Escola Politècnica Superior d'Edificació de Barcelona

GRAU EN CIÈNCIES I TECNOLOGIES DE L'EDIFICACIÓ

TREBALL FINAL DE GRAU

DISSENY, CÀLCUL I PROJECTE DE L'ESTRUCTURA D'UN POLIESPORTIU

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ABSTRACT

This Final Year Project stems from the interest in expanding the knowledge acquired during my studies in the field of structures; and it aims to design, calculate and project the structure of a sport center located in La Riera del Gaià, a town in Tarragona.

In order to introduce the reader into the topic treated in this FYP, it should be mentioned that the structure plays a very important role within any building, just because the building stands up thanks to it. In other words, we are talking about the skeleton of the building.

The structure of a building is intended to withstand the loads to which it is subject because of the actions it can receive, directly or indirectly. To accomplish its mission, the structure must meet the basic requirements of balance, strength and stability, and thus ensure the basic requirement of structural safety.

Based on these premises, and in order to achieve the ultimate goal of this FYP, a number of partial objectives broadly listed below are carried out. And all of them comply with the current legislation in the field of construction.

It starts with a Basic Project, and once it is reviewed, various options of structural solutions are studied until the appropriate one is achieved; always proving both the criteria and conditions applied and the calculation of the shares the building receives, and also the measuring elements of the structure.

Right after, the program *Tricalc* does the structural calculation and the process followed since the introduction of the structure to the calculation and results is highly explained and detailed so that the reader understands how the program works.

Finally, once the approval to the result of the structure is made, we proceed to create the documentation relating to the project and necessary for the implementation of the structure, such as the report of calculation, the size, the budget and plans.

This FYP also includes an assessment of the energetic cost of the structure projected, as well as a calculation of the CO_2 emissions that can be generated because of its implementation, given the importance that everything regarding to environment and sustainability in the construction sector has been taking in recent years.

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1 INTRODUCTION

1.1 Objectives of the FYP

The objective of this work is to solve the structure of a building from its Basic Project; trying to strengthen the knowledge and skills acquired throughout this career. And it is also to get a specialization and preparation for professional practice in the field of design and calculation of building structures.

1.2 Description of the building

1.2.1 Location

The building is placed in La Riera del Gaià, a town in the region of Tarragona, Sant Jordi Street, polygon 10, and site 53.

The site is located in the north of the town, in an area of new development; and it is surrounded by Sant Jordi Street, the T- 203 road and fields dedicated to cultivation.

1.2.2 Features of the site

The site has an area of 7860 m² and it has no constructions on it.

Regarding to the topography of the land, this one has slopes. It can be said that the level ± 0'00 sets at the corner where Sant Jordi Street and T-203 road meet. The area where the building will be built has a slope of 3'52 m, and as we will see later, a part of the sport center will be built on the underground.

1.2.3 Features of the building

The building under study, intended for sports, has a longitudinal volume. The layout of both the basement floor and the ground floor give the building the shape of a rectangular prism, from where two roofs stand out, as shown in the following figure 1.1. and 1.2.

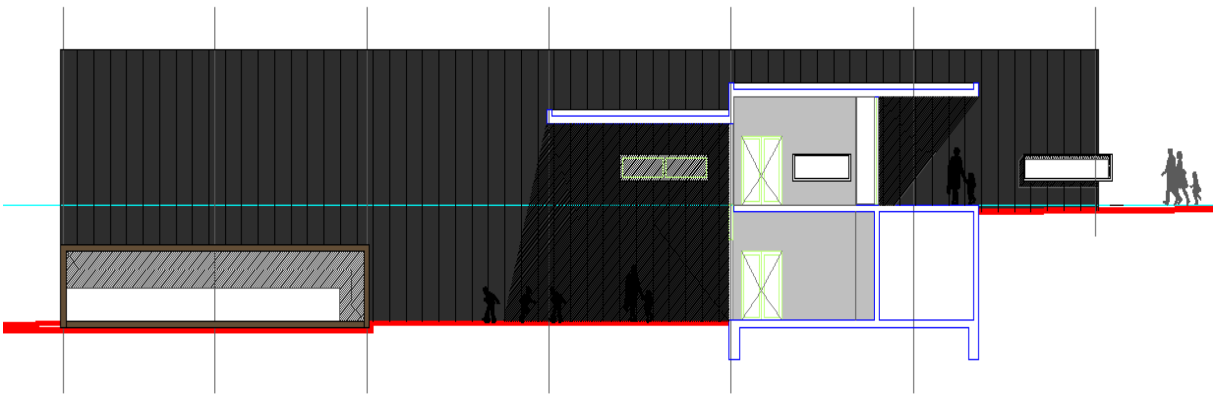

Figure 1.1: Longitudinal section of the building. South facade.

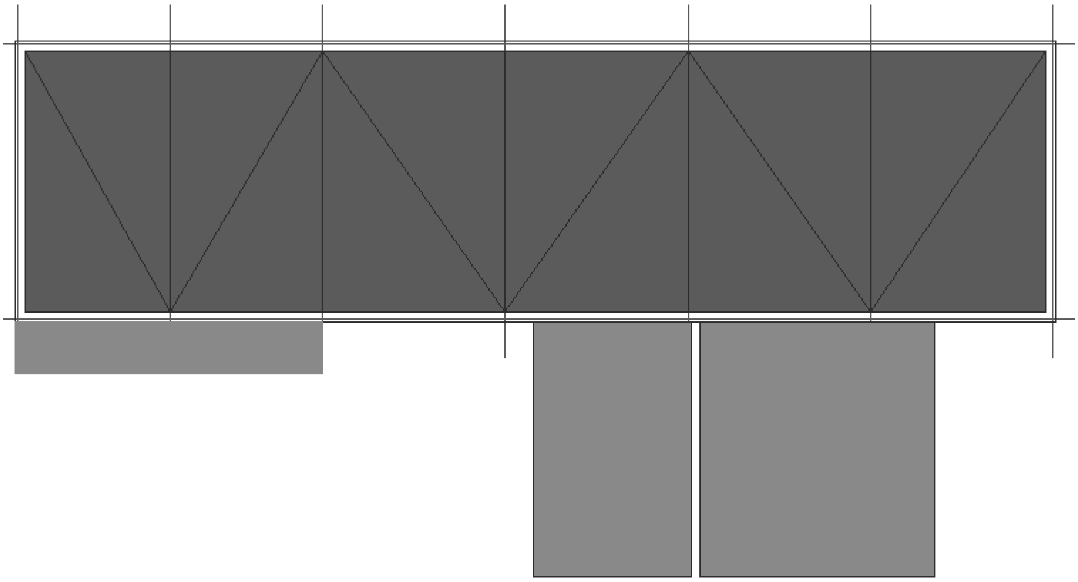

Figure 1.2: Floor of the building

The sports center has a basement, a ground floor and a ground covert by a plain typology, reaching an overall building floor area of 691'76 m².

The basement is equipped with two entrances and it contains spaces for fitness area, locker rooms and storage (see *Figure 1.3*). The ground floor has access to the areas designed for bodybuilding and fitness, as well as administrative areas (see *Figure 1.4*). Both plants are connected by an elevator and a staircase located in the entrance area of both floors.

The height between floors is 3'22 m, except in the gym area, which is 6'74 m, since it is only one floor, due to its use and its need to be an open space. The total height of the building, taking into account the faces of the flat roof is 8'24 m (see *Figure 1.5*).

The floor area of the basement is 656'15 m², the ground floor is 386'54 m²; and all of them compute a total built area of 1042'69 m².

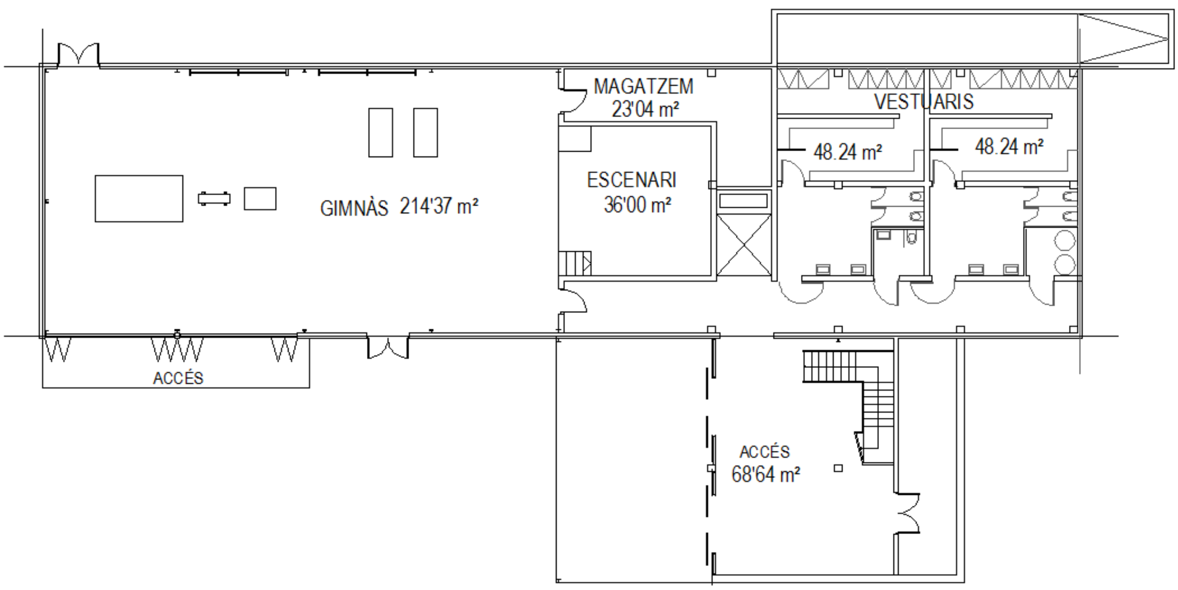

Figure 1.3: Horizontal section of the Basement

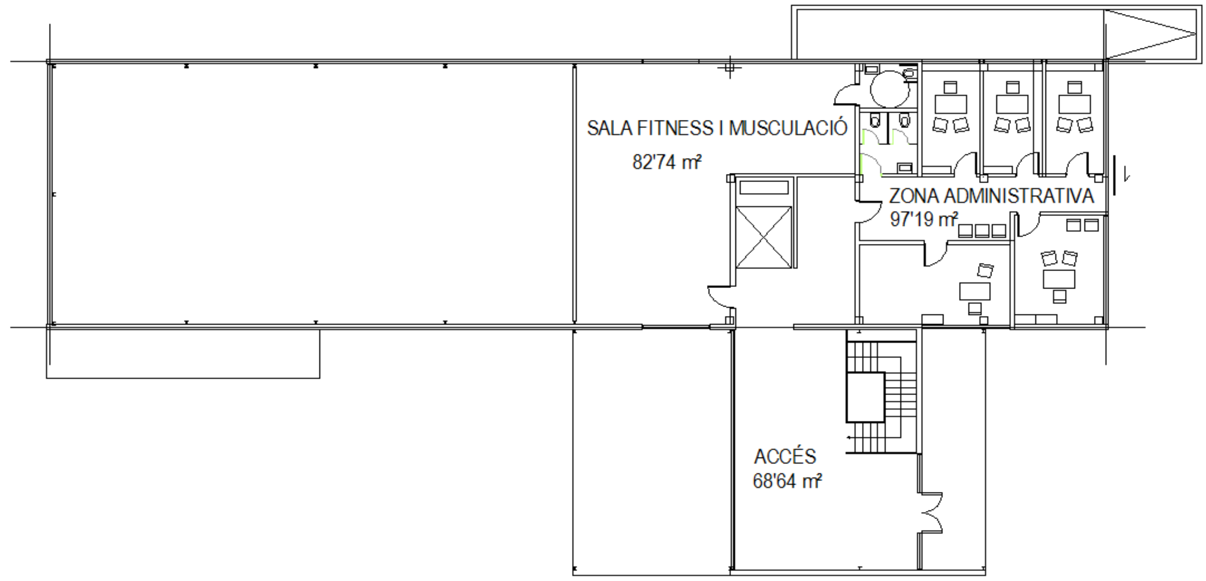

Figure 1.4: Horizontal section of the ground floor

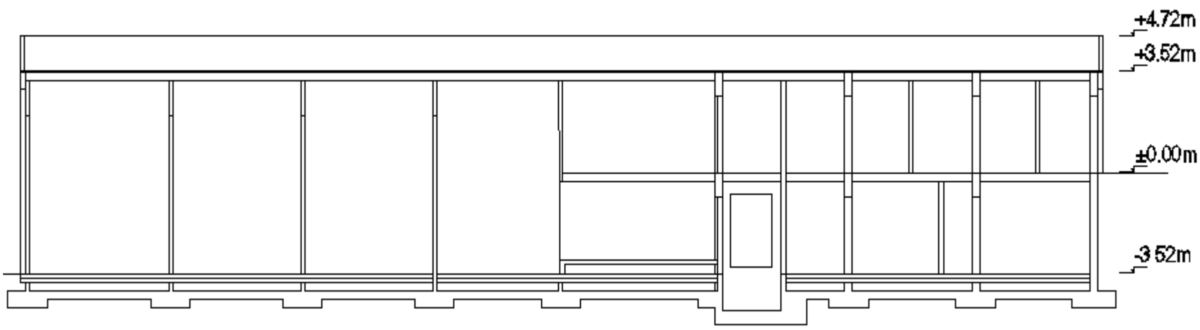

Figure 1.5: Vertical longitudinal section of the building

1.3 Methodology of work

To achieve the ultimate goal of this FYP, that is, solving the structure of a building, the work has been organized in different phases, which are explained below:

In the first phase, the basic project documentation, as well as the geotechnical study have been reviewed and studied. Different structural solutions have also been studied and analyzed in order to adopt the most appropriate one.

In the second phase, the structural solution has been defined and a measuring of the structural elements has been carried out.

In the third phase, the complete calculation of the structure has been solved, with the help of software *Tricalc* 7.4.

In the fourth phase, after having checked the results obtained by the program, the documentation of the structure's project has been written. That includes all the necessary plans so that the structure can be successfully executed: the memory of calculation and measurement of the proposed structure, and also the budget's preparation, and the evaluation of the energy cost and CO_2 emissions.

Finally, in the last phase, the writing of this project has been carried out.

1.4 Contents of the report

This report consists of the following contents:

Chapter 2: Definition of the structural solution. This chapter sets out the criteria and conditioned elements taken into consideration in order to define the structural solution, as well as a description of the structural solution finally adopted, calculating actions and structural measuring elements.

Chapter 3: Calculation by the program *Tricalc*; the process undertaken by the calculation of the structure with the help of the program and its operation *Tricalc* is described. The steps followed since the modelling of the structure until the final results are also detailed.

Chapter 4: Project of the structure. This chapter explains the process followed to achieve the creation of the project documentation: plans, memory calculation, measurement and budget structure.

Chapter 5: Energy costs and CO_2 emissions. This part details the procedure followed to calculate the energy cost of the projected structure, and it also describes the process used to calculate the CO_2 emissions that are generated.

Besides the chapters just described, we can also find the following appendices:

Appendix A: Geotechnical study. This appendix includes the geotechnical study of the land where the sports center is to be completely built.

Appendix B: Calculation notes. It includes the memory structure calculations (calculation method, standards applied, combination of hypotheses criteria, verifications done...)

Appendix C: Plans. This appendix contains all the necessary plans to execute the structure correctly.

Appendix D: Measuring and quote. This part contains information on the measurement and the budget of the structure with its breakdown.

Appendix E: Energy costs and CO_2 emissions. This appendix includes the documents with the calculation of the energy cost of the structure and CO_2 emissions with its corresponding breakdown.

Appendix F: Technical datasheets from the manufacturers. The last appendix contains the details of all precast structure.

2 DEFINITION OF STRUCTURAL SOLUTION

In order to define the most appropriate structural solution, both the characteristics related to the project and the characteristics related to the ground have been taken into account.

In the following sections, the criteria applied to the definition of the structural solution are set out and the solution finally adopted is described.

2.1 Criteria and conditional elements

Firstly, according to the characteristics of the land and once consulted the geotechnical study, it can be said that three geotechnical levels are presented. The characterization of these levels is due to the resistance of the ground, which is based on explorations, the information provided by the observation of materials in the area, and also on the regional geological information that can be extracted and observed in *Appendix A- Geotechnical Study*.

The geotechnical levels presents in the field are:

Level H: farmland

It is a surface level where the farmland and removed land lie. This level includes those materials in which foundation is not possible. Powers of 0'20 to 0.30 m have been detected through the whole plot.

Level A: lime

This level has brown sandy silt, and powers of 1'20 and 0'20 meters.

Level B: Socket rocky

This level presents siltstones, sandstones and conglomerates. It corresponds to a set of layers of sedimentary rock, with a thickness greater than the ten meters.

Level B is below the layers H and A, with a thick surveyed between 4'00 and 4'50 meters.

Then a table with soil parameters is exposed:

Table 2.1: Parameters of the soil

Level	(ϒ)	(C_u)	(Φ)	R
H	1'7 g/cm^3	0'00 kg/cm^2	24	Good
A	2'02 g/cm^3	0'10 kg/cm^2	26	Good
B	2'20 g/cm^3	0'50 kg/cm^2	34	Difficult

ϒ = density = Cu cohesion; Φ = angle of friction; R = possibility of excavation

The land is classified as T -1, favorable land according to CTE DB SE- C.

Relating to hydrology, the presence of a groundwater level is not detected in the explorations that have been carried out. And relating to concrete aggressiveness, aggression effects are not expected for concrete, according to what has been analyzed in the geotechnical study of soil. It has been always followed what is established in the norm EHE- 08: Statement of Structural Concrete. (*EHE-08:Instrucción del Hormigón Estructural*.).

According to what has been exposed, the possibility of foundation on levels H and A is ruled out. All elements of foundation will rest on level B, in which a foundation surpassing the level of alteration can be built (ripability limit).

Then, to solve the foundation, the technique of surface foundation has been chosen. Footings are used to convey the floor job stresses of 3'50 kg/cm² in the case of isolated footing foundations; and 3'00 kg/cm² in the case of foundations with strip footing. The settlements predictable for the load values permitted will be less than 2.5 cm.

Moreover, according to the characteristics relating to the project, we have the following conditional elements.

As mentioned in Chapter 1, the building has two floors with a height of 3'22 m between them, except the gym area that has a height of 6'74 m. The basement floor has dimensions of 41 m x 11 m; and the ground floor has a size of 11 x 20'60 m.

Given the intended use of the building sporting activities, open areas are required, specifically in the area of the gym, and adjacent to this, the area of the stage. So lights are important to save 10.6 m; this fact is resolved by metal portico structures. The rest of the building does not present great difficulties relating to light. What may condition the disposition of porticos with a concrete structure is the distribution of plants, giving priority to the adoption of a good structural solution.

The basement has two entrances, one of them, which gives direct access to the gym area is solved with a cantilever. The ground floor has an access that corresponds to the same volume of the other access of the basement. This area provides access to both floors and it is resolved structurally with independence of the sport center. It can be said that it has two distinct areas, one open area with dimensions of 10 x 6 m and a height of 6'20 m, which is solved with a canopy sheet and a metal structure; and a closed area containing the accesses. The latter one has dimensions of 10 x 10 m and a total height of 3'52 m between plants and it is also solved by a metal portico and a metal sheet for the roof.

In addition, as already mentioned, the land has a height of 3'52 m. This gap does not affect the entire basement, but almost half of it. Then this part of the building is solved by a basement wall.

2.2 Solution structure adopted

Once reviewed the basic and geotechnical study, it is considered appropriate, as already stated, to make a part of the structure of sports with a metal portico structure and to reinforce the other part with a concrete structure.

The following sections detail the structural solution adopted.

2.2.1 Vertical structure

The vertical structure of the sport center is done by porticos.

On the one hand, metal structure porticos are made in the gym area and also in the area of the access floor.

The gym area has 5 porticos, consisting of pillars and beams lattice with lights wheelbase of 5'00 m. The pillars, which have a height of 6'74 m, are made with HEB profiles, steel S275; its placement and distribution can be seen in *Figure 2.1.*

As previously mentioned, the gym area must be transparent; and in order to cover the light of 10.6 m lattice beams are used, due to the fact that these ones allow to save great lights and to lighten the weight of the beam. There will be Pratt type beams, since gravitational loads predominate, with HEB profiles, steel S275, and articulated joints that will ensure the rigidity of the shape of the beam (see *Figure 2.3*).

All lattice beams have a depth of the order of 1/10 or 1/15 of light, except in the area of fitness and bodybuilding, which will present a depth of 3'52 m, that is, it will be fabricated wrought. The fact that the provision of this edge is due to the stage beneath the area of fitness and bodybuilding should also be open. Thus, the placement of pillars where the slab floor can support and transmit loads to the ground floor is not possible. Therefore by supporting the floor on the beam lattice the problem is solved (see *Figure 2.4*).

The gym area will be built with crosses (see *Figure 2.5*) which will avoid the structure from deforming.

Relating to the floor access, it is solved structurally independent of the sport center. It is also performed by porticos consisting on pillars and lattice type Pratt beams; which present wheelbase light pillars of 6'00, 5'00 and 4'80 m. The light beams lattice that is to be covered is 10.00 m, and it will be held by HEB profiles, steel S275 and articulated joints. The pillars have a height of 6'20 m and 3'52 m, and these will be also resolved by HEB profiles, steel S275 (see *Figures 2.1 and 2.4*).

Structured porticos of reinforced concrete are made along the rest of the sports center. The porticos are resolved with pillars and beams of reinforced concrete with characteristic compressive strength fck=25 N/mm² and B500 and steel. These ones have lights between wheelbase pillars 6'00, 5'00, 4'80 and 4'40 m. The distribution between axles of pillars and lights can be seen in *Figures 2.1 and 2.2.*

Finally, in the basement of the building, to perform the function of containment floor, there is a basement wall with a height of 3'52 m. The wall will be made of reinforced concrete HA-25 and B500 steel. (See *Figure 2.2*)

The pillars will rest on the basement wall, and so will the forged in her coronation transmitting loads upstairs.

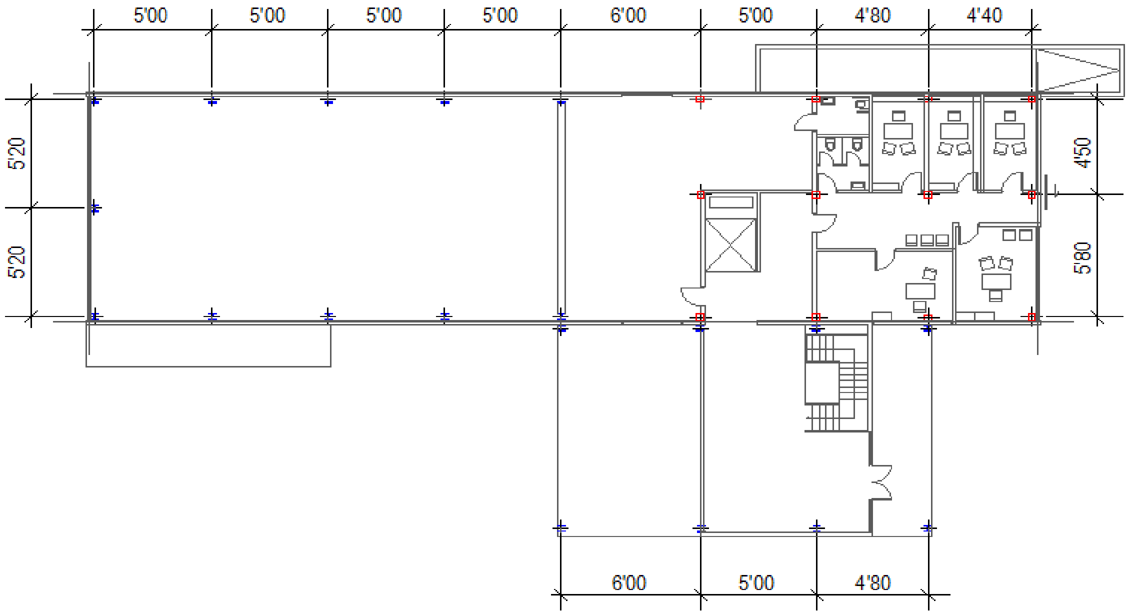

Figure 2.1.: Distribution of pillars on the ground floor. Horizontal section PB

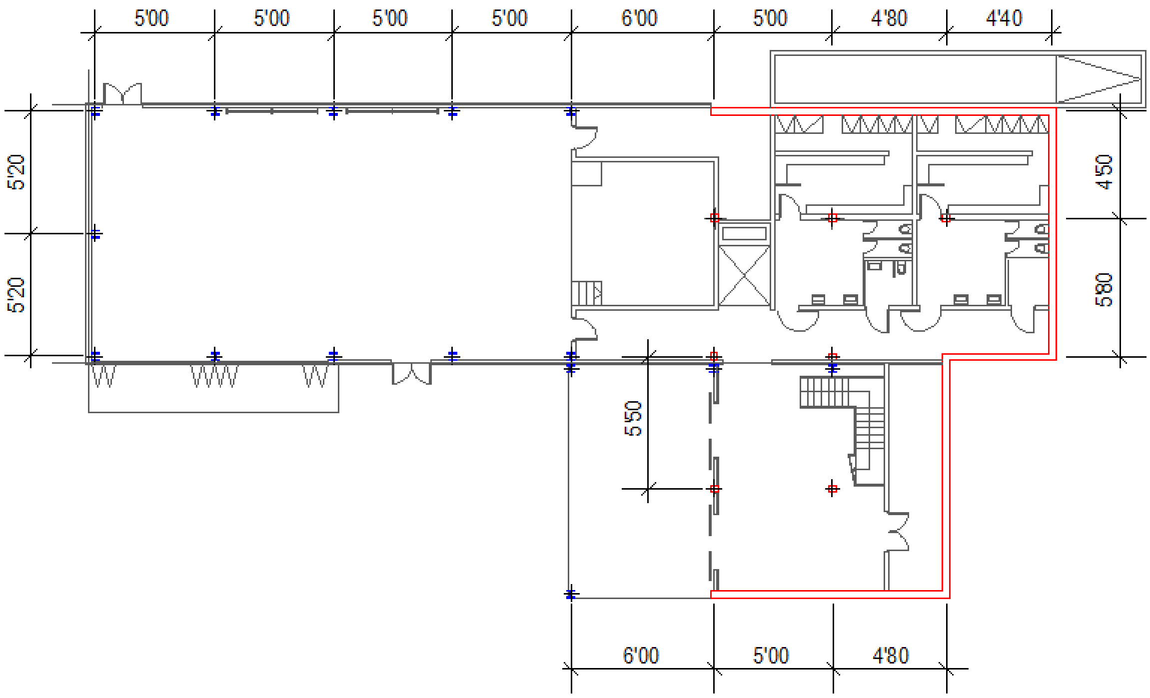

Figure 2.2: Distribution of pillars and location of the wall in the basement. PS horizontal section

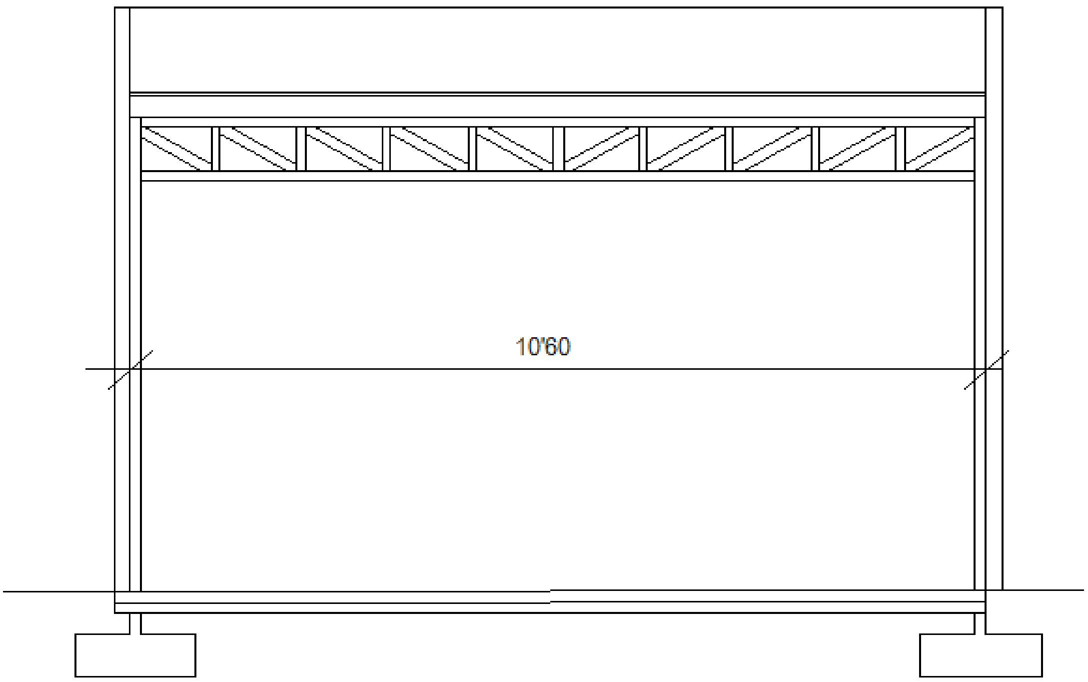

Figure 2.3: Schematic drawing of the porticos of the gym area.

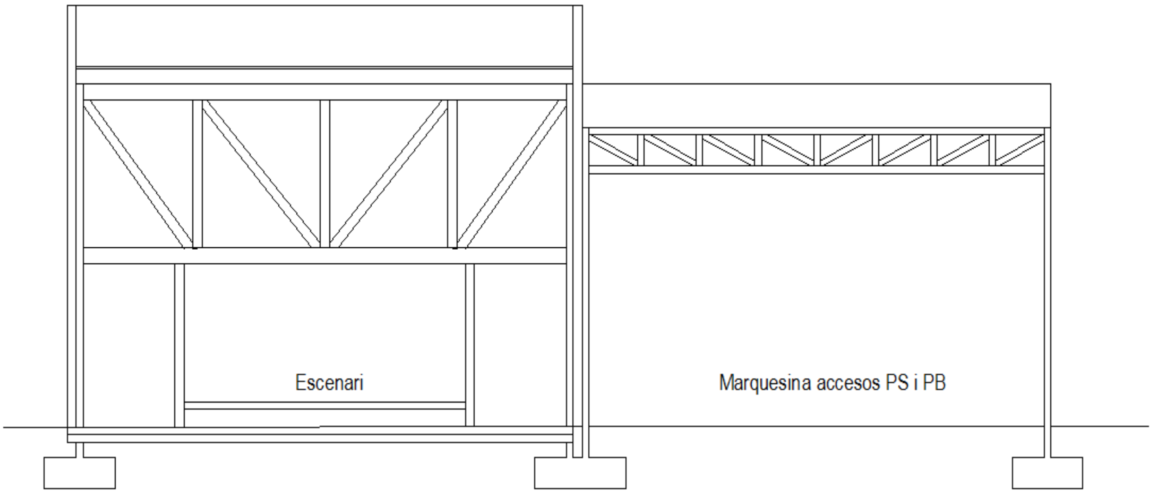

Figure 2.4: Schematic drawing of the portico of fitness and porches of access.

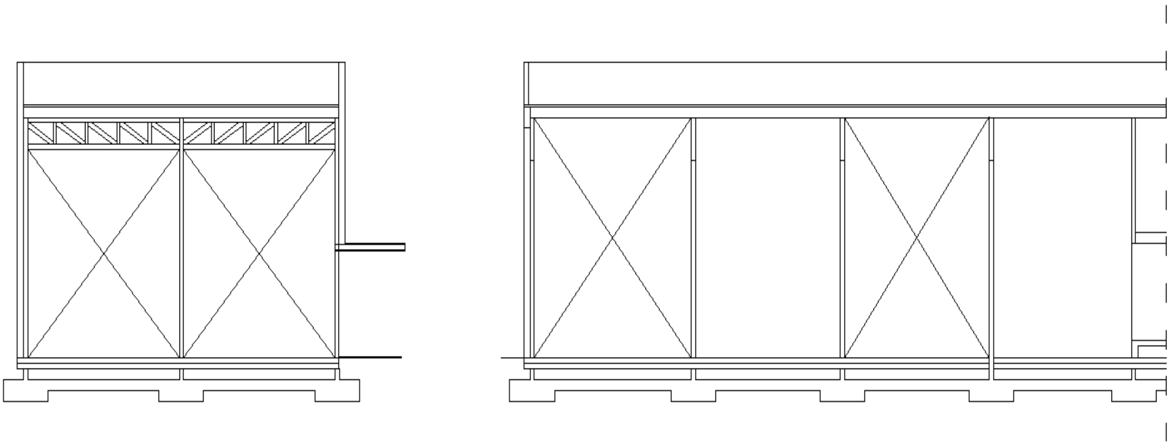

Figure 2.5: Building of the Sports Centers. Transverse and longitudinal vertical sections.

2.2.2 Horizontal structure

The horizontal structure is solved by unidirectional slabs of concrete beams and curved ceramic floor, except for the basement which is solved with a hearth and a road gravel surface. The lights, the direction and sense of slabs can be seen in *Figures 2.6* and *2.7*.

The horizontal structure of the basement access is resolved by a cantilever. This cantilever consists of three steel beams rigidly connected to three metal pillars that face the access. The beams have a length of 2'20 m and resolved profiles IPE, steel S275. On these cantilever beams, straps are supported by articulated joints. These belts, on which a metal plate in the form of light cover will be located, will also be resolved by profiles IPE, steel S275 , and present some lights 5'25 m. (See *Figure 2.6*)

The access to the ground floor is also solved by straps that will support the weight of the roof element, in this case it also means sheet metal and they will also transmit the loads to the lattice beams. The straps, which show lights of 6'00, 5'00 and 4'80 m, will be biarticulated, reporting profiles IPE, steel S275. (See *Figure 2.7*)

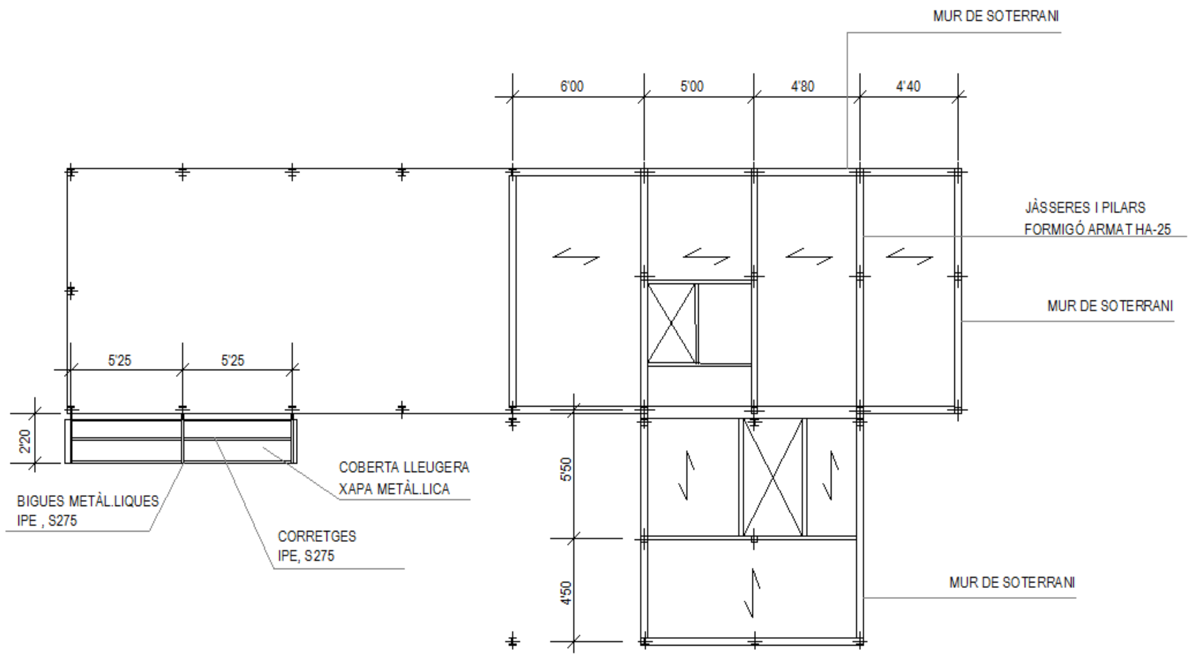

Figure 2.6: Schematic structure of the basement ceiling.

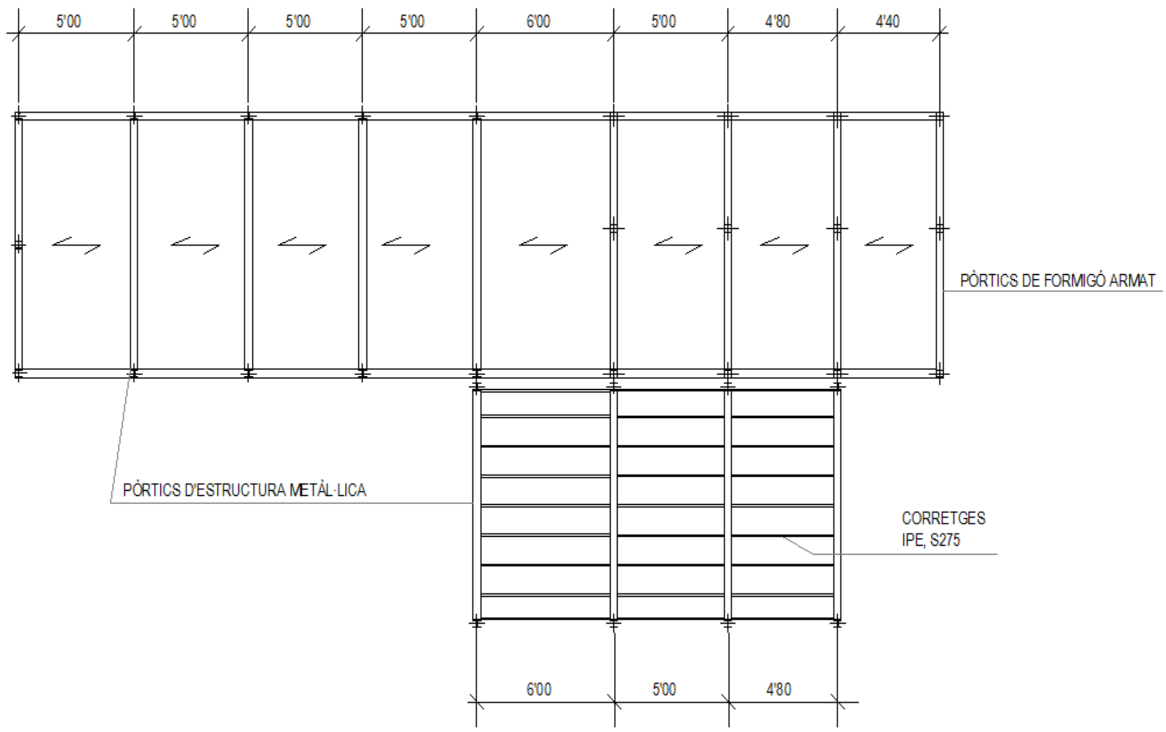

Figure 2.7: Schematic structure of the roof of the ground floor

2.2.3 Basis

Once the geotechnical study is reviewed, and once it is seen that the land has a good resistance, we opt for a shallow foundations established in Level B upon the rocky soil.

Since the building is isolated, foundation under the pillars will be made by focusing on isolated footing. There will also be combined footings, due to the presence of several sets of pillars quite close between them in the area of access. Finally, there will be run footing under the basement wall. (See *Figure 2.8*)

The footings will be joined by beams to absorb the possible actions that can receive horizontal foundation, and thus prevent the lateral displacement.

All the foundations are made with concrete and steel B500 HA-25.

The tensions that are permissible in the ground are 3'50 kg/cm² for isolated footing; and 3'00 kg/cm² for strip footing.

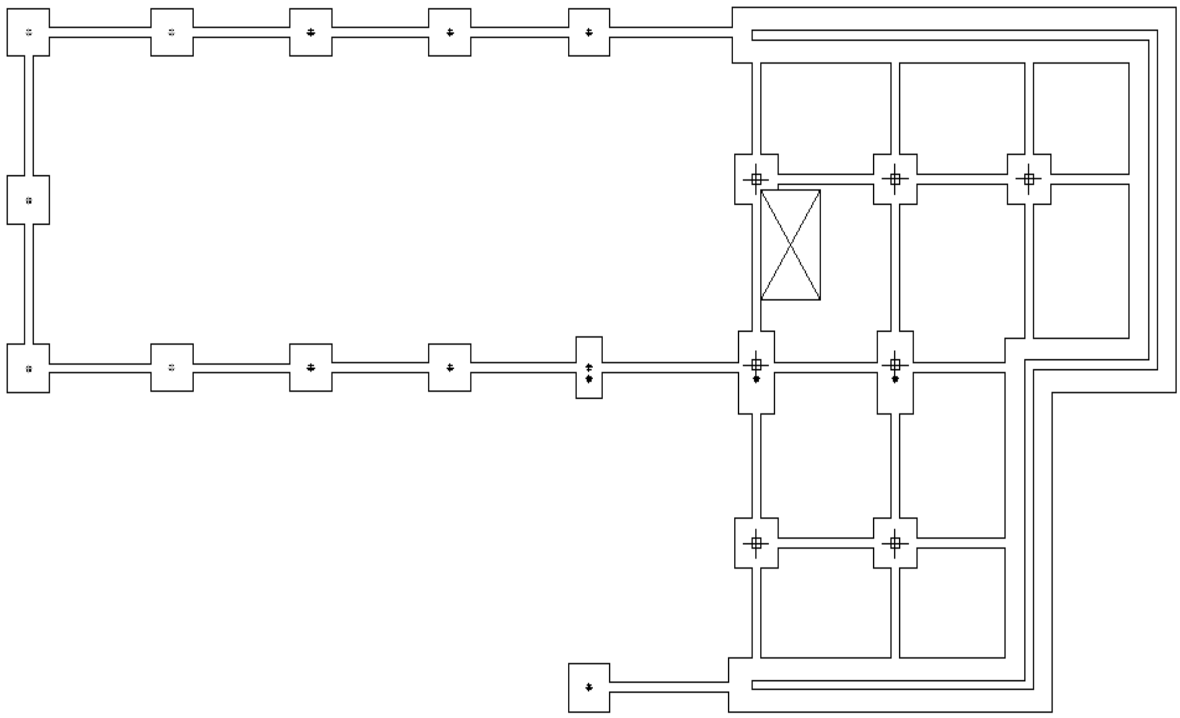

Figure 2.8: Schematic of plant foundations.

2.2.4 Elements of vertical communication

The sport center has two vertical communication elements, a lift and stairs. Their location can be seen above, in *Figures 2.1 and 2.2*.

The stairs, which must save a height of 3'52 m, are solved with three sections of 8, 7 and 5 steps, a total of 20 steps with a footprint of 28 cm and a riser of 17'6 cm; scope of 1'20 m.

The stairs will be solved with concrete slab 20 cm thick, with concrete HA-25 and steel B500. The lift hole has a dimension of 2'15 x 3'40 m, while the hole ladder has a dimension of 2'70 x 5'00 m. Both holes are solved by headers, as shown in the Figure 2.6, above. The beams yokes are made of reinforced concrete HA-25 and B500 steel.

2.3 Actions

Once that the project documentation and features of the building have been studied, the different types of actions that the building can receive are defined. These may be permanent, variable or accidental.

2.3.1 Permanent actions. Own weights.

Weigh itself is considered as permanent load, because it is constant in magnitude and position.

The following weights are extracted from Appendix C of the CTE DB SE- AE, technical and manufacturers of prefabricated elements that exist in the structure.

Forge: according to the manufacturer *Formesa* sheet (see *Appendix G*), we establishe a proper weight 2'97 kN/m² for a unidirectional forge with concrete beams, ceramic and lightweight with a curved edge 25 +5 cm. The edge 25 +5 cm is justified in section 2.4.1 .

Cover: For an inverted flat roof finish of gravel we take into account the own weight of 2'5 kN/m².

Elements of interior layout: It takes as a value of its own weight partitions 1 kN/m². The walls of the elevator which have a thickness of 15 cm weigh himself as the CTE of 5 kN/m. They are considered as a linear load on the beams that will support them.

Pavement: It is a weight of 1 kN/m² own pavement.

Front of prefabricated panels: According Tecnyconta manufacturer catalog (see *Appendix G*), the proper weight for a prefabricated façade with a 20 cm thick, as established in the project is 2'5 kN/m².This weight is considered a linear load.

The facade is self-supporting, and simply fulfills the envelope function.

Sheets of light roofs: Sandwich panels Delphi model from the house Europerfil are chosen (see *Appendix G*). The panel thickness is 40mm, and it has a maximum distance between supports 2'5 m overload allowable 217 daN/m and a weight of its own 0'109 kN/m².

Since the panel determines the distance between the belts, we opt for the choice of three panel supports and continuity, establishing alight webbing between 1'25 m.

2.3.2 Variable actions. Overloading use

According to the CTE DB SE- AE overload use is the weight of everything that can gravitate on the building because of its use.

The following table indicates the values of overhead to be considered for the calculation of the structure of the sport center, taken from Table 3.1 Values overload of use typical of the CTE DB SE- AE.

Table 2.2: Category and values of use overload

USE OVERLOAD		
SUBCATEGORY OF USE	UNIFORM LOAD	AREAS OF THE BUILDING WHERE THEY ACT
B. Administrative areas	2 kN/m²	Buros of the administrative area in the ground floor.

C3. Areas without obstacles to the free movement of people and lobbies of public buildings, administrative, etc..	5 kN/m²	Foyer entrance area of the ground floor areas and distributors of the same plant.
C4. Areas for fitness or physical activity..	5 kN/m²	Fitness area and body on the ground floor.
G1. Covers only accessible for maintenance. Covered with inclination less than 20 °.	1 kN/m²	Inverted flat roof with gravel finish of the building. Forged PB roof..
G1. Covers only accessible for maintenance. Covers light on straps (not forged)	0'4 kN/m²	Marquee access downstairs. Marquee access to the fitness area in Basement.

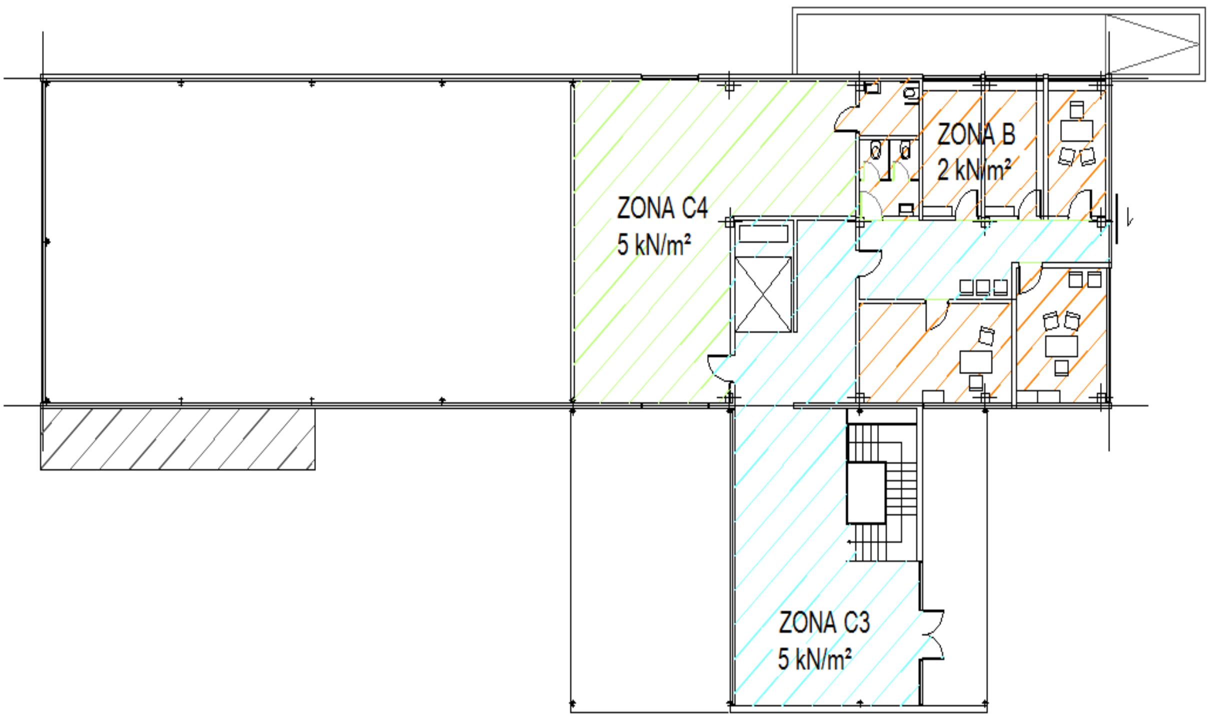

Figure 2.9: Overhead of use of ground floor roof

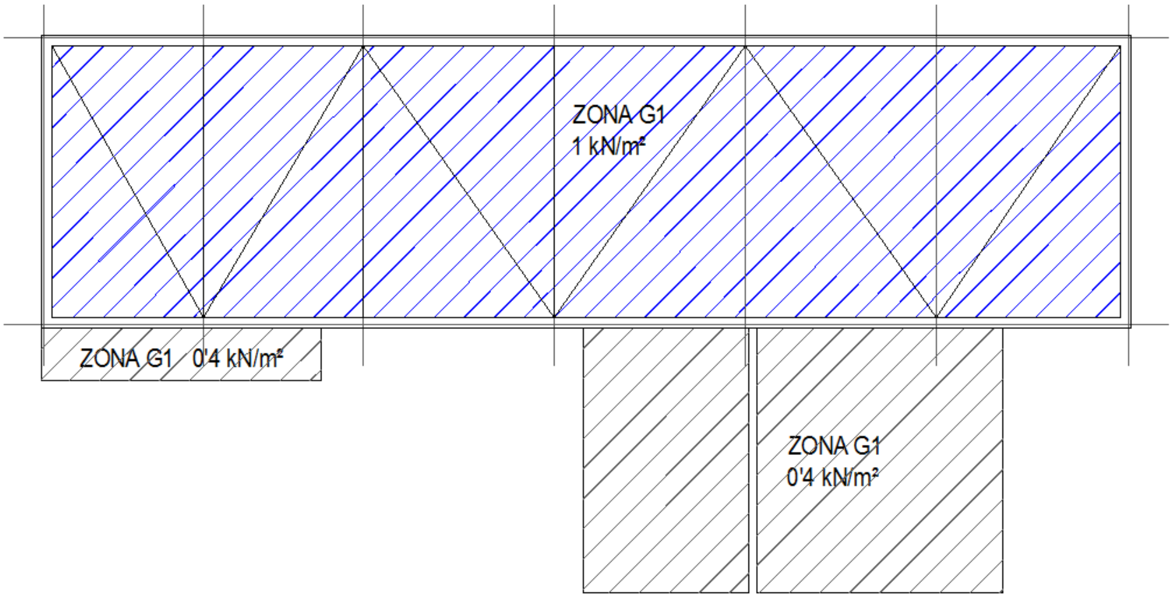

Figure 2.10: use overload Plant Cover.

2.3.3 Variable actions. Thermal actions.

According to CTE DB SE- AE section 3.4.1, we choose not to have expansion joints in the building. Therefore, the variations in temperature of the external environment that may affect the structural elements and that may submit the structure to geometric deformations and changes must be taken into account.

Then, citing the Technical Building Code SE- AE section 3.4.2, it can be stated that:

The overall effects of the thermal action can be obtained from the variation in average temperature of the structural elements, usually for the purpose of summer (dilation) and winter effects (contraction); from a reference temperature when it was built and the item can be taken as the average annual placement or 10℃.

The extreme ambient temperatures of winter and summer can be obtained from Appendix E of the CTE DB SE- AE, and these are the following ones:

According to *Figure 2.11*, the maximum temperature in summer Tarragona is 42 to 44℃.

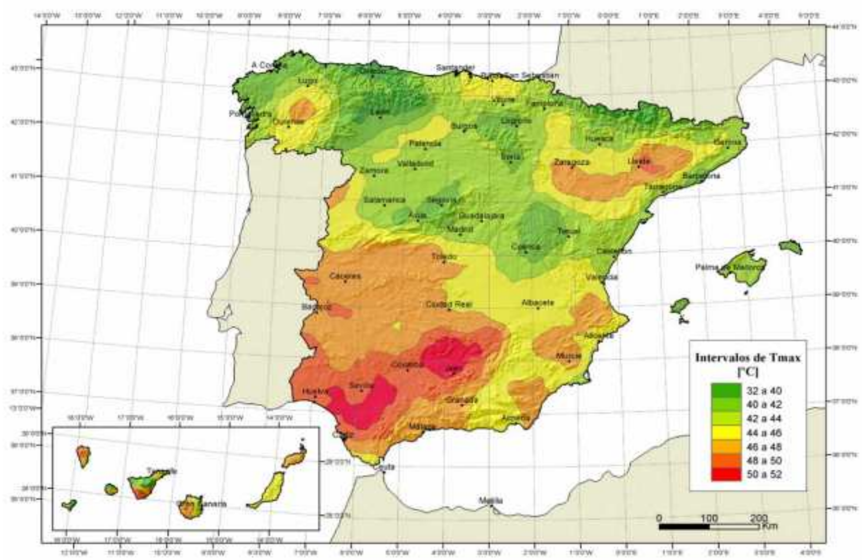

Figure 2. 11 Figure E.1. Isotherms of maximum annual air temperature (Tmax in °C)

According to *Figure 2.12* and Table 2.3, the minimum temperature in winter because of the fact that we are on zone 2 and an altitude of 0 m is -11 °C.

Figure 2.12: Figure E.2 Yields of winter

Table 2.3: Table E.1. Minimum temperature of the outside air (°C)

Altitud (m)	**Zona de clima invernal**, (según figura E.2)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
0	-7	-11	-11	-6	-5	-6	6
200	-10	-13	-12	-8	-8	-8	5
400	-12	-15	-14	-10	-11	-9	3
600	-15	-16	-15	-12	-14	-11	2
800	-18	-18	-17	-14	-17	-13	0
1.000	-20	-20	-19	-16	-20	-14	-2
1.200	-23	-21	-20	-18	-23	-16	-3
1.400	-26	-23	-22	-20	-26	-17	-5
1.600	-28	-25	-23	-22	-29	-19	-7
1.800	-31	-26	-25	-24	-32	-21	-8
2.000	-33	-28	-27	-26	-35	-22	-10

Extreme minimum temperature of the environment will be adopted because of the exposed elements. And as summer maximum the extreme environment will be adopted and enhanced by the effect of solar radiation according to the following table.

Table 2.4: Table 3.7. Temperature rise due to solar radiation

Orientación de la superficie	**Color de la superficie**		
	Muy claro	Claro	Oscuro
Norte y Este	0 ºC	2 ºC	4 ºC
Sur y Oeste	18 ºC	30 ºC	42 ºC

Then for the elements exposed to weather, if you consider an average temperature of 10 °C we have the following temperature variations:

T1 = 35℃ (north and east) 65℃ (south and west) in summer considering the effect of solar radiation.

T2 = -20℃ in winter.

Round 20℃ can be taken all year as the temperature of the interior structural elements.

Finally, as the temperature of the envelope elements not directly exposed to the weather it can take the average of the two previous cases.

These temperature values are considered and applied as loads in structural temperature through the program TRICALC 7.4.

2.3.4 Variable actions. Snow

Pursuant to section 3.5 of the CTE DB SE- AE, distribution and intensity of the snow load on your roof or a building depends on the weather, the type of precipitation, the relief of the environment, the shape of the roof, the effects of the wind and the exchange of heat in the outer walls.

Next, the snow load in the case of natural reservoir of this must be calculated, since it is provided by the Technical Building Code.

q_n is taken as the value of snow load per unit area in horizontal projection,:

$$\boldsymbol{q_n = \mu \cdot s_k}$$

μ is the coefficient of the roof

s_k Characteristic value of the snow load on a horizontal ground

The value of the coefficient for the flat roof with finished gravel is considered 1, because its own walls avoid the sliding of the snow.

1 is also taken for the access of the shelters, since it is not considered and obstacle and its slope is less than 30 °.

The value of the snow load on a horizontal ground from Appendix C of the CTE DB SE- AE is deduced for $s_k$follows, depending on the area and the topographic elevation of the site of the work. The topographic elevation of La Riera de Gaià is 28 m and the area of winter weather is 2, then from Table 2.5 an overload of snow value 0.4 kN/m² can be taken.

Table 2.5: Table E.2 Overhead horizontal snow on ground (kN/m²)

Altitud (m)	**Zona de clima invernal**, (según figura E.2)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
0	0,3	0,4	0,2	0,2	0,2	0,2	0,2
200	0,5	0,5	0,2	0,2	0,3	0,2	0,2
400	0,6	0,6	0,2	0,3	0,4	0,2	0,2
500	0,7	0,7	0,3	0,4	0,4	0,3	0,2
600	0,9	0,9	0,3	0,5	0,5	0,4	0,2
700	1,0	1,0	0,4	0,6	0,6	0,5	0,2
800	1,2	1,1	0,5	0,8	0,7	0,7	0,2
900	1,4	1,3	0,6	1,0	0,8	0,9	0,2
1.000	1,7	1,5	0,7	1,2	0,9	1,2	0,2
1.200	2,3	2,0	1,1	1,9	1,3	2,0	0,2
1.400	3,2	2,6	1,7	3,0	1,8	3,3	0,2
1.600	4,3	3,5	2,6	4,6	2,5	5,5	0,2
1.800	-	4,6	4,0	-	-	9,3	0,2
2.200	-	8,0	-	-	-	-	-

Value of snow load per unit area in horizontal projection:

$q_n = \mu \cdot s_k$ = 1 . 0'4 kN/m² = **0'4 kN/m²**

2.3.5 Variable actions. Wind

According to what has been said in section 3.3.1 of the CTE DB SE- AE , the distribution and the value of the pressures exerted by the wind on a building and its resulting forces depend on the shape and dimensions of the building, the characteristics of the surface and the direction and intensity of the wind.

According to what has been cited and the regulations explained, the wind loads considered in structural design are calculated.

The wind action is determined by the following expression: $\mathbf{q_e = qb \cdot ce \cdot cp}$

From CTE DB -AE get each of these parameters:

- **qb**: dynamic pressure

Depending on the geographic location according to Annex D of the CTE DB-AE the following expression is taken as a value: qb =0'52 kN/m² (Area C).

- **ce**: coefficient of exposure

According to Table 2.6 and the surroundings of the building a grade of roughness is considered: IV. Urban area in general.

Given that the sport center has different heights due to its underground part, we take an average height of the façade.

Table 2.6: Table 3.4. Coefficient values of exposure ce

	Grado de aspereza del entorno	Altura del punto considerado (m)							
		3	6	9	12	15	18	24	30
I	Borde del mar o de un lago, con una superficie de agua en la dirección del viento de al menos 5 km de longitud	2,4	2,7	3,0	3,1	3,3	3,4	3,5	3,7
II	Terreno rural llano sin obstáculos ni arbolado de importancia	2,1	2,5	2,7	2,9	3,0	3,1	3,3	3,5
III	Zona rural accidentada o llana con algunos obstáculos aislados, como árboles o construcciones pequeñas	1,6	2,0	2,3	2,5	2,6	2,7	2,9	3,1
IV	Zona urbana en general, industrial o forestal	1,3	1,4	1,7	1,9	2,1	2,2	2,4	2,6
V	Centro de negocio de grandes ciudades, con profusión de edificios en altura	1,2	1,2	1,2	1,4	1,5	1,6	1,9	2,0

The average height of the building, hi = 6'48 m, is between 6 and 9 m. Its value cannot be extracted directly, so the corresponding value must be interpolated and extracted.

ce = 1'448

- **cp**: wind or pressure coefficient depending on the shape and orientation of the surface according to the wind.

- Calculation of vertical wind

The calculation of the vertical wind is done by following the provisions of Annex D Table D.3 CTE DB SE-AE.

Longitudinal and transverse wind affect the building in different ways, so the wind is calculated for the four hypotheses and directions observed in the figure below.

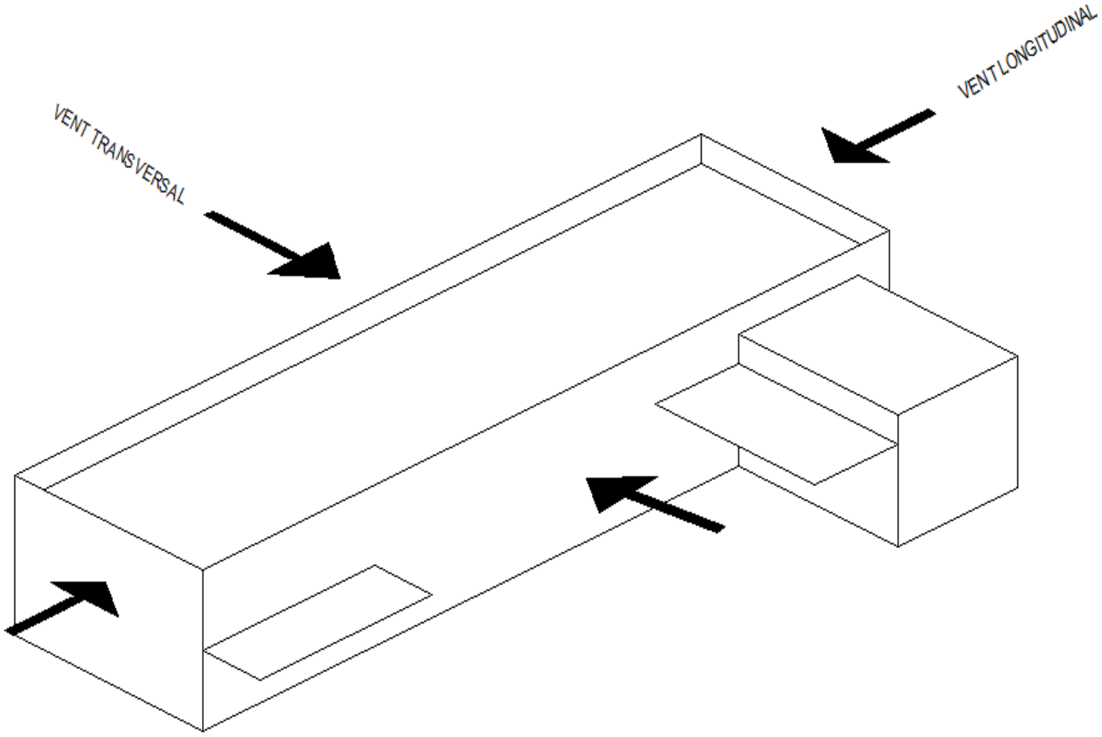

Figure 2.13: Wind longitudinal and transverse wind on the building

Transverse wind

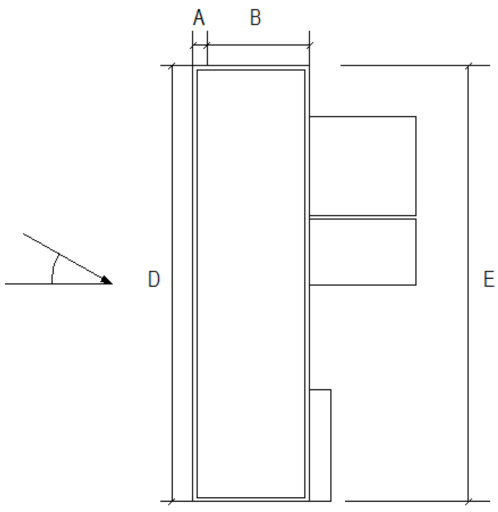

Figure 2:14: Transverse wind on face D

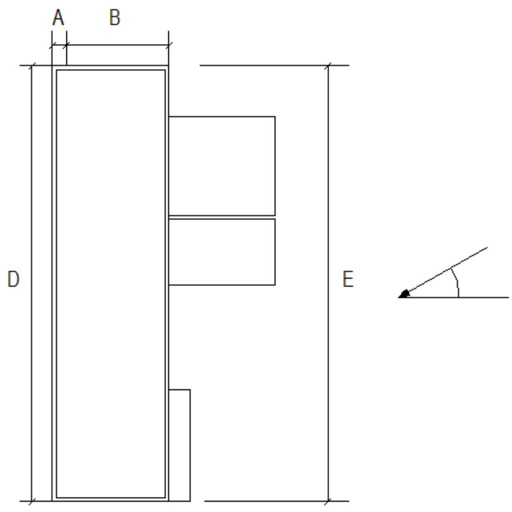

Figure 2:15: transverse wind on face E

$e_{mín.}$ = (6'48 . 2 ; 41)= 12'96 m~ 13 m h/d = 0'59

Table 2.7: Calculation of the vertical wind. Transverse wind

Zone	Area	C_{pe}	Q_e = qb · ce · cp	Wind load (kN/m^2)	
A	1'3 · 6'48 = 8'43 m^2 5 < A < 10	-1,23	0'52 . 1'448. -1'23	- 0'93	Suction
B	9'7 · 6'48 = 62'86 m^2 > 10 m^2	-0,8	0'52. 1'448. -0'8	- 0'60	Suction
D	41 · 6'48 = 265'68 m^2 > 10 m^2	0,745	0'52 . 1'448. 0'745	0'56	Pression
E	41 · 6'48 = 265'68 m^2 > 10 m^2	-0,39	0'52 .1'448. -0'39	- 0'29	Suction

The values obtained correspond to the hypotheses of transverse wind included in *Figure 2.14*, the wind pressure on face D and it sucks out E; plus areas A and B.

In the case of *Figure 2.15*, the values of suction and pressure will remain the same but in the opposite direction. That is, the face has a pressure of E 0'56 kN/m^2 and the face of a suction - 0'29 kN/m^2; in addition to the suffering that can suck the faces A and B.

<u>Longitudinal wind</u>

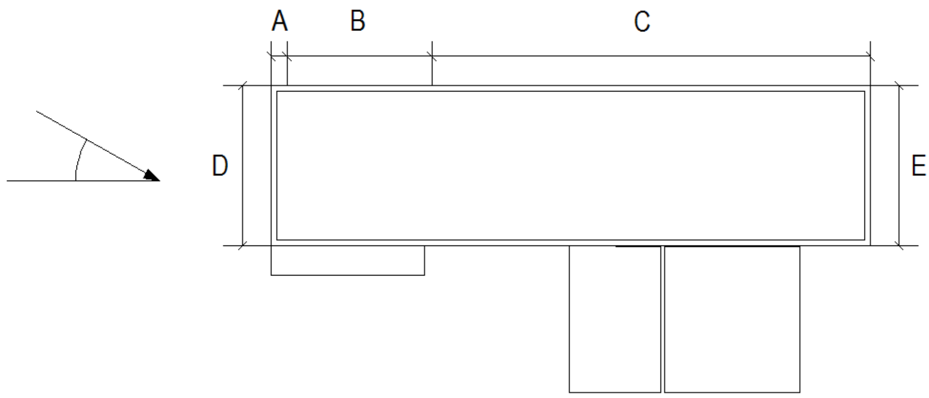

Figure 2.16: longitudinal wind on face D

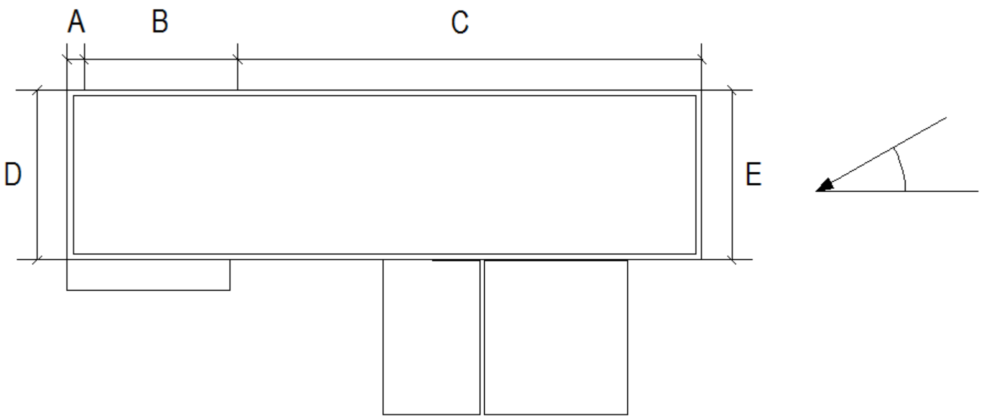

Figure 2.17: longitudinal wind on face E

$e_{mín.}$ = (6'48 . 2 ; 11)= 11 m   h/d = 0'16

Table 2.8: Calculation of the vertical wind. longitudinal wind

Zone	Area	C_{pe}	Q_e = qb · ce · cp	Wind load (kN/m^2)	
A	1'1 · 6'48 = 7'13 m^2 5 < A < 10	-1'26	0'52 . 1'448. -1'26	-0'95	Suction
B	9'9 · 6'48 = 64'15 m^2 > 10 m^2	-0'8	0'52 . 1'448. -0'8	-0'60	Suction
C	30 · 6'48 = 194'4 m^2 > 10 m^2	/	/	/	/
D	11 · 6'48 = 71'28 m^2 > 10 m^2	0'7	0'52 . 1'448. 0'7	0'53	Pression
E	11 · 6'48 = 71'28 m^2 > 10 m^2	-0'3	0'52 . 1'448. -0'3	-0'23	Suction

As in the previous case, the values obtained correspond to the hypotheses of longitudinal wind in *Figure 2.16*, the wind presses face D and sucks out face D and E; plus areas A and B

In the case of *Figure 2.17*, the values of suction and pressure will remain the same but in the opposite direction. That is, the face has a pressure of E 0'53 kN/m² and the face of suction - 0'23 kN/m²; In addition to the suffering that can suck out the faces A and B.

As shown in the following figure, to perform structural design, the wind TRICALC in the program will be considered as a linear distributed load on the structural elements that have to endure; depending on wind direction.

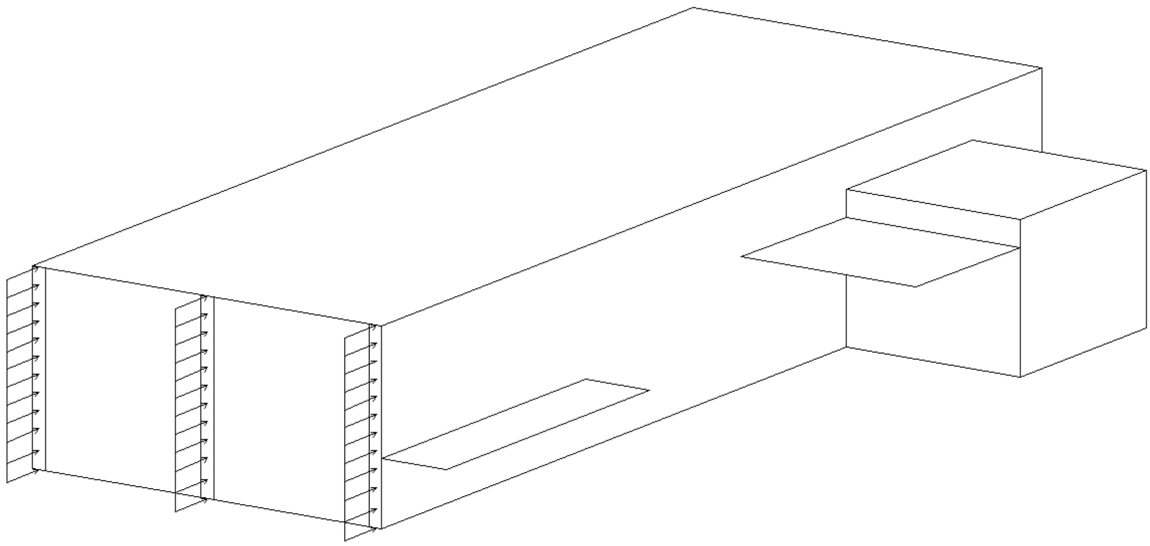

Figure 2.18: Treatment of the wind by Tricalc program.

- <u>Calculation of wind on the flat roof of the sports center</u>

In the sport center, wind will be treated through vertical parameters; because the suction that the flat roof could suffer is counteracted by its own weight.

According to section 3.3.4. CTE DB SE-AE buildings with flat roof, the action of the wind, usually suction, operates normally in a safe way, and it can be disregarded.

➢ Calculation of wind on the canopy access Basement

The following calculation is carried out in accordance with the provisions of Table D.10 Canopies to Appendix D of the CTE DB SE-AE.

Transverse wind

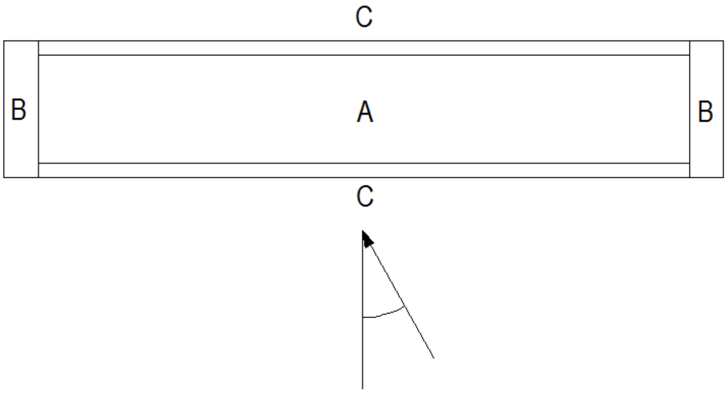

Figure 2.19: Wind cross the canopy Basement

Table 2.9: Calculation of the suction of the wind on the canopy. Transverse wind

α	Degree of obsruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$\varphi = 1$	A	0'52· 1'448 · (-1'5)	-1'13
		B	0'52· 1'448 · (-1'8)	-1'36
		C	0'52· 1'448 · (-2'2)	-1'66

Table 2.10: Calculation of the wind pressure on the canopy. Transverse wind

α	Degree of obsruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$0 \leq \varphi \leq 1$	A	0'52· 1'448 · (0'5)	0'38
		B	0'52· 1'448 · (1'8)	1'36
		C	0'52· 1'448 · (1'1)	0'83

Longitudinal wind

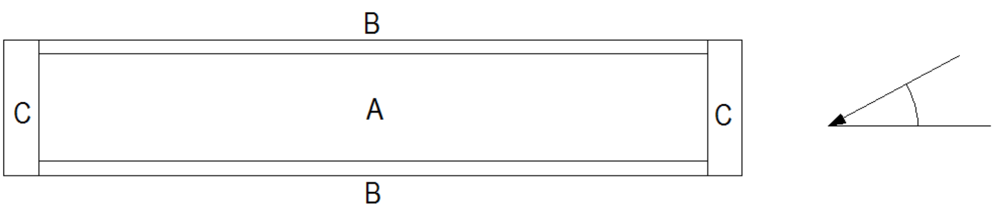

Figure 2.20: Wind longitudinal canopy basement.

Table 2.11: Calculation of the suction of the wind on the canopy. Longitudinal wind

α	Degree of obstruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$\varphi = 0$	A	0'52· 1'448 · (-0'9)	-0'45
		B	0'52· 1'448 · (-1'3)	-0'98
		C	0'52· 1'448 · (-1'4)	-1'05

Table 2.12 : Calculation of the wind pressure on the canopy. Longitudinal wind

α	Degree of obstruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$0 \leq \varphi \leq 1$	A	0'52· 1'448 · (0'5)	0'38
		B	0'52· 1'448 · (1'8)	1'36
		C	0'52· 1'448 · (1'1)	0'83

- Calculation of wind on the canopy access Floor

To perform the calculation, and given the conditions and geometry, a part of the access should be considered as a flat roof, and the other one as a water canopy.

And following the criteria above the wind to the canopy is calculated.

Transverse wind

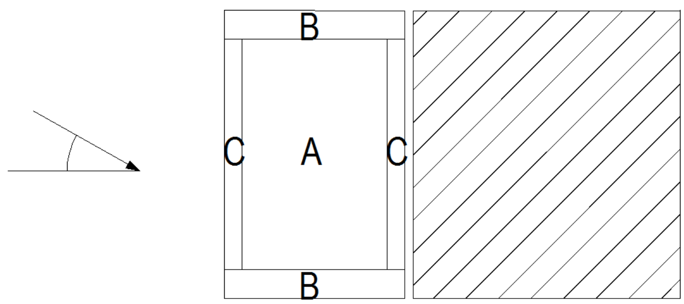

Figure 2.21: Wind cross the canopy Floor.

Table 2.13: Calculation of the suction of the wind on the canopy. Transverse wind

α	Degree of obstruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$\varphi = 1$	A	0'52· 1'448 · (-1'5)	-1'13
		B	0'52· 1'448 · (-1'8)	-1'36
		C	0'52· 1'448 · (-2'2)	-1'66

Table 2.14: Calculation of the wind pressure on the canopy. Transverse wind

α	Degree of obstruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$0 \leq \varphi \leq 1$	A	0'52· 1'448 · (0'5)	0'38
		B	0'52· 1'448 · (1'8)	1'36
		C	0'52· 1'448 · (1'1)	0'83

<u>Longitudinal wind</u>

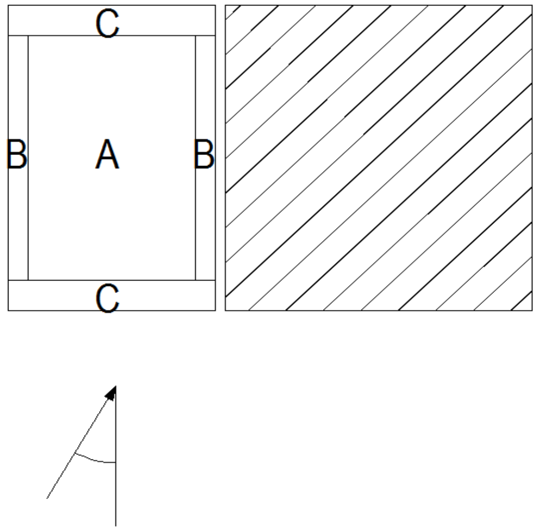

Figure 2.22: Wind longitudinal on the Ground Floor Canopy

Table 2.15: Calculation of the suction of the wind on the canopy. Longitudinal wind

α	Degree of obstruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$\varphi = 1$	A	0'52· 1'448 · (-1'5)	-1'13
		B	0'52· 1'448 · (-1'8)	-1'36
		C	0'52· 1'448 · (-2'2)	-1'66

Table 2.16: Calculation of the wind pressure on the canopy. Longitudinal wind

α	Degree of obstruction	Area	Qe = qb · ce · cp	Wind load (kN/m^2)
0º	$0 \leq \varphi \leq 1$	A	0'52· 1'448 · (0'5)	0'38
		B	0'52· 1'448 · (1'8)	1'36
		C	0'52· 1'448 · (1'1)	0'83

Meanwhile, another area is calculated according to the access provisions in Table D.4. Flat roofs in Annex D of the CTE DB SE-AE.

$e_{mín.}$ = (6'48. 2, 10) = 10 m

<u>Transverse wind</u>

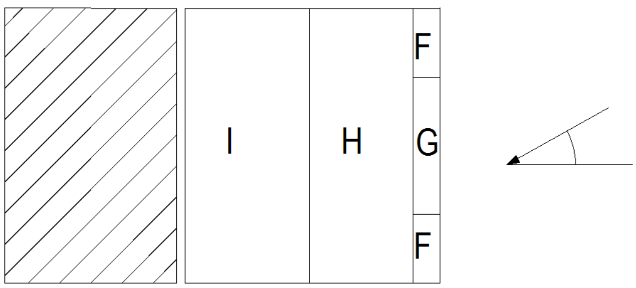

Figure 2.23: Wind transverse deck access Floor

Table 2.17: Calculation of the wind on the flat roof. Transverse wind

Zone	Area	C_{pe}	Q_e = qb · ce · cp	Wind load (kN/m^2)	
F	1 · 2'5 = 2'5 m^2 1< A < 10	-2'38	0'52 . 1'448. -2'38	-1'79	Suction
G	5 · 1 = 5 m^2 1< A < 10	-1'64	0'52 . 1'448. -1'64	-1'23	Suction
H	4 ·10 = 40 m^2 > 10 m^2	- 0'7	0'52 . 1'448. -0'7	-0'53	Suction
I	10 · 5= 50 m^2 > 10 m^2	- 0'2	0'52 . 1'448. -0'2	-0'15	Suction
I	10 · 5= 50 m^2 > 10 m^2	+0'2	0'52 . 1'448. 0'2	0'15	Pression

Longitudinal Wind

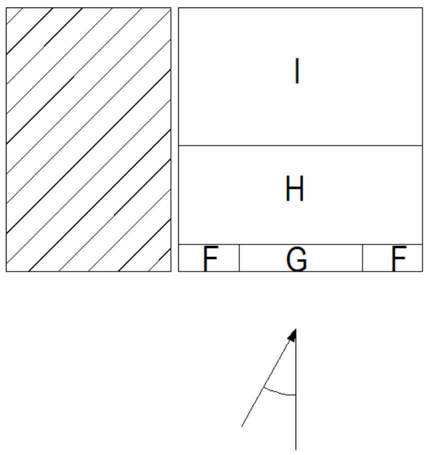

Figure 2.24: Wind longitudinal deck access Floor

Table 2.18: Calculation of the wind on the flat roof. Longitudinal wind

Zone	Area	C_{pe}	Q_e = qb · ce · cp	Wind load (kN/m^2)	
F	1 · 2'5 = 2'5 m^2 1< A < 10	-2'38	0'52 . 1'448. -2'38	-1'79	Suction
G	5 · 1 = 5 m^2 1< A < 10	-1'64	0'52 . 1'448. -1'64	-1'23	Suction
H	4 ·10 = 40 m^2 > 10 m^2	- 0'7	0'52 . 1'448. -0'7	-0'53	Suction
I	10 · 5= 50 m^2 > 10 m^2	- 0'2	0'52 . 1'448. -0'2	-0'15	Suction
I	10 · 5= 50 m^2 > 10 m^2	+0'2	0'52 . 1'448. 0'2	0'15	Pression

Since the flat roof is square, 10 x 10 m, the values for cross wind and longitudinal wind are the same ones; but they affect different areas depending on wind direction.

4 PROJECT OF THE STRUCTURE

This chapter explains the process of the preparation of all project documentation, that is, the memory calculation, the plans, the measurement and budget. This documentation is included in Annexes B, C and D.

4.1 Plans

For the preparation of the plans, firstly these ones has been generated in the program Tricalc, because it allows composition from the structural solutions sketches and export them to AutoCAD program.

Once exported to AutoCad program, all the necessary changes for a better understanding and interpretation of drawings are carried out manually, and all necessary construction details to run a properly structure are performed.

All the plans of the proposed structure are in Appendix C - Plans.

4.2 Calculation report

Tricalc program provides a comprehensive calculation report explaining all the processes and methods of calculation carried out for stress analysis and resolution of all structural elements.

The development of memory calculation is based on this original file, including in the memory of computation all computational methods and processes referred only to the structural elements that form the building under study.

Appendix B – Calculation report, in addition to the aforementioned explanation of the calculation methods provided by the program, the rules applied, the loads and combinations of actions considered in the calculation, the calculation parameters established efforts to determine and calculate the structural elements, the material characteristics of the structure and level of control are explained, as well as a sample of the results obtained numerically and graphically.

4.3 Measure and budget

In order to prepare these documents, firstly an extraction of the measurements of the structure that provides a detailed program Tricalc must be arranged. Measurements are manually exported to an Excel spreadsheet, and the chapter earthmoving that the program does not provide is also added.

From these measurements, an estimate of the structure is made on an Excel spreadsheet too. The budget is divided into four chapters: earthworks, foundations, reinforced concrete structure and steel structure. Each of these chapters is organized by items with its composite unit prices and total prices, these prices are taken from the database of the Itec.

Finally, we made a last sheet of the final budget execution and budget execution by contract.

The documentation on this section is included in *Appendix D - Measure and budget*.

5 ENERGY COSTS AND CO_2 EMISSIONS

Nowadays the increased awareness regarding to environment is evident. This has led to the concept of sustainability, which has gained importance in the field of construction, ensuring criteria applied in construction. These are environmentally friendly and minimize environmental impact.

It is known that the construction sector is one of the polluting industries that exist, and consequently produce an environmental impact. This environmental impact generated as begins with the extraction of materials from the existing resources, to manufacturing and execution of the work. All these processes generate energy expenditure, production and CO_2 emissions and waste production that can cause environmental changes.

All these aspects lead to the need of controlling everything and trying to minimize the cost and energy cost and CO_2 emissions produced by construction.

This chapter is written with this aim: explaining the steps performed in order to assess the energy cost and a calculation of the CO_2 emissions generated by the structure.

5.1 Evaluation of the energy cost of the structure projected

For the assessment of energy consumption and cost structure projected kWh are calculated, that is, the energy consumed during the execution of the structure, from the database of BEDEC the Itec (see *Figure 5.1*).

Once the kWh, is obtained, an economic evaluation of energy consumption is done, using the energy consumed per established company supplying energy.

Consum	Pes	Cost energètic		Emissió CO2
	Kg	MJ	kwh	Kg
Components constitutius de materials	2.539,07	1.308,64	363,51	235,56
aigua	170,63	1,02	0,28	0,049
àrid	2.105,95	315,89	87,75	16,85
ciment	262,50	991,73	275,48	218,66
Total	2.539,07	1.308,64	363,51	235,56

Figure 5.1: Example of data energy costs and CO_2 emissions per m³ of concrete pillars HA-25/B/20/I.

5.2 Calculation of CO_2 emissions

The calculation of CO_2 emissions is also based on the data provided by the bank BEDEC Itec, as can be seen in *Figure 5.1*., taking into account the items of work values for CO_2 emissions generated in the manufacture of materials and CO_2 emissions produced in the use of machinery during the execution of the structure.

The documentation on this chapter is included *in Appendix E - Energy costs and CO_2 emissions*.