Edificios colgantes / Edificis penjants / Hanging buildings

26 / 06 / 2017

GRADO EN ARQUITECTURA TÉCNICA (MODALIDAD DE INTERCAMBIO-MOVILIDAD)

TRABAJO FIN DE GRADO - CURSO 2016-17

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SILESIAN UNIVERSITY OF TECHNOLOGY

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ENGINEERING FINAL PROJECT

Hanging Buildings Study and Analysis in Spain-Poland

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2016/2017

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Hanging Buildings

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

INGENIERÍA DE EDIFICACIÓN

SILESIAN UNIVERSITY OF TECHNOLOGY

Forés Montesinos, Juan Manuel

Final Project

Grade: 2016/2017

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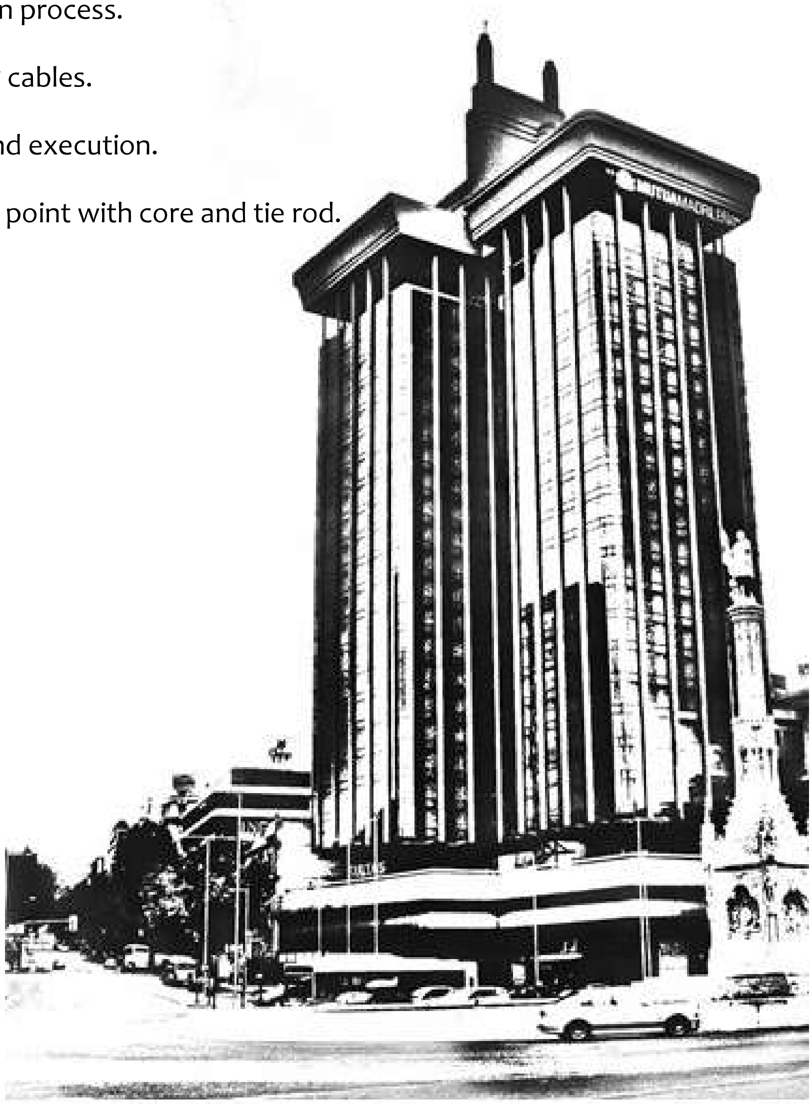


1. INTRODUCTION

INTRODUCTION

Juan Manuel Forés Montesinos, student of Technical Arquitecture at the "Universitat Politècnica de València" (Polytechnic University of Valencia), and as Erasmus student at the Silesian University of Technology, Politechnika Śląska, is going to be the author of the project comparing the method of construction of hanging buildings.

To explain this one needs to know the characteristics of the buildings studied, and the structural problems that these types of tall buildings have, as well as the advantages and disadvantages by which it is decided to execute this type of structure hung.

Once defined the type of structure to be executed, we proceed to study the different ways in which they solve and study the coincidences and differences that occur between both buildings, analyzing the why of the different elections.

ABOUT THE BUILDINGS

TORRES DE COLÓN

The building about our study trates is an icon of the construction of Madrid and, therefore, Spanish, of the late sixties. It was a time of change in the Spanish society, because the economy began a phase of development, of a fast decline, generating an improvement in the quality of life of citizens, a sudden fall in unemployement levels, and the emergence of a middle class with a medium a high purchasing power. This situation propitious the emergence of singular constructions that serve as headquarters of important companies, or luxury houses to show the new economic power adquired. In our case, the construction of "Torres de Colón" (Columbus Towers) had, as an original objective, to contain luxury houses, and once built also served as the national headquarters of Rumasa (Spanish Enterprise). And it was the model of Hungings buildings in the following years. The Lamela Study of architecture was in charge of its design and execution, proposing a very new construction sistema, as we develop below.

1. View of the "Torres de Colón"

2. Headquarters Estudio Lamela. Av. Arroyo del Santo, Madrid. Spain

AUTHOR.

The responsable to develope the proyect of the Torres Colón was Estudio Lamela, wich is an architectural firm founded by Antonio Lamela, who is the general director of the Project we are dealing with, and currently directed by Carlos Lamela, with an international presence trough of own offices in Madrid, Warsaw, México DF and Doha. This Company has a team of more tan 80 professionals, and its vocation to achieve excellence has led it to collaborate with prestigious studies of architects from different countries to equip their projects with the best equipment, shared knowledge and multidisciplinary approach since its foundation in 1954.

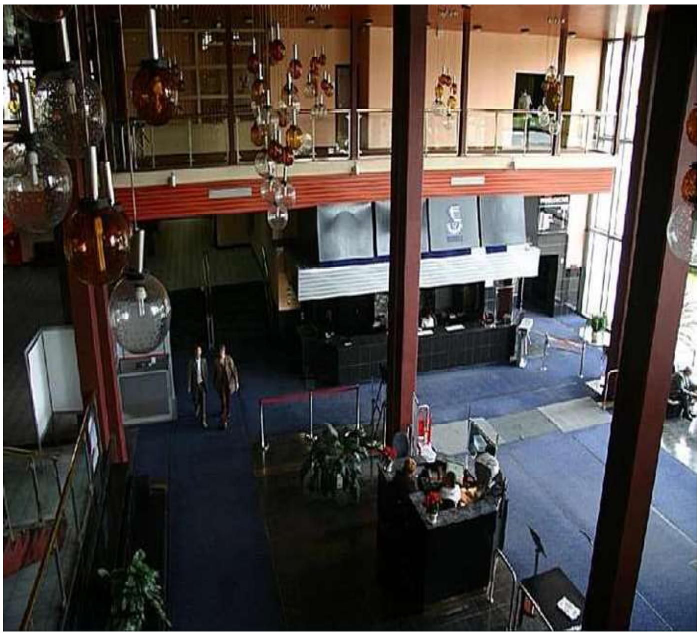
The firm cover all areas of architectural activity: Sports architecture, offices residential, sanitary, hotel, and urban planning and transportation architecture, within wich it has developed different projects worlwide.

STALEXPORT

This type of hung buildings became popular at the time in different countries of Europe, in Poland, one of the most representative cases is the so-called Stalexport building. Built between the end of the 70s and the beginning of the 80s. this period coincides with the end of the communist period coincides with the end of the communist period in this country and the opening of the economy. In the region of Silesia a strong industry developed around the mining, particularly the export of coal.

The city of Katowice did not have office land to meet the demand demanded by the economic strength of the área. And due to these two conditions than coincided in time, together with the political positions that were changing, led to the tender for the construction of a unique building, wich introduced a modern way of building in the area of Silesia outside of Warsaw, since they were already developing there. In the competition for the execution of this building, the architects Zygmunta Winnickiego and Tadeusz Krzysztofiaka were finalists offering some proposals, which for unknown reasons were not finally built. Outside the competition, the office building project of Georgowi Grucicowi, an architect of Yugoslav origin, was chosen with the help of a Swedish construction company running the Stalexport towers, being the tallest buildings outside of Warsaw and breaking with all the preconceived ideas of how to design and execute tall buildings, creating two twin towers of 92 and 97 meters that are beginning to build from top to the bottom.

3. View of the towers Stalexport, Katowice, Poland.

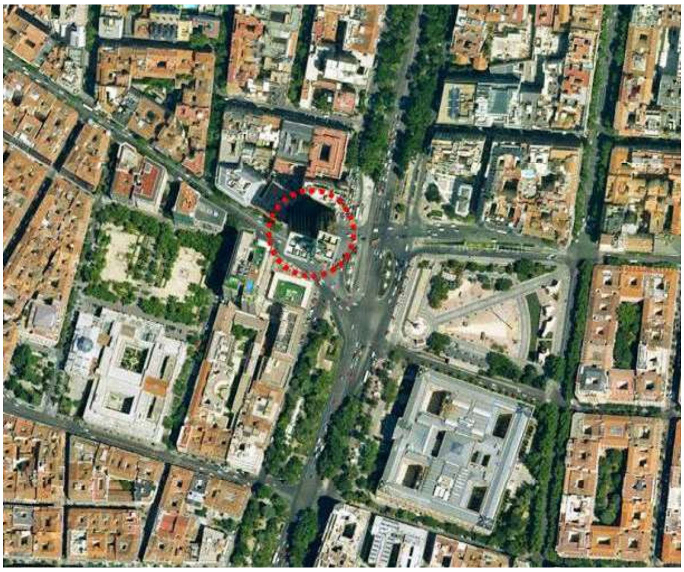


4. View of the low floors of towers Stalexport.

2. BUILDING DESCRIPTION

BUILDING DESCRIPTION

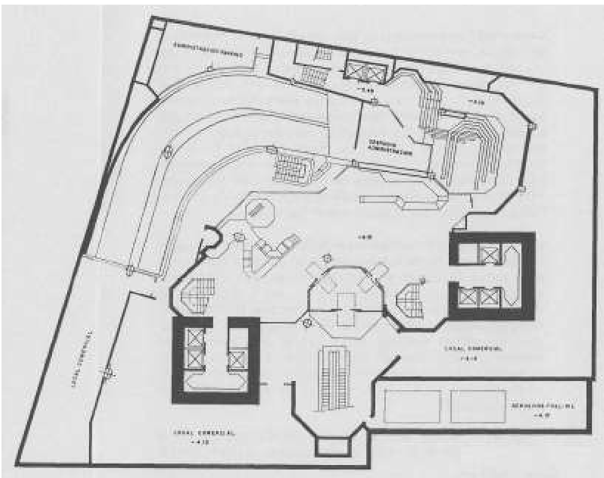
The "Torres de Colón" building, of Madrid, is located in the square formed by the streets Castellana and Genoa, in the Salamanca's neighboroud, one of the most importants places of the capital of Spain. It consists of three clearly differentiated parts: the buried part, formed by six basements that serve as parking of vehicles; the intermediate zone, composed of three plants and located inmediately above the natural soil, intended for various uses; and a third part that is constituted by two twin towers of twenty one plants.



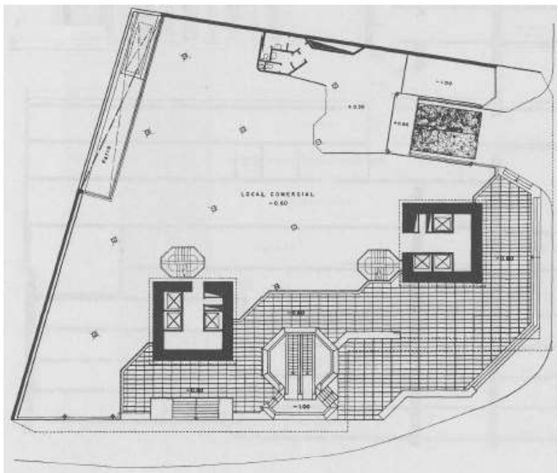
5. Aerial view of the "Torres de Colón"

The total height above the ground was originally84,5 meters, and the depth to which it descends under the ground to reach the foundations, 18,3 meters. The buried plants occupy the entire Surface of the site, which is about 1.700 square meters, while the two towers occupy an área of about 700 square meters.

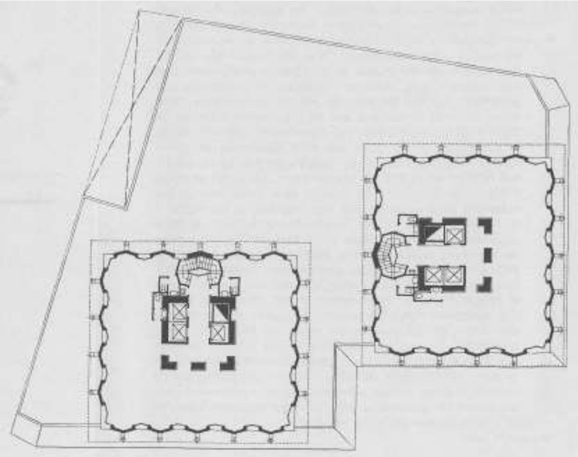
The Torres de Colón, with its characteristic upper deck, is one of the most recognizable architectural symbols of the city of Madrid. Its construction began in 1967, and, in addition to the dimensions of the building, it astonished the residents of Madrid for its peculiar costruction method.
This twin skyscrapers are currently the ninth tallest buildings in the Spanish capital, with its 116 meters of altitude due to the aforementioned roof and its 23 floors. They have a suspended structure, the building is composed of two large pillars (called central core) conected at the top by a platform from wich hang the two towers by large perimeter beams up to six meters in the corner with pendulums that support each floor with steel cables. For its construction, the works were first executed for the concrete foundations on which the two pillars were plantede and then the upper platform join both of this centrals cores.



6. Basement



7. Low level

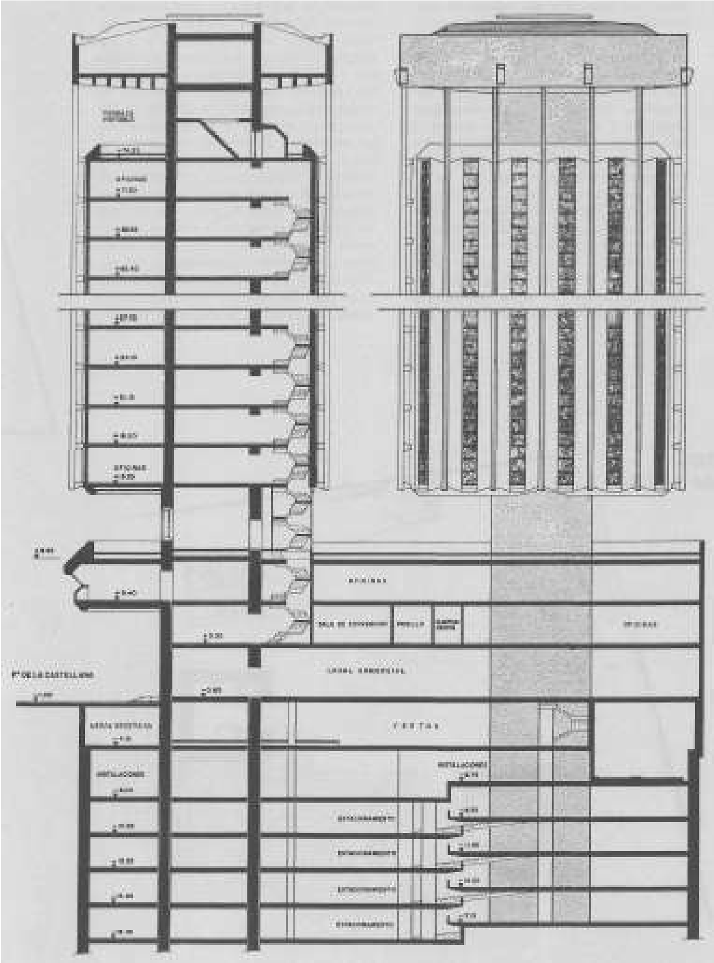


8. Type plant

Finally the plants of the towers were constructed from top to bottom, thus making the saying of "begin to build the house on the roof", it is obtained that, from the upper platform approaching plant to plant, to the base of the construction. And at his feet, a basal body of three floors and six more forged basaments, this time built from the the bottom up.

This allows us to enjoy a diaphanous interior space, covered by an epidermis of colored glass of garnet tones, which projects over the wide space of Plaza Colón some chromatic games depending on the light received during the day. A Green structure in the top, added after the ensemble and popularly known by the singular name of "The plug", because of the visual similarity, and It crowns the ensemble.

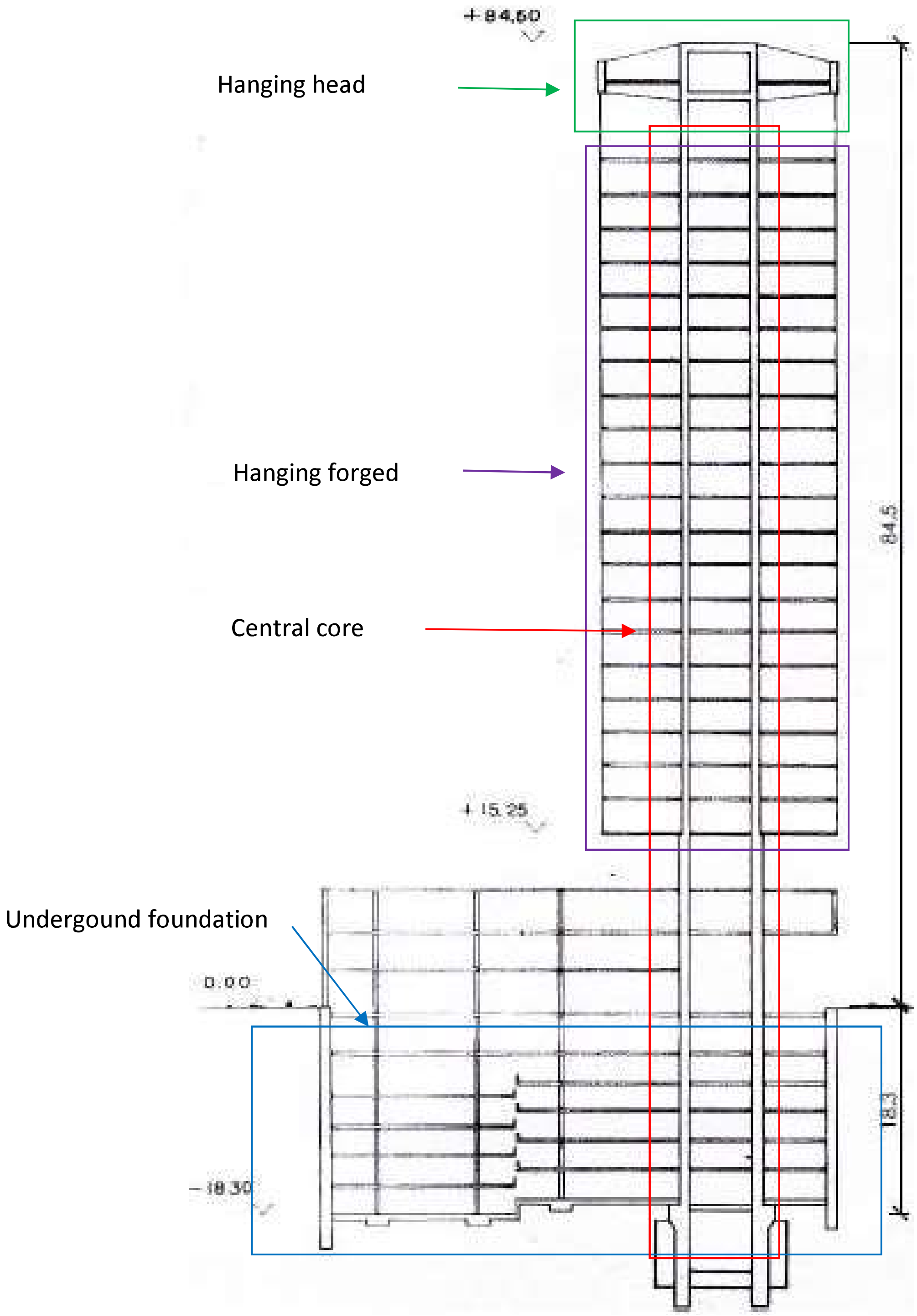
The building has offices of different companies and on the ground floor, some shops. This article describes the general guidelines and details for the organization and execution of the concrete structure of this unique building, which has been imposed by inescapable imperatives concerning the dimension of the site and maximum utilization of the resultings plants.



9. Section and rear elevation

10. Construction of towers plants up to down

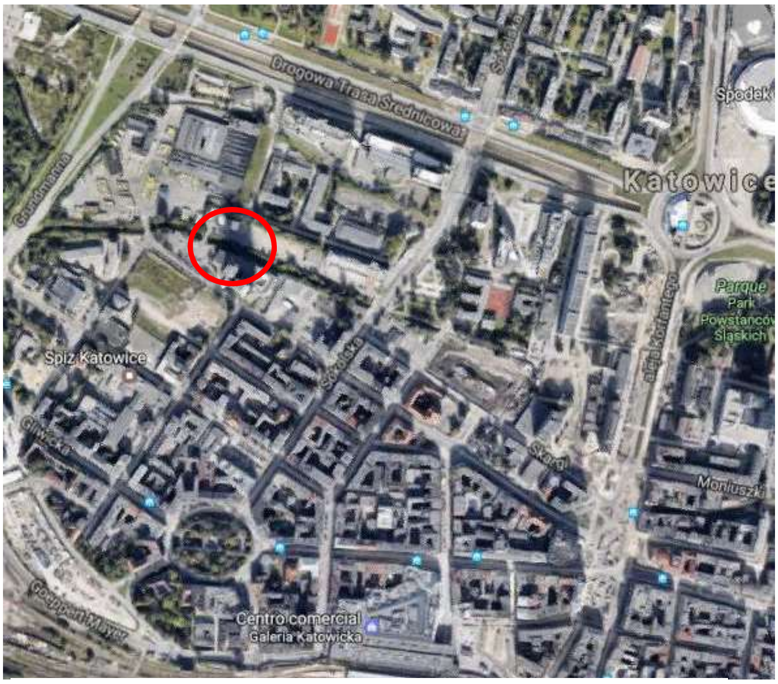
In the first place, the constructive solution of the main specific problem is discussed and described, which are the hunging towers in themselves and their behavior resistant against effects and actions that affects the skycrapers. For this, the most complex and innovative milestones developed at the time for the construction of the towers will be studied separately; these are, firstly, the execution of the foundation, and of the central core, secondly the upper or hanging platform, together with the cimbra used and the system of execution used, and, finally, it is developed is system of hang by means of tie rods, the unión of the slabs with the tie rods and the central core, besides the process of execution and concreting said slabs.



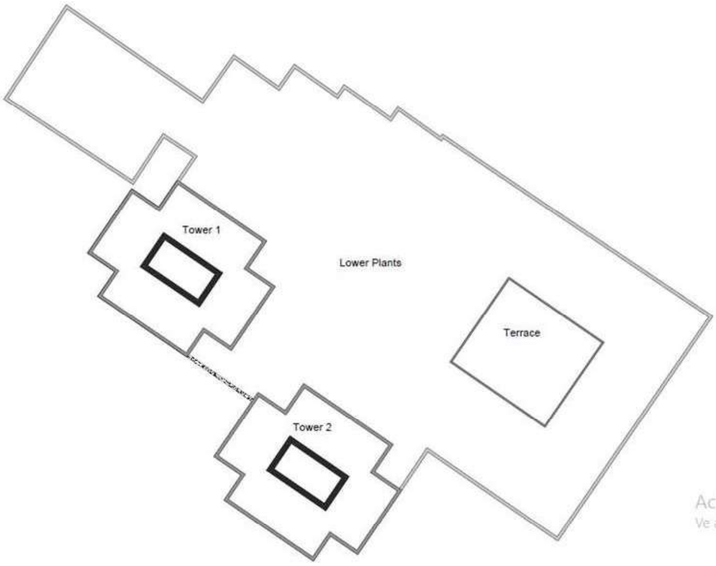
The Stalexport building began to be built in 1976 by order of the companies Stalexport, Weglokoks, Centrozap and Bank Handlow, and the towers were finally delivered in 1982, and because the companies that promoted its construction are the same ones that went to use the offices of the building, were executed a state of the art facilities of the momento which currently continuer to maintain the stalexport towers as one of the most comfortable and useful buildings in the city.

The building is located at Street Mickiewicza 29, about five minutes of distance walking from the Katowice train station and in an area close to the city center, that is, it is very well located facilitating the connection and acces to itself, important concept for a business center of this magnitude.

On the floor of the building you can observe three differentiated zones, two of which are the towers where the offices and the headquarters of the companies are located there and with an available space of 5834 square meters in the tower 1 plus 5178 square meters in the tower 2, and the inferior plants that occupy a greater percentage of the Surface of the lot, where we can to find the entrance hall, and different types of facilities of all kinds, from auditórium to bank branch, through pharmacy, restaurant with its respective outdoor terrace, and different meeting romos available for business. Also note that this building does not have an underground garage, since at the time of its construction was not commonly used int the country and was not anticipated as a near need in time, to fill this gap, was built on the plot surrounding the building an outdoor parking for private Access for workers with the possibility of using up to 346 spaces.



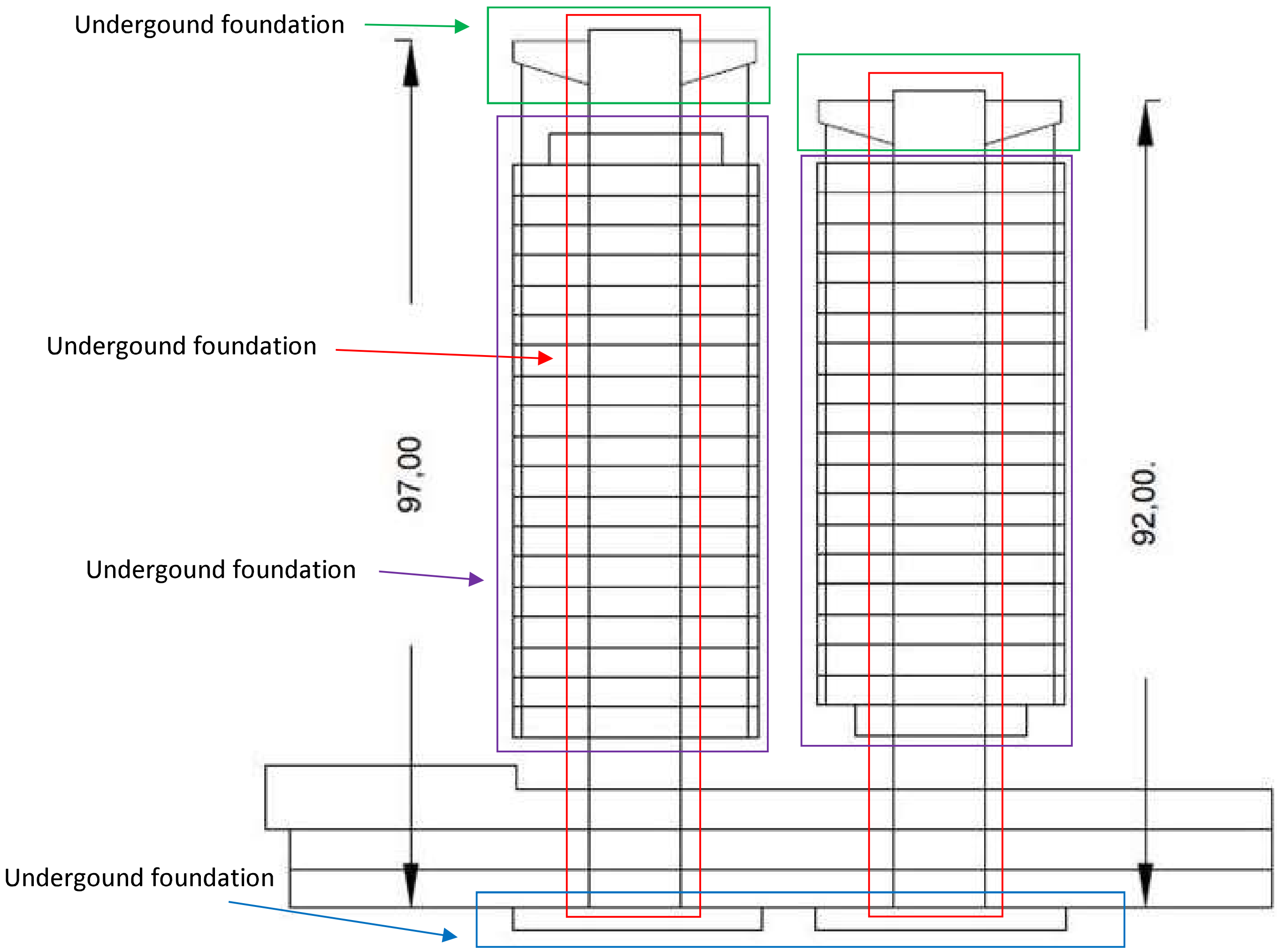
11. Construction of towers plants up to down



12. Plan of the general plant of the building.

In the following diagram we can see the different structural elements that make up the towers, in the lower zone we can appreciate the foundation, this one is base don a slab of large dimensions that makes platform of support and stabilization of the central core of the two towers, this slab directly transmits the stresses to the ground. Next we have the central core that, as we explained in the building of the "Torres de Colón", will collect the effort generated by the weight of the plants and will transmit it to the foundation. On the upper part of the building, supported on the central core is the ganging head, a singular element that characterizes this type of buildings, from which hang the suspenders, in number of eight, it is possible to emphasize that the head is formed by four beams of great dimensions that we will define later. Finally we have the forged, elements of reinforced concrete that are united by two parts to the rest of the structure, in the outer zone supported by the tie rods, and in the inner zone joined to central core.

The set consists also of three heights, in the plants immediately above the ground, constructed with the traditional method of pillar, forged, and shoes, made of reinforced concrete, whose main function is to join the two towers and to homogenize the whole.



3. ESTRUCTURAL ACTIONS

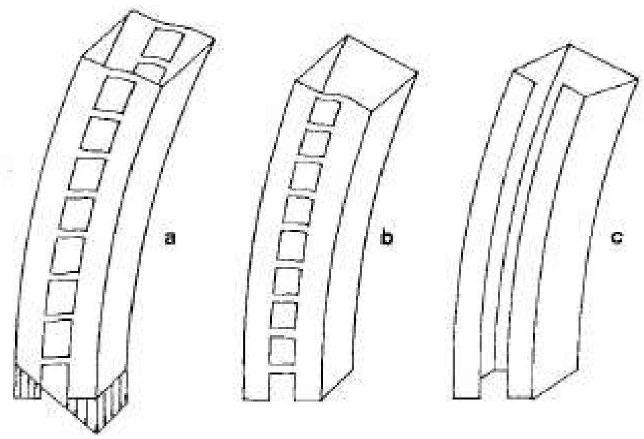
STRUCTURAL BEHAVIOR

First, the complexities of high-rise buildings must be understood, and the structural system was designed to overcome these obstacles. If we consider only the resistant problem, a tall building could be considered as a large vertical bracket, with the fixed point embedded in the gorund and the grater deviation in the upper part. The tough demands of this large bracket are more pressing as the building grows in height and its coupling to the functional needs of the most difficult building. In this study an analysis of the resistant typology used as a solution of the “Torres de Colón”and “Stalexport” , consisting of a resistant core base don screens, carried out.

A building, any building, is subject to series of actions from the medium that the structure must resist, which we will describe below.

We must take into account the gravitational actions, about the own weight; wind, more important when the building increase the altitude; earthquake, that can broke the concrete structure; temperatura variations; creep; retraction; etc… Some are direct actions, and other imposed deformations before which the structure must respond with adequate a safety coefficient, without disturbingthe user, or the other costituent structures of the building, with excessive deformations or movements. In addition it should be noted that, these actions, when applied to a high building have an effect that is very different with respect to a building of normal height, despite being the same, conceptually speaking.

Also note that sice the appearance of modern materials, Steel and concrete, the resistant structure has been adapted to the functional conditions of the building imposing a few constraints. This has become a series of vertical slabs. The gravitational actions those that determine to a greater extent the form and amount of the structure. All other actions are resisted without their influence interfering only with the final design.

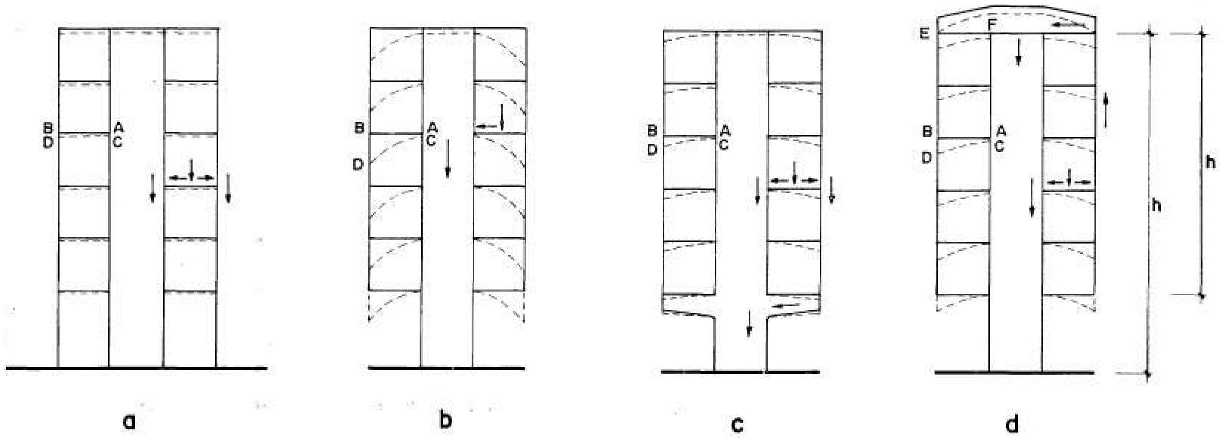


13. Deformation of the nucleus to the horizontal actions

14. Construction of the “Torres de Colón”

GRAVITATORY ACTIONS:

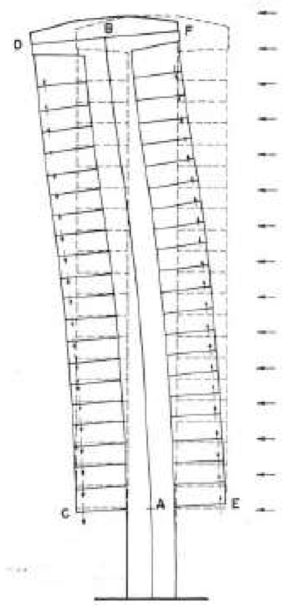
Both the own and the service weight, have an increasing effect with height, due to its accumulation along the number of plants, which determines a significant increase in the size of the supports. In order to minimize the effect of this load, two methods have been used: the first of these methods has led in many concrete structures to use lightweight concrete in slabs, with densities ranging from 1700 to 1900 kilograms per cubic meter. Considerable relief in the weight of the building, and on the other hand has been used high-strength concrete, in pillars, in the lower plants, achieving an optimization of the free space by reducing the dimensión of the supports ensuring their final strength.



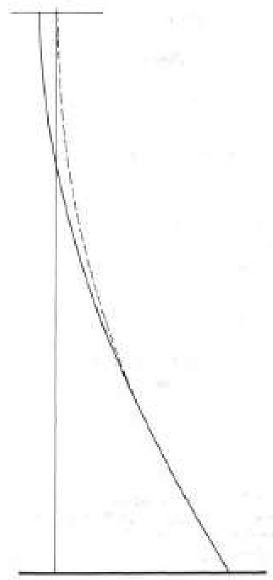
15. Response to the external loads of four structural schemes of the building

HORIZONTAL ACTIONS

This actions are constituted by the pressure of the wind and the forces of inertia produced in the seismic movements, it is the significant actions that make the determitation of the resistant structure in tall buildings. Against them the building is a bracket. Wind actions, generally considered in their static dimensión, depend on the wind speed for a given period of return, it mind, height, surface, shape of the building, as well as the place where the building is to be lifted. Emphasize that the amount of the solicitation must be obtained in models subjected to wind tunnel test, it is because the value given by the different national codes is usually a rough aproximation, valid only when the height in the constructions is moderate.



16. Wind deformation effects



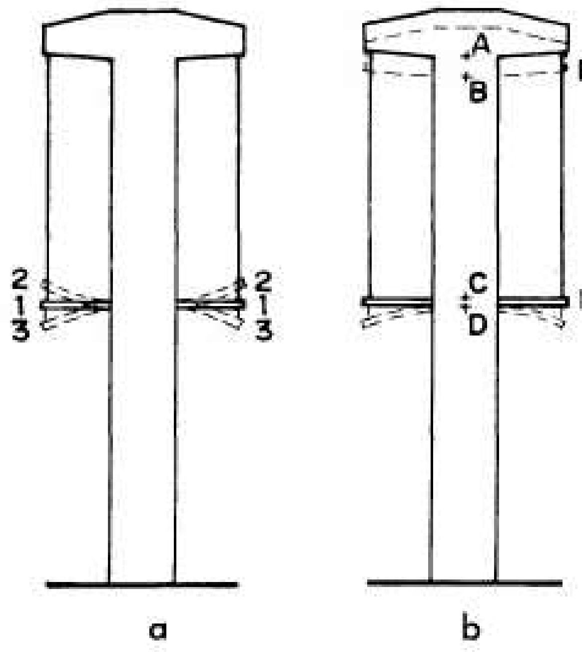
17. Law of bending moments in the central core

SEISMIC ACTIONS.

They are more complex because their value depends not only on the acceleration of the soil, but also on the characteristics of the resistant structure, the building mass, rigidity of the structural elements and damping, which determine the natural modes of vibration and periods. The national model generated on the basis of the terrain studies and the historical data of earthquakes in the zone will have a great influence.

TEMPERATURE VARIATIONS.

In general and because of the deformations imposed due to the fluency and retraction in the concrete structures, wich in normal buildings lead only to determine the position of the expansión joints, in the high buildings can cause very significant efforts in the slabs by accumulation of elongations or shortenings in the plants of the top. Of the particular importance is the control of the temperaturas in the pilars in the perimetrer that are exposed to the environment, when the interiors can be in a controlled environment.



18. Deformatión of losas of the floor because of temperature.
a) Fluency y b) Retraction

Therefore, it can be concluded that the resistant structure of a building in heights is a large vertical bracket subjected to horizontal and vertical loads. The resistant problem of this well-formed bracket is very simple, because it is a problema about an element mainly requested for shear and bending, and its answer is perfectly solved by the current technology for the large brackets that have been presented to construct different kind of bridges and towers of communications.

Here we are interested in the proposed resolution for these cases, because it highlights the problem that will shape the way forward in the design of its resistant structure. This bracket, that has been foreseen hollow and definitely perforated, is going to be very deformable to shear, which greatly reduces the resistence to flexural strength that the building volumen could provide. As the building grows in height, the fight against deformation to shear will be more demanding and the structure will take more conditioned morphologies. To overcome these technical problems, we proposed in our building the creation of a structure based on a resistant core, wich we develop below.

4. STRUCTURAL SYSTEM EMPLOYEE

STRUCTURAL SYSTEM EMPLOYEE

RESISTANT CORE

The resistant core constitutes a particular case of the structures formed by concrete screens. The screen is folded forming a drawer beam of great rigidity to bending and twisting. This solution is tipical, mainly, in the office buildings, because it facilitates the existence of a diaphanous space in the rest of each of the plants. The nucleus is located in the center of the building and inside are lifts, stairs and some services, like electrical, gas and water instalations. To it is assigned the vertical and horizontal load of the building.
The necessary penetration inside the core forces to perforate its walls, which introduces into the core a complementary shear deformation controlled by the flexural stiffness of the joining beams. If the dimensioning of these beams is sufficiently large and the ratio of height and width of the core also, which is often the case in tall buildings, the vertical tensile state coincides fairly well with beam theory and frat deformation of the V sections, therefore, the resistant efficiency of the nucleus against to the horizontal actions is very great.

19. Central Core of the "Torres de Colón"

The penetrations reduce much more the stiffness to twist of the nucleus when we compare it with the one that would have of not existing these. This fact determines the need to center the core in the plant to avoid complementary torsor stresses and the need for its Surface, compared to that of the plant, to be sufficiently large. The shape of the cores is very diverse and is governed by the needs of the elements of elevation of the building. They can be unicelular and multicelular, rectangular curved, and so on.
The analysis of the resistant cores must be done by the theory of drawer beams, which takes into account the torsional wraping with perforated walls. The finite elements method is particulary precise, in these cases, to take into account all the resistant phenomena we have pointed out. In no case should the distortion, that is, deformation of the cross-section be taken into account being clearly constrained by the floor slab surrounding it.
A characteristic case of buildings supported by the central core, exclusively, are those that use large platforms, and which, collecting all the load of the building's plants, transmit it to the central core. In these cases the functional misión of these platforms is to reléase the lower plant and/or intermediate plants from the presence of the peripheral pillars. And already within this gropu, it is posible to distinguish between the hung buildings and the supported ones.

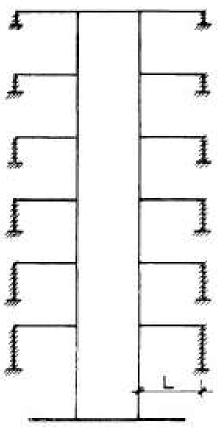
In the case of the hanged buildings, we are dealing with particular representativity, the "Torres de Colón" in Madrid, a 30-storey building of which the top 21 floors are hang from a rigid platform on the upper floor. Concrete plants, with small surface dimensions, 19,4 x 17,4 meters, are supported on the one hand in the central core of 7 x 6.9 meters, and on the other hang from 18 prestressed concrete tie rods.
The central core is very compressed throughout its height, because the load that acts on the plants is divided in two parts: on the one hand part of the loads of own weight and use of the plants go directly to the nucleus. And others ascend by the tie rods up to the top of the hanging head to go down using the central core, the amount of one and another depends on multiple factors, but the intention that guides us is that the load that ascends by the straps is the same as the one down by the outer pillars in a normal building. In this way we will ensure that the bending work of the type plants does not increase the price of its structure, and in addition, for this reason, the core is very well shaped to withstand the effects of the wind in buildings in height.

20. Inside of the Central Core

RESISTANT PROBLEM IN HANGED BUILDINGS

It constitutes the unevenness of supports that exists in any floor between the zones supported in the nucleus, and those that hang of the tie rods, in order to abtain the maximum benefit of the tensile work, the union to the plants mus be articulated, avoiding the flexions. This unevenness is due to the fact that the zones joined to the central core experience a decrease corresponding to the shortening of the core from the foundations to the slab we consider, while the points attached to the tie rods descend corresponding to the total height of the core plus the elongations of the Braces from the top of the tower to the plant in question, plus the arrows that the platforms experience.

21. Execution of the different plants by tie rods



22. Elastic simulation of a hanging building

In these we must consider not only the elastics due to the load, but also those corresponding to temperature, creep and retraction.The unevenness is all the more important the lower the plant being considered and the greater the number of plants due to the accumulation of the described effect. There is, also, another factor of major importance which is the relationship between the width and height of the building. It is understood that the less tall and wider the building is, The solution hanging to the structural suitability is the better adjusted, whereas in the case of a tall and narrow building the differential deformation indicated above may be so important that the support effect of outer tie rods disappearss, for practical purposes, and the floor plants behave as if they were cantilevered from the core.

23. Hanging floors

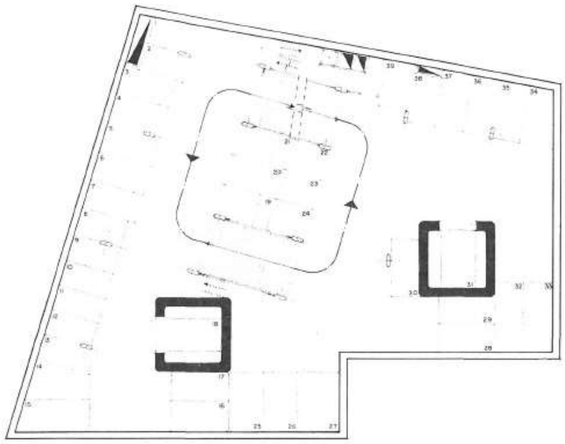
24. High and narrow building

This problem leads to two questions: What should be the number of plants hanging from a single platform? And what material should be used in the tie rods? Hanging metal structures provide lighter, faster mounting solutions and simpler construction solutions, while the structures hung from concrete, provide heavier solutions, slower execution demanding special auxiliary means. In "Torres de Colón" the most unfavorable conditions for a hanging building are presented; since it is a slender building, that is, tall and narrow, with twenty hanging plants.
As a solution the use of pretressed concrete tie rods is adopted, due to its many advantages. The main one is that it does not respond to the load passively, as it happens to the metal tie rods, but it is an active support. This is because the prestressing iron introduces a shortening deformation which eliminates the permanent load gradient and even the overload can be averaged. Creep and retraction deformations also go in the direction of reducing differential seating. It also has more termal inertia tan metallic ones, which can be left outside.In Torres de Colón this problem was also presented but with a much smaller effect. Greater flexibility was provided for the tie rods for three reasons: their length is quite large, their inertia is very small and, in addition, a joint is stablished between the upper platform and the tie rod.

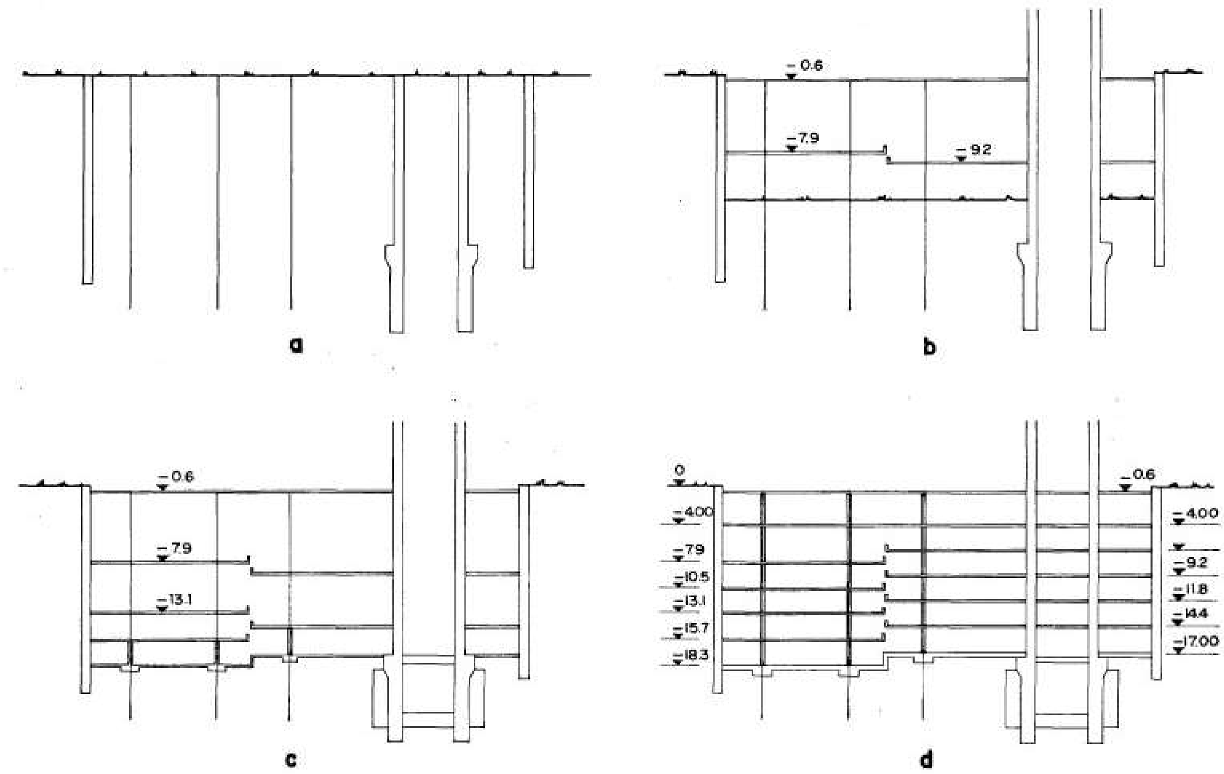
5. MILESTONES

MILESTONE 1. EXECUTION OF FOUNDATION

We went on to describe the foundation of the building, and how it developed its peculiar system of execution.
The buried plants of the “Torres de Colón” are six, of which the four lower are intended for car parking, the situation of the pillars are thought to be adapted to the passage of cars to the parking places. While the upper two floors lodge the general porter’s lodge of the building and mechanical plant. The surface of each plant is about 1.700 square meters and is approximately trapezoidal.



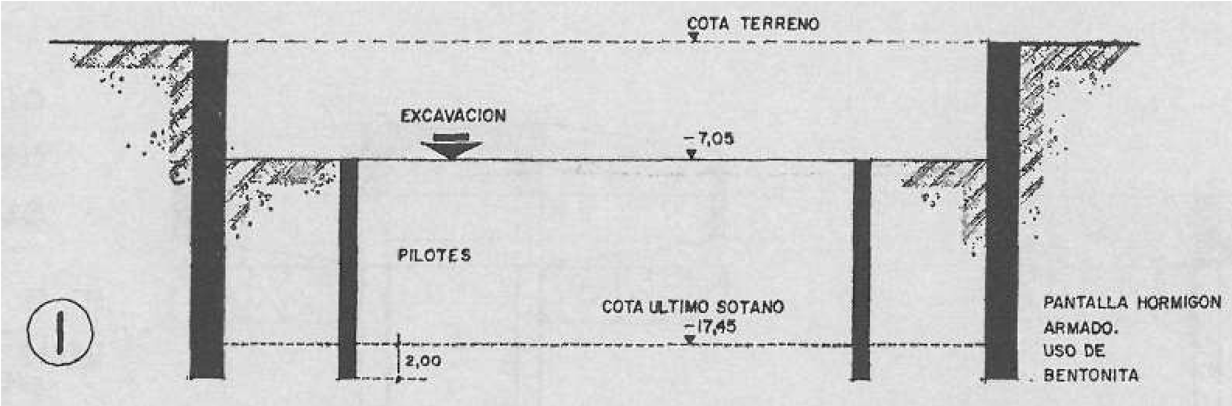
25. Floor type to the parking



26. Phases of execution of the basement plants

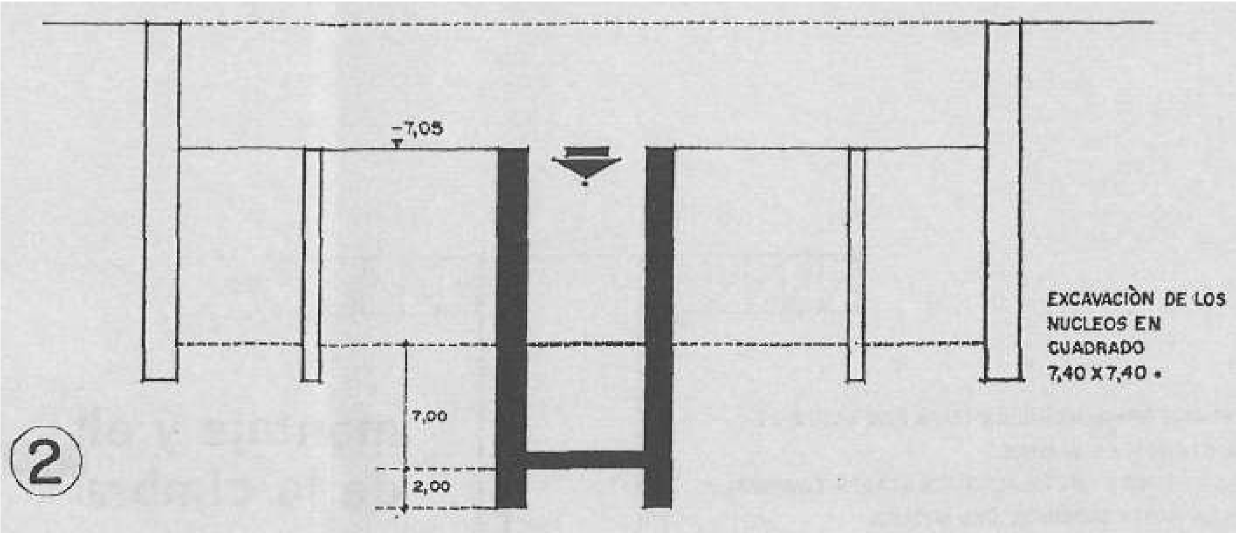
It structure is formed by reinforced concrete slabs 40 centimeters of thick, which are lightened with plastic and recoverable waffle. The distribution of reinforced concrete supports is very irregular, since it has been necessary to couple them to the needs of vehicle traffic. The separations that are created between them are of approximately 11 meters. The central nucleus to the towers are also used as support of the plants, with the aim of stabilizing the structure and optimizing the available final space.
The particularity that presents this work lies in the construction procedure used, which follows the following phases:

1. At first, piles with 60 centimeters in diameter are placed at the points where the columns supporting the plants will be located. In the same way, it is proceeded to the excavation of the perimetral screens, as well as of the nucleus of the towers. The steel reinforcing bars are then placed and finally the perimetral screens and the core are concreted, using a continuous supply of concrete with a pumping truck and a concrete plant located on the site.

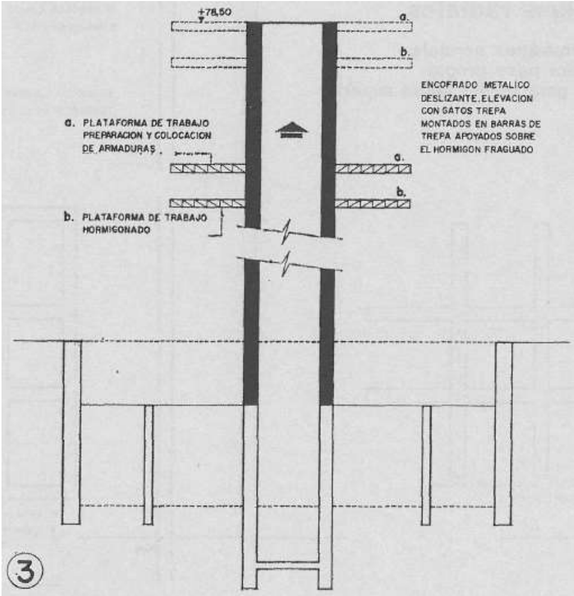


27. Excavation and construction, retaining walls and piles.

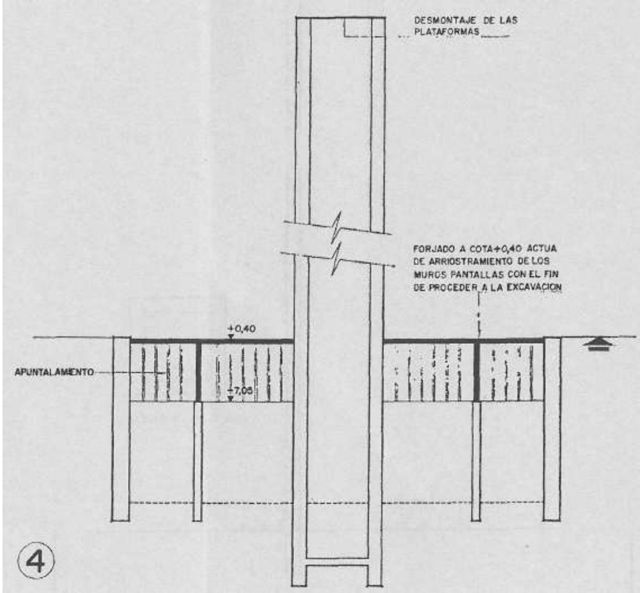
2. Once we have the deep foundation executed, we proceed to the excavation of the ground of the basement, could not be made with the help of ground anchors that stabilized the perimeter screens because it was located between the foundations of other buildings already built and the presence of the subway in the streets of Genova and Castellana.
This makes it necessary to resort to a system of direct counteracting of the thrust by means of the floor slabs, which supported their own weight on the piles previously introduced. Thus, the upper floor was built, located at the -0,6meters level, and the excavation of land at the height of two floors was carried out. Afterwards, the plants located at the heights of -7,9meters and -9,2meters, were built, and the excavation was continued to the floors at the level -13,1meters, -14,4meters, and finally the site was completely excavated.



28. Excavation and concreting of the cores of the two towers.

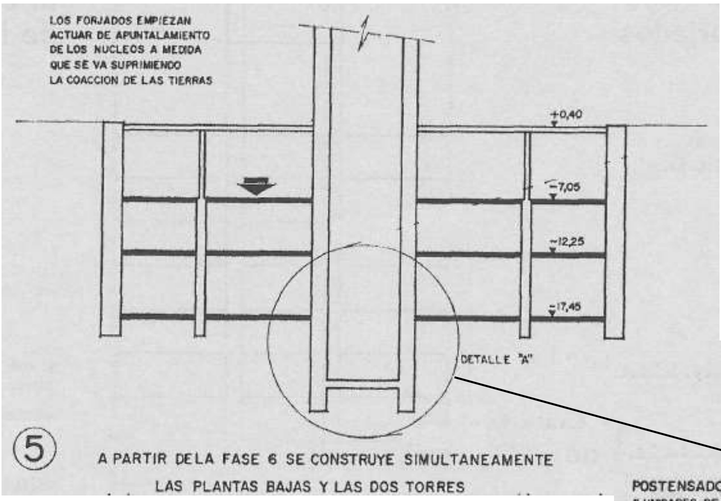


29. Elevation of the two cores.

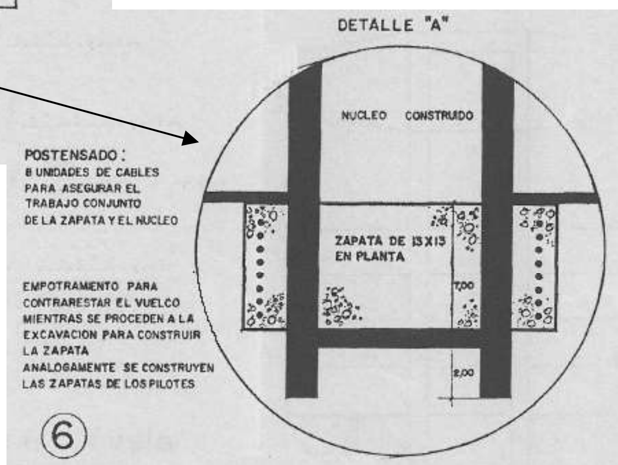


30. Concrete forging. The quota +40 meters.

The junction between the sunks piles and the plants was made by means of a metallic collar. But the interior plants were not continuous throughout in all of their surface, as indicated in the level of the plants and in the schemes represented. This meant that at this point a direct counterbalance could not be established from the thrust of the walls, but the plants had to function as beams of great song, which transmitted the push of lands to the side walls, with this method can solve dangers of collapse during the execution.

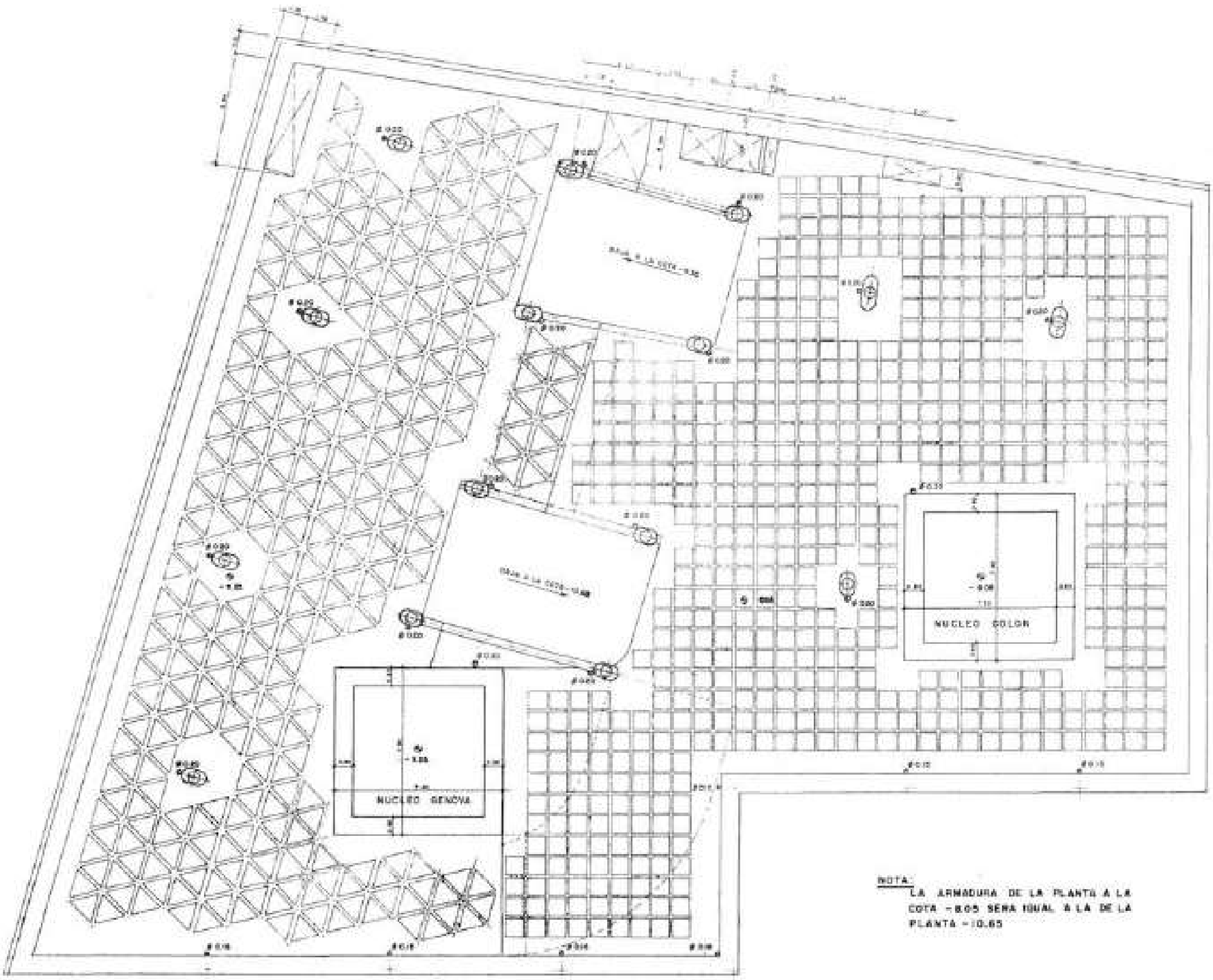


31. Excavation and construction of the floors of the basements of “two in two”



32. Excavation and concreting of the core shoes and the pillars

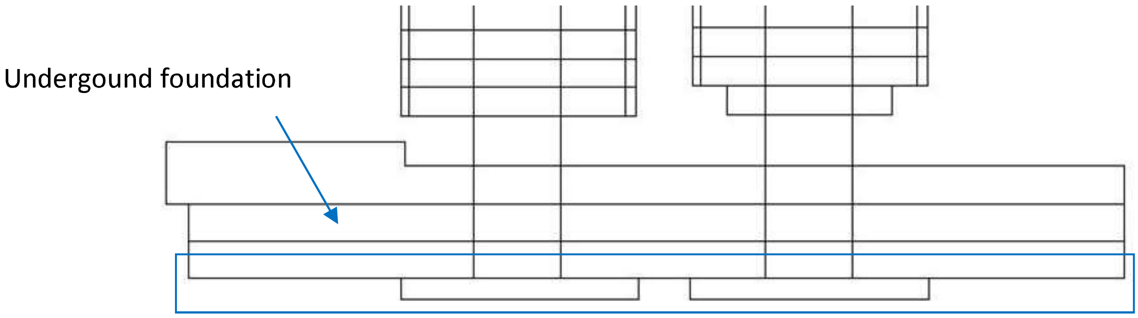
Between these beams there are two, those located at the heights -7,9 meters and -13.1 meters, whose separation of flexion reaches 40 meters, and which re also subject to a huge load of land because of its location in elevation. In these cases, we adopted a triangular paneling that determined a structure of the horizontal plants more rigid that the one corresponding to a rectangular paneling, this is because when you apply a force on any of the vertices of a triangle of beams, automatically the two beams that depart of this vertex are working to compression, and the other one will be subjected to a tensile force, more stable. It is also noteworthy that the support of these plants on the cores of the towers was realized with sliding support to not transmit thrust of earth towards such so rigid elements.



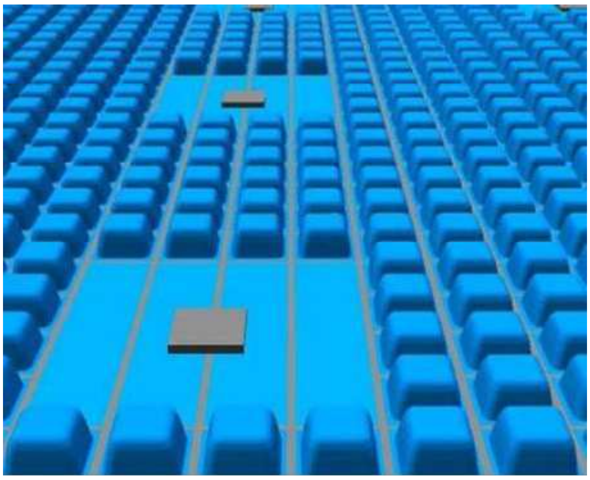
33. Basement slab plant

Once all the land was excavated, the foundations of the main core were complemented by the excavation of the lands and a was executed a concrete basement, which was attached to the core by transverse prestressing, using low retraction concrete, that provide a correct functioning of this important structural element. The stability of the central core was guaranteed, since its depth was something greater tan the one corresponding to the excavation of the basement. In addition, it was provisionally bent with timbers crossed between at the plant located at the quota -0,6 meters.

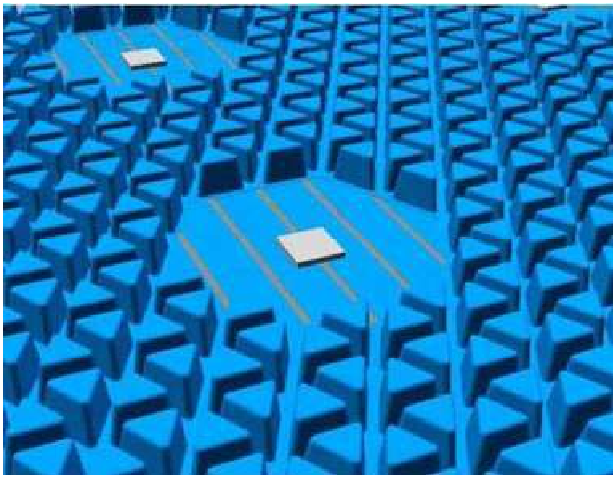
In the construction of the towers Stalexport, two types of foundations were executed, one first with the objective to support the central core of the two towers, that is base don the execution of a large slab of reinforced concrete, from which the central core grow up, and whose objective is to work as a plate that collects the efforts and distributes them throughout its dimensions towards the terrain on which it is directly suported.
On the other hand, for the execution of the three plants that form the lower levels, a foundation was made based on the concrete shoes to support the pillars, this foundation is totally united to the slabs of the towers, which contributes a point of stability to the whole construction, providing the necessary characteristics in the sustenance of a high dimension building.



The reticular slabs are executed with square and triangular shaped plastic panels, this is due to the need to save large dimensión lights, with elements that are undergoing great efforts. The choice of triangular panel has the advantage of a greater resistance since it Works in two directions more tan the rectangular ones and, therefore, the reinforcement that these forged suppots is greater.
The disadvantages of the use of a trianguales paneling versus squares or rectangular is the execution, due to the greater number of Steel bars for the assembly, one must be very carefull in its placement and in the choice of the dimensions of the same, and base don this, a concrete must be chosen, taking into account the dimensions and the shape of the arids that form it, being preferably smaller and rounded, and consistency o the same, which should be more liquid, with the extra cost that entails this choice.

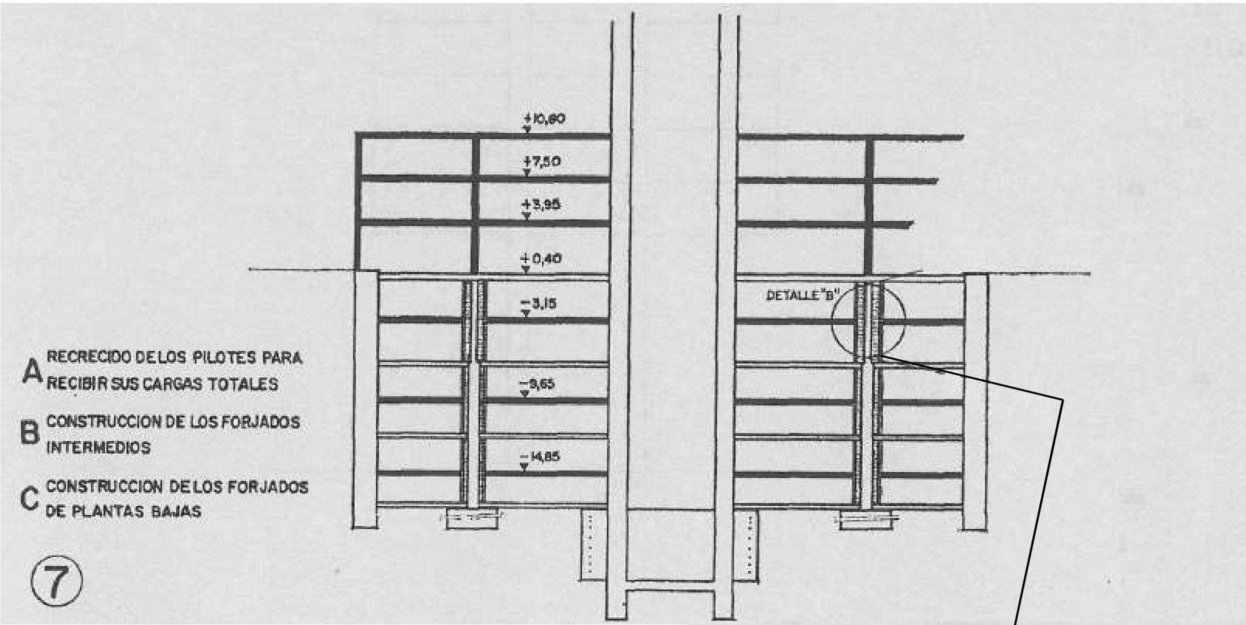


34. Forged made with rectangular paneling.

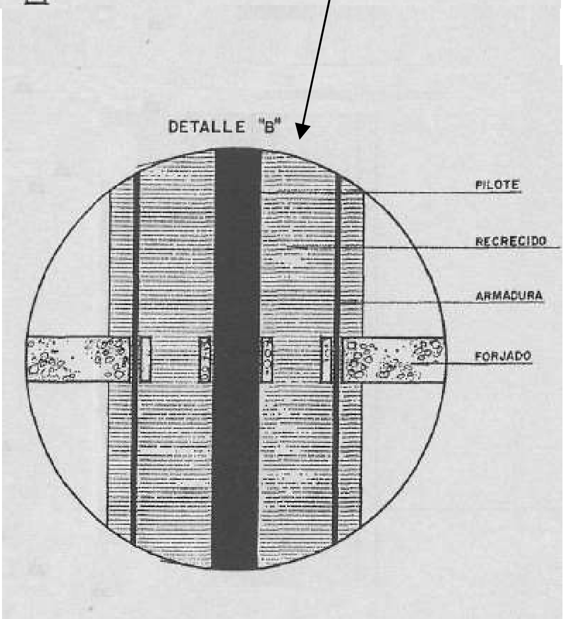


35. Forged made with triangular paneling.

In the same way, at the points where the piles were located, a direct foundation was excavated, which would serve as a support for the load of the pillars supporting the plants. Since the piles and their depth were only dimensioned to support the weight of the constructed plants and these were raised ahile the plants were not constructed.
Is necessary to consider possible seats for the differents loading hypotheses, because the foundation is independent between the structure of the low and underground floors, and the top floors.
As these raised piles had to support not only the new plants, but also those that were built during the descent phase of the excavation, we proceeded to leave superior holes in these plants, through wich the board that was obligatorily at the junction between an element that is concreted from bottom to top and the slab built at the top. This filling was complemented by an injection of the gasket.



By this procedure the construction of the basements from bottom to top was completed.
It can be said that the construction of the building was considered, in its totality simultaneously the construction of the towers and the buried plants.
That is to say, simultaneously to the operations of excavation and construction of slabs was proceeded to raise the core in all its height by sliding of its formwork in spite of not comleting foundation foot of the entral core were being constructed the pretensioned heads of wich hang the towers, as explained below.



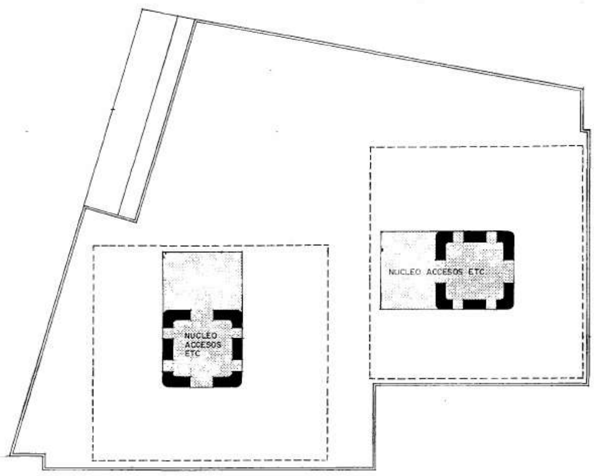
36. Ridged of pills.

MILESTONE 2. CENTRAL CORE AND THE SLIDING COATING SYSTEM.

Th estructurals core of the "Torres de Colón" is rectangular, 7,00 x 6,80 meters, and with walls of 0,6 meters of constant thickness along the 69,25 meters corresponding to the hanging part. Inside the vertical circulations of the building, these elements of vertical support receive functions that in the traditional model must be solved by means of auxiliary elements added, outside the structure while in these towers, each one of the two central cores of concrete, which act as the only "super-pillars" with ground support, this walls are buried more than 15 meters below the last basement, and are home to three elevators, in addition to a staircase, vertical pipes and the office acces distributor, with seven doors per floor, which have for the object to stablish the passage to type plants.

37. The walls have a thickness of 0,60meters.

Their construction was carried out by continuous concreting, at the same time as the structure of the basements was realized, since these acted like elements of subjection of the core, preventing lateral movements, to approximately 110 meters of height from the foundation quota using sliding formwork. During their construction they were left with metal plates embedded in the concrete, which would later serve to support the floor slabs. Their size is greater than that required by calculation, the calculations were made with a large coefficient of safety, in order to take precautions with regard to misplacement during slippage.



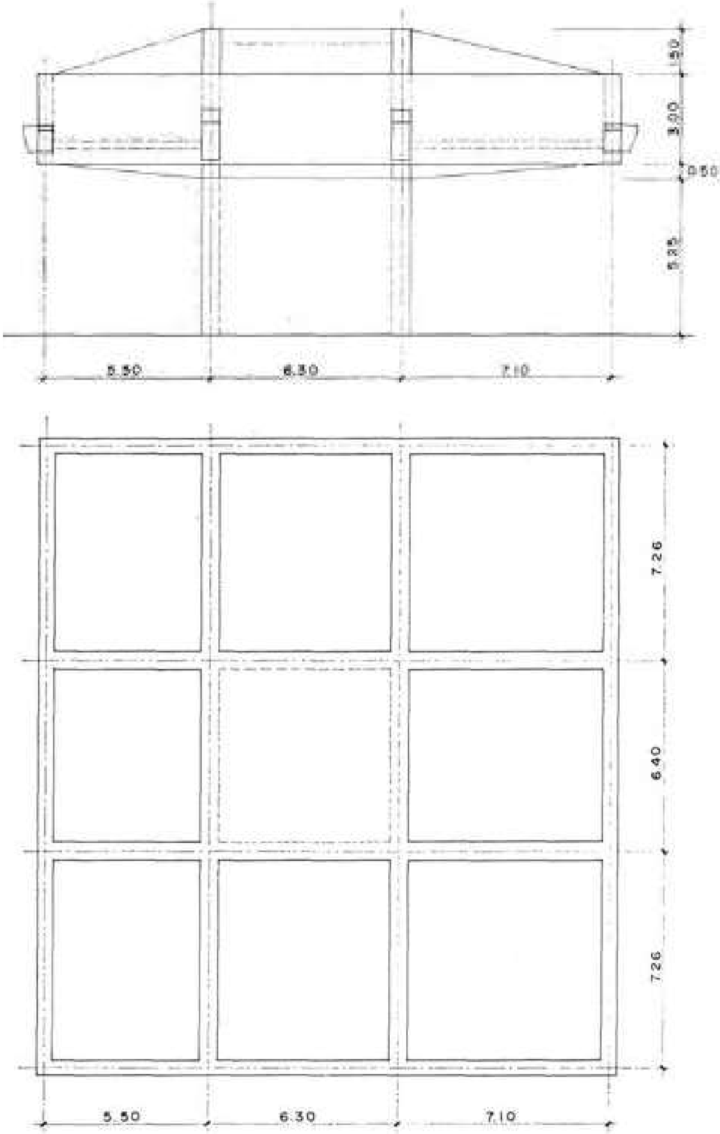
38. The core was made by continuous concreting.

The sliding formwork system used is a construction technique consisting of the execution of a double formwork of small height, with the same shape of the walls to be built, which is moving without waiting for the concrete to finish completely from setting, but with the necessary strength to support the formwork. It is hung by frames and powerfull lifting devices move the formwork upwards at a continuous speed.
The sequence of formwork, reinforcement, concreting and stripping, taking into account the projected voids and other singular points, will be carried out in a continuous way, with the complexity in the coordination of these works that entais, the company in charge of the execution carried out a detailed study of the times in order to optimize the economic resources used in the same.
As we said before, the concrete used must comply with characteristics of fast initial hardening that allows the continuation of the works and that these are carried out with the guarantee of resistance to the own weight of the structure. The advantages of this system are based on saving working times, saving materials by using the same formwork continuously, while improving the finishes of the built element, although it has the problema of large initial outlay, which only counteracts with the execution of a continuous element of really large dimensions.

39. The system of execution of the central nucleus of the tower will be realized with doublé formwork of small height.

MILESTONE 3. HEAD BEAR IN HEAD

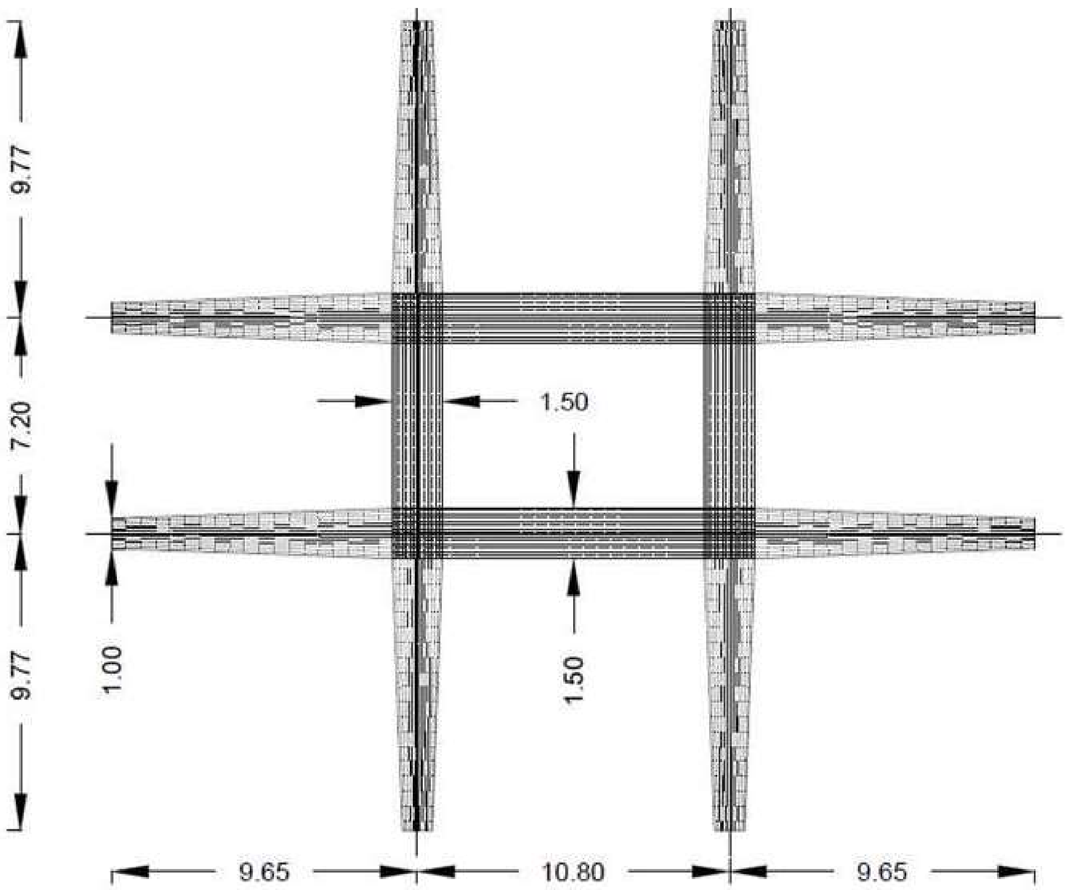
The hung structure refers to the horizontal supports to a solid structural system located in the crowning of the tower, type aerial foundation. The upper platform from which floors are hung is a strongly requested element and, therefore, constitutes a very slender and very rigid structure. And the vertical supports to a central reinforced concrete core and to a system of metallic braces distributed in the perimeter of the facade, hanging of the head structure, so that they reverse the decreasing ratio of the sections, which are greater in the crowning of the building tan in the first floor. This structural system assumes a 10-15% increase in the costs of construction compared to the traditional structure of pillars, which is a relative increase and not yet sufficiently studied, which will be compensated widely by the various functional advantages.
In this case, it allows the hunging type plants, which are of small surface, to be entirely diaphanous, that is to say, free of pillares and beams that may interfere with the distribution schemes, as well as the horizontal lines, which in the case of a traditional structure, with numerous important pillars projected on the ground through the three lower floors above grade, and of the five underground floors would have made it impossible to locate the access ramps to the basements, and if has reduced the transparency and, therefore, the utility of the commercial, parking or office plants, would diminish its value and possibilities.



40. Upper head plant and elevation.

41. Bottom of hanging head, where the principle of concrete strut appears

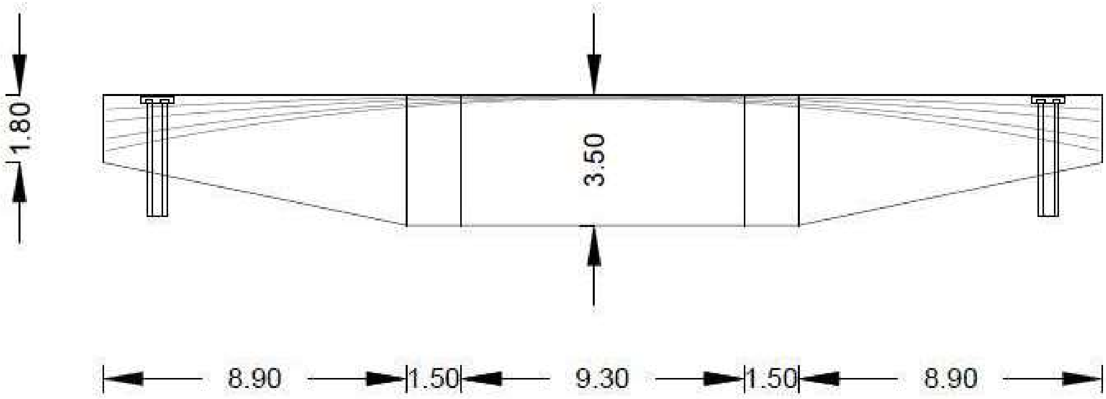
Now we can see an scheme of the hung head of the Stalexport towers, It is formed by four beams of large dimensions, designed two parallel and perpendicular to thw other two, made with prestressed reinforced concrete, the central part has the shape of a rectangle and its supported by the central core of the towers, and from each of the vertex, two sections of two beams grow perpendicularly continuing the way of the central core.
A tie rod hangs from each end of the beams, being a total of eight the tie rods in each tower, that exert perimetral pillar son the plants, which are hung from these. The dimensions and shape of the head are designed by the method of finite elements that was already developed in these years.



42. Plan of the plant of the hanging head in towers Stalexport

The execution of the ganging head is carried out by concreting in situ for a better unión of the main beams with the central core and among themselves, so that tis element Works in a reliable way since it is the sensitive part of the construction.
The design is made considering sufficient for the support of the plants eight tie rods apart from the joining of the floors with the central core, here had a great influence the intention to build a modern and occidental-style office building, and with this design of the upper zone was obtained a diaphanous area of great dimensiones in each plant, and to wcecute it was made using of the most modern techniques of the time with the support of the Swedish company of construction, and using materials of first quality that allow its duration in the time being both important milestones of the Polish construction, due to the innovation of the system, as much as the opening of the possibility of work of a company of a country that was not within the dominant soviet influence at the moment.

The beams have a total length of 30,10 meters, a ridge between 3,50, in the middle part, and 1,80 meters at the ends of the beam , and a thickness that varies between 1,50 and 1,00 meters, being the big one in the central part of the beam too, forming an element in which one of the dimensions predominates which directly affects its resistant characteristics, within this large concrete beam we find a prestressed reinforcement that runs through the entire elements by its upper part, and combinwed with the design of the beam shape itself, manages to whitstand efforts in an appropriate manner.
Another detail to take into account is, as can be seen in the lower diagram, we find the upper part of the straps, which consists of a head plate from which hang the Steel cables of big diameter that hold the first level, in this case the first leve lis the one located at the top, and from which the following are linked.

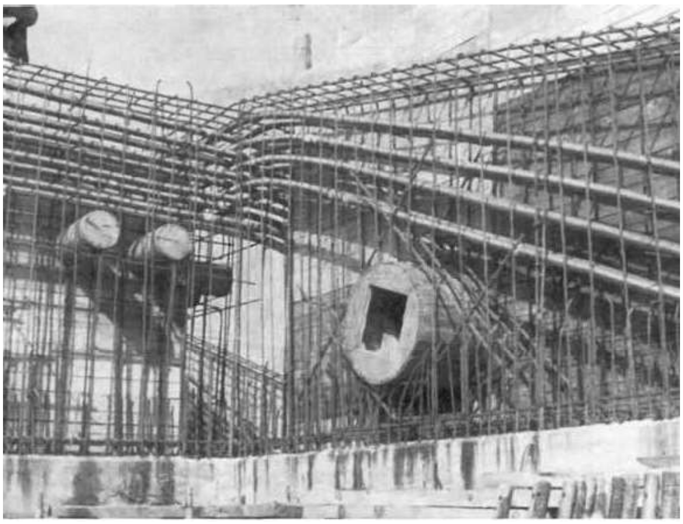


43. Section of the beam of the hunging head in the towers Stalexport

As the main difference between the two hanging heads of the buildings is that in the Madrid's building there are beams in the perimeter of the four central beams, and from wich hang the tie rods, in a number of 9 in each tower, being 2 more than those Stalexport. In addition, the dimensions of the edge of the beams is more greater in the Spanish building, almost doubling the ridge to the Polish case.
This is due mainly to two characteristics, on the one hand that the dimensions of "Torres de Colón" are greater in height and therefore in the own weight, that must be transmitted because of the bigger number of plants, and because the techniques used in the design and construction of the Stalexport towers were more advanced.

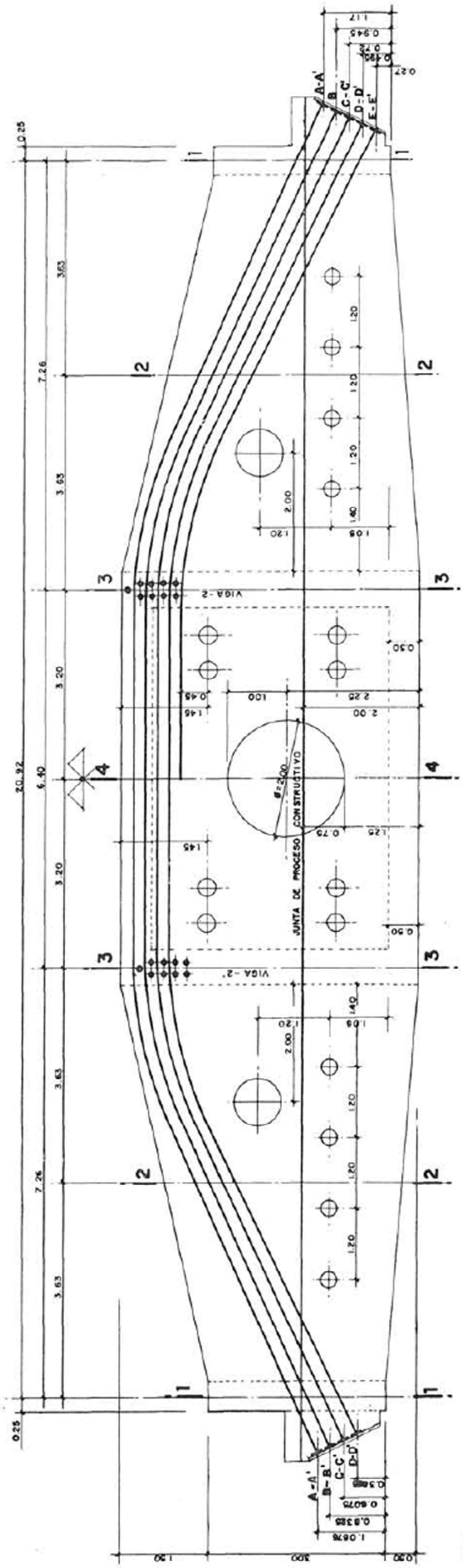
44. Aereal view of the top of the towers Stalexport

The calculation of the head was made as a linear piece, forming a grid, and taking into account all the deformation by shear stress, which in these elements of great thickness and little separation, is significant. A finite element method study was not carried out, as is desirable for pieces whose slenderness is extraordinarily small, since at the time the project was developed in 1968, this type of studies were still not well developed in our country. Aniway for the assembly of the pieces was considered everything related to the beams of great song. It is a very evolutionary construction process, which has as a special point a great interaction of efforts between both parts.

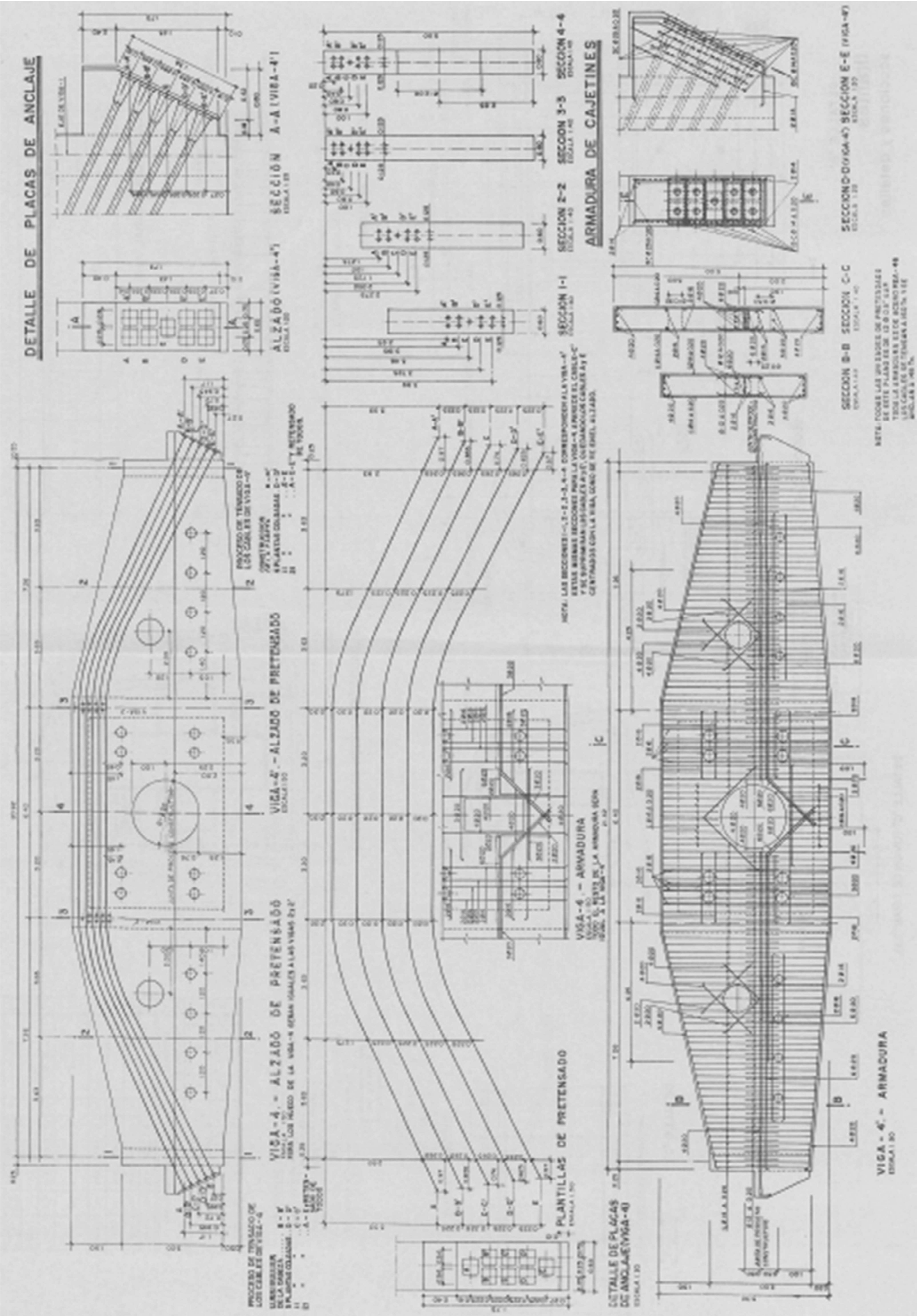


45. Pretensioning of two head centering beams

46. Large deck beam



47. Prestressing one of the head beams



48.a) Beam 4-4´. Pretension and steel reinforcing bars

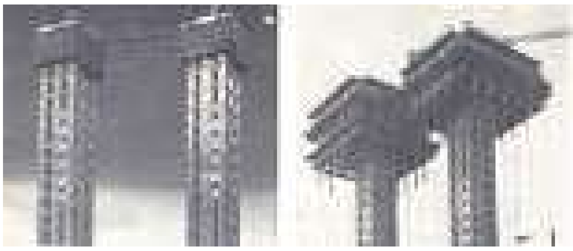
49.b) Execution of the head beams

MILESTONE 4. FRAMEWORK AND ANCHORING AND RISING SYSTEM.

Once this spine was built, a temporary auxiliary platform was built, in metal profiling and wooden panels which was designed particulary for this case, and which was hoisted by climbing bars and special jacks that prevented pitching, untill the crowning of the tower; with this support platform the beams were built.

At first it was thought as more convenient to carry out the construction according to the following steps:

1. Slip the core.
2. Prefabricate flooring floors on the bottom.
3. To construct the head in situ, by advance in successive overhangs.
4. Live floors of floors.



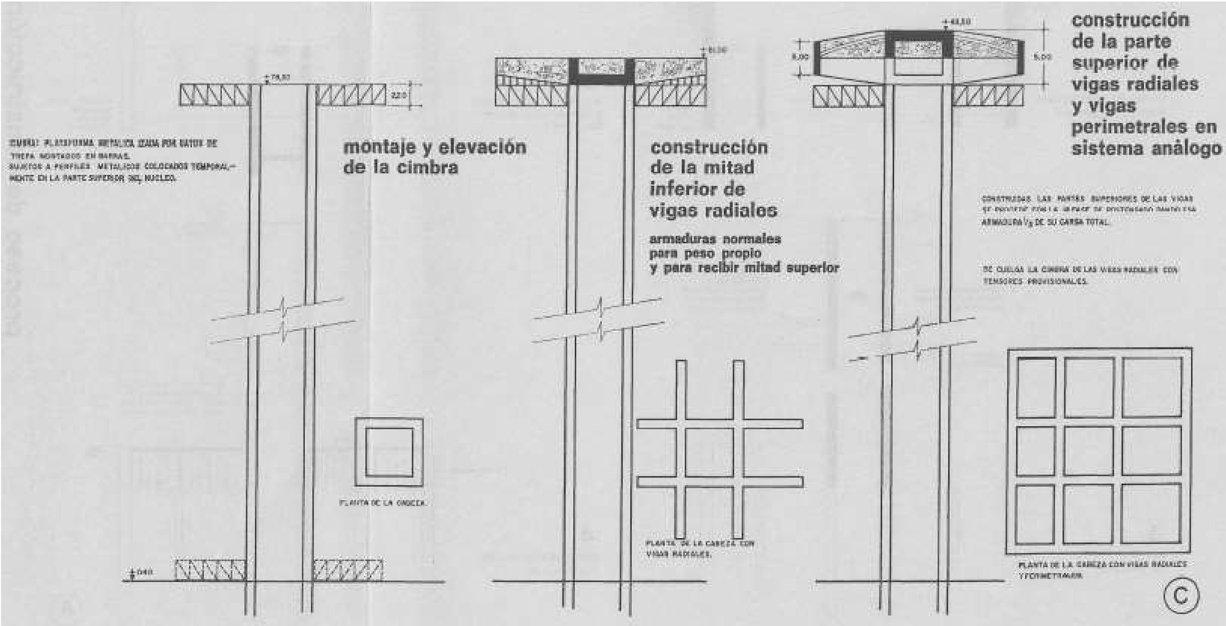
50. Framework

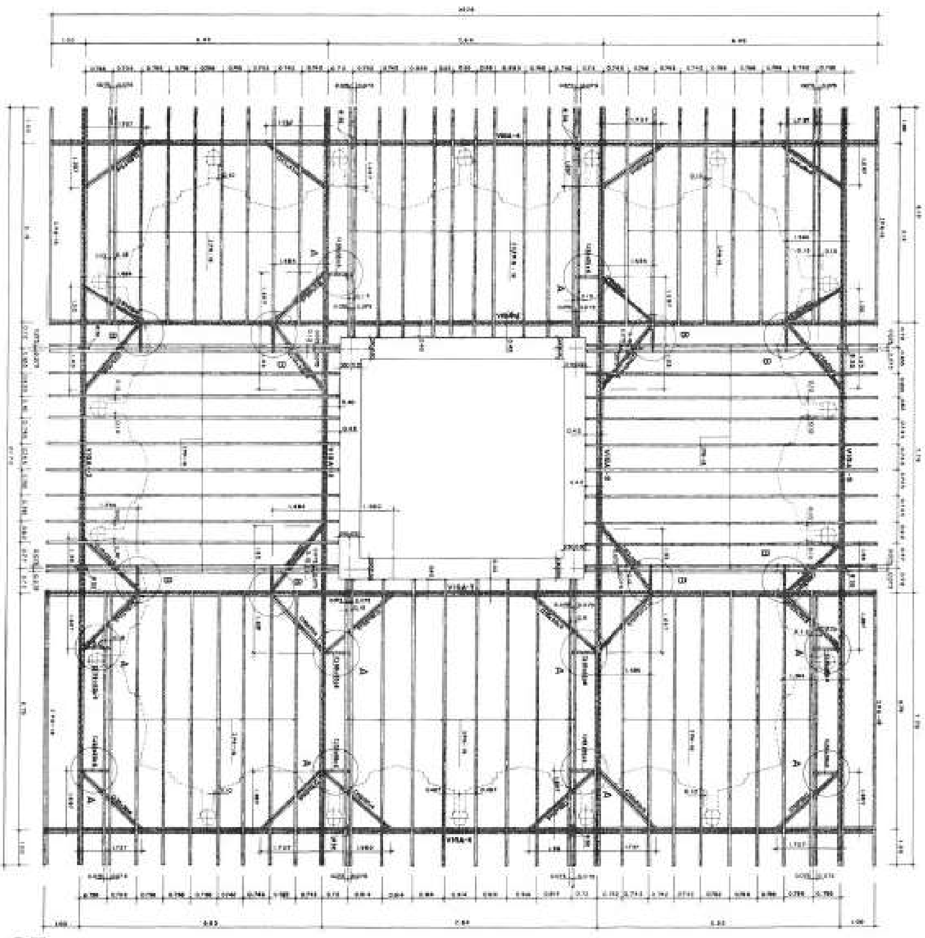
However, this construction procedure was discarded, using a more traditional procedure, in-situ concreting of the entire tower. For this, it was absolutely necessary to construct a large metal structure, and on this structure the top head was first concreted and the type plants were subsequently concreted by successive descents of the same.
The sizing of the platform was very different according to whether it was used as criterion to support the type plants or to support the upper head. Finally it is decided to size it to support the type plants, which entailed the obligation to establish a concreting in phases of the upper head, being in the first phase half of the central beam-brackets were concreted, resting on the platform and then the upper half was concreted, using as support the lower part already concrete and hardened.

The metal framework used consisted of four lattice beams that surrounded the core and four other perimeter beams, also in lattice. Its dimension in plant is a little greater than the plant type 21,72 x 23,74 meters, and its thickness, of 2,2 meters. On these beams was a metal forge and the floorboard that was going to support the formwork. Said floorboard had a form contrary to the arrow deformed of the cimbra during the concreting of the type plant, to compensate for the deformation caused by the weight of the reinforced concrete to be form.

51. Lifting of the framework by bars and climbing jacks.

The lifting and lowering operations of the framework were performed by means of double jaw climbing jacks that were supported on square bars of steel of high elastic limit, hung from the top of the core by means of small metal brackets.
In the picture you can see schematically in the first place the assembly and elevation of the framework, the construction of the lower half of the hanging head, and then the upper one.

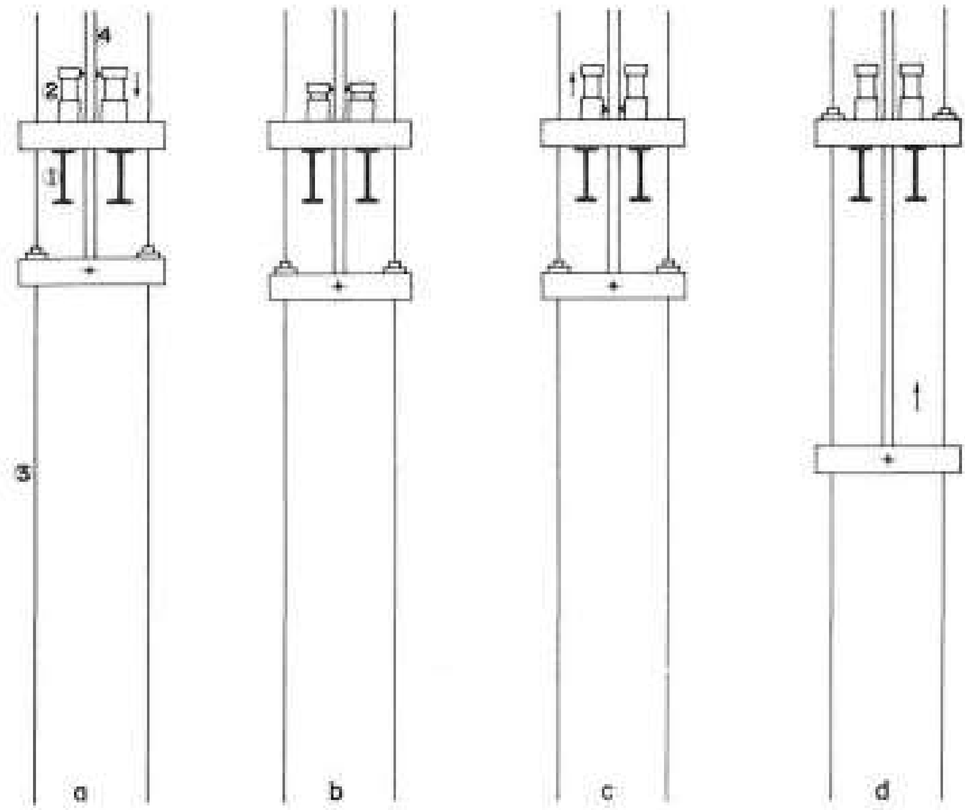




52. Plant of the metal framework.

During the concreting of the type plants, this fastening of the formwork was not sufficient and was replaced by Dywidag bars, which also hung from the top of the core. The Dywidag bars are prestress bars that are hot-rolled, tempered by the heat of the rolling process, expanded and cooled with a circular cross-section according to EN10138-4
The diagram of the operations for lowering and securing the frame is shown in the following figure, indicating the elements and the sequence of movements to be performed by the mechanism.
The descent of the cimbra was made of two in two plants, which required that the prefabricated tie rod had a length of two plants. When the plant had hardened and the formwork descended two more plants, proceeded to the construction of the plant that had been left between them, which was done by traditional procedure, supported on the lower floor.
By this procedure it was possible to perform two plants per week in each of the towers.

53. Detail of the hanging bar of the formwork.



1) Metal core clamping beams

2) Double-jawed cats.

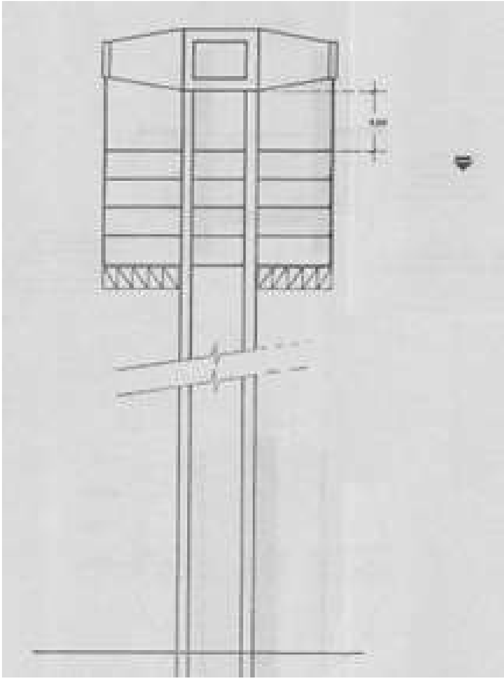
3) Dywidag bars.

4) Square bar.

54. a) and b) Lowering of the jack 2 and with it, the square bar and the bars Dywidag.
c) Recovery of the jack and return to the phase a) - b) until the metal structrure has descended from plant.
d) Anchoring of the Dywidag bars at the top during plant concreting and recovery of the square rod.

MILESTONE 5. HEAD EXECUTION PROCCES

Once we have defined the support platform we proceeded to construct the radial bams in two phases. The lower half was made first, supporting the formwork on the work platform; this half, which had been calculated to withstand, once the concrete had set, to the upper half, since the auxiliary platform did not have sufficient strength to withstand the full load of the radial beams. And then proceeded to make a first prestressing of these beams.
This constructive system forces to establish a process of concreting of head very evolutionary, with clearly differentiated phases, which obtain a good union of the concrete that support correctly the futures efforts.



55. Elevation of the tensioners, lowering of formwork and construction of the slabs

Once the beam-brackets were jointed, the metal platform was hung from the end of the beams; in this way it was able to support the weight of half of the beams in the contour, on which, once hardened, the rest of said beams were concreted and concluded by performing the prestressing process.

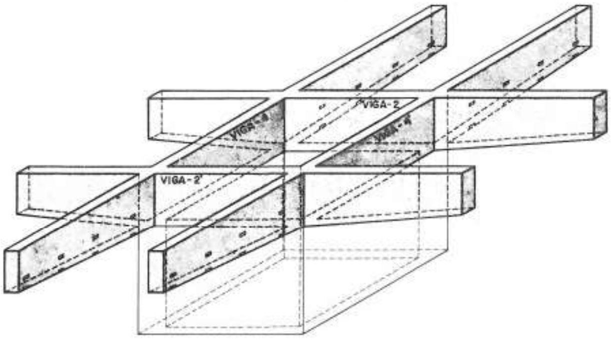
As mentioned, it is a very evolutionary construction process, which has as an unfavorable point a very great interaction of efforts between both parts, due not only to the deformations produced by the vertical load, but also by the creep and retraction deformations of concrete of different ages. This resulted in the need to dispose of much more passive reinforcement tan was necessary, but nevertheless compensated for the extra cost necessary for the metal platform, if it had been dimensioned to support the entire load of the concrete head. The method of buit the hunging head was similar in the Stalexport building because was made concreting in situ.

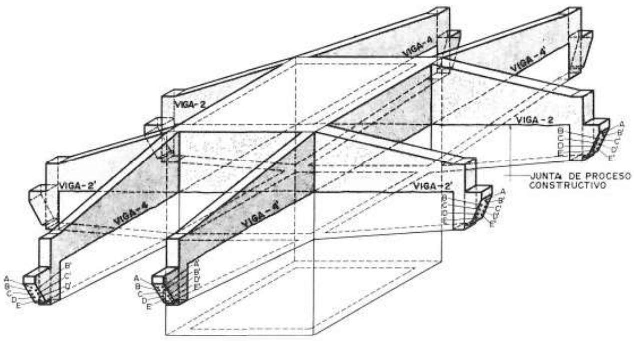
56. Support-formwork platform.

The pretensioning of the head was not carried out at one time, because the load of the floors was very important and was applied in the time as its construction took .place. This forced a pretensión in three stages.

First phase

1 Construction of the bottom of the beams 2 – 4 and of the core slab.
2 The joint will be roughened and the surface grout will be chopped.
3 The fences of beams 2 and 4 will be placed.
4 The holes for the passage of lower beam reinforcements will be left.



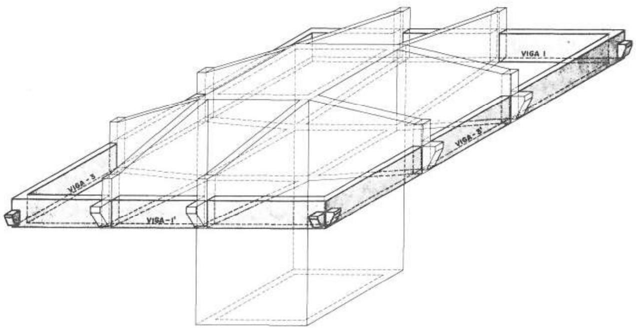


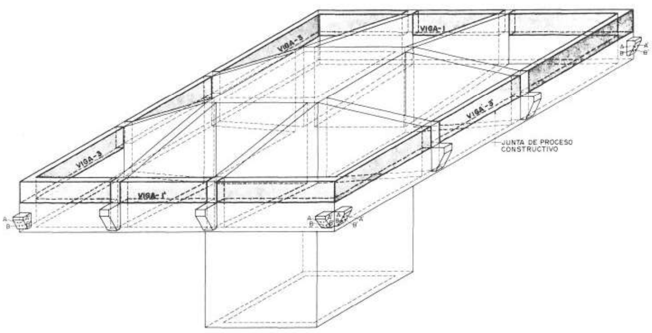
Second phase

1 Construction of the upper part of the beams 2 and 4 and of the head slab of the core.
2 The joint will be cleaned and painted with epoxy prior to concreting.
3 The D-D' and E-E' cables shall be pretensioned after hardening of the upper part. The rest of the cables will be anchored at 10Tn load.

Third phase

1 Construction of the bottom of beams 1 and 3.
2 Before the concreting, the joints of the beams will be painted with epoxy.
3 The frame will be fastened to the heads of the beams 2-4.
4 The joint will be roughened and the Surface grout will be chopped.
5 Fences of the beams 1 and 3 will be placed.





Fourth phase

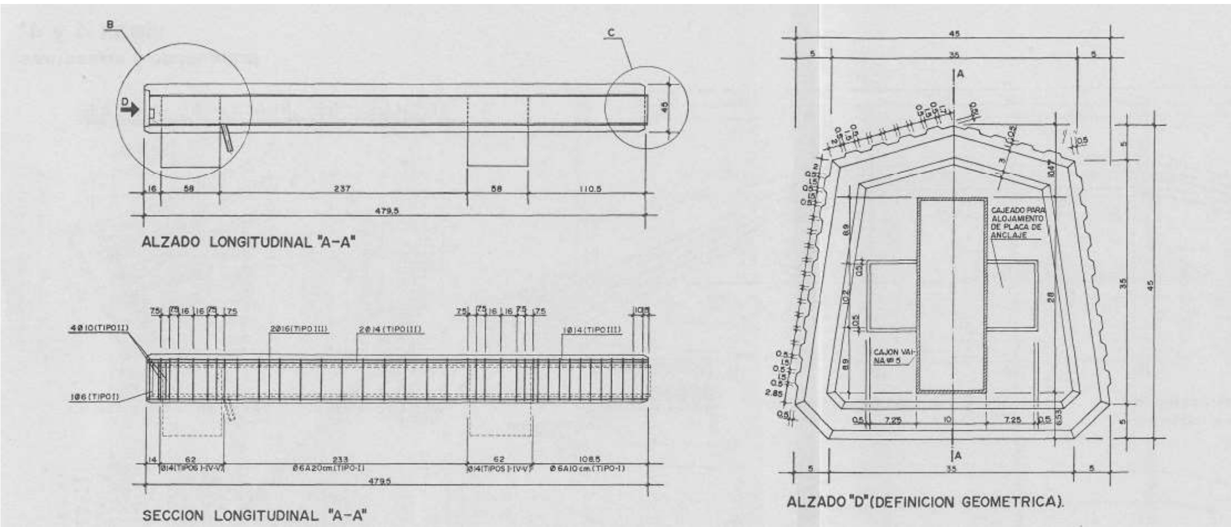
1 Construction of the top part of the beams 1 and 3.
2 The joint will be cleaned and painted with epoxy prior to concreting.
3 The cables B-B' of the beams 1 and 3 shall be pretensioned, after the hardening of the upper part, the rest of the cables shall be anchored to the face of 10 Tones.

MILESTONE 6. PRETENSED CABLES

A system of 18 tie rods, or pendulums, hangs from the perimetral beams, attached to them by means of a wedge system, and which serve to support, through steel brackets, the 21 forged of the tower type plants, by their outer edges, these perimeter post-tensioned concrete pendulums arranged at regular distances attachment of the entire external enclosure, made of anodized aluminum, which in turn has inside the primary air supply ducts conditioned. The load is transmitted to the top head through the tie rod, to end down to the foundation, from the structural central core.To make more stable the hall slab structure against the efforts in high buildings.

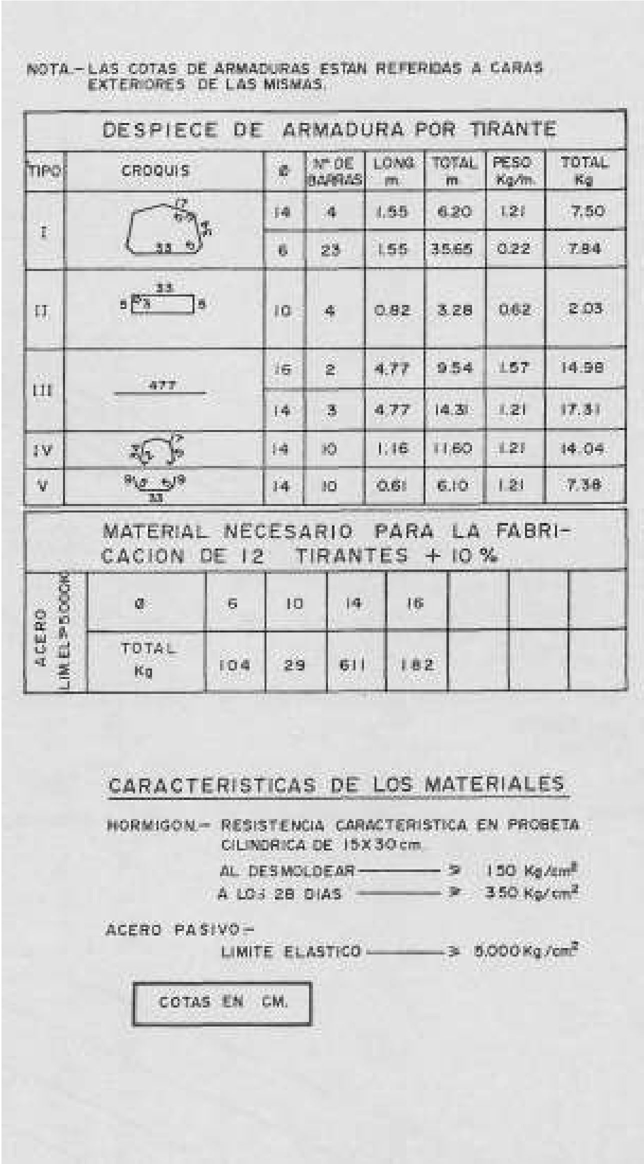
57. Bottom view with suspended tie rods.

The tie rods of the “Torres de Colón” have approximately rectangular shape of 42 x 42 centimeters. Inside, a 27 x 10 centimeters hole was provided to serve as a passage and housing for the pretensioning cables.
The tie rods were prefabricated outside the site, in lengths of 5,9 meters, corresponding to the height of two plants. Only the first section of the tie rod, wich joins the head, is 6,15 meters in length. These were lifted to their final position by means of a long-stroke, single-stranded plunger jack which was placed over the top of the head. They were threaded in the lower part with all the pretension cables and it was risen by means of that that would serve to him of final subjection.



58. Section and elevation of tie rods.

The number of prestressing cables that were introduced into the struts varied from one to another, depending on the load to be requested, the mínimum number of cables being 11, since 11 are the lengths of struts that will be attached, and the máximum 17 wires of 0,6 inches of diameter, in this case, being anchored more than one of them the maximun number of prestressing cables is at the top, decreasing as the position of the tie rod is lower. For the inner anchoring of the cables, metal plates are placed in a transversal position to the box that it has them, and thus constitute a compressed element to which the type plants were attached. The joining together of two sections of a single tie rod was establissed by means of epoxy resins, and the connection with the upper head was carried out by means of a neoprene brace, which allowed the elastic creep and retractions, of the prestressed head without introducing important push-ups on the tie rod once it starts to work.



NOTA.– LAS COTAS DE ARMADURAS ESTAN REFERIDAS A CARAS EXTERIORES DE LAS MISMAS.

DESPIECE DE ARMADURA POR TIRANTE

TIPO	CROQUIS	Ø	Nº DE BARRAS	LONG m	TOTAL m	PESO Kg/m	TOTAL Kg
I		14	4	1.55	6.20	1.21	7.50
		6	23	1.55	35.65	0.22	7.84
II		10	4	0.82	3.28	0.62	2.03
III	477	16	2	4.77	9.54	1.57	14.98
		14	3	4.77	14.31	1.21	17.31
IV		14	10	1.16	11.60	1.21	14.04
V		14	10	0.61	6.10	1.21	7.38

MATERIAL NECESARIO PARA LA FABRICACION DE 12 TIRANTES + 10 %

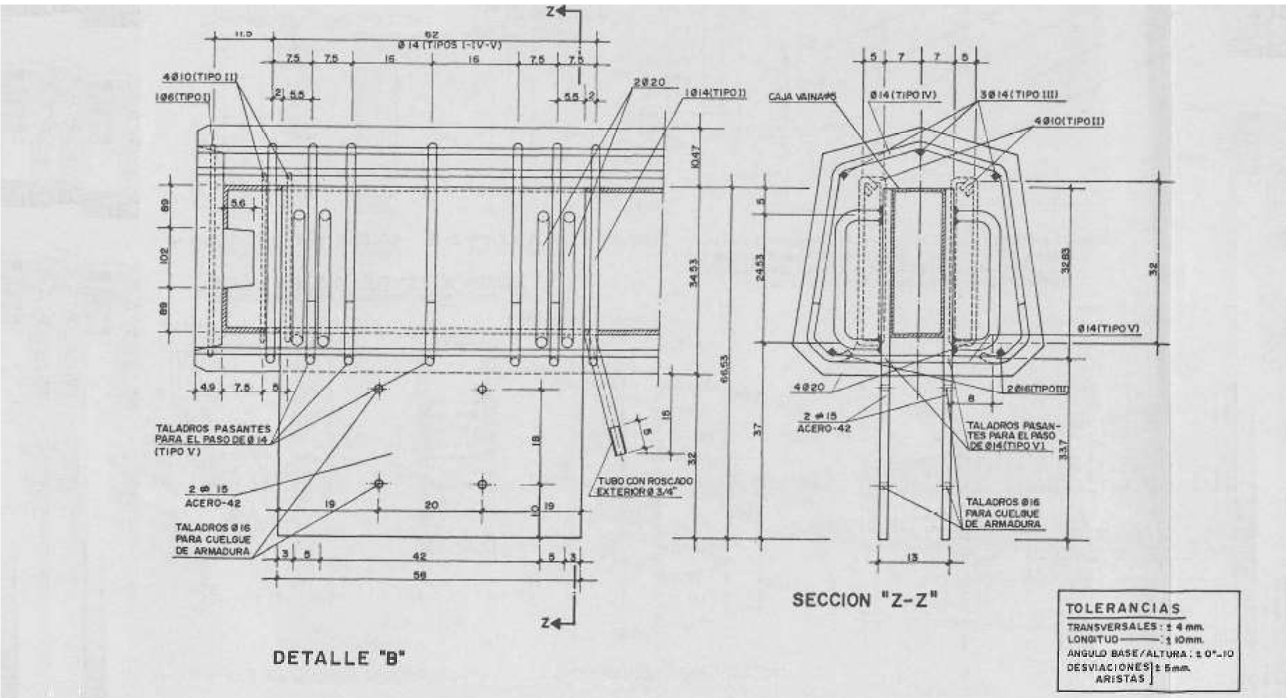
ACERO LIM.EL.>5000K	Ø	6	10	14	16			
	TOTAL Kg	104	29	611	182			

CARACTERISTICAS DE LOS MATERIALES

HORMIGON.– RESISTENCIA CARACTERISTICA EN PROBETA CILINDRICA DE 15 X 30 cm
AL DESMOLDEAR → 150 Kg/cm²
A LOS 28 DIAS → 350 Kg/cm²

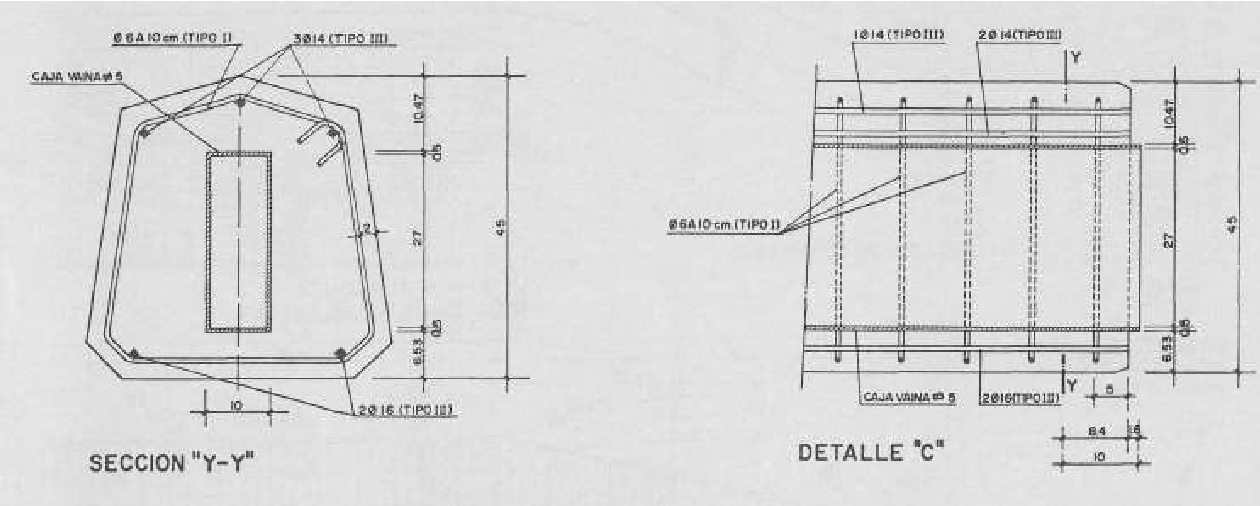
ACERO PASIVO.–
LIMITE ELASTICO → 5.000 Kg/cm²

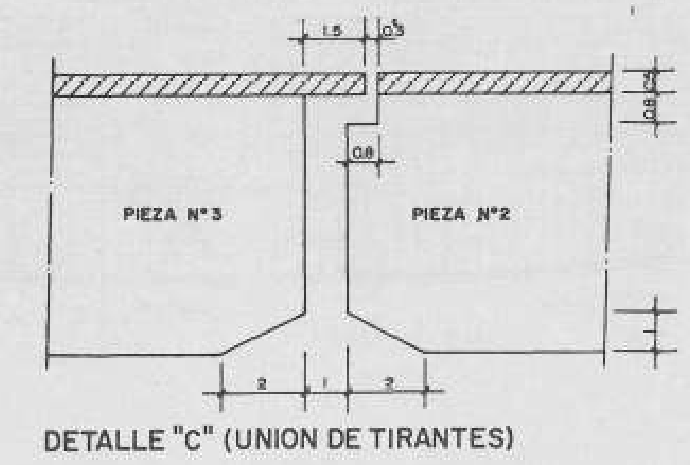
COTAS EN CM.



59. Section and lifting tie rods.

The cables of the tie rods are loaded from the top of the head and processed in two stages, with the flap that the allowable stresses in the overlying concrete are not exceded.
Once all the plants are finished, the internal cavity is injected to protect the steel against external oxidizing agents, ensuring its durability.

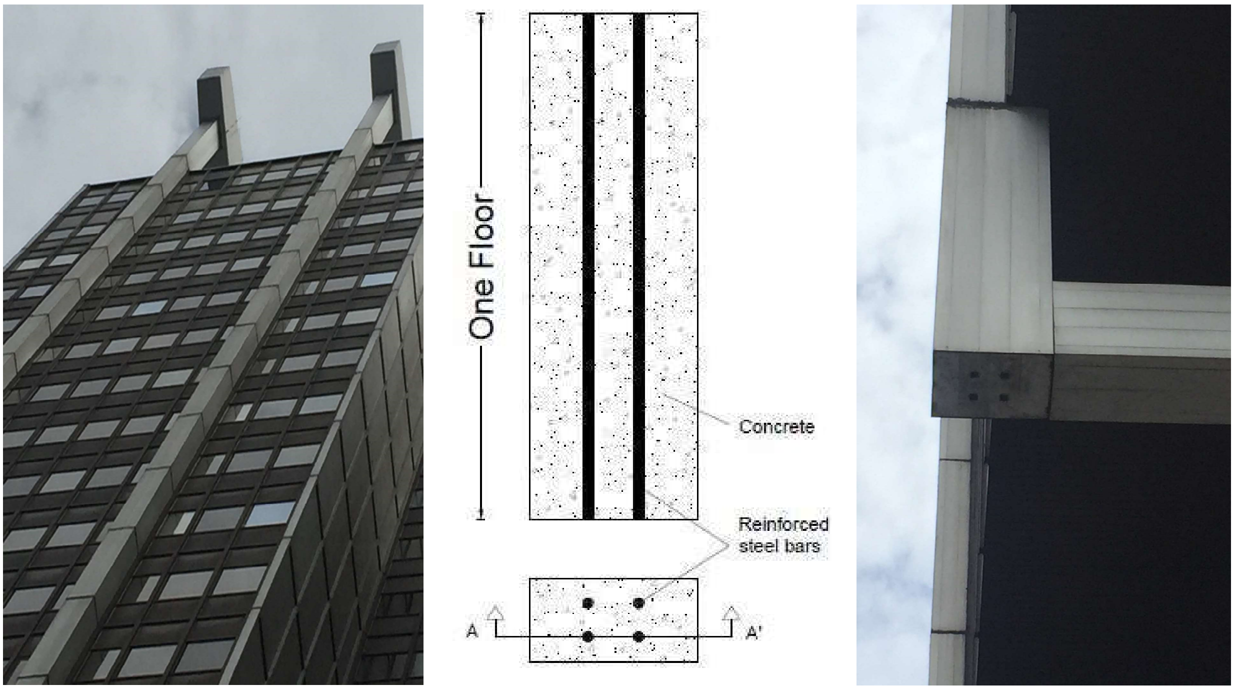




60. Bottom view of finished facade.

61. Joining of prefabricated tie rods

The Stalexpot building has eight perimetral ties rod per building, wich are born from the hanging head and down all the floors, holding each of the prefabricated slabs.
The composition of these tie rods is concrete that covers the steel rods of great dimension, and as it happens in the building of "Torres de Colón" this has great benefits in the operation on the one hand, the steel cables work of way suitable for the weight, while the concrete provides rigidity and resistance to the whole, in addition to protecting the steel cables against the effects of the oxidation because the weather in a more durable and efficient way than any other type of protection.

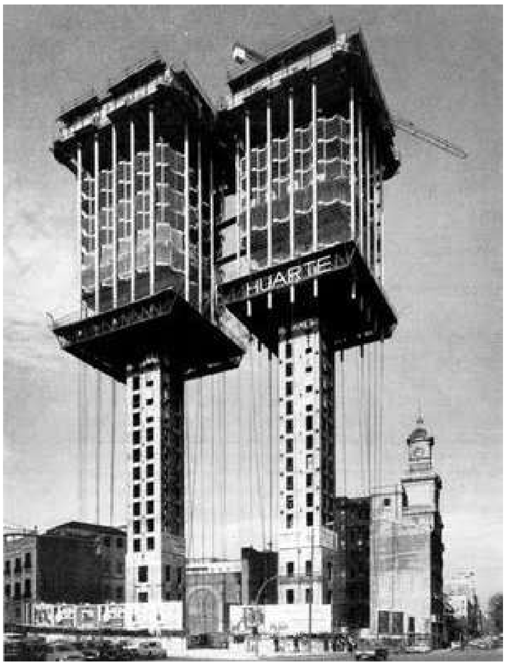


62. Tie rods view of the towers Stalexport

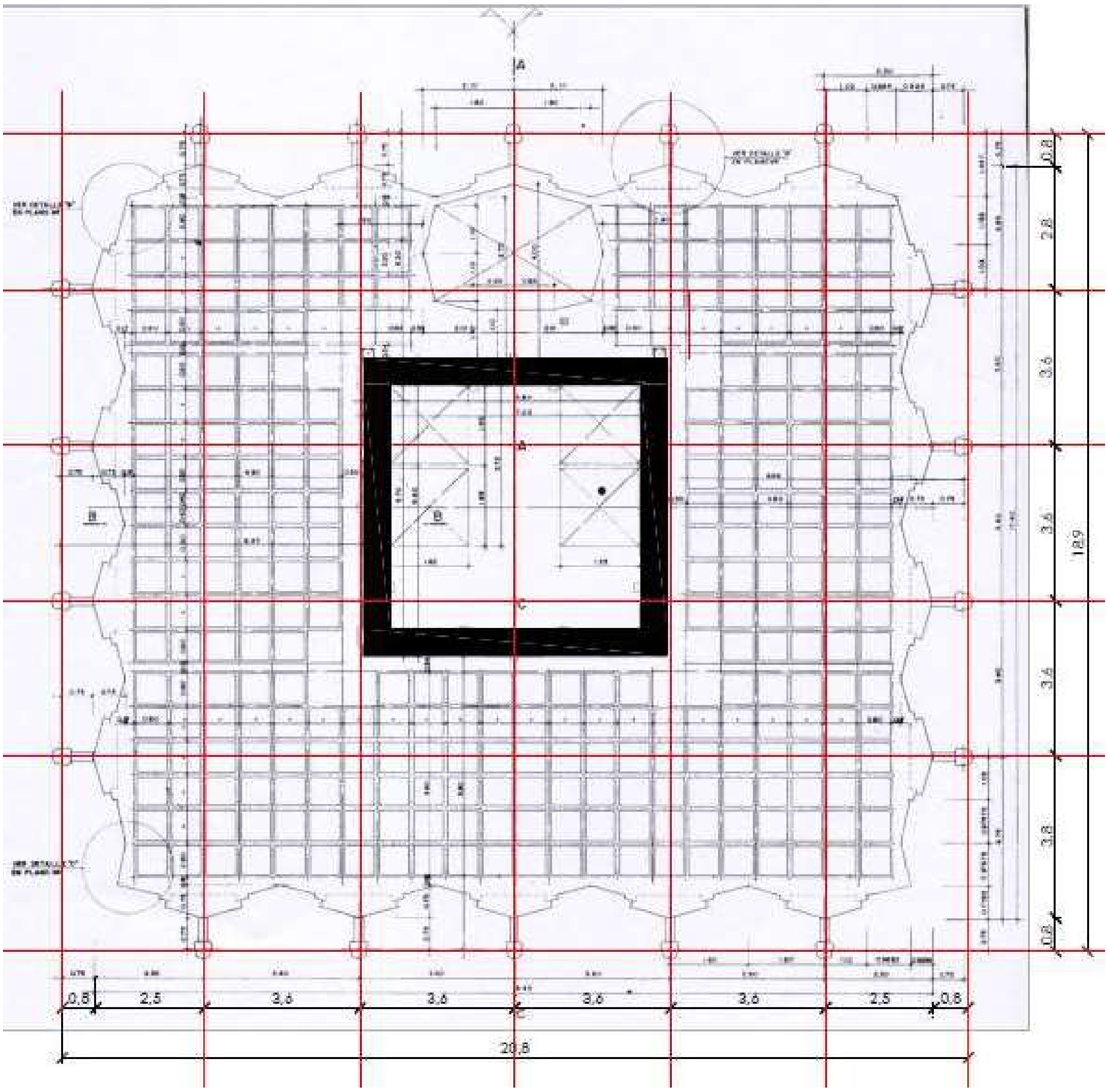
The differencies between the tie rods of the towers Stalexpor and the "Torres de Colón" are more than remarkable, on the one hand we have the length, while in the Spanish building they cover the distance between two floors while in the Stalexport building they cover only one floor, this is mainly due to the execution system, because the first one building was thought to built the plants on pairs to trim down the execution time because of the need to arrange the building soon.
The size of the tie rods is very different too, the difference about the total effort that they have to do is significative, in the "Torres de Colón" they have to suppor 116 and 107 meters of height, while in the Stalexport the height is 97 and 92 meters, another characteristic is the number of them, the difference between both buildings is only one tie rod per tower, it made possible than in the towers Stalexport the size of could be smaller than the other and also the number and the diameter of the steel reinforced bars that were used.

MILESTONE 7. FORGED TYPE AND EXECUTION

Once the hanging head is executed, and having the tie rods to be used defined, the first row of said tie rods was anchored in the perimetral beams forming the head. And it goes down the auxiliary platform that was going to serve as formwork, to start to construct the first one forged. During the concreting process of the type plants the fastening of the formwork was not sufficient and was replaced by Dywdag bars, which also hung from the top of the core.
The execution system of the floors is very similar in both cases and the main problema comes from the supply of the concrete at these height of execution.



63. Construction of type plants

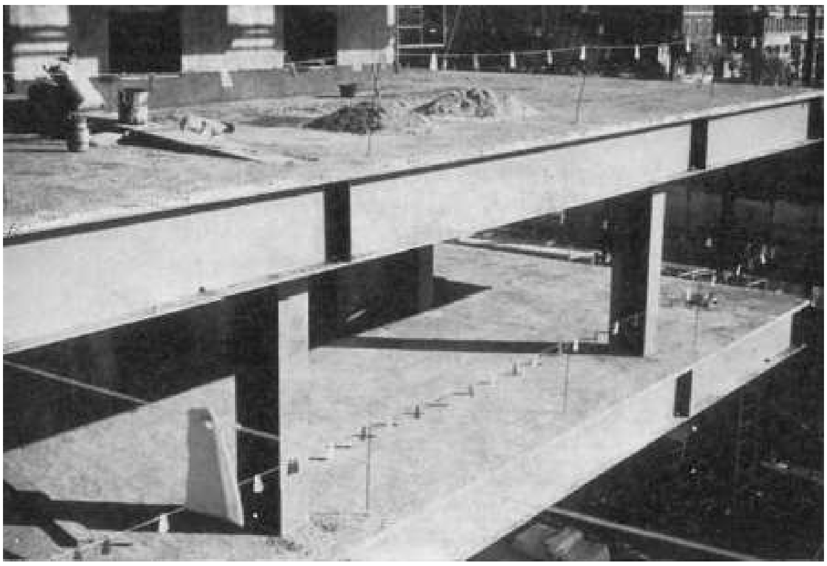


64. Bounded type plant.

As we have commented, the descent of the cimbra was made of two in two plants in the "Torres de Colón" and one by one in Stalexport, which required that the prefabricated tie rod was of sufficient length to save the heights. When the plant had hardened and the cramp descended two more plants, the plant that had been left unattended between them was made, which was done by traditional procedure, supported on the lower floor and made by means of continuous shuttering propped.
By this procedure, it was possible to follow a rhythm of execution of two plants per week in each one of the towers.

65. Construction of the lower floor.

The reinforcemente of the slab varies depending on its position in the tower. This is because in the plants placed in the lowers levels, more important bending moments occur in the zones near the central core due to the longer elongation of the tie rods. For this reason the floors of the building are divided into three packages of seven floors each one, with a different kind of armor corresponding to each one of these packages.
The concreting of the slabs was done in a circular way around the central core, beginning with the areas near to it and finishing in the most distant ones. When the concreting was finished, the concrete was also filled with the areas on the metal brackets that came out of the core and the welding of the metal sheets with tie rods. Later these sheets were also concreted to protect them.

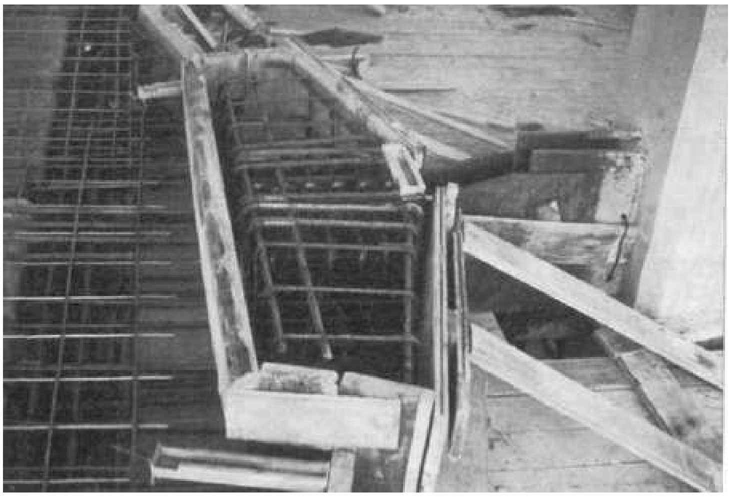

66. Metallic upright connecting two flown plants

MILESTONE 8. FORGED JOINTING POINTS WITH CORE AND TIE RODS

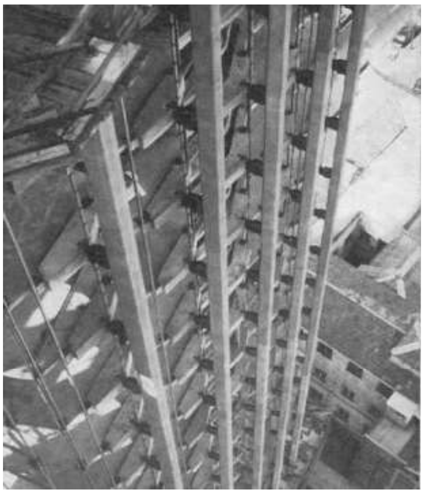
The type floor of each of the two hanging towers is constituted by a concrete slab of 25centimeters thick, lightened with plastic panels. The joining of this slab with the resistant structure is solved by two means, on the one hand it is supported on the central core by means of metal brackets, located in the corners and in the middle points of the central core. The supporting metal brackets were welded to the metal sheets left in the core during sligind. On the other hand, a system of the 18 hangers or hanging pendulums of the perimetral beams, subject to these by means of wedges, were arranged and used to support, through steel brackets, the 21 floor slabs of the tower type plants in the part of its outer edges. The loads are always transmitted to the central core, either directly or through the head structure, being driven by central core to the ground by means of a concrete shoe.

The unión of the type plants with the tie rods was object of special study. It was solved after a few attempts, a very simple solution consisting of two metal sheets, which came out of the upright tie rods, and two other sheet that came out of the plant and also arranged in an upright position were reached. The bonding of both sheets was done by welding once the whole fall of the formwork had occurred, while they could slide slightly next to each other.

67. Tie rods attached to forged bottom view.

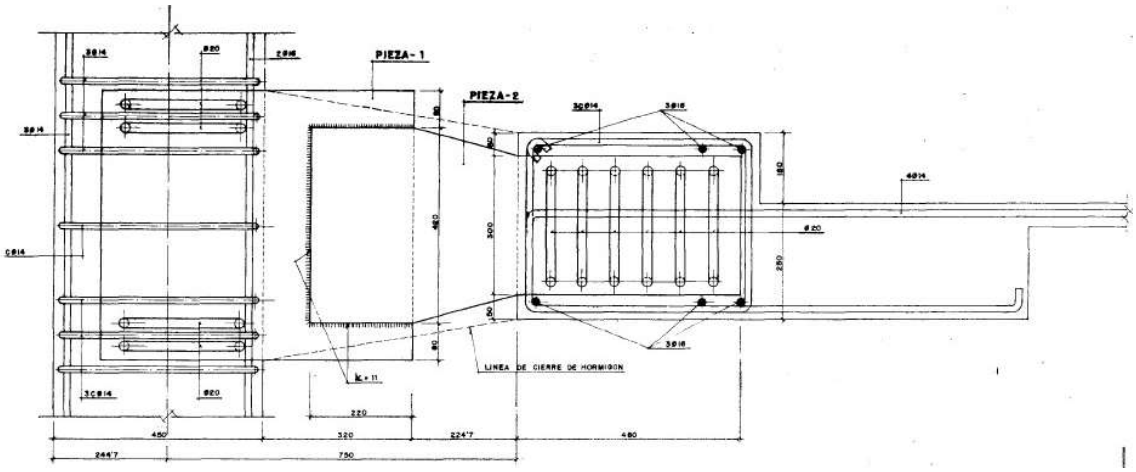


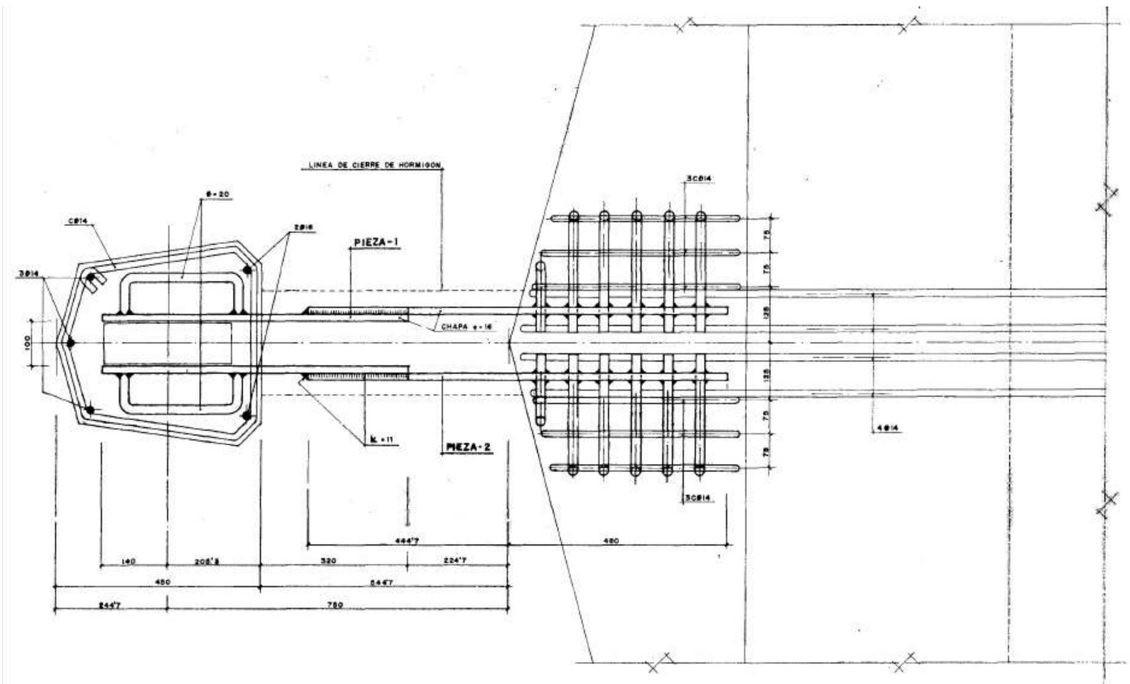
68. Detail of the plant.



69. Tie rods attached to forged, top view.

The reason for this unión was that the decreases of the formwork during the concreting of the type plants was very important, since they hung by means of bars Dywdag, of the head of the tower and, therefore, as lower was the plant, greater elongations were produced, and were producing in the bars and also a greater decrease occurred in the formwork.





70. Details tie rods attached to forged.

6. CONCLUSION AND BIBLIOGRAPHY

CONCLUSION

We are faced with two buildings between 40 and 30 years old, that was innovative in its time, to such an extent that its solutions were the base from which this type of execution was developed in Spain and Poland.

It teaches us that we should not limit ourselves to the conventional construction system, the current materials, steel and concrete, combined, offer us a multitude of structural solutions, which allow us to adapt to any type of design of placement requirements. And

The post-tensioning system allows a great increase of the resistant capacities in the materials, to even allow to redirect the loads, that instead of lowering directly towards the underground foundation, first rise until the hanging head and descend by the central nucleus until the shoe, totally opposite to usual.

And as technicians in charge of solving all the requirements of the project, we must have an open mind to solve in an unconventional way the problems that can arise us for the execution of a project, leaving our mind ready to find everything turned upside down and to be able to solve it because there is nothing impossible, as we have seen in these pecular cases.

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