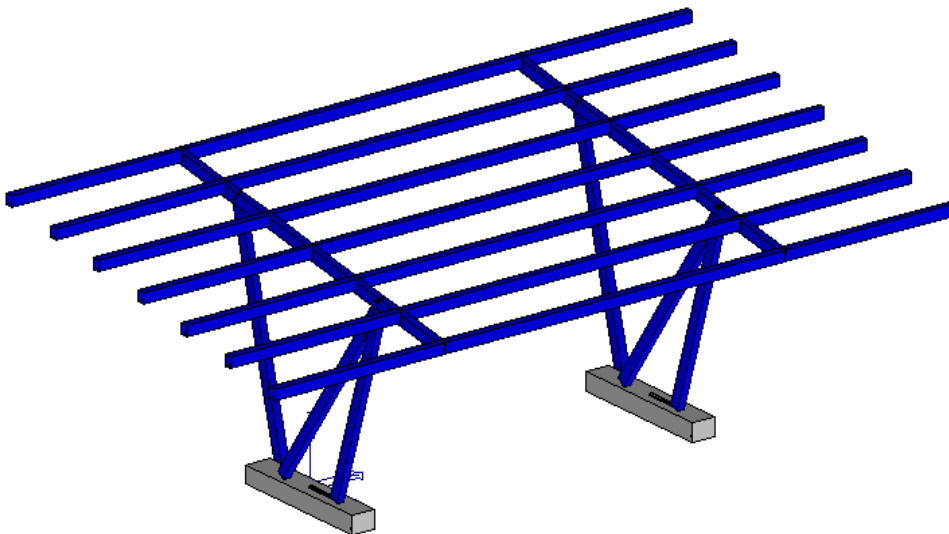


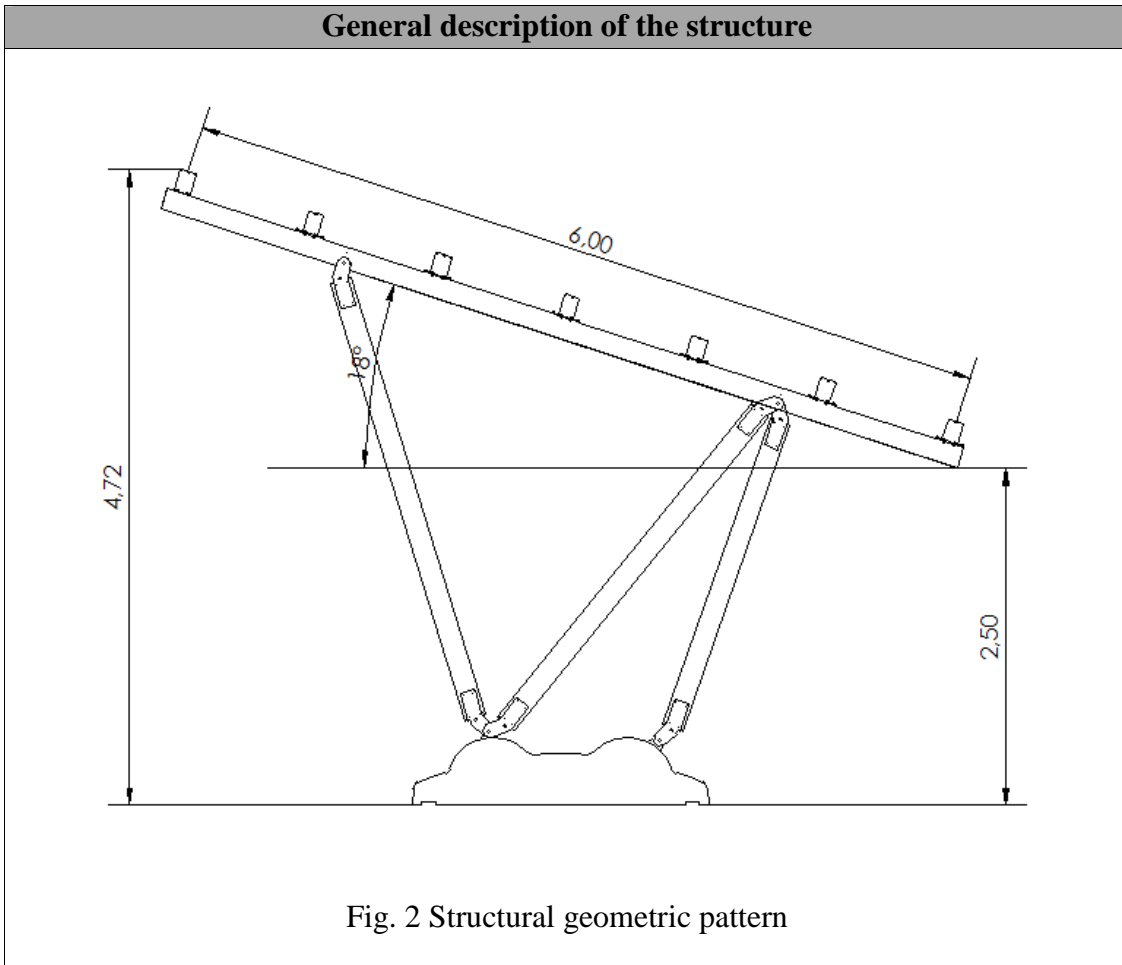
Fig. 1 Three-dimensional modelling of the structure with **4 parking spaces**

Structural calculation:

Dott. Ing. Arianna Quartari
Registered by the “Ordine degli Ingegneri” of Ferrara n°1745



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Verification method: limit states (**Eurocode 3, Eurocode 9**);

LOADS:

SNOW: Q = 150 daN/mq	WIND: Wind pressure = 150 daN/mq
LOADS: Ballast weight = 670 daN	ANCHORING TO THE GROUND: Fz= 3392 daN

GENERAL INSTRUCTIONS:

Snow must be promptly removed from the cover when it exceeds the recommended load.

All components characterised by joints have to be well fixed in order to avoid any removal.
The floor must be flat and compact.
The prescriptions must be periodically checked. (See maintenance plan attached)

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REPORT OF STRUCTURAL CALCULATION

ANALYSIS AND CHECKS WITH THE AID OF CALCULATION CODES

This report of structural calculation, according to point § 10.1 of DM 14/01/08, includes a general description of the structure and of the general criteria for analysis and verification. In addition the information provided in § 10.2 of the DM itself regarding analyses and verifications conducted with the help of calculation codes.

Location of the structure	
Town	STANDARD
Region	

Parameters of the structure			
Use class	Use parameter	Vr period [years]	
II (Normal building)	1	50	

The table below indicates the origin and the characteristics of the software codes, in particular, title, producer, distributor, version and details of licensing agreements:

Origin and Characteristics of the Codes of Calculation	
Title:	PRO_SAP PROfessional Structural Analysis Program 8.5.0
Version:	ENTRY (build 2010-10-153)
Producer-Distributor	2S.I. Software e Servizi per l'Ingegneria s.r.l., Ferrara

A careful preliminary examination of the documentation accompanying the software made it possible to **assess it reliable and suitable for the specific case**. The documentation, provided by the producer and distributor of the software, contains a comprehensive description of the theoretical bases and algorithms used, the identification of the fields of use, as well as test cases entirely resolved and commented, accompanied by the input files necessary to reproduce the elaboration:

Reliability of codes
<p>2S.I. has tested the reliability and robustness of the software code through a significant number of test cases in which the results of numerical analysis were compared with theoretical solutions.</p> <p>Documents containing some of the most significant cases handled are available at the following address: http://www.2si.it/Software/Affidabilità.htm</p>

Below the kind of structural analysis (static, dynamic, linear or non-linear) and the method adopted to solve the structural problem as well as the methodologies followed for the verification or design-verification of the sections. It is reported the load combinations used and, in case of non-linear calculations, the load paths followed; the load configurations considered for the design of the structure in question **were effectively comprehensive for design-verification**.

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The safety verification of structural elements is carried out according to the construction science methods. In order to estimate the tensile-deformation state induced by the static loads, the structural analysis is performed with the displacement method.

The structural analysis is performed according to the finite element method. This method is based on the schematization of the structure by using elements only connected in a fixed number of points, called nodes. The nodes are specified by the three Cartesian coordinates within a global reference system. The unknowns of the problem (within the method of displacements) are the displacement components of the nodes referred to the global reference system (translations with respect to X, Y, Z, rotations around X, Y, Z). The problem is solved by means of a system of linear algebraic equations, whose known values represent the loads applied to the structure and appropriately concentrated on nodes:

$$\mathbf{K} * \mathbf{u} = \mathbf{F}$$

where \mathbf{K} = stiffness matrix
 \mathbf{u} = nodal displacement vector
 \mathbf{F} = nodal force vector

The stresses and/or tensions of each element, which are generally referred to the local reference system, are deduced from the displacements obtained with the system solution.

The reference system used consists of a clockwise system of Cartesian coordinates XYZ. Z-axis is assumed as vertical and upwards oriented.

The elements utilised for the modelling of the structure static scheme are listed below:

TRUSS type element (truss-D2)
BEAM type element (beam-D2)

General information on the calculation and reasoned assessment of acceptability of the results.

The program provides a series of automated controls (checks), which allow the identification of modelling errors. At the end of the analysis, an automatic control identifies the presence of abnormal movements or rotations. We can therefore claim that the calculation is correct and complete. The calculation results were checked proving their reliability. This assessment has included a comparison with the results of simple calculations, performed with traditional methods and adopted even during the first proportioning of the structure. In addition, according to considerations relating to determined states of tension and deformation, the validity of the choices made by schematising and modelling the structure and actions was evaluated. Enclosed at the end of this report, a concise list of the checks carried out (balance checks between constraint reactions and loads applied, comparisons between the results of the analyses and those of simplified assessments, etc.).

For the structure at issue, it is proved that the action of seismic forces, calculated according to the Eurocode 8, is less than the action of wind load and snow load.

Project Engineer:

Ing. Arianna Quartari



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REFERENCE RULES

- UNI EN 1990:2006 13/04/2006 Eurocode 0 – Basis of structural design.
- UNI EN 1991-1-1:2004 01/08/2004 Eurocode 1 – Actions on structures - Part 1-1: General actions – Densities, self-weight, imposed loads for buildings.
- UNI EN 1991-2:2005 01/03/2005 Eurocode 1 – Action on structures - Part 2: Traffic loads on bridges.
- UNI EN 1991-1-3:2004 01/10/2004 Eurocode 1 – Actions on structures - Part 1-3: General actions – Snow loads.
- UNI EN 1991-1-4:2005 01/07/2005 Eurocode 1 - Actions on structures - Part 1-4: General actions – Wind actions.
- UNI EN 1991-1-5:2004 01/10/2004 Eurocode 1 - Actions on structures - Part 1-5: General actions – Thermal actions.
- UNI EN 1993-1-1:2005 01/08/2005 Eurocode 3 – Design of steel structure - Part 1-1: General rules and rules for buildings.
- UNI EN 1993-1-8:2005 01/08/2005 Eurocode 3 - Design of steel structure - Part 1-8: General – design of joints.
- UNI EN 1997-1:2005 01/02/2005 Eurocode 7 – Geotechnical design - Part 1: General rules
- UNI EN 1998-1:2005 01/03/2005 Eurocode 8 – Structures design for seismic resistance - Part 1: General rules, seismic actions and rules for buildings.
- UNI EN 1998-3:2005 01/08/2005 Eurocode 8 - Design of structures for earthquake resistance - Part 3: Assessment and retrofitting of buildings.
- UNI EN 1998-5:2005 01/01/2005 Eurocode 8 - Design of structures for earthquake resistance - Part 5: Foundations, retaining structures and geotechnical aspects.
- Eurocode 9 – Design of aluminium structures.

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MODELLING OF SECTIONS

LEGEND OF THE TABLE OF SECTION DATA

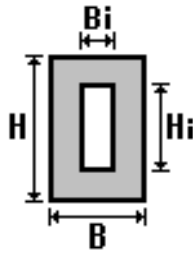
The program allows to use various sections. The following section types are considered:

- 1 section of general type
- 2 simple sections
- 3 coupled and special sections

The sections utilised for modelling are identifiable by means of an identification code and a numerical code (the latter is actually specified in the description of the structural elements). For each section, the table reports the following data:

Area	area of the section
Jt	torsional stiffness factor
J2-2	moment of inertia of the section referred to axis 2
J3-3	moment of inertia of the section referred to axis 3
W2-2	section modulus referred to axis 2
W3-3	section modulus referred to axis 3
Wp2-2	plastic section modulus referred to axis 2
Wp3-3	plastic section modulus referred to axis 3

The data above are used to determine the inertia loads and to define the stiffness of the structural elements; if the value of Area V2 (and/or Area V3) is zero, the shear deformation V2 (and/or V3) is negligible. The inertial characteristics of the sections are estimated within the 2-3 reference of the element.



As regards simple and coupled sections, the reference axis 2 coincides with the x-axis, mentioned in the most widely known section reference charts.

As far as general type sections (type 1) are concerned:
 dimensional values labelled with B refer to the axis 2
 dimensional values labelled with H refer to the axis 3

Id	Type	Area	A V2	A V3	Jt	J 2-2	J 3-3	W 2-2	W 3-3	Wp 2-2	Wp 3-3
10	Rectangular tube: b =12.00 h =16.00 bi=11.20 hi=15.50	18.40	0.0	0.0	778.30	489.30	620.38	81.55	77.55	89.92	95.30

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MODELLING OF MATERIALS

LEGEND OF THE TABLE OF MATERIAL DATA

The materials utilised in the present modelling are identifiable by means of an identification code and a numerical code (the latter is actually indicated in the description of the structural elements). The table shows the following data for each material:

<i>Young</i>	Young's modulus
<i>Poisson</i>	Poisson's ratio
<i>G</i>	shear modulus
<i>Gamma</i>	specific weight
<i>Alfa</i>	coefficient of thermal expansion

The above data are used to simulate the static performance and to determine inertial and thermal loads. In addition, the following information are reported relating to the type of material:

2	aluminium	Ft	breaking tensile strength
		Fy	yield stress
		Fd	estimated strength

TABLE OF MATERIAL DATA

Id	Type / Note		Young	Poisson	G	Gamma	Alfa
		N/mm2	N/mm2		N/mm2	N/mm3	
10	ALUMINIUM Fe = 275.00		7.000e+04	0.30	2.700e+04	2.70e-05	2.32e-05
	ft	275.0					
	fy	240.0					
	fd	218.0					

PARTIAL SAFETY FACTORS

(EC 9 – Design of aluminium structures)

$$\gamma_m - \text{partial safety factor} = 1.10$$

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MECHANICAL CHARACTERISATION OF THE MATERIALS

(EC 9 – Design of aluminium structures)

ALUMINIUM (PROFIL 1) material archive no. 10

f_{cd} - tensile strength = 2.75 kN / mm²

f_{yd} - yield stress = 2.18 kN / mm²

ρ - specific weight = 27.00 kN / m³

E - Young's modulus = 70.00 kN / mm²

G - shear modulus = 26.00 kN / mm²

α - coeff. of thermal expansion = 23x10-6 per ° C

Poisson - Poisson's ratio = 0.35

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WIND AND SNOW ACTIONS

For this calculation report, a standard value for snow load and wind load has been considered as load applied; these values are the maximum values calculated for the structure. The calculation is considered valid also for lower values calculated for the specific areas where the structure is installed.

SNOW LOAD: Q = 150 daN/mq	WIND LOAD: Wind pressure = 150 daN/mq
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LOAD COMBINATION DEFINITION

LEGEND OF THE TABLE OF LOAD COMBINATIONS

The program combines various types of load cases (CDC) according to the standards provided for by the current regulations. These combinations are intended for the safety control of the structure and the verification of displacements and stresses.

The first table of load combinations below contains the following information: *Number*, *Type* and *Identification Code (Id)*. The second table shows the load cases affecting the structure and involved in the load combination, each one indicated with its respective weight.

CDC	Type	Id	Note
1	Ggk	CDC=Ggk (own weight of the structure)	
2	Gsk	CDC=G1sk (permanent load cover)	
3	Qvk	CDC=Qvk (wind load)	
4	Qnk	CDC=Qnk (snow load)	

Cmb	Type	Id	P-delta effect
1	SLU	Comb. SLU A1 1	
2	SLU	Comb. SLU A1 2	
3	SLU	Comb. SLU A1 3	
4	SLU	Comb. SLU A1 4	
5	SLU (Terr. A2)	Comb. SLU A2 5	
6	SLU (Terr. A2)	Comb. SLU A2 6	
71	SLE(r)	Comb. SLE(rare) 71	
72	SLE(r)	Comb. SLE(rare) 72	
73	SLE(f)	Comb. SLE(freq.) 73	
74	SLE(f)	Comb. SLE(freq.) 74	
75	SLE(p)	Comb. SLE(perm.) 75	

Cmb	CDC 1/15...	CDC 2/16...	CDC 3/17...	CDC 4/18...	CDC 5/19...	CDC 6/20...	CDC 7/21...	CDC 8/22...
1	1.30	1.30	1.50	0.75	0.0	0.0	0.0	0.0
2	1.00	1.00	1.50	0.75	0.0	0.0	0.0	0.0
3	1.30	1.30	0.90	1.50	0.0	0.0	0.0	0.0
4	1.00	1.00	0.90	1.50	0.0	0.0	0.0	0.0
5	1.00	1.00	1.30	0.65	0.0	0.0	0.0	0.0
6	1.00	1.00	0.78	1.30	0.0	0.0	0.0	0.0
71	1.00	1.00	1.00	0.50	0.0	0.0	0.0	0.0
72	1.00	1.00	0.60	1.00	0.0	0.0	0.0	0.0
73	1.00	1.00	0.20	0.0	0.0	0.0	0.0	0.0
74	1.00	1.00	0.0	0.20	0.0	0.0	0.0	0.0
75	1.00	1.00	0.0	0.0	0.0	0.0	0.0	0.0

Fundamental combination for the ultimate limit states (SLU):

$$\gamma_{G1} \cdot G_1 + \gamma_{G2} \cdot G_2 + \gamma_{Qk} \cdot Q_K$$

Seismic combination, used for the ultimate and the serviceability limit states connected with the seismic action E:

$$E + G_1 + G_2 + \psi_k \cdot Q_K$$

Characteristic combination (rare), used for irreversible serviceability limit states (SLE):

$$G_1 + G_2 + Q_K$$

Frequent combination, used for reversible serviceability limit states (SLE):

$$G_1 + G_2 + \psi_{11} \cdot Q_K$$

Almost permanent combination (SLE), generally used for long-run effects:

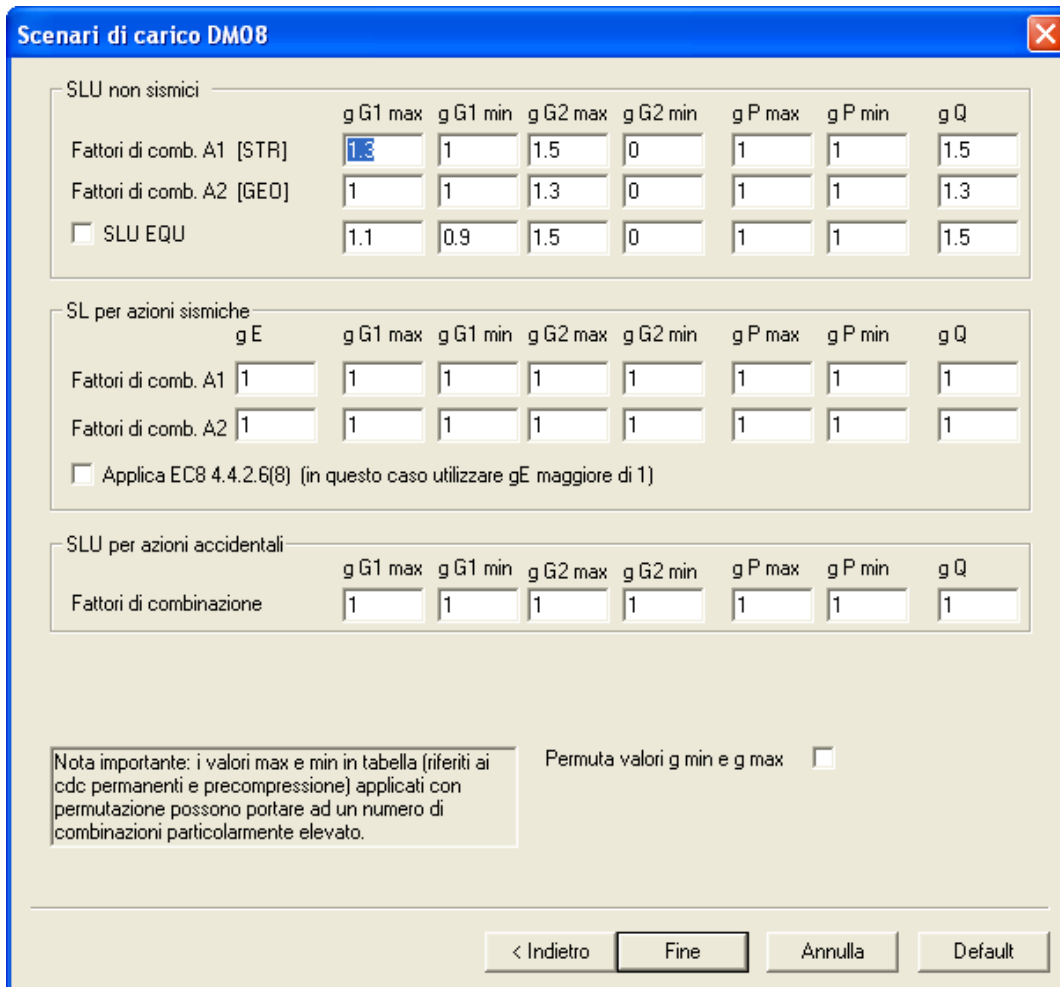
$$G_1 + G_2 + \psi_{21} \cdot Q_K$$

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The following is the description of the coefficients related to the regulations in use:

- **gG1max (γ_{G1})** – partial coefficient of the own weight of the structure, as well as of the own weight of the soil and water, when appropriate, with maximum value;
- **gG1min (γ_{G1})** – partial coefficient of the own weight of the structure, as well as of the own weight of the soil and water, when appropriate, with minimum value;
- **gG2max(γ_{G2})** – partial coefficient of the own weights of the non-structural elements with maximum value;
- **gG2min(γ_{G2})** – partial coefficient of the own weights of the non-structural elements with minimum value;
- **gQ (γ_{Qk})** – multiplier coefficient of the case of variable load;

The values of the partial safety coefficients on actions, assumed at the SLU, in accordance with DM2008, are shown in the following table, derived from the calculation program Pro-Sap:



Scenari di carico DM08							
SLU non sismici							
	g G1 max	g G1 min	g G2 max	g G2 min	g P max	g P min	g Q
Fattori di comb. A1 [STR]	1.5	1	1.5	0	1	1	1.5
Fattori di comb. A2 [GEO]	1	1	1.3	0	1	1	1.3
<input type="checkbox"/> SLU EQU	1.1	0.9	1.5	0	1	1	1.5
SL per azioni sismiche							
g E	g G1 max	g G1 min	g G2 max	g G2 min	g P max	g P min	g Q
Fattori di comb. A1	1	1	1	1	1	1	1
Fattori di comb. A2	1	1	1	1	1	1	1
<input type="checkbox"/> Applica EC8 4.4.2.6(8) (in questo caso utilizzare gE maggiore di 1)							
SLU per azioni accidentali							
	g G1 max	g G1 min	g G2 max	g G2 min	g P max	g P min	g Q
Fattori di combinazione	1	1	1	1	1	1	1
Nota importante: i valori max e min in tabella (riferiti ai cdc permanenti e precompressione) applicati con permutazione possono portare ad un numero di combinazioni particolarmente elevato. <input type="checkbox"/> Permuta valori g min e g max							
<input type="button" value=" < Indietro"/> <input type="button" value=" Fine"/> <input type="button" value=" Annulla"/> <input type="button" value=" Default"/>							

For the structure in question, A1 combination factors have been used.

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Legend of the screenshot

Scenari di carico DM08	Load scenarios DM08
SLU non sismici	Non-seismic SLU
Fattori di comb. A1 (STR)	Combination factors A1 (STR)
Fattori di comb. A2 (GEO)	Combination factors A2 (GEO)
SLU EQU	SLU EQU
SL per azione sismiche	SL for seismic actions
Fattori di comb. A1	Combination factors A1
Fattori di comb. A2	Combination factors A2
Applica EC8 4.4.2.6(8) (in questo caso utilizzare gE maggiore di 1)	Apply EC8 4.4.2.6(8) (in this case use gE greater than 1)
SLU per azioni accidentali	SLU for accidental actions
Fattori di combinazione	Combination factors
Nota importante: i valori max e min in tabella (riferiti ai cdc permanenti e precompressione) applicati con permutazione possono portare ad un numero di combinazioni particolarmente elevato.	Important note: max and min values in the table (referred to permanent cdc and prestress) applied with permutation can lead to a particular elevated number of combinations.
Permuta valori g min e g max	Permutation values g min and g max

SAFETY RESULTS FOR STABILITY

Safety against overturning is carried out as follow (point 7.2 UNI EN 13782:2006):

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

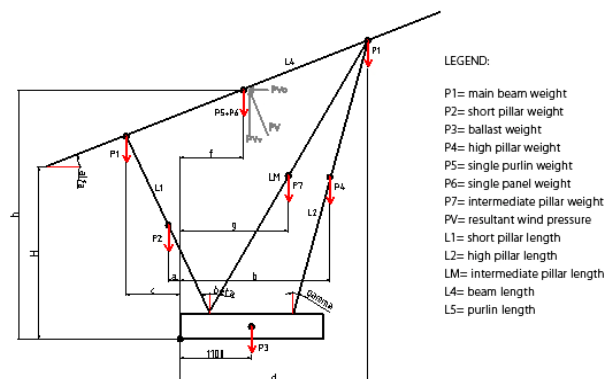
where:

γ - safety factor

$M_{ST,k}$ - single components of the stabilizing moment (SLE)

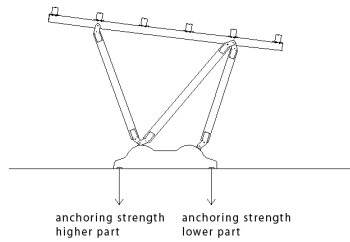
M_{Kk} - single components of the overturning moment (SLE)

The picture below shows the calculation scheme used in the spreadsheet to perform the verifications for the stability of the structure.



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This figure represents the anchoring scheme of the structure to the ground:



DATA ENTRY				
BEAM LENGTH		m	PROFILE TYPE (1/2/4)	No. ELEMENTS
SHORT PILLAR L1 =	L1	2.40	1	2
HIGH PILLAR L2 =	L2	3.40	1	2
PILLAR LM =	LM	3.00	1	2
PURLIN L5 =	L5	9.00	1	7
BEAM L4 =	L4	6.00	1	2
BALLAST WEIGHT =	Gball		-	2
PANELS / FABRIC	Gcov		PANELS	
	α	18	m	
	β	19.38	m	
	γ	17.18	m	
	a =	-0.137	m	
	b =	2.232	m	
	c =	-0.326	m	
	d =	2.734	m	
	e =	2.734	m	
	f =	1.530	m	
	H =	2.500	m	

Mstab = 5441,98 kgm

wind pressure 150 kg/mq
 Rwind 8100 kg

Moverturning = 20367.06 kgm

Fsafety 0.27 <1 (anchoring is needed)

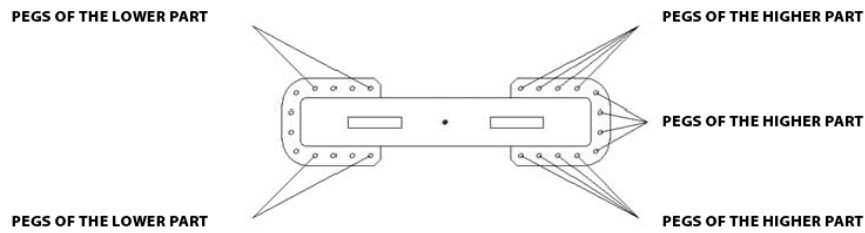
Anchoring strength 3392 kg **The program reports the value of the anchoring to the ground of each ballast for the stability of the structure**

For the foundation, it is required to use such a number of pegs that the overturning of the structure is avoided ensuring an anchoring strength of the higher part according to the values reported in the table for each ballast; for the lower part, it is required a value of safety anchoring against acts of vandalism.

WIND Kg/mq	ANCHORING daN
150	3392
100	1849
80	1232

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The picture below shows the rough schematic of the position of the pegs:



The estimated values for the peg extraction, to be considered depending on the soil characteristics, are shown in the table below (point 8 UNI EN 13782:2006):

SOIL TYPES	PEG BEARING CAPACITY l'=100 cm d= 3 cm Zd (daN)
Rigid cohesive soils and inconsistent compact soils	195
Very rigid cohesive soils	240
Cohesive soils with consistency not less than medium to rigid	300
Inconsistent compact soils	510

Given the geotechnical characteristics of the installation site of the structure, data supplied by the design architect or by the customer, it is possible, according to the previous table, to evaluate the number of pegs needed for the carport anchoring to the ground in order to ensure safety against overturning, sliding and lifting.

Safety against slide (point 7.2 UNI EN 13782:2006) is performed as follow without pegs to the ground:

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

γ - safety factor

N - normal force (SLE)

H - horizontal force (SLE)

μ - coeff. of friction (0,5)

with pegs anchored to the ground:

$$\sum \gamma \mu N + Z_{d,h} \geq \sum \gamma Hk$$

where :

$Z_{d,h}$ - resistant horizontal force of the pegs

The Pro-Sap calculation program indicates values of the horizontal force in foundation:

$$F_x = 23 \text{ kN e } F_y = 16 \text{ kN}$$

the number of pegs (N°) should be for every ballast as follow:

$$F_{res} = N^\circ \times A \times f_{tk} \text{ (Fe 360-S235)} = 2N^\circ \times 706.5 \text{ mm}^2 \times 360 \text{ N/mm}^2 = 508 \text{ kN} \gg 23 \text{ kN} = F_x$$

Lift verification is considered satisfied as the overturning verification is positively tested.

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CALCULATION SCHEME

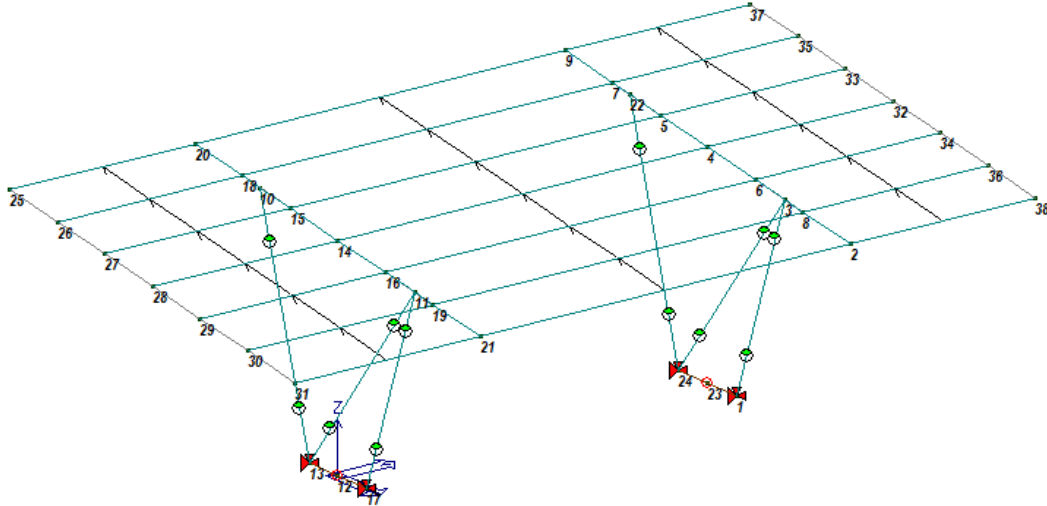


fig. 3 Node numbering of the structure

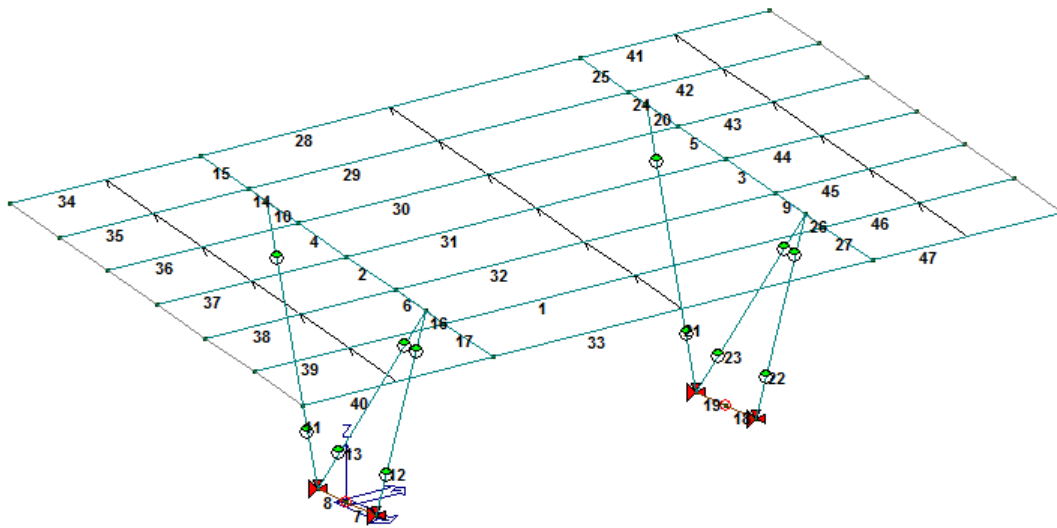


fig. 4 D2 numbering of the structure

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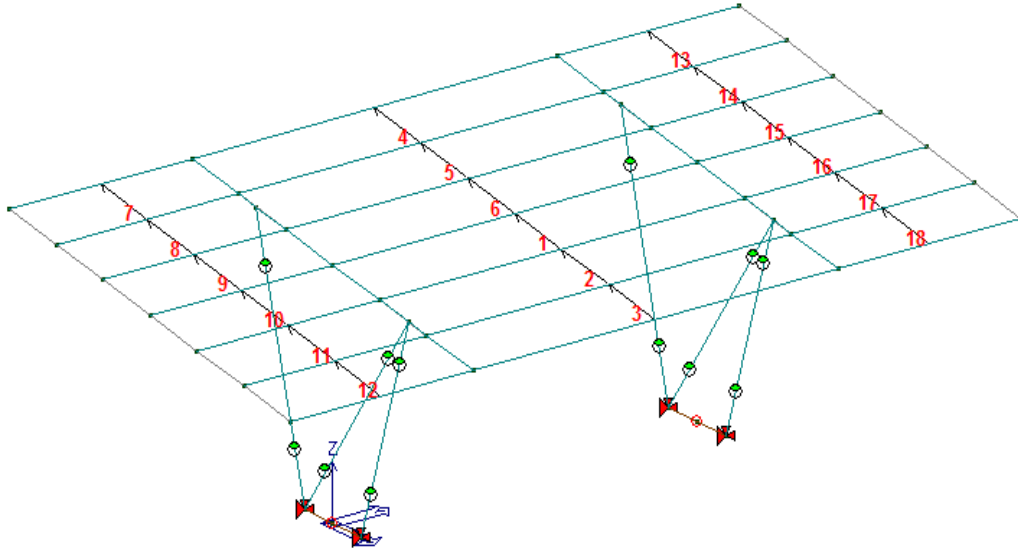


fig. 5 Numbering of covering elements

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LOADS

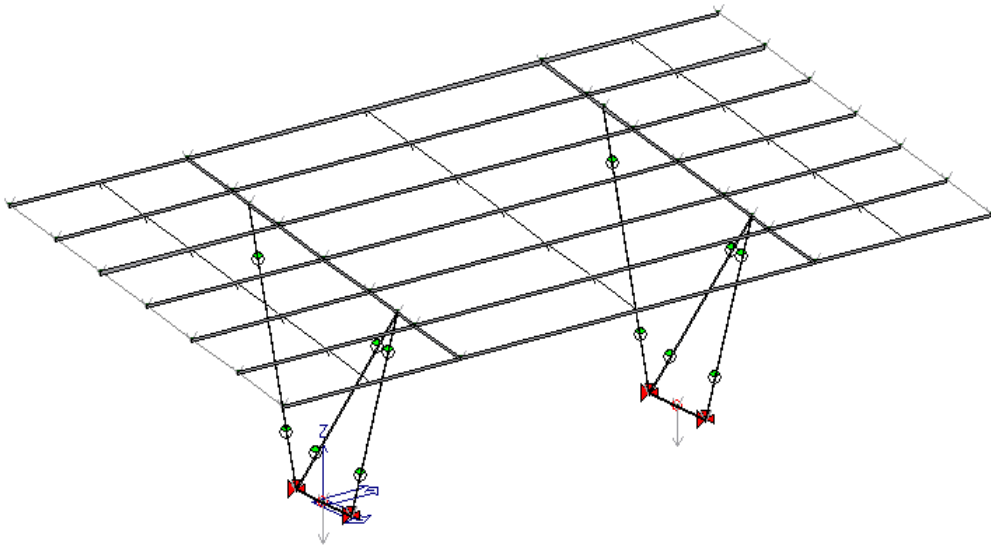


fig. 6 Own weight G_{gk} (own weight of the structure)
complete structure scheme

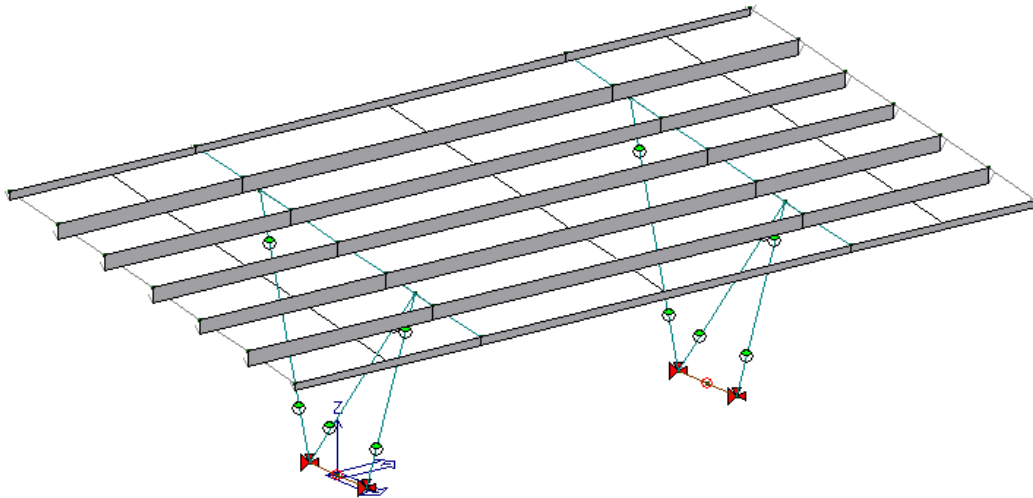


fig. 7 G_{1sk} (permanent load cover)

OWN WEIGHT OF COVERING PANELS

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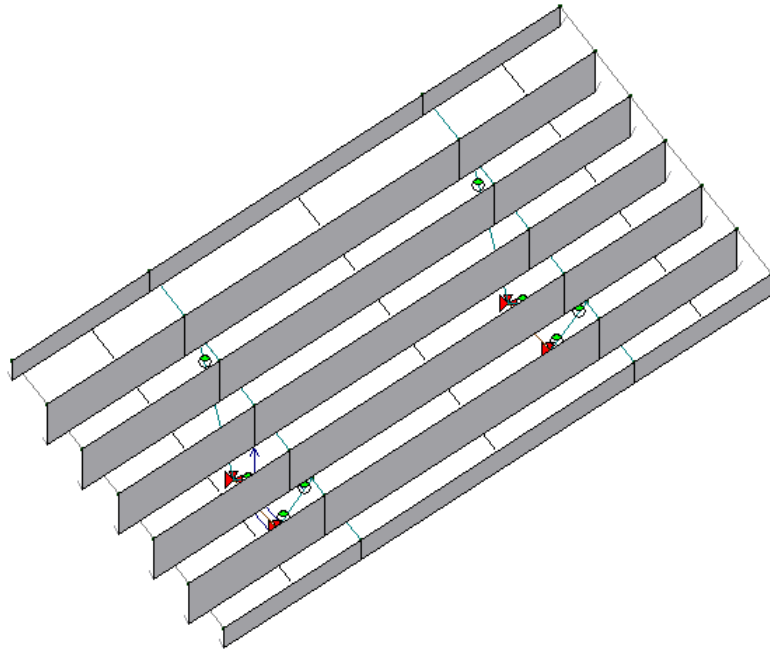


fig. 8 Q_{nk} (snow load)

SNOW LOAD

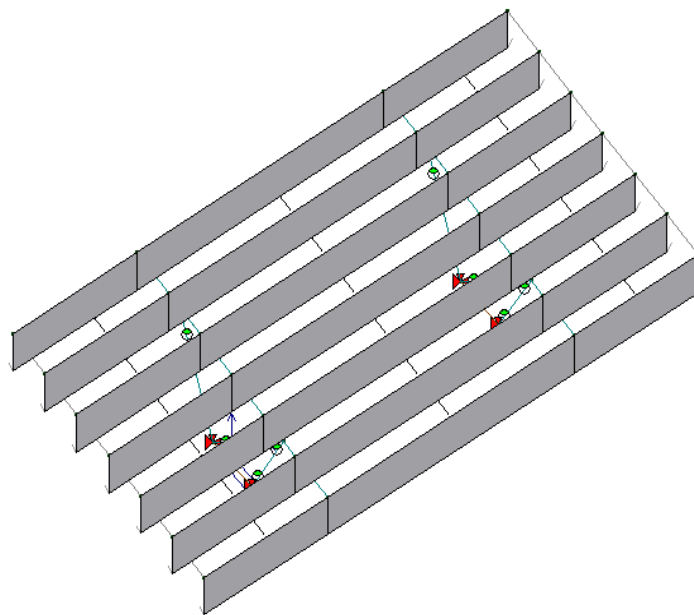


fig. 9 Q_{vk} (wind load - compression)

WIND LOAD

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RESULTS OF STRESS ACTIONS N-M-T

The following pages show the results of structural calculation:

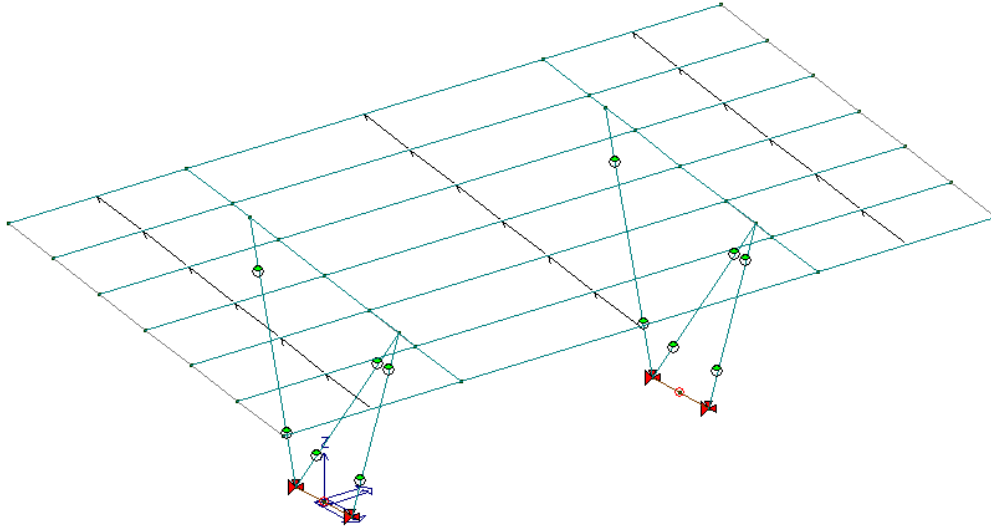


fig. 10 Structural scheme

The results concerning the following stress actions are listed below:

- Normal stress
- Moment 3-3
- Moment 2-2
- Shear 2
- Tension N-M

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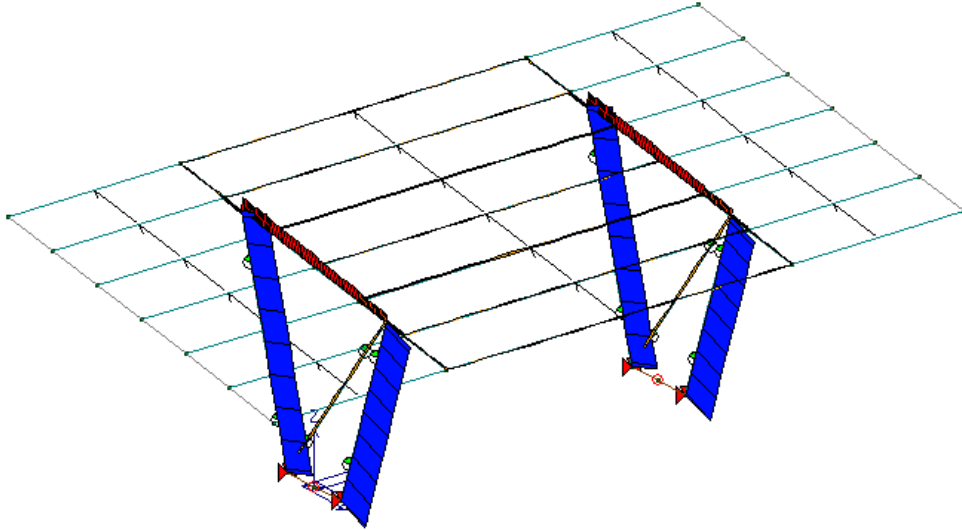
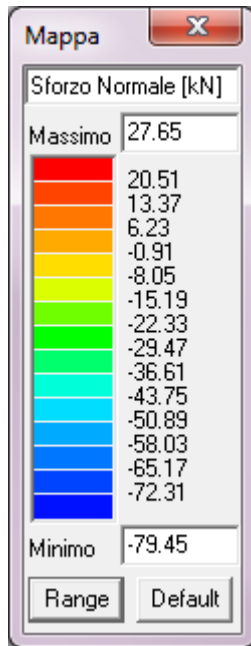


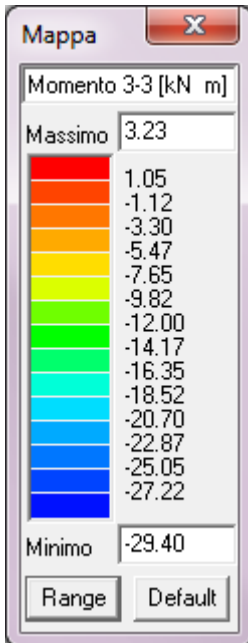
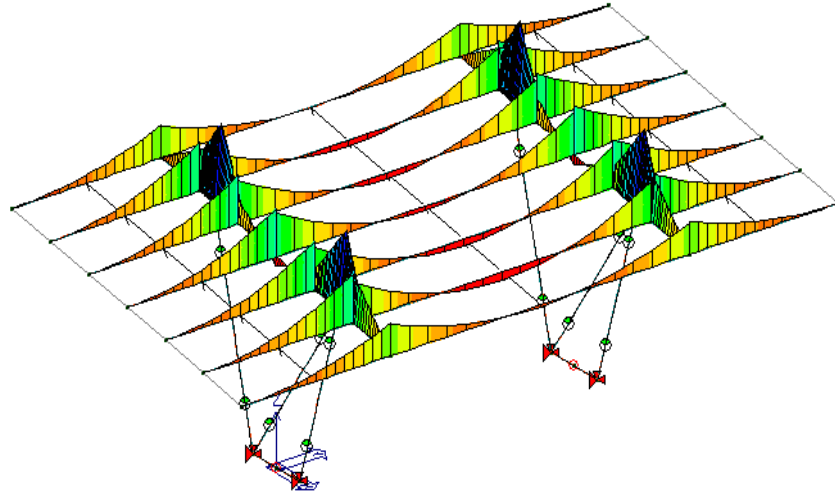
fig. 11 Normal stress - Comb. SLU 3
SNOW + WIND compression



Legend	
Mappa	Function
Sforzo normale [kN]	Normal stress
Massimo	[kN]
	Maximum
Minimo	Minimum
Range	Range
Default	Default

Max normal stress on pillars = - 79.45 kN

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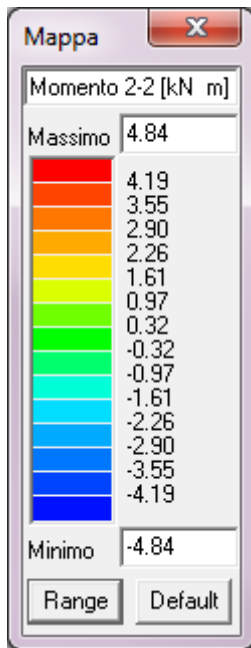
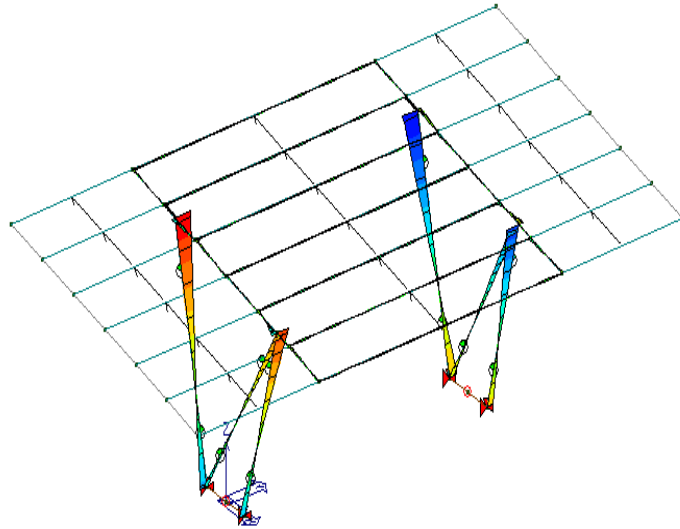


Legend	
Mappa	Function
Momento 3-3 [kN m]	Moment 3-3 [kN m]
Massimo	Maximum
Minimo	Minimum
Range	Range
Default	Default

fig. 12 Moment M 3-3 - Comb. SLU 3
SNOW + WIND compression

Max. negative moment beam= - 29.40 kNm
Max. positive moment beam = + 3.23 kNm

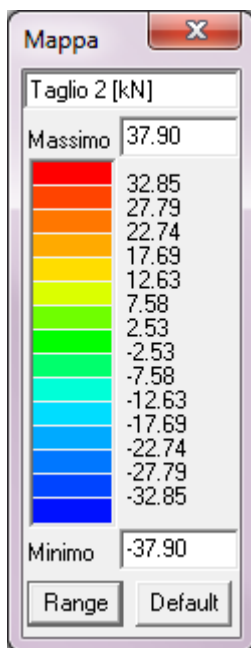
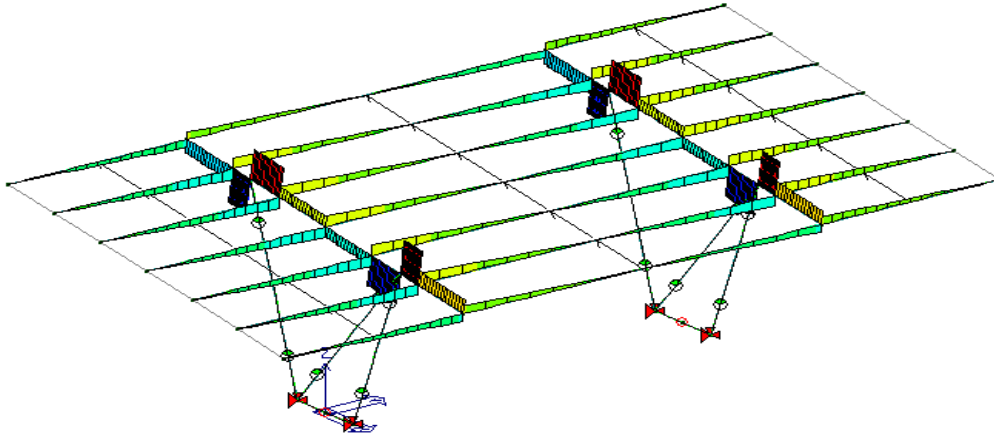
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Legend	
Mappa	Function
Momento 2-2 [kN m]	Moment 2-2 [kN m]
Massimo	Maximum
Minimo	Minimum
Range	Range
Default	Default

fig. 13 Moment M 2-2 - Comb. SLU 3
SNOW + WIND compression

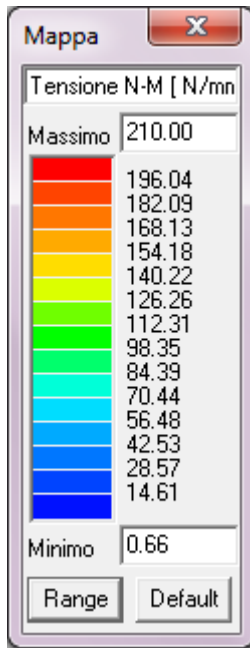
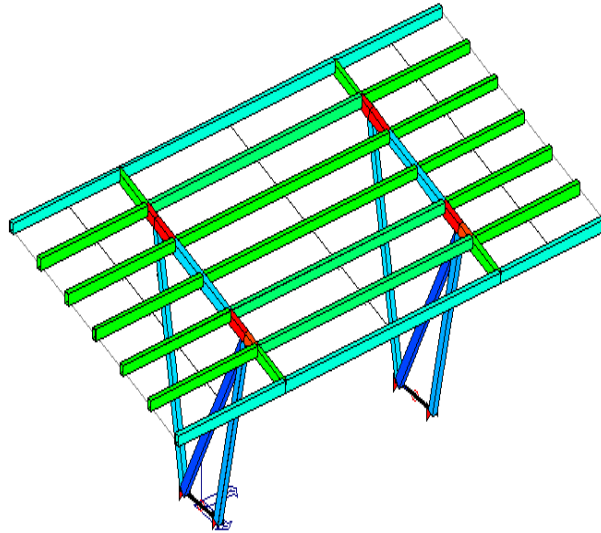
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Legend	
Mappa	Function
Taglio 2 [kN]	Shear 2 [kN]
Massimo	Maximum
Minimo	Minimum
Range	Range
Default	Default

fig. 14 Shear 2 - Comb. SLU 3
SNOW + WIND compression

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Legend	
Mappa	Function
Tensione N-M [N/mn]	Tension N-M [N/mn]
Massimo	Maximum
Minimo	Minimum
Range	Range
Default	Default

fig. 15 Tension N-M - Comb. SLU 3
SNOW + WIND compression
Tension < 210N/mm²

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CHECK RESULTS

In the following pages, it is reported a summary of the results concerning the structural calculation checks:

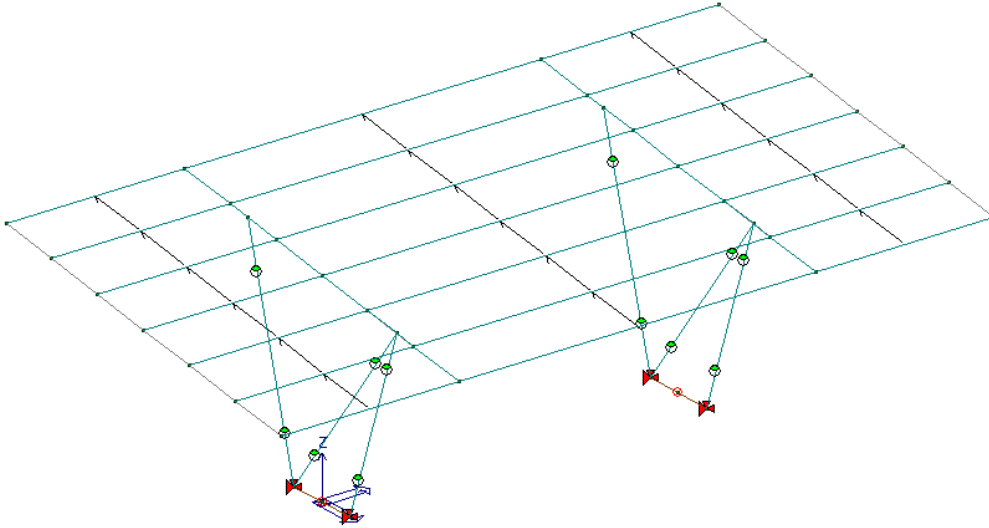
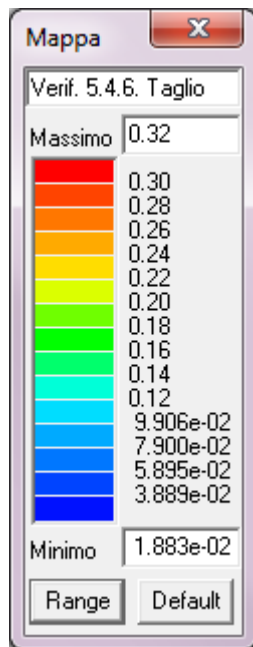
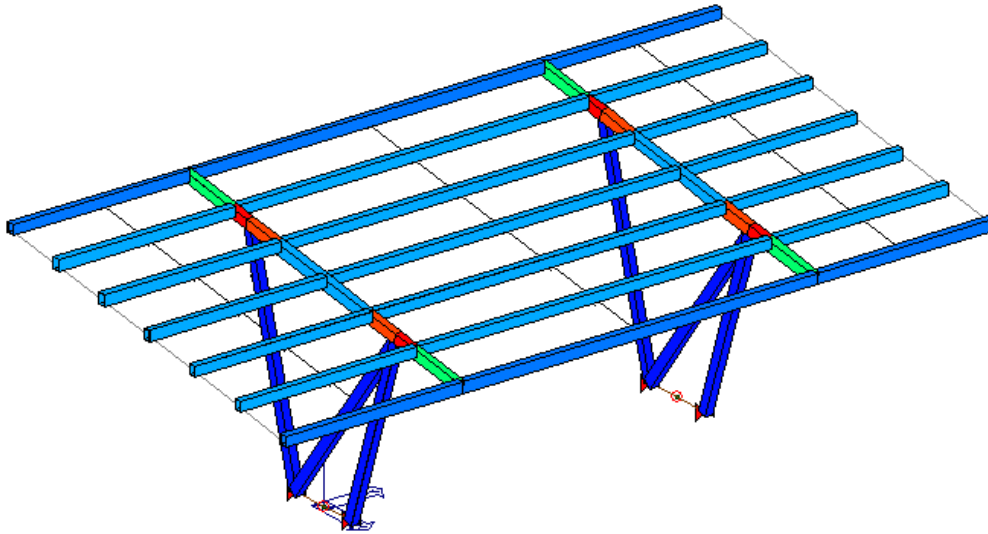


fig. 16 - Structural scheme

The results of the following verifications are listed hereunder:

- Shear check SLU
- Normal stress, moment, shear check SLU
- Bending check SLE

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Legend	
Mappa	Function
Verif. 5.4.6 Taglio	Verif. 5.4.6 Shear
Massimo	Maximum
Minimo	Minimum
Range	Range
Default	Default

fig. 17 Verif. 4.2.4.1.2 V/T (Shear) SLU
(positive check < 1)

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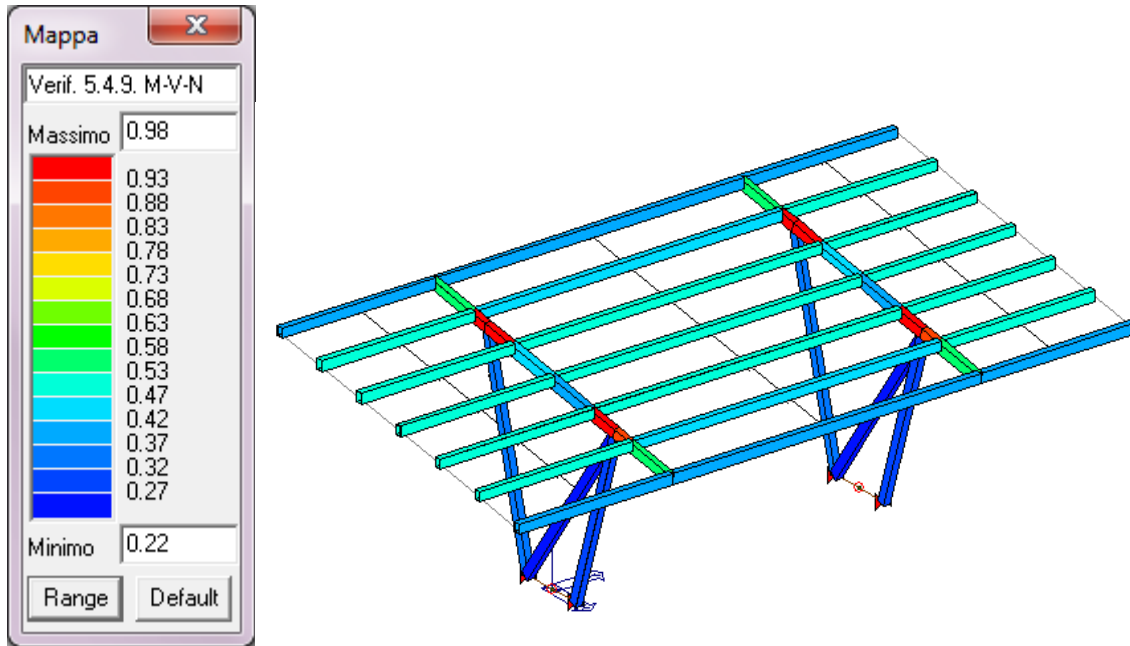
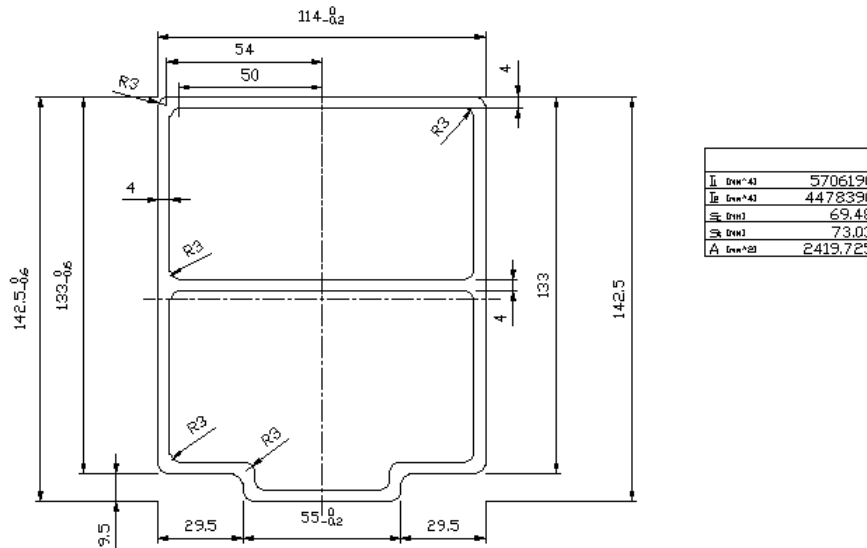
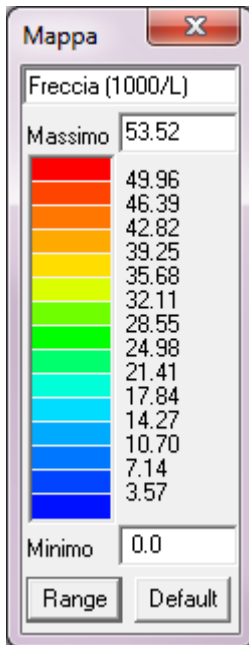
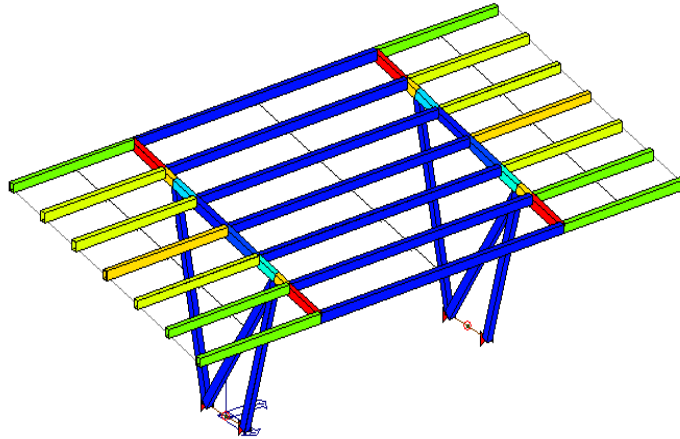


fig. 18 Verif. 4.2.4.1.2 M/V/N (Moment, shear, normal stress) SLU
(positive check < 1)

The main beam, in correspondence to the cantilever, will be reinforced in the most stressed points, in particular at the intersection with the pillars through an inner support:



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Legend	
Mappa	Function
Freccia (1000/L)	Bending (1000/L)
Massimo	Maximum
Minimo	Minimum
Range	Range
Default	Default

fig. 19 Bending check SLE

EC9 CODE CHECKS FOR ALUMINIUM ELEMENTS

LEGEND OF THE TABLE FOR EC9 CODE CHECKS FOR ALUMINIUM ELEMENTS

The program can check the following element types:

1. **trusses/rods** 2. **beams** 3. **pillars**

The result of the code checks expressed by the following symbols:

- Ok:** positive check
NV: negative check
Nr: check not required or not meaningful

For convenience, results are grouped in three tables depending on the type of element.

Regarding code check (as UNI ENV 1993-1-1 June 1994) elements can differ as in the following table:

Code check	Trusses	Beams	Pillars
5.3 Section class	X	X	X
5.4.3 Traction	X	X	X
5.4.4 Compression	X	X	X
5.4.6 Shear		X	X
5.4.9 Bending, shear and axial force		X	X
5.5.1 Members in compression	X	X	X
5.5.2 Flexural-torsional buckling		X	X
5.5.3 Axial bending and traction		X	X
5.5.4 Axial bending and compression		X	X
5.6.7 Resistance to shear buckling (shear, moment and axial force)		X	X
5.9.4 Built-up members with small spacing	X	X	X
5.9.5 Built up members with cross section	X	X	X
5.2.5 Stability for lateral displacements			X
5.2.6 Frame stability			X

The above code checks are applied to elements if their section is appropriate, as reported in the table below:

Action	PARAMETRIC SECTIONS	SIMPLE SECTIONS	BUILT-UP SECTIONS
5.3 Automatic section class	L, double T, C, rectangular tube and circular pipe	All	From simple section
5.3 Section class default 2	Circular		
5.3 Section class default 3	Remaining		
5.4.3 Traction	Yes	Yes	Yes
5.4.4 Compression	Yes	Yes	Yes
5.4.6 Shear	Yes	Yes	Yes
5.4.9 Bending, shear and axial force	Yes	Yes	Yes
5.5.1 Members in compression	Yes	Yes	with small spacing and cross
5.5.2 Flexural-torsional buckling	Symmetrical double T	Double T	No
5.5.3 Axial bending and traction	Symmetrical double T	Double T	No

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5.5.4 Axial bending and compression	Yes	Yes	with small spacing and cross
5.6.7 Resistance to shear buckling (shear, moment and axial force)	Simmetric double T	Double T	No

The results of the tables describe code checks. Verifications are reported as the ratio of design forces on ultimate capacity so they are positive if ratio is less or equal 1.

Truss/rod		Beam		Pillar		Element number
State						Code check for resistance, stability and twist
Note						Section and materials used for the element
V5.4.3/5.4.4						(TRUSSES) code check as point 5.4.3 and 5.4.4
V5.4.6						(BEAMS AND PILLARS) code check as point 5.4.6
V5.4.9						(BEAMS AND PILLARS) code check as point 5.4.9
N	M3	M2	V2	V3	T	Design forces interesting verification
V5.5.1						(TRUSSES) code check as point 5.5.1
V5.5.4						(BEAMS AND PILLARS) code check as point 5.5.4 (without flexural-torsional buckling reported at point 5.5.2)
BetaxL		B22xL		B33xL		Buckling lengths (if indicated relating to the normal plane with 2-2 or 3-3)
Slenderness		Snel22		Snel33		Slenderness (if indicated relating to the normal plane with 2-2 or 3-3)
Chi mn						Reduction coefficient for buckling for bending
Rif. cmb						Load combinations that gave maximum code check value
V5.5.2						(BEAMS AND PILLARS) code check as point 5.5.2 (considering flexural-torsional buckling with tension and compression as 5.5.3 and 5.5.4)
B1-1 x L						Buckling length for torsion
Chi LT						Reduction coefficient for buckling in torsion

Truss	State	Note	V5.4.6	V5.4.9	V5.5.4	B22xL	B33xL	Snel22	Snel33	Chi mn	V5.5.2	B11xL	Chi LT	Rif. cmb
1	ok,ok,nr,nr	s=10,m=10	0.09	0.82		cm	cm					cm		3,3,0,0
2	ok,ok,ok,nr	s=10,m=10	0.09	0.73	0.11	3.0	4.0	0.6	0.6	1.00				3,1,29,0
3	ok,ok,ok,nr	s=10,m=10	0.09	0.73	0.11	3.0	4.0	0.6	0.6	1.00				3,1,26,0
4	ok,ok,nr,nr	s=10,m=10	0.09	0.78										3,1,0,0
5	ok,ok,nr,nr	s=10,m=10	0.09	0.78										3,1,0,0
6	ok,ok,nr,nr	s=10,m=10	0.28	0.98	0.31	3.0	4.0	0.6	0.6	1.00				3,1,27,0
9	ok,ok,nr,nr	s=10,m=10	0.28	0.98	0.31	3.0	4.0	0.6	0.6	1.00				3,1,24,0
10	ok,ok,nr,nr	s=10,m=10	0.28	0.98										3,1,0,0
13	ok,ok,ok,nr	s=10,m=10	0.02	0.29	0.29	3.0	4.0	0.6	0.6	1.00				24,24,24,0
14	ok,ok,nr,nr	s=10,m=10	0.32	0.98	0.98	3.0	4.0	0.6	0.6	1.00				1,1,1,0
15	ok,ok,nr,nr	s=10,m=10	0.14	0.98	0.98	3.0	4.0	0.6	0.6	1.00				1,1,1,0
16	ok,ok,nr,nr	s=10,m=10	0.32	0.98	0.19	3.0	4.0	0.6	0.6	1.00				1,1,27,0
17	ok,ok,nr,nr	s=10,m=10	0.14	0.98	0.09	3.0	4.0	0.6	0.6	1.00				1,1,23,0
20	ok,ok,nr,nr	s=10,m=10	0.28	0.98										3,1,0,0
23	ok,ok,ok,nr	s=10,m=10	0.02	0.29	0.29	3.0	4.0	0.6	0.6	1.00				27,27,27,0
24	ok,ok,nr,nr	s=10,m=10	0.32	0.98	0.98	3.0	4.0	0.6	0.6	1.00				1,1,1,0
25	ok,ok,nr,nr	s=10,m=10	0.14	0.98	0.98	3.0	4.0	0.6	0.6	1.00				1,1,1,0
26	ok,ok,nr,nr	s=10,m=10	0.32	0.98	0.19	3.0	4.0	0.6	0.6	1.00				1,1,24,0
27	ok,ok,nr,nr	s=10,m=10	0.14	0.98	0.09	3.0	4.0	0.6	0.6	1.00				1,1,28,0
28	ok,ok,ok,nr	s=10,m=10	0.07	0.73	0.15	3.0	4.0	0.6	0.6	1.00				1,1,23,0
29	ok,ok,ok,nr	s=10,m=10	0.09	0.86	0.86	3.0	4.0	0.6	0.6	1.00				3,3,3,0
30	ok,ok,ok,nr	s=10,m=10	0.09	0.89	0.12	3.0	4.0	0.6	0.6	1.00				3,3,10,0
31	ok,ok,ok,nr	s=10,m=10	0.09	0.91	0.91	3.0	4.0	0.6	0.6	1.00				3,3,3,0
32	ok,ok,nr,nr	s=10,m=10	0.09	0.87										3,3,0,0
33	ok,ok,ok,nr	s=10,m=10	0.07	0.71	0.71	3.0	4.0	0.6	0.6	1.00				1,1,1,0

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Truss	State	Note	V5.4.6	V5.4.9	V5.5.4	B22xL	B33xL	Snel22	Snel33	Chi mn	V5.5.2	B11xL	Chi LT	Rif. cmb
34	ok,ok,ok,nr	s=10,m=10	0.07	0.74	0.74	3.0	4.0	0.6	0.6	1.00				1,1,1,0
35	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.14	3.0	4.0	0.6	0.6	1.00				3,3,16,0
36	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.97	3.0	4.0	0.6	0.6	1.00				3,3,3,0
37	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.97	3.0	4.0	0.6	0.6	1.00				3,3,3,0
38	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.97	3.0	4.0	0.6	0.6	1.00				3,3,3,0
39	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.97	3.0	4.0	0.6	0.6	1.00				3,3,3,0
40	ok,ok,ok,nr	s=10,m=10	0.07	0.74	0.74	3.0	4.0	0.6	0.6	1.00				1,1,1,0
41	ok,ok,ok,nr	s=10,m=10	0.07	0.74	0.06	3.0	4.0	0.6	0.6	1.00				1,1,7,0
42	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.13	3.0	4.0	0.6	0.6	1.00				3,3,7,0
43	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.11	3.0	4.0	0.6	0.6	1.00				3,3,7,0
44	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.10	3.0	4.0	0.6	0.6	1.00				3,3,7,0
45	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.11	3.0	4.0	0.6	0.6	1.00				3,3,25,0
46	ok,ok,ok,nr	s=10,m=10	0.09	0.97	0.12	3.0	4.0	0.6	0.6	1.00				3,3,9,0
47	ok,ok,ok,nr	s=10,m=10	0.07	0.74	0.06	3.0	4.0	0.6	0.6	1.00				1,1,9,0
Truss			V5.4.6	V5.4.9	V5.5.4	B22xL	B33xL	Snel22	Snel33	Chi mn	V5.5.2	B11xL	Chi LT	
			0.32	0.98	0.98	3.00	4.00	0.61	0.65	1.00				

Truss	State	Note	V5.4.6	V5.4.9	V5.5.4	B22xL	B33xL	Snel22	Snel33	Chi mn	V5.5.2	B11xL	Chi LT	Rif. cmb
						cm	cm					cm		
11	ok,ok,nr,nr	s=10,m=10	0.03	0.55	0.98	543.5	543.5	109.8	88.1	0.21				28,3,3,0
12	ok,ok,ok,nr	s=10,m=10	0.03	0.48	0.94	472.0	472.0	95.4	76.5	0.28				24,3,3,0
21	ok,ok,nr,nr	s=10,m=10	0.03	0.55	0.98	543.5	543.5	109.8	88.1	0.21				23,3,3,0
22	ok,ok,ok,nr	s=10,m=10	0.03	0.48	0.94	472.0	472.0	95.4	76.5	0.28				27,3,3,0
Truss			V5.4.6	V5.4.9	V5.5.4	B22xL	B33xL	Snel22	Snel33	Chi mn	V5.5.2	B11xL	Chi LT	
			0.03	0.55	0.98	543.54	543.54	109.82	88.06	0.21				

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FOUNDATION REPORT

No. of ballasts	=	1			
No. of purlins	=	7		Length of the purlins	= 6
No. of pillars lower part No.1	=	1		Length of the pillar lower part	= 2.4
No. of pillars higher part	=	1		Length of the pillar higher part	= 3.4
No. of pillars lower part No.2	=	1		Intermediate pillar length	= 3
No. of main beams	=	1		Length of the beams	= 6
K – covered area	=	36	m ²		
W _{snow}	=	150	kgm ²		
W _{wind}	=	150	kgm ²		
W _{cover}	=	23	kgm ²		
Weight cover of the structure =	=	204	kg		
Weight pillars of the structure =	=	42.8	kg		
Weight beams of the structure =	=	29	kg		
No. of ballasts =	=	1			
Weight of ballasts =	=	670	kg		
W_{tot}	=	946.0			
	1	x	W_{tot} structure		= 946.0
	1	x	W _{cover}	x	S = 828
	1	x	W _{snow}	x	S = 5400
	1	x	W _{wind}	x	S = 5400
Wloads SLE					12574.0

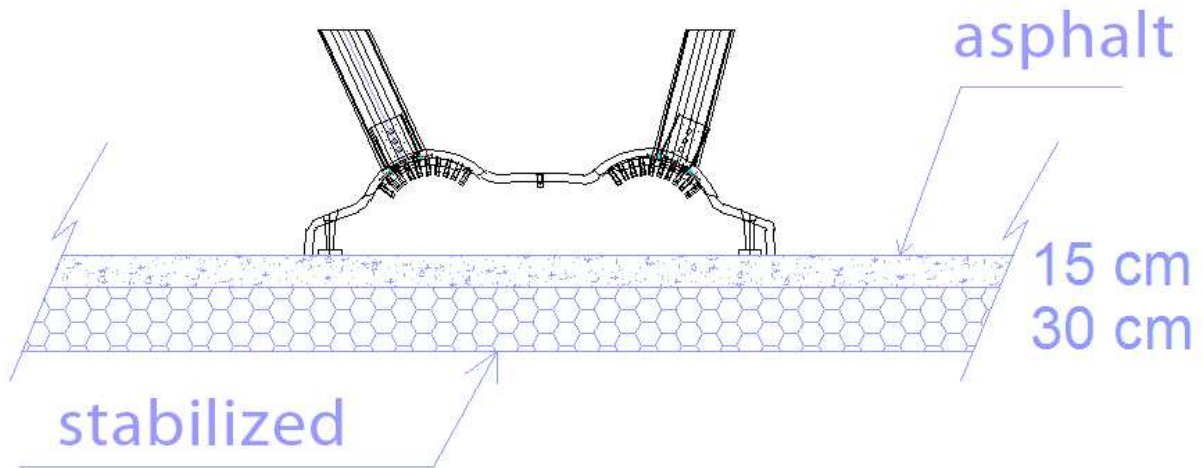
Pressure on the soil = Ploads/Ballast-surface = **1.59** kg/cm²

This tension value must be lower than the limit load of the bearing capacity of the ground.

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From the Excel spreadsheet we get a pressure on the ground of **1.59 kg/cm²**; the value of the limit bearing capacity of the ground must be greater than such limit value compatible with the characteristics of the soil and the subsidences calculated in relation to the central ballast most heavily loaded. On the destination site, there is a paved foundation that will ensure the distribution of the stresses on the ground to make them compatible with those of the foundation ground.

The structure will be built on a slab foundation that will distribute the loads on the ground helping to reduce tensions on the ground.



Note:

For any doubt concerning the interpretation of the present translation, please refer to the original Italian document.

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MAINTENANCE PLAN

MANUFACTURER:

Giulio Barbieri S.r.l.
Via Ferrara, 41
44028 Poggio Renatico (Ferrara) Italy

PROJECT ENGINEER:

Ing. Arianna Quartari



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FOREWORD

The maintenance plan is the complementary document to the working project. It delineates, in due consideration of the achieved project works, the expected, planned and scheduled maintenance activities of the structure in order to keep its functionality, quality features, efficiency and economic value over time.

The maintenance plan consists of the following documents:

- user guide;
- maintenance guide with maintenance schedule.

DESCRIPTION OF THE STRUCTURE

Type of structure: structure with aluminium framework.

Intended use: photovoltaic.

USER GUIDE

The user guide is referred to the most important parts of the structure, with particular attention to those parts that may cause risks if not correctly used. The user guide includes information about the position of the parts to be maintained, their graphic representation, description and proper use.

Structure n. 1 – Foundation ballasts

Description:

Non-underground foundation structures, placed at the base of the pillars.

Position:

See working drawings.

Graphic representation:

See constructional drawings.

Proper use:

Transfer of the structure static stresses to the ground within the pressure and subsidence limits laid down by the project.

Structure n. 2 - Aluminium columns

Description:

Vertical structures made of metal profiles.

Position:

See working drawings.

Graphic representation:

See constructional drawings.

Proper use:

Transfer static stresses diffused from the superstructure levels to the foundation level.

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Structure n. 3 - Aluminium beams

Description:

Horizontal or inclined structures that transfer loads to pillars or walls.

Position:

See working drawings.

Graphic representation:

See constructional drawings.

Proper use:

Transfer the loads of the cover to vertical structures.

Element n. 4 – Connecting nodes

Description:

Joints between:

- upright – ballast
- upright – main beam
- purlin – main beam

Position:

See working drawings.

Graphic representation:

See constructional drawings.

Proper use:

Transfer loads to vertical and horizontal structures.

MAINTENANCE GUIDE:

The maintenance guide refers to the maintenance of the most important parts of the structure. It reports the performance minimum standard, possible anomalies, maintenance interventions carried out directly by the user and those by a qualified personnel.

The maintenance schedule sets maintenance interventions and checks to be accomplished following specified deadlines.

Structure n. 1 – Foundation ballasts

Position:

See working drawings.

Graphic representation:

See constructional drawings.

Performance minimum standard:

Resistance to project stresses. Production with materials having specific characteristics required by the project.

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Possible anomalies:

Subsidences, damages of the superstructure, caused by changes of the soil conditions due to: variations of the phreatic aquifer, broken drainage system or water pipes placed close to the foundation, etc.

Type of control:

Visual.

Control frequency and operator:

Every year, carried out by the user.

Type of intervention:

- land consolidation works determined after specific checks.
- check of the anchorages at the base of the structure.

Intervention frequency and operator:

When it is needed, carried out by qualified personnel.

Structure n. 2 – Aluminium columns**Position:**

See working drawings.

Graphic representation:

See constructional drawings.

Performance minimum standard:

Resistance to project stresses. Production with aluminium in compliance with project requirements, see the material certificates.

Possible anomalies:

Nothing was noticed.

Type of control:

Visual.

Control frequency and operator:

Every year, carried out by the user.

Type of intervention:

None foreseen.

Intervention frequency and operator:

When it is needed, carried out by the user.

Structure n. 3 – Aluminium beams**Position:**

See working drawings.

Graphic representation:

See constructional drawings.

Performance minimum standard:

Resistance to project stresses. Production with aluminium in compliance with project requirements, see the material certificates.

Possible anomalies:

Nothing has been noticed.

Type of control:

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Visual.

Control frequency and operator:

Every year, carried out by the user.

Type of intervention:

None foreseen.

Intervention frequency and operator:

When it is needed, carried out by the user.

Structure n. 4 – Connecting nodes

Position:

See working drawings.

Graphic representation:

See constructional drawings.

Performance minimum standard:

Resistance to project stresses. Production with steel in compliance with project requirements, see the material certificates.

Possible anomalies:

None.

Type of control:

Visual.

Control frequency and operator:

Every year, carried out by the user.

Type of intervention:

- use of anti-rust products and restoration of the protective layer.
- check that the screws of the nodes are properly fastened.

Intervention frequency and operator:

When it is needed, carried out by the user.

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