Omniflow

WIND & SOLAR POWER

INDEX

1. **PURPOSE**

This document describes the scaling and security verification of the elements that support the **OmniLED 07** (rotor, generator and external cap), in particular, column/support pole and its foundation to the conditioning action ï Wind, to:

- Omniled 07 with **6m (19' 8 7/32")** height column;
- Omniled 07 with **8m (26' 2 31/32")** height column.

2. **BRIEF DESCRIPTION**

The OmniLED 07 is a lamp (smart) 100% autonomous powered exclusively by the action of wind and sun, composed by a wind turbine with a vertical and omni-directional axis, operating according to any wind direction, and solar panels arranged on top of the OmniLED cap, materializing by so, a renewable energy solution that combines wind and solar energy.

Figure 1 ï OmniLED 07 model illustration ï autonomous lamp (no scale)

The OmniLED 07 (PCT ï Patent pending), as well as the remaining range of Omniflow wind turbines, can be subdivided into two main groups: OmniLED wind turbine support structure and the OmniLED itself. This second group is composed primarily by the outer cap, especially designed to maximize the effectiveness of air mass circulation throughout the inside of the structure, to house the photovoltaic panels and the LEDs, conditioning it aesthetic appearance, 5 blades rotor and permanent magnet generator, of which we highlight the following:

Dimensions (approx..)	Rotor: 2' 3 9/16" diameter; Structure: 3' 11 1/4" diameter; 11 13/16" height; in a recycable composite material
Generator	Permanent magnets generator; non-ferrous stator
Power control	12v regulator, Hybrid ï wind/solar
Power	Wind: 100 W @ 36'/s Solar: 60 Wp
Operating speeds	Start up at sustained 4' 11 1/32"/s; cut in sustained 9' 10 3/32"/s
Battery	12V 500Wh C10 Lead Crystal (embedded)
Lighting power	10W (standby); 35W/ 45W (optional) ï movement detection and activation
Lumen/ illuminance	5100 lm/ 7200 lm (optional)
Color temperature	4000K
Lifetime expectancy	25 years (annual inspections recommended)
Rotor	Recycable material ï reinforced polyamide PAG
Column / Pole	6,0m (19' 8 7/32") or 8,0m (26' 2 31/32")
Weight (approx.)	44.09 lb

Table 1 ï OmniLED key features

Regarding the OmniLED itself, it can be highlighted the head of the column/pole and the interface base with the generator (where the hood wind turbine, the generator and the rotor will be installed later), and the support column/pole and it base for fixation in the installation point.

With the exception of the support column/pole and it fixation base ï mass/foundation ï in addition to the visual interaction, these components have no direct interference with the installation point, even in what regards the

propagation of vibrations, in phase of OmniLED operation, where these are minimized or canceled at the level of the columnôs head and interface with the generator, by use of a stripe of resilient material in the assembly of these component to the column support.

With respect to the support column and it fixation base (as a whole) thereôs no need for a direct interaction with the installation point ï the connection to the ground via a foundation of reinforced concrete mass, it is therefore necessary to adjust the solution of fixation of these elements according to local conditions and characteristics, ie, the geological and geotechnical characteristics of the soil that will seat to that foundation.

3. **DIMENSIONING ASSUMPTIONS**

3.1. Quantification of the conditioning action – Wind (w)

To determine the resulting stresses at the foundation level it was carried out a model of the column at 19' 8 7/32" and 26' 2 31/32" respectively, built-in at the level of the base and on this were applied forces that result from actions on the column and in the diffuser of the OmniLED.

It was decided to resort to the Security Regulation and Actions in Buildings and Bridges Structures (simplified called RSA) to proceed to the quantification of the actions, since, in identical conditions, in structures with less than 32' 9 45/46" height, this regulation tends to be more onerous than the European standard (transposed into Portuguese norm) NP EN 1991-1-4, also known has ñEuricodeò EC1 (part 4, wind action quantification) ï in *“Wind Action – quantification according to EC1, Luciano Jacinto – Instituto Superior de Engenharia de Lisboa, January of 2014”.*

According to the Regulation it was also considered the most unfavorable condition of exposure to wind, particularly regarding to the orography (zone B ï regions of the continent situated along the coastal region with 3.10 ml width or 656.17 yards altitude, or the Azores and Madeira archipelagos) and to the aerodynamic roughness of the soil (Type II roughness ï rural and/or peripheral urban areas).

3.2. Conditions of the site – Geology and Geotechnics

With regard to the interaction soil/foundation structure, and not being possible to define general conditions which are likely to apply to any location in which is desired to install an OmniLED, it were defined, for the basic scaling of the foundation structure, conservative conditions. These conditions are simplified translated into properties and strength of the soil foundation ï moderate geotechnical parameters likely to be encountered in most natural land

(no landfill materials, topsoil and/or organic matter), naturally consolidated, compact/hard and not saturated.

Thus, for the purpose of dimensioning, were admitted geotechnical parameters and characteristics/minimum conditions of the foundation soil that will be need to be verified and confirmed in each installation site:

- allowable stress in the basic ground where the foundation will sit **≥ 10.87 psi**;

- soil friction angle at the level of the foundation base and confining material foundation, **Ø ≥ 30^0**;

- coefficient of side reaction of the soil, **K ≥ 254.8 lb/ft^3**.

3.3. Characteristics of structural materials – column and foundation mass

With regard to the characteristics of the materials that form the support column and respective foundation, in the current design and safety verification the following characteristics were considered:

Concrete

- Concrete NP EN 206-1; C25/30; XC2 (Pt)

Steel

- Passive armor in ribbed bars A500NR
- Steel screws 8.8
- Steel anchors A500
- Steel profiles and plates S275

Covering the armor

- In concrete foundations ..... 1 31/32" (1 3/8" , in the case of prefabricated elements).

Note that for the mass/foundation shoe is considered that the density of the element must be equal or superior to **152.88 lb/ft^3**, regardless of whether it is a fresh concrete casting element at the installation site itself or a prefabricated element.

3.4. Verification of scaling assumptions

This technical note and present scaling are valid only for the conditions set forth herein, or others who, in any case, do not reflect unfavorable conditions as those which are defined here by other assumptions.

For conditions and resulting assumptions worse than those set forth herein, one shall proceed to the verification of the structural elements safety ï support column, basis setting and foundation and, of necessary, make a new scaling suitable to the specific requirements of the new conditions.

4. OMNILED 07 FOUNDATION AND SUPPORT STRUCTURE ACTIONS AND SCALING

The considered actions in scaling the various structural elements (in this case only the wind has been considered to promote a conditioning action to the scaling of the support column and foundation), as well as it combinations, where applicable, were made in accordance with the provisions in the Security Regulation and Actions in Buildings and Bridges Structures (RSA). The following describes the actions considered to the general scaling of the structure.

4.1. Permanent actions

Permanent actions are those that assume constant values or with little variation around the average value, during the whole or virtually the entire life of the structure, namely:

- Concrete elements ..... γ = 159.25 lb/ft^3
- Steel elements ..... γ = 500.682 lb/ft^3
- OmniLED (cap + structure of the cap + generator + rotor) ..... 44.96 lbf

The weight of the remaining structural elements (support column, column base plates and other connecting elements) was automatically considered in computer program, through the geometry of the sections and specific weights of the constituent materials.

4.2. Variable actions

Variable actions are those that assume values with significant variation around its average value during the life expectancy of the structure.

Due to the low mass of the OmniLED and it reduced deposition area (on considering the available area for the deposition of snow), the variable actions Earthquake (E) and Snow (S), regardless the location of such wind turbine, donôt reveal constraints to the design and verification of safety limit states, last and of use/service (ELU e ELS, respectively). Thus, as already mentioned in this case, it has been considered for the design of the support structure and foundation only the conditioning action, ie, the wind.

The next section it is defined the action considered to act on the support column at the cap level of the OmniLED.

4.2.1. Wind (W)

In wind action setting to act in the column support and the cap of the OmniLED, according to the regulation, were considered the most unfavorable conditions of exposure to wind, namely:

- zone B (land orography ï regions of the continent situated along a coastal strip with 3.10 miles width or 656.17 yards altitude, or the Azores and Madeira);

- Roughness type II (soil aerodynamic roughness ï rura and/or peripheral urban areas).

Since the column height is less than 10.0m (32' 9 45/64") , for aerodynamic roughness soil type II, the characteristic value of the dynamic pressure (wk) is constant and assumes the value of 0.13053 psi (standard value for zone A). However, considering that for the B zone the characteristic values of the average speed to be adopted must be multiplied by 1.1, then the characteristic value of the dynamic pressure results into:

- w_k =0.14359 psi

In turn, the force (F) ï acting force into the support column and/or OmniLED cap, is the result of:

- $F = \delta_f \times w_k \times (d \times h)$; where:

  - δ_f is the force coeficiente, which depends on the shape of the section, slenderness, section and characteristic value of the dynamic pressure (for the column, assuming a form of a ñdodecagonalò section, δ_f = 1,3; for the OmniLED cap, assuming a form of a circular section with a smooth surface, δ_f = 0,5);

  - *d* is the diameter of the section;

- *h* is the height of the section considered.

For each column, 6m (19' 8 7/32") and 8m (26' 2 31/32"), with variable section height (conical), the acting forces on these elements due to wind action would assume, respectively, the following distribution:

Column	H [ft]	Diam. [in]	F [lb/ft]
6,0m	19'8 7/32"	3 1/2	7.88
	16'4 27/32"	4 9/64	9.25
	13'1 31/64"	4 23/32	10.55
	9'10 7/64"	5 5/16	11.92
	6'6 47/64 "	5 29/32	13.22
	3'3 3/8"	7 3/64	15.76

Column	H [ft]	Diam. [in]	F [lb/ft]
8,0m	26'2 61/64"	3 1/2	7.88
	22'11 19/32"	4 9/64	9.25
	19'8 7/32"	4 23/32	10.55
	16'4 27/32"	5 5/16	11.85
	13'1 31/64"	5 29/32	13.15
	9'10 7/64"	6 29/64	14.52
	6'6 47/64 "	6 59/64	15.82
	3'3 3/8"	8 15/64	18.43

Table 2 ï Acting forces on the conical column due to the action of the regulatory wind ï RSA, respectively to a 6,0 and 8,0m column

For calculation purposes was simply admitted, for each column, a regular trapezoidal diagram, with the maximum and minimum values in the above table.

With regard to the OmniLED cap, wether it is on a column of 6.0 or over a column of 8.0m(since H Ò32' 9 45/64"), the resulting acting force is:

OmniLED	H [in]	Diam. [ft]	F [lb/ft]
Cap	11 13/16	3'11 1/4"	12.19

Table 3 ï Forces acting on the OmniLED cap due to the action of the regulatory wind - RSA

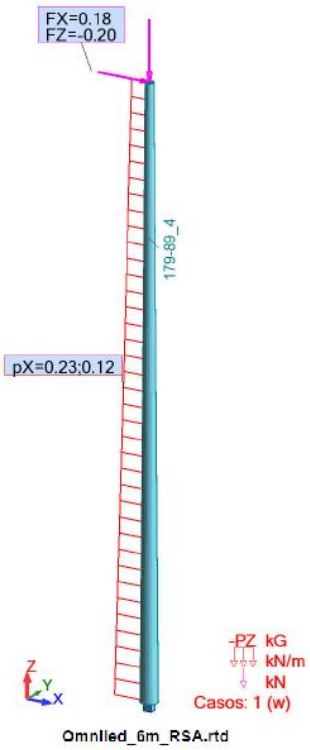
4.3. Share combinations

On the security check concerning the various limit states the combination of actions whose simultaneous action is likely to produce the most unfavorable effects in the structure are considered.

Combined actions considered for scaling are proposed by RSA for a wind base variable action (w), being the analysis concerning the support structure carried out towards the Ultimate States Limits, while the deformations are checked by the United Service Limit.

4.4. Modelling and scalling

The actuating efforts at the support level (foundation structure) of the support column of the OmniLED, the combined actions and it consequent security verifications where obtained with the aid of a software developed to perform the calculation and scaling of the structures as well as obeying to the various regulations and legislation in force.



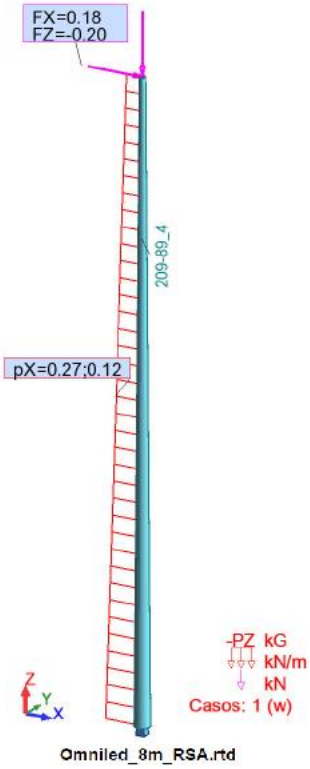


Figure 3 ï Modeling of the support structure of the OmniLED (column of 6,0 to 8,0m) ï acting loads (S/scale)

It was considered the column base with support built-in to the indicated heights of 6,0 and 8,0m, referring to the height differences between the top surface of the mass/foundation and the top of the column head of the OmniLED.

4.4.1. Results

Reactions in the base of the column

The following figures illustrate the reactions on the basis in Limit State Service and Ultimate State Limit of the combined actions and therefore the resultant forces for the scaling of the foundation structure:

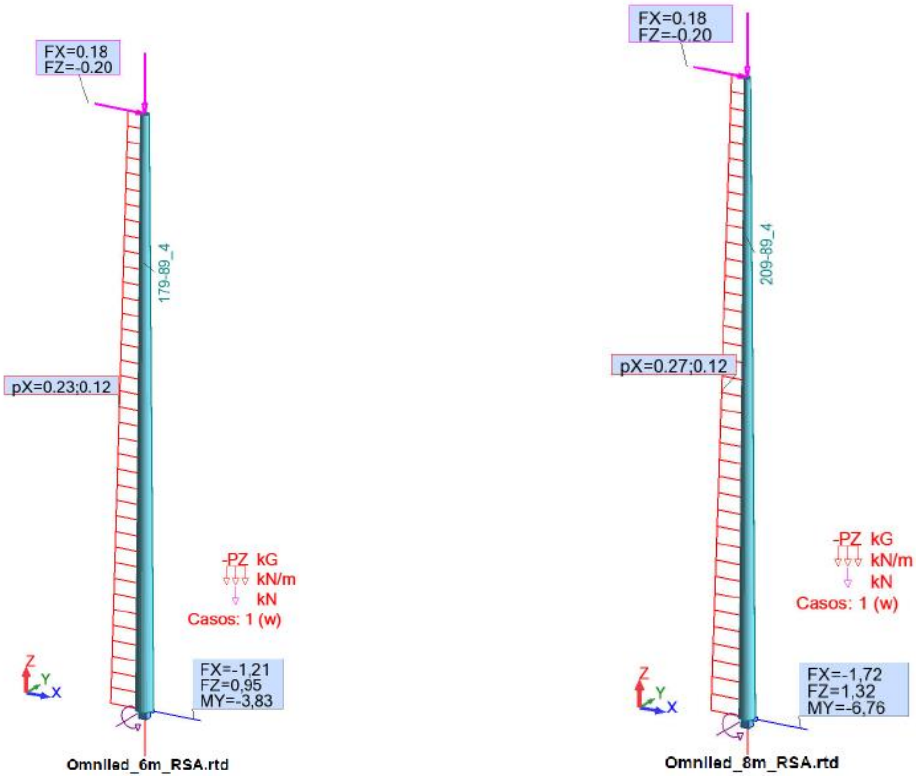


Figure 4 ï Modeling of the OmniLED support structure (column of 6,0 and 8,0m) ï Reactions in the vase (ELS) - S/esc.

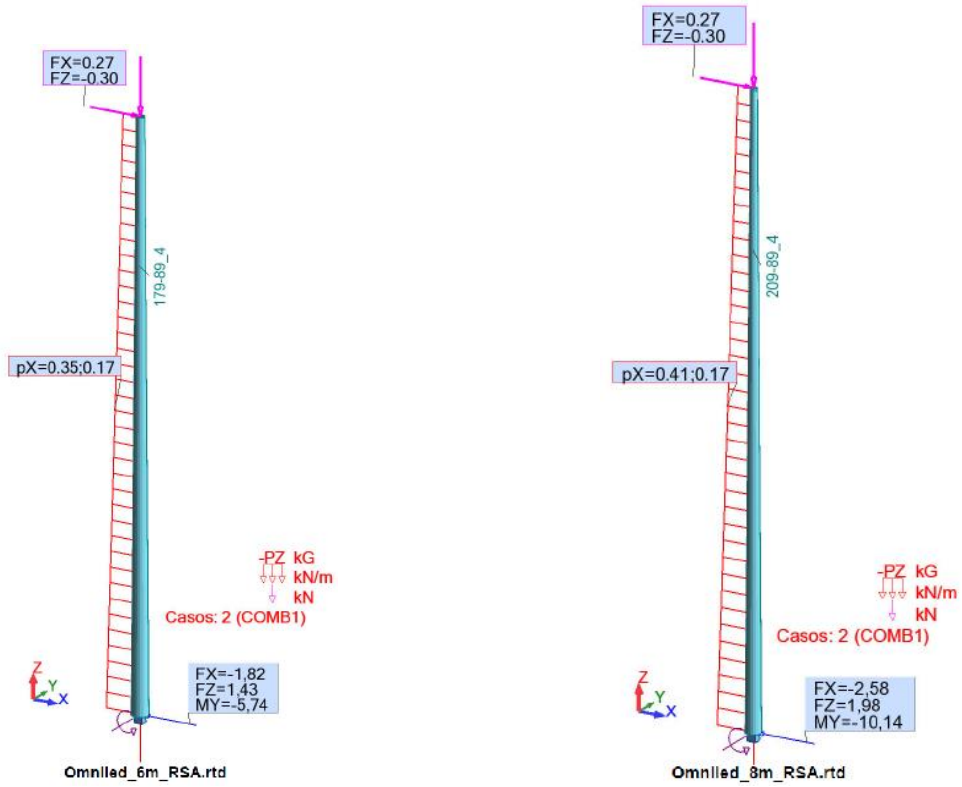


Figure 5 ï Modeling of the OmniLED support structure (column of 6,0 and 8,0m) ï Reactions in the base (ELU) - S/esc.

In the following table the results are summarized for each type of column and for each considered State:

Column	Horizontal reaction Fhd/ Fhsd (Fx) – [lbf]	Normal reaction Nd/ Nsd (Fz) – [lbf]	Rotation moment Md/ Msd (My) – [lbf/ft]
6,0m [ELS/ ELU]	-272.01 / -409.15	213.56 / 321.47	-262.43/ -393.31
8,0m [ELS/ ELU]	-366.43 / -548.53	341.70 / 510.31	-446.76/ -670.14

Table 4 ï Summary of the reactions at the base of the columns (6,0 and 8,0m)

Deflection and maximum stress

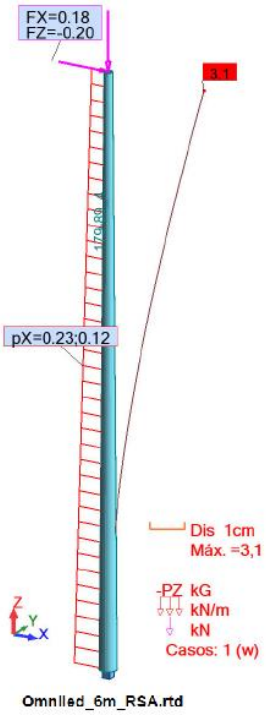
With regard to the maximum deflection at the top of the column and the maximum stress verified at the bottom of

the column, these, in addition to the acting loads, depend on the material and section considered. As mentioned above, the support columns present with variable section height (conical), having considered the following sections and material for each type of column:

Column	Base section [in]	Top section [in]	Thickness [in]	Material
6.0m	$7\ ^{3}/_{64}$	$3\ ^{1}/_{2}$	$^{5}/_{32}$	Steel - S275
8.0m	$8\ ^{15}/_{64}$	$3\ ^{1}/_{2}$	$^{5}/_{32}$	Steel - S275

Table 5 ï Characteristics of the columns - 6,0 and 8,0m

Based on these section and material, were obtained deflections (in State Service Limit) and stress (in the Ultimate Limit State) identified in the following figures.



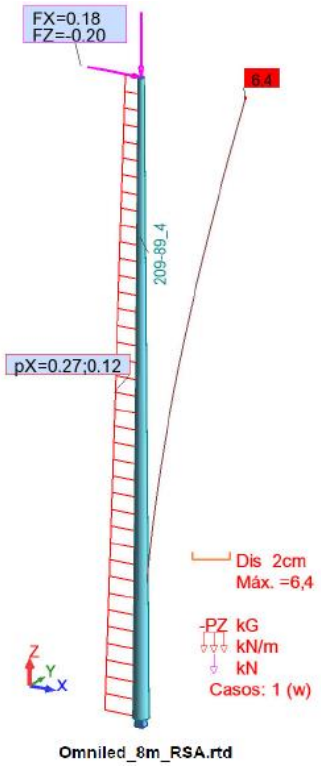


Figure 6 ï Modeling of the OmniLED support structure (column of 6,0 and 8,0m) ï Maximum deflation (ELS) (S/esc.)

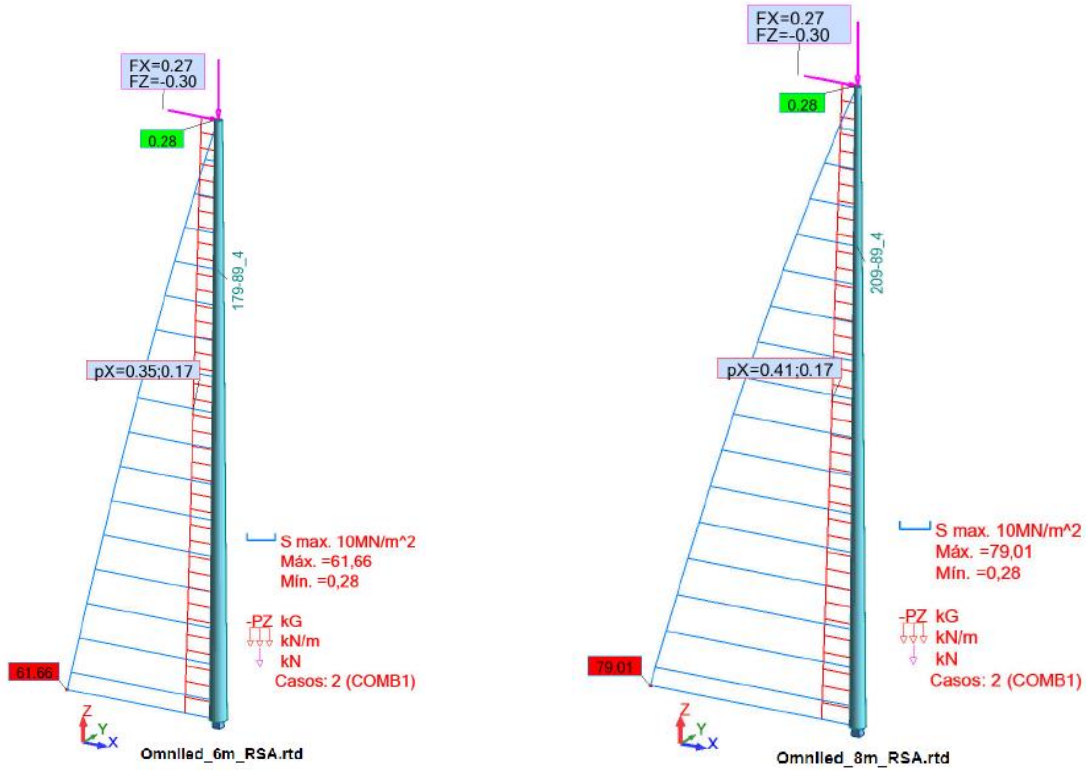


Figure 7 ï Modeling of the OmniLED support structure (column of 6,0 and 8,0m) ï Maximum stress (ELU) (S/esc.)

By the exam of the results obtained for the maximum deflection at the top of the column, in what concerns the Service Limit States, it is possible to verify that, whether for the column of 6,0m, or the column with 8,0m, the values donôt exceed deflation greater than L/100, ie, respectively for the column of 6,0 and 8,0m, it appears that 1 7/32" <6/100 and 2 33/64" <8/100. Thus, it is considered that the behavior of the patterned sections, in what respects to the deflation under wind action, is satisfactory.

Similarly, by the analysis of the results obtained for the maximum stress at the base of the columns, in this case, with respect to the Ultimate Limit States, it turns out that both to the 6,0m column section as for the 8,0m column section, the maximum values obtained, respectively 8,943 and 11,459.43 psi, are well below the steels yield stress value (maximum mobilized stress), ie, 39,885.37 psi, for the strength class of the steel considered ï S275.

4.4.2. External Security Verification and Scaling

Based on the results of the calculation for each OmniLED model (column of 6,0 and 8,0m height), we proceeded with the scaling and external security verification of the foundation mass.

Since these are extremely light structures, subject essentially to horizontal actions, namely, wind, it weight sparsely contributes to the stabilization of the base, referring the equilibrium condition almost exclusively for the geometry and weight of the mass or shoe foundation of the OmniLED structure.

For the same foundation conditions, ie, assuming the verification of characteristics allowed in the section 3.2 of this document, to ground conditions where the foundation of any OmniLED will be installed, the use of a solution of mass blocks allows optimizing the volume and geometry of this element, being that, unlike the solution of a directly based shoe on the ground, allows to consider and mobilize the soil reaction on the side walls of the block when it is requested by horizontal action, reducing the contact pressure on the base, and therefore the area needed to assure the maintenance of the stress levels to equal or bellow values to the permissible, that is, **10.87 psi**.

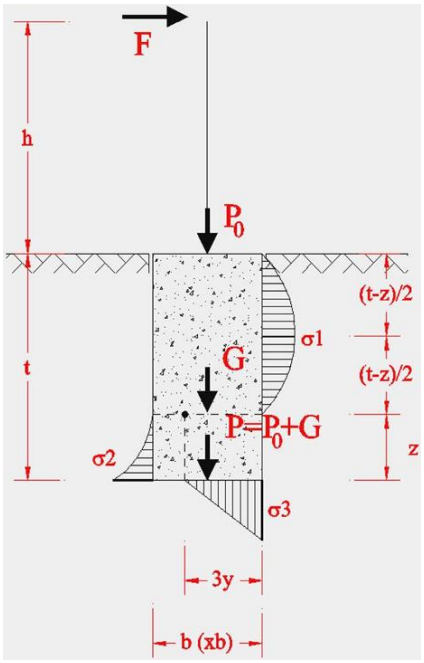


Figure 8 ï Scheme of forces and reactions to obtain the balance in foundations of blocks (S/esc.)

Foundation blocks result, therefore, into smaller area elements in plan, but with greater depth as compared to

standard foundations, by use of foundation shoes.

For the design of the blocks/foundation mass we used the Burklin method, which, as illustrated in the figure above, consider the side reaction of the ground in contact with the block to check the balance between the destabilizing forces, in this case, the action of the wind on the support column and cap of the OmniLED 07 ï represented in the figure by the horizontal resultant force ñFò acting at a height ñhò which will correspond to a collapse moment (M) ï and stabilizing forces to which contribute the vertical load from the dead weight of the OmniLED structure, the self-weight of the foundation block and the side reaction of the land, according to their geomechanical characteristics.

The following table summarizes the results of calculation and desgin of foundation blocks of reinforced concrete, considering the resulting reaction in the column base, in State Service Limit, to the wind action (w) in column of 6,0 and 8,0m height.

OmniLED	**Comb**	**Forces/reactions**			**Efforts (Fig. 8)**			σ_{adm}	**Dim. Block**		**Results**					$\sigma_3 <$ σ_{adm}
Column		F_X	F_Z	M_Y	h	P_0	F		b	t	P *	Q	z	y	σ_3	
(m)		(lbf)	(lbf)	(lbf/ft)	(m)	(tf)	(tf)	(psi)	(ft)	(ft)	(tf)	(tf)	(ft)	(in)	(psi)	
6,00	Wind (w)	272.01	213.56	262.43	10'4 $51/64$"	0.1	0.12	**10.87**	**2'5 $17/32$"**	**3'3 $3/8$"**	1.03	0.57	1'3 $3/4$"	7 $31/64$"	5.48	**ok**
8,00		382.17	292.25	465.94	13'1 $31/64$"	0.13	0.17		**3'3 $3/8$"**	**3'3 $3/8$"**	1.8	0.91	1'2 $9/16$"	7 $3/32$"	7.53	**ok**

Table 6 ï Design of foundation blocks for columns of 6,0 and 8,0m height ï Summary table

It should be noted that during the security check was considered a safety factor (SF) equal to 2.0, considered in calculating of the corresponding reactions to the State Service Limit.

It is also important to note that the on the determination of the block own weight (G), at $P = P_0 + G$, (P*), it was consider only for purposes of calculating a density of the material to the block with **104.25 lb/ft^3**, in order to simulate a trapezoidal mass, with top area = 2/3 of the base area, and therefore, he consequent reduction in volume compared to a regular rectangular mass. This geometry (trapezoidal) aims the economy of material and favoring in the operating mechanism as foundation block.

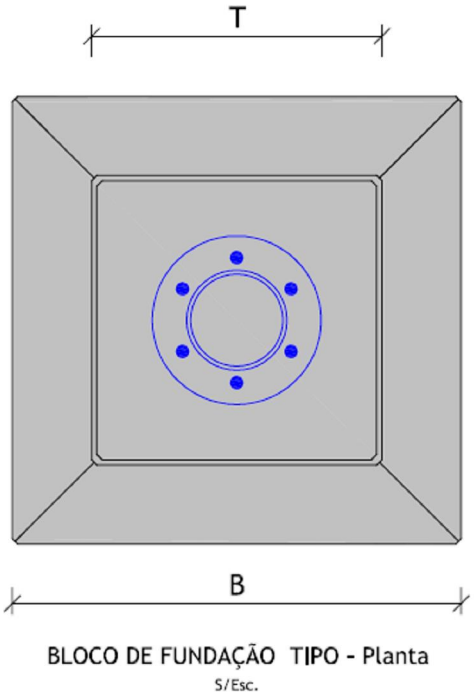
Beware, however, that the density of the material of the actual block canô be inferior to **149.82 lb/ft^3**, corresponding to foundation blocks of reinforced concrete.

In the following figure and table it is indicated the geometry and its minimum dimensions that the foundation

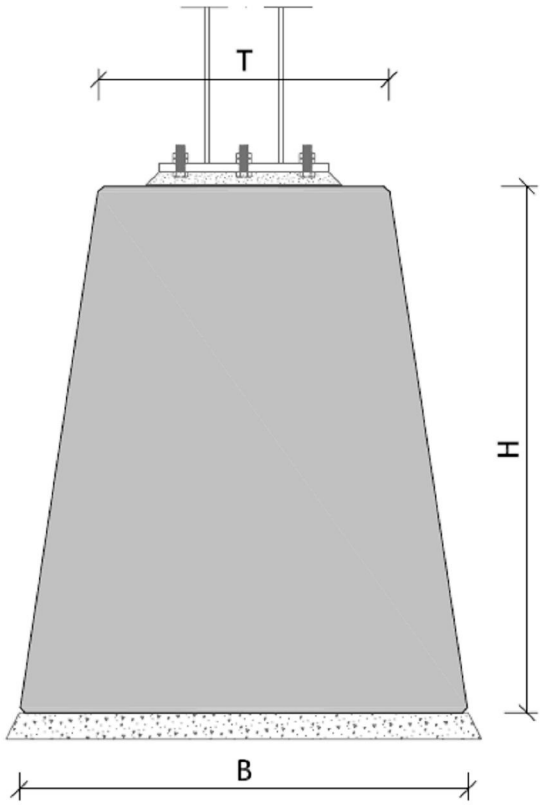
blocks should have, in accordance with the design assumptions here considered.

Block/Mass	Basis - B [ft]	Top - T [ft]	Height - A [ft]	Approx. Min. Weight [lb]
Column 6,0m	2'5 17/32"	1'7 11/16"	3'3 3/8"	2094.39
Column 8,0m	3'3 3/8"	2'3 9/16"	3'3 3/8"	3747.85

Talbe 7 ï Geometry type of the foundation blocks ï Minimum dimensions to respect



BLOCO DE FUNDAÇÃO TIPO - Planta
S/Esc.



BLOCO DE FUNDAÇÃO TIPO - Alçado
S/Esc.

Figure 9 ï Geometry type of the foundation block (S/esc.)

With regard to the armature of the foundation block, it must be adopted a constructive reinforcement, arranged in a square mesh of vertical stirrup and horizontal straps.

The armor, made by rods Ø 8mm (5/16") (A50NR), must not have, in whatever direction in which it is available, a top clearance bigger than 0.15m (5 29/32") between stirrups and straps.

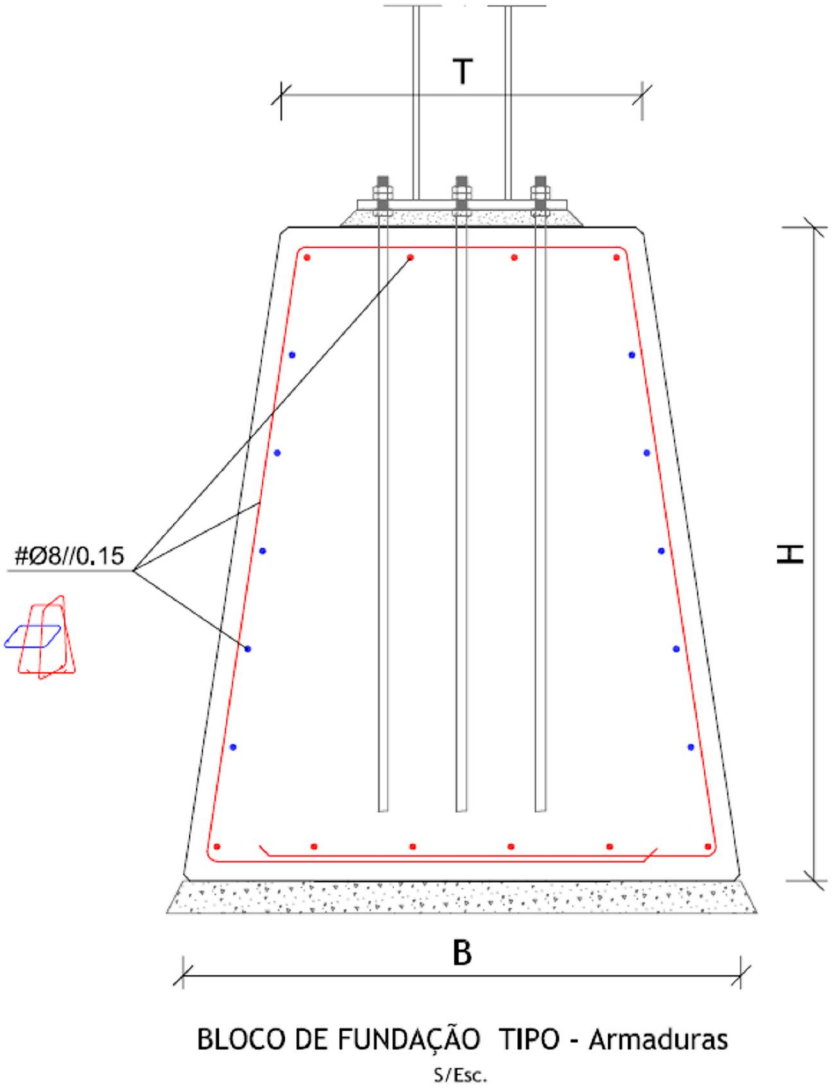


Figure 10 ï Typical foundation block ï Armor layout (S/esc.)

4.4.3. Scaling ot the connection of the Columns basis to the Foundation Mass

As regards to the fixation of the column basis in the mass/foundation block, its scaling and verification of safety was performed by a computer program, specific to this type of analysis (Hilti Profis Anchor).

In this check were considered the resulting reaction at the bottom of the column, ie, in combination with increased loads ï Ultimate Limit State, to the action of the wind (w), in columns with 6,0 and 8,0m height.

In addition to the check to the tensile strength (rupture by pulling the concrete cone and rupture by cracking of the concrete), shear (yield of the steel anchors, rupture by leverage effect ï concrete cone and rupture of the board of the concrete in the direction of the cut) and the combination between tension and shear load, also performed of the dimension of the base plate and its thickness.

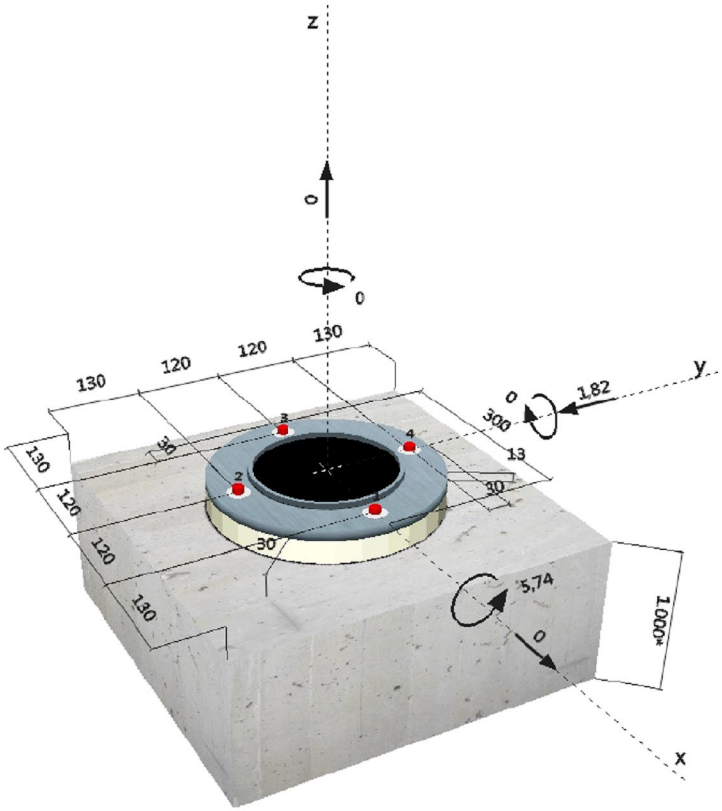


Figure 11 ï Fixing modulation ï for example the column basis of 6,0m ï the massive foundation (no scale).

The following table summarizes the results obtained and constructive dispositions to be taken in the connection of the basis of the 6,0 and 8,0m columns to the foundation mass.

Fixation	Basis plate Min. Diam. [ft]	Basis plate Min. Thick [mm]	Material	Filling height (grout) on the basis [mm]	Anchor bolts min. [un/ Ømm]	Drilling [Ømm]	Total lenght of the anchor bolts [mm]	Material
Column 6,0m	11 $^{13}/_{16}$"	$^{33}/_{64}$"	S275	1 $^{3}/_{16}$"	4 Ø $^{35}/_{64}$"	Ø$^{5}/_{8}$"	3'3 $^{3}/_{8}$"	Rod A500 screwed, galvanized
Column 8,0m	1'$^{19}/_{32}$"	$^{3}/_{4}$"		1 $^{3}/_{16}$"	4 Ø $^{5}/_{8}$"	Ø$^{45}/_{64}$"	3'3 $^{3}/_{8}$"	

Table 8 ï Geometry type of foundation blocks ï Minimum dimensions to respect

(*) ï If the connecting bolts are applied to the foundation mass after concreting, should be considered anchor bolts, sealed using chemical sleeve HIT-RE 500, from Hilti or equivalent.

5. **CONSIDERATIONS**

As already mentioned, this technique and its scaling are valid only to the conditions set forth herein, or others who, in any case, do not reflect the most unfavorable conditions as those which are defined here by other assumptions.

For conditions and resulting worst assumptions than those set forth herein, it shall be taken-in the safety check of the structural elements ï support column, basis and foundation fixation, and, if necessary, to make a new scaling, suitable to the specific requirements of said conditions.

Porto, February 2015