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TFG

STUDY AND DESIGN OF THE RESTRUCTURING OF AN EXISTING CONVENTIONAL CAR PARK FOR THE USE OF ELECTRIC VEHICLES

ANNEXES

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1.0.-Survey:

A survey of approximately 100 inhabitants of Castellbisbal has been carried out to know the use they give to conventional car parking. We know that this survey is not very relevant because the number of inhabitants of Castellbisbal is 12,332 people according to the National Statistics Institute in 2018. Therefore, we have done a survey of 0.8% of the residents, but it has helped us to know the use that respondents give to the parking lot and in this way to be able to choose the type of recharge that we will implement.

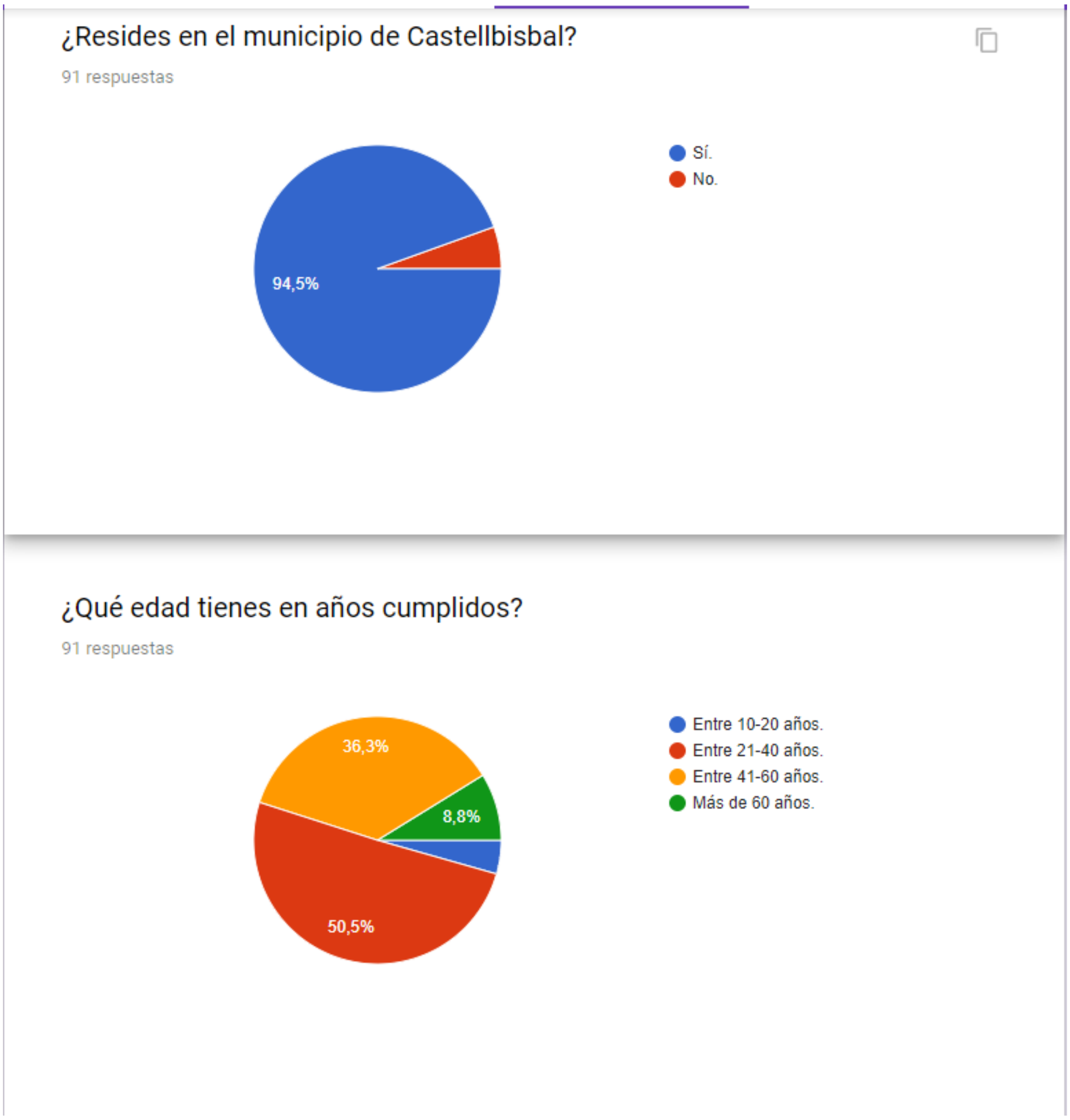
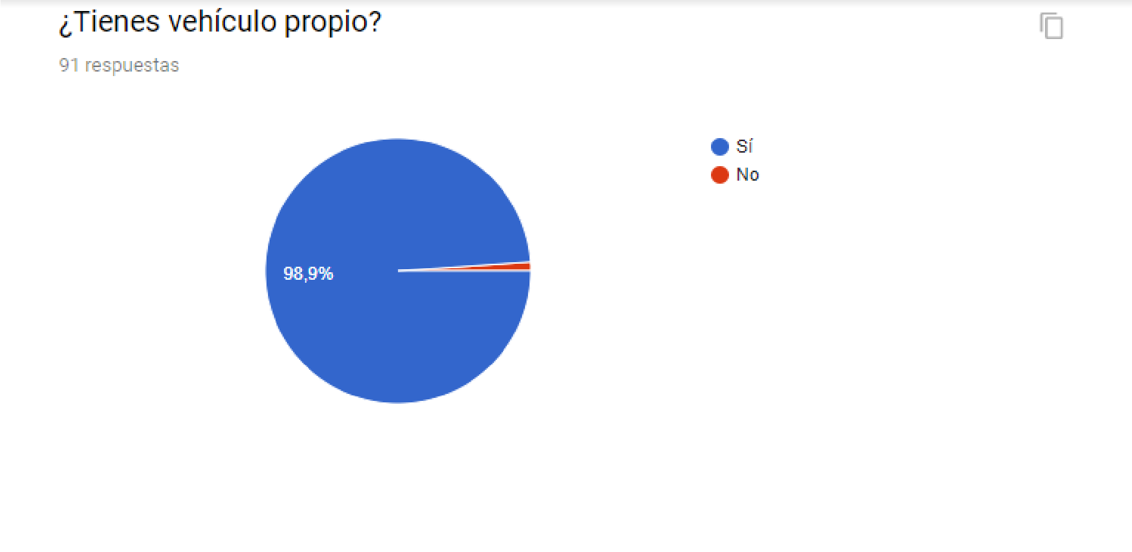


Figure 1.Questions 1 and 2 of the survey (Own Source)



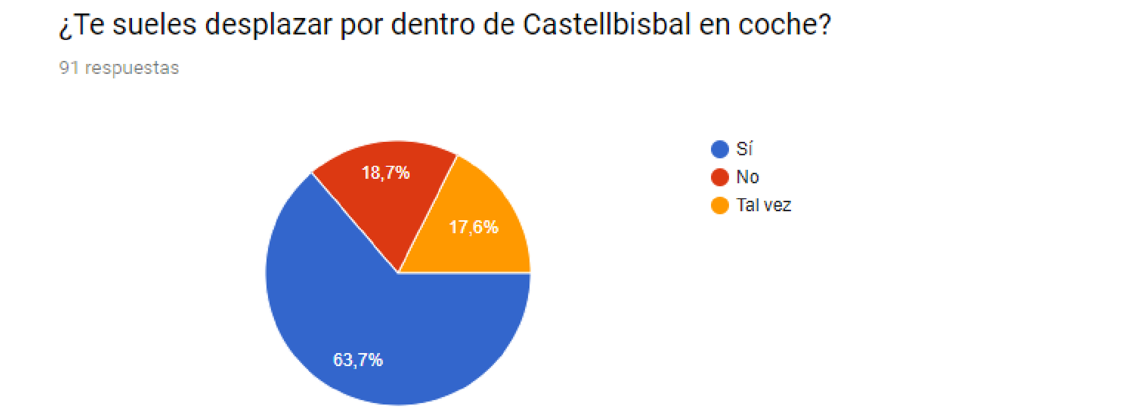


Figure 2.Questions 3 and 4 of the survey (Own Source)

¿Utilizas el aparcamiento colindante al ayuntamiento para aparcar tu coche?

91 respuestas

¿Cuánto tiempo sueles dejar el coche estacionado en el aparcamiento colindante al ayuntamiento?

87 respuestas

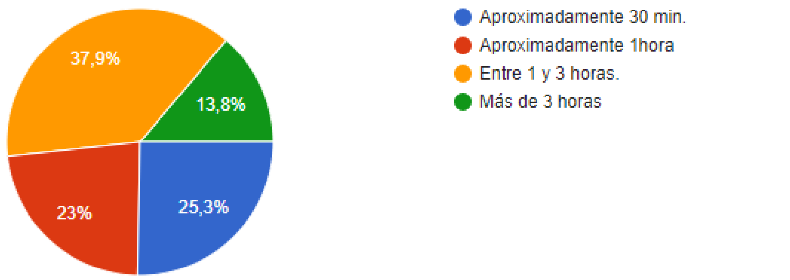
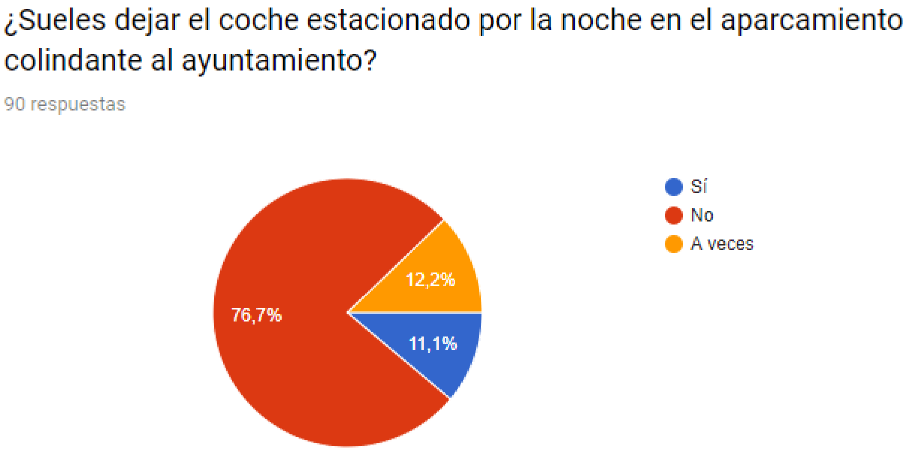


Figure 3.Questions 5 and 6 of the survey (Own Source)



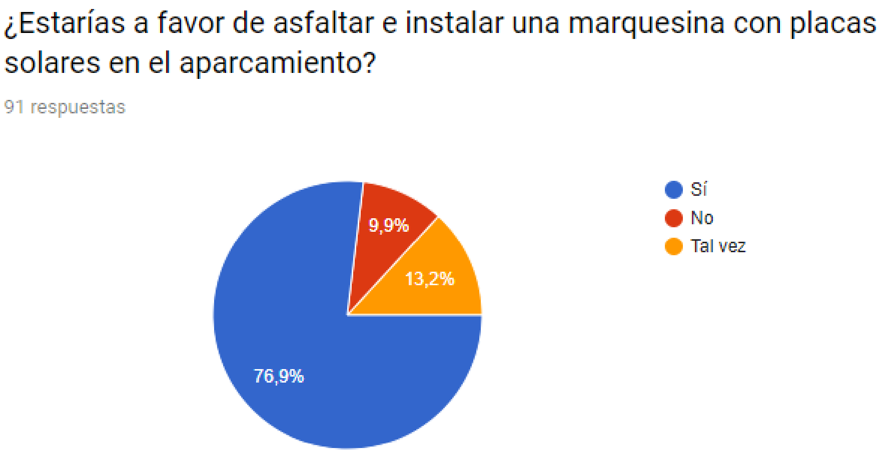


Figure 4.Questions 7 and 8 of the survey (Own Source).

2.0.- Structural effort calculations:

2.1.-Own weight of the structure:

In order to realize the weight that the structure exerts and to be able to introduce it in the calculation program we have divided the own weight into different parts, on the one hand the weight that the pillars exert, on the other the weight of the beams and then we have taken into account the weight of the solar panels, the one of the cover and the one of the straps.

Pillar weight (HEB100):

Pillars weight HEB : 20.4 Kg/m.

A_{HEB100}= 26cm^2= 0.0026m^2.

Inertia: 45·10^{-7}m^4.

H= 2.6m

g=9.8m/s^2

$$\boldsymbol{P} = 20.4 \cdot 9.8 = 199.92 \frac{N}{m} = \frac{0.1992kN}{m} \cdot 2.6 \cdot 2 = \mathbf{1.04\ kN}$$

Beams weight (IPE160):

In our structure we have two IPE160 beams, one measuring 6 meters in length and the other 10 meters in length. We will calculate the own weight of the two beams separately.

-IPE160 (6m):

Beam weight IPE: 8.1 Kg/m

g=9.8m/s^2

A=10.3·10^{-4}m^2.

$$\boldsymbol{P} = 8.1 \cdot 9.8 = 79.38 \frac{N}{m} = \frac{0.07938kN}{m} \cdot 6 \cdot 3 = \mathbf{1.43\ kN}$$

This calculation is made to obtain the beam's own weight, but we will introduce it as a distributed load in our program.

As we have 3 beams spread over 10 meters, that means that every 3.33 m there is an IPE160 beam.

$$\boldsymbol{P_{distributed}} = \frac{1.43kN}{3.33m} = \mathbf{0.43\ kN/m}$$

-IPE160 (10m):

$$\boldsymbol{P} = 8.1 \cdot 9.8 = 79.38 \frac{N}{m} = \frac{0.07938kN}{m} \cdot 10 \cdot 30 = \mathbf{2.38\ kN}$$

$$\boldsymbol{P_{distributed}} = \frac{2.38kN}{3.33m} = \mathbf{0.72\ kN/m}$$

Own weight of a solar panel:

To carry out this calculation we have taken some data of the weight of a solar panel and the dimensions of the standard panel to be able to make an approximate calculation of the own weight that the solar panels would generate on the roof of our structure.

Mass: 26,5 Kg

Dimensions: $2m^2$

Therefore, if we divide the two data, we obtain that each meter of plate weighs $13.25Kg/m^2$.

$$\boldsymbol{P} = 13.25 \cdot 10 = 132.5\ \frac{Kg}{m} = 132.5 \cdot 9.8 = \mathbf{1299.5 \frac{N}{m}} = \mathbf{1.30\ kN/m}$$

The first operation of the previous equation is because we take a differential of 10 meters.

Own weight of sheet metal:

Own weight of sheet metal: 7,55 Kg/m^2

$$\boldsymbol{P} = 7.55 \cdot 10 = 75.5\ \frac{Kg}{m} = 77.5 \cdot 9.8 = 739.9 \frac{N}{m} = \mathbf{0.74\ kN/m}$$

Straps weight:

Straps weight: $5Kg/m^2$

$$\boldsymbol{P} = 5 \cdot 10 = 50\ \frac{Kg}{m} = 50 \cdot 9.8 = 490 \frac{N}{m} = \mathbf{0.49\ kN/m}$$

2.2.- Use overload calculation:

Tabla 3.1. Valores característicos de las sobrecargas de uso

Categoría de uso		Subcategorías de uso		Carga uniforme [kN/m²]	Carga concentrada [kN]
A	Zonas residenciales	A1	Viviendas y zonas de habitaciones en, hospitales y hoteles	2	2
		A2	Trasteros	3	2
B	Zonas administrativas			2	2
C	Zonas de acceso al público (con la excepción de las superficies pertenecientes a las categorías A, B, y D)	C1	Zonas con mesas y sillas	3	4
		C2	Zonas con asientos fijos	4	4
		C3	Zonas sin obstáculos que impidan el libre movimiento de las personas como vestíbulos de edificios públicos, administrativos, hoteles; salas de exposición en museos; etc.	5	4
		C4	Zonas destinadas a gimnasio u actividades físicas	5	7
		C5	Zonas de aglomeración (salas de conciertos, estadios, etc)	5	4
D	Zonas comerciales	D1	Locales comerciales	5	4
		D2	Supermercados, hipermercados o grandes superficies	5	7
E	Zonas de tráfico y de aparcamiento para vehículos ligeros (peso total < 30 kN)			2	20 (1)
F	Cubiertas transitables accesibles sólo privadamente (2)			1	2
G	Cubiertas accesibles únicamente para conservación (3)	G1 (7)	Cubiertas con inclinación inferior a 20º	1 (4) (6)	2
			Cubiertas ligeras sobre correas (sin forjado) (5)	0,4 (4)	1
		G2	Cubiertas con inclinación superior a 40º	0	2

Figure 5. Characteristic values of overload use.

To know the use overload value, we have not needed to perform any calculation, because in the CTE-DBSE-AE (Table 3.1), it gives us the value to be taken into account.

Our parking for electric vehicles would fall into the use category E, therefore, it has a uniform load of **2kN/m²**.

But as our cover, it is not a passable place, neither for people, nor will it be used as a warehouse, nor will any structure be built above we will take into account an overload of use of 4 operators working on top of the cover, since, they will have to install photovoltaic panels. This overload of weight will be taken into account as 4 point loads at the most unfavorable points of the structure and applied as point loads of **1 kN**.

Operator mass: 100kg

Operator weight = m·g = 100·9.8= 980N =**0.98kN** ≈ **1 kN**

2.3.-Wind calculation on the structure:

The action of the wind, in general a force perpendicular to the surface of each exposed point, or static pressure, which can be expressed as:

$$q_e = q_b \cdot c_e \cdot c_p$$

qb: Represents the dynamic wind pressure. Simplified, as a value at any point in the Spanish territory, 0.5kN/m² can be adopted. Although more precise values can be obtained through Annex D depending on the geographical location of the work.

Ce: This is the exposure coefficient, variable with the height of the point considered based on the degree of roughness of the environment where the construction is located. The value is determined by the CTE but in urban buildings with up to 8 floors a constant value can be taken, and regardless of the height, of a 2.0 value.

C_P: The wind coefficient or pressure coefficient depends on the shape and orientation of the surface with respect to the wind, and where appropriate, on the situation of the point with respect to the edges of that surface, a negative value indicates suction. The value is established in the tables of CTE 3.3.4 and 3.3.5.

To know the value of the dynamic wind pressure, Annex D indicates that qb is calculated with the equation:

$$q_b = 0.5 \cdot \delta \cdot v_b^2$$

Although the CTE specifies the value of qb depending on the region of the territory where the structure is located.

Figure 6. Map of the basic speed of the wind zones(CTE Source)

The basic value of the wind speed in each locality can be obtained from the previous map. The dynamic pressure is, respectively, 0.42 kN/m^2 (Zone A), 0.45kN/m^2 (Zone B), 0.52kN/m^2 (Zone C). In our case, as the car park is located in Catalonia, our area would be the C, therefore, the default value of the dynamic wind pressure is **0.52kN/m^2**.

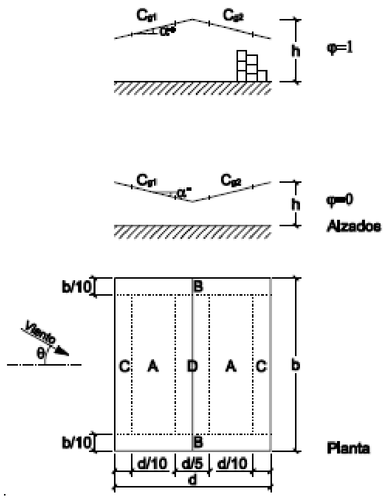
To obtain the exposure coefficient as indicated by the CTE, this varies depending on the height of the construction, in our case the parking lot is 2.7 m high and therefore we consider it as a small one-story building. The technical code specifies that for buildings with up to 8 floors a constant value of the exposure coefficient can be taken, with a value of 2.0.

Therefore, our exposure coefficient that we will take into account will be C_e = 2.0.

To be able to finish the calculation of the static wind pressure, we only need the value of the wind coefficient. This is calculated using Table D.11-double fall downs roof:

In which it indicates a value of the pressure coefficient depending on the slope of the roof, the effect of the wind and the clogging factor.

Tabla D.11 Marquesinas a dos aguas



Pendiente de la cubierta α	Efecto del viento hacia	Factor de obstrucción φ	Coeficientes de presión $c_{p,10}$ Zona (según figura) A	B	C	D
-20°	Abajo	0 ≤ φ ≤ 1	0,8	1,6	0,6	1,7
	Arriba	0	-0,9	-1,3	-1,6	-0,6
	Arriba	1	-1,5	-2,4	-2,4	-0,6
-15°	Abajo	0 ≤ φ ≤ 1	0,6	1,5	0,7	1,4
	Arriba	0	-0,8	-1,3	-1,6	-0,6
	Arriba	1	-1,6	-2,7	-2,6	-0,6
-10°	Abajo	0 ≤ φ ≤ 1	0,6	1,4	0,8	1,1
	Arriba	0	-0,8	-1,3	-1,5	-0,6
	Arriba	1	-1,6	-2,7	-2,6	-0,6
-5°	Abajo	0 ≤ φ ≤ 1	0,5	1,5	0,8	0,8
	Arriba	0	-0,7	-1,3	-1,6	-0,6
	Arriba	1	-1,5	-2,4	-2,4	-0,6
5°	Abajo	0 ≤ φ ≤ 1	0,6	1,8	1,3	0,4
	Arriba	0	-0,6	-1,4	-1,4	-1,1
	Arriba	1	-1,3	-2,0	-1,8	-1,5
10°	Abajo	0 ≤ φ ≤ 1	0,7	1,8	1,4	0,4
	Arriba	0	-0,7	-1,5	-1,4	-1,4
	Arriba	1	-1,3	-2,0	-1,8	-1,8
15°	Abajo	0 ≤ φ ≤ 1	0,9	1,9	1,4	0,4
	Arriba	0	-0,9	-1,7	-1,4	-1,8
	Arriba	1	-1,3	-2,2	-1,6	-2,1
20°	Abajo	0 ≤ φ ≤ 1	1,1	1,9	1,5	0,4
	Arriba	0	-1,2	-1,8	-1,4	-2,0
	Arriba	1	-1,4	-2,2	-1,6	-2,1
25°	Abajo	0 ≤ φ ≤ 1	1,2	1,9	1,6	0,5
	Arriba	0	-1,4	-1,9	-1,4	-2,0
	Arriba	1	-1,4	-2,0	-1,5	-2,0
30°	Abajo	0 ≤ φ ≤ 1	1,3	1,9	1,6	0,7
	Arriba	0	-1,4	-1,9	-1,4	-2,0
	Arriba	1	-1,4	-1,8	-1,4	-2,0

Figure 7.Table of double fall downs roof(CTE Source)

In this case we would look at roof of 5º of inclination of the roof and with a φ = 1 and we will use the pressure coefficient of zone B because it is the worst situation we can find. In short, the C_p for our structure will be -2.0.

Once we have all the values of each variable we can calculate the static pressure that the wind will exert on our structure.

By the equation described previously:

$$q_e = q_b \cdot c_e \cdot c_p = 0.52 \cdot 2.0 \cdot (-2.0) = -1.872\ kN/m^2$$

That the value is negative means that the effect of the wind creates a suction force on the structure.

2.4.-Snow calculation on the structure:

The distribution and intensity of the snow load on a building, or in particular on a roof, depends on the climate of the place, the type of precipitation, the relief of the environment, the shape of the building or the roof, the effects of wind and thermal exchanges in the external parameters.

In our case we will determine the snow load as if our roof were flat, since it only has a 2% inclination. In this way, we can consider a building with a flat roof located in a town with an altitude of less than 1,000m, since Castellbisbal is about 200-300 meters from sea level and therefore, take into account a load of 1.0kN/m^2 snow. But this value can only be taken into account if we are dealing with a building or a large structure, in our case, and in the technical building code reflects it is a light structure and sensitive to vertical loads, with the consequence that we will have to analytically determine the real value that snow will exert on our parking lot.

As a snow load value per unit area on a horizontal roof, it can be calculated as:

$$q_n = \mu \cdot s_k$$

Being µ the shape coefficient of the roof and S_k the characteristic value of the snow load on a horizontal terrain.

The CTE indicates the value of the shape coefficient and the characteristic value of the snow load, in Table 3.8 it indicates the S_k according to the different capitals and the altitude at which they are found.

Tabla 3.8 Sobrecarga de nieve en capitales de provincia y ciudades autónomas

Capital	Altitud m	s_k kN/m^2	Capital	Altitud m	s_k kN/m^2	Capital	Altitud m	s_k kN/m^2
Albacete	690	0,6	Guadalajara	680	0,6	Pontevedra	0	0,3
Alicante / *Alacant*	0	0,2	Huelva	0	0,2	Salamanca	780	0,5
Almería	0	0,2	Huesca	470	0,7	SanSebastián/*Donostia*	0	0,3
Ávila	1.130	1,0	Jaén	570	0,4	Santander	0	0,3
Badajoz	180	0,2	León	820	1,2	Segovia	1.000	0,7
Barcelona	0	0,4	Lérida / *Lleida*	150	0,5	Sevilla	10	0,2
Bilbao / *Bilbo*	0	0,3	Logroño	380	0,6	Soria	1.090	0,9
Burgos	860	0,6	Lugo	470	0,7	Tarragona	0	0,4
Cáceres	440	0,4	Madrid	660	0,6	Tenerife	0	0,2
Cádiz	0	0,2	Málaga	0	0,2	Teruel	950	0,9
Castellón	0	0,2	Murcia	40	0,2	Toledo	550	0,5
Ciudad Real	640	0,6	Orense / *Ourense*	130	0,4	Valencia/*València*	0	0,2
Córdoba	100	0,2	Oviedo	230	0,5	Valladolid	690	0,4
Coruña / *A Coruña*	0	0,3	Palencia	740	0,4	Vitoria / *Gasteiz*	520	0,7
Cuenca	1.010	1,0	Palma de Mallorca	0	0,2	Zamora	650	0,4
Gerona / *Girona*	70	0,4	Palmas, Las	0	0,2	Zaragoza	210	0,5
Granada	690	0,5	Pamplona/*Iruña*	450	0,7	Ceuta y Melilla	0	0,2

Figure 8. Snow overload table in provincial capitals and autonomous cities

As you can see in the previous figure, Barcelona has an associated $s_k = 0.4\ kN/m^2$.

Finally, in section 3.5.3 of the CTE it mentions that for the situation of a structure with a lower limited gable, and in which there is no impediment to snow slippage, the shape coefficient will obtain a value of 1 for sloping roofs less or equal to 30º. In short, we obtain from the regulations that μ = 1.

$$q_n = \mu \cdot s_k = 1 \cdot 0{,}4 = \mathbf{0{,}4\ kN/m^2}$$