



Escola Politècnica Superior
d'Edificació de Barcelona

UNIVERSITAT POLITÈCNICA DE CATALUNYA

GRADO EN CIENCIAS Y TECNOLOGÍAS DE LA EDIFICACIÓN PROYECTO FINAL DE GRADO

DISEÑO, CÁLCULO Y PROYECTO DE LA ESTRUCTURA DE UN EDIFICIO DESTINADO A RESIDENCIA PARA LA TERCERA EDAD

ANEXO B: TRADUCCIÓN AL INGLÉS

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1 INTRODUCTION

This project consists of carrying out the final design of the structure of a building. Basic design drawings and parameters reflected in the geotechnical study are the starting point for design. Also previous conditions are established in the absence of a specification.

Throughout the project we deal with the entire process of design, calculation and writing the project of a structure. In this case, as an academic work, it will not be limited exclusively to define a solution, but also focus into different alternatives and the reasoning of the solutions adopted.

Project's working process has consisted mainly of the following steps:

1. Previous study of available documentation: basic design drawings and geotechnical study
2. Study of different alternatives for the resolution of the structure, taking into account all technologies available and their suitability for use in the project's building.
3. Predimensioning the structure elements by estimating actions applicable to the building.
4. Definition of real actions applicable to the building according to the current regulations.
5. Complete calculation of the structure, defining and fully sizing each of its elements.
6. Preparation of all necessary documentation for the construction of the structure calculated above, which will be contained in the project implementation. In this phase will take place all necessary changes in order to: facilitate and optimize the material execution of the construction process.
7. Assessment of the economic cost of the structure by developing the PEM (budget implementation). As well as the environmental impact study of the structure construction (gas emissions and energy costs).
8. Drafting of project report, conclusions and annexes.

The basic premises throughout this process will be:

- Respect, within the parameters of economy and sustainability, the original configuration of the building.
- Designing a structure that meets the criteria of safety, durability, economy and energy saving.

- Define and explain clearly the solutions adopted

2 PROJECT OVERVIEW AND GENERAL INFORMATION

2.1.1 BUILDING

The building under study is a day center-residence for the elderly. The complex consists of a single isolated building and its associated facilities (recreational areas, gardens, parking and access roads). The building has a basement floor, a ground floor, four upper floors and a flat roof. The occupancy is 1,080 m² in floor plan, and the total planned construction area is 6,480 m².

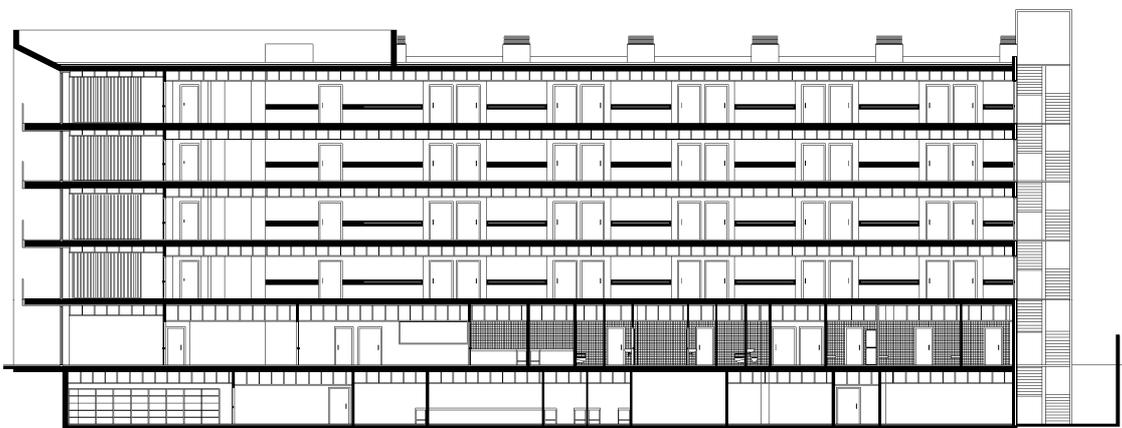


Figure 2.1: longitudinal section

The geometrical arrangement of the building is formed by the intersection of two rectangular sections, defining two wings (which will be referred as East and West Wing from now on) with differentiated functions, especially at higher floors.

The west wing is designed almost as a square with measures 21.75 x 17.8 meters, and consists of several terraces. The East wing is a rectangular prism, with sides more differentiated than in the previous case, with dimensions of 42.7x17, 8 meters. In the meeting area of both wings lies the vertical communication core. The building has also a fire escape outside of the east facade.

Basement level is mainly focused in service areas: kitchen, dressing rooms, storage, and other auxiliary facilities. In the southern facade of the East wing, this floor is on the ground level, which favors the existence of an acces to the outside through the parking lot.

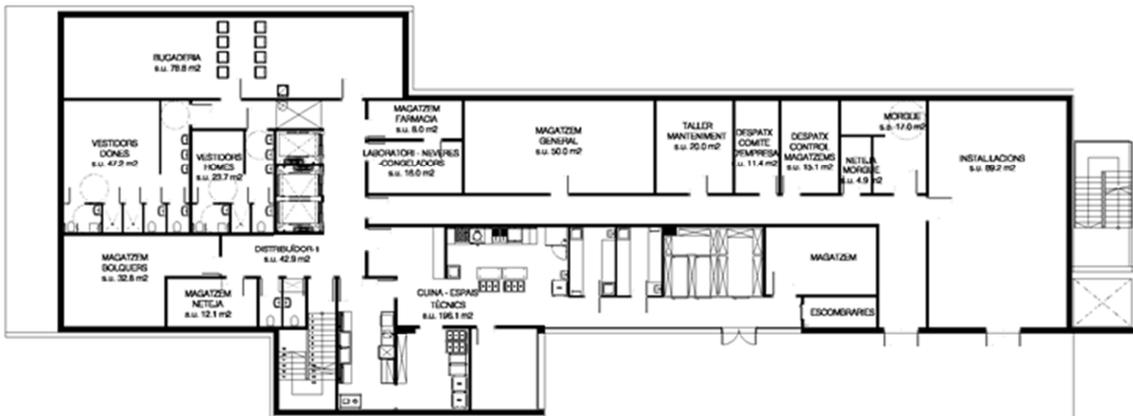


Figure 2.2: basement floor

Ground floor has mostly day-center functions, including consulting rooms, gymnasium, multipurpose room, etc. Most offices and other rooms for administrative use are also located on this floor. Main entrance, reception and bar are located in the west wing.

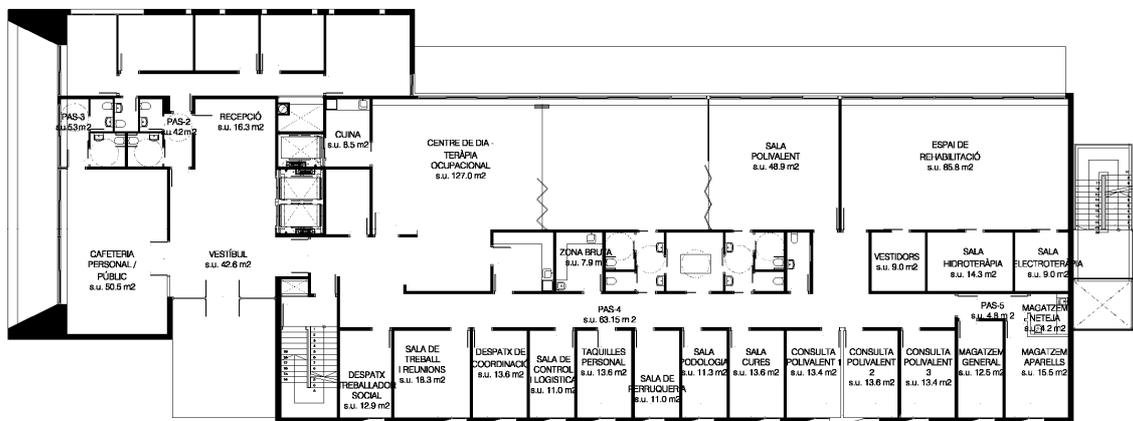


Figure 2.3: ground floor

The upper floors are designed to perform the functions of residence, being at the East Wing the areas specified to be private rooms (21 on each floor, all of them with several closets and a private bathroom). In the west wing there are the dining-living rooms, facilities and service areas are too located there. From living room there is acces to two terraces, a larger one located on the west facade, and a smaller balcony located on the front door.

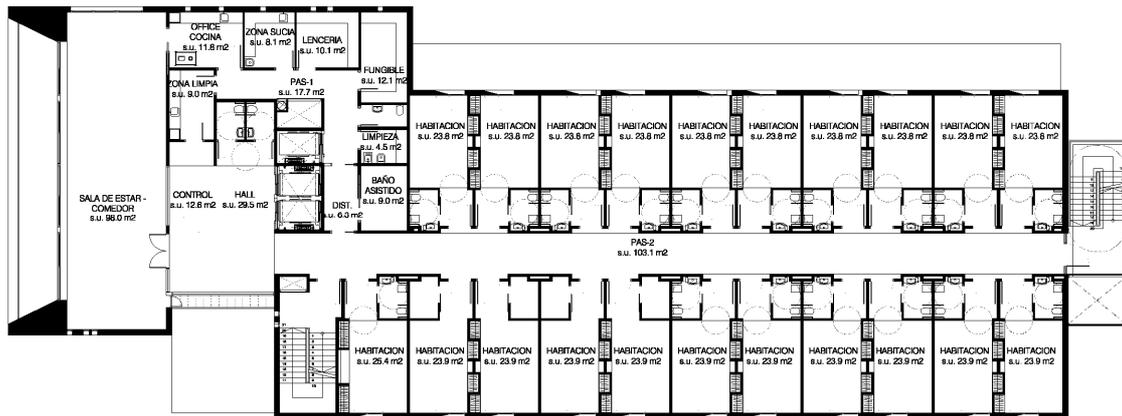


Figure 2.4: upper floor

2.1.2 SURROUNDINGS

Having no memory of the original project and the actual location of the same, it is considered that the building will be located at the Bacardi street of l'Hospitalet de Llobregat, in the land of which it is available the information required, reflected in a geotechnical study. Likewise this location has been used as the basis for any other calculations, such as wind or seismic loads which determines regulations for the calculation of the structure.

It is a building in an urban area, within the metropolitan area of Barcelona. This location provides easy access to all kinds of common supplies (materials, fluids, machinery, etc..), So they are not considered potential constraints related to the

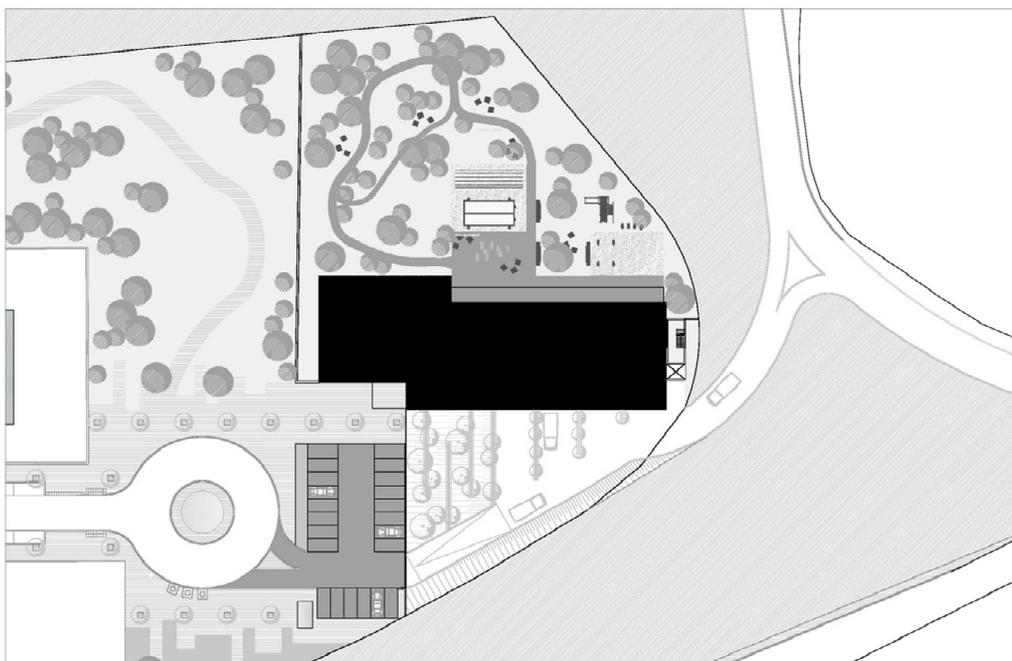


Figure 2.1: building's surroundings

lack of supplies that may somehow affect normal performance of the structure.

According to the plans, and despite being in urban areas, the building object of this project is isolated, so we see no surrounding buildings likely to be affected by the construction. Similarly, no obstacles are expected to become a problem, if it were necessary, when using large machinery (piling, diaphragm walls, etc.). In the same way, it is understood that there are no problems of access to the site for its location.

2.2 METHODOLOGY AND SOFTWARE

To carry out this work we first analyzed the available data and found a consistent design within the criteria mentioned in previous sections.

Subsequently, the relevant calculations have been performed using the calculation program TRICALC, from the structures company Arktec SA. The version used was 7.4, which has been provided for free by the company for carrying out this project. The use of this program has obtained several information (drawings, measurements, etc.), which consists in the project report.

TRICALC is a computer program for calculating structures using matrix analysis to obtain predictable strengths for a model structure generated by introducing the geometry, forces, and calculation conditions (considering regulations, limiting deformation, reinforced limitations, etc.). From these strengths the program can also perform the computation and checking of the various constituent elements of the structure.

The program also offers the possibility of obtaining various documents necessary for the drafting of the structure's project, such as CAD format drawings, measurements, etc.. Similarly, the program provides facilities for the execution of the project, such as the armed fabrication drawings.

In the case of this project, the process of working with the program TRICALC, consisted of:

- 1- Definition, within the options available in the program, the appropriate parameters for the project structure's purpose. In particular, selection of rules, constraints, permitted warps, etc..
- 2- Introduction of structure's geometry.
- 3 - Definition of the sections according to the data obtained in the pre-dimensioning.
- 4 - Introduction of the anticipated loads.
- 5 - Calculation of wind and seismic forces.
- 6 - Modelling of the structure and calculating strengths.

7 - Checking sections and calculating armed ones

8 - Resolution of errors and recalculating

9 - Getting Results (drawings and reports)

2.3 ADDITIONAL INFORMATION

Given impossibility of knowing the original memory, and the actual circumstances of the building to be built, it was decided to define some assumptions as to justify decisions. In that sense, it was considered that:

- There are no further external conditions that affect the design of the structure, from the listed in the previous sections.

- The construction of the building is not urgent, and therefore is not justified a reduction of deadlines which significantly impact in the final cost of the building.

- The location of the building in an urban area, which allows access to all necessary services, the availability of all types of machinery, and offers a wide range of suppliers of materials and products commonly used in the construction of structures.

- It will be maintained to the extent possible the configurations of partitions and other elements in the plans.

During the design, it has been taken into account the final user of the building. For this reason, since it will be used by a high percentage of dependent people, all kind of barriers will be avoided. It is also necessary to address the safety of the structure, ensuring in particular the existence of escape routes without barriers and safety regulation compliance.

2.4 REGULATIONS

The regulations applicable to this project includes, among others:

- TECHNICAL BUILDING CODE (particularly basic documents Structural Safety DB SE, SE-AE DB Shares in construction, DB SE-A Steel, DB SE-C Foundation, DB SI, safety in case of fire).
- Norma EHE-08 instruction Structural Concrete
- Earthquake resistant building standards NCSE-02.

3 CONSIDERATION OF ALTERNATIVES

3.1 MATERIALS

To define the structural system, the first important decision is to choose the type of material that will constitute the system. It has been taken the decision to build the structure with a single type of material so the transmission of forces is carried out more efficiently and rationally. This also reduces the possibility of error and simplifies the implementation.

For the election of the constituent material of the structure, we have studied several alternatives applicable to the case at hand:

a) Structure made of rolled steel.

This structural type main advantage is its greater speed of execution, which would shorten the time of construction of the structure in a significant way. However, the cost is higher, almost tripling the cost of a reinforced concrete structure.

It also has other disadvantages:

- The large existing lengths in some areas of the building require high inertia profiles, which increases the cost of the structure, and can be detrimental to the layout of the ceiling installations.

- The fire behavior of the metal structure is worse in general than the concrete, which would imply important supplementary protective elements. For the same reason, because of the demand for higher sections which will also increase in floor occupation of the elements.

Since in our case there is no remarkable reduction requirement for deadlines, we believe that the metal structure is not the best option for this project.

b) laminated wood structure.

This is a very lightweight system, and also ecological. Although to the date, it is seldom used in the construction of buildings of this size. This type of structure would require large squareness to withstand anticipated loads, main reason to reject its use.

Other disadvantages of this construction system are:

- Lack of skilled labor and the consequent rise of the work.
- Problems to ensure durability, given the perishability of wood.
- Increased squareness to meet fire regulations.

c) Reinforced concrete structure.

It's currently the structural system most used for this type of building, under normal conditions. This construction system has several advantages over other systems exposed:

- Economy.
- Good strength / weight ratio.
- Versatility
- Good behavior against fire.
- Relative ease of implementation.
- Existence of skilled labor.
- Wide availability of suppliers of materials in the environment.

As there is no special need to shorten construction time, and since compliance of fire regulations would significantly increase the value for metal or wood buildings, there is no justification for using these systems.

For all the above, it was decided to perform the reinforced concrete structure. The exterior stairs must be produced of rolled steel because it is an auxiliary element in the project whose impact is minimal and not affected by the rules of fire protection because its situation.

3.2 VERTICAL STRUCTURE

The next step for the definition of the structural system has been the study of the floor of the building to find the best location for the system supports. As noted above, one of the fundamental premises during the design process of this structure is to maintain, to the extent possible, the original distribution of the baseline.

Another vital aspect to care about is, given the use of the building, the need to remove all kinds of barriers. That is why within the possibilities, it has avoided the presence of obstacles in the building, and it has tried to place the brackets in places where their presence does not constitute a nuisance, especially in areas intended for public use.

As a criteria, it has been dismissed the possibility of using dismantled pillars as a solution for the location of the supports, since they are an expensive solution, irrational, and therefore not advisable; particularly in a new building construction which should allow a certain freedom in the design of the structure, and the possibility of making changes in the distribution, if necessary. Among the possibilities, we have tried to create a structure whose way of working is the most rational, with balanced lengths, conformed dimensions, etc. So that each element works optimally. In some cases, however, the distribution or other circumstances do not allow simple solutions and it has been chosen complex solutions which minimize the extent possible.

EXPANSION BOARD

A prelude to the location of the supports, based on the geometry of the building, and given the need of a structural expansion joint due to its amplitude as length (57 meters in maximum dimension) has been placing such joint. Subject to the limitations imposed by the regulations, it is necessary to perform the board perpendicular to the maximum length ground.

We have studied two possibilities, the first option (A) is the meeting place where the intersection of the two bodies that make up the building, and choice (B) is to conduct the meeting in the median plane of the building. We have chosen the first option because it separates areas with different functions, and therefore different load areas, optimizing the operation of the structure.

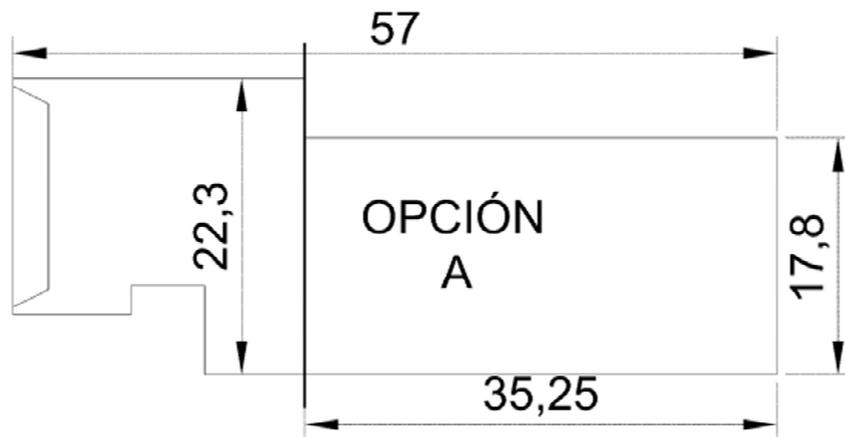


Figure 3.1 "A" alternative for expansión board

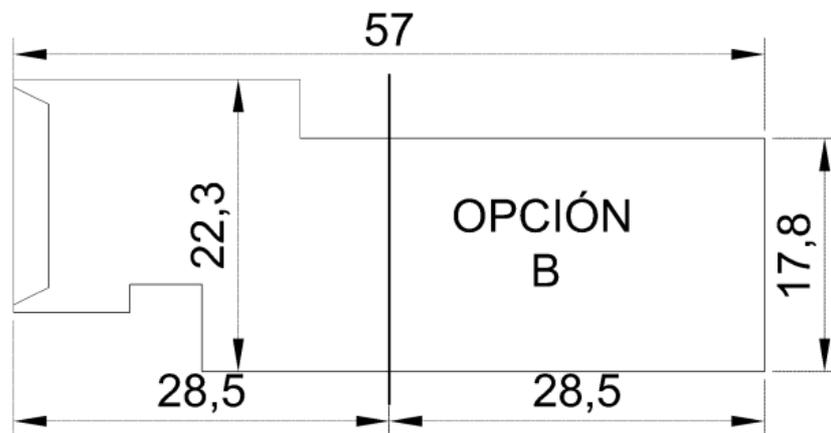


Figure 3.2 "B" alternative for expansión board

After defining the premises for the supports location, the first option was to study the possibility of locating the pillars so that the system functioned in the most rational way. This is intended to test the impact of the distribution in the design of the structure.

For this, supports are positioned to form a grid of lengths about 6 meters and 1.5 meters exterior overhangs. These lengths allow the use of a great range of floor systems, they greatly reduce the stresses transmitted to the pillars, simplifying the solution and hence the cost

This solution would facilitate the choice of slabs, and generate a technically simple solution, with spans that would reduce the time offset applied to substrates, and therefore the necessary reinforcements. However, as can be seen in the table below, this location of the supports is not compatible with the distribution of all the floors.

This distribution of pillars, which theoretically improves the efficiency of the structure, has several points of conflict with the original layout of the building. At drawings, pillars can be seen in the center of some units, there are also supports that match facade holes, doors and passageways.

It has been attempted to adapt the location of the supports with small variations in some of them, without finding a solution that does not interfere seriously in distribution of any of the plants.

The existence of spaces that need to be kept airy due to its use (multipurpose rooms, fitness center, etc.), impede floor solution with small lengths (the pillars propping is not considered as a solution).

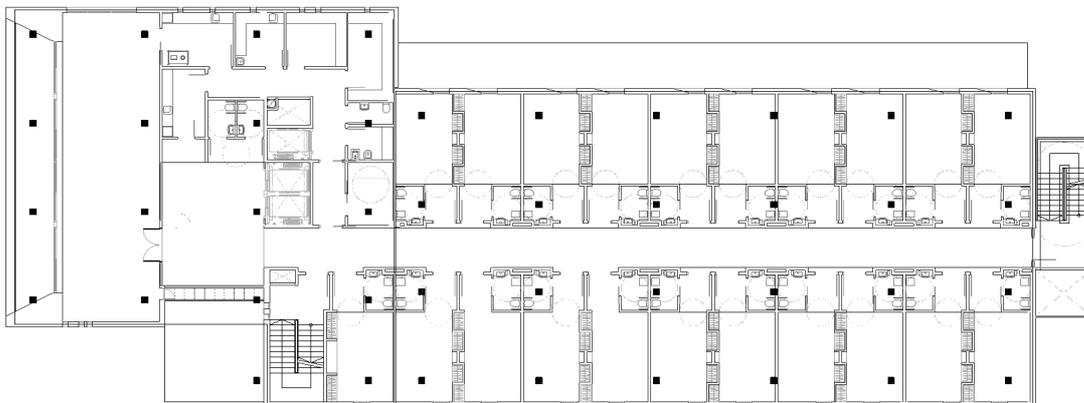


Figure 3.1: best theoretical setting for pilars in basement floor.

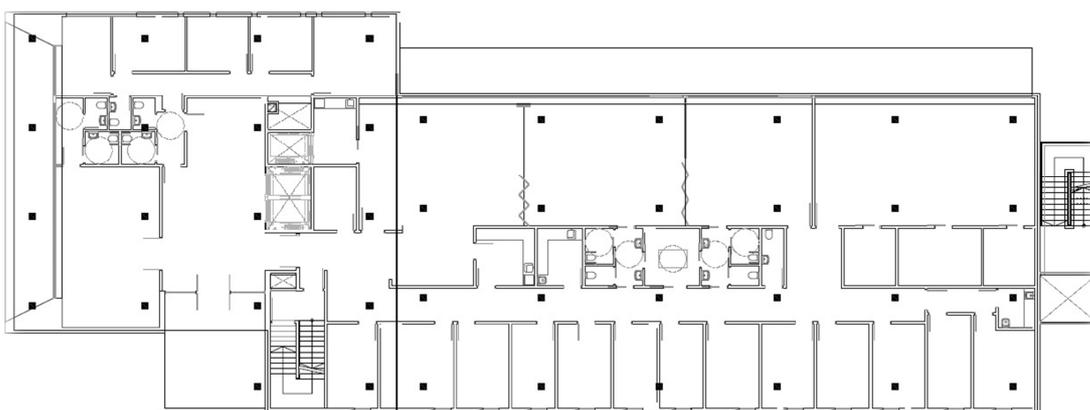


Figure 3.2: best theoretical setting for pilars in ground floor

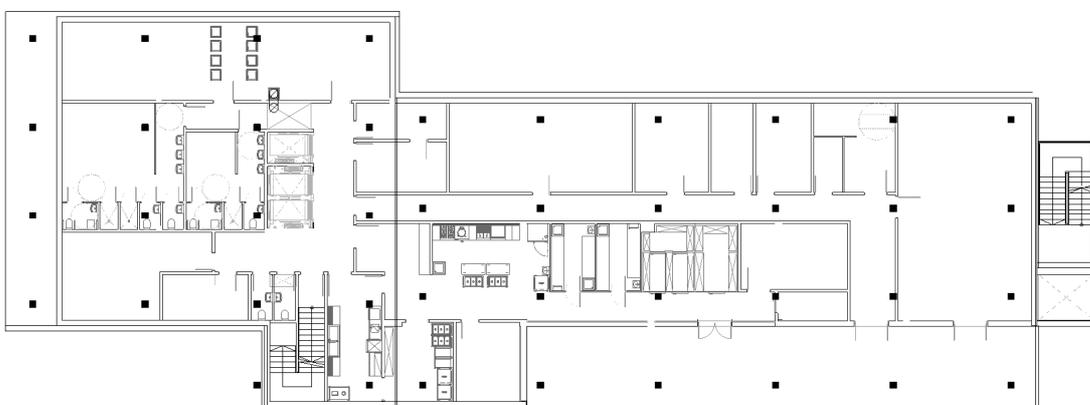


Figure 3.5: best theoretical setting for pilars in upper floors

The existence of open spaces in some plants, precludes the use of small interaxial distances between pillars. The largest span, the order of 7.5 meters, reduce the possibilities when choosing the type of floor to be used within the parameters of economic and structural safety.

As it has been demonstrated, the possibility of removing the pillars of the front line is not feasible because of the interior partitions distribution of the building and because some of the spaces that are to be diaphanous are located in front. Therefore they are incompatible with this media location. Similarly, even if it were possible to set back supports, interior layout require large deviations of the pillars with respect to the line of the gantry. Since such solutions significantly increase the reinforcements on pillars and slabs, definitely rule out this solution.

As for the other option, placing the supports on the front line, the distribution of partitioning in plants (with spans around 7 meters) makes several alternatives. We studied two separate wings, because they have a markedly different distribution inside, and thus generates different problems.

EAST WING

On the west wing, the distribution of partitions allows greater flexibility of the solution of the supports. Moreover, vertical communication cores, to be built with concrete walls, thus serving to counteract lateral pressures influence the possible solution.

In the case of the east wing there are two options defined by the position of the partitions of the plant type and the holes in front of the plant. Distribution have been termed A and B.

“A” PILLARS SETTING

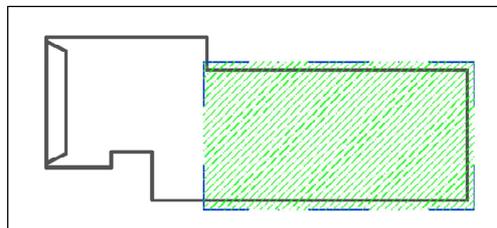
First alternative is to match studied gantry lines with walls that form the cabinet, although the space is reduced to the Cabinet, it isn't a serious variation in plant type design. Spans are defined by the distribution of the partition on lower floors.

This solution generates few alterations in the partitioning of the upper floors. The existing spans are acceptable but slenghtly unbalanced.

Moreover, the supports are separated from the downspouts, so it reduces the chances of damages to the structure due to these elements.

However, the view of the ground and basement, shows the coincidence of the situation stands projected voids in walls and some interior doors.

The slight displacement of the pillars affected with the aim of avoiding the afore mentioned holes creates new problems in higher plants is therefore only possible to discard the solution.



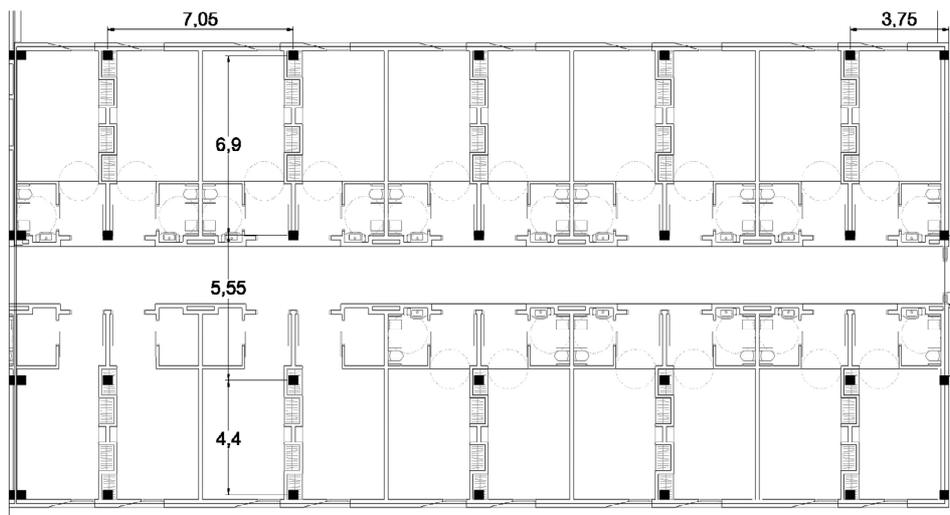


Figure 3.6 "A" pillars placement for pilars in upper floor

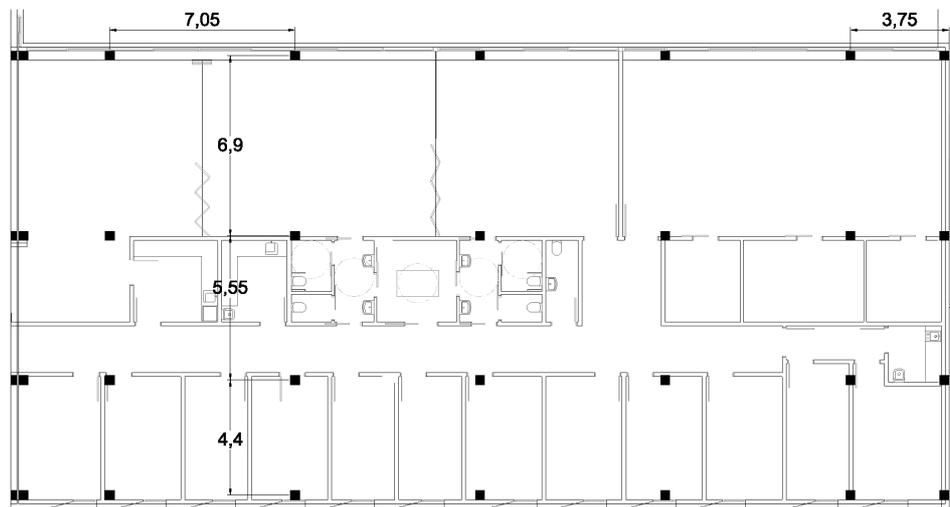


Figure 3.7: "A" pillars placement for pilars in ground floor

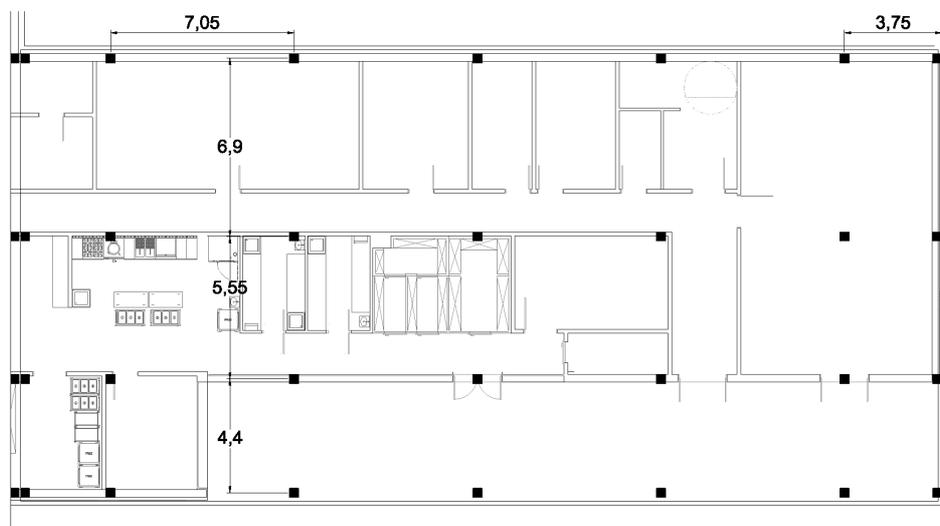


Figure 3.8: "A" pillars placement for pilars in basement floor

“B” pillars setting

Once discarded the previous solution, the alternative that allows partitioning of the lower floors, consists of matching the transversal frames of the floor with linear partitions in type floors. In the longitudinal direction of the west wing floor, virtual gantry lines are the same used in the previous solution.

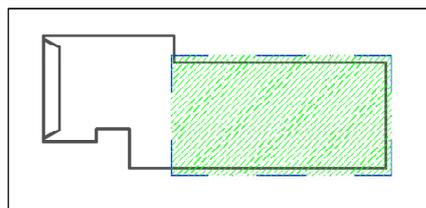
One of the disadvantages of this solution is the proximity of some interior pillars steps sanitation facilities, this fact must be conveniently analyzed when calculating the structure, and in the design phase of the sanitation system, taking appropriate measures to ensure the durability of the structure and prevent the onset of problems over the life of the building. This point will require careful execution, and disposition of registration holes to enable proper maintenance.

This solution, with the introduction of small modifications enables compliance with the premise of respecting the interior layout of the building. Furthermore, no significant disturbance generated regarding mobility inside the building, making it a correct solution.

This solution does not interfere decisively on the original layout of the building. Similarly, it does not interfere in the internal circulation of the building.

Resultant spans are acceptable but are slightly unbalanced due to the distribution of partitions in the lower floors. This circumstance theoretically affect the amounts and size of the materials and elements, however is acceptable and an additional cost in any case, a preferable solution to the above alternatives

Another advantage respect to the above solution is to leave the space for diaphanous premises. And therefore it prevents affectations on the structure.



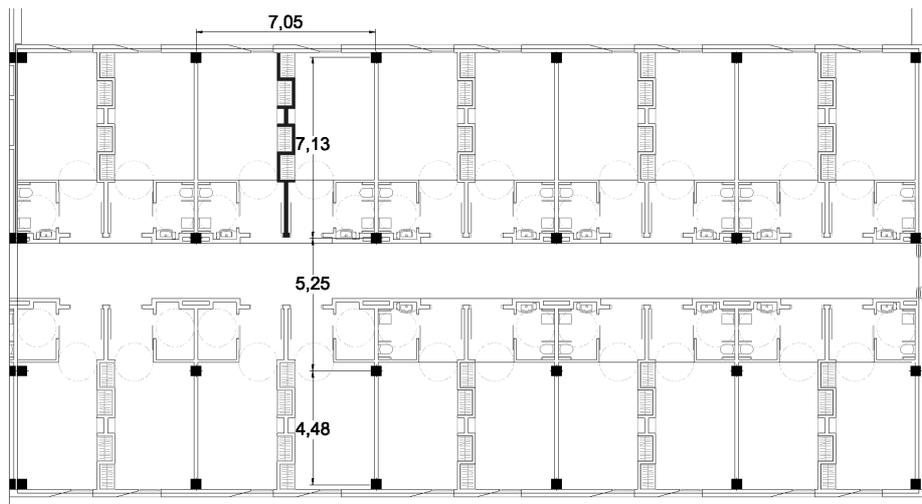


Figure 3.9: "B" pillars placement in upper floors

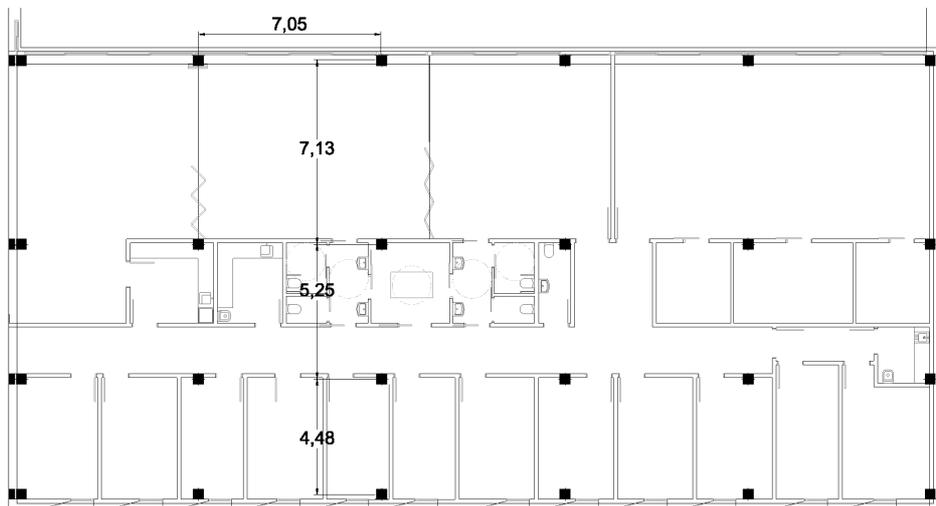


Figure 3.10: "A" pillars placement in ground floor

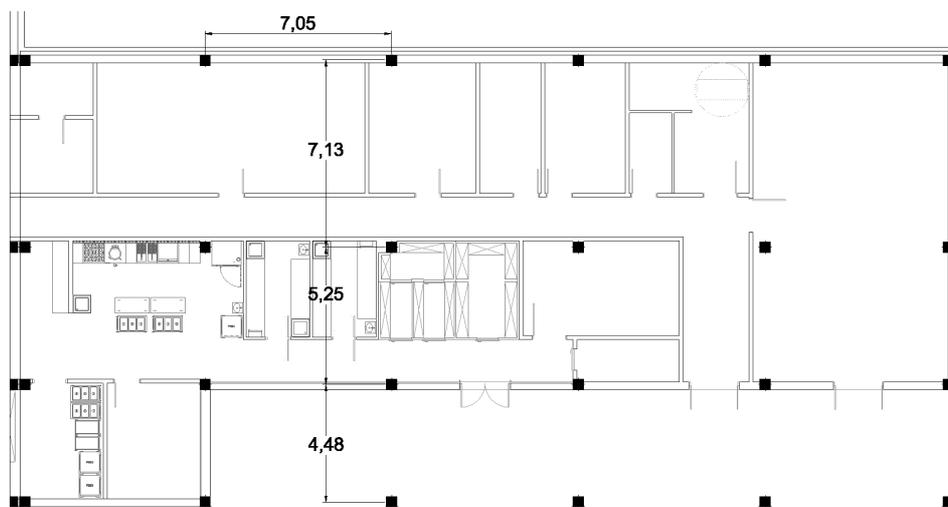


Figure 3.11: "A" pillars placement in ground floor

Western wing

Once defined the possibilities east wing of the building, shows the solutions for support locations in the west wing of the same.

The location of the pillars in this area is easier due to the shape of it and distribution of partitions, which define a simple distribution and compensated spans. Partition lines, can keep gantry lines established in the East Wing, simplifying the problem.

On one hand, there is a terraced area, where the pillars are set back and are inserted concrete walls that meet structural function while aesthetics. On the inside the lines of the east wing pillars are followed in order to avoid strain differences, and at the same time it allows to bend the pillars of the expansion joint.

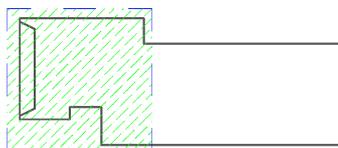
There are also several vertical communication cores, where continuous concrete walls are used instead of pillars to provide rigidity and strength to the entire face to horizontal

Pillar distribution follows EastWing pillars distribution setting. In this case, the partition of the building allows more compensated lights.

There are two communication nodes that are addressed by vertical concrete screens so that the building is given rigidity against horizontal actions.

The terrace of the west façade is equally defined by concrete screens, carrying both structural and aesthetic.

This solution does not particularly affect the internal distribution of any plants. The greater impact is produced by the appearance of some partitions pillars corridors



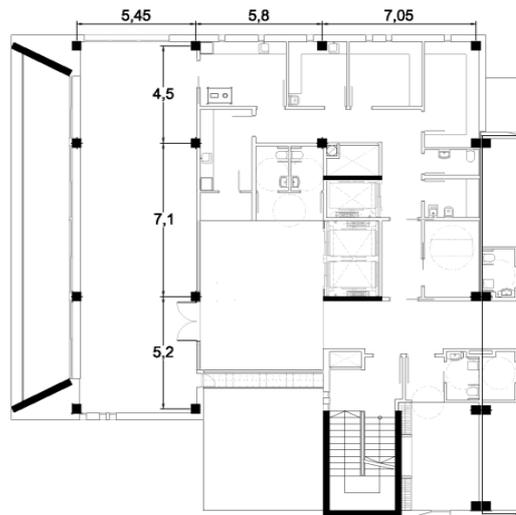


Figure 3.3: West Wing pillar setting for upper floors

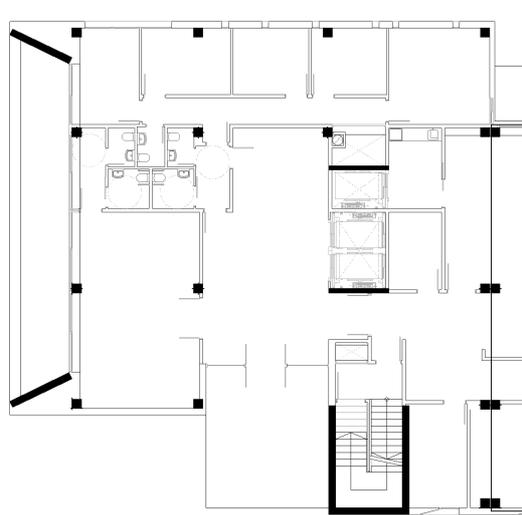


Figure 3.4: West Wing pillar setting for ground floor

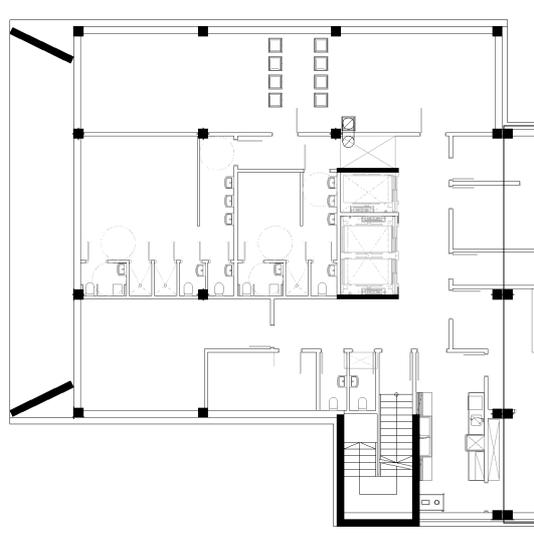


Figure 3.14: West Wing pillar setting for basement floors

3.3 HORIZONTAL STRUCTURE

The choice of horizontal structure transcends mere structural performance. Bearing in mind that the main function of a floor is the structural function (hold loads, maintain rigidity, transmit forces, etc.), it also has to take into account that floors perform other functions that can't be obviated in the design phase, as systems elements support, perform functions of thermal and acoustic isolation, spatial separation, etc.

In the purely structural, the decision of the type of floor to use is conditioned by the following features:

- Large spans (up to 7.5 meters)
- Resistance to medium loads
- Deformations in an acceptable level.
- Monolithism
- Increased length as possible
- Durability
- Reaction to fire
- Technical Simplicity (and skilled labor availability)
- Economy

Moreover, other requirements relating to the function of plant spacing element are as follows:

- Good thermal and acoustic insulation.
- Ability to accommodate facilities
- Acceptable esthetic finishings (if necessary due to placement of elements).

The existing spans in the building left out of the range of possibilities the unidirectional standard frameworks for lengths that would be considered uneconomical due to armed disproportionate or excessive weight needed due to the need of a great thickness.

Within unidirectional framework can be taken into consideration in this work alveolar type prefabricated slabs. The advantage of these slabs are its large spans allowable, and also the execution speed versus floor systems in situ.

On the other hand, are heavier and more expensive items (in direct costs) in relation to its competitors. They also require the presence of special machinery for assembly. The main disadvantage of this system, and that makes it unsuitable for use in this work is the geometric stiffness. The west wing of the building project contains several gaps and several pretty body overhangs that would raise the costs of the solution with this structural system.

Another alternative is to perform bidirectional concrete slabs. There are two main types: Solid slabs (further divided into two subtypes: flat slabs and slabs with the abacus highlenghted) and waffle slabs.

The solid concrete slabs are probably the best solution as far as the transmission of forces is concerned, since they work in a multidirectional way. They also offer greater isolation against airborne noise because of its massiveness. However, the slab has several disadvantages compared with waffle slabs: first, the solution is much heavier, but still requires theoretically lower edge. They are also slenghtly more expensive than waffle and the consumption in material and in energy are, at first sight, higher.

The other alternative to consider is the waffle slab. This system has several advantages:

- It is suitable for large spans.
- Has a bidirectional force transmission system.
- The relationship between strength and lenghtness is optimal.
- Geometrically is a flexible system which allows some variability in the location of the supports (although the cost increases in proportion to the irregularity of the floor).
- The cost of this system is smaller than those discussed above.

The drawbacks to this system are:

- Criminalization of the system by the fire regulations.

- It needs a meticulous execution control

In the absence of any limitations in terms of construction time, and since it is a system of proven results for use in this type of construction, it was decided to use waffle slabs.

Within the waffle slabs, there are two types to be differentiated. Waffle slabs of temporary coffers and waffle slabs of ceiling coffers. The former have the advantage of greater lengths, which it translates into a lower theoretical ridge with a smaller material consumption and therefore a lower economical cost. Another advantage is the esthetic of this manufacture, which can be left at sight. By contrast, and as discussed below, it has a significant drawback, which comes from the limitation of fire regulations, which penalizes the system so that they lose much of the benefits described above.

The other type of waffle slabs, the ceiling coffers, although heavier than the other ones, represent a solution rather lighter than a solid slab. Moreover, this type of manufacture requires a coating (in this case a suspended ceiling is necessary, among other reasons, to house building facilities). The other benefit that this solution has to be applied in this case is the least penalty on fire resistance regulations.

Taking these alternatives into account, we consider first the solution by lost coffered waffle slab, although given the facilities of the calculation program, will explore other possible alternatives for performance and cost.